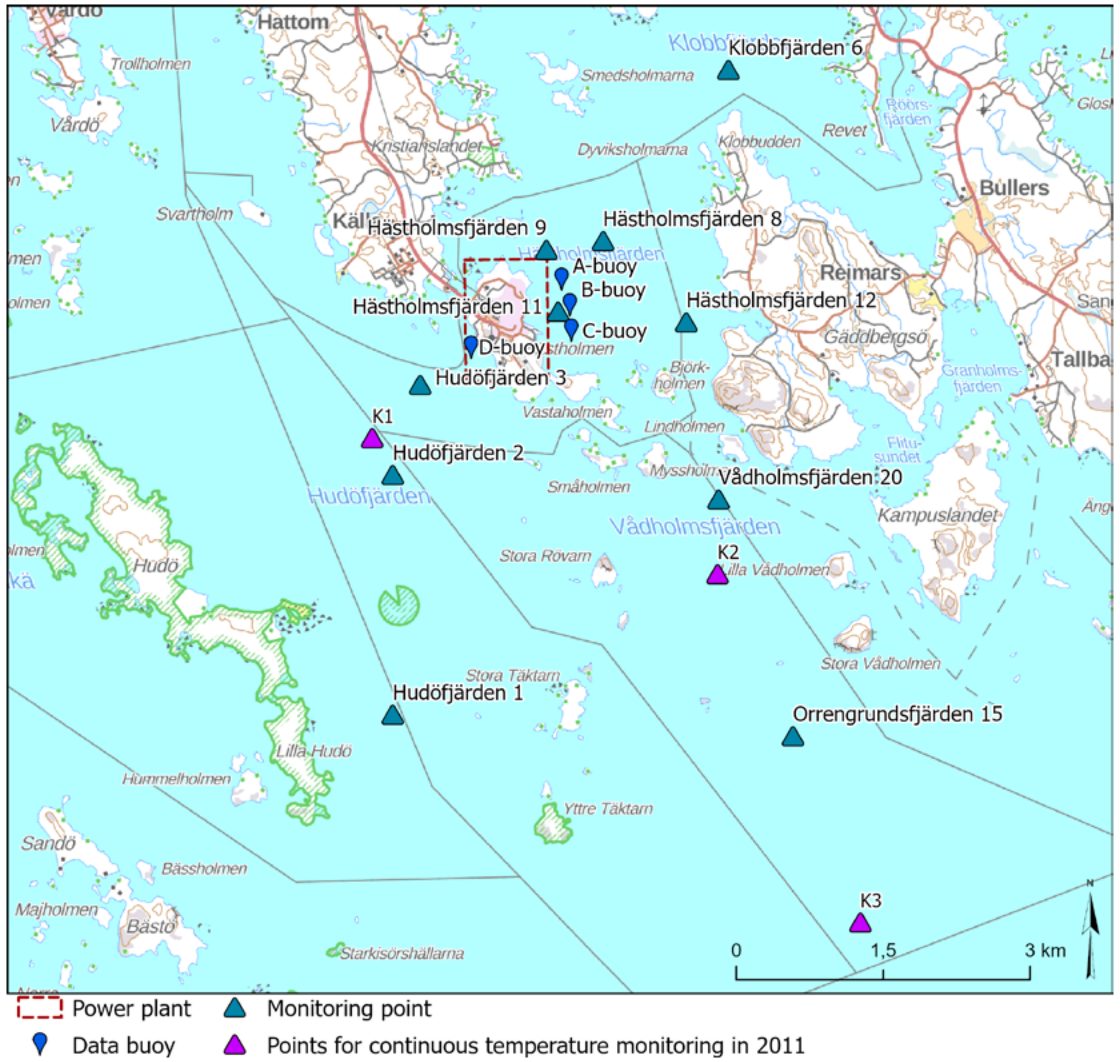

Figure 9-37. Monitoring points for the required monitoring of the quality of seawater in the sea area near Loviisa power plant (source: National Land Survey of Finland 2019, Anttila-Huhtinen & Raunio 2018).

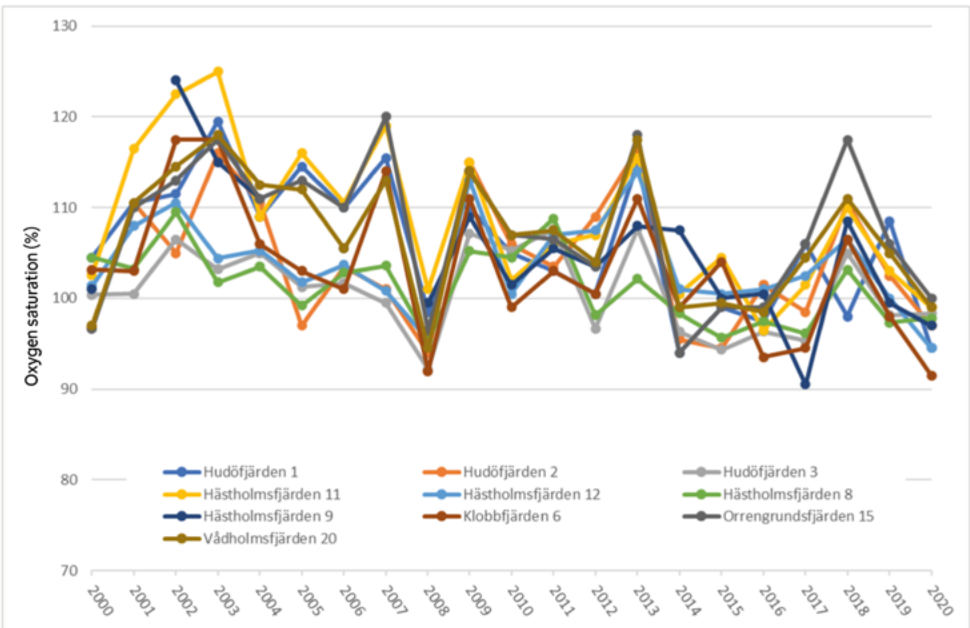

Figure 9-38. Average oxygen saturation in the surface layer of seawater (average in May–October) in the Loviisa sea area in 2000–2020 (Open data, Hertta database, 11 February 2021).

9.16.3.5 Quality of seawater

The water quality of the sea area adjacent to Loviisa power plant has been monitored for decades. The power plant's required monitoring includes the monitoring of water quality at various depths. The points for monitoring the quality of seawater are shown in Figure 9-37. The figure also shows the locations of the continuous temperature data buoys A–D and the continuous monitoring points K1–K3 related to the monitoring of seawater temperature, carried out during the ice-free season in 2011.

Loviisa power plant's discharges of radioactive substances into the sea are described in Chapters 4.12.2 and 9.8.3.2. The present state of the environment in terms of radiation is described in Chapter 9.8.3.

The oxygenation conditions during the surface layer's (0–1 metre) growing season (May–October) have been generally good at the monitoring points for water quality (Figure 9-38). Oxygen saturation has ranged from 70% to 130% during the growing season. Oxygen supersaturation resulting from the accelerated production of phytoplankton, a typical phenomenon in eutrophic waters, has been observed at all monitoring points in the surface layer. The oxygenation conditions of the hypolimnion have generally been poorer than that of the surface water during the growing season, due to the water's temperature stratification, among other things. No distinct trend in the oxygenation conditions was observed in the 2000–2020 period (Figure 9-39) (Anttila-Huhtinen & Raunio 2018). The regional fluctuation, in contrast, is clearly

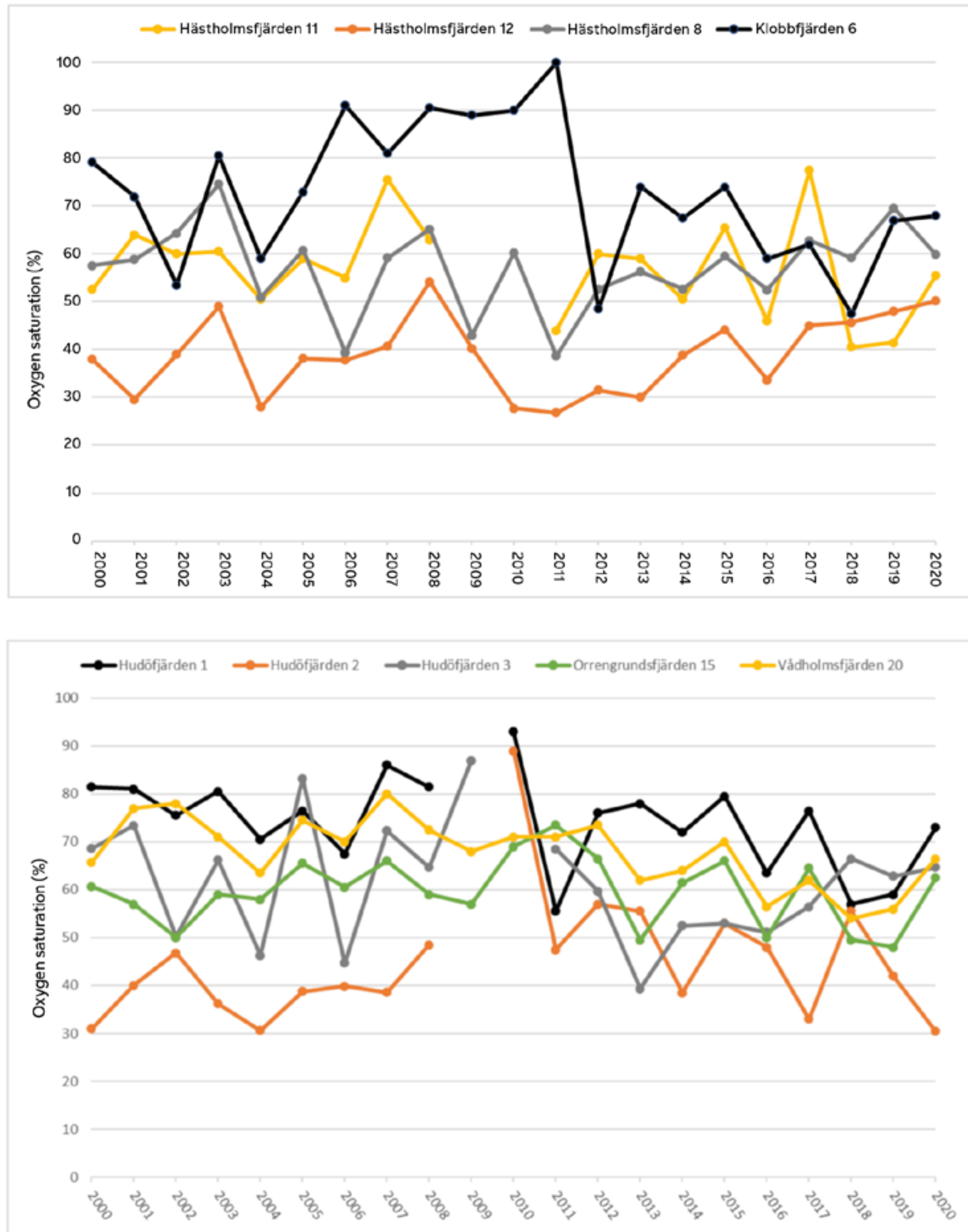

Figure 9-39. Average oxygen saturation in seawater's water layer close to the bottom (average in May–October) in the Loviisa sea area in 2000–2020. The top figure concerns the Hästholmsfjärden and Klobbfjärden area, while the lower figure concerns the Hudöfjärden area as well as Vådholmsfjärden and Orrengrundsfjärden (Open data, Hertta database, 11 February 2021).

greater than in the surface layer. Anoxic conditions have been detected in the hypolimnion in recent years, primarily in the deeps of Hästholmsfjärden and occasionally in the thermocline, but hypoxia has also occurred on the Hudöfjärden side. According to the data on water quality, the hypolimnion's oxygenation conditions have been weak in the deeps of Hästholmsfjärden since the 1970s, before the power plant's commissioning, while the oxygenation conditions in the thermocline weakened in the 1990s (Open data, Hertta database, 24 March 2021).

Based on the average nutrient content in the growing season (May–October), the surface water of the sea area near Hästholmen has been slightly eutrophic or eutrophic. The growing season's average total phosphorus content in 2000–2020 varied in the surface layer at the monitoring points for water quality between 12–41 µg/l (Open data, Hertta database, 11 February 2021) (Figure 9-40). No actual trend has been observable in the fluctuation of phosphorus content during the 2000s. The surface water's average total nitrogen content has ranged between 250–475 µg/l (Figure 9-41). The total nitrogen content dropped significantly in 2009, after which the content has increased slightly, nevertheless remaining at the same level, on average, as in 2000–2008.

The nutrient content in the hypolimnion near the bottom has typically been higher than in the surface water (Figure 9-42 and Figure 9-40). The hypolimnion's bad oxygenation or anoxic conditions, resulting in nutrients from the sediment dissolving into the water, has repeatedly caused total phosphorus and nitrogen content in the Hästholmsfjärden deeps (Hästholmsfjärden 12) that is higher than in other points. In May–October of 2000–2020, the phosphorus content in the hypolimnion close to the bottom was 200 µg/l, on average, while the total nitrogen content was 613 µg/l. The same phenomenon was observable at the Hudöfjärden 2 monitoring point. At the other points, the average phosphorus content in the hypolimnion varied on either side of 50 µg/l, while the nitrogen content was in the region of 375–434 µg/l. The content may nevertheless rise considerably from time to time as a result of the hypoxia.

Visibility depth has been measured in the Loviisa sea area since the 1970s. Visibility depth describes the depth which is visible from the surface of the water. Visibility depth is reduced by particulate matter in the water (including phytoplankton algae and clay-based turbidity carried by river waters) or strong wind, for example, which mixes particulate matter from the sediment into the water. Eutrophication is a significant factor reducing depth visibility in waterways.

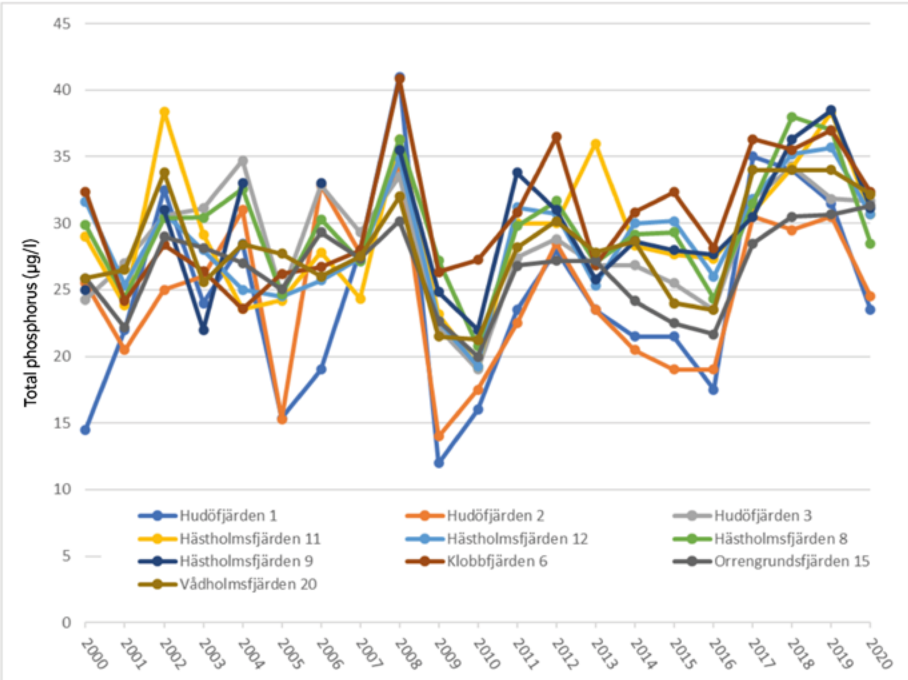

Figure 9-40. Total phosphorus content in the surface layer of seawater (average in May–October) in the Loviisa sea area in 2000–2020 (Open data, Hertta database, 11 February 2021).

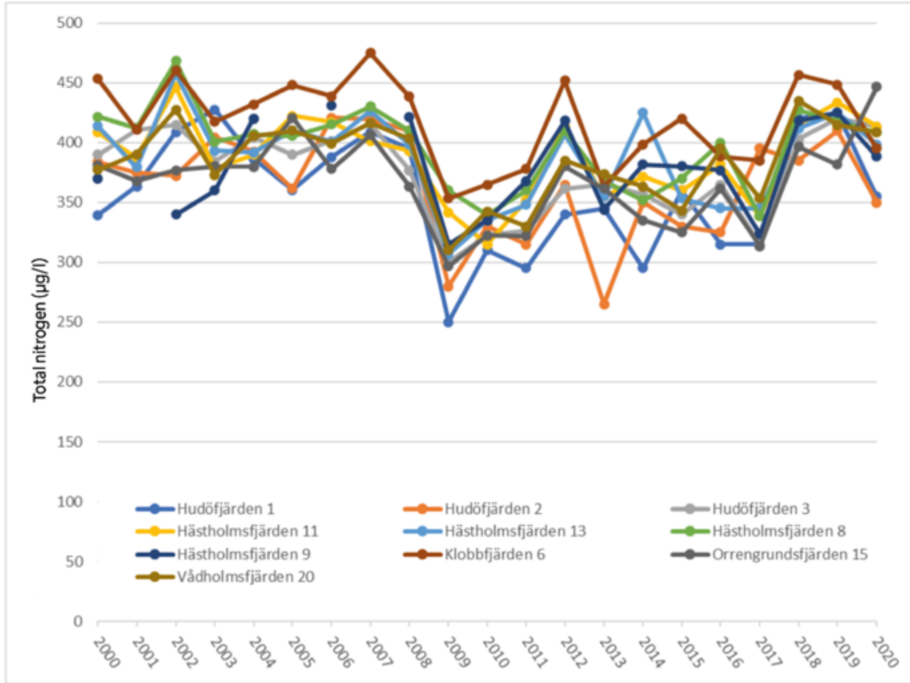

Figure 9-41. Total nitrogen content in the surface layer of seawater (average in May–October) in the Loviisa sea area in 2000–2020 (Open data, Hertta database, 11 February 2021).

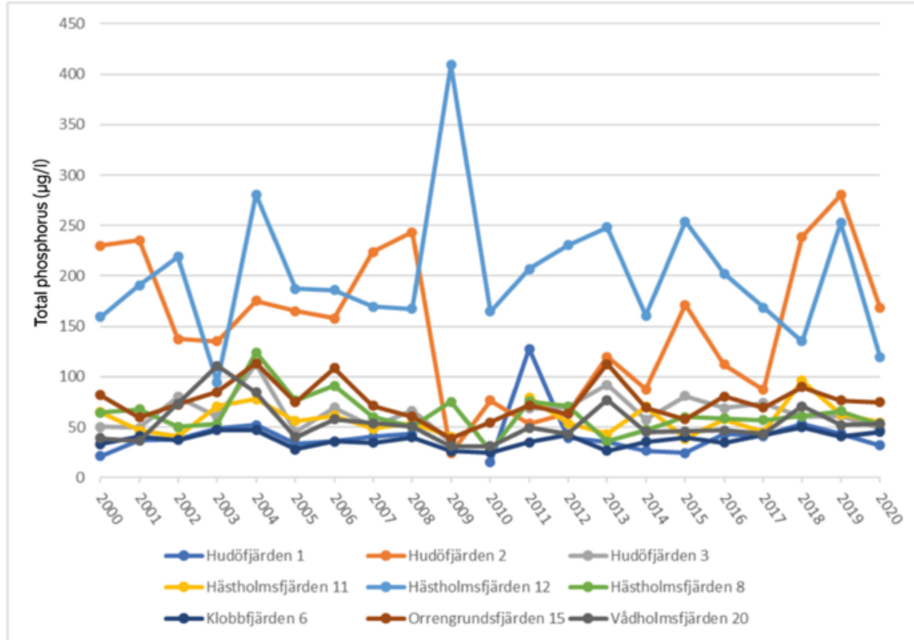

Figure 9-42. Total phosphorus content in the hypolimnion layer of seawater (average in May–October) in the Loviisa sea area in 2000–2020 (Open data, Hertta database, 11 February 2021).

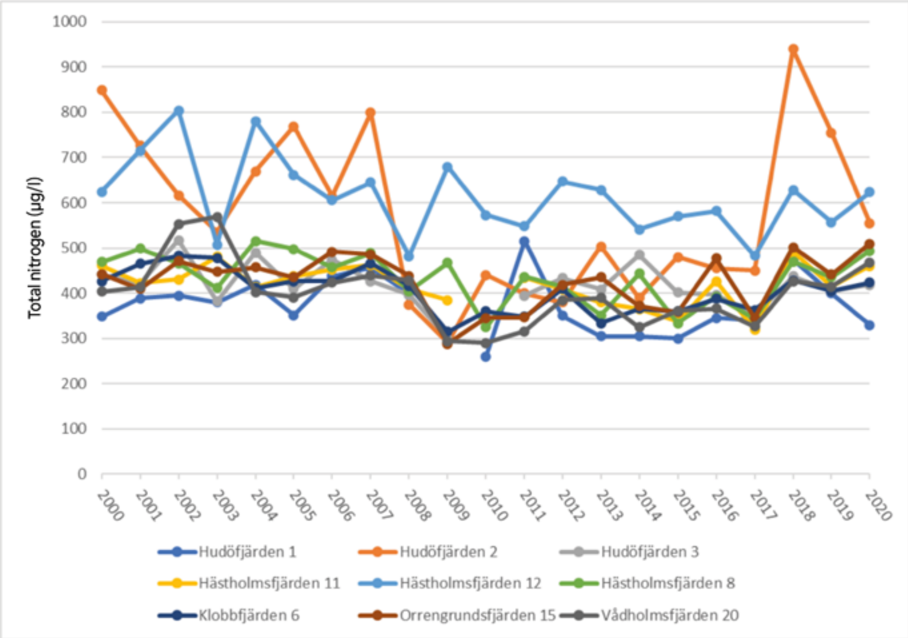

Figure 9-43. Total nitrogen content in the hypolimnion layer of seawater (average in May–October) in the Loviisa sea area in 2000–2020 (Open data, Hertta database, 11 February 2021).

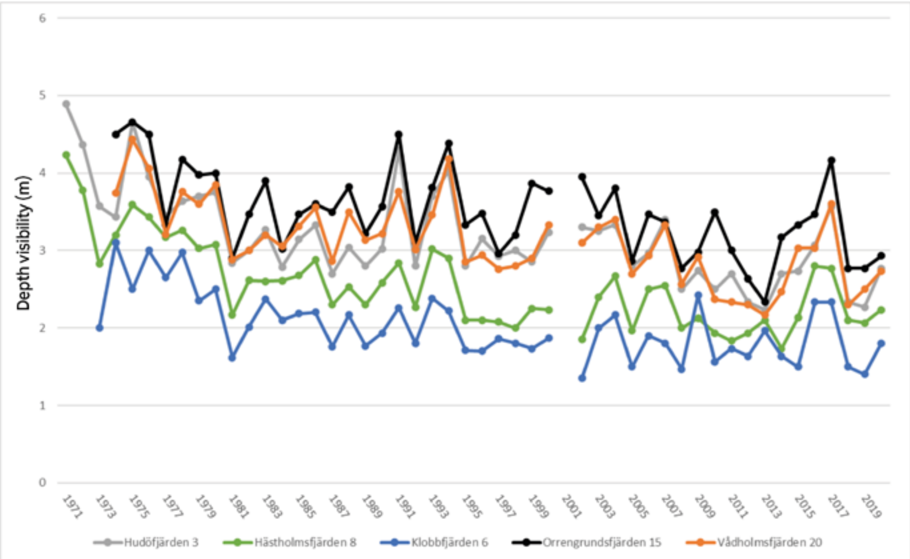

Figure 9-44. Depth visibility (m) in Hästholmen's nearby sea area in high summer, June–August (Open data, Hertta database, 12 February 2021).

Based on the monitoring of water quality, depth visibility in the sea areas close to Hästholmen has decreased (Figure 9-44). In Klobbfjärden and Hästholmsfjärden, depth visibility has been smaller than in the surrounding sea areas since the 1970s, and a declining trend has been apparent in the entire nearby sea area from the beginning of the observation until the 2000s. The reduction in depth visibility is a consequence of the Gulf of Finland's general eutrophication trend, but local factors also contribute. Klobbfjärden's lower depth visibility is explained by the river water input, rich in solids and nutrients, arriving via Jomalsund from the river Tesjoki (Figure 9-35). In recent years, the declining trend in depth visibility seems to have levelled off.

9.16.3.6 Phytoplankton

Phytoplankton algae are small single-cell organisms forming, as primary producers, the base of food webs in the marine ecosystem. The phytoplankton community is regulated by several different physico-chemical factors, including light, temperature, nutrient content and relations, as well as biotic factors, which include the grazing of zooplankton and competition over nutrients. The Gulf of Finland's phytoplankton community has a clear seasonal succession, which comprises a spring bloom, a summer minimum, a late-summer maximum and sometimes a smaller autumn bloom.

In the power plant's nearby sea area, the phytoplankton species and biomass, as well as the phytoplankton's seasonal succession (development), have been typical of the coastal waters in the Gulf of Finland. In the winter, the amount of light and the mixing conditions of the sea area limit the growth of phytoplankton, even though enough nutrients are available for algal production. Primary production is at its greatest during phytoplankton's spring bloom, and its strength varies regionally and from one year to the next, being the greatest in the Gulf of Finland (Fleming and Kaitala 2006). In the 2017 monitoring, typical algae groups of the spring bloom in the power plant's nearby sea area consisted of the taxa most abundant in May – dinoflagellates (with the large *Peridiniella catenata* being the dominant species) and diatoms (Hakanen 2018).

In the summer, phytoplanktons use mainly recycled nutrients, given that the thermocline prevents nutrients from moving from the deeper layers of water to the productive surface layer with abundant light, and that the content of soluble nutrients in the surface layer is low. Dominant groups of algae in the summer typically include filiform cyanobacteria (i.e. blue-green algae), pyrrophyta as well as small autotrophic flagellates and nanoflagellates. The amount of blue-green algae in the power plant's nearby sea area has varied from one year to the next, and blue-green algae's share of the community is at its greatest in late summer (Hakanen 2018). The most abundant species of blue-green algae in the 2017 monitoring was the non-toxic filiform Aphanizomenon (Hakanen 2018). In the Gulf of Finland, eutrophication has led to the average strengthening of mass occurrences of blue-green algae in late summer, although the regional and temporal variation in the strength of the occurrences, and the variation between different years in this regard, is great (Bruun et al. 2010). The dominant algae in the autumnal phytoplankton community are the large cold water diatoms found in the Loviisa sea area (Hakanen 2018).

Only fragmented data is available on the annual averages of the chlorophyll a concentrations, which describe the amount of algae in the water, from the initial years of monitoring. Chlorophyll a concentrations have grown compared to the initial years of the monitoring, which indicates an increase in the amount of algae (Table 9-51). The most complete monitoring data is available from monitoring points Hästholmsfjärden 8 and Hudöfjärden 3. At these points, the average chlorophyll concentration pointed to a declining

Table 9-51. Annual averages of chlorophyll a concentrations during different periods as of 1970. The data from the initial years are fragmented, and the sample size (n) was very small (Open data, Hertta database, 17 February 2021).

Piste	1970-1980	n	1981-1990	n	1991-2000	n	2001-2010	n	2011-2020	n
Hudöfjärden 1	—		—		—		22.5	2	—	
Hudöfjärden 2	0.2	1	7.3	8	3.1	1	17.3	2	—	
Hudöfjärden 3	—		—		12.03	12	10.9	72	8.3	62
Hästholmsfjärden 11	3.8	1	14.8	1	—		8.6	17	7.9	61
Hästholmsfjärden 12	3.7	1	7.9	16	7.7	1	8.7	19	9.1	62
Hästholmsfjärden 8	2.9	5	—		12.8	11	10.9	72	9.1	56
Hästholmsfjärden 9	—		12.8	1	—		9.4	25	9.1	60
Klobbfjärden 6	—		—		—		11.6	19	9.9	61
Orrengrundsfjärden 15	—		—		—		7.3	19	7.9	61
Vådholmsfjärden 20	—		—		—		7.5	19	9	61

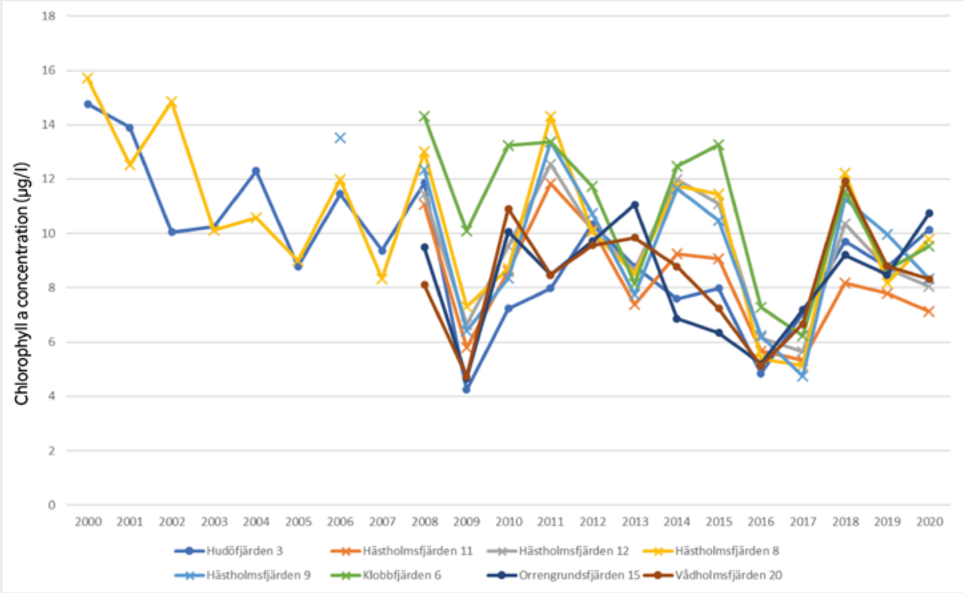

Figure 9-45. Surface layer's station-specific average chlorophyll a concentration (µg/l) during the growing season (May–October) in the Loviisa sea area in 2000–2020 (Anttila-Huhtinen & Raunio 2018).

trend (a decrease in the amount of algae) in the 2000s, up to 2009 (Figure 9-45) (Anttila-Huhtinen & Raunio 2018). The same trend was also observed at the points added to the monitoring in 2008 (Anttila-Huhtinen & Raunio 2018). The chlorophyll concentration then rose again, and the variation from one year to the next has been great. The highest concentrations were observed in 2011 and 2014. In the present state, the chlorophyll concentrations reflect mainly a eutrophic waterway. In the cooling water's discharge location at Hästholmsfjärden, the thermal load caused by the power plant has contributed to an acceleration of eutrophication.

The changes that have taken place in the status of the Gulf of Finland are also reflected in the state of the power plant's nearby sea area. In the Gulf of Finland, the amounts of algae grew until the early 2000s due to eutrophication. The amounts of algae there began to grow again in the late 2010s. This was indirectly related to the major Baltic inflows of the 2010s, which pushed hypoxic water rich in phosphorus from the Baltic Proper (the Gotland Basin) into the Gulf of Finland. For example, the impact of the major Baltic inflows in 2014–2016 was visible in the 2018 results of the Loviisa waterway monitoring as an increase in the chlorophyll a concentration and primary production (Anttila-Huhtinen & Raunio 2019).

Regular monitoring data on the total biomass of phytoplankton are available starting from 2008 (Open data, Phytoplankton register, 15 February 2021). The most extensive data are derived from the monitoring points Hudöfjärden 3 and Hästholmsfjärden 8. The biomasses are considerably greater than the biomass in 1967, which was calculated on the basis of only a single sample in July and is of indicative nature only (Figure 9-46). The changes are probably a result of the general eutrophication in the Gulf of Finland. The aver-

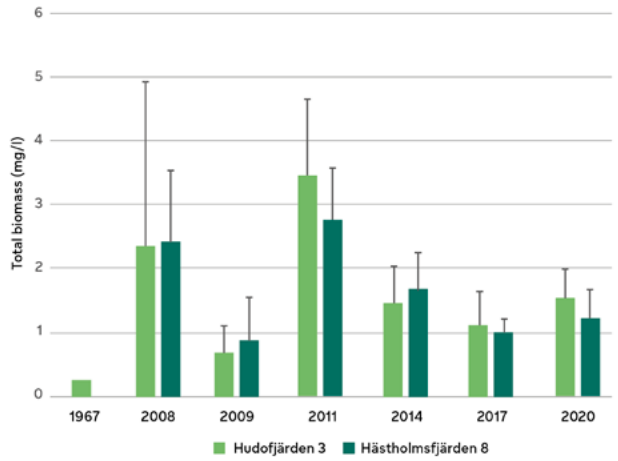

Figure 9-46. Phytoplankton's total biomass in Hudöfjärden and in Hästholmsfjärden. Only one measurement is available in terms of 1967, from July. In terms of other years, the sample size is 2–6 (Open data, Phytoplankton register, 15 February 2021).

age amount of biomass in 2014–2020 was 0.9-1.7 mg/l. The biomass has begun to decline since 2011.

The measurement data on the primary production of phytoplankton in the Loviisa sea area are exceptional in terms of their time span, with the earliest results being from 1967; the production of phytoplankton seems to have declined since 1997 (Anttila-Huhtinen & Raunio 2018). During this monitoring, the amount of primary production increased both at the discharge and intake locations of the cooling

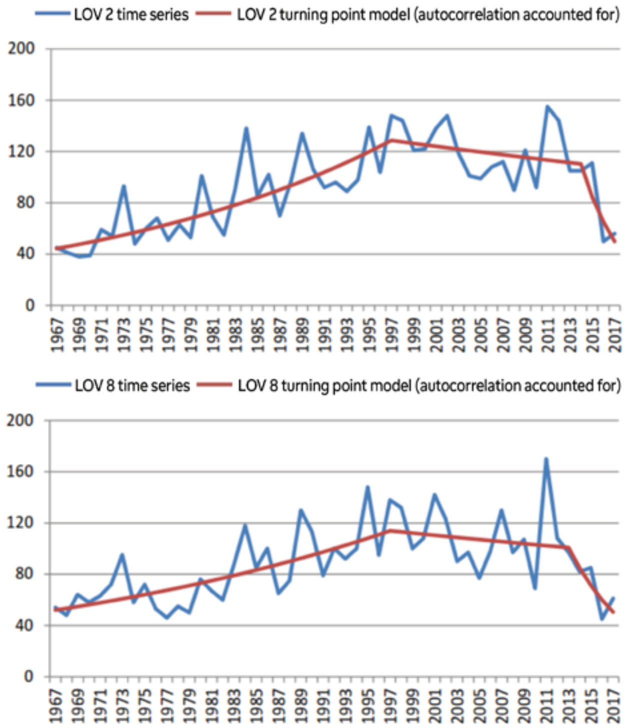

Figure 9-47. Primary production per unit area (mg C/m2d) in the cooling waters' impact area at Hästholmfjärden (station LOV 2, upper figure) and in the reference area at Hudöfjärden (station LOV 8, lower figure) in 1967–2017 (Anttila-Huhtinen & Raunio 2018).

water until the mid-1990s. The increase is connected to the general increase in the Gulf of Finland's nutrient content and the general eutrophication trend in the Gulf of Finland. The eutrophication trend has nevertheless been stronger in Hästholmsfjärden (station 2, Hästholmsfjärden 8) than in the nearby reference area in Hudöfjärden (station 8, Hudofjärden 3). For its part, this points towards the impact of the power plant's cooling water (Anttila-Huhtinen & Raunio 2018). In the 2000s, the primary production increased to a level clearly indicative of a eutrophic waterway. However, based on the turning point model adapted for the data, the eutrophication trend seems to have taken a downward turn (Figure 9-47). While the variation between different years is great, the turning point model suggests that the changes in the amount of primary production took place in 1997 and in 2013–2014. The declining trend first began in 1997, but gained further strength in 2013–2014. The low primary production figures of 2016 and 2017, in particular, strengthened the declining trend.

9.16.3.7 Aquatic vegetation

Aquatic vegetation has been monitored in the sea areas near Loviisa power plant since 1971. The seabed on the shores of the island of Hästholmen is mostly rocky and usually drops off steeply close to shore, which is why the aquatic vegetation zones are generally narrow (Ilus 2019). In 2017, a total of 12 aquatic plant species belonging to vascular plants and macroalgae were found in the areas being monitored. The species were customary to the area, and included hornwort, spiked water-milfoil, spiny naiad, perfoliate pondweed, fennel pondweed, *Fucus radicans* brown alga, *Cladophora glomerata* macroalga, *Ectocarpus siliculosus* brown alga, bladder wrack, and sea lettuce (Monivesi Oy 2018).

No significant change in the abundance of aquatic plants has been observed in Hästholmsfjärden and Hudöfjärden between the years 2008, 2011, 2014 and 2017. Between 1977 and 2017, aquatic vegetation in Hästholmsfjärden and Hudöfjärden changed in such a way that aquatic plants sensitive to physico-chemical inputs (nutrients, temperature, depth visibility) declined in both sea areas since 1980, whereas some vascular plants and filamentous algae have benefited from the warmer water. The change in Hästholmsfjärden has been greater than the change in Hudöfjärden. Annual filamentous algae, in particular, have benefited from the longer growing season. The thermal effect is especially visible in the greater occurrence of aquatic plants – from the surface of the water down to a depth of 1.5 metres – in the monitoring lines of the Hästholmsfjärden area (the impact area of the power plant's cooling water) (Monivesi Oy 2018). The increase in the coastal vegetation and the eutrophication of the shore areas can be seen at a distance of approximately one kilometre from the cooling water intake.

9.16.3.8 Benthic fauna

The benthic fauna populations in the sea area surrounding Loviisa power plant were first studied in 1966, when the quantity of species was deemed fairly low. The quantity of species in the Gulf of Finland is limited by the salinity of the brackish water, which is too low for marine species and too high for freshwater species. Benthic fauna monitoring of a more regular nature in Loviisa power plant's nearby sea area began in 1973. There have been considerable changes in the condition of the seabed of the area and in the benthic fauna over the last 40 odd years.

The state of the seabed and benthic fauna in the eastern Gulf of Finland has long been weak due to the bad oxygenation conditions. Since the 1980s, the state of the seabed has weakened particularly steeply in the deeper areas. After the major Baltic inflows in the first half of the 1990s, benthic fauna communities declined dramatically, particularly in the deeps of the Gulf of Finland (Jaale & Norkko 2008). Loviisa power plant's monitoring area has separate pools, set apart by low thresholds, in which the exchange of water close to the bottom is poor. The power plant's thermal load also exacerbates the weak oxygenation conditions, because the increased temperatures further impair the oxygenation conditions on the seabed through both degradation activity and increased primary production (Anttila-Huhtinen & Raunio 2018). The deterioration has been visible as the strong decline of the Baltic macoma and *Monoporeia affinis* – benthic fauna typical of the eastern Baltic Sea – and very few, if any, findings of these species have been made in the deepest stations of Loviisa power plant's impact monitoring.

Changes in the benthic fauna in the 2000s have not been equally significant. Based on an extensive survey of the benthic fauna conducted in 2017 (Anttila-Huhtinen & Raunio 2018, Monivesi Oy 2018), the benthic fauna in the shallow mud floors of Klobbfjärden and Hästholmsfjärden consisted of the Oligochaeta of a eutrophic seabed and chirominid larvae. However, at the sample station close to the power plant's discharge location, the benthic fauna has been more diverse than at the other stations throughout the 2000s (Figure 9-48). This is probably due to the area's better exchange of water and the coarser material of the seabed. The thermal effect of the cooling water may also favour the occurrence of some alien species. One such alien species is the New Zealand mud snail *(Potamopyrgus antipodarum)*. Its abundant occurrence at station 5b, close to the discharge location, began in the 1990s and continued into the 2000s, up until 2008 (Figure 9-48).

The condition of the seabed in the deeper zones – the profundal zones in which the amount of light no longer enables the growth of green plants – of Hästholmsfjärden (station 3) and Hudöfjärden (station 8), Vådholmsfjärden (station 4) and Orrengrundsfjärden (station 7) has been largely bad in the 2000s (Figure 9-49 and Figure 9-50). Even so, the condition of the seabed in Vådholmsfjärden (station 4) has been better over the last three years of research than during previous years (Figure 9-50). The *Marenzelleria* worm has become more widespread in recent years at the outer sample stations in Vådholmsfärden and Orrengrundsfjärden (Figure 9-50).

According to the Benthic Biotic Indices (BBI), which describe the benthic fauna communities on the soft coastal seabed, the state of the Klobbfjärden body of water's seabed has been largely bad in the 2000s, when as recently as the 1970s and 1980s, it was poor (Anttila-Huhtinen & Raunio 2018). Further out in the sea area, in the Loviisa–Porvoo body of water, the state of the seabed has been more varied, but improved from poor to moderate over the 2013–2017 period (Anttila-Huhtinen & Raunio 2018). The BBI assumes that the diversity of species and the share of sensitive species in a benthic fauna community decrease as the environmental stress grows (Perus et al. 2007). The BBI is based on quantitative samples and is calculated from the benthic fauna community's composition of species and the values set for the sensitivity of the species. Given that the BBI was originally developed for the Kvarken area and is therefore not necessarily well suited for the Gulf of Finland and the species there, the status classes pursuant to the BBI values should be treated with some caution. Among other things, the index fails to recognise the freshwater chirominid and oligochaetes, typical of the Gulf of Finland's coastal archipelago, at the

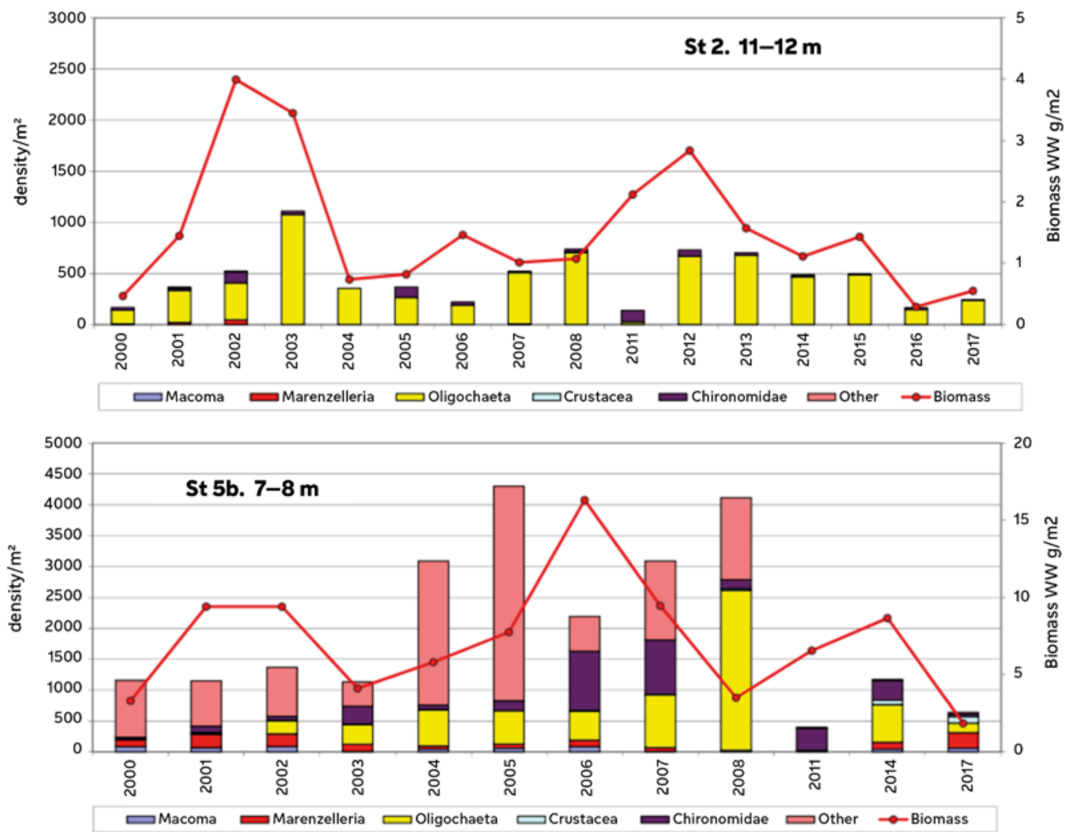

Figure 9-48. Population densities and biomasses of benthic fauna groups in the 2000s at Hästholmsfjärden (stations 2 and 5b), Loviisa. The group "Others" includes the number of New Zealand mud snails. The scales of the figures' Y axes are not identical (Anttila-Huhtinen & Raunio 2018).

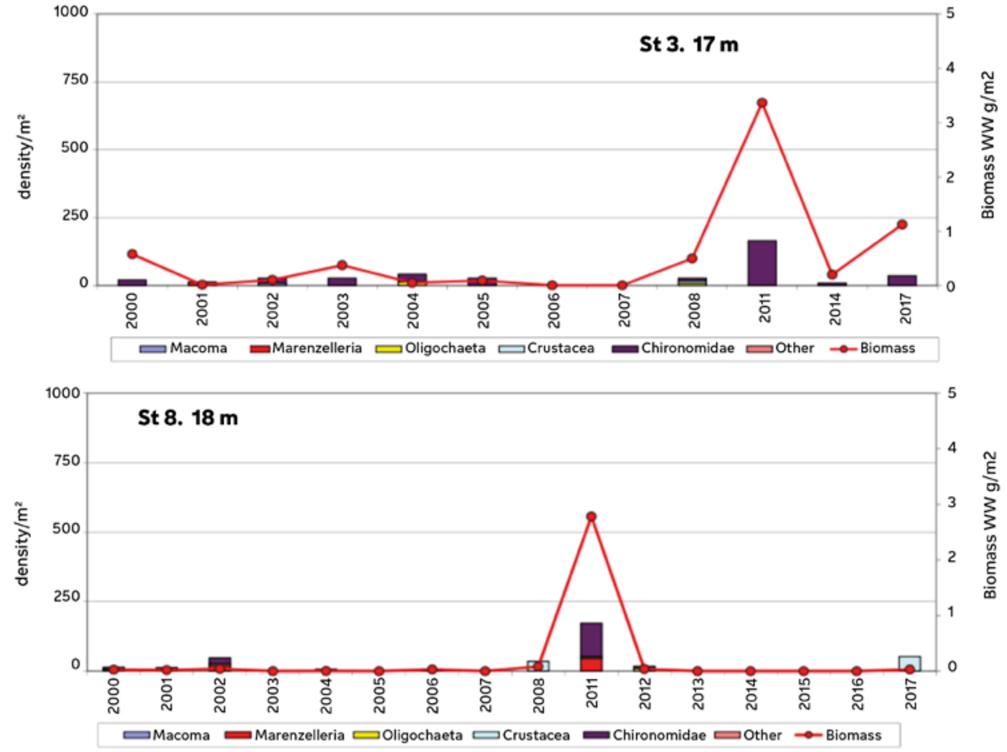

Figure 9-49. Population densities and biomasses of benthic fauna groups in the 2000s in Hästholmsfjärden's profundal zone (station 3) and Hudöfjärden (station 8). The scale of years in the figures is not identical (Anttila-Huhtinen & Raunio 2018).

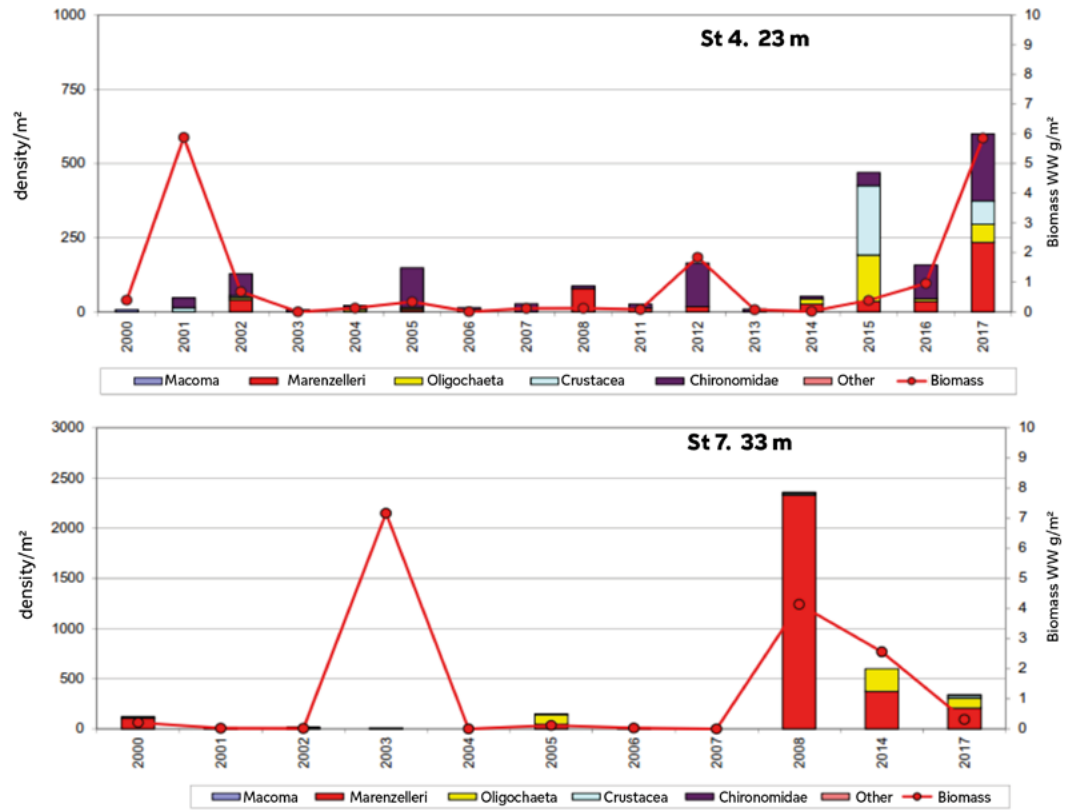

Figure 9-50. Population densities and biomasses of benthic fauna groups in the 2000s in Vådholmsfjärden (station 4) and Orrengrundfjärden (station 7), Loviisa. The scale of years in the figures is not identical (Anttila-Huhtinen & Raunio 2018).

species level, meaning that the occurrence of more demanding species remains unaccounted for. In addition, the index gives the *Marenzelleria* worm the same sensitivity value as the Baltic macoma, even though *Marenzelleria* can live in poor and hypoxic conditions (Anttila-Huhtinen 2018).

The benthic fauna in the littoral zone exhibits variation from one year to the next (Anttila-Huhtinen & Raunio 2018). In 2017, the share of insects was much higher than in the 2014 study, when the community was more marine. The most abundant group of benthic fauna at all sample points in the littoral zone in 2014 and 2017 was crustaceans (including amphipoda of the genus Gammarus). At the sample station closest to the shore, important groups in the benthic fauna consisted of mussels and insects, including chironomid larvae, in addition to crustaceans. The most abundant species of insects was the Caenis horaria mayfly, and among mussels, the small Macoma baltica clams. Further offshore, the share of insects declined and the share of gastropods and oligochaetes increased correspondingly.

The benthic fauna samples covered by the monitoring have also included the larvae of Macroplea pubipennis. Three species of Macroplea beetles are found in Finland. Of these species, Macroplea pubipennis has been categorised as near threatened (NT) in Finland (Hyvärinen et al. 2019). The species of Macroplea beetles cannot be identified during their larval stage, due to which the occurrence of Macroplea pubipennis southwest of Fallholmen, Hudöfjärden, and in the monitored areas in Myssholmen's littoral zone, cannot be ruled out. Macroplea pubipennis is a species listed in Annex II to the Habitats Directive and a species for which Finland is internationally responsible.

Non-native species, or species which do not occur in the monitored area naturally, but have been introduced there inadvertently by human activity, have also spread to the sea area near Loviisa. Given that they often do not have natural predators or competitors, non-native species may reproduce and spread rapidly in their new environment and take up space from other species. In 2017, a total of nine non-native species was detected in the benthic fauna

Table 9-52. Non-native species observed in benthic fauna monitoring and general information on these species (Anttila-Huhtinen & Raunio 2018, Invasive Alien Species Portal 18 February 2021).

Non-native species	English name/group	General information on the species
Marenzelleria	worms, annelids, polychaetes	Soft seabed. Tolerant of hypoxia. First found in the Gulf of Finland in 1990. A dominant species in the outer monitoring stations of the research area. Range covers the entire Baltic Sea.
Paranais frici	oligochaeta	Soft seabed.
Potamopyrgus antipodarum	New Zealand mud snail	Soft seabed/littoral. Spread to the Finnish coast in the 1920s. Has so far not been observed to pose a risk to the ecosystem of the Baltic Sea.
Murchisonella	a marine gastropod mollusc	Littoral. First observed in Hamina in 2013 and in 2014, found in Loviisa. A formal description of the species is yet to be published.
Amphibalanus improvisus	bay barnacle	Hard seabed/littoral. Arrived in the Baltic Sea in the 1840s. Since its spread, has shaped the biotic community of the coasts as a result of competition for space and food. Prevents bladder wrack and mussels, among others, from attaching to surfaces. Causes biofouling.
Cordylophora caspia	brackish hydroid	Hard seabed. Arrived in the Baltic Sea in the 1800s. *Cordylophora* caspia is a warm-water species which can overwinter in cold climates with the help of resting phases. The species may compete for space and food with blue mussels and other species attaching themselves to hard surfaces. Causes biofouling.
Mytilopsis leucophaeta	dark false mussel	Hard seabed/littoral. Currently found only in the surroundings of Loviisa and Olkiluoto power plants. Found in Loviisa in 2003; abundant in Hästholmsfjärden. Competes for habitat and food with other organisms attaching themselves to bases. Causes biofouling.
Gammarus tigrinus	crustaceans	Hard seabeds. First observed in Finland in the area of the Port of Hamina in 2003. Has displaced original species in some places in the Baltic Sea; is an aggressive competitor.
Paleomon elegans	grass prawn	Hard seabed. First found in Finland in 2003. May have displaced original species in some places in the Baltic Sea; is a good competitor.

studies conducted in the joint monitoring of the sea area off Loviisa (Table 9-52). Most of the non-native species were found in the littoral zone. Non-native species found in the area include barnacles (Balanus improvisus), brackish hydroid (Cordylophora caspia) and the dark false mussel (Mytilopsis leucophaeta). The dark false mussel is a species that benefits from the thermal effect. In Finland, it has been found in the nearby sea areas of Loviisa and Olkiluoto nuclear power plants (Invasive Alien Species Portal, 7 April 2021), and only in the monitored areas located within the impact area of the cooling water. The aforementioned three species also cause what is referred to as biofouling, which entails the biological contamination of various underwater surfaces (Anttila-Huhtinen & Raunio 2018).

Among organisms involved in fouling, dark false mussels cause the most problems in the cooling water systems of Loviisa power plant, which is why the power plant has engaged in monitoring and studies of the nearby sea areas in relation to the dark false mussel since 2005. The number of organisms in the seawater systems is also regularly monitored at Loviisa power plant in connection with periodic inspections, and growths which have become too large are removed during annual outages, for example.

9.16.3.9 Sediments

The layers of soil on the seabed near Loviisa power plant consist mainly of moraine or rough soil types, gravel and sand, with clay and silt sand of varying thickness layered on top in places.

The quality of the sediment was studied in the western sea area of Hästholmen, at the intake side of the cooling water, in 2019 (Lindfors et al. 2020). In the report, sediments are categorised in accordance with dredging and stacking guidelines (Ministry of the Environment 2015) (Figure 9-51). The quality of sediment in terms of radioactive substances is described in Chapter 9.8.3.4.

Based on the results, the metal content of normalised sediment samples was of level 1–1A (clean/no impact on stacking suitability). The dioxin and furan contents exceed level 2 (primarily unsuitable for stacking) in eight out of the eleven samples analysed, and all the samples analysed exceeded level 1C (stackable in a "good" stacking area). The content of tributyltin (TBT), which belongs to organotin compounds, and the analysed polyaromatic hydrocarbons (PAH compounds) in the sediments were slightly elevated, but for the most part, the values were at level 1A or lower, and only in isolated cases was the content at level 1B.

Elevated dioxin and furan contents are typical of river basins in the eastern Baltic Sea and the river Kymijoki, due to the area's industrial history. Harmful dioxins and furans are generated inadvertently in various industrial processes, including waste incineration and chemical production. Correspondingly, compounds containing TBT were formerly used in the primers of vessels, for example, to prevent organisms from attaching themselves to the hulls, and in agriculture, as an anti-mildew agent for seeds (Lindfors et al. 2020).

9.16.3.10 Lappomträsket lake

Lappomträsket lake, from which the raw water needed by the power plant is taken, is located roughly five kilometres north of the power plant (Figure 9-30). The lake's water level was lowered decades ago to dry out additional arable land, but later in the 1970s, it was raised again due to the water supply needs of Imatran Voima, now Fortum (Ramboll Finland Oy 2012a). Pike fry are transplanted in the lake, oxidised by Fortum, every year.

The inflow of Lappomträsket lake is in the region of 2.3 million m^3 a year. Water for the power plant's needs is pumped at an average rate of 20–30 m^3 per hour, and the annual need has been roughly 200,000 m^3 a year. Fortum uses less than 10% of the inflow. According to the regulation permit, the regulation's upper limit is 3.25 m, and the lower limit is 2.3 m (N60). According to the permit conditions, water may be taken from the lake at a rate of 180 m^3 per hour on a

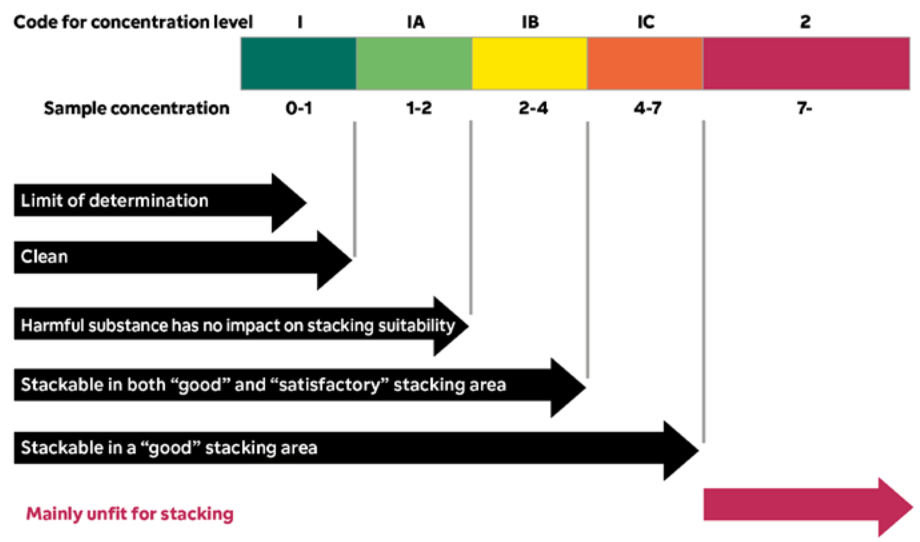

Figure 9-51. Quality grading of normalised sediment (Ministry of the Environment).

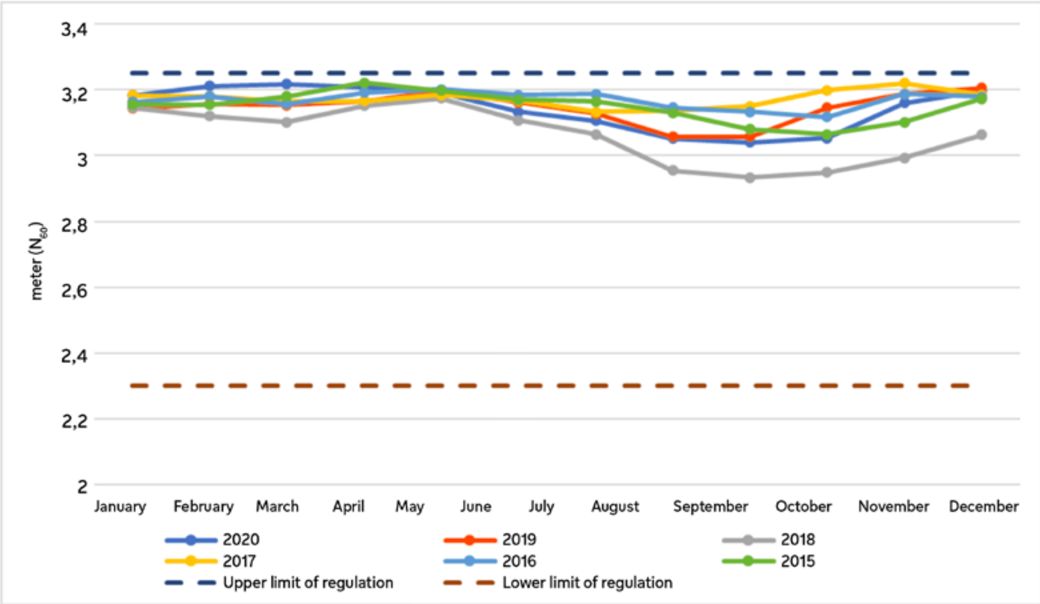

Figure 9-52. Lappomträsket lake's water level as monthly averages in 2015–2020 as well as the upper and lower limit of regulation.

short-term basis and at a maximum rate of 150 m³ per hour over every three months. In 2015–2020, the water level as monthly averages has been fairly stable and remained close to the upper limit of the regulation (Figure 9-52). Variation from one year to the next has also been minor, and there has been no need to empty the lake close to the lower limit. The drainage ditch of Lappomträsket lake has a dam south of Långstrandintie through which water can be run to the bay of Lappomviken when necessary.

According to the data in the watershed model, the phosphorus input entering the lake is fairly minor, 128 kg per year (Watershed model, 18 February 2021). Nor has any internal input been detected in the lake (Niiranen & Hagman 2012). The data on the water quality of Lappomträsket lake from 2011–2018 (Open data, Hertta database, 15 February 2021) have been collected in Table 9-53.

The oxygen content and oxygen saturation of Lappomträsket lake have remained at an at least satisfactory level. The oxidising carried out in the lake has improved the oxygenation conditions. The lake water has been neutral and its alkalinity – or ability to resist pH changes – has been at a good level. The colour standard number of Lappomträsket lake is typical for humic waters. The total phosphorus content and chlorophyll a concentration are typical of mildly eutrophic waters. The total nitrogen content is characteristic of humic waters. The turbidity of the water describes mildly turbid water. As a shallow lake, Lappomträsket is susceptible to sediment resuspension (mixing of sediment into water) (Niiranen & Hagman 2012). On the whole, the quality of the water is good.

The vegetation of Lappomträsket lake consists of common reed and common club-rush, both of which are helophytes. In front of these is a dense accumulation of broad-leaved pond weed, yellow water lily and water lily (Niiranen & Hagman 2012). Elodeids are represented by perfoliate pondweed and water moss. The broadleaved pond weeds form large growths, as do the yellow water lilies and water lilies. No data has been recorded on the lake's benthic fauna community (Open data, Hertta database, 26 March 2021). There have also been drifting turf rafts in the lake, which are thought to have been formed in the shallow peaty shore areas when the lake's surface was raised in the 1970s (Niiranen & Hagman 2012). The vegetation in the shallow shores of Lappomträsket lake is rooted in the littoral zone's organic soil. Currents have carried the rafts detached from the littoral zone by ice in the winter for short distances around the lake. The impacts of regulation are indeed usually the most visible in the littoral zone.

9.16.3.11 Water resources management and marine strategy

The Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy) aims to improve the quality of surface

Table 9-53. Lappomträsket lake's average water quality in 2011–2018. The samples were taken between January and March as well as in July–August.

July–August				January–March	
	Unit	Average	n	Average	n
Oxygen saturation rate	saturation (%)	88	4	67	4
Oxygen, soluble	mg/l	7.6	4	9.3	4
pH		7.1	3	6.6	4
Alkalinity	mmol/l	0.2	3	0.3	4
Total phosphorus	µg/l	18.7	3	13.7	4
Total nitrogen	µg/l	653	3	757	4
Turbidity	FNU	2.0	3	3.0	4
Electrical conductivity	mS/m	7.3	3	8.5	3
Colour number	mg/l Pt	62	3	96	3
Chlorophyll a	µg/l	6.2	2	—	—

waters so as to attain a good status in all surface waters and groundwaters. The targeted schedule for the attainment of good ecological potential and chemical status was 2015. The attainment of the objective can be postponed until 2027. Among other things, the goals of the Water Framework Directive involve the prevention and reduction of contamination, the promotion of sustainable water use, environmental protection and the improvement of aquatic ecosystems. In practice, the Water Framework Directive covers the littoral zone in sea areas up to one nautical mile from the boundary of a territorial sea.

Finland's Marine Strategy implements the EU's marine policy and the corresponding Marine Strategy Framework Directive (Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy) at the national level. Finland's marine strategy area extends from the shoreline to the outer limit of the exclusive economic zone and is divided over six Baltic Sea basins in line with HELCOM's agreed basin division. The sea area of Loviisa is located within the Gulf of Finland's sea area.

In Finland, the directives have been implemented with the Act on the Organisation of River Basin Management and the Marine Strategy (1299/2004), the Government Decree on Water Resources Management (1040/2006) and the Government Decree on Water Resources Management Regions (1303/2004). The Finnish government approved the water resources management plans for 2016–2021 in December 2015. The water resources management plans include information on the status of the water environment, the pressures to which the environment is subject, the monitoring of the environment's status, and the measures which have been carried out to attain the goals in terms of the status of surface waters. The coastal waters in the Gulf of Finland are subject to the valid water resources management plan for 2016–2021, concerning the water resources management region of the river Kymijoki-the Gulf of Finland, and the proposal for a water resources management plan for 2022–2027 (Karonen et al. 2015, Mäntykoski et al. 2020).

The Programme of Measures for the attainment of a good status of the environment in sea areas was approved by the government in December 2015 (Laamanen 2016). The programme contains a summary of the status of the marine environment (the qualitative descriptors of the sea's good status) and the human-derived pressures on the marine environment. It also includes details on the measures to be carried out to promote the good status of the marine environment.

Finland's water resources management plans and marine strategy are updated every six years. The plans for 2022–2027 have been drawn up, and the hearings on them ended on 14 May 2021. The water resources management plans and the Programme of Measures will be submitted to the government for approval at the end of 2021.

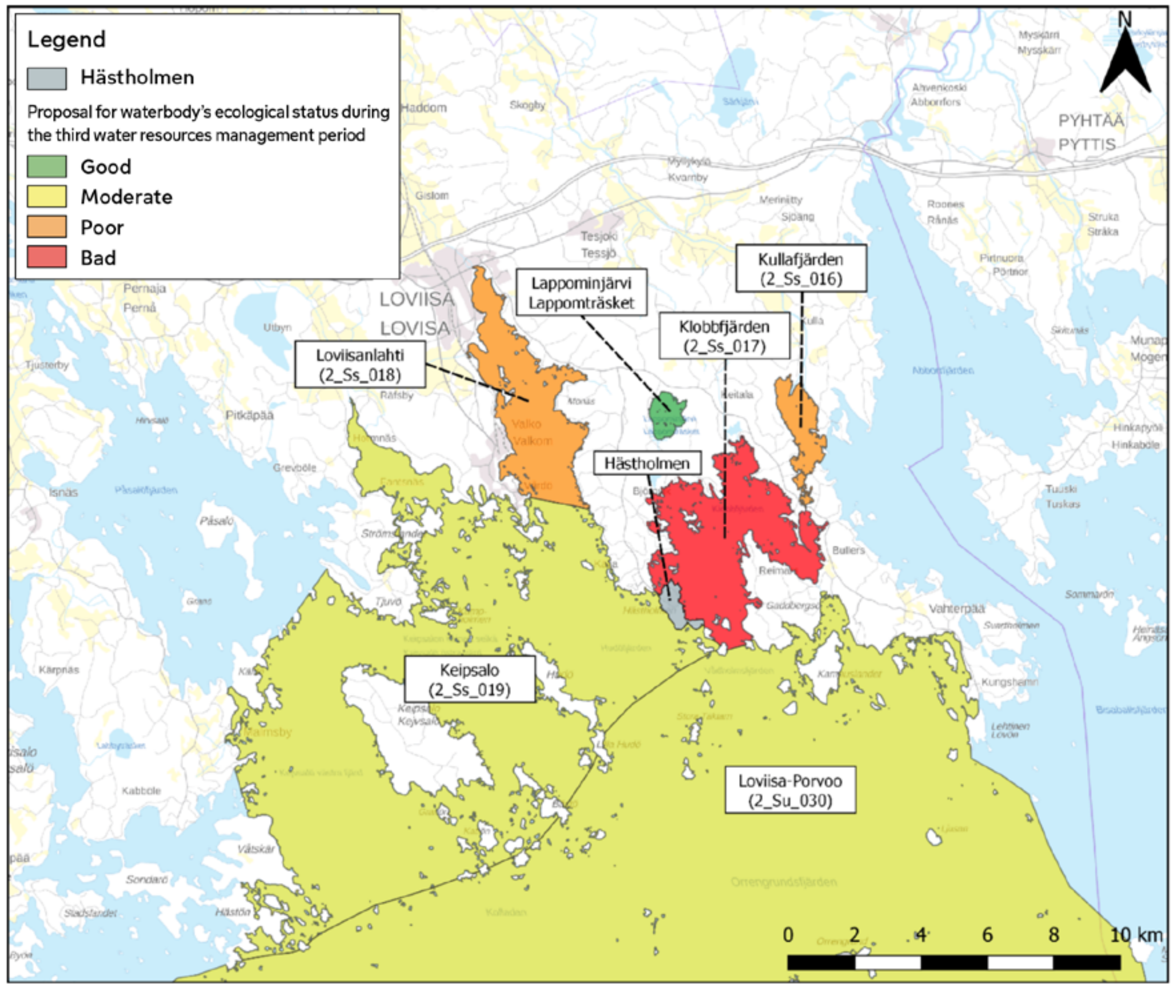

Figure 9-53. A map of the ecological status of surface waters in the bodies of water close to Hästholmen according to the preliminary categorisation of the third planning period of water resources management (SYKE).

A preliminary assessment (the third planning period of water resources management) of the ecological and chemical status of Finland's surface waters has been published (Figure 9-53). According to the assessment, eutrophication is still the biggest problem. The status of the Gulf of Finland's coastal waters has partly improved and is mostly moderate or poor. Nevertheless, the nutrient input continues to be too big and has led to eutrophication, algae blooms and anoxia in the water layer close to the bottom, which has also maintained the internal phosphorus input (Mäntykoski et al. 2020).

The following tables detail the categorisation of the ecological and chemical status of surface waters in Loviisa power plant's nearby sea area and in Lappomträsket lake during the second period of water resources management as well as the preliminary categorisation of the third planning period (Table 9-54 and Table 9-55). The bodies of water in the sea area fall under the surface water type Gulf of Finland's coastal archipelago (Ss) or Gulf of Finland's outer archipelago (Su). Lappomträsket lake is of the surface water type shallow humic lakes (Mh).

None of the sea area's bodies of water in Table 9-54 attained a good status within the original deadline. The grounds for extending the deadline included technical unreasonableness and the superiority of natural conditions. The objective during the third water resources management period is the good status of bodies of water by 2027 (Open data, Hertta database, 3 March 2021).

The area of the **Klobbfjärden** body of water is 15.7 km². Small improvements have occurred in the individual quality factors of the ecological status. Of the biological quality factors, the status of benthic fauna has improved to poor in the preliminary categorisation of the third planning period of the water resources management, and the category of physico-chemical improved from bad to poor. Based on the additional physico-chemical variables (there are no category limits for the variables in question), most of the water column suffers from oxygen depletion or hypoxia every year. In the preliminary status assessment of the third planning period, the ecological status has remained the same as during the previous water resources management periods (Open data, Hertta database, 3 March 2021).

The area of the **Loviisanlahti** body of water is 11.3 km². No significant changes have taken place in the status. Of individual quality factors, total nitrogen has improved from poor to moderate, but there are no changes in the ecological status assessment.

Table 9-54. The ecological and chemical status of the bodies of water surrounding Loviisa power plant during the second planning period of water resources management and a preliminary assessment of the status of the third planning period. Numerical values have been given in terms of the biological and physico-chemical variables. The categorisation data have been retrieved from the Open data Hertta database.

		Biological quality factors					Physico-chemical quality factors				Hydro-morphological change	Ecological status	Chemical status
Body of water		Chloro-phyll a	Phyto-plankton total biomass	Benthic fauna	Bladder wrack minimum sheltered/ open	Biological Category, total	Total phosphorus	Total nitrogen	Depth visibilit	Physico-chemical category, total			
	Water resources management period	µg/l	mg/l	BBI	m		µg/l	µg/l	m				
Klobbfjärden 2_Ss_017	2nd period	10.5	—	0.07	—	Bad	28.7	401.4	2.1	Bad[1]	Good	Bad	Good
	3rd period	9.39	—	0.19	—	Bad	28.6	379.1	2.2	Poor[2]	Good	Bad	Less than good
Loviisanlahti 2_Ss_018	2nd period	13.4	—	—	—	Poor	38.4	486.1	1.3	Poor	Poor	Poor	Good
	3rd period	7.62	—	—	—	Poor	39.6	415.4	1.51	Poor	Poor	Poor	Less than good
Keipsalo 2_Ss_019	2nd period	7.9	—	0.06	2.5/2.8	Poor	26.9	389.4	2.6	Moderate	Excellent	Poor	Good
	3rd period	5.86	—	0.58	1.9/2.6	Moderate	27.8	355,1	2.86	Moderate	Excellent	Moderate	Less than good
Loviisa-Porvoo 2_Su_030	2nd period	6.2	1.1	0.23	3.5/3	Poor	24.4	371.6	3	Moderate	Excellent	Poor	Good
	3rd period	5.73	0.83	0.45	3.4/3.3	Moderate	23.2	339.4	3.4	Moderate	Excellent	Moderate	Less than good

Ecological status	Excellent	Good	Moderate	Poor	Bad
Chemical status	Good	Less than good			

[1] Significant observed oxygen problems
[2] Oxygen problems

Table 9-55. The ecological and chemical status of the Lappomträsket lake body of water during the second planning period of water resources management and a preliminary assessment of the status of the third planning period. Numerical values have been given in terms of the biological and physico-chemical variables. The categorisation data are narrow. The categorisation data have been retrieved from the Open data Hertta database.

Quality factor	Unit	Lappomträsket lake 81V026.1.004_001					
		2nd period			3rd period		
		Numerical value	Ecological status	Chemical status	Numerical value	Ecological status	Chemical status
Chlorophyll a	µg/l	5.6			6.2		
Phytoplankton total biomass	mg/l	3.39			3.17		
Percentage of harmful algae	%	4.38	Good	Less than good	0	Good	Less than good
TPI		0.66			-0.66		
Biological category, total		Good			Good		
Total phosphorus	µg/l	15			24		
Total nitrogen	µg/l	660			740		
Physico-chemical category, total		Excellent			Good		

Ecological status	Excellent	Good	Moderate	Poor	Bad
Chemical status	Good	Less than good			

The ecological status of the **Keipsalo** and **Loviisa-Porvoo** bodies of water has improved from poor to moderate. The improved status is the result of an improvement in the status of the biological quality factors (chlorophyll a and benthic fauna) compared to the earlier categorisation. The area of the Keipsalo body of water is 98.5 km^2 and that of the Loviisa-Porvoo body of water 1,050 km^2.

The category of the physico-chemical quality factors of the **Lappomträsket lake** body of water has declined from excellent to good, but the change is so minor that there has been no change in the ecological status. The chemical status has remained less than good; it is influenced particularly by the quality norm of mercury being exceeded in perch. The mercury derives primarily from atmospheric deposition, which ends up in the waterways as a result of leaching.

The **chemical status** of surface waters has remained largely unchanged, but the strict environmental quality norm of polybrominated diphenyl ethers (PBDE), used as flame retardants, results in a less-than-good chemical status in all of Finland's surface waters. The chemical status has therefore also declined to less than good in the bodies of water within the Loviisa sea area.

In the marine strategy, the current status of the marine environment is assessed in relation to the qualitative descriptors of a good status, of which there are 11 in all. Condensation waters, i.e. cooling waters, are mentioned in connection with two qualitative descriptors of the current status: "permanent changes in hydrographic conditions do not have an adverse impact on marine ecosystems" and "conducting energy into the sea, including underwater noise, is not of a level that would have an adverse effect on the marine environment (energy and underwater noise)". In terms of the qualitative descriptor describing hydrographic conditions, the Programme of Measures states that "the condensation waters of power plants raise the temperature of water locally, which strengthens eutrophication in discharge locations and creates conditions for changes in the species of organisms. New non-native species are often found in the impact areas of condensation waters. These impacts are largely local." In terms of the qualitative descriptor related to the conduction of energy into the sea, it is stated that the impacts are local and extend to a distance of a few kilometres from power plants (Laamanen ed. 2016)

The proposal for the programme of measures for the development and implementation of the marine strategy in Finland 2022–2027 states the following: "Heat is conducted into the sea as a by-product of electricity production in the condensation waters of power plants or within the cooling waters of various processes in the industrial sector. The impacts are usually local and extend to a distance of a few kilometres from the power plant. The impact of the thermal load is so local that it is not found to have an impact on the status of the sea" (Laamanen et al. 2020).

The following table shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4). Table 9-56 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

9.16.4 Environmental impact of extended operation

Impact formation

In extended operation, the operations would continue to be similar to what they currently are. The most significant impact would be attributable to the thermal load on the sea area, which results from the conduction of cooling water there. No changes to the annual level are expected.

The potential impacts of the thermal load are attributable, among other things, to changes in the temperature and stratification conditions of the water close to the discharge location and the longer growing season. The temperature stratification weakens the mixing between the surface and hypolimnion layers as well as the exchange of oxygen and nutrients occurring between the layers. The higher temperature of the seawater may also accelerate the metabolism and growth of the aquatic organisms, increasing the production of organic matter. This being the case, the thermal effect may also contribute to the eutrophication trend, provided that other factors, such as the availability of nutrients or light, do not limit primary production. In addition, the elevated temperature of the seawater accelerates the microbiological degradation of organic matter, meaning that the oxygen consumption may increase hypoxia in the water layer close to the bottom. Hypoxia or anoxia intensify the internal input, which is manifested as high nutrient concentrations in the hypolimnion and is a factor increasing eutrophication. Hypoxia furthermore weakens the living conditions of benthic fauna. In addition to the aforementioned, the potential consequences of eutrophication include the growing abundance of phytoplankton and aquatic vegetation as well as structural changes in the water ecosystem.

Sea areas in which the water temperature remains higher than the natural temperature throughout the year may function as areas receiving non-native species, in which the spread and adaptation of a new species are easier than in sea areas not impacted by the thermal effect.

The impacts on Lappomträsket lake's raw water source are attributable to variations in the water level. Alternative ways to obtain raw water have been reviewed in terms of raw water sourcing.

Table 9-56. Sensitivity of affected aspect: surface waters.

Sensitivity of affected aspect: surface waters	
General factors impacting the sensitivity of surface waters include factors related to the area's value, such as conservation values and the occurrence of protected or sensitive species or underwater natural habitats. The area's resilience is impacted by the environmental factors of the impact area, including the size of the catchment area, the volume of the water area, and the current and mixing conditions. The risk of a deterioration in the ecological or chemical status of a body of water is also considered a criterion increasing sensitivity.	
Moderate	There are no special or sensitive aspects within the immediate vicinity of the **sea area's** impact area which would be impacted by the quality of water and any changes to it, but the near threatened Macroplea pubipennis may be found in the area. The water exchange of the principal affected aspect, the Hästholmsfjärden sea area, is limited by fairly narrow and shallow straits, which weakens the mixing conditions in the cooling water's discharge area. Further offshore, the mixing conditions are more favourable. The ecological status of the bodies of water within the impact area has not attained a good category, although small improvements compared to earlier water resources management periods have been observable. This is considered a factor increasing sensitivity. **Lappomträsket lake** is small in terms of its volume and shallow, which increases the lake's sensitivity. The lake is regulated for the needs of Fortum's raw water intake. The objective for the lake's ecological status has been attained.

9.16.4.1 Results of the cooling water modelling

The thermal load's impact on the sea area's temperatures and water quality was assessed by modelling the dispersal of the cooling water (see Chapter 9.16.2.2 and Appendix 4). The impact of climate change was accounted for in the modelling concerning the ice-free season (summer situation) (Chapter 9.16.2.2). The impacts of the thermal load are also described in the section on the present state in Chapter 9.16.3.3.

In terms of the impacts of the thermal load, it should be noted that the impact is not an aggregating (accumulating) variable, given that heat transfers to the atmosphere continuously during the ice-free season, and that the warmed cooling water mixes with the cooler seawater. The seawater's surface temperature impacts the transfer of heat so that as the water evaporates into the atmosphere, the higher the surface temperature is, the more heat is transferred (An et al. 2017). Heat transfer from the surface via convection likewise increases. This limits the temperature increase resulting from intensified stratification and the maximum temperatures themselves on the surface of the water.

According to the cooling water modelling, the thermal impact of the ice-free season is at its greatest in the immediate vicinity of the discharge location and decreases when moving further away. The average increase in the temperature of the seawater (Figure 9-54) would be roughly similar to its current level. In Hästholmsfjärden, at buoys A, B and C, close

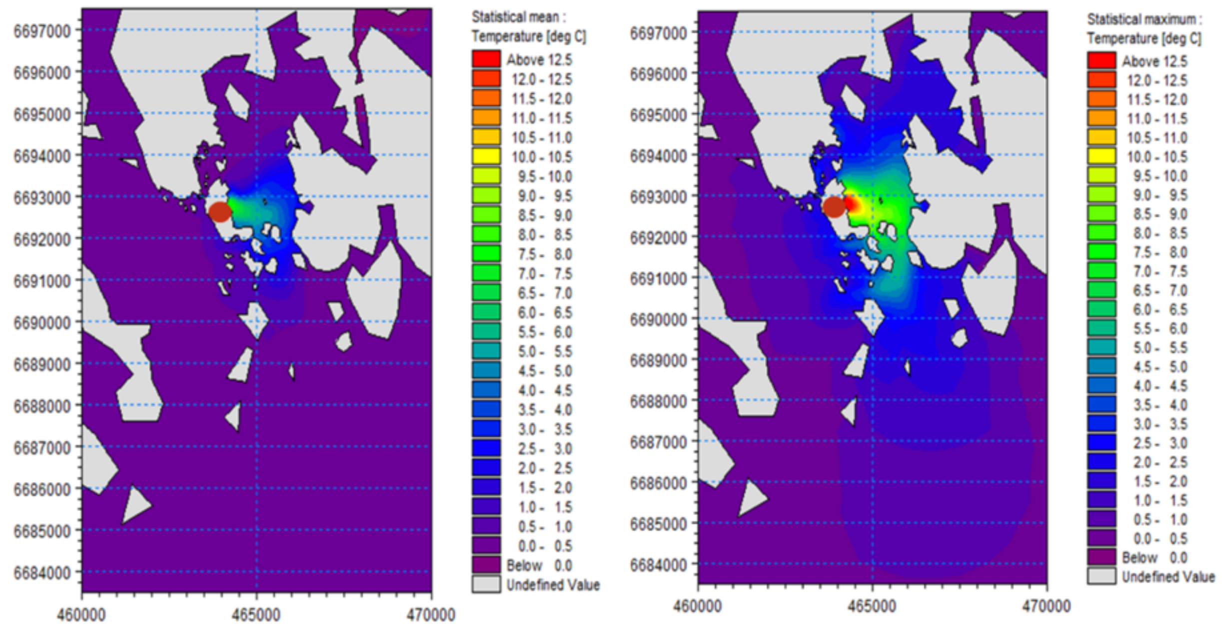

Figure 9-54. Difference image of the temperature increase caused by the power plant's operation in summer (difference: power plant in operation – power plant decommissioned). The image on the left shows the average, and the image on the right the maximum. Hästholmen's location is indicated with a red dot (Lahti 2021; Appendix 4).

to the cooling water's discharge location (see Figure 9-37 for the location of the buoys), the surface temperature of seawater is 1–11 °C warmer than in situations when the power plant is not in operation (Figure 9-54). The range of variation in the surface temperatures is largely explained by changes in the wind conditions, which impact the transport of the cooling water. In Hästholmsfjärden, close to the bottom, the temperature increase occurs gradually over the summer and is approximately 2–3 °C in August.

As can be seen from the images depicting the dispersal, the average surface temperature of the seawater in the immediate vicinity of the discharge location can be around 25–27 °C during a warmer than average summer, and roughly 30 °C in a maximum situation (Figure 9-54 and Figure 9-55). However, the surface temperature rapidly drops when moving further away, given that the surface water is mixed with the rest of the water column horizontally and vertically, and heat is also transferred into the atmosphere. The average surface temperature increases by roughly 2 °C in southern Hästholmsfjärden. In western and northern Hästholmsfjärden, the estimated impact no longer exceeds parts of a degree due to the slow flow of water into these areas. Based on the modelling results, surface water temperature may nevertheless occasionally rise in some of these areas due to the thermal effect of the cooling water, with the maximum increase being 2 °C. When calculated for the Klobbfjärden body of water, the average rise in surface temperature is approximately 1 °C (Lahti 2021; Appendix 4).

Based on the cross-sectional views, the warm water stratifies in the surface layer of the seawater (Figure 9-56), being bounded mainly to the topmost five-metre layer of water in the southern part of Hästholmsfjärden (Lahti 2021; Appendix 4).

In Hudofjärden, at point K1, the temperature is, on average, approximately 0.1–0.9 °C higher than in a situation in which there is no thermal effect attributable to cooling water. The thermal effect in Hudöfjärden is minor and usually limited to the northeastern sea area, close to Hästholmen (Figure 9-54 and Figure 9-55). However, under some weather conditions, the surface temperature can occasionally rise by a maximum of 2 °C in the parts of Hudöfjärden close to Hästholmen.

In Vådholmsfjärden, at point K2 in front of the straits from Hästholmsfjärden, the surface temperature of the seawater can be 0–4.5 °C higher than in a situation where there is no thermal effect attributable to cooling water. Based on the images depicting the dispersal, the most intense thermal effect is focused on the surface layer and limited to the northern part of Vådholmsfjärden, in front of the straits leading there from Hästholmsfjärden (Figure 9-54 and Figure 9-55), where the average increase in temperature is around 2 °C (Figure 9-54). In the southern part of Vådholmsfjärden, the maximum temperature increase is around one degree centigrade. Deeper down, the impact is smaller (Lahti 2021; Appendix 4).

At observation point K3 in Orrengrundsfjärden, the thermal effect on the surface layer is very small. In a small area in the northwestern part of Orrengrundsfjärden, the effect is close to 0.5 °C, the maximum being approximately 1.5 °C at the part leading to Vådholmsfjärden (Figure 9-54) (Lahti 2021; Appendix 4).

According to the modelling, during the ice season in Hästholmsfjärden, at data buoys A, B and C, close to the discharge location (see Figure 9-37 for the location of the

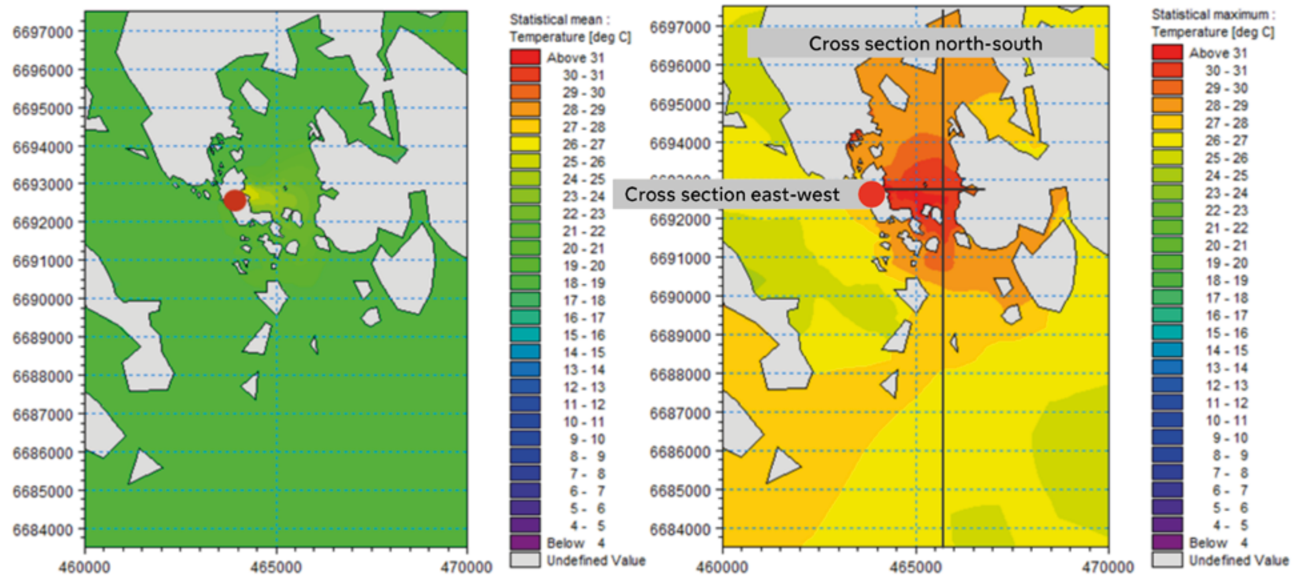

Figure 9-55. Temperature of seawater in the surface layer in the summer, when the power plant is in operation. The image on the left shows the average, and the image on the right the maximum, situation. The locations of the cross sections in the east-west direction and in the north-south direction are indicated in the image on the right (see following image). Hästholmen's location is indicated with a red dot (Lahti 2021).

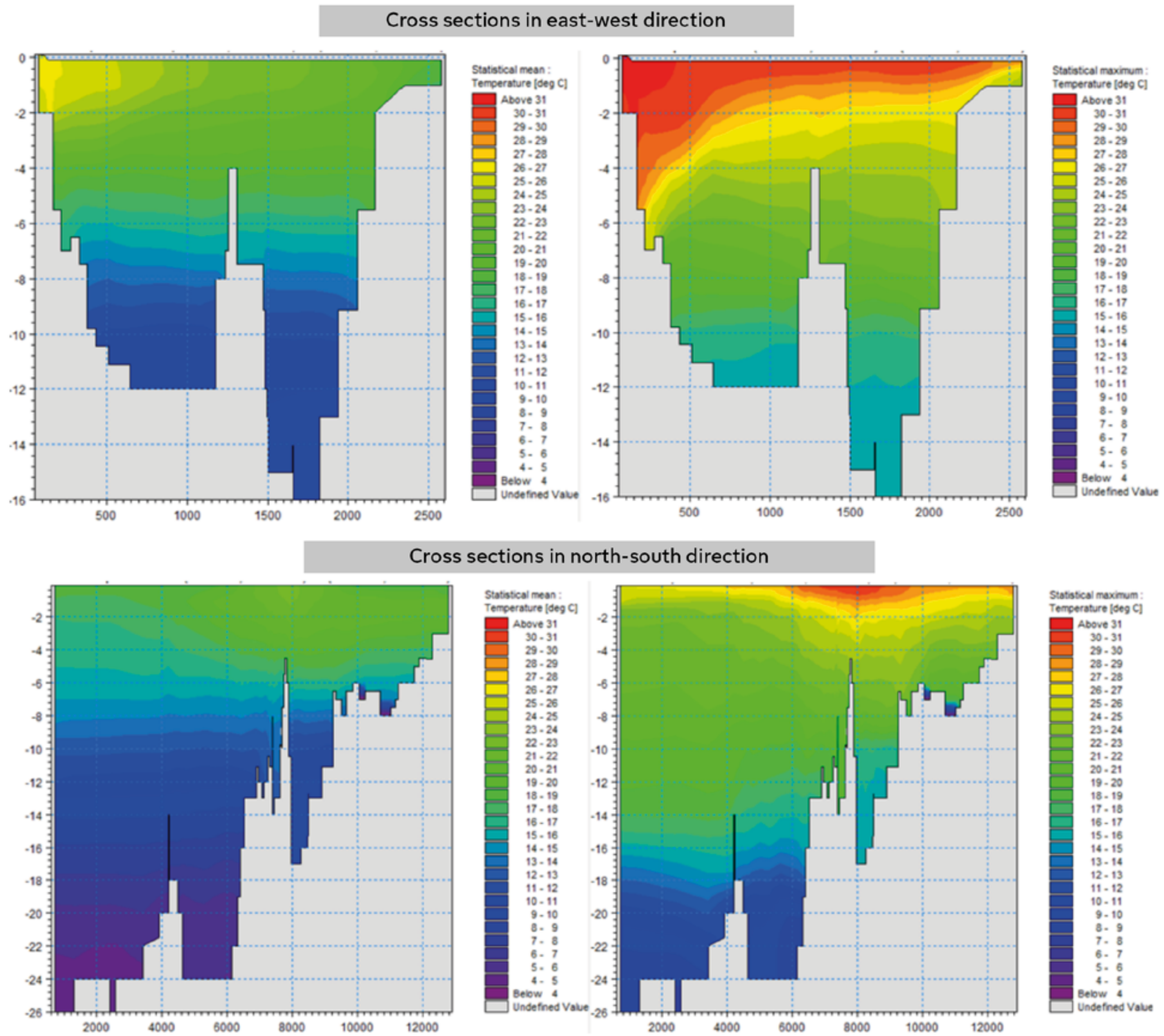

Figure 9-56. The temperature's vertical distribution in the east-west direction (upper image) and in the north-south direction (lower image) in the summer, when the power plant is in operation. The image on the left shows the average, and the image on the right the maximum, situation. In the east-west cross section, the discharge of the cooling water is in the upper left-hand corner of the image.

buoys), the temperature of the seawater is around 5–16 °C, 5–9 °C and 3–5 °C higher at a depth of one metre, four metres and near the bottom, respectively, compared to a situation in which the power plant is not in operation (Lahti 2021; Appendix 4). As can be seen from the images depicting the dispersal, the greatest thermal effect in the winter focuses on the area of Hästholmsfjärden, close to the surface layer (Figure 9-57 and Figure 9-58).

A temperature increase of roughly 0–3 °C attributable to the recirculation of warm cooling water can be detected at point K1 in Hudöfjärden when the power plant is in operation. This increase is primarily confined to a depth of 4–5 m (Lahti 2021).

In Vådholmsfjärden, the temperature increase is focused on the northern part of Vådholmsfjärden, in front of the straits leading there from Hästholmsfjärden (Figure 9-57 and Figure 9-58), where a thermal effect can be seen to varying degrees at all depths at point K2. The thermal effect is at its greatest at a depth of approximately five metres, being around 5 °C higher than in a situation in which the power plant is not in operation. The temperature increase is at its smallest close to the surface (Lahti 2021). In Orrengrundsfjärden, the thermal effect is minor, ranging between 0 and 0.8 °C, and focusing at depths below five metres.

9.16.4.2 Impacts on the sea area's temperature and stratification conditions

The thermal effect on the sea area (57,000 TJ per year, on average) attributable to the conduction of the cooling water used by the power plant would remain of the same annual magnitude as its current level. The impacts would not last beyond 2050 or so, following the expiration of the current operating licences.

During the ice-free season, the thermal effect is local, and mainly observable in Hästholmsfjärden and occasionally in front of the straits between Hästholmsfjärden and Vådholmsfjärden, in the surface layer of the northern part of Vådholmsfjärden. The temperature increase caused by the cooling water would remain unchanged, because no changes are expected to occur in the permit conditions for the temperature and flow of cooling water conducted from the plant to the sea. However, due to the impact of climate change, the probability of warmer than average summers is likely to grow. The selection of an exceptionally warm modelling year therefore offers an opportunity to assess the development in the temperature conditions of seawater in the future, as the climate warms.

The surface temperatures that form during a warmer than average year are slightly higher than the average and maximum temperatures of the ice-free seasons (June–September) in 2010–2020 (Table 9-50). The summer temperatures of 2011 are likely to be fairly typical of the climate conditions in 2030–2050, or at least significantly more common than at the beginning of the 2010s. The modelling results of the review period therefore provide an idea of the seawater temperatures during the middle of this century. A rise in surface temperatures may also have an impact on the discharge of cooling water in the future. According to Loviisa power plant's environmental permit, the hourly average temperature of the cooling water conducted to the sea may not exceed 34 °C. In other words, when the temperature of the cooling water taken from the sea rises to a degree where the power plant's power must be limited for the temperature of the discharged cooling water to remain below 34 °C, the relative share of the power plant's thermal effect will also reduce.

According to the assessment based on the modelling, the temperature and stratification conditions during the ice-free season would remain largely unchanged from their current levels. In the present state, the seawater's temperature and stratification conditions in the discharge side are significantly shaped by the thermal effect of the cooling water, but the effect is primarily confined within the area of Hästholmsfjärden, in which the thermal effect has intensified the vertical temperature stratification (Chapter 9.16.3.3).

During the ice season, the thermal effect would remain unchanged from its current level, and the extended operation would not result in a significant change. In terms of the present state, it should be noted that particularly the temperature and stratification conditions of Hästholmsfjärden clearly depart from the natural conditions. The thermal load's impact on the nearby sea area is the easiest to detect in wintry conditions, when the warm cooling water keeps the sea area close to the discharge location free of ice.

As the section concerning the present state describes (Chapter 9.16.3.4), climate change is expected to reduce the area of the Baltic Sea's ice cover and shorten the ice winter (Climate Guide 2021). The variation between winters is nevertheless expected to remain a natural feature of ice conditions. The ice cover is effective in preventing the thermal energy from transferring to the atmosphere, once the cooling water has sunk more deeply and passed beneath the ice. During mild winters, when the area covered by ice is small or there is no ice at all, the thermal effect of the cooling water will be proportionately smaller, and the warm water will not disperse to as large an area as described above. On the other hand, the thermal effect of the cooling water and the impact of climate change may result in a mild combined impact in the future, due to which the area covered by the ice may reduce slightly, and the ice may become thinner than its present level, disrupting movement on the ice, for example.

The impact of the thermal effect is local, mainly confined within the area of Hästholmsfjärden and partly maintaining the temperature and stratification conditions in the nearby sea area of Hästholmen. The impact further out in the sea area is minor. The temperature increase caused by the thermal load would be of the same magnitude as in the present

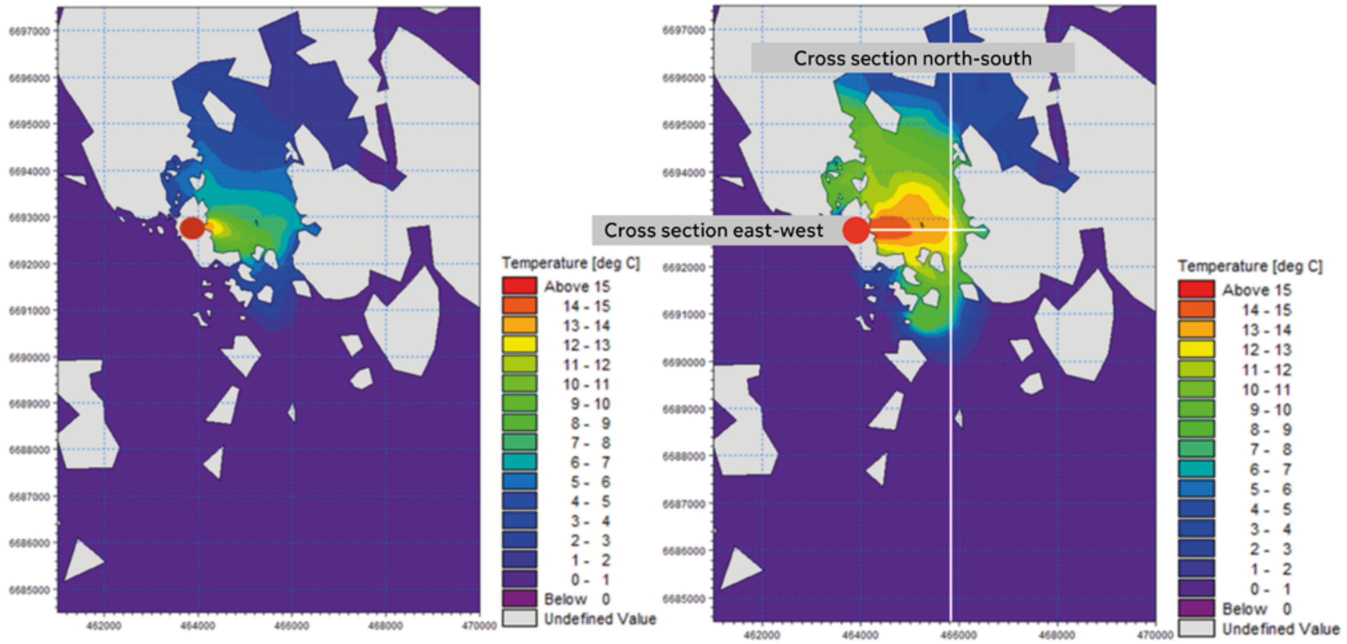

Figure 9-57. Temperature of seawater in the surface layer in the winter, when the power plant is in operation. The image on the left shows the average, and the image on the right the maximum, situation. The locations of the cross sections in the east-west and north-south directions are indicated in the image on the right (see following images). Hästholmen's location is indicated with a red dot (Lahti 2021).

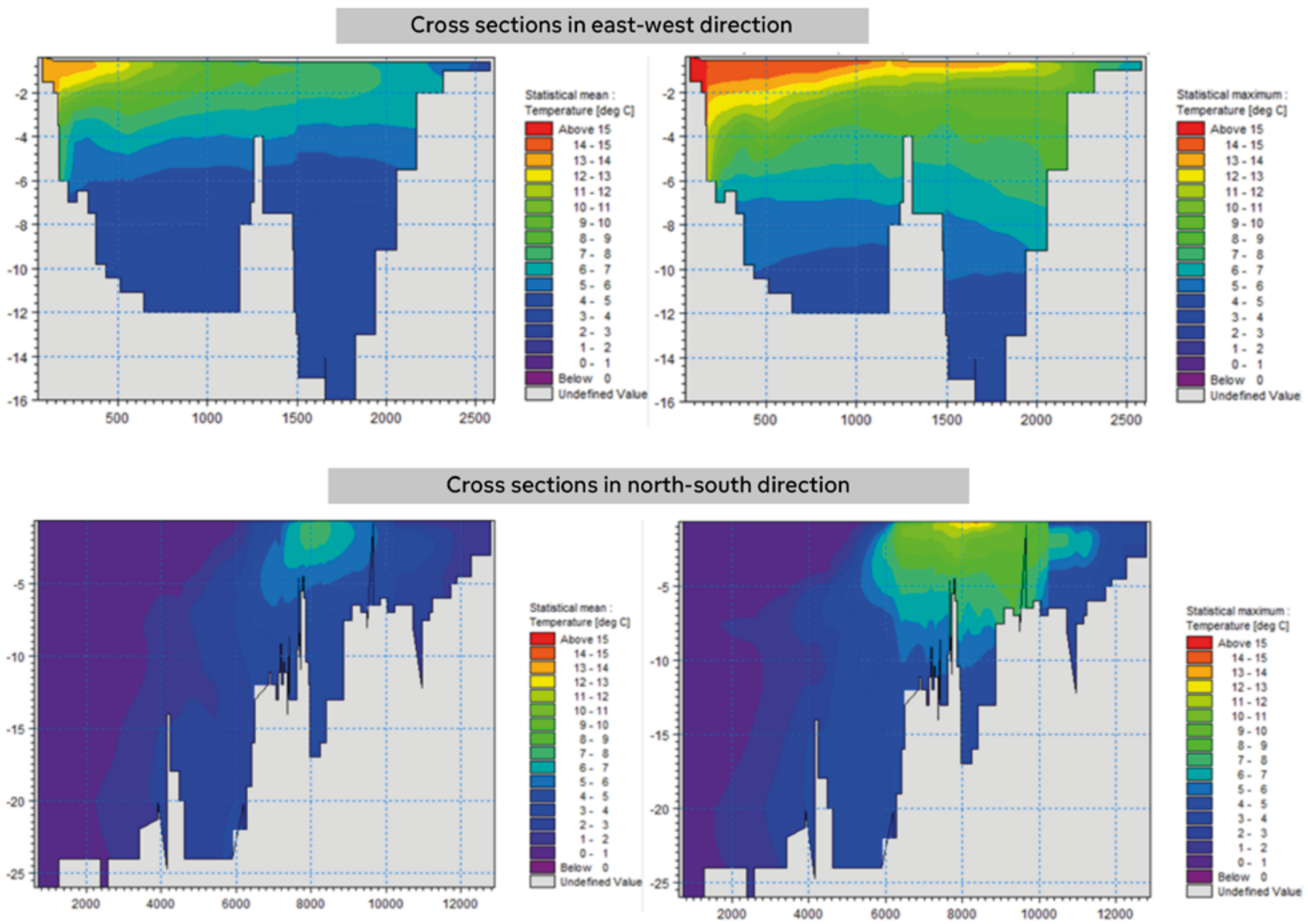

Figure 9-58. The temperature's vertical distribution in the east-west direction (upper image) and in the north-south direction (lower image) in the winter, when the power plant is in operation. The images on the left show the average, and the images on the right the maximum, situation. In the east-west cross section, the discharge of the cooling water is in the upper left-hand corner of the image.

state, but an increase in the number of warmer-than-average years may translate in the coming decades into a slight increase of the seawater's surface temperature compared to the present state. An increase in the number of mild winters may impair the sea area's use in the winter to a minor degree, due to the weaker ice cover. In extended operation, the thermal load would maintain atypical temperature and stratification conditions that would be more intense than the natural ones in Hästholmsfjärden. These would continue for some 20 years following the expiration of the current operating licences, until around 2050 at the latest. Based on this, the magnitude of the change compared to the present state was deemed moderate and negative in Hästholmsfjärden, and at most minor and negative in the other nearby sea areas.

9.16.4.3 Impacts on the quality of water

The impacts on the temperatures and stratification of the sea area described above also have an impact on the water quality. The Gulf of Finland's general eutrophication trend is visible in the sea areas near Loviisa power plant, where distinguishing the thermal effect from the general eutrophication is challenging. Based on the long-term monitoring of the nearby sea area of Loviisa, it is known that the warmed seawater has contributed to a strengthening of eutrophication attributable to an excessive nutrient input within the thermal effect's impact area, especially in Hästholmsfjärden. Climate change increases the mean annual temperature, which is expected to increase the diffuse source input of nutrients. The impact assessment must therefore account for the impact that climate change will have on the development of the nutrient pollution.

In the case of extended operation, the power plant's wastewater discharges would remain unchanged. The impact of radioactive emissions is assessed in Chapter 9.8. In terms of nutrient pollution, Loviisa power plant's share of the sea area's other point source pollution and diffuse pollution would continue to remain very low (Chapter 9.16.3.2). Currently, the sanitary wastewaters are treated in the power plant area's wastewater treatment plant and conducted to Hudöfjärden. In the case of extended operation, the continued use of the power plant area's wastewater treatment plant for the treatment of the sanitary wastewaters is one alternative. Another alternative to the current method for treating sanitary wastewaters is being considered as part of the possible change in the procurement of service water. In this alternative, the sanitary wastewaters would be conducted to the town of Loviisa's (Loviisan Vesiliikelaitos) Vårdö wastewater treatment plant, in which case the impact would still focus on Hudöfjärden, but on a different location within it. The potential change would not have an impact on the input which, in the power plant's case, is extremely low in relation to the other input sources. The input's impact on the sea area's water quality is expected to be extremely small.

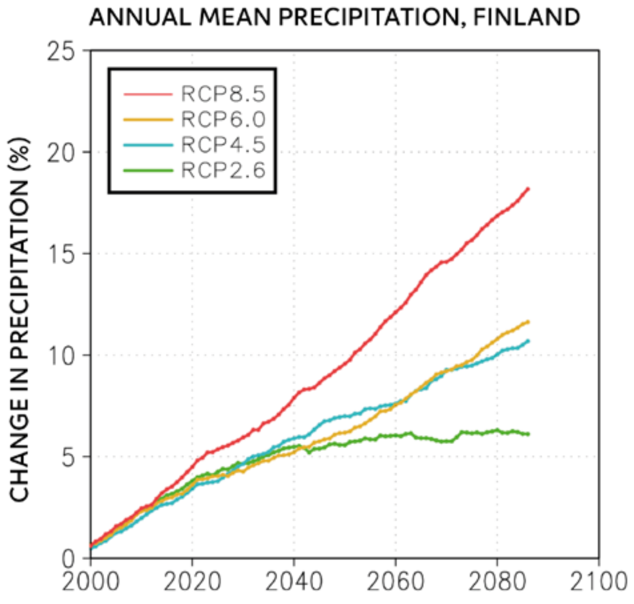

Figure 9-59. Change in annual precipitation in Finland in 2000–2085 compared to the average of 1981–2010 (as percentages). The changes are averages of the results of 28 global climate models presented separately for four greenhouse gas scenarios (RCP8.5: very high emissions; RCP6.0: comparatively high emissions; RCP4.5: comparatively low emissions; and RCP2.6: very low emissions) (Climate Guide 2021, Ruosteenoja et al. 2016).

Climate change is expected to increase the nutrient pollution of waterways in general and thereby eutrophication, given that the lack of snow on fields is likely to increase the leaching of nutrients – phosphorus and nitrogen – into waterways in the winter (Mäntykoski et al. 2020). This is the result of increased precipitation and increasingly strong rainstorms as the climate warms (Climate Guide 2021, Ruosteenoja et al. 2016) (Figure 9-59). An increase in run-offs and rainstorms is also likely to increase nutrient pollution in forests, since a significant part of the nutrients of forested land leach into waterways during floods. The coastal regions of southern and southwestern Finland are expected to experience the greatest impact of the increased input (Mäntykoski et al. 2020).

The watershed model assesses various input scenarios in relation to different RCP scenarios (see Chapter 9.16.2.2 for descriptions of the RCP models) and the agricultural sector's water protection measures. In the period 2021–2050, the total phosphorus input in the Gulf of Finland is expected to grow slightly (by approximately 1.5–72 t per year) compared to 2010–2019 in climate scenarios in which current water resource management measures would be in use. "Current measures" refers to agriculture continuing as at present, and other input sources remaining at the current level. Were the agricultural measures applied in full, the input is expected to decline (depending on the climate scenario, the decrease would be in the range of 50–134 t per year). In addition to applying gypsum to agricultural fields, "agricultural measures" refers to the adoption of focused fertilisation, a maximum quantity of wintertime plant cover, catch crops, structural liming/fibre treatment and slurry placement, while the cultivation areas and yields of various crops would remain similar to their current levels. In the watershed model scenario, the attainment of the targeted input of phosphorus with current measures is unlikely, but with the full-scale adoption of the agricultural measures, the targeted input could be attained (VEMALA, data retrieved 3 March 2021).

According to the watershed model, the Gulf of Finland's nitrogen input would appear to decrease in the 2021–2050 period in the scenario in which the agricultural measures are in full-scale use (a decrease of approximately 400–1,570 t a year). With the current measures, the input would grow slightly in the RCP scenarios RCP4.5 (intermediate climate change scenario) and RCP8.5 (strong climate change scenario) (VEMALA, data retrieved 3 March 2021).

The phosphorus and nitrogen inputs off shore of Loviisa are likely to remain around the current level for the 2021–2050 period in climate scenarios in which the current measures are in use. If the agricultural measures are applied in full, the input is likely to decline (VEMALA, data retrieved 3 March 2021).

Climate change and the resulting warming of the Baltic Sea could also have other impacts on the marine ecosystem. Changes in the severity of winter affect the mixing of water in the winter and thereby the spring conditions. In ice-free winters, significant amounts of the phosphorus in a halocline in the Baltic Proper and in the Gulf of Finland may mix with the water column above during winter storms. Strong blue-green algae blooms may emerge if there are calm and warm periods during the following summer, as was the case in 2014 and 2018. This stock of nutrients, mainly located in the deep water of the Baltic Proper, will also slow down any improvement in the status of the Gulf of Finland, even if the external nutrient pollution is cut, given that the Gulf of Finland's sea area falls under the sphere of influence of the anoxic waters in the Baltic Proper. Any upwelling events caused by wind also transport nutrient-rich water into the surface water which, under favourable conditions, intensifies algal blooms. A decrease in the number of revitalising major Baltic inflows, combined with a high level of primary production and the consequential abundant sedimentation of organic matter, has led to a situation in which there was more hypoxic water across the entire Baltic Sea in 2018–2020 than ever before during the measurement history (Laamanen et al. 2020).

Based on the monitoring, the changes that have taken place in the status of the Gulf of Finland are also reflected in the state of the power plant's nearby sea area. For example, the impact of the major Baltic inflows in 2014–2016 was visible in the 2018 results of the Loviisa waterway monitoring as an increase in the chlorophyll a concentration and primary production (Anttila-Huhtinen & Raunio 2019).

In extended operation, the quality of water in Loviisa power plant's nearby sea area is expected to remain close to the present state (see Chapter 9.16.3.5). However, the long-term projections of the nutrient pollution involve uncertainties attributable to the uncertainty related to the materialisation of climate change scenarios and particularly to the extent to which and how fast the measures reducing agricultural pollution will be implemented in the catchment area of the Loviisa coast. What is especially significant with respect to the status of the Klobbfjärden body of water is the long-term development of the input carried by the river Tesjoki. As was stated in terms of the thermal load (Chapter 9.16.4.1), an increase in the number of warm summers in the long term as a result of climate change, coupled with the thermal load of the cooling water, may increase the thermal effect in the sea area to a minor degree. According to the modelling, the impact would be most significant in Hästholmsfjärden. Should nutrient pollution simultaneously increase, Hästholmsfjärden's water quality would be subject to a combined impact, given that the thermal effect is known to contribute to a strengthening of the eutrophication trend resulting from excessive nutrient pollution. The impact on the water quality would probably be manifested as a slightly rising trend in nutrient pollution in long time series. The oxygenation conditions in the hypolimnion of Hästholmsfjärden's deeper areas would continue to be weak, enabling the potential occasional continuation of the internal input of phosphorus.

On the other hand, if all the agricultural measures are adopted, nutrient pollution would probably reduce, and eventually result in the decline of nutrient concentration in the sea area and a decrease in the production level, which would reduce the oxygen-consuming effect of organic matter in the water layer close to the bottom, thereby improving the oxygen conditions. This scenario is expected to have a positive impact in the Klobbfjärden body of water. Potential changes in the quality of water are reflected in the food web with a delay. These impacts are discussed in the following chapters.

In extended operation, the impacts would not continue beyond the 2050s, but the changes compared to the present state are expected to be minor. The materialisation of the climate and input scenarios introduces uncertainty to the assessment. The magnitude of the change in the water quality compared to the present state is deemed, in extended operation and accounting for the precautionary principle, minor and negative in Hästholmsfjärden (in the Klobbfjärden body of water). In the other sea areas, the water quality is determined primarily on the basis of the long-term development of the nutrient pollution and the general development in the status of the Gulf of Finland, and the water quality is not expected to be impacted.

9.16.4.4 Impacts on phytoplankton and aquatic vegetation

The impacts on phytoplankton and the aquatic vegetation are indirect and partly attributable to a potential change in the quality of water. Based on the water quality assessment, the impacts are expected to remain more or less similar to their current levels (see Chapter 9.16.3.6 and 9.16.3.7). Based on the long time series, eutrophication has been slightly stronger in the area of Hästholmsfjärden than in the other sea areas close to the power plant. Several annual filamentous algae and vascular plants, among others, have benefited from the warmed water and longer growing season, whereas some aquatic plants sensitive to the deterioration of water quality have declined (see Chapter 9.16.3.7). The strongest eutrophication is seen at a roughly 1 km radius of the cooling water's discharge location (Ilus 2009).

Ice winters are projected to shorten from both ends over the long term as a result of climate change, but the freezing period will change more than the date on which the ice melts (Climate Guide 2021). In the present state, ice winters in sea areas near Hästholmen have been varying, ranging from nearly ice-free winters to more severe ones. This variation is expected to continue over the long term, and the combined impact of the thermal effect of the cooling water and climate change is not expected to impact the length of the growing season in the power plant's nearby sea area compared to the present state.

A possible minor weakening of water quality in Hästholmsfjärden (see Chapter 9.16.4.2) may increase the production of phytoplankton and aquatic vegetation to a minor degree, which would be manifested as a slight increase in the chlorophyll a concentration and primary production as well as in the aquatic vegetation becoming more abundant. Ilus (2009) has suggested that changes in primary production at Hästholmsfjärden are best explained by the water's temperature, followed by the depth visibility and total phosphorus. The blue-green algae binding nitrogen from the atmosphere can furthermore benefit from potential warming, because their optimal temperature is slightly higher than that of other groups of species. Nor is the production of the algae groups in question as dependent on the water's nutrient concentration, as many other groups of species are. The long-term development depends partly on the materialisation of climate change scenarios and measures that reduce inputs, and the input carried to the sea area may also decline in the long term if the agricultural measures are adopted on a wide scale. This is expected to have positive impacts, given that the declining amount of nutrients will reduce the production of phytoplankton and prevent aquatic vegetation from becoming more abundant. In this scenario, the impacts would be manifested as a decline in the production level (a reduction of primary production and in the chlorophyll a concentration as well as in the biomass of filamentous algae). The impact assessment concerning primary production and the phytoplankton community nevertheless involves uncertainty, given that the complex interactive relationships of the food web – including the regulation of the consumers (zooplankton, fish) – could not be accounted for in this assessment.

Due to the uncertainties, a detailed assessment of the impacts on phytoplankton and aquatic vegetation is difficult. In the case of extended operation, the impact on the aquatic vegetation and phytoplankton is expected to be local and primarily confined to the Hästholmsfjärden sea area in the Klobbfjärden body of water. In the rest of Loviisa's nearby sea area, the impacts are determined on the basis of the long-term development of the nutrient pollution and the general development in the status of the Gulf of Finland.

The magnitude of the change concerning phytoplankton and the aquatic vegetation is deemed, compared to the present state and accounting for the precautionary principle, minor and negative in Hästholmsfjärden, given that the impacts will not continue beyond the 2050s in extended operation. The other sea areas are not expected to be impacted.

9.16.4.5 Impacts on benthic fauna

The impacts on the benthic fauna are indirect and attributable to the sea area's temperature and stratification dynamics as well as a potential change in water quality (Chapters 9.16.4.1 and 9.16.3.8). Based on the monitoring, the power plant's thermal effects are local and impact mainly Hästholmsfjärden's benthic fauna, the status of which has been, alongside the rest of the nearby sea area, largely poor during the 2000s. The most significant factors on the discharge side are expected to consist of the stratification conditions departing from their normal levels, which weakens the aeration of the hypolimnion, and the oxygen consumption resulting from eutrophication, which has resulted in hypoxia in the deeper seabed. The seabed has also been in poor condition on the intake side of the cooling water, meaning that the status of the benthic fauna has also been impacted by the Gulf of Finland's general eutrophication.

In the sea area further offshore, the status of the seabed has been impacted more by the development of the general status of the Gulf of Finland, which was visible as a strong decline in the benthic fauna communities of the deeps following the major Baltic inflows of the early 1990s, for example. In the sea area further offshore, the status of the benthic fauna seems to have improved slightly in recent years.

Based on the quality of water, no significant changes are to be expected in the long term. The aforementioned combined impact of nutrient pollution and the thermal effect, the materialisation of which involves uncertainty, may impair the oxygen conditions locally to some extent. This is attributable to an increase in the production level, which increases the amount of oxygen-consuming organic matter sinking to the bottom. On the other hand, the impacts may also be positive and depend on the materialisation of the climate and input scenarios. The potential impact is primarily focused on the deeps in Hästholmsfjärden.

Sea areas in which the water temperature remains higher than the natural temperature throughout the year may function as areas receiving non-native species, in which a new species' spread and adaptation to the new habitat is easier than in sea areas not impacted by the thermal effect. The risk of new spreading is greater in such environments. Based on the monitoring, there are currently nine species defined as non-native in the sea area near Loviisa, of which the bay barnacle, brackish hydroid and dark false mussel cause biofouling by forming growths in Loviisa power plant's seawater systems. Of these three species, the dark false mussel finds the thermal effect particularly beneficial. In terms of non-native species, the status is expected to remain similar to its current level, but projecting the spread of potential new non-native species is difficult. For example, according to HELCOM's assessments, the spread of non-native species has reduced somewhat in 2011–2016 compared to 2000–2010, but remains higher than the goal (State of the Baltic Sea – holistic assessment: non-indigenous species). A total of 12 non-native species, most of which were crustaceans, spread to the Baltic Sea area in 2011–2016. Non-native species in terms of icthyofauna are discussed in Chapter 9.17.

In extended operation, the thermal load would continue for approximately 20 years following the expiration of the current operating licences, at most until circa 2050, and maintain temperature and stratification conditions departing from the natural in the nearby sea areas of Hästholmen. These conditions have also contributed to the status of the benthic fauna in the area. A continuation of the thermal effect will increase the risk of the spread of non-native species. Changes in the benthic fauna are likely to be minor, but due to the long-term nature of the impacts, the magnitude of the change, compared to the present state, is expected to be at most moderate and negative in Hästholmsfjärden and at most minor in Hudöfjärden and Vådholmsfjärden. The other nearby sea areas are not expected to be impacted.

9.16.4.6 Impacts on sediment (harmful substances)

The impact of radioactive emissions is assessed in Chapter 9.8. The process water and wastewater discharges of Loviisa power plant do not impact the quality of the sediment.

The elevated dioxin and furan content found in the sediment are typical of river basins in the eastern Baltic Sea and the river Kymijoki due to the area's industrial history. Harmful dioxins and furans are generated inadvertently in various industrial processes, including waste incineration and chemical production. Correspondingly, compounds containing TBT were formerly used in the primers of vessels, for example, to prevent organisms from attaching themselves to the hulls, and in agriculture, as an anti-mildew agent for seeds (Lindfors et al. 2020).

The water engineering projects in front of the intake location of Loviisa power plant and the nearby sea area, mentioned in the EIA Programme, are no longer being planned, due to which there will be no impact on the sediment.

The quality of the sediment in Loviisa power plant's nearby sea area is not expected to be impacted.

9.16.4.7 Impacts on Lappomträsket lake

According to plans, the power plant's service water will continue to be taken from Lappomträsket lake, either entirely, as today, or partially, in which case part of the intake of water from Lappomträsket lake will be replaced by the procurement of other service water. The plans for the sourcing of service water are presented in Chapter 4.3. If the service water is sourced from elsewhere, the power plant's current raw water supply system and water treatment plant would, for reliability purposes, remain in the power plant's process and domestic water use, and the lake would continue to be regulated.

The status of Lappomträsket lake is currently good and is not expected to be subject to any special pressures. The impacts would remain unchanged in both water supply options. The lake's water level has remained stable and close to the upper level of regulation in recent years. Should the intake of water reduce, the water level will be regulated with a regulating dam. The regulation maintains a greater-than-natural dilution volume, or volume into which the nutrient pollution entering the lake mixes. In addition, the oxidising has improved the lake's oxygenation conditions.

In extended operation, the intake of water would continue for roughly 20 years, until around 2050 at the latest. Neither the water intake nor the water supply option is expected to have an impact on the lake's present state.

9.16.4.8 Impacts on ecological and chemical status as well as on marine strategy

The impacts on the quality of water and the water environment (phytoplankton, aquatic vegetation, benthic fauna) are assessed above. The ecological and chemical status of Klobbfjärden and the outer bodies of water is presented in Chapter 9.16.3.11.

The power plant's cooling water is discharged into the Klobbfjärden body of water. The ecological status of the Klobbfjärden body of water has been deemed bad. The status is partly attributable to the thermal effect of the cooling water, which has intensified the impacts of the eutrophication trend in the body of water. In practice, the thermal effect has no impact on the ecological status of Loviisa sea area's other bodies of water, which are mainly impacted by changes in the general status of the Gulf of Finland. In the vicinity of the discharge location of the cooling water, the quality of water and biological status of the water area are expected to remain similar to what they currently are or to at most weaken slightly as a result of the combined impact of climate change and the thermal effect. The long-term development of the ecological status will also depend on the development of the diffuse source input. In extended operation, the impacts would continue for roughly 20 years, during which the magnitude of the change on the water quality and water environment is expected to vary between minor or moderate and negative in the vicinity of the cooling water's discharge location in the Klobbfjärden body of water (Chapters 9.16.4.2–9.16.4.4).

The assessment of the impacts on the biological and physico-chemical quality factors involves uncertainty, which derives from the length of time reviewed, the uncertainty related to the long-term projections of climate change and

Table 9-57. The changes that occurred in the status of the biological and physico-chemical quality factors between the second and third planning period, and an assessment of how the status of the waterbodies can develop over the long term and how the implementation of the extended operation option would impact the ecological status.

Biological quality factors	Physico-chemical quality factors	Assessment on the potential development directions of the ecological status
Klobbfjärden body of water		
The decrease in the chlorophyll a concentration has been minor. The BBI of the benthic fauna indicates a tolerable status, but has varied a great deal and indicated a bad status in the second period. The biological category has remained bad. To attain a good status, the chlorophyll a concentration, for example, should decrease by approximately 6 µg/l, which is a significant decrease in relation to the changes observed during the water resources management periods (Table 9-54).	The status of total phosphorus and total nitrogen is moderate. The numerical value of phosphorus is close to the boundary of a poor status. The physico-chemical status has improved to poor. Additional physico-chemical variables: hypoxia occurs regularly up to the thermocline.	For its part, the thermal load has shaped the temperature and stratification conditions of the body of water and intensified the eutrophication trend. The status is also influenced by the general development of the Gulf of Finland's status and, more locally, the development of the river Tesjoki's quality of water. The development of the waterbody's status is a sum of many different factors, and in the long term, it is influenced by the materialisation of climate change scenarios and agricultural measures, among other things. It is unlikely that the body of water will attain a good status by 2027, because the responses to the changes are slow. In the long term, approaching the 2050s, the status is not expected to be subject to a significant change, but nor can a minor deterioration of the status be ruled out. Based on the assessment, the categories of benthic fauna and total phosphorus are at risk of deterioration if efforts aiming to curb the diffuse source input fail. On the other hand, if the agricultural measures are adopted on a wide scale in the catchment area of the river Tesjoki, the status of the Klobbfjärden body of water is likely to improve. The materialisation of the climate and input scenarios introduces uncertainty to the assessment. *For its part, the continuation of the thermal effect for approximately 20 years, until around 2050 at the latest, may slow down the waterbody's attainment of a good status.*
Loviisanlahti body of water		
The chlorophyll a concentration has decreased considerably and is approaching a moderate status.	Of the total nutrients, the phosphorus content has increased slightly, but is not at risk of dropping to a bad status. The nitrogen content has declined significantly and is moderate.	The impact of the thermal effect does not extend to the body of water. The power plant's significance as a point source is minor compared to other point source and diffuse source inputs, and a possible change in the conduction of wastewaters is not expected to have an impact on the ecological status of the body of water. The status of the body of water is influenced, above all, by the development of the area's other input. *Extended operation would not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Keipsalo body of water		
The biological status has improved to moderate as a result of an improvement in the categories of chlorophyll a and the benthic fauna.	Of the quality factors concerning the physico-chemical status, the numerical values of total nitrogen and depth visibility have improved slightly, but the category has remained unchanged.	The ecological status of the body of water has improved to satisfactory. The intake side of the cooling water is located in the body of water, and the cooling water's recirculation, which extends to the north-eastern part of Hudöfjärden and causes a slight increase in temperature, covers only a small section of the waterbody's area. The significance of the nutrient pollution caused by the power plant is minor. Above all, the status of the body of water is influenced by the development of other inputs (including the river Loviisanjoki) and the general development of the Gulf of Finland's status. *Extended operation would not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Loviisa-Porvoo body of water		
The ecological status of the body of water has improved to moderate.	Of the quality factors concerning the physico-chemical status, the numerical values of total phosphorus, total nitrogen and depth visibility have improved slightly, but the category has remained unchanged.	The ecological status of the body of water has improved to satisfactory. The most intense thermal effect of the cooling water focuses on the surface layer in the northern part of the body of water (in Vådholmsfjärden, in front of the straits of Hästholmsfjärden). The impact area is small compared to the area of the body of water. The status of the body of water is influenced, above all, by the development of other inputs and the general development of the Gulf of Finland's status. *Extended operation would not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Lappomträsket lake body of water		
There have been no changes in the biological category.	The numerical values of the total phosphorus and total nitrogen quality factors have increased slightly, but the categories have not changed. The physico-chemical status was deemed good, whereas in the previous period, it was excellent.	There has been no change in the ecological status. According to plans, the intake of service water will continue as it is now/decrease. The intake of water is not expected to impact the lake's present state (quality of water). *Extended operation would not put the good status at risk.*

diffuse source input, and the food web's complex interactive relations. Table 9-57 presents assessments of the potential development paths of the waterbodies' ecological status. Based on the assessment, the continuation of the thermal effect in the optioncase of extended operation would contribute to maintaining the weakened status of the Klobbfjärden body of water, which is not expected to improve significantly in the long term. Without the thermal effect of the cooling water, the waterbody's ecological status would probably fall under the same category as the other inner bay areas within the Gulf of Finland in the preliminary categorisation of the third planning period of the water resources management.

The proposal on the programme of measures for the Uusimaa water resources management (Ahokas et al. 2020) mentions the planning and implementation of the eutrophied bay's rehabilitation as a measure of the Klobbfjärden body of water. Furthermore, the programme states, in terms of the Klobbfjärden body of water, that measures for the operation, maintenance and increased efficiency of plants will be presented to the industrial sector during the third planning period. The need to intensify the protection of the waters will be assessed in connection with the review of the environmental permits. The measure includes the operation of industrial facilities subject to a licence so that the operating level remains at least at the level of the initial phase of the planning period about to begin (the third planning period of water resources management), meeting the licence regulations.

The proposal concerning the 2022–2027 water resources management plan of the water resources management region of the river Kymijoki-the Gulf of Finland (Mäntykoski et al. 2020) states that, for a justified reason, the attainment of the objective may be delayed beyond 2027, but that all of the measures should be underway by then. The proposal points out that the postponement of the objective can only be justified by the slowness of the change occurring in the natural conditions, waterways and biota.

In the proposal for the programme of measures for the development and implementation of the marine strategy in Finland 2022–2027, the impacts of a thermal effect are considered local, and they are not expected to have an impact on the sea's status on a wider scale (Laamanen et al. 2020).

9.16.5 Environmental impact of decommissioning

Impact formation

The power plant will be in operation during the expansion of the L/ILW repository, and the impacts on the surface waters (the most significant of them being the thermal effect of the cooling waters) will remain unchanged, as described in Chapter 9.16.4.

Construction waters will be generated during the L/ILW repository's expansion. These are composed of the water used in the excavation and the waters filtering into the repository. The water conducted to the sea contains soluble nitrogen (ammoniacal nitrogen) derived from explosives and small quantities of solids. The oxidation of the ammoniacal nitrogen may increase the oxygen consumption of the receiving waterway. Soluble nitrogen represents a nutrient which is in a form directly available to phytoplankton, meaning that the nitrogen input may accelerate the production of phytoplankton, particularly in conditions where nutrients are limited (in the summer following the spring bloom of phytoplankton, for example).

Once the power plant's commercial use comes to an end, the need for cooling water and the thermal effect will decrease to a fraction of what the emissions were during the electricity production. As the thermal emission reduces, the impact area's temperature and stratification conditions will return to their natural state. After dismantling phase 1, the volume of the cooling water will remain low, in addition to which the volume of wastewaters will reduce considerably.

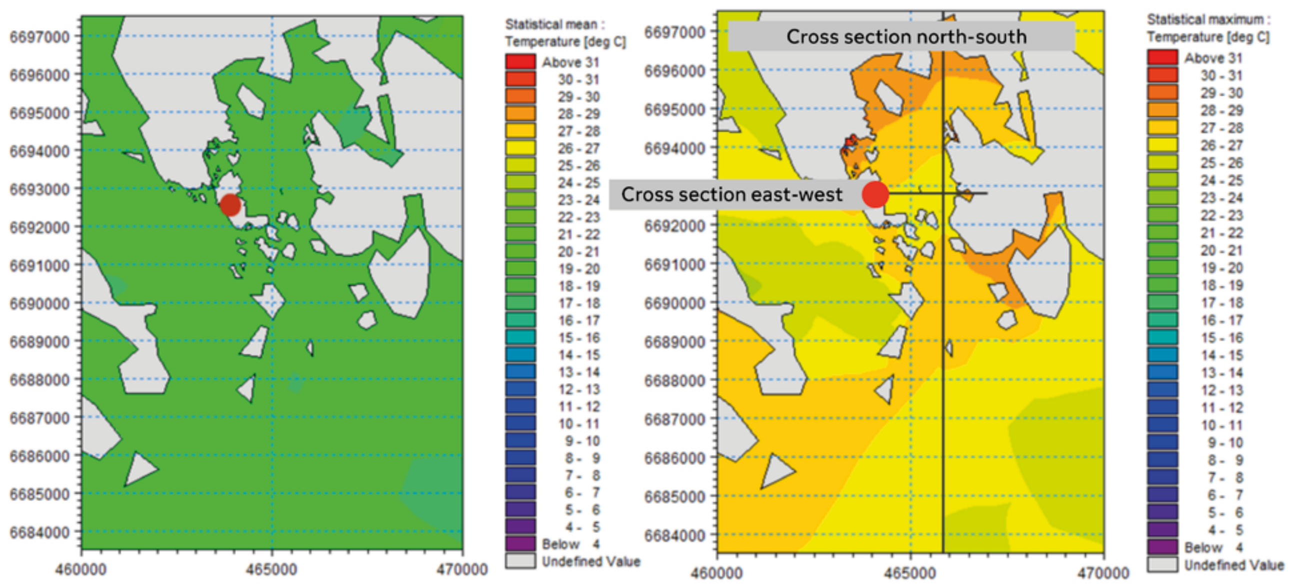

Figure 9-60. Seawater temperature in the surface layer in the summer in a situation where the power plant is not in operation. The image on the left shows the average, and the image on the right the maximum, situation. The locations of the cross sections in the east-west and north-south directions are indicated in the image on the right (see following images). Hästholmen's location is indicated with a red dot (Lahti 2021; Appendix 4).

9.16.5.1 Results of the cooling water modelling

The map images show the result of the modelling of the ice-free season's situation in the warmer than average summer of 2011 without the thermal load and cooling water flow generated by the power plant (Figure 9-60 and Figure 9-61). According to the modelling, the seawater's surface temperature in Hästholmsfjärden is approximately 1–11 °C cooler than in a situation in which the power plant is in operation. In Hudofjärden, it is roughly 0.1–0.9 °C cooler, and in Vådholmsfjärden, approximately 0–4.5 °C cooler.

During the ice-free season, in a summer situation, the thermal effect of the cooling water is not there to intensify the stratification, which is easily visible in the cross-sectional images of the temperature's vertical distribution (Figure 9-61). In other words, while the water column is still stratified in terms of its temperature, which is typical of the summer, the thermocline is no longer as strong as it was when the plant was in operation, meaning that the significance of factors influencing the water column's mixing will grow.

In the winter, once the power plant is no longer in operation, the water column in Hästholmsfjärden will be markedly cooler and of a fairly even temperature (Figure 9-62 and Figure 9-63), which will decrease the intensity of the winter stratification. In the winter, the thermal effect of the cooling water has increased the temperature of the seawater close to the discharge location by approximately 5–16 °C, 5–9 °C and 3–5 °C at a depth of one metre, four metres and near the bottom, respectively. In addition, the water column has also been stratified temperature-wise during the winter.

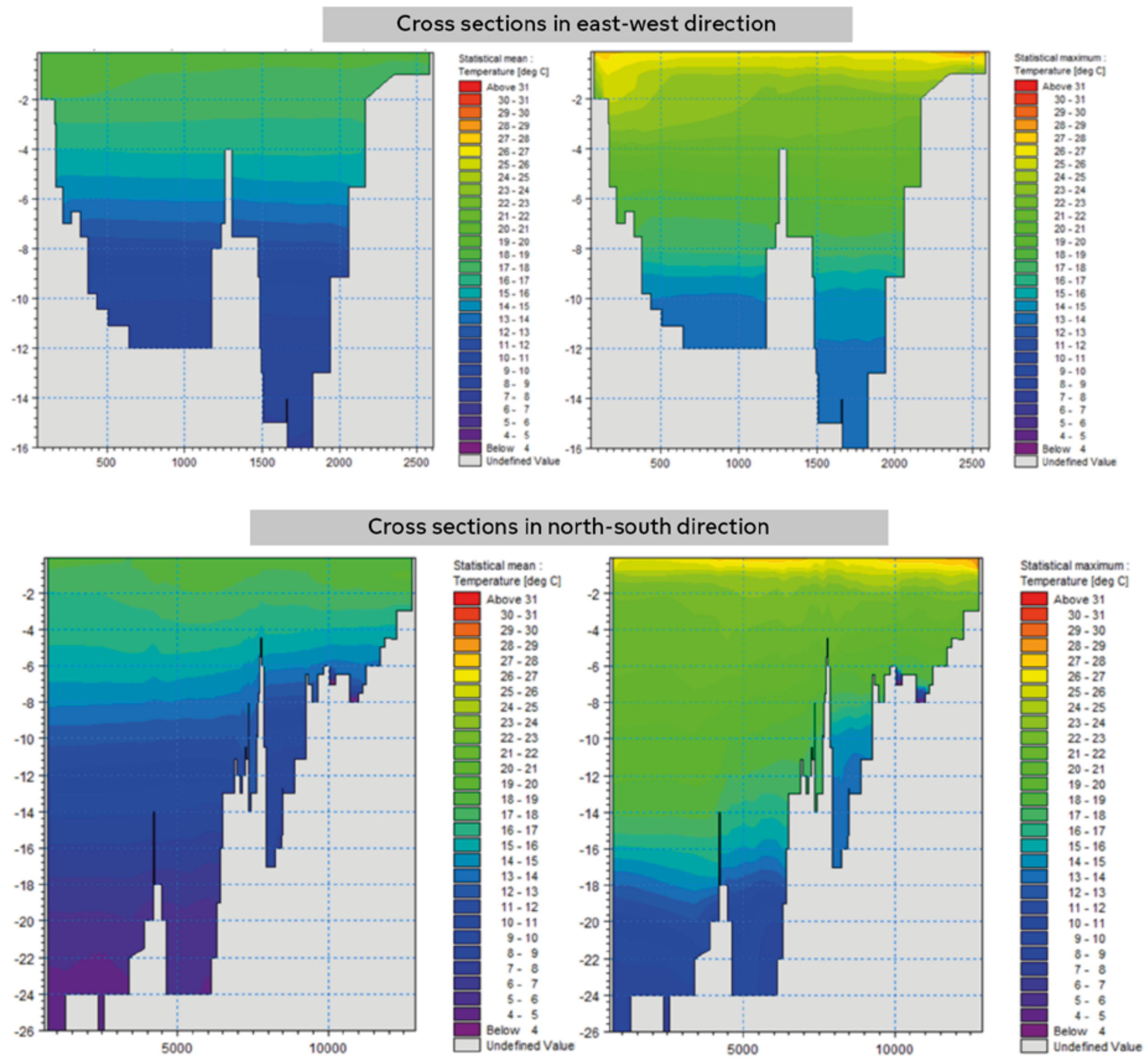

Figure 9-61. The temperature's vertical distribution in the east-west direction (upper image) and in the north-south direction (lower image) in the summer in a situation where the power plant is not in operation. The image on the left shows the average, and the image on the right the maximum, situation. In the east-west cross section, the eastern side of Hästholmsfjärden is on the image's left-hand side.

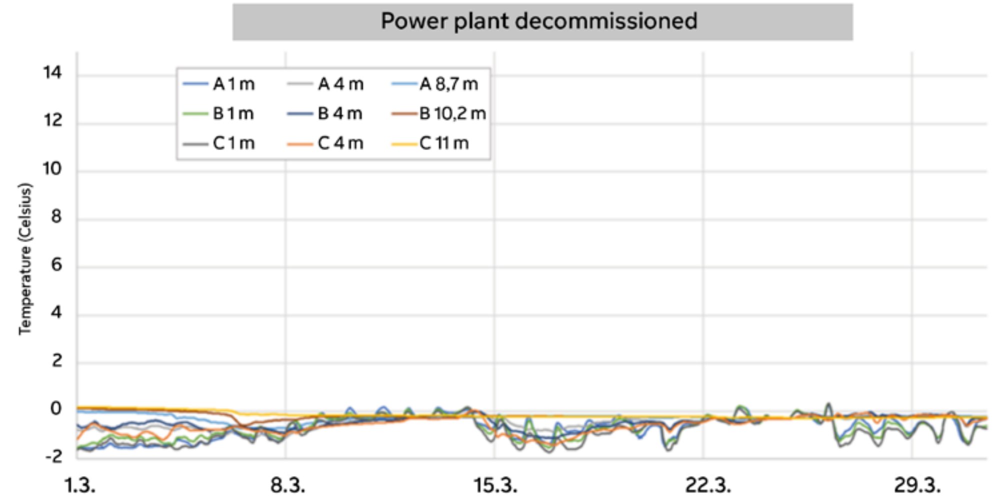

Figure 9-62. The modelled water temperature at various depths and buoys A, B and C on the discharge side in Hästholmsfjärden in the winter and a situation in which the power plant is not in operation.

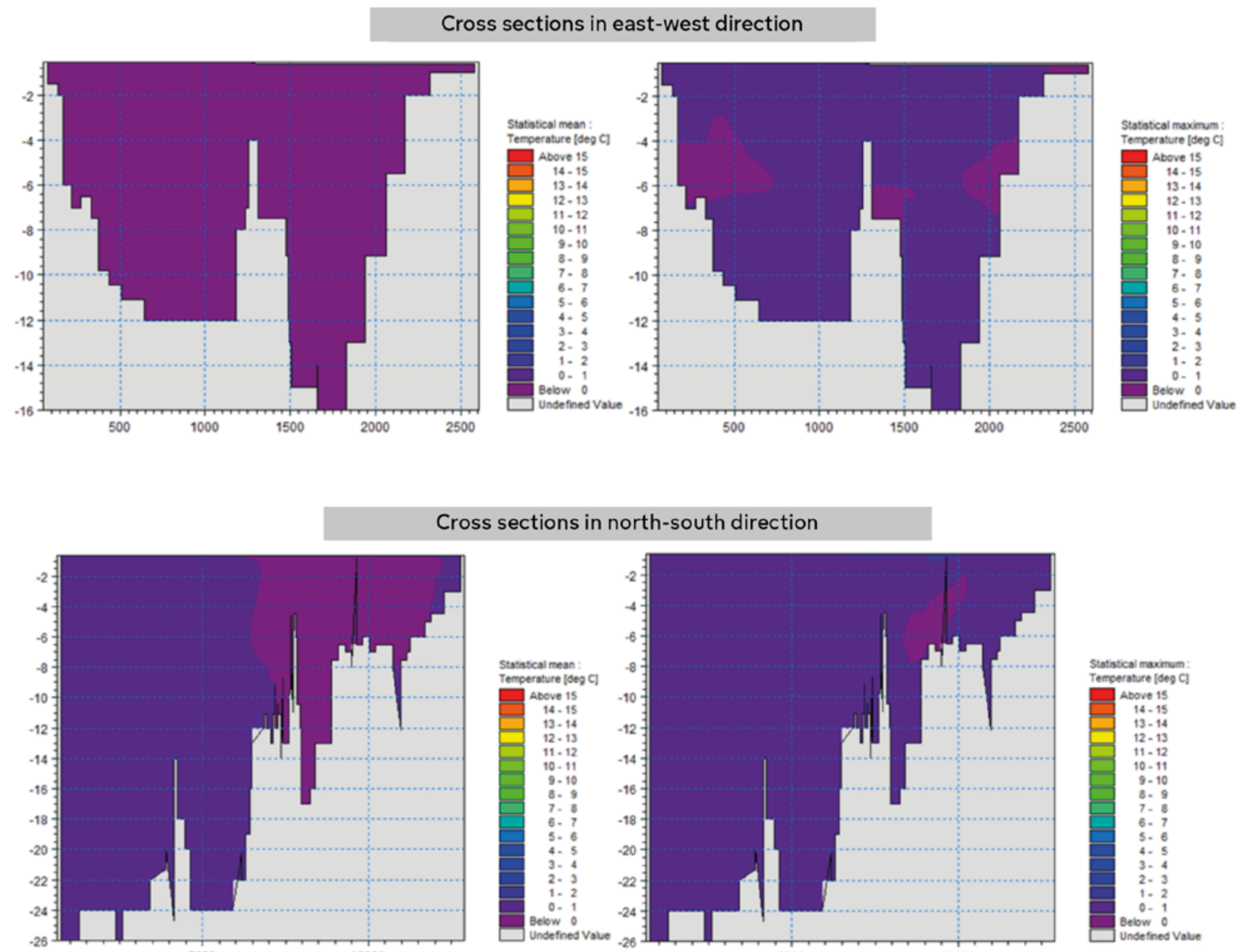

Figure 9-63. The temperature's vertical distribution in the east-west direction (upper image) and in the north-south direction (lower image) in the winter in a modelling situation in which the power plant is no longer in operation. The image on the left shows the average, and the image on the right the maximum, situation. In the east-west cross section, the eastern edge of Hästholmsfjärden is on the image's left-hand side.

9.16.5.2 Impacts on the sea area's temperature and stratification conditions

The impacts of the thermal load are described above, in Chapter 9.16.4.1. In the decommissioning, as the production of electricity halves after 2027 and ends after 2030, the need for cooling water will be reduced to a fraction of its former level. The thermal load generated by cooling water during the independent use of the interim storage for spent nuclear fuel is a mere 0.08% (46.5 TJ a year) of the power plant's current thermal load. The impact that the thermal load of the interim storage has on the sea area's temperature and stratification conditions is negligible.

Once the power plant's thermal load has concluded, the sea area's temperature and stratification conditions will return to correspond to the natural conditions fairly quickly, and the annual development of the seawater's temperature will follow the development of the air temperature. While the water column will still be stratified in terms of its temperature, which is typical of the summer, the thermocline will no longer be as strong as it was when the plant was in operation, meaning that the significance of factors influencing the water column's mixing will grow. In natural conditions, repeated mixing caused by wind also occurs in shallow sea areas during the summer's stratified periods. When the wind is strong, mixing can also occur in the deeper areas of Hästholmsfjärden. The end of the cooling water flow may prolong the water's retention time at Hästholmsfjärden to a slight extent. The retention time estimated for Hästholmsfjärden's (including Klobbfjärden) water prior to the power plant's commissioning was 50–60 days (Launiainen 1975). Once the power plant is no longer in operation, the winter stratification will be minor, and during ice-free winters, for example, Hästholmsfjärden's water column is expected to mix repeatedly due to the impact of wind.

In decommissioning, the thermal effect will reduce to a negligible level after 2027–2030, when the power plant's commercial operation will come to an end. Once the input ends, Hästholmsfjärden's temperature and stratification conditions will return to a natural state. The change will be local and primarily confined to Hästholmsfjärden, in the Klobbfjärden body of water. In other nearby sea areas, the change will remain minor. The magnitude of the change concerning the temperature and stratification conditions compared to the present state is deemed moderate and positive in Hästholmsfjärden and at most minor and positive in other nearby sea areas.

9.16.5.3 Impacts on the quality of water

The most significant change is expected to be the end of the thermal load attributable to the cooling water in Hästholmsfjärden. In addition, Hudöfjärden's water quality will be subject to impacts during the excavation of the L/ILW repository, which is expected to take a total of three years.

The estimate on the total emissions of the excavating over a period of three years is:

- nitrogen 1.9 t
- solids 90 t
- oils and greases 1.5 t

In addition to nitrogen derived from explosives, the L/ILW repository's excavating waters will contain inorganic solids. The waters will be conducted to Hudöfjärden via regulating reservoirs and oil separation. The methods for assessing the input of nitrogen derived from explosives are described in Chapter 9.16.2.3.

The excavation's nitrogen input is distributed over three years and expected to be around 630 kg a year, which corresponds to the daily wastewater input of some 123 people (PE). The nitrogen deriving from the traces of explosives is primarily soluble ammoniacal nitrogen. The annual input comes to only 2% of the sea area's annual point source pollution (Table 9-48). The water conducted to the sea area also contains rock-based inorganic solids, the daily input of which is expected to be around 82 kg. The nitrogen's calculated mixing concentration close to the discharge location (500- x 500-m sea area with an average depth of 5 m) is 1.4 µg/l, while that of the oils and solids is 1.1 µg/l and 0.07 mg/l, respectively. The increases in the concentrations are minor and local. The minor increase in turbidity is focused on the immediate vicinity of the discharge location. The pH values of the site waters are in the same region as those of seawater (the average in Loviisa's sea area being 7.9). The input generated during the construction is not expected to impact the Hudöfjärden sea area's water quality. The impact of the reduction in the nutrient point source pollution caused by Loviisa power plant in Hudöfjärden is also expected to be minor.

The most significant impact on the quality of water will be attributable to the normalisation of the temperature and stratification conditions, and will focus primarily on the area of Hästholmsfjärden in the Klobbfjärden body of water. The change in the physical temperature and stratification conditions will improve Hästholmsfjärden's mixing conditions. In the present state, the oxygenation conditions have been weak in the water close to the bottom, but deteriorated oxygenation conditions have also occurred in the middle of the water column. The water volume suffering from hypoxia is expected to reduce due to the change, which is expected to reduce the internal input in turn. Internal input has occasionally been detected, particularly in Hästholmsfjärden, in the water close to the bottom.

However, it should be noted that the oxygenation conditions in Hästholmsfjärden's deeps were weak as early as in the 1960s, prior to the power plant's commissioning. This is primarily attributable to the poor exchange of water in the bay, resulting from the topography (narrow straits and underwater thresholds). This being the case, the improvement in the deeps' oxygenation conditions may remain minor. The reduction in the internal input is likely to have a slight local impact, reducing nutrient levels and eutrophication, but the impact will appear with a delay. What is clearly more significant in terms of the waterbody's status is the long-term development of the external nutrient pollution (especially from the river Tesjoki). The decrease in temperatures will also have an impact on the level of organisms in the form of slower microbiological degradation. These factors are expected to contribute to a reduction in the hypolimnion's oxygen consumption. In other sea areas close to the power plant, the impacts are expected to be minor.

The magnitude of the change concerning the quality of water compared to the present state is deemed to be at most *moderate and positive* in Hästholmsfjärden. Elsewhere in the sea area, the impact will remain minor.

9.16.5.4 Impacts on phytoplankton and aquatic vegetation

The impacts of the discontinuance of the thermal effect will be attributable to the shortening of the growing season and the slow recovery of the water quality, which is expected to be local. The impacts will extend to the level of organisms, as stated above. The eutrophication trend has occasionally been stronger in Hästholmsfjärden than in Hudöfjärden, which points to, for its part, the thermal effect of the power plant's cooling water (Anttila-Huhtinen & Raunio 2018). The impact has been observable primarily in the aquatic vegetation and, to a small degree, in the primary production. Annual filamentous algae, in particular, have benefited from the longer growing season. The increase in coastal vegetation and the eutrophication of the shore areas has been visible at a radius of approximately one kilometre from the cooling water discharge location.

The impacts on the biological environment are expected to become visible after a delay, given that the sea area's status is impacted by a variety of environmental factors, the most important of them being the development of the external nutrient pollution. As mentioned in Chapter 9.16.5.2, the long-term development of the input involves uncertainty. The impact is expected to be local and primarily confined to the area of Hästholmsfjärden, in the Klobbfjärden body of water, which is expected to remain eutrophic when the thermal effect comes to an end. The biological interactions of the water environment's food web are complex, due to which an assessment of production and community-level changes is difficult. It is nevertheless likely that the change will be manifested as a moderate declining trend in primary production, due to which a declining trend is also expected to be observable in the phytoplankton's biomass and chlorophyll a concentration. In general, it can also be noted that the species which have found the longer growing season particularly beneficial stand to lose some of their competitive advantage. This can be expected to reduce the amounts of annual filamentous algae, for example, to some extent and on a local basis. It is also possible that species sensitive to heat, which have declined in the area, may gradually return there.

The magnitude of the change concerning the phytoplankton and aquatic vegetation compared to the present state is deemed to be at most moderate and positive in Hästholmsfjärden, in the Klobbfjärden body of water. In the other sea areas, the impacts will remain very small.

9.16.5.5 Impacts on benthic fauna

The impacts of the discontinuance of the thermal effect will be attributable to the normalisation of the temperature and stratification conditions, and the slow recovery of the water quality, which is expected to be local. Of special importance in terms of the benthic fauna are the oxygen conditions in the water layer close to the bottom. The status of the benthic fauna living in the deeps of Hästholmsfjärden may gradually improve as the oxygen conditions in the hypolimnion improve. The change is expected to be manifested after a delay and be primarily visible as an increase in the biomass of benthic fauna. No significant changes are expected to take place in the benthic fauna species. The number of species within the sea area's benthic fauna was small as long ago as during the first surveys conducted in the 1960s.

Changes are also expected to occur in the status of Hästholmsfjärden's shallow waters and in the littoral zone's benthic fauna. For example, at the sampling station near the power plant's cooling water discharge location, the benthic fauna population has been more diverse than at the other stations throughout the 2000s, which is probably due to the better water exchange and the coarser materials of the seabed. The thermal effect of the cooling water has favoured the occurrence of some non-native species. Such species include the New Zealand mud snail and the dark false mussel. It is likely that species which have significantly benefited from the thermal effect will lose their competitive advantage and begin to decline. Projections concerning biological interactive relations are challenging, due to which the assessment involves uncertainty. Given that many of the species in question are non-native, the change is deemed positive.

Compared to the present state, the magnitude of the change concerning the benthic fauna is deemed to be at most moderate and positive in Hästholmsfjärden. In the other sea areas, the impacts will remain very small.

9.16.5.6 Impacts on sediment (harmful substances)

The impacts on the sediment are assessed in Chapters 9.8 and 9.16.4.6. The decommissioning is not expected to have impacts on the quality of the sediment.

9.16.5.7 Impacts on Lappomträsket lake

The need for service water varies from one phase to the next during decommissioning. The need for service water will increase temporarily during the excavation and construction of the L/ILW repository, when the power plant is still in operation. Estimates put the total need during excavation at approximately 300,000 m^3. Distributed over the three years of construction, the average pumping need attributable to the excavating of the L/ILW repository is roughly 11.4 m^3 per hour. When the plant is simultaneously in operation, the estimated total need for service water is approximately 31–42 m^3 per hour. The pumped volume of water falls significantly below the volume allowed by the permit conditions (180 m^3 per hour on a short-term basis and at a maximum rate of 150 m^3 per hour over every three months). The minor increase is not expected to have an impact on the present state of Lappomträsket lake.

The volume of domestic water needed during independent operation will decrease to a fraction of its current level. This will be accounted for in the regulation, and when necessary, more water will be run through the dam so that the water level will not rise above the regulation limit.

Deregulation may become topical in the future. The measure requires a permit pursuant to the Water Act; the environmental impact is assessed in connection with the permit process. The planning will typically be carried out by accounting for the various interests as well as the established use of the waterway and the shores. Following the possible deregulation, the obligations of the permit holder (including the obligation to transplant pike) will come to an end. The oxidising carried out by Fortum is also likely to be discontinued, which may have a negative impact on the water quality.

In decommissioning, changes in the intake of water will initially be very small, and the intake will continue in the current manner. A small change in the intake of water is not expected to have an impact on the present state of Lappomträsket lake. The potential end of the regulation would take place far into the future and could result in negative impacts on the quality of water if oxidising is abandoned. In this case, the magnitude of the change concerning the water quality, compared to the present state, is deemed *minor and negative*.

9.16.5.8 Impacts on ecological and chemical status as well as on marine strategy

The impacts on the quality of water and the water environment (phytoplankton, aquatic vegetation, benthic fauna) are assessed above. The ecological and chemical status of Klobbfjärden and the outer bodies of water is presented in Chapter 9.16.3.11.

In decommissioning, the cooling water's thermal effect on the Klobbfjärden body of water will decrease to a fraction of what it was once the commercial operation of the power plant concludes, and it will end completely after the phase of independent operation. As a result of the change, the body of water's temperature and stratification conditions will return to their natural state. The change was deemed to have a minor/moderate and positive local impact on the water quality and water environment, primarily focused on Hästholmsfjärden, in the Klobbfjärden body of water (Chapters 9.16.5.2–9.16.5.5).

The assessment concerning the impact on the biological and physico-chemical quality factors involves uncertainty, which is derived from the complexity of the food web's biological interactions. The potential development paths of the waterbodies' ecological status in the case of decommissioning are assessed in Table 9-58. Changes that have taken place in the status of the biological and physico-chemical quality factors are shown in Tables 9-54 and 9-57.

The targeted schedule in water resources management for the attainment of good ecological potential and chemical status in surface waters was 2015. The attainment of the objective can be postponed until 2027. In the case of decommissioning, it is unlikely that the Klobbfjärden body of water will attain a good status by 2027, given that the improvement of the status will occur with a delay and that the long-term development of the external nutrient input is a significant factor alongside the thermal effect.

In the proposal for the programme of measures for the development and implementation of the marine strategy in Finland 2022–2027, the impacts of a thermal effect are considered local, and the impacts, or their end, are not expected to impact the sea's status on a wider scale (Laamanen et al. 2020).

9.16.6 Radioactive waste generated elsewhere in Finland and its impact

The reception, handling, interim storage and final disposal of any radioactive waste generated elsewhere in Finland within the power plant area would not have an impact on surface waters.

Table 9-58. Assessment of the potential impact that decommissioning would have on the ecological status. Changes that have taken place in the status of the biological and physico-chemical quality factors are presented above in Tables 9-54 and 9-57.

Body of water	Assessment on the potential development directions of the ecological status
Klobbfjärden body of water	The ecological status is bad. As the thermal effect comes to an end, the temperature and stratification conditions, as well as the length of the growing season, will normalise. The change will improve the mixing conditions of the layers in Hästholmsfjärden's water column, which is expected to improve the oxygenation conditions of the hypolimnion and reduce the internal input of nutrients. The change is likely to have local significance in reducing nutrient levels and eutrophication, but the impacts will become apparent only after a delay. Based on the assessment, the total phosphorus and total nitrogen content may decrease slightly at the local level; when combined with the shorter growing season, the change is likely to manifest as a decrease in primary production, for example, which may be visible as a decreasing biomass and chlorophyll a concentration. The impact on the benthic fauna is expected to be delayed and visible primarily as an increase in the biomass of benthic fauna in the deeps. The status of the body of water is nevertheless influenced, above all, by the development of the external input (the river Tesjoki). The status of the body of water is expected to gradually return to a status corresponding to that of the other inner bays in the Gulf of Finland. *Decommissioning will not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Loviisanlahti body of water	The ecological status is poor. The impacts of the project's thermal effect have not extended to the body of water. The impact of the end of the power plant's wastewater load was deemed negligible. The status of the body of water is influenced, above all, by the development of the area's other external inputs and the general development in the status of the Gulf of Finland. *Decommissioning will not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Keipsalo body of water	The ecological status is moderate. The impacts of cooling water have been minor in the body of water. The impact of the end of the power plant's wastewater load was deemed negligible. The status of the body of water is influenced, above all, by the development of the other external inputs and the general development in the status of the Gulf of Finland. *Decommissioning will not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Loviisa-Porvoo body of water	*The ecological status is satisfactory. The most intense thermal effect of the cooling water is focused on the front of Hästholmsfjärden's straits, and the impact area is small compared to the waterbody's area. The thermal effect is therefore not expected to have an impact on the body of water's status. The status of the body of water is influenced, above all, by the development of other inputs and the general development of the Gulf of Finland's status.* *Decommissioning will not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Lappomträsket lake body of water	The ecological status is good. The regulation and the attendant obligations will continue until deregulation is sought. Once Fortum's obligations, far into the future, potentially come to an end, a discontinuation of the oxidising may impair the water quality. The magnitude of the change concerning the present state is at most minor and negative. *Decommissioning will not weaken the category of the quality factors or put the retention of a good status at risk.*

9.16.7 Significance of impacts

Table 9-59 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (see Chapter 9.1.4).

9.16.8 Mitigation of adverse impacts

The most significant impact is attributable to the thermal effect of the cooling water, which has contributed to the eutrophication of the Klobbfjärden body of water. Currently, increases in the temperature of the cooling water and its maximum temperature are limited in the power plant's environmental permit.

Loviisa power plant has improved its efficiency, which has had a minor impact on the thermal load. The efficiency can still be improved slightly in connection with the replacement of old equipment.

As part of Option VE1extended operation, the EIA programme of Loviisa power plant investigated the possibility of conducting water engineering projects in the area in front of the cooling water intake and the adjacent sea area. Based on the preliminary investigations, it could be assumed that by decreasing the temperature of the abstracted cooling water, it would be possible to reduce the temperature of the discharged cooling water, although this would not affect the thermal load being conducted to the sea. Based on the techno-economic investigations carried out, the water engineering projects were nevertheless removed from the environmental impact assessment procedure. The matter will continue to be studied, separate from the EIA Report, in Fortum's research project, which aims to find the most cost-effective technical solutions for reducing the temperature of the abstracted cooling water with the help of modelling.

In terms of the Klobbfjärden body of water, the reduction of the diffuse source input, a significant portion of which derives from the river Tesjoki, plays a key role. The most effective measures include the agricultural measures to be carried out in the river's catchment area, such as the application of gypsum in agricultural fields. Fortum could participate in investigations aiming to reduce the impacts on the Klobbfjärden body of water attributable to other activities and the planning of corrective measures.

9.16.9 Uncertainties

The cooling water's impact on the temperature and stratification conditions of the sea area was assessed on the basis of hydraulic modelling. Modelling results typically include uncertainties that are derived from the fact that the model simplifies the physical phenomena which have an effect on the dispersion of the modelled variable to some extent (in this case, temperature). The uncertainty is reduced by the careful verification and validation of the model. In this modelling, the extensive monitoring data available on the sea area allowed the suitability of the model to be assessed. Based on the comparison, the modelled values correspond to the sea area's measured temperatures fairly well. The temperature modelled in the hypolimnion matches the observations made in June and July, but increases more towards the end of August. What is key in terms of the assessment of temperature effects is that the modelled temperatures close to the surface correspond with the observations. The equivalence was deemed adequate to assess the effects of the cooling water.

The effects on waterways were assessed from a long-term perspective, given that in extended operation, the thermal effect would continue, at most, until around the 2050s. In terms of the seawater temperatures formed, the uncertainty is related to the materialisation of climate change scenarios and the uncertainty included in the different RCP scenarios. The aim was to account for climate change's temperature-increasing impact by using 2011, which was an unusually warm year, as the modelling year. The impact assessment also had to consider the potential change in the point source diffusion of nutrients over the long term. However, the long-term projections of the nutrient pollution involve uncertainties attributable to the uncertainty related to the materialisation of climate change scenarios, and the extent to which and how fast the measures reducing agricultural pollution will be implemented in the catchment areas of the rivers emptying into the coast of Loviisa.

The assessment also involves uncertainty attributable to the complexity of the water environment's biological and physico-chemical interactions and lengthy response times. For example, it is difficult to forecast the extent to which and how rapidly the sea area will recover from the environmental pressure caused by the thermal effect. The long-term development in the status of the Gulf of Finland will also be reflected in the status of the coastal areas. The Gulf of Finland's nutrient dynamics and the development of the status are also indirectly impacted by the major Baltic inflows, the occurrence of which cannot be projected in the context of this impact assessment. The upwelling and downwelling phenomenon which occurs on the coast, and which also has an impact on the status of Loviisa's nearby sea area, can also be considered an uncertainty from the perspective of the assessment.

9.17 FISH AND FISHING

9.17.1 Principal results of the assessment

In the case of extended operation, the impact that the power plant's cooling waters would have on the Klobbfjärden sea area, and thereby on the fish and fishing, would remain similar to its current level but continue for another 20 years or so. The continuation of the cooling water's thermal effect maintains a situation which favours fish species adapted to warm water, such as pike-perch and cyprinids. Waters warmer than the sea surrounding the area may also allow the non-native species round goby to become more abundant there. Yet this is not expected to have an adverse impact on the area's abundant pike-perch population. The winter fishing opportunities will remain at the same level while ice conditions vary in the sea area surrounding the power plant, but the extent of the ice cover may decrease slightly, and the ice may also remain thinner in the future due to climate change. The significance of the impact that the power plant's extended operation would

Table 9-59. Significance of impacts: surface waters.

Significance of impacts: surface waters			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	**Moderate (Hästholmsfjärden, in the Klobbfjärden body of water)**	**Moderate/ minor negative**	**The significance of the impacts is at most moderate and negative,** because in the long run, the increase of warm summers, combined with the thermal load, may slightly increase the thermal effect in the sea area. The power plant's thermal load is known to have contributed to the change in the waterbody's temperature and stratification conditions, the lengthening of the growing season and the intensification of eutrophication at a local scale. The significance of the impacts was deemed to vary according to the affected aspect from minor and negative (water quality, phytoplankton and aquatic vegetation) to moderate and negative (temperature and stratification conditions, benthic fauna). Above all, the status of the sea area is impacted by a diffuse source input, which may also reduce in the long run, provided that the agricultural measures are adopted on a wide scale. The continuation of the thermal effect until at least around 2050 would slow down the waterbody's attainment of a good status.
	Moderate (other nearby sea areas)	**Minor negative/ no change**	**The significance of the impacts is at most minor and negative,** given that the thermal load's impact on the temperature and stratification conditions of the other nearby sea areas will continue until around 2050 at the latest. The other affected aspects (including water quality, benthic fauna) are not expected to be subject to an impact. In the other nearby sea areas too, the quality of water and the status of the water environment are largely influenced by the long-term development of the nutrient inputs and the general development in the Gulf of Finland's status.
	Moderate (Lappomträsket lake)	**No change**	**No impact,** given that the regulation has not been found to impair the lake's water quality.
Decommissioning	**Moderate (Hästholmsfjärden, in the Klobbfjärden body of water)**	**Moderate positive**	**The significance of the impacts is moderate and positive,** since after the thermal load comes to an end, Hästholmsfjärden's temperature and stratification conditions and the length of the growing season will return to the natural state and the oxygenation conditions of the hypolimnion are expected to improve gradually; this will contribute to a reduction of the internal input. The positive impacts may become apparent only after a delay as a decline in the nutrient level, changes in the aquatic flora (a decrease in the number of one-year filamentous algae) and an improvement in the status of the benthic fauna. The decommissioning will not weaken the category of the quality factors of the ecological status or prevent the body of water from attaining a good status.
	Moderate (other nearby sea areas)	**Minor positive/ no change**	**The significance of the impacts is at most minor and positive,** given that the thermal load's impact on the temperature and stratification conditions will remain minor in the rest of the nearby sea area. The excavation of the L/ILW repository is not expected to impact Hudöfjärden's present state.
	Moderate (Lappomträsket lake)	**Minor negative**	**The significance of the impacts is at most minor and negative,** because the changes in the intake of water will be very small initially, and the change is not expected to have an impact on the lake's present state. The potential end of the regulation, which would take place far into the future, could nevertheless result in negative impacts on the quality of water if oxidising is abandoned.
Radioactive waste generated elsewhere in Finland	**Moderate (sea areas, Lappomträsket lake)**	**No change**	**No impact,** given that the operations would have no impact on the surface waters.

have in relation to the present state was deemed, from the perspective of fish, moderate and negative, and from the perspective of fishing, *minor and negative.*

As a result of decommissioning, the impact that the cooling water's thermal load has on the marine ecosystem will end, and the area will gradually return to the state prevailing in the inner bay areas of the surrounding coastal area. At the same time, the likelihood of the increased abundance of non-native species in the area will decrease. The fishing opportunities during the winter will also return to a better level as the ice conditions normalise, but in this option, the occurrence of ice winters is also likely to reduce as a result of climate change. The significance of the impact is expected to be moderate and positive from the perspective of fish and minor and positive from the perspective of fishing.

In terms of the fish in Lappomträsket lake, the lake's potential deregulation and the replacement of the dam structure by a submerged weir would open a migration connection for the fish to Lappomviken after the deregulation, but the discontinuance of the lake's oxidising could expose the lake's fish to a deterioration in the quality of water.

The radioactive waste generated elsewhere in Finland and its storage or final disposal in Hästholmen would have no impact on the fish or fishing.

9.17.2 Baseline data and assessment methods

The assessment of the impact on fish and fishing relied on monitoring studies carried out in the project area, data on the fish and fishing industry in the Gulf of Finland as well as research data on the impact that cooling waters have on fish and on non-native species, including in areas other than the project area. The assessment of the impact on the fish and fishing also relied on the results of the assessment of the impact on the quality of water, including the cooling water modelling (see Chapter 9.16). The indirect impacts that the project activities with an impact on the quality of water would have on the fish and fishing were assessed in the form of an expert assessment.

The fish and fishing in Loviisa power plant's nearby sea area have been monitored since 1971. The data on the ichthyofauna of the area is based on the observations obtained from fishing surveys and fish bookkeeping as well as reviews of the biomass carried to the power plant within the cooling water.

Further information on the area's icthyofauna was obtained by carrying out a fish survey in Loviisa power plant's nearby sea area in the spring and late summer of 2020 (Roikonen & Kangas 2021). The methods employed in the research consisted of Gulf Olympia fry netting and exploratory net fishing. The Gulf Olympia is a net attached to the sides of a boat's bow with vertical rods. The net tows water, collecting the fry in a water column. The aim of the fry netting was to study the locations of the fishes' breeding areas in the intake and discharge sides of the cooling water, and by observing the occurrence of small fry in pelagic zones in the control area. The control areas in the fry netting were the offshore area west of the island Hudö, located in the eastern open sea of Keipsalo, and the head of Loviisanlahti bay. The aim of the exploratory fishing was to examine the structure of the icthyofauna in Loviisa power plant's nearby sea area and the eastern open sea in Keipsalo, selected as the control area. The study was carried out according to widely used research methods and complied with the guidelines for fish studies published by the game and fisheries research institute (Riista- ja kalatalouden tutkimuslaitos) (Borg 2012).

The fish data concerning Lappomträsket lake is derived from the catch data of the exploratory fishing carried out by the Uusimaa ELY Centre in 2011, which is referred to in the preliminary report on the survey and removal of turf rafts in Lappomträsket lake (Niiranen & Hagman 2012).

The emissions of radioactive substances and their impacts are discussed in Chapter 9.8.

9.17.3 Present state

The ichthyofauna in the sea area surrounding Hästholmen consists of both marine fish and freshwater fish species adapted to the brackish water. Marine species important for fishing can be found in the area, such as Baltic herring and Baltic sprat, salmon, sea trout, as well as Coregonus lavaretus and Baltic whitefish, eel and flounder. Among these, migratory species include salmon, sea trout, Baltic whitefish, Baltic herring and eel. Key freshwater species important in terms of fishing include pike-perch, pike, common perch and burbot. Other abundant fish species include cyprinids: roach, silver bream, bream and ide.

Based on the observations made in the exploratory fishing, the structure of the icthyofauna in the research area (Figure 9-64) does not differ significantly from observations made elsewhere in the Gulf of Finland (Roikonen & Kangas 2021). The common perch and roach are generally the most abundant fish species in the coastal area, often accounting, together with silver bream and ruffe, for more than 80% of the total catch. However, compared to observations made elsewhere, the share of common perch in the areas investigated was markedly high, which is explained, particularly with regard to the eastern open sea of Keipsalo (control area 1), by the large number of small individuals. Based on its large pike-perch catch, Hästholmsfjärden differed from the other areas covered by this study. This can be at least partly explained by the effect of the power plant's cooling water, which increases the temperature of the seawater, given that pike-perch favours habitats with warm water. The exploratory fishing caught a few individuals of round goby (Neogobius melanostomus), categorised as a non-native species, from both the intake side of power plant's cooling water and the control area, the eastern open sea of Keipsalo. None were caught in the cooling water's discharge location in Hästholmsfjärden, however.

The breeding areas of the ichthyofauna in the Gulf of Finland have been studied in connection with the Finnish Inventory Programme for the Underwater Marine Environment (VELMU). Based on data from field studies, maps have been prepared in the online service of the environmental administration (VELMU Map Service, 2019) on the breeding areas of various fish species, based on incidence probability

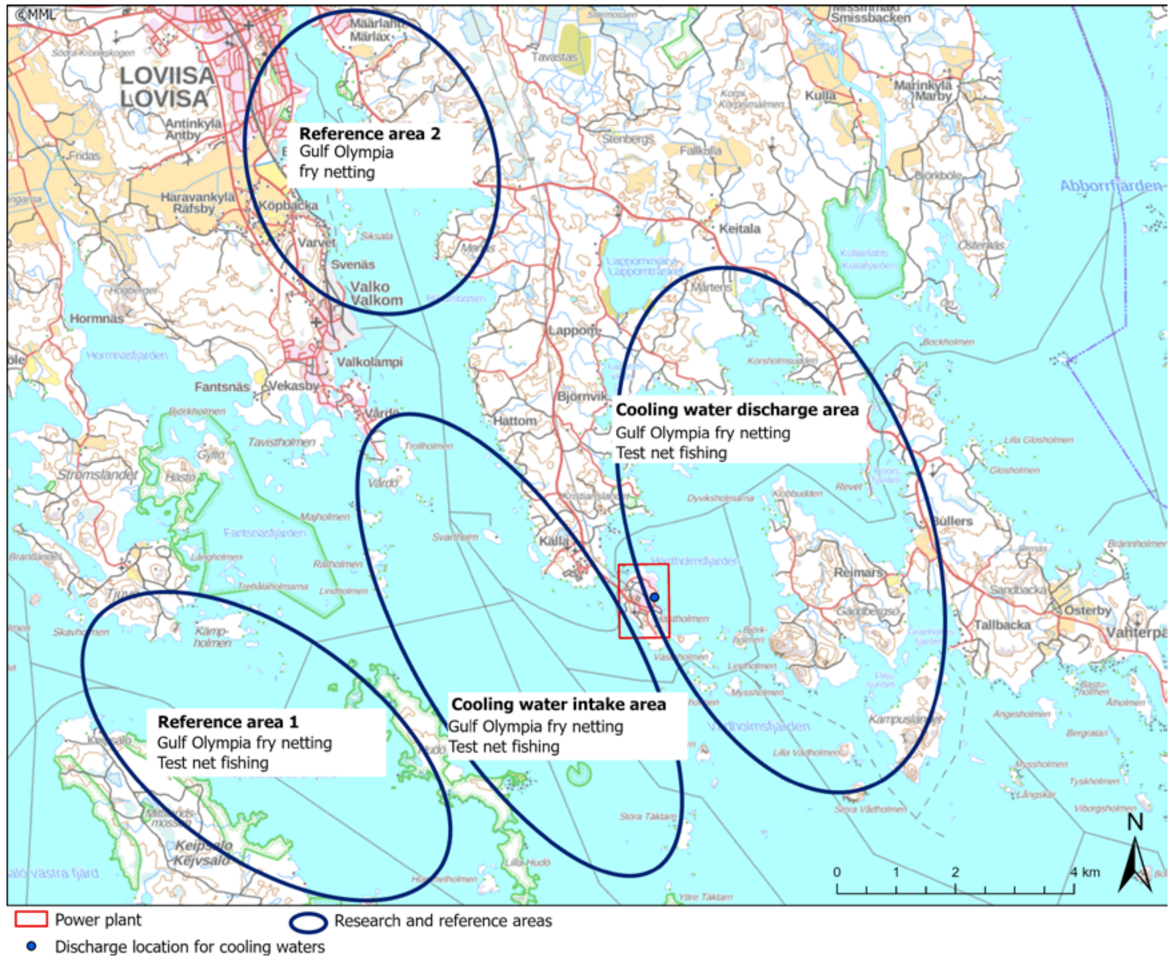

Figure 9-64. The observation areas and research methodologies employed in the 2020 fish study in the sea area off Loviisa.

modelling. According to the model, favourable breeding areas exist in the vicinity of Hästholmen for common perch and pike, among other species. Based on the incidence probability modelling, pike-perch breeds primarily in the far end of the Loviisanlahti bay and on the northern and south-eastern shores of Klobbfjärden. The most favourable breeding areas for Baltic herring include the shallow vegetation areas of the middle and outer archipelagos as a whole. Loviisanlahti has been identified as an important breeding area for icthyofauna and a potential migratory route for the migration of the sea trout, which may swim upstream in the river Loviisanjoki in the future. Partly based on these grounds, Loviisanlahti has indeed been named as one of Finland's most ecologically significant marine underwater areas, or what are referred to as EMMAs (Lappalainen et al. 2020). Modelling results for the breeding area of whitefish that spawns in the sea are not presented for the sea area off Loviisa in the VELMU map service.

The fry production areas in Gäddbergson and Kampuslandet were mapped in 2009 (Pöyry 2009) as part of the surveys concerning the current status of the nuclear power plant project being planned by Fennovoima Oy in Ruotsinpyhtää. The survey area is located on the south-eastern side of the island of Hästholmen, at a distance of up to approximately one kilometre from Loviisa power plant. Based on the surveys, there are significant breeding areas for Baltic herring and Gobiidae in the southeastern sea area near Hästholmen. The surveyed area also included shores with sand and gravel floor that whitefish spawning in the sea use as spawning areas.

According to the results of the fish study carried out in Loviisa power plant's nearby sea area (Roikonen & Kangas 2021), Baltic herring and Gobiidae and, to a lesser extent, common perch use Hästholmsfjärden, the discharge area of Loviisa power plant's cooling water, as their spawning ground. While the far end of Loviisanlahti was identified as the breeding area for pike-perch, the discharge area of the power plant's cooling water (Hästholmsfjärden and Klobbfjärden) was also found to be an area favoured by young pike-perch.

Most of the biomass carried to the power plant with the cooling water intake has consisted of fish, primarily Baltic herring or smelt (Leino 2011). The amount of fish carried to the power plant has been 10–25 tonnes a year. The fish are removed from the water with coarse and fine screens and travelling basket filters. The screenings, which consist

Table 9-60. Sensitivity of the affected aspect: fish and fishing.

Sensitivity of the affected aspect: fish and fishing	
The sensitivity of fish and fishing as an affected aspect was assessed on the basis of the fish occurring in the area, the location of the breeding areas in relation to the project area and the fishing carried out in the area.	
Moderate	The fish found in the project area are the fish normally occurring in the Gulf of Finland, which do not differ from the fish occurring elsewhere to any significant degree. Fry production areas of the Baltic herring and Gobiidae, fish species common across Finland's entire sea area, are found in the project area. The area supports some commercial fishing and recreational fishing. 5

of aquatic plants and algae in addition to fish, are taken to an external waste management company for appropriate processing and utilisation as material in the same manner as other organic waste generated in the power plant. This being the case, the collection of the screenings may be seen to have a cleaning impact on the sea, given that roughly 40–100 kg of phosphorus is removed from the sea alongside the screenings every year.

According to monitoring carried out by the Radiation and Nuclear Safety Authority, no nuclides originating from Loviisa power plant have been found in fish (see Chapter 9.8.3.4). The activity concentrations of caesium in Baltic Sea fish are low (STUK 2021g). The most significant source of radiation in fish in the Gulf of Finland is the caesium-137 derived from the Chernobyl nuclear power plant accident.

Fishing in the area is monitored as part of the required monitoring by requesting commercial fishermen to report their catches, and fishing is monitored with annual bookkeeping. Three commercial fishermen who practise fishing in the area submitted their bookkeeping on fishing for 2018. Their primary fishing method was net fishing, focusing on the spring and autumn. In bottom-set gillnet fishing, pike-perch accounted for the majority of the catch (57%), although pike (30%) was also caught. The results were in line with previous years' monitoring results (ÅF-Consult Oy 2019).

According to a survey conducted among recreational and subsistence fishermen, the calculated total catch of recreational fishermen was an estimated 14.9 tonnes and approximately 20.7 kg per household in 2017. The catch consisted primarily of pike, Baltic herring, perch, bream and pike-perch. The recreational fishing in the area focuses strongly on the summer months (ÅF-Consult Oy 2018).

The fish in Lappomträsket lake consist mainly of common perch and roach, which accounted for a majority of the fish caught in the exploratory fishing carried out in 2011 (Niiranen & Hagman 2012). Predatory fish accounted for 23% of the biomass and 7% of the number of fish. The average weight of the common perch was around 35 g and that of the roach 45 g, meaning that the majority of the prey fish were small. Fortum uses Lappomträsket lake as its source of raw water and regulates the lake's surface level (see Chapter 9.16.3.10). The water permit also involves an obligation to transplant 10,000 newly hatched pike fry every year.

Loviisa power plant's nearby sea area is also used for fish farming. Loviisa power plant is on the island of Hästholmen. The Oy Loviisan Smoltti Ab fish farm operates in the northern section of the island. The farming of the fry exploits the power plant's warm cooling water. The Oy Semilax Ab fish farm operates in the archipelago south of the island of Hästholmen. The area is mentioned in the national aquaculture site selection plan (Ministry of Agriculture and Forestry 2014) as a future aquaculture concentration area.

Table 9-60 shows the sensitivity of the affected aspect and some factors determining sensitivity (see Chapter 9.1.4).

9.17.4 Environmental impact of extended operation

Impact formation

A high water temperature accelerates the metabolism of fish and increases their need for nutrition. Generally speaking, a high temperature is expected to increase the growth of fish, provided that there are no factors restricting growth. A high water temperature also contributes to a waterway's primary production, provided that there are enough nutrients for it. Furthermore, through more abundant primary production, a high water temperature increases the risk of hypoxic conditions in the hypolimnion, which has a negative impact on the habitat of fish.

The power plant's extended operation would result in impacts on the area's fish and fishing, and mainly on Hästholmsfjärden, through the local impact on the marine ecosystem caused by the warming cooling water. The cooling water, coupled with the impact of climate change which warms the sea area, favours the occurrence of fish species adapted to warm water in the impact area. Non-native species favouring warm water may also benefit from the situation and impact the stocks of local fish species by becoming more abundant. The impact resulting from the power plant's operation on the operating conditions of fishing would remain unchanged, but climate change may have adverse effects on winter fishing possibilities in the future. Projections expect the occurrence of ice-free winters to increase in the future.

In the case of extended operation, Loviisa power plant would conduct warm cooling water east of the island of Hästholmen to Hästholmsfjärden, which would have an impact on the local marine ecosystem and thereby also the fish on the discharge side. Based on the cooling water modelling (see Chapter 9.16), the temperature and stratification conditions are expected to remain largely unchanged from their current levels. The thermal effect is local, and during the ice-free season, its impact is mainly observable in Hästholmsfjärden, close to the surface in the vicinity of the discharge location, but also occasionally in the surface layer of the northern part of Vådholmsfjärden.

The likelihood of warmer-than-average summers will increase as a result of climate change, and this will also have an impact on the environment in Hästholmsfjärden. According to the impact assessment concerning surface waters (see Chapter 9.16.4), the long-term development of Hästholmsfjärden's water quality is above all influenced by the development of point source diffusion. Compared to the present state, the change in the quality of water may manifest in the long run as a slight increase in nutrient concentration and the level of primary production. The assessment expects the hypolimnion's oxygenation conditions to remain weak. On the other hand, the possible long-term reduction of point source diffusion would improve the quality of water and the status of the water environment. But poor oxygenation conditions in the seabed are also common on the discharge side of the cooling water, as in the entire eastern Gulf of Finland, which is reflected in the benthic fauna and fish stocks in general.

A number of studies have found warm water to increase the fish biomass locally by improving the reproductive success of species benefiting from warm waters and by accelerating growth (Balkuvienė & Pernaravičiūtė 1994, Hakala et al. 2003, Marttila et al. 2005, Keskinen et al. 2011). An increase in the water temperature benefits fish species spawning in the spring and summer, such as common perch, pike-perch and cyprinids. The Baltic herring has also been found to benefit from the higher water temperature and a slight increase in the nutrient concentration. In particular, the juvenile phases of fish have been found to benefit from an increase in water temperature. In several species, this may increase the number of plentiful year classes and further the amount of food available to predatory fish. However, the increase in temperature impacts different species in different ways. The study conducted in the sea area of Forsmark nuclear power plant (Sandström 1990) found the growth of common perch to be positively correlated for the first few years, but to become negative in the following years as the fish reaches sexual maturity. The temperature's positive impact on the growth rate was also found to make a return in common perch at the age of six. The increase in temperature is the most disadvantageous for coldwater species such as European whitefish, sea trout, salmon, burbot and grayling.

Climate change is expected to increase the temperature of seawater (BACC II Author Team 2015), which will increasingly favour fish species adapted to warm water and their thriving in the discharge location of the cooling water. Several studies have found pike-perch, in particular, to benefit from the increase in temperature (among others, Pekcan-Hekim et al. 2011, Lappalainen et al. 2005, Fontell et al. 2004). Pike-perch has been found to produce more numerous year classes with more rapidly growing individuals in warm water. Fast growth and a larger size improve the chances of fry surviving their first winter. This may further favour the status of pike-perch and cyprinid stocks in the Hästholmsfjärden–Klobbfjärden area. Small pike-perch were found to be more numerous in Hästholmsfjärden than in the reference area in the exploratory fishing (Roikonen & Kangas 2021), which indicates the area's suitability for pike-perch. The inner bay area may therefore also produce more fish for the surrounding sea area through spreading, when the fry of some species begin to favour cooler water as they grow and swim away from the inner bay.

The rise in temperature may also increase fish's stress levels due to the adverse effects resulting from parasites and diseases becoming more widespread. The prevalence of fish diseases and parasites was studied in the impact area of Forsmark nuclear power plant in Sweden, but no increase in the number of diseases or parasites in local fish was detected there (Sandström 1990). The increased production of fry was deemed to compensate for the adverse effect this had on the fish stocks. While this has not been studied in the Loviisa area, the situation there can be considered similar to that in the Forsmark area, given that both areas are located in the Baltic Sea and at nearly the same latitude.

A temperature higher than that of the surrounding environment is also likely to favour the spread of round goby, a non-native species in the area. The species originates in the Black Sea and Caspian Sea areas, from where it has been carried to the Baltic Sea in ships' ballast waters (Vieraslajit.fi). Observations of the round goby in Finland's sea area have been made in the sea area between Oulu and Hamina, especially in the areas surrounding ports (Natural Resources Institute Finland 2021). Round gobies were caught in the 2020 exploratory fishing in the areas west of Hästholmen, but not from Hästholmsfjärden, the discharge side of Loviisa power plant. Round goby is likely to spread to Hästholmsfjärden as well, where the seawater temperature is higher than in the surrounding sea area. While the species is likely to spread to Hästholmsfjärden in the future even without the power plant's warming effect, its high optimum temperature may provide it with a competitive edge over other fish species in Hästholmsfjärden. Given that the species has been found to tolerate high temperatures, with its optimum occurrence temperature being 26 °C (Lee & Johnson 2005), it can be assumed that it will thrive in the conditions of Hästholmsfjärden. Generally speaking, round goby tolerates a temperature range of -1–30 °C (Moskal'kova 1996), while its critical maximum temperature is approximately 33 °C (Cross & Rawding 2009). The round goby is an aggressive competitor which has been suspected of impacting, in its new range in the Baltic Sea, the incidence of common perch, roach and flounder in the same areas (Kornis et al. 2012).

Nevertheless, the impact of round goby on the fish stocks of Hästholmsfjärden-Klobbfjärden is difficult to project due to the complex ecological interactions. Round goby may have an adverse effect on the reproduction of other species by taking over habitats with its aggressive behaviour, but at the same time, it may represent an important food source for predatory fish such as pike-perch and common perch, in addition to cormorants, for example. The biodiversity of the marine nature may be adversely affected if endemic species of goby, such as the black goby, disappear as they make way for non-native species.

Observations of predatory fish and cormorants focusing on the predation of round goby have been made in the southern Baltic Sea (Kornis et al. 2012). Based on exploratory fishing, the surroundings of Hästholmen support a strong stock of common perch, and since common perch has been found to prey on the round goby (Kornis et al. 2012), the common perch could play a significant role in limiting its further abundance. According to a study carried out in the Åland Islands (Herlevi et al. 2018), on the other hand, the round goby competes with large common perch for the same benthic fauna nutrition. Further, according to exploratory fishing, the stock of pike-perch is also strong in the Hästholmsfjärden-Klobbfjärden area. This being the case, pike-perch may also be assumed to focus its predation on the round goby stock, which is becoming more abundant in the area. In a study conducted in the Kiel Canal in Germany (Hempel et al. 2016), pike-perch has been found to have made a clear shift to exploiting the round goby as an important food source. Male pike-perch guard their spawning nests against other predatory fish (Hempel et al. 2016), and it may be presumed that the round goby is unable to disrupt pike-perch's reproduction in the area. The stock of pike-perch, which is important to fishing, is therefore not expected to be adversely affected by the potential increasing abundance of the round goby. Instead, it is possible that the pike-perch stock's nutritional situation will improve. In this case, pike-perch's share of the catch in the fishing practised in the area could even improve.

Entirely ice-free winters are expected to become more common as a result of climate change. Combined with the local thermal effect of the power plant's cooling water, weak ice winters may become more common in Hästholmsfjärden. This may further impair the conditions needed for winter fishing in the power plant's nearby sea area. Among other things, the impaired ice situation makes it more difficult for fishermen to reach their fishing gear and select fishing grounds, which would weaken the opportunities for using static gear.

In the optioncase of extended operation, the impact that the power plant's cooling waters would have on the nearby sea area, and thereby on the fish and fishing, would remain similar to its current level but continue for another 20 years or so. Climate change may slightly intensify the impacts of the thermal load on the impact area. Round goby's possible spread to the Hästholmsfjärden-Klobbfjärden area and a strong increase in its abundance could change the structure of fishing in the area. Taking into account these factors, the magnitude of the change concerning the fish in the impact area is deemed *moderate and negative*. However, from the perspective of fishing, the continuance of the thermal load alongside the impact of climate change, warming the seawater, is not expected to have a greater than *minor negative* impact. The power plant's extended operation is not expected to have an adverse effect on pike-perch, which is an important target species of fishing in the area.

9.17.5 Environmental impact of decommissioning

Impact formation

With decommissioning, the impact of the power plant's cooling water will reduce and eventually end. The structure of the icthyofauna and the fishing opportunities will gradually return to the level prevailing in the surrounding sea area, as the warming effect of the cooling water disappears. In terms of Lappomträsket lake, the end of the water intake may also mean the abandoning of regulation and the replacement of the dam structure of the lake's outlet by a submerged weir, enabling the migration of fish. Discontinuing the lake's oxidising may nevertheless expose the fish to the adverse effects of deteriorating oxygenation conditions.

Once the decommissioning begins, and the volume of discharge water drops to a fraction, the ecosystem in Hästholmsfjärden will slowly start to be restored to a status corresponding to that of the surrounding inner bays of the Gulf of Finland's coastal area. The strong stock of pike-perch in the impact area of the cooling water is likely to decline slightly compared to the present state. Climate change may nevertheless, in the long run, increase the populations of fish species which favour warm water, which will simultaneously favour the incidence of pike-perch.

The round goby is not expected to benefit from a competitive advantage stronger than anywhere else in the Gulf of Finland compared to the other species, because the temperature of seawater in Hästholmsfjärden will no longer differ from the temperatures in the rest of the coastal area. However, climate change in general also promotes the spread of round goby as the seawater warms, and it is probable that in this situation, the species will also spread to Hästholmsfjärden at some point. Nevertheless, it would be positive for the biodiversity of the area's icthyofauna if the round goby does not increase its abundance in the project's impact area to any degree stronger than elsewhere in the coastal area, and thereby change the natural structure of the icthyofauna. The impact on the icthyofauna will be confined to the Hästholmsfärden-Klobbfjärden area.

The ice situation will return to that typical for the area, and the conditions needed for winter fishing will no longer be subject to a similar local impact as when the power plant's thermal load weakened the ice. With regard to winter fishing, the improvement of the ice situation locally covers the area across the northern parts of Hästholmsfjärden and Vådholmsfjärden.

The magnitude of the change concerning the fish as a result of decommissioning is expected to be moderate and positive. The fish in the impact area may recover to the natural status prevailing in the surrounding coastal area. In terms of fishing, the decommissioning is expected to have a minor and positive impact on winter fishing through the improvement in the required conditions.

Ending regulation at Lappomträsket lake would allow the dam structure built in the lake's outlet to be replaced by a submerged weir that would enable the migration of fish. The change would open a route for the fish between the lake and Lappomviken. The route would allow the sea area's pike, among others, to swim all the way up to Lappomträsket lake for spawning. On the other hand, there is no certainty on how the lake's oxygenation conditions will develop when the regulation and oxidising activities come to an end, due to which the magnitude of the impact's positiveness in terms of the icthyofauna is difficult to assess. The restoration of the migration connection would have a positive impact, but if the lake's oxygenation conditions deteriorate at the same time, it would have adverse effects on the living conditions of the fish in the lake.

9.17.6 Radioactive waste generated elsewhere in Finland and its impact

The reception, handling, interim storage or final disposal of radioactive waste generated elsewhere in Finland would not have an impact on the icthyofauna of the sea area surrounding the power plant or the fishing practised in the area.

9.17.7 Significance of impacts

Table 9-61 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (see Chapter 9.1.4).

Table 9-61. Significance of the impacts: fish and fishing.

Significance of the impacts: fish and fishing			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	**Moderate**	**Moderate negative (fish)**	**The significance of the impacts is moderate and negative,** because combined with the effect of climate change, which would warm the seawater, the fish species most successful in the impact area would be those favouring warm water, such as pike-perch and many cyprinids, and the impact that the power plant's cooling water would have on the sea area, and thereby on the icthyofauna, would continue for some 20 years. Furthermore, the local thermal effect could give a competitive advantage to the round goby, an invasive alien species, which could become more abundant in the Klobbfjärden body of water.
		Minor negative (fishing)	**The significance of the impacts is minor and negative,** because the fishing opportunities in the winter season would remain at the same level or could, as a result of the combined impact of the cooling water's thermal effect and climate change, deteriorate slightly in the power plant's nearby sea areas. Pike-perch, which is an important target species for fishing, is not expected to be impacted.
Decommissioning	**Moderate**	**Moderate positive (fish)**	**The significance of the impacts is moderate and positive,** given that as a result of decommissioning, the impact that the cooling water's thermal load has on the area's fish will end, and the impact area will gradually return to the state prevailing in the surrounding coastal area. The waters warmer than the surrounding sea area will no longer provide a competitive advantage for possible non-native species.
		Minor positive (fishing)	**The significance of the impacts is minor and positive,** because the opportunities for winter fishing will return to a better level as the ice conditions normalise, although climate change itself will impair fishing opportunities in the future.
Radioactive waste generated elsewhere in Finland	**Moderate**	**No change (fish and fishing)**	**No impact,** because the operations would not impact the sea area.

9.17.8 Mitigation of adverse impacts

The mitigation of impacts on surface waters is discussed in Chapter 9.16.8.

Fortum compensates for the impacts that the cooling water has on the area's fishing industry by paying an annual fisheries charge. The funds accumulated from the fisheries charges paid by Fortum are used for fish transplanting carried out in the Uusimaa sea area. The transplanting aims to strengthen fish stocks and increase the sea area's recreational value by improving the fishing opportunities there. Fortum also transplants pike fry in the Lappomträsket lake every year, in accordance with the order of the water abstraction permit.

9.17.9 Uncertainties

The assessment involves uncertainty due to the uncertainty related to the impacts of climate change. The temperature of seawater in the area is expected to rise due to climate change, but there can be no certainty by how much. The data on fishing in the area, on which the impact assessment was based, were gathered as a time series covering decades, and are not considered to involve uncertainty. The study of the reproductive area of the fish is based on materials obtained in 2020 and therefore involves uncertainty, given that the variation from one year to the next remains invisible in the data of one year. The picture concerning the structure of the area's icthyofauna also involves uncertainty, because the data, based on the exploratory fishing data collected during one year alone, does not reveal annual variation. The ecosystem impacts attributable to the spread of round goby likewise involve uncertainty, given that the complex interactive processes between species are extremely hard to project with a time frame covering several decades.

9.18 FLORA, FAUNA AND CONSERVATION AREAS

9.18.1 Principal results of the assessment

In extended operation, the power plant's cooling waters would maintain Hästholmsfjärden's significance as regionally important wintering ground for waterfowl. If the thermal effect continued for some 20 years longer, it would slow down, for its part, the waterbody's attainment of a good status, which could have an adverse effect on the number of pairs of some archipelago birds in the area through changes in the food web. Overall, extended operation is expected to have a minor and favourable impact in terms of the avifauna and otters. Extended operation would not have significant impacts on conservation areas. In the case of extended operation, the power plant's impact on the flora and fauna of land areas would remain similar to their current levels.

Concerning flora, fauna and biodiversity as a whole, the decommissioning is expected to have a minor and negative impact, which would be manifested as the removal of the regionally important wintering grounds for waterfowl. However, this is not expected to have a significant impact on the populations of the birds in question. The decommissioning will not have an impact on conservation areas. Should the decommissioning be carried out according to the brownfield principle, buildings and other infrastructure will remain in the area, due to which vegetation in the area would not increase to any significant degree. If the decommissioning is carried out according to the greenfield principle, the power plant area's landscaping will increase the area covered by plants, which would increase local biodiversity.

Radioactive waste generated elsewhere in Finland would not have impacts on the flora, fauna or conservation areas.

9.18.2 Baseline data and assessment methods

The assessment concerning the impacts on the flora, fauna and conservation areas relied on the results of the impact assessment concerning noise, dust, traffic and surface waters, including the results of the cooling water modelling (Lahti 2021).

The impact assessment is also based on a survey of the area's avifauna (Metsänen 2021), which covered the nesting bird survey conducted in the vicinity of Loviisa nuclear power plant, the results of the counts of agglomerations during migration, and winter observations of the area's birds. The fieldwork in the area was carried out during a period which lasted a year (December 2019 – December 2020). In addition to the actual survey area (power plant area–Hästholmsfjärden), comparative counts were carried out in terms of the sea area west of the power plant (Hudöfjärden) and Loviisanlahti, in front of the town, during the same counting periods. Besides this monitoring, the avifauna survey also made use of other existing material.

The impact assessment also relied on data available from public sources, the most important of which included the databases of the environmental administration and the Finnish Environment Institute as well as data from the BirdLife Finland association on important bird areas (FINIBA and IBA), and other reports on bird areas deemed regionally important.

The assessment was carried out in the form of an expert assessment, which involved the assessment of the probable impact that each identified impact type had on the flora, fauna and conservation areas found within the impact area. The impact assessment concerning the natural environment also relied on data accumulated in other assessments and scientific studies on the probable impacts that each impact type (such as noise or dust) had on the occurrences and species assessed.

With regard to the impacts on aspects included in the Natura 2000 network, the assessment aimed to determine if the options being assessed were likely to cause significant impacts on the protected nature values in the Natura areas. With regard to aspects in other nature conservation areas and nature conservation programmes, the assessment determines whether significant impacts in terms of the conservation objectives.

Aquatic vegetation, benthic fauna and phytoplankton, as well as the impacts on them, are discussed in Chapter 9.18. The impacts on the avifauna are discussed in Chapter 9-17.

The emissions of radioactive substances and their impacts are discussed in Chapter 9.8.

9.18.3 Present state

9.18.3.1 Overview of the biotopes and vegetation

From the botanic geography perspective, the Loviisa region is located in the anemone belt, and its Lounaismaa part in the southboreal zone. This part of the southboreal zone has the most favourable climate and a rich vegetation. The rich grass-herb vegetation and groves differentiate the area from the rest of southern Finland. The demanding woodland plants of the area include the hepatica, yellow anemone and wood anemone, lung-wort, pilewort, white satin flower, fumitories, wall lettuce, alternate-leaved golden saxifrage and tor-grass. Ash, European hazel and European white elm have also spread to the Loviisa area.

The island of Hästholmen is approximately 75 hectares in area, about half of which is the built-up environment intended for the power plant's operations. Hästholmen is connected to the smaller island of Tallholmen by a narrow isthmus. In addition, the small islands of Hässjeholmen and Tallören are almost connected to the island of Hästholmen by isthmuses, very shallow water areas and cobble deposits. The dominant tree on the islands of Hästholmen and Tallholmen is pine. The islands also feature some patches of bare rock with few or no trees, and plenty of rocky soil. The narrow isthmus between Hästholmen and Tallholmen features typical alder grove stands. The shores of the islands are primarily rocky, and larger reed stands or other flood meadows are rare. Only the shallow between Hässjeholmen and Hästholmen and the isthmus of Tallholmen feature small reed stands. Aquatic plants are reviewed in more detail in Chapter 9.16.3.7.

9.18.3.2 Fauna in land areas

In the area of the town of Loviisa, the fauna consists primarily of typical species that have adapted to living in managed forests, such as fox, brown hare and cervids. The only large predator more generally seen in the Loviisa region is the lynx (Natural Resources Institute Finland 2019a).

A blue hare, a fox and some deer were observed on the island of Hästholmen in 2020, during the avifauna survey (Metsänen 2021). The elk population is fairly strong near the power plant area and in the surroundings of the road leading to the area south of the centre of Loviisa.

Two otter individuals were observed at the intake location of the power plant's cooling water during the avifauna survey (Metsänen 2021) prepared in connection with the impact assessment. There is no prior research on the incidence of the species in the area, but the fact that the sea area remains unfrozen throughout the winter may induce the species to spend its winters and breed in the area. The otter is mentioned in Annex IV(a) to the Habitats Directive, and its breeding and resting areas are therefore protected pursuant to the Nature Conservation Act.

No information is available on the incidence of the other species listed in Annex IV(a) to the Habitats Directive (including the Siberian flying squirrel and bats) in the power plant area. The incidence of Siberian flying squirrels and bats was studied when land use planning was carried out in the component master plan area of the northern part of Loviisa and Tesjoki in 2005. The only breeding area for the whiskered bat and brown long-eared bat observed in the land use plan area is approximately 10 km from Hästholmen. There are no habitats preferred by the Siberian flying squirrel on the island of Hästholmen or the cape next to it, and there are no known breeding or resting areas for the Siberian flying squirrel in the vicinity of the power plant (Fortum Power and Heat Oy 2008). During the spring and autumn migrations, migrating/migratory bats can be found practically everywhere in the coastal region, so it is probable that bat species will also be found in the vicinity of Hästholmen during these migrations.

9.18.3.3 Marine mammals

According to surveys conducted among fishermen, seals have been observed in Loviisanlahti bay. Both grey seals and Baltic ringed seals can be found in the Gulf of Finland area. The grey seal is considerably more common than the ringed seal in the eastern Gulf of Finland. Based on the counts carried out in 2019 by the Natural Resources Institute Finland, the grey seal population of the Gulf of Finland was 685 seals (Natural Resources Institute Finland 2019b). The population (in Finland and Russia combined) of the Baltic ringed seal in the Gulf of Finland is estimated at fewer than 200 seals (Ministry of Agriculture and Forestry 2018). This means that the seals observed in the Loviisa region are probably grey seals. Grey seals were observed in Hästholmsfjärden in connection with the avifauna survey conducted in 2020 (Metsänen 2021).

9.18.3.4 Valuable marine areas

Finland's ecologically significant marine underwater areas (EMMAs) were determined as part of the Finnish Inventory Programme for the Underwater Marine Environment (VELMU). No sites categorised as valuable are located in the vicinity of the power plant or the impact area of the waterways impact (SYKE 2020). The closest EMMA sites are the head of Loviisanlahti (some 8 km northwest of the power plant), due to its valuable fish stock, and the Vahterpää flads (some 8 km east-southeast).

9.18.3.5 Avifauna

In terms of the landbird species, the Loviisa region is representative of the typical forest areas in the southern coastal region. In Loviisa, the landbird species are abundant, but

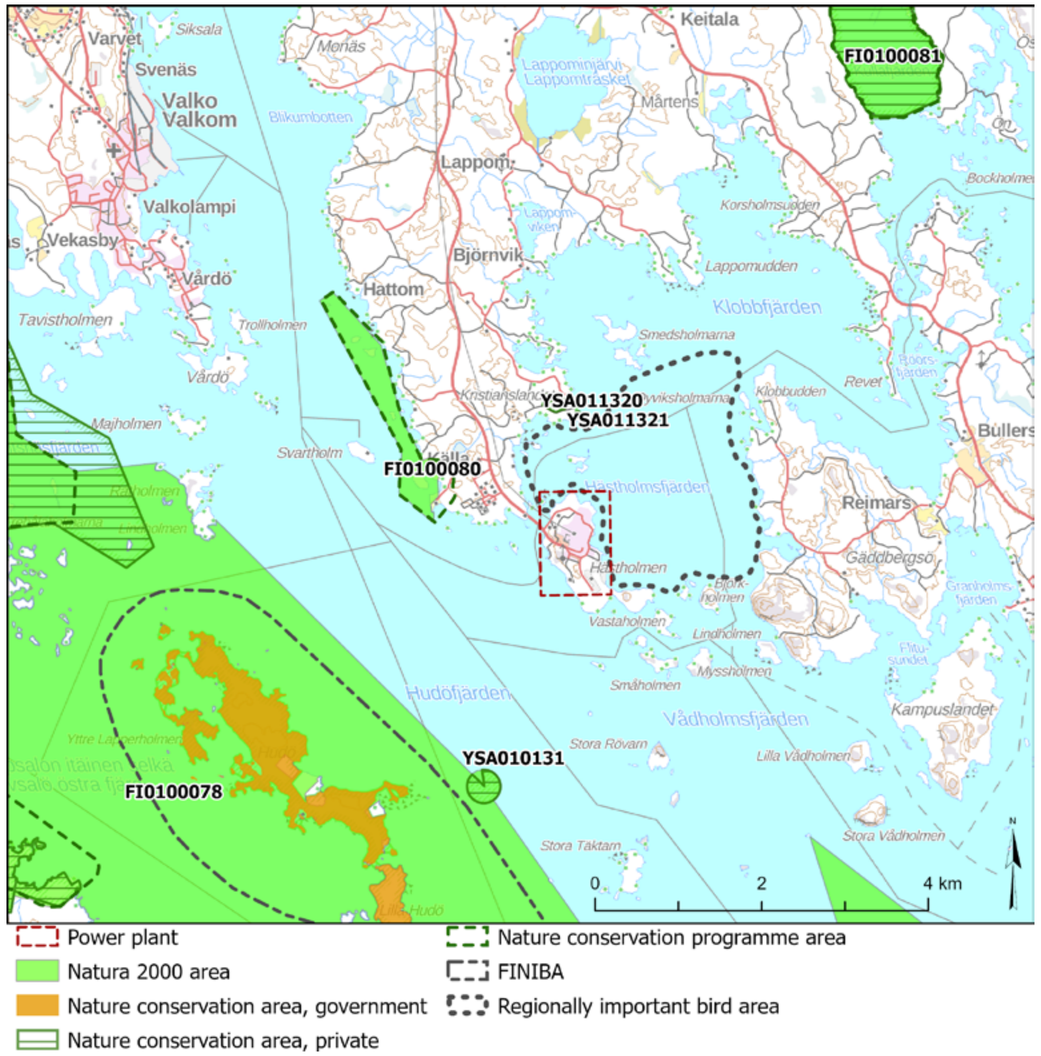

Figure 9-65. Nature conservation areas, sites covered by conservation programmes, Natura 2000 sites and a nationally important bird area (FINIBA) in the vicinity of the power plant.

rare species are few. Waterfowl species and individuals are abundant in Hästholmsfjärden, particularly in the winter and during the spring and autumn migratory seasons. The abundance of winter avifauna in Hästholmsfjärden, in particular, is explained by the thermal effect of the power plant's cooling water; Hästholmsfjärden has indeed been categorised as a regionally important bird area, at least partly due to the influence of the power plant.

There are no internationally important (IBA) or nationally important (FINIBA) bird areas in the power plant area or its immediate vicinity. The sea area east of the power plant, Hästholmsfjärden, has been categorised as a regionally important bird area (MAALI) due to the diverse population of waterflow wintering in the area. The impact area of the cooling water remains unfrozen throughout the winter, enabling waterfowl to overwinter in the area. Mallard, goldeneye, tufted duck and goosander are some of the species wintering in the area in large numbers (Leivo & Lehtiniemi 2019). The nesting grounds of the species wintering in the area are located primarily outside Hästholmsfjärden. Some of the birds may even nest beyond Finland's borders, given that the waterfowl wintering in the Baltic Sea are part of a larger population, the wintering grounds of which vary greatly, depending on the ice situation. The nearest bird area categorised as nationally important is the sub-area included in the FINIBA area of the archipelago in the eastern Gulf of Finland, more than two kilometres to the southwest (Figure 9-65).

The avifauna survey related to the EIA procedure was carried out over a one-year period, beginning in December 2019. The power plant's warm cooling water in the impact area can be considered a positive impact attracting birds in the winter, and partly also during the spring and autumn (Metsänen 2021).

Large numbers of goldeneye, tufted duck and goosander were observed during the 2019–2020 winter season. The number of white-tailed eagles in the winter can also be seen as notable, at least regionally. In the spring of 2020, a large number of black-throated divers and cormorants gathered

Table 9-62. Sensitivity of affected aspect: flora, fauna and conservation areas.

Sensitivity of affected aspect: flora, fauna and conservation areas	
In respect of the flora, fauna and conservation areas, the aspect's sensitivity is influenced by incidences of notable species, the presence of bird areas categorised as valuable or other categorised natural sites in the area, and the presence of nature conservation areas, conservation programmes and sites belonging to the Natura 2000 network in the area.	
Moderate	No conservation areas or sites of the Natura 2000 network are located in the power plant area or its vicinity. While no notable habitat types are located within the power plant area, endangered or protected species have been found there. Hästholmsfjärden, located within the area of the power plant's waterways impact, is categorised as a regionally important bird area.

in Hästholmsfjärden. The agglomeration of roughly 50 black-throated divers counted in late April can be considered regionally notable. The abundant occurrence of black-throated divers is probably explained by the fact that the bay offers them a sheltered, nutrient-rich resting area along their migratory route. The greatest numbers of cormorants approached 500 individuals, greatly exceeding the numbers present in the reference areas (Hudöfjärden and Loviisanlahti) at the same time. Cormorants gathered particularly in the vicinity of the discharge locations of water and on the small islet of Flitun in Hästholmsfjärden (Metsänen 2021).

The maximum number of gadwalls counted in the autumn of 2020 was 75, which can be considered a regionally significant agglomeration. A large number of great crested grebes, at most 179 individuals, gathered in Hudöfjärden, in the sea area west of the power plant, in the autumn of 2020 (Metsänen 2021).

The birds nesting in Hästholmsfjärden consist of species typical of the coastal archipelago, and the lack of actual bird rocks is visible as the scarcity of both communal species (such as the common tern and black-headed gull) and the species comfortable nesting under their protection (including goosander and shoveller). Notable species nesting in Hästholmsfjärden in the 2020 survey included the endangered goosander; one nest was found on the islet of Flitun. A great black-backed gull and a herring gull, both listed as a vulnerable species (VU) in the most recent conservation status, were also found nesting on the same islet. Notable species found in the power plant area and its vicinity during the inventories made in the summer of 2020 included the black redstart (near threatened, NT). Barn swallows (vulnerable) and common house martins (endangered, EN) were also apparently nesting in the power plant's structures. Early in the spring, a woodlark displayed south of the power plant. While the species does not nest in Finland in great numbers, it is still listed as a species of least concern.

9.18.3.6 Nature conservation

The Natura 2000 network site closest to the power plant area is the Källaudden–Virstholmen area (ID FI0100080), located at least approximately 1.3 km to the southwest (Figure 9-64). The area is protected as a site referred to in the Habitats Directive (a SAC area). The next closest Natura 2000 network site is the marine reserve (FI0100078) in Pernajanlahti bay and the Pernaja archipelago located at least approximately 2.3 km to the southwest. It is markedly vast and protected as a site compliant with both the Wild Bird and Habitats Directives (a SAC and SPA area). The Natura area in the marine reserve of Pernajanlahti bay and the Pernaja archipelago also includes the small islet of Kuggen, which is protected as an avifauna conservation area (YSA010131). The Kullafjärden waterfowl habitat (FI0100081) is approximately 7 km to the northeast of the power plant.

The established nature conservation areas closest to the power plant, at a distance of 0.8–1 km to the north, are the privately owned nature conservation areas of Karhulahti shore (YSA011320) and Bastuängen common forest (YSA011321) (Figure 9-64). The nature conservation area of Karhulahti shore is approximately 0.2 hectares, and the area of the Bastuängen common forest is approximately 4 hectares.

Table 9-62 shows the sensitivity of the affected aspect and some factors determining sensitivity (see Chapter 9.1.4).

9.18.4 Environmental impact of extended operation

Impact formation

Loviisa power plant's most significant environmental impact on flora and fauna is the warming effect of the cooling water in the sea area on the discharge side. In extended operation, the power plant's impact on the flora and fauna would remain similar to its current level.

In extended operation, the impact of the thermal load would continue for a longer period of time, in line with the extended operating time, which would maintain Hästholmsfjärden's significance as important wintering grounds for waterfowl. The continuation of the cooling water's thermal effect would maintain ecosystem changes that favour the abundant occurrence of cyprinids in Hästholmsfjärden. This is likely to benefit the fish-eating waterfowl currently abundant in the area (including the great crested grebe, tufted duck and cormorant). The power plant's cooling water also maintains meltwater in the area during cold winters, which allows otters to fish by the areas free of ice.

SYKE monitors the status of the Baltic Sea with the aid of several different indicators, one of which is the development in the number of pairs in the avifauna of the Baltic Sea. Of the 29 species being monitored, a declining trend is observable in the stock of 14 species, and a rising trend in as many species (SYKE 2018). Examples of sea birds which, based on indicators, have been declining in recent decades (since the beginning of the 1980s) and which nest in the Loviisa nest area, include the tufted duck, velvet scoder, eider and black guillemot. The reasons for the decline of many of the aforementioned species include changes in their food chains and other indirect changes caused by the chemical status of the Baltic Sea. Thus, the status of the bird stocks is also a wider indication of the status of the Baltic Sea's biodiversity.

A minor deterioration in the quality of water on the discharge side contributed to by the power plant's thermal load cannot be entirely ruled out (see Chapter 9.16.4.2). In extended operation, a potential, minor change in the quality of water is not expected to have a detectable impact on the biodiversity of the water environment (phytoplankton, aquatic vegetation, benthic fauna) compared to the present state. In respect of the impact on avifauna, the potential spread of the round goby to the discharge side is expected to have a negative effect on biodiversity if endemic species of gobies, such as the black goby, disappear to make way for non-native species (see Chapter 9.17.4). With some archipelago birds, the potential minor deterioration in water quality may have an adverse effect on their pairs in the area of Hästholmsfjärden.

The continuation of the thermal effect may have both positive and negative effects on some species. The number of tufted ducks wintering in the power plant's vicinity, for example, is higher than usual due to the meltwater in the area during winter. On the other hand, the increasingly abundant stock of cyprinids may reduce the benthic fauna on which the tufted duck feeds (Finnish Wildlife Agency 2019).

Without the impact of the cooling water, the area would lack the meltwater enabling the otter's wintering, at least during cold winters. The most important factor in terms of otters and seals (mainly the grey seal occurring in the area) in extended operation would be the impact on the area's fish stocks. Based on the assessment of the impact on the icthyofauna, the warm water on the cooling water's discharge side favours fish species adapted to warm water, such as pike-perch. The Baltic herring has also been found to benefit from the higher water temperature and a slight increase in the nutrient concentration. In the present state, this is expected to benefit the otter and seal populations in Hästholmsfjärden.

Climate change is expected to increase the temperature of seawater (BACC II Author Team 2015), which will increasingly favour fish species adapted to warm water and their thriving in the discharge location of the cooling water. Several studies have found pike-perch, in particular, to benefit from the increase in temperature.

Overall, extended operation is expected to have a minor and favourable impact in terms of the avifauna and otters.

Extended operation would not have an impact on the land area's flora or fauna. The fauna in the power plant's impact area can be expected to be accustomed to human-derived disturbance (noise, the movement of people and machinery). Nor would extended operation require the clearing of new built-up areas.

The most significant environmental impact of extended operation would be the thermal load on Hästholmsfjärden and the resulting indirect impact on this body of water's ecological status. The closest site of the Natura 2000 network, which is protected on the basis of habitat types dependent on the water ecology, is the Källauden–Virstholmen area, 1.3 km to the northwest, on the side of Hudöfjärden (ID FI0100080) (Table 9-63). Based on the cooling water modelling (Lahti 2021) and the assessment on the waterways impact (see Chapter 9.16), the thermal effect on the intake side of the cooling water in the Källaudden–Virstholmen Natura area will be very small, practically negligible, during the ice-free season. The Natura area in question is therefore not subject to adverse effects. During ice cover, the thermal effect does not extend to the Källauden–Virstholmen Natura area. Based on this, the Natura area in question is not expected to be subject to adverse effects.

Nor is any other more distant site within the Natura 2000 network expected to be subject to adverse effects. Based on the cooling water modelling and the assessment concerning the impact on waterways, the thermal effect on the area will be negligible (Figure 9-66). As is evident from the figure concerning the modelling (Lahti 2021), the thermal effect on the Natura area, even in the case of the maximum temperature differences, is small, principally in the region of 0–1°C. At its greatest, the effect may be 1.5–2.0 °C at the Natura area's sharp headland extending to Vådholmsfjärden. Any situations involving maximum temperature differences are nevertheless short-lived, and in average conditions, the thermal effect of the power plant's operation does not, in essence, extend to the Natura area at all during the ice-free season.

Table 9-63. The habitat types mentioned as grounds for protection with regard to the Källaudden–Virstholmen Natura area (FI0100080), their connection to the waterways impact and the probability/significance of the impact.

Code and name of natural habitat type	Potential impact on waterways
1150 Flads, gloe lakes and coastal lagoons	The impact on the area attributable to the thermal load is negligible in the present state and the indirect **impacts are deemed negligible.**
1210 Annual vegetation of drift lines	The impact on the vegetation of drift lines would require extremely strong eutrophication and the resultant increased abundance of helophytes. **The habitat type is not impacted.**
1610 Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation	**The impact on the area attributable to the thermal load is negligible in the present state and the indirect** impacts are deemed negligible.
1640 Boreal Baltic sandy beaches with perennial vegetation	The impact on the vegetation of sandy beaches would require extremely strong eutrophication and the resultant increased abundance of helophytes. **The habitat type is not impacted.**
9080 Fennoscandian deciduous swamp woods	The status of the sea area has no impact on the habitat type. **The habitat type is not impacted.**

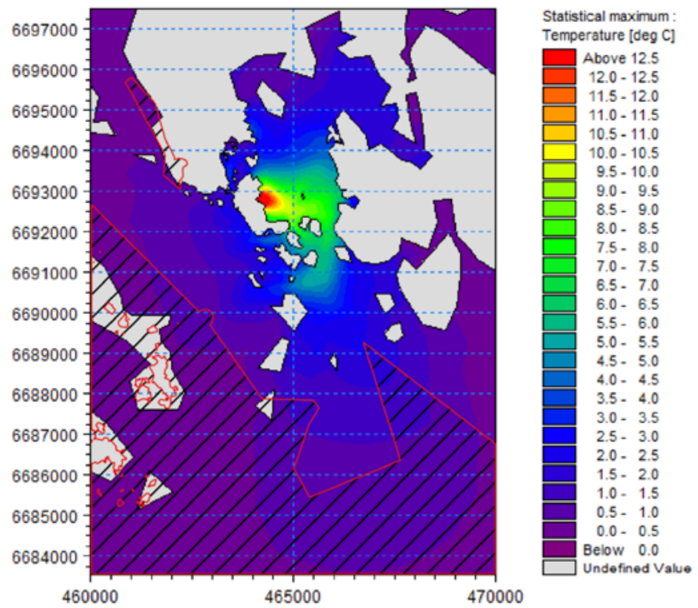

Figure 9-66. The maximum difference in surface temperature (power plant in operation – power plant not in operation) according to the modelling during the ice-free season. The hatched area delimited in red is the Natura area (Lahti 2021).

The grounds for protection mentioned with regard to the sea conservation area of the Pernaja bays and archipelago include a large number of different types of water habitat and waterfowl (Table 9-64), but not the species which gather in the power plant's meltwater area in the greatest numbers for wintering. This being the case, the minor positivefavourable impact on the avifauna will have no indirect impacts on the grounds for protection related to the sea conservation area of the Pernaja bays and archipelago.

The power plant's other operations (noise, dust) or traffic have no impact on the conservation areas.

9.18.5 Environmental impact of decommissioning

Impact formation

With decommissioning, the impact of the power plant's cooling water will end. The local impacts on the flora and fauna related to decommissioning will be caused primarily by dismantling measures and transport as well as the possible interim storage of quarry material. For the most part, the measures concern the built areas.

Table 9-64. The habitat types mentioned as grounds for protection with regard to the sea conservation area of the Pernaja bays and archipelago Natura area (FI0100078), their connection to the waterways impact and the probability/significance of the impact. The bird species mentioned as grounds for protection and the fauna listed in Annex II to the Habitats Directive are given at the bottom of the table.

Code and name of natural habitat type	Potential impact on waterways
1110 Sandbanks which are slightly covered by sea water all the time 1150 Flads, gloe lakes and coastal lagoons 1160 Large shallow inlets and bays 1170 Reefs 1610 Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation 1620 Boreal Baltic islets and small islands 1650 Boreal Baltic narrow inlets	In the present state, the impact on the Natura area attributable to the thermal load concerns a very small area, and even in this area, the impact is very small. The indirect **impact is deemed negligible.**
1130 Estuaries	The Estuaries habitat type principally depends on the impact of the freshwater carried by a river. Incidences of the habitat type are located far from the project area. **The habitat type is not impacted.**
1210 Annual vegetation of drift lines 1220 Perennial vegetation of stony banks 1640 Boreal Baltic sandy beaches with perennial vegetation	The impact on the littoral vegetation would require extremely strong eutrophication and the resultant increased abundance of helophytes. **The habitat types are not impacted.**
1230 Vegetated sea cliffs of the Atlantic and Baltic coasts 1630 Boreal Baltic coastal meadows 6270 Fennoscandian lowland species-rich dry to mesic grasslands 7140 Transition mires and quaking bogs 7160 Fennoscandian mineral-rich springs and springfens 8220 Siliceous rocky slopes with chasmophytic vegetation 9010 Western Taiga 9020 Fennoscandian hemiboreal natural old broad-leaved deciduous forests (Quercus, Tilia, Acer, Fraxinus or Ulmus) rich in epiphytes 9050 Fennoscandian herb-rich forests with Picea abies 9080 Fennoscandian deciduous swamp woods 91D0 Bog woodland	The sea area's temperature has no impact on the habitat type. **The habitat types are not impacted.**
large white-faced darter	A species of eutrophic reed fields. **The species is not impacted.**
grey seal, ringed seal	The seals are dependent on the development of the Natura area's fish stocks and the sea area's ecological status. The project will not have an impact on the Natura area's icthyofauna or the ecological status of its sea area. As an indirect impact, Hästholmsfjärden's abundant cyprinid and other fish species may have a **minor positive impact** on the grey seal.
great reed warbler, razorbill, pintail, shoveller, garganey, gadwall, taiga bean goose, ruddy turnstone, greater scaup, Eurasian bittern, black guillemot, western marsh harrier, corn crake, tundra swan, whooper swan, Eurasian hobby, common kestrel, great snipe, common crane, red-backed shrike, lesser black-backed gull, little gull, velvet scoder, smew, osprey, European honey buzzard, ruff, spotted crake, common eider, Caspian tern, common tern, Arctic tern, barred warbler, wood sandpiper, common redshank, common murre	The species mentioned as grounds for protection do not feed or winter in the area of Hästholmsfjärden to any significant degree. **The project will not have an impact on the species.**

With decommissioning, the impact of the warm cooling water will end, and the occurrence of winter birds in Hästholmsfjärden will decline. As a result of this change, it is likely that Hästholmsfjärden can no longer be categorised as a regionally important bird area. As the thermal load reduces, the status of the Klobbfjärden body of water, located on the cooling water's discharge side, is expected to improve. In general, the change is expected to have a favourable local impact on the living conditions of archipelago birds and the marine environment's biodiversity once the thermal load impairing the natural state in the area comes to an end. When examining solely impacts on the avifauna, and particularly the significance of the impact in terms of bird areas categorised as valuable, the decommissioning will have a negative impact.

The otter's possibilities for wintering in the area will be adversely affected when the meltwater area in the winter disappears, but the improvement in the sea area's status is considered a positive change of an equal magnitude. Therefore, the impact in terms of the otter is considered neutral.

The decommissioning will not have direct impacts on conservation areas, given that the disturbance caused by the dismantling activities will not extend to the conservation areas or the sites which are part of the Natura 2000 network.

The local impacts on the flora and fauna related to decommissioning are primarily caused by dismantling measures and transport. For the most part, the measures concern the built areas. The impact will concern conventional vegetation, and there is no knowledge of any particularly notable species or endangered habitat types occurring in the impact area. If the quarry material generated in the excavation of the L/ILW repository is placed in interim storage within the power plant area, the clearing of the potential storage area may require the removal of trees or the levelling of topsoil. Should the decommissioning be carried out according to the brownfield principle, buildings and other infrastructure will remain in the area, due to which vegetation in the area would not increase to any significant degree. If the decommissioning is carried out according to the greenfield principle, the power plant area will be restored to a state as close to its natural state as possible, and the area of plant cover there will increase compared to the present state. The impact that the landscaping will have on the fauna depends on the vegetation used, but in principle, the change can be expected to increase the flora and fauna, and thereby biodiversity, in the area. The impact is local and small in area.

As a whole, decommissioning is expected to have a minor and negative impact, which will be manifested as the disappearance of the regionally important wintering grounds for waterfowl. This is nevertheless not expected to have a significant impact on the populations of the birds in question, because their primary wintering grounds are naturally further west and south within the area of the Baltic Sea.

9.18.6 Radioactive waste generated elsewhere in Finland and its impact

The reception, handling, interim storage and final disposal of any radioactive waste generated elsewhere in Finland within the power plant area would not have an impact on the flora, fauna or conservation areas. The increase in disturbance caused to traffic by the transports along the transport route is deemed a negligible factor compared to other traffic on the transport route.

9.18.7 Significance of impacts

Table 9-65 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (see Chapter 9.1.4).

Table 9-65. Significance of impacts: flora, fauna and conservation areas.

Significance of impacts: flora, fauna and conservation areas			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	**Moderate**	**Minor positive**	**The significance of the impacts is minor and positive,** given that the continuance of the cooling water's thermal load would maintain Hästholmsfjärden's significance as regionally important wintering grounds for waterfowl. The thermal load may nevertheless contribute to a deterioration of the quality of water on the discharge side, which may, in terms of some archipelago birds, have an adverse effect on their pairs in the area and, more generally, on the sea area's biodiversity. Extended operation would have no impact on conservation areas.
Decommissioning	**Moderate**	**Minor negative**	**The significance of the impacts is minor and negative,** given that the end of the cooling water's thermal load will weaken the regionally important wintering grounds for waterfowl in Hästholmsfjärden. However, this is not expected to have a significant impact on the populations of the birds in question. The decommissioning will not have an impact on conservation areas.
Radioactive waste generated elsewhere in Finland	**Moderate**	**No change**	**No impact** on the flora, fauna or conservation areas.

9.18.8 Mitigation of adverse impacts

The impacts of the dismantling activities can be mitigated by planning the interim storage of the machinery and materials on site so that the impact on the flora and habitats occurring in the area is as minor as possible.

9.18.9 Uncertainties

Due to climate change, the number of winters with ice cover, or the number of days with ice cover during the winter, is likely to decrease in the Loviisa area, which will increase the number of wintering grounds suitable for waterfowl in the Loviisa area and beyond. This will complicate the assessment of Hästholmsfjärden's significance in terms of avifauna in the coming decades.

9.19 PEOPLE'S LIVING CONDITIONS AND COMFORT

9.19.1 Principal results of the assessment

The significance of the impacts of extended operation was deemed, as a whole, minor and negative, given that the impacts on people's living conditions and comfort under extended operation would continue for approximately 20 years. The discharge of warm cooling water, combined with the changes brought about by climate change, may impact the recreational value of the area's waterways, mainly in Hästholmsfjärden. In other respects, the impacts and adverse effects experienced by people will remain largely similar to their current levels. The potential additional construction could cause some additional adverse effects. In extended operation, the possible concern over safety risks would continue and could grow as the waste volumes increase and the plant ages. Extended operation could also have a positive impact on the area's demographics.

The power plant's decommissioning will result in a clear and observable change in the operations taking place in the power plant area. All in all, the various phases of the decommissioning will take several decades. A change of such duration may give rise to uncertainty among residents about the future, with the associated related concerns and expectations. The significance of the impacts was deemed moderate and negative. The occasional noise caused by the operations carried out during the decommissioning may impact particularly the comfort of holidaymakers staying in holiday homes in the vicinity of the power plant and the recreational experiences of people using the waterways and shores. The increased traffic during the most active dismantling phase may impair the nearby area's road safety and affect the smooth flow of traffic. The interim storage and transports of spent nuclear fuel may involve concerns about safety risks. Transports may especially raise concerns, even on a wider scale. The power plant's decommissioning and termination of electricity production may result in changes to the local identity and concerns about the effect that the change will have on the vitality of the Loviisa region.

Once the L/ILW repository has been closed, the significance of the impacts will become minor and positive. As operations in the power plant area come to an end, any concerns about the risk of accidents or other incidents related to the operations will end. As a result of the end of operation, the need for cooling water and the thermal load will first reduce to a fraction during the operation of plant parts to be made independent and ultimately terminate completely. The positive impacts that the change will have on the status of Hästholmsfjärden's water environment may have a positive impact on the year-round recreational use of the waterbody and on residential comfort in the lakeside properties in the long run If all power plant structures and buildings are dismantled at the end of the decommissioning, and the area is landscaped according to the greenfield principle, the impact on the nearby area's residential comfort and recreational use will be more positive than the impact of a partial dismantling of the structures (the brownfield principle).

The transports, handling and final disposal of radioactive waste generated elsewhere in Finland would not result in impacts on people's living conditions and comfort. Loviisa power plant's reception of waste generated elsewhere in Finland nevertheless raises concerns among residents. Even if there were no realistic grounds for such concerns, it is still an actual social impact, the magnitude of which has been deemed minor and negative.

9.19.2 Baseline data and assessment methods

The assessment of social impacts reviewed the potential impacts on humans, the community or society as follows:

- the comfort and safety of the residential and living environment;
- traffic and mobility;
- the nearby areas' recreational use;
- community spirit and local identity;
- services and economic life;
- demographics;
- the use of tangible property and real estate in the nearby area.

The results of the assessment concerning impacts on the regional economy are presented in Chapter 9.13. The possible impacts of incidents and accidents are addressed in Chapters 9.21 and 9.22.

Social impacts are tightly linked to other impacts (such as the regional economy, noise, emissions, traffic and landscape), either directly or indirectly. In addition, social impacts – in the form of residents' concerns, fears, wishes, and uncertainty about the future – may emerge as early as during the planning and assessment stage of a project, for example.

The assessment concerning social impacts was carried out in the form of an expert assessment, based on the following baseline data:

- the results of other impact assessments;
- the results of the residential survey;
- the feedback received in the small group event;
- the opinions submitted on the EIA Programme;
- any other feedback received during the assessment procedure (in public events, the meetings of the audit group and evening meetings held with fishermen);
- population, map and other statistics.

Table 9-66. Activeness in responding to the survey among different groups of respondents. Three control forms have been added to the number of forms sent to residents and holidaymakers at a minimum distance of 5 km from the power plant.

	Forms sent	Number of respondents	Response rate
Permanent resident, 0–5 km	37	30	81%
Resident of secondary home, 0–5 km	258	99	38%
Permanent resident, 5–20 km	831	158	19%
Resident of secondary home, 5–20 km	177	75	42%
Total	**1303**	**362**	**28%**

Table 9-67. Population structure of the town of Loviisa in 2019 (Statistics Finland 2021a) and respondents to the survey.

	Residents, total	Women	Men	aged 18–30	aged 31–50	aged 51–65	over 65
Town of Loviisa	14,772	50%	50%	12%	27%	28%	33%
All respondents	362	41%	59%	3%	17%	32%	49%

The impact on people's living conditions and comfort was assessed with the aid of guidelines prepared by the National Research and Development Centre for Welfare and Health ("Ihmisiin kohdistuvien vaikutusten arvioiminen", Kauppinen and Nelimarkka 2007) and a handbook of the Ministry of Social Affairs and Health ("Ympäristövaikutusten arviointi, Ihmisiin kohdistuvat terveydelliset ja sosiaaliset vaikutukset", Ministry of Social Affairs and Health 1999).

9.19.2.1 Resident survey

A survey conducted among the residents living in the vicinity of Loviisa nuclear power plant during the EIA report phase aimed to gauge the use and meaning of the power plant's nearby areas, the respondents' views of the present state of their residential environment and their perceptions of the planned operations.

The resident survey was sent to a total of 1,300 households on 9 December 2020. The survey was sent to all permanent residents and secondary homeowners within a 0–5 km radius of the power plant, including the residents of the lakeside properties of Lappomträsket lake. The total number of households in this area was 295. In addition, the survey was sent by way of random sampling to households located at a distance of 5–20 km from the power plant.

In accordance with the selection criteria, the survey was only sent to households with residents aged 18–80 who have not chosen to opt out of direct marketing. According to the data in the registry of the Digital and Population Data Services Agency, households were sent a total of 1,303 survey forms. This figure includes three control forms posted for the purposes of the survey's official inspection to Posti Group, the main postal service in Finland, and the Digital and Population Data Services Agency.

Respondents were given the choice to respond to the survey either by posting the completed form, or by responding to the questions online, by 11 January 2021. The number of responses received by this date was 362.

The response rate was 28%. Table 9-66 shows a breakdown of response activity according to respondent groups. Permanent residents in the nearby area made up the most active group of respondents. The residents of secondary homes nearby and further away also responded to the survey at a higher rate than in general.

The proportion of male respondents and respondents who were aged 65 or more was greater than their proportion of the population (Table 9-67). Half (49%) the respondents had lived or holidayed in the nearby region for more than 40 years, and 25% for at least 20 years. Respondents who had lived or holidayed in the area for less than 10 years made up only 9% of the total number of respondents.

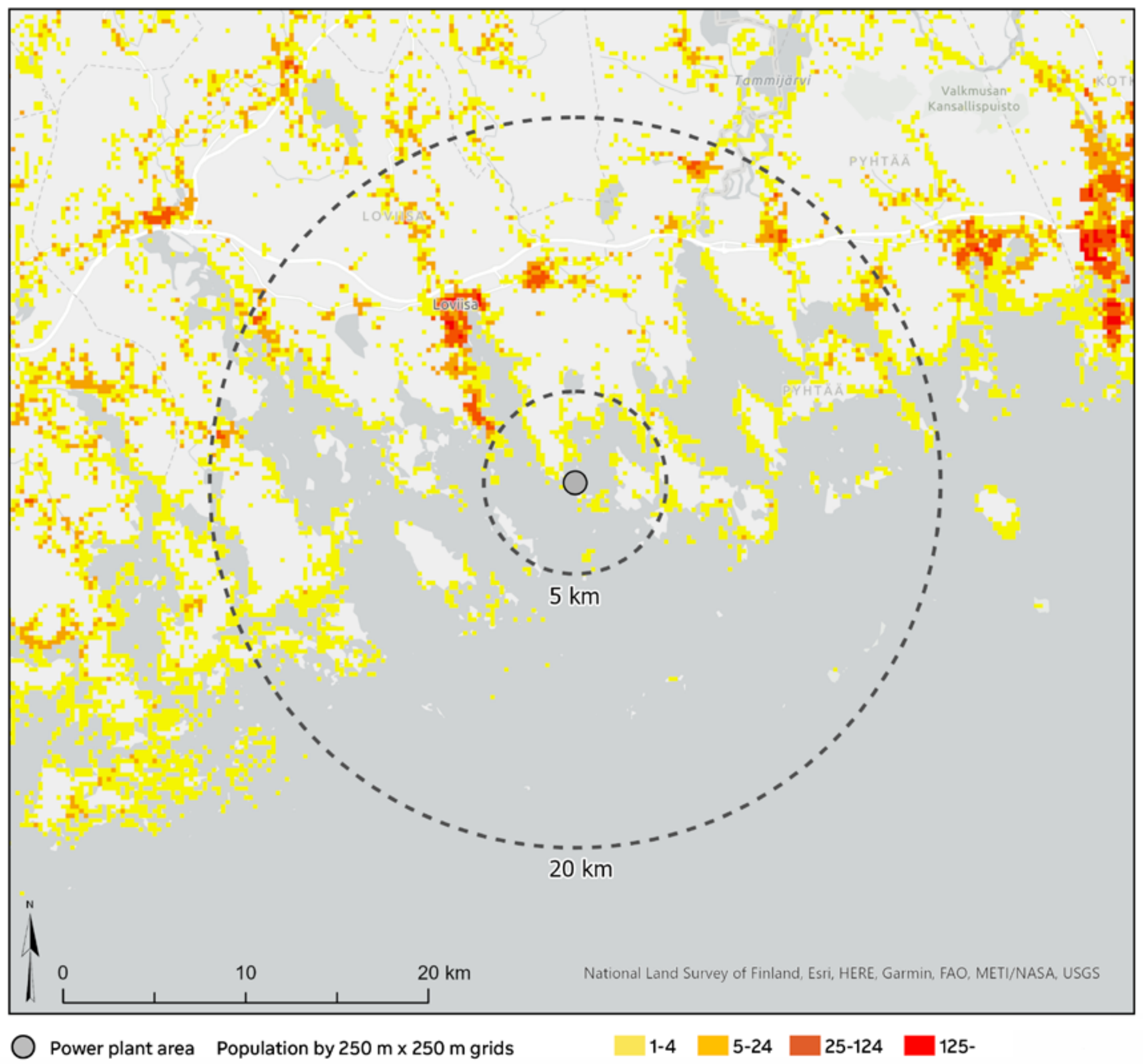

Figure 9-67. Distribution of population at a distance of 5 and 20 kilometres from the power plant.

The results of the resident survey were processed with a statistical application (the Excel-based Tixel application). The statistical significance in relation to the underlying variables (respondent's gender, age group, stage of life, duration of residence and the location of their permanent residence/secondary home) was investigated with a chi-squared test. The review of the results focuses only on the statistically significant results which hold practical relevance in terms of the survey and the assessment of the social impacts. The charts showing the results of the resident survey show only the questions in which there is a statistically significant difference (P=0.005) between neighbouring residents and respondents living further away.

9.19.2.2 Small group events

A small group event for residents was held in February 2021. Information about the small group event was distributed in the cover letter of the resident survey, which contained a link through which two of the participants expressed their interest in participating in the event. In addition to these two residents, an invitation to the event was sent to two individuals who gave their contact details on the resident survey's response form.

Due to the prevailing Covid-19 situation, the small group event was held remotely, using the Microsoft Teams application. The participants were composed of one resident, two representatives of the project owner and two representatives of the EIA consultant. The topics discussed at the event included the progress of the EIA Procedure, the preliminary results of the resident survey and the results of the assessment concerning the impacts on the regional economy.

9.19.2.3 Other feedback received during the assessment procedure

During the assessment procedure, feedback was also received through other channels, including the public event held during the EIA Programme phase and the meetings of the audit group set up for the EIA Procedure (see Chapter 8.5.3) as well as the evening meetings organised for the area's fishermen. The opinions on the EIA Programme submitted to the coordinating authority and their consideration are discussed in Appendix 3.

A total of 11 opinions was submitted on the EIA Programme. The issues raised in the opinions included the nuclear safety risks which would increase as the plant ages, uncertainties related to the final disposal of nuclear waste, the impacts that the intake of raw water would have on the eutrophication and water level of Lappomträsket lake, the scope of the waterbody's monitoring programme, and the impacts of cooling water. One opinion was in favour of extending the operating licences so that Finland would be able to attain its climate objectives.

The topics discussed in the EIA Programme's public event included potential investment needs, the reception of radioactive waste generated elsewhere in Finland and the future of the plant building after decommissioning. A member of the public also raised a question concerning the impacts on the value of real estate in the power plant's vicinity.

9.19.3 Present state

9.19.3.1 Population and residents

The town of Loviisa lies on the coast of the Gulf of Finland, approximately 90 km east of Helsinki. Its neighbouring municipalities are Lapinjärvi, Pyhtää, Myrskylä, Kouvola and Porvoo. Loviisa forms the Loviisa sub-regional area with Lapinjärvi. In 2019, Loviisa's population was 14,772. Of the neighbouring municipalities, Lapinjärvi had a population of 2,606, while the population of Pyhtää was 5,140, Myrskylä 1,882, Kouvola 82,113 and Porvoo approximately 50,380.

The share of Swedish-speaking population in Loviisa (40.5%) and in Lapinjärvi (30.4%) is considerably higher than in Pyhtää (7.2%). In the Loviisa sub-regional area, the share of people aged 65 years or older is higher, and the share of people under 15 is lower than in Uusimaa and the average for Finland as a whole. The share of people of studying and working age in the population is slightly lower than in Uusimaa and the average for Finland as a whole. The demographic trend in the Loviisa region has been declining for a long time. In 2019, net emigration amounted to 15 people in Loviisa, 29 in Lapinjärvi and 11 in Pyhtää (Statistics Finland 2021b). According to the population forecast, the population in the Loviisa area will remain fairly unchanged until 2040 (Helsinki-Uusimaa Regional Council 2019).

There are about 40 year-round residents up to a distance of five kilometres from the power plant (Figure 9-67). The closest residential buildings in private use are located in Bodängen, at a distance of roughly 900 metres from the power plant area (Figure 9-3). For the most part, the permanent residents are concentrated in the areas of Björnvik and Lappom, both north of the power plant. There are about 12,400 year-round residents up to a distance of 20 kilometres from the power plant (Figure 9-67). The largest population concentration in the vicinity is the centre of the town of Loviisa, roughly 12 km from the power plant. Tesjoki and the municipal centres of Ruotsinpyhtää and Pyhtää are built-up areas of less than 1,000 inhabitants each. Smaller population centres include Kuggom, the Pernaja municipal centre, the village of Isnäs in Pernaja and the village of Purola in Pyhtää.

There are many secondary/holiday homes in the vicinity of Hästholmen (Figure 9-3). The secondary homes closest to the power plant area are owned by Fortum. The other closest secondary homes are located on the islands to the south and southeast of Hästholmen (Vastaholmen, Småholmen, Måsholmen, Högholmen, Myssholmen, Björkholmen and Kojholmarna) and on the mainland, no closer than 1.3 km from the power plant. There are a little less than 500 secondary homes within five kilometres of the power plant and approximately 3,000 secondary homes within 20 kilometres of it.

9.19.3.2 Sensitive sites as well as tourist destinations and recreational sites

The nuclear power plant is surrounded by a precautionary action zone extending to a distance of five kilometres, in which land use restrictions are in force (STUK Y/2/2018). The precautionary action zone may not contain, for example, facilities inhabited or visited by a considerable number of people, such as schools, hospitals, care facilities, shops, or significant places of employment or accommodation that are not related to the nuclear power plant (YVL A.2).

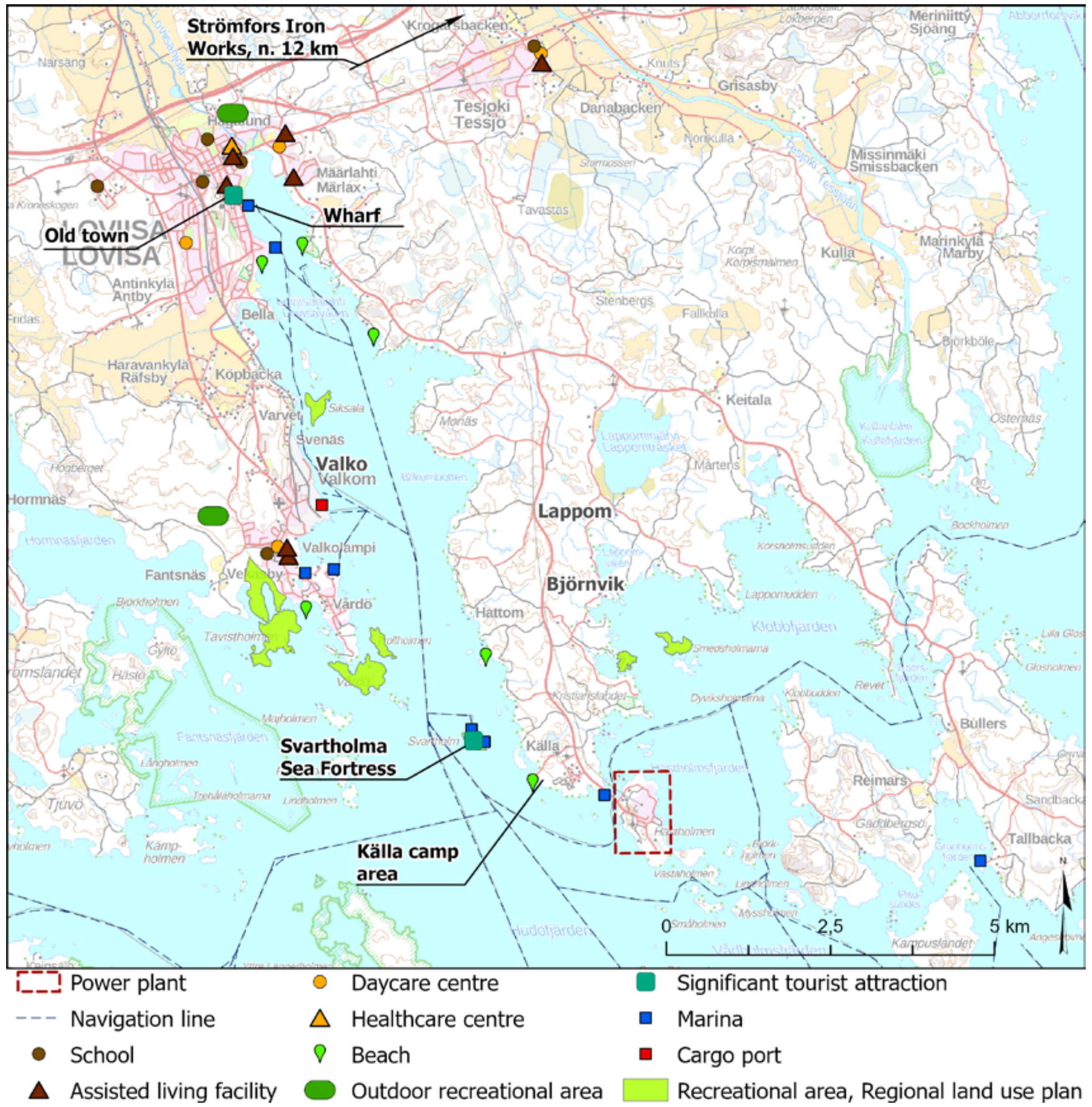

Figure 9-68. The sensitive sites as well as tourist destinations and recreational sites closest to the power plant area.

The sensitive sites as well as tourist destinations and recreational sites closest to the power plant area are shown in the figure (Figure 9-68). The nearest school and day care centre are in the village of Valko, approximately seven kilometres from the power plant.

The closest tourist destination is the Svartholma Sea Fortress, roughly two kilometres from the power plant. Other tourist destinations located further away include the old town of Loviisa, the Laivasilta marina and the Strömfors Iron Works. Svartholma is a popular destination which can be reached by private boats in addition to a regular service vessel. Loviisa's other marinas and docks include Bockhamn, Lillfjärden, Kabböle, Rönnäs and Backstensstrand. The Loviisa area is home to a number of enterprises offering fishing, accommodation, nature and activity services. While tourism to the area has been increasing in recent years, it is not among the key travel destinations in Finland (Visit Loviisa 2021).

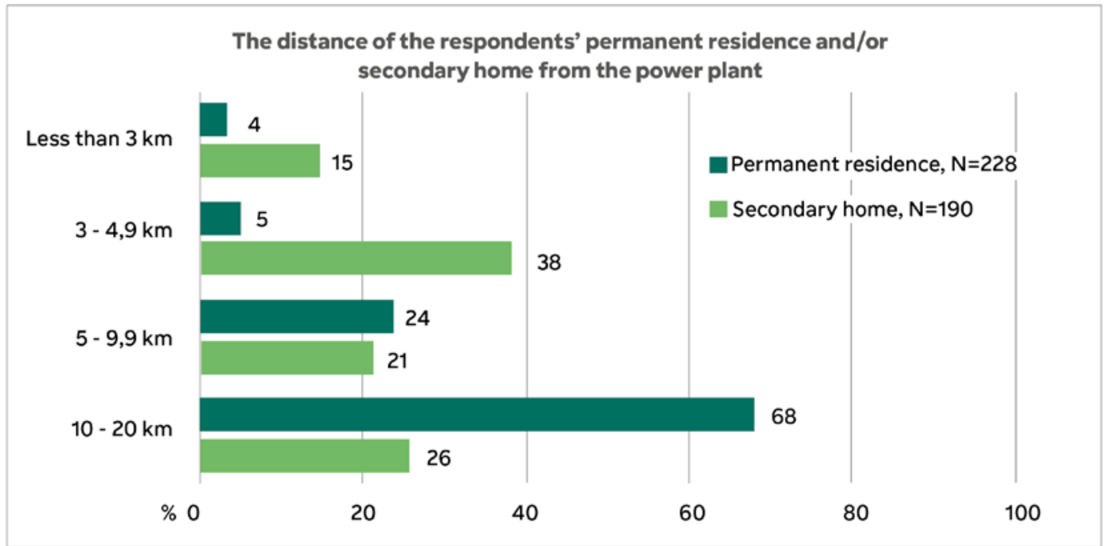

Figure 9-69. The distance of the respondents' permanent residence or secondary home from the power plant area. The percentages of residences located at different distances and the number of respondents (N) are shown in the figure.

The town of Loviisa's Källa camp area is located approximately a kilometre west of the power plant. The camp area is intended for the camping, outing and recreational activities of the town's various branches of government as well as local associations and communities, with priority given to youth activities. Loviisa offers several recreational destinations in its water areas, as well as hiking trails, nature trails and outdoor recreation areas.

9.19.3.3 Residents' use of the areas

Of the people who responded to the resident survey, 228 have a permanent residence in the distribution area, while 190 people have a secondary home there. The distance of the respondents' homes or secondary homes from the power plant is shown in Figure 9-69. The respondents in the survey who reported living or holidaying at a distance of less than five kilometres (0–4.9 km) from the power plant were categorised as neighbouring residents. The residents of the lakeside properties at Lappomträsket lake were also counted as neighbouring residents. Of all the respondents, 36% (129 respondents) were neighbouring residents, and a fourth of them permanent residents. The permanent residence or secondary home of some of the neighbouring residents who responded to the survey was located in the area of Hästholmsfjärden or Klobbfjärden. The areas delimited

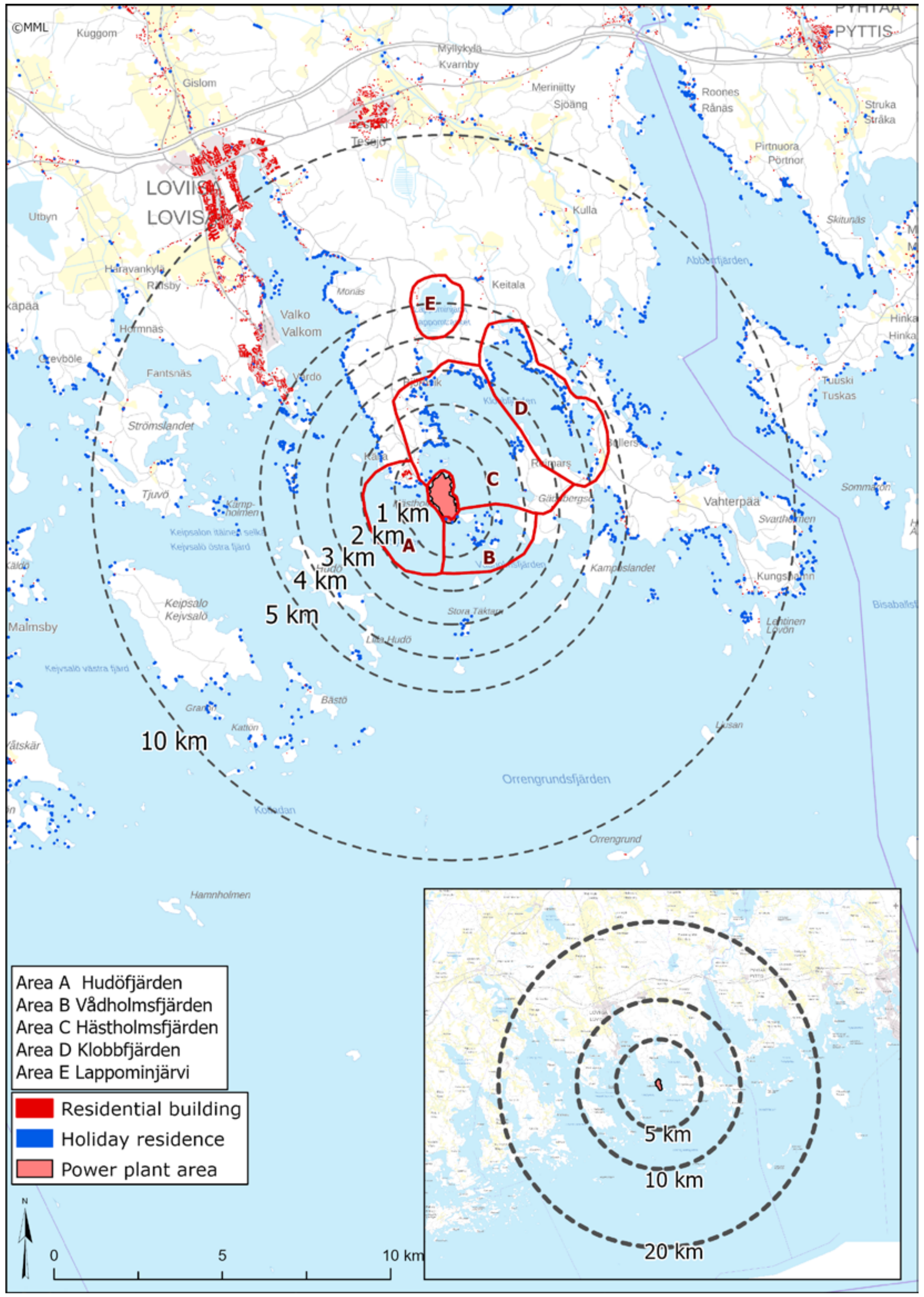

Figure 9-70. The map in the resident survey's cover letter on the water areas and the location of residential areas in the vicinity of the power plant. The distance sectors are counted from the shoreline of the island of Hästholmen.

on the map in the survey's cover letter (Figure 9-70) were Hudofjärden, Vådholmsfjärden, Hästholmsfjärden, Klobbfjärden and Lappomträsket lake.

According to the resident survey, the residents use the water areas and shores surrounding the nuclear power plant in the summer to spend time at their secondary home and for outdoor activities, boating and nature observation (Figure 9-71 and Figure 9-72). There is a statistically significant difference in all of the responses between the neighbouring residents and respondents living further away, in that the neighbouring residents are more active in using the areas. Although most of the residences located at a distance of less than 5 km from the power plant are secondary homes, some of these holiday properties are in year-round use. More than a third of the neighbouring residents reported spending time at their secondary home or in outdoor activities in the area at least monthly during the winter. A statistically significant difference between the responses of neighbouring residents and respondents living further away was observable when the respondents were asked how well they knew the bodies of water. The best known of them were Hästholmsfjärden and Klobbfjärden, east and north-east of the power plant. A little less than half the neighbouring residents viewed these areas as personally important and familiar, whereas some 10% of those living further away thought this.

Table 9-68 shows the sensitivity of the affected aspect and some factors determining sensitivity (see Chapter 9.1.4).

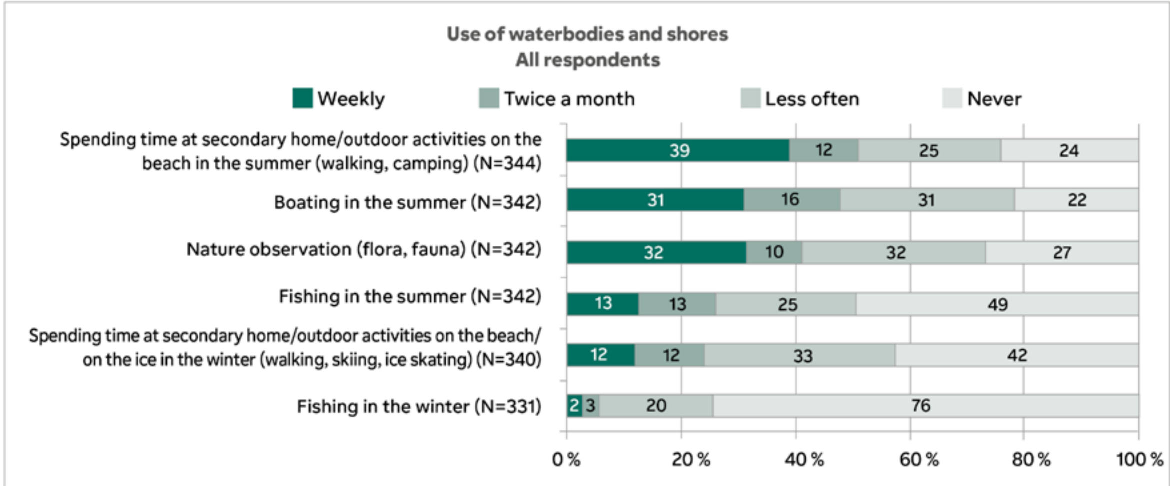

Figure 9-71. The views of the resident survey's respondents on the use of the waterbodies and shores in the vicinity of the power plant area (all respondents). The figure shows the percentages of the respondent groups and the number of respondents (N).

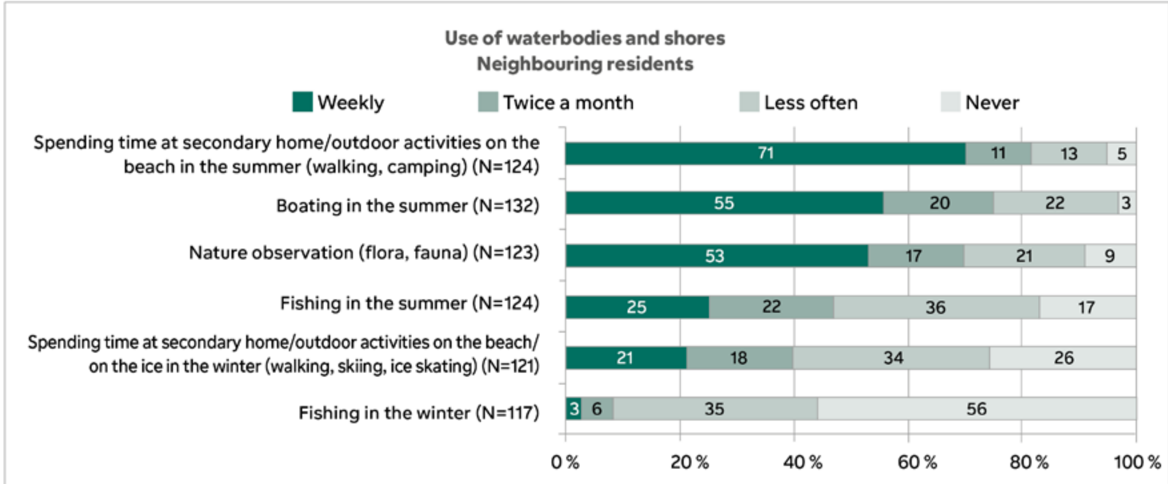

Figure 9-72. The views of the resident survey's respondents on the use of the waterbodies and shores in the vicinity of the power plant area (neighbouring residents). The figure shows the percentages of the respondent groups and the number of respondents (N).

Table 9-68. Sensitivity of affected aspect: people's living conditions and comfort.

Sensitivity of affected aspect: people's living conditions and comfort	
The sensitivity of the affected aspect is influenced by the number of people in the area who are potentially subject to adverse effects and by the location of particularly sensitive aspects such as schools, daycare centres or assisted living facilities. The sensitivity increases if the area has hobby or recreational value or landscape values, and no alternative areas are available. In addition to the affected aspects, the sensitivity is influenced by the status of the area's current environmental nuisances (such as traffic and noise) and the environment's process of change.	
Moderate	The area of the nuclear power plant is surrounded by a precautionary action zone extending to a distance of five kilometres. This precautionary action zone may not contain facilities inhabited or visited by a considerable number of people, such as schools, hospitals, care facilities or shops. There are many secondary homes at a distance of less than five kilometres from the power plant. Loviisa offers several recreational destinations in its water areas, as well as hiking trails, nature trails and outdoor recreation areas. The camp area Källa and the Svartholma Sea Fortress are located in the vicinity of the power plant. The power plant area has been in the area for a long time, and its construction has previously altered the island of Hästholmen and its environment, due to which the adaptability for changes is moderate. The area has remained unchanged for a fairly long time and is today subject to very little environmental nuisance, such as operations emitting noise.

9.19.4 Residents' views

9.19.4.1 Residents' views on the impact of current operations

The respondents' views on the impact that the power plant's current operations have on the nearby areas varied (Figure 9-73 and Figure 9-74). The results included statistically significant differences in relation to a residence's distance and the stage of life. The neighbouring residents viewed the impacts of the current operations more negatively than those living further away.

The analysis of the resident survey's results focused on the responses of the neighbouring residents in questions concerning the impacts of the operations in the vicinity of the power plant. The proportion of respondents who viewed the impacts negatively was the greatest in questions concerning the impacts on the landscape; the impacts that the discharge of the warm cooling water would have on Hästholmsfjärden, Klobbfjärden and Vådholmsfjärden; and the impacts on residential comfort and fishing. The respondents' views were more neutral in terms of the impacts on boating, road safety, recreational conditions and the noise situation (Figure 9-73).

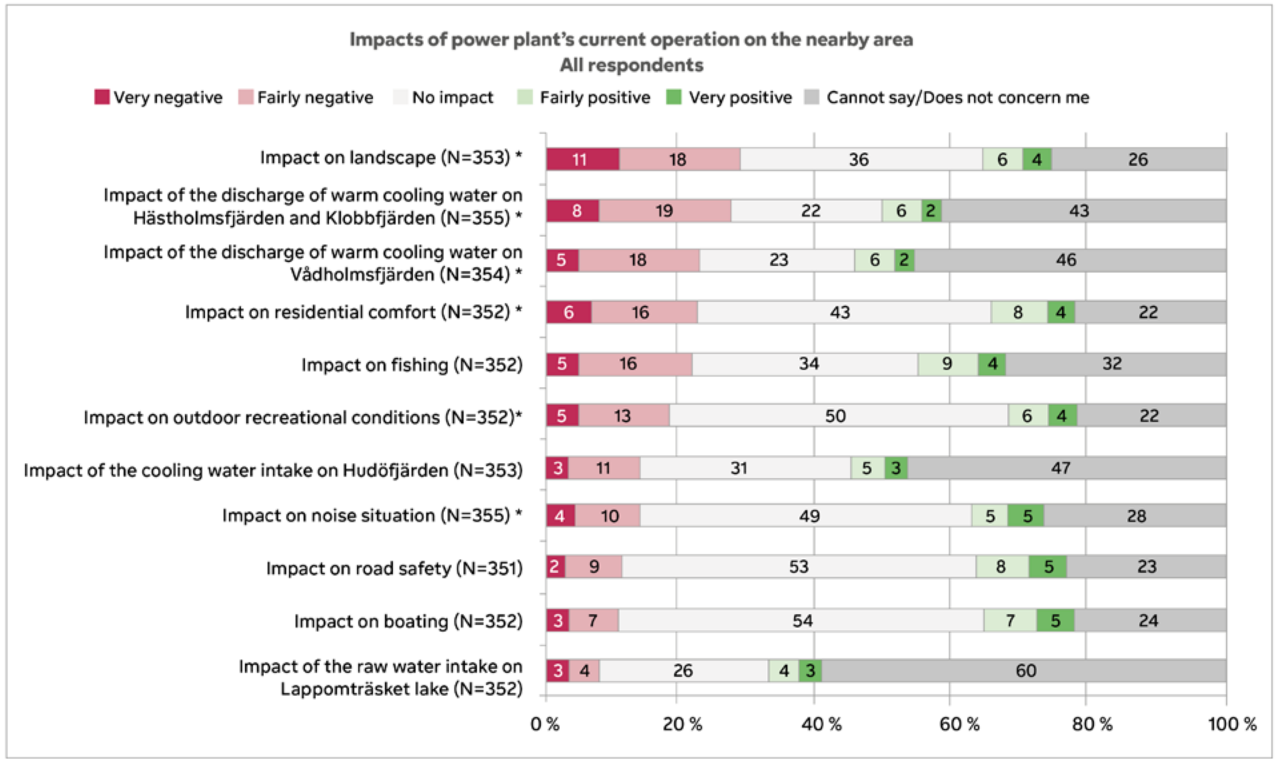

Figure 9-73. The views of the resident survey's respondents on the impact that the power plant's current operations have on its vicinity (all respondents). The figure shows the percentages of the respondent groups, the number of the respondents (N); the issues marked with an asterisk (*) indicate a statistically significant difference per respondent group in relation to a residence's distance.

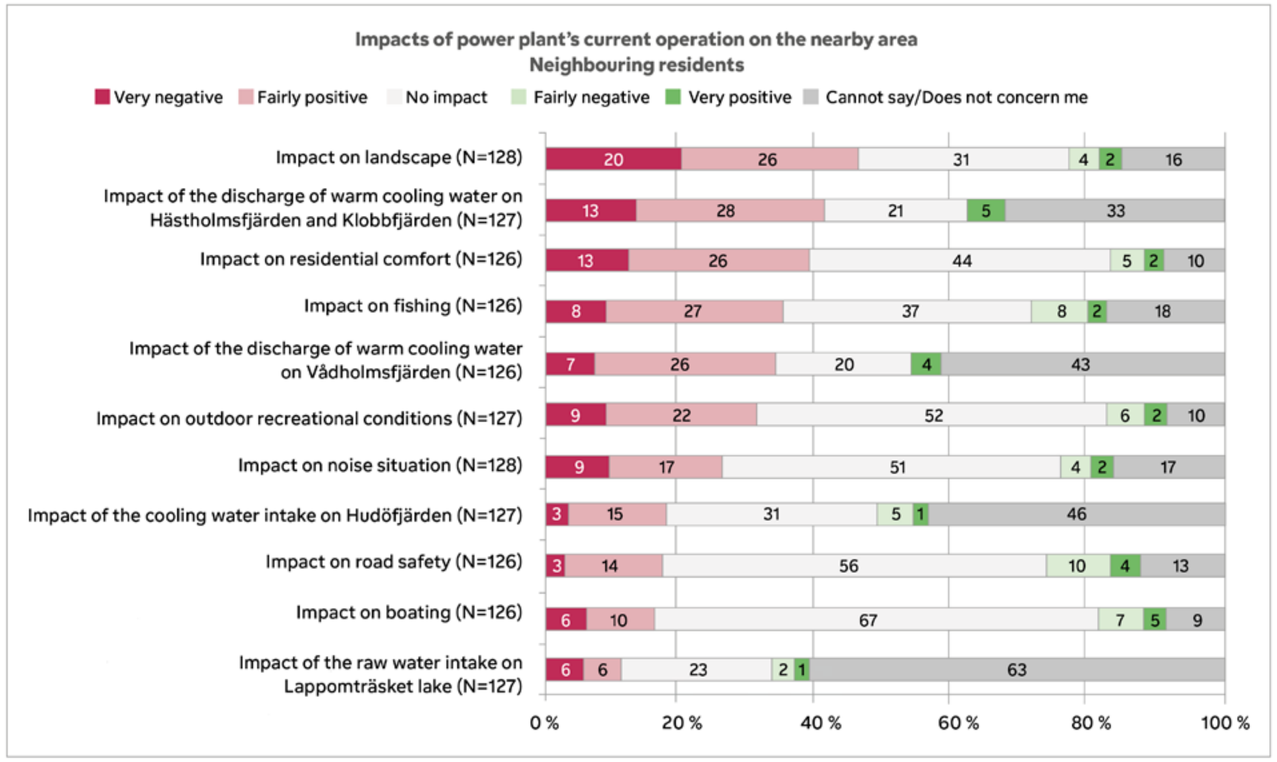

Figure 9-74. The views of the resident survey's respondents on the impact that the power plant's current operations have on its vicinity (neighbouring residents). The figure shows the percentages of the respondent groups and the number of respondents (N).

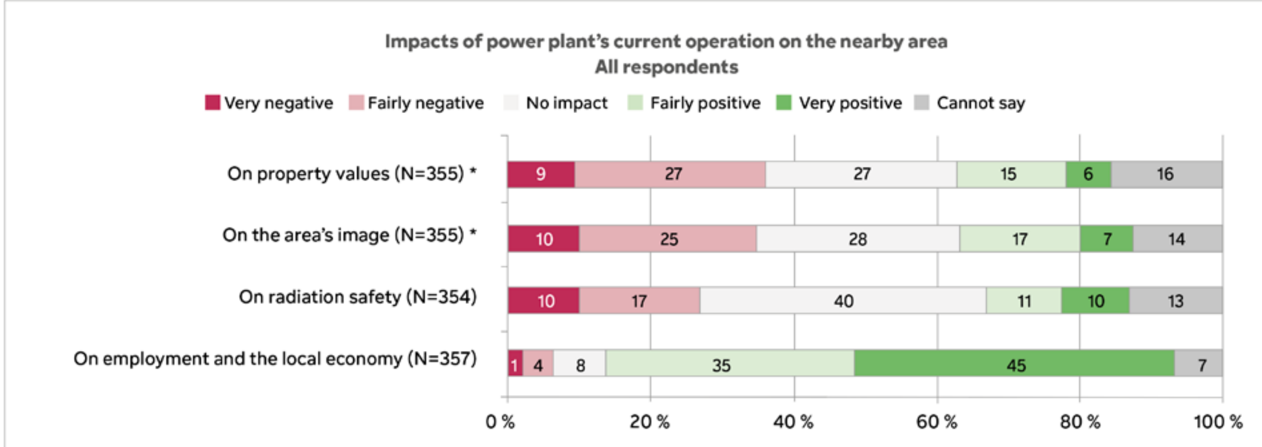

Figure 9-75. The views of the resident survey's respondents on the impact that the power plant's current operations have in the region (all residents). The figure shows the percentages of the respondent groups, the number of the respondents (N); the issues marked with an asterisk (*) indicate a statistically significant difference per respondent group in relation to a residence's distance.

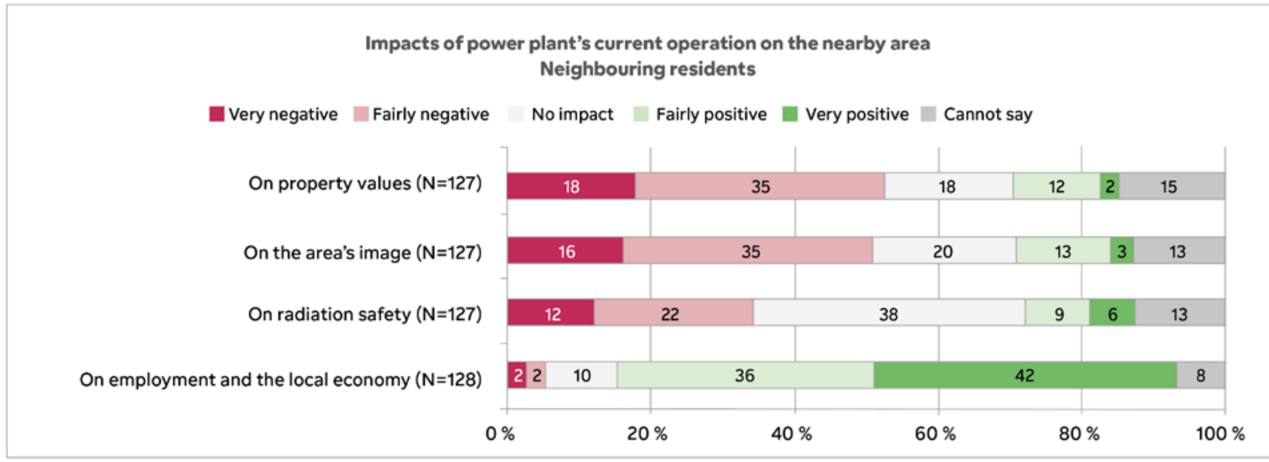

Figure 9-76. The views of the resident survey's respondents on the impact that the power plant's current operations have in the region (neighbouring residents). The figure shows the percentages of the respondent groups and the number of respondents (N).

The respondents were given the opportunity to specify their responses in the comment section of the open-ended questions. Negative observations included the eutrophication of the shores, the impacts on movement on ice and winter fishing, the adverse effect of the power plant's floodlights as well as the occasional noise and hum from the power plant. Some of the comments perceived the high driving speeds on Atomitie, and the traffic volumes there during annual outages, as well as the lack of a pedestrian and cycle lane, as a factor impairing road safety. On the other hand, some of the respondents appreciated the good maintenance of the roads leading to the power plant, which also benefits holidaymakers. Concern over the eutrophication of the Lappomträsket lake and Lappomviken was also mentioned in a few of the open-ended responses and in one opinion submitted on the EIA Programme.

The high number of "cannot say/does not concern me" responses to questions pertaining to the power plant's nearby bodies of water suggests that some of the respondents have been unable to assess the operations' impact on waterways.

When asked about the impact of current operations in the region, most of the respondents were of the opinion that the operations had a positive impact on employment and the local economy (Figure 9-74 and Figure 9-75). When asked about the impact on property values, the area's image and radiation safety, the responses included more variation between positive, neutral and negative views. Neighbouring residents saw the impacts on property values and the area's image as more negative than those living further away.

In the resident survey, the respondents were asked about their attitude to nuclear power at a general level. Three quarters of the respondents reported having a positive attitude to nuclear power (Figure 9-77).

9.19.4.2 Residents' views on the planned operations

The views of the resident survey's respondents on the planned operations varied, but they had the most positive attitude to extending the power plant's operation until 2050 (Figure 9-78, Figure 9-79 and Figure 9-80). There was a statistically significant difference in all the responses between the neighbouring residents and respondents living further away. The neighbouring residents had a more negative attitude than those living further away to any operations other than the end of operation in 2027/2030. Nearly three quarters of the neighbouring residents had a negative attitude on radioactive waste generated elsewhere in Finland being handled, placed in interim storage and deposited for final disposal at Loviisa power plant. More than half the neighbouring residents likewise had a negative attitude to the expansion of the L/ILW repository.

Among all respondents to the resident survey, extended operation received more support than the termination of operation (Figure 9-81). The results showed statistically significant differences between the neighbouring residents and respondents living further away. While a clear majority of those living further away was in favour of extended operation, the responses of the neighbouring residents were distributed more evenly between extended operation and the termination of operation.

When the respondents' views on the best project option were analysed to take their attitude to nuclear power into account, statistically significant differences between the respondents were observed. Of those with a positive attitude to nuclear power, 78% were in favour of extended operation, while the corresponding percentage among those with a neutral attitude was 34%. Of those with a negative attitude to nuclear power, 86% were in favour of decommissioning, while the corresponding percentage among those with a neutral attitude was 57%. The reception of radioactive waste generated elsewhere in Finland garnered some support among all groups.

As can be seen from the responses to the survey, there is a great deal of variation in the respondents' views. In addition to uncertainties and concern, the operation of the nuclear power plant involves positive views.

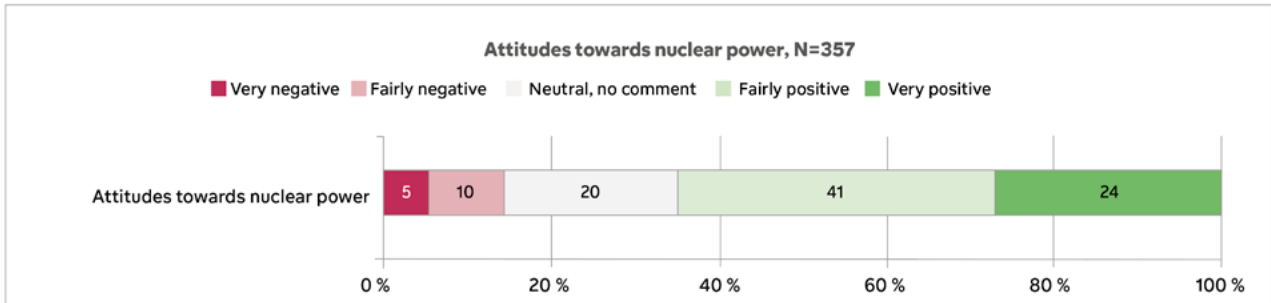

Figure 9-77. Respondents' attitudes to nuclear power. The percentages of the respondent groups are shown in the figure.

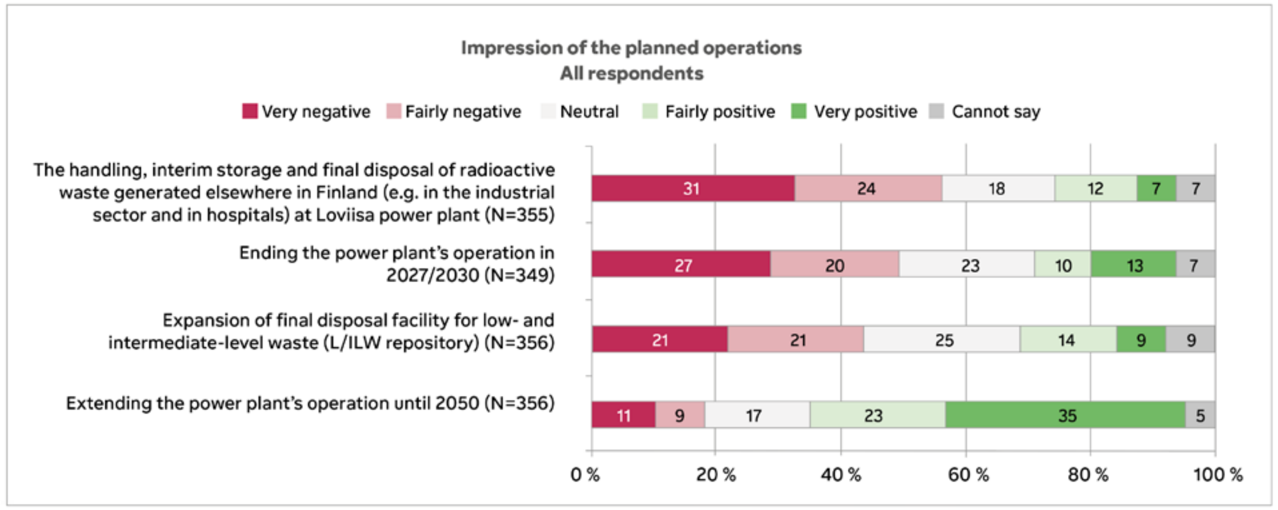

Figure 9-78. Respondents' views on the planned operations (all respondents). The figure shows the percentages of the respondent groups and the number of respondents (N).

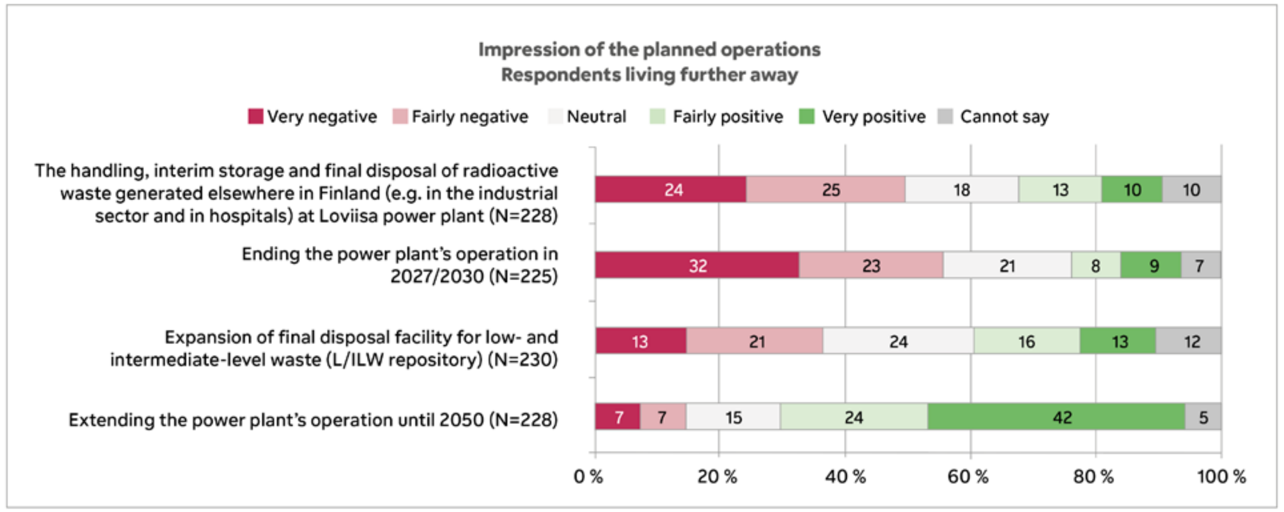

Figure 9-79. Respondents' views on the planned operations (respondents living further away). The figure shows the percentages of the respondent groups and the number of respondents (N).

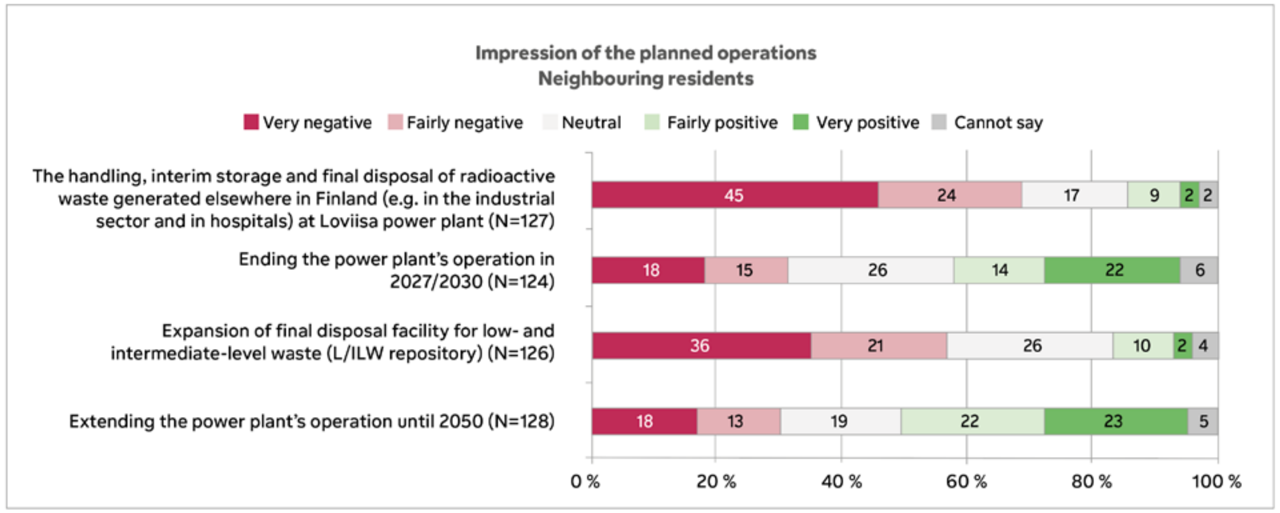

Figure 9-80. Respondents' views on the planned operations (neighbouring residents). The figure shows the percentages of the respondent groups and the number of respondents (N).

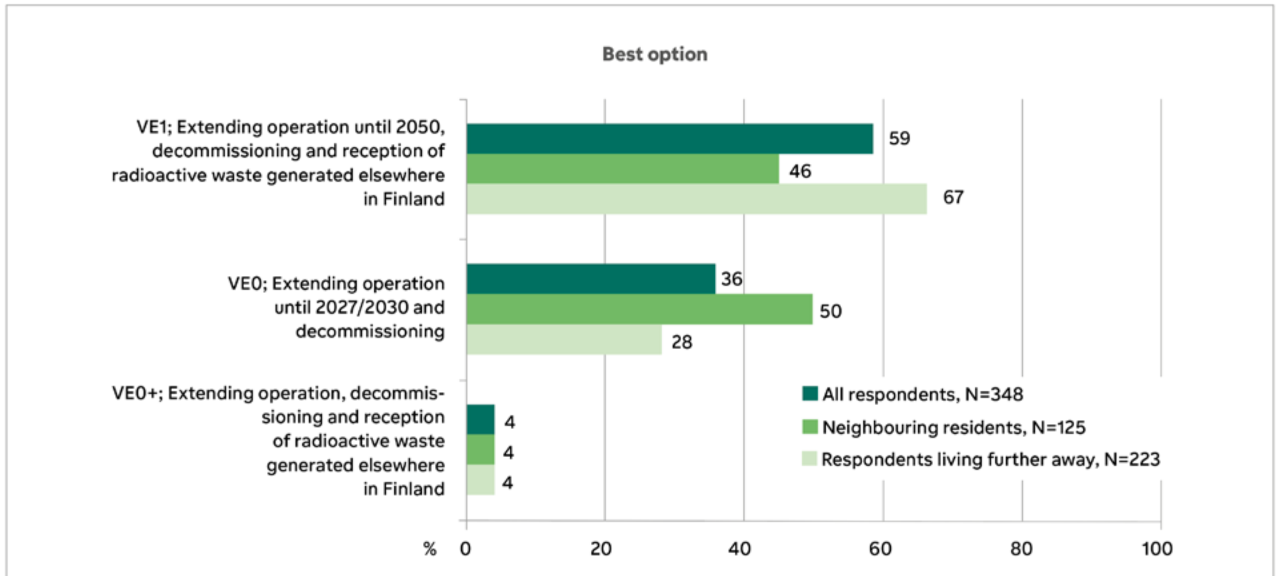

Figure 9-81. The resident survey's respondents' view of the best option. The figure shows the percentages of the respondent groups and the number of respondents (N).

Several of the open-ended responses indicated satisfaction with the power plant's current operations and support for extended operation. The power plant's positive significance for the economy and employment of the town of Loviisa was brought up in several comments. Some of the respondents in favour of extended operation considered it important that the existing power plant and the expertise on nuclear power accumulated over the years be taken advantage of in future operations. An extension to the operation of the power plant was also considered a form of energy production to be favoured until the facilities for replacing energy produced with nuclear power with renewable methods were in place.

"I hope the power plant extends its operation. It will provide the area with much needed jobs. The placement of nuclear waste here is not an attractive thought."

"Electricity must be produced somewhere anyway (with climate impacts as small as possible), and given that the plant in Loviisa is already there and has operated well, I see extended operations as a good alternative – provided that the maintenance and repair investments related to extended operation are carried out appropriately."

"The entire lifecycle of a good plant should be put to use as well as possible, accounting for the safety aspects."

"The nuclear power plant is important for the town of Loviisa in terms of employment, among other things. It would be important in terms of the future to investigate how the heat of the cooling waters could be used to heat properties in Loviisa or some of the other nearby towns and cities, for example."

"Back in the old days, I was unsure and concerned about safety. Now I have confidence in safety being maximised. The alternatives are limited, and few of them are clean. We need various [forms of energy production], and nuclear power is one of them."

"Loviisa power plant possesses all the facilities needed for continuing the production of safe nuclear power until at least 2050. The competence in the storage of radioactive waste should also be put to use."

"I'm not in favour of building new nuclear power. Even so, the operation of old plants should be extended for as long as they are safe, and the climate issues/adequacy of renewable energy have/has been solved."

The responses to the survey also show that the expansion of the L/ILW repository and the handling and final disposal of radioactive waste generated elsewhere in Finland, in particular, raise concern; this could also be seen in the open-ended responses. Several comments favoured extending operation until 2050 without radioactive waste brought from elsewhere. A few of the respondents who provided an open comment were under the impression that radioactive waste transported from other nuclear power plants would be placed in the area of Loviisa. The uncertainties and risks associated with the operation of an ageing nuclear power plant and the final disposal of spent nuclear fuel were also brought up in the opinions given on the EIA Programme. A lack of knowledge and uncertainty about the content and impacts of the radioactive waste to be handled and deposited in final disposal in the future may have caused conflicting emotions in the respondents.

"Extending operation until 2050 is OK, but we have enough to take care of in the waste we've generated ourselves."

"Conflicting emotions; the need for energy will not reduce and if/when Loviisa's units are decommissioned, the energy must still be produced somewhere else in another way."

"Even in Finland, seismic stability and the integrity of the bedrock are not perfect, so why would the waste be placed at the shore of a sea from where pollution can spread via the sea over time?"

"We are not in favour of extending the operation of Loviisa nuclear power plant post 2030. This opinion is a result of the location of the Baltic Sea and the obsolescence of nuclear power. Nuclear power feels unnecessarily difficult and burdensome, especially from the perspective of final disposal."

Loviisa power plant has been in operation for a long time now, and the residents have an idea of the impacts generated during the power plant's operation, which mainly concern the nearby areas. The power plant's impacts on the region's economy and employment are considered positive, and they also have an impact on many residents who are in favour of extending operation until 2050. However, some respondents in favour of extended operation have a negative attitude to the expansion of the L/ILW repository. The project raises hopes of positive impacts on the economy and employment, while raising concern and uncertainty about the safety of the handling and final disposal of nuclear waste and the operations' impacts in nearby areas.

People's concerns or expectations can be construed as effects or indicators of impacts that people generally consider important, because they would change the people's surroundings. The concerns and expectations are usually at their greatest during the project's planning phase, when there is more room for speculation, the planning is still incomplete, and not all decisions have been made. Once the possible construction, dismantling or other activity gets underway and the potential impacts begin to materialise, the expectations and concerns usually begin to dissipate, provided that no adverse effects emerge, and that uncertainty is replaced by more precise and concrete information. The experience and intensity of the concern may be impacted by the light in which Loviisa nuclear power plant's operations or issues related to nuclear power in general are discussed in public and within a community. People can sometimes change their perceptions even during the project, based on interaction, additional information, the results of impact assessments and news. Concerns or expectations are considered social impacts as they are, regardless of the results of expert assessments and recipients' related knowledge, because they have a certain kind of impact on the recipient.

9.19.5 Environmental impact of extended operation

Impact formation

The impacts of extended operation would form largely in the same manner as in the power plant's current operation. Operations with an impact on people's living conditions and comfort consist especially of the impact that the discharge of warm cooling waters have on the recreational use of Hästholmsfjärden's waterway, the power plant structures' visibility in the landscape, the restrictions to the use of nearby areas resulting from the operations, the traffic on the roads leading to the power plant area as well as the impacts on employment and the regional economy, which are also reflected in the population structure. Social impacts also include any concerns and expectations that extended operation would raise among residents, and impacts on the local identity. Any modification and additional construction work that may be carried out in the area during extended operation may cause vibration, noise, landscape, air quality and traffic impacts in the power plant's vicinity.

While the social impacts of extended operation would form largely in the same manner as in the power plant's current operation, they would continue for some 20 years beyond the end of the current licence period, i.e. until roughly 2050.

The impacts on the landscape and on the waterways attributable to the discharge of warm cooling water, as well as the impacts on residential comfort and fishing, were considered the most negative impacts of the power plant's current operation in the resident survey.

The power plant's construction has altered the island of Hästholmen and its environment since the 1970s, and the power plant has been an element visible in the landscape for several decades. Over the years, some people living and holidaying in the area have grown accustomed to the power plant's visibility in the landscape, but in the resident survey, nearly 50% of the neighbouring residents still viewed the power plant's impact on the landscape as negative. The power plant area's bright lighting has also been considered disturbing. Alongside the yard of a secondary home, the power plant can also be visible in the landscape when residents and other recreational users use the bodies of water surrounding the power plant for boating or recreational fishing, for instance. In extended operation, the landscape impacts would continue to be largely similar to their current levels. The changes to the landscape resulting from the construction of any additional buildings in the area would be only minor, and they would br primarily concentrated in the vicinity of the power plant (see Chapter 9.3).

The impacts that the power plant's extended operation would have on the residential comfort of nearby areas and the use of nearby recreational sites such as the Svartholma Sea Fortress and the Källa camp area would remain largely unchanged. The possible adverse effects experienced by residents would remain unchanged.

The discharge of cooling water into Hästholmsfjärden has had an impact on the lives of people living or holidaying in the power plant's nearby areas for several decades. According to the impact assessment concerning waterways (see Chapter 9.3), the thermal load caused by the cooling water has impacted the extent of the ice cover and may itself have intensified Hästholmsfjärden's eutrophication. On the other hand, eutrophication in general has increased across the entire Gulf of Finland. According to the impact assessment concerning waterways, the thermal load caused by the cooling water may slightly intensify eutrophy in the long run locally, and primarily in the area of Hästholmsfjärden. In addition to the thermal load, the extent of the ice cover and the sea area's use during winter may be affected by the increasing number of mild winters. Based on the impact assessment concerning the icthyofauna (see Chapter 9.17), the temperature increase will benefit, through the longer growing season, species such as the common perch, pike-perch and cyprinids. At the same time, the temperature increase may bring non-native species to the area that may displace local fish species.

Should the discharge of warm cooling water continue, the recreational value of the area's waterways and the residential comfort of the shores would remain largely unchanged from the present state, but when accounting for the possible impact of climate change as well, the future recreational value of Hästholmsfjärden, for example, may deteriorate slightly, particularly in terms of the ice situation. A deteriorating ice situation may weaken the opportunities for movement on the ice and winter fishing.

According to plans, the power plant's service water would continue to be taken from Lappomträsket lake, either entirely, as today, or partly, in which case some of the water intaken from Lappomträsket lake would be replaced by the procurement of other service water. Based on the impact assessment concerning the waterways, extended operation would not have an impact on the present state of Lappomträsket lake.

The traffic impacts of current operations are at their greatest in the summer, during annual outages, when some of the residents have perceived road safety to have weakened as the traffic on the roads leading to the power plant has increased. The annual outages last for 2–8 weeks, and they are implemented between July and October. According to the impact assessment concerning traffic (see Chapter 9.4), the impacts in the event of extended operation would be similar to their current levels. While the impacts would also largely remain similar to their current levels, according to the impact assessment concerning noise and vibration (Chapters 9.5 and 9.6), temporary noise or vibration may be generated during the construction of any additional buildings. Some of the neighbouring residents have found the hum emitted from the power plant and the sounds generated during annual outages disturbing. The possible adverse effects experienced by residents would remain unchanged. The potential additional construction could cause some additional adverse effects.

According to the impact assessment concerning the regional economy (see Chapter 9.13), the Loviisa area has a narrow economic structure and high unemployment. Extended operation would have a positive employment impact in both the Loviisa sub-regional area and beyond it. Extended operation could also have a positive impact on the area's demographics if the power plant's operations employ working age population and encourage them to stay in the area.

The power plant is surrounded by a five-kilometre precautionary action zone that may not contain sensitive sites such as schools or healthcare centres. In addition, the sea area in the vicinity of the power plant is monitored, and disembarkation in the power plant area is prohibited. In extended operation, the restrictions would remain in force. A little fewer than 500 secondary homes, some of which are in year-round use, are located at a distance less than five kilometres from the power plant. There are many long-term residents in the power plant's nearby areas, given that roughly half the respondents to the survey reported having lived or holidayed there for more than 40 years. Some of the neighbouring residents expect the power plant's current operation to have a negative impact on property values. The proximity of the power plant and uncertainty about the future may be reflected in the attractiveness of property in the power plant's vicinity.

Risks related to the nuclear power plant's operation may give rise to concern about the safety of nuclear energy both in the nearby area and more generally among Finland's population, as well as beyond the country's borders. Nuclear safety is described in more detail in Chapters 7.5–7.8, while the impacts of a severe reactor accident and other incidents and accidents are described in Chapters 9.21 and 9-22, respectively. If the operations continue, concern about the risk of accidents would continue and could increase as the plant ages. Furthermore, should the operations continue, the volume of the spent nuclear fuel in interim storage within the area and the volume of the low and intermediate-level radioactive waste to be deposited for final disposal in the L/ILW repository would increase, which could increase any concern over the safety risks related to the handling of the waste.

The magnitude of the change in the social impacts of extended operation was deemed minor and negative as a whole when accounting for the power plant's additional years of operation.

9.19.6 Environmental impact of decommissioning

Impact formation

During the decommissioning phase, impacts on living conditions and comfort will result primarily from the excavating related to the L/ILW repository's expansion, the crushing and transports of the quarry material, the dismantling of buildings and the potential crushing of concrete as well as from heavy vehicle traffic, both on the roads leading to and within the power plant area. The volume and thermal load of the warm cooling water conducted into Hästholmsfjärden will reduce and eventually end, which will have an impact on the waterway's recreational use. The termination of the power plant's operation may result in changes to the local identity. Social impacts also include the potential concerns and expectations to which the decommissioning will give rise in residents.

The power plant's current operations have continued for a long time. Although some residents, especially those living and holidaying in the nearby areas, have experienced adverse effects attributable to the current operation, the impacts of the current operation have remained largely similar. The power plant's decommissioning will result in a clear and discernible change in the operations taking place in the power plant's area and their impacts at different phases of the decommissioning. All in all, the various phases of the decommissioning will take several decades. A change of such duration may give rise to uncertainty among residents about the future, with the associated related concerns and expectations.

Loviisa power plant is Finland's first nuclear power plant. It has been in the area since the 1970s and has become part of the identity of the Loviisa area. The power plant's decommissioning and the end of its electricity production may result in changes to the local identity. The changes can be both positive and negative, and they will also be influenced by the long duration of the decommissioning. The plans related to the decommissioning, and the changes it will introduce to the operations, may give rise to concerns in the residents about the impact that the changes will have on the vitality of the Loviisa region, when both the adverse effects and benefits of the operations come to an end during the final phase of the decommissioning.

Expansion of the L/ILW repository

The L/ILW repository's expansion is expected to take about three years, and it will be carried out while the power plant is still in operation. The blasting related to the expansion of the L/ILW repository and the possible crushing of the excavated rock and its transport either to the power plant area or elsewhere for interim storage will generate noise, traffic, vibration and dust impacts.

In line with the impact assessment concerning vibration, the blasting work will be carried out so that the radioactive waste already in the L/ILW repository will not be adversely affected. The increased heavy vehicle transports may increase the vibration caused by traffic to a slight degree in the immediate vicinity of roads. The vibration impact of the decommissioning is expected to be minor and negative. The noise and dust resulting from the blasting done within the rock is not expected to spread beyond the power plant area other than to a minor degree.

Although the vibration and noise of the blasting work is not expected to have adverse effects on housing or recreation, residents may nevertheless become concerned about the impacts of the work. In addition to the mere magnitude of the vibration, the degree to which people find it disturbing is influenced by the circumstances in which it is detected. How people experience vibration is individual. It can be found disturbing particularly in situations in which the noise emitted by the source of the vibration is also found disturbing.

According to the noise impact assessment, the most significant source of noise in the L/ILW repository's expansion is the transport of quarry material. Furthermore, if the quarry material is crushed above ground rather than under it, in the L/ILW repository, the noise may be momentarily audible on the nearby islands and the mainland. The crushing of the quarry material will not be continuous. Instead, it will be carried out occasionally, when necessary. If the quarry material is placed in interim storage within the power plant area, its placement will result in a momentary noise impact on the vicinity. If the quarry material is transported elsewhere for interim storage, it will increase the noise, vibration and air quality impacts of traffic along the transport routes.

For example, the occasional banging sound generated in connection with the loading of vehicles is short in duration, but may be found very disturbing. The same applies to the reversing alarms of machinery. How people experience noise is subjective, which is why individuals experience sound differently. The experiences of noise are also influenced by expectations and hopes on the environment's soundscape. In addition to the acoustic properties of noise, the degree to which a noise is found disturbing is affected by factors related to the situation and circumstances, such as the exposed individual's living conditions, their ability to influence the source of the noise and psychological factors related to noise, such as preconceived notions about and attitudes towards the source of the noise as well as fears and concerns related to it (Jauhiainen et al. 2007). The shores of the waterbodies surrounding the power plant are home to a lot of holiday housing. Given that the bodies of water are used for recreation, it is likely that at least some of the holidaymakers may find the sounds of heavy vehicle traffic and machinery generated in the power plant area disturbing.

According to the noise impact assessment, the planning of the operations makes use of the experiences gathered in the power plant area in connection with the previous excavation of the L/ILW repository. The noise impacts and how to mitigate them are known. Based on them, the activities will be planned so that the noise impacts can be mitigated. The interim storage of the quarry material in the power plant area or outside it will last for some 30–40 years. If the quarry material is placed in interim storage within the power plant area, it will have minor and negative impacts, according to the assessment concerning the landscape impacts. The impact that the L/ILW repository's expansion will have on the living conditions and comfort was deemed minor and negative in terms of its magnitude.

First dismantling phase

The first dismantling phase involves the dismantling of most of the activated and contaminated parts. This dismantling phase is expected to take around seven years. The radiation impacts of the dismantling work are assessed in Chapter 9.10.5.

Of the impacts generated during the dismantling phase, the noise and traffic impacts, in particular, will be detectable outside the power plant area. For example, the sounds of machinery may carry beyond the area. According to the assessment concerning the traffic impacts, traffic volumes during the first dismantling phase will increase from the present volume and will, at their greatest, be temporarily comparable to the traffic volumes during the annual outages in current operation. The increased traffic may impair especially the road safety of permanent residents and holidaymakers using the roads leading to the power plant and impact the smooth flow of traffic. In the present state, the impacts of the increased traffic have occurred during the annual outages, but during the dismantling phase, the traffic impacts will coincide with different seasons.

According to the impact assessment concerning waterways, when the operation of the power plant units ends, the need for cooling water and the thermal load will reduce to a fraction of their levels during the power plant's operation. In the long run, the change's positive impacts, especially on the status of Hästholmsfjärden's water environment, may have a positive impact on the year-round recreational use of the waterbody and on residential comfort in the lakeside properties. The magnitude of the impacts will be minor and positive.

According to the impact assessment concerning waterways, the changes in the intake of water from Lappomträsket lake during the decommissioning option will initially be very small, and the intake will continue in the current manner. In the future, the potential end of regulation related to the termination of the water intake may have minor negative impacts on the quality of water. The impacts that any deregulation would have on the recreational use of Lappomträsket lake and residential comfort in the lakeside properties cannot be assessed with the currently available information.

The impact that the first dismantling phase will have on living conditions and comfort was deemed moderate and negative in terms of its magnitude.

Operation of the plant parts to be made independent, second dismantling phase and the closure of the L/ILW repository

According to the expert assessment, the noise, dust or vibration nuisance possibly generated in the power plant area during the operation of the plant parts to be made independent – which will continue for several decades – is so minor that it is not expected to have an impact on the residential comfort of the closest secondary homes or permanent residences, or the waterbodies' recreational use.

The spent nuclear fuel which has remained in interim storage in the power plant area during the operation of the plant parts to be made independent will be transported in phases from Loviisa to Olkiluoto, Eurajoki, either as road transports or as road-maritime-road combinations. As the storage of spent nuclear fuel in the Loviisa power plant area comes to an end, any concern about risks related to the storage will also end. Yet concern about the safety of the transport of spent nuclear fuel and the final disposal to take place in Olkiluoto, Eurajoki, may have social impacts in an area wider than the power plant's nearby areas. The impacts of the spent nuclear fuel's handling, transport and final disposal are described in Chapter 9.10.5.1. The radiation exposure of people and the environment resulting from the transport of spent nuclear fuel in a normal situation is very small, and the additional exposure is practically indistinguishable from the exposure caused by the environment's background radiation. The long-term safety of the final disposal of the spent nuclear fuel in Olkiluoto, Eurajoki, is described in Chapter 9.10.5.1.

The dismantling of the plant parts to be made independent (the second dismantling phase) and the operations during the L/ILW repository's closing phase will generate noise and vibration impacts. If the rock excavated during the L/ILW repository's expansion is placed in interim storage in the power plant area, it will not need to be transported from outside the power plant area during the L/ILW repository's closing phase. If the quarry material is placed in interim storage elsewhere, it will increase heavy vehicle traffic to some degree during the closing phase and the resulting adverse effects along the transport routes.

A decommissioning carried out according to the brownfield principle would not have a significant impact on the landscape of the nearby area, because the power plant area's buildings would remain in place.

According to the impact assessment concerning the regional economy (see Chapter 9.13), the positive impacts on the economy and employment of the Loviisa region would disappear as a result of the power plant's decommissioning. At the same time, businesses operating in the Loviisa sub-regional area would face new demand. The impacts during operation and the impact of the decommissioning will nevertheless concern largely different industries and operators, meaning that the impacts will be positive for some of the operators and negative for others. The positive impacts will conclude at the end of the decommissioning phase, when operation has ended.

The magnitude of the impacts that the operation of the plant parts to be made independent and their dismantling phase will have on living conditions and comfort was deemed moderate and negative before the impacts become minor and positive with the L/ILW repository's closure.

Finalisation of dismantling measures and landscaping

All buildings and structures containing radioactivity will be dismantled from the area during the first and second dismantling phase of decommissioning (the brownfield principle). If all the remaining buildings in the plant area are also dismantled according to the greenfield principle, noise and traffic impacts would especially be generated during this conventional dismantling work. The measure generating the loudest noise will be the occasional crushing of concrete, the noise of which may be audible on the nearby islands and the mainland, thereby diminishing residential comfort and the recreational use of the bodies of water, nearby islands and shores. Even so, the noise impact of such activities can be mitigated with the selection of the crushing location and dimensioned noise shields. The sounds of machinery may also be found disturbing. According to the impact assessment concerning air quality (see Chapter 9.7), the dismantling work and crushing of concrete will result in some dust and tailpipe emissions, but they are expected to have an impact primarily on the island of Hästholmen and along the transport routes of the heavy vehicle traffic. The vibration possibly caused by the dismantling measures is small in scale and not expected to have adverse effects on housing or recreational use.

The dismantling of the buildings will have an impact on the landscape when viewed from both a short or long distance. The power plant structures are an element visible in the landscape, and their dismantling will have positive impacts on the landscape. The positive landscape impact would be diminished by the long timespan of the decommissioning, given that the dismantling work would be carried out in phases, and the landscape would change over several decades. The dismantling of the power plant's buildings can also be seen as a negative matter, given that the power plant is part of the area's landscape and built environment.

If all power plant structures and buildings are dismantled at the end of the decommissioning, and the area is landscaped according to the greenfield principle, the impact on the nearby area's residential comfort and recreational use will be more positive than the impact of a partial dismantling of the structures (the brownfield principle).

The magnitude of the impacts of the conventional dismantling measures were deemed, in terms of the dismantling, moderate and negative, before the impacts become moderate and positive with landscaping.

9.19.7 Radioactive waste generated elsewhere in Finland and its impact

Based on the resident survey, the residents have a negative attitude to the reception of radioactive waste generated elsewhere in Finland at Loviisa power plant and its final disposal in the L/ILW repository. The respondents are concerned about the impacts of this despite the fact that the radioactive waste generated elsewhere in Finland would account for a maximum of 2% of the total volume of waste generated by the power plant.

The emergence of concerns and negative views may partly be influenced by the fact that the nature of radioactive waste, the volume of the waste generated, and the risks related to its handling may be challenging to understand. The operating models involved in the handling and final disposal of radioactive waste are not clear to everyone. Radioactive waste generated elsewhere in Finland and brought to Loviisa power plant can also be perceived as an additional and unnecessary adverse effect, given that it does not provide electricity production benefits like the power plant.

The transports, handling and final disposal of radioactive waste generated elsewhere in Finland would not, according to other impact assessments, result in impacts that would affect people's living conditions and comfort. Even if there were no realistic grounds for such concerns, it is still an actual social impact, the magnitude of which has been deemed minor and negative.

9.19.8 Significance of impacts

Table 9-69 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (see Chapter 9.1.4).

Table 9-69. Significance of impacts: people's living conditions and comfort.

Significance of impacts: people's living conditions and comfort			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	Moderate	Minor negative	**The significance of the impacts is minor and negative,** given that the impacts on people's living conditions and comfort under extended operation would continue for approximately 20 years. The discharge of warm cooling water, combined with the changes brought about by climate change, may impact the recreational value of the area's waterways, mainly in Hästholmsfjärden. In other respects, the impacts and adverse effects experienced by people will remain largely similar to their current levels. The potential additional construction could cause some additional adverse effects. In extended operation, the possible concern over safety risks would continue and could grow as the waste volumes increase and the plant ages. Extended operation could also have a positive impact on the area's demographics.
Decommissioning: *Expansion of the L/ILW repository* *First dismantling phase* *Operation of the plant parts to be made independent* *Second dismantling phase*	Moderate	Moderate negative	**The significance of the impacts is moderate and negative,** given that the power plant's decommissioning will result in a clear and observable change in the operations taking place in the power plant area. Overall, the various phases of the decommissioning will take several decades, which may give rise to uncertainty about the future and related concerns and expectations in residents. The occasional noise caused by the operations carried out during the decommissioning may impact particularly the comfort of holidaymakers staying in holiday homes in the vicinity of the power plant and the recreational experiences of people using the waterways and shores. The increased traffic during the most active dismantling phase may impair the nearby area's road safety and affect the smooth flow of traffic. The interim storage and transports of spent nuclear fuel may involve concerns about safety risks. Transports may especially raise concerns, even on a wider scale. The power plant's decommissioning and termination of electricity production may result in changes to the local identity and concerns about the effect that the change will have on the vitality of the Loviisa region.
Decommissioning: *After the closure of the L/ILW repository*	Moderate	Minor positive	**The significance of the impacts is minor and positive,** given that operations related to the nuclear power plant in the area will end. As operations in the power plant area come to an end, any concerns about a risk of accidents or other incidents related to the operations will end. As a result of the end of operation, the need for cooling water and the thermal load will first reduce to a fraction during the operation of plant parts to be made independent and ultimately terminate completely. The positive impacts that the change will have on the status of Hästholmsfjärden's water environment may have a positive impact on the year-round recreational use of the waterbody and on residential comfort in the lakeside properties in the long run If all power plant structures and buildings are dismantled at the end of the decommissioning, and the area is landscaped according to the greenfield principle, the impact on the nearby area's residential comfort and recreational use will be more positive than the impact of a partial dismantling of the structures (the brownfield principle).
Radioactive waste generated elsewhere in Finland	Moderate	Minor negative	**The significance of the impacts is minor and negative,** because the reception of radioactive waste generated elsewhere in Finland at Loviisa power plant concerns residents, even though there will be no actual direct impacts on people's living conditions and comfort.

9.19.9 Mitigation of adverse impacts

Many concerns related to the production of nuclear energy are linked to radiation safety. Potential changes to current operations, such as the expansion of the L/ILW repository or the dismantling of the reactor buildings, may increase such concerns. Communications and interaction contribute to reducing unfounded concerns, fears and uncertainty.

The reception, handling and final disposal of radioactive waste generated elsewhere in Finland at Loviisa power plant has also raised concerns in the residents. To mitigate the concerns, it is important to provide people with clear communication. The matter may be clarified by using illustrative examples of the quality and quantity of the waste to be received as well as of the significance of safe handling, interim storage and final disposal. Increased knowledge will help people understand the kind of waste that may be received. The same principles are also effective when communicating about the handling, interim storage and final disposal of the radioactive waste generated at the power plant.

The provision of researched information, monitoring data and open communications also reduces the spread of false or distorted information, and the emergence of rumours which give rise to concerns. Examined from another perspective, any adverse effects during operation can be monitored and responded to better with the help of adequate information, if an already effective communication channel to the surrounding community exists.

Adverse effects during the planned operations can be partly reduced with planning. The means by which adverse effects are mitigated will be discussed in more detail in the impact assessment chapters on noise, dust, vibration, traffic, emissions of radioactive substances and radiation.

9.19.10 Uncertainties

The impacts on living conditions and comfort are subjective and bound to the person who experiences them, as well as the time and place. During the impact assessment, the views and thoughts of individual residents – i.e. the subjects of the impacts – must be brought to a more general level, at which point some of the individual information will be lost. On the other hand, it would be impossible to perform the impact assessment individually, due to which some degree of generalisation in terms of the information will be necessary.

The spread of the planned operations over a long period of time will increase the assessment's uncertainty, particularly in terms of assessing impacts that may not materialise or be felt for several decades. Uncertainty increases due to future global phenomena and technological advancements, for example.

The documentation of the assessment process aims to minimise uncertainties related to subjectivity, so that the person reading the assessment can deduce the grounds for the impact assessor's view. Possible uncertainties of other impact assessments may be repeated in the assessment of social impacts insofar as they impact the comfort of the residential and living environment.

9.20 PEOPLE'S HEALTH

9.20.1 Principal results of the assessment

Noise, vibration, tailpipe emissions and dust, among other things, will be generated during extended operation and decommissioning in the same manner as during the power plant's current operation. The operations occurring in the power plant area are not expected to have direct health detriments to residents in the nearby area. The tailpipe emissions and dust caused by road traffic are confined to the vicinity of the road network, due to which exposure to conventional health detriments is minor.

The impact that radioactive emissions resulting from normal operation would have on the radiation load of the surrounding nature is expected to remain very low, as it currently is, and no direct health detriments will result. The dismantling methods to be used in decommissioning are selected so that the emission limits for radioactive substances confirmed by the authorities will not be exceeded, which means that health detriments will not be formed.

The handling and transport of radioactive waste generated elsewhere in Finland is not expected to cause conventional health effects. Radiation exposure is confined solely to the personnel handling waste, and the radiation doses remain clearly below the set dose limits.

9.20.2 Baseline data and assessment methods

The assessment of the health effects aimed to investigate the probable direct and indirect health detriments which the project's different optionsextended operation or decommissioning could cause. The Health Protection Act (763/1994) defines a significanthealth detriment as a disease diagnosed in a human, another health disorder, or a factor that can reduce the healthiness of the population's or an individual's living environment.

The common grounds for identifying significant health effects include:

- severity (death, injury, the risk of an epidemic, disease, disease symptoms, sleep disorders);
- variation according to time (hourly, daily and seasonal variation);
- duration (permanent, years, months);
- a focus on certain groups (children, the elderly, the infirm, individuals sensitised to various predisposing factors);
- pattern of exposure (transdermal, inhaled, ingested, through the sensory organs);
- the number of individuals exposed (one person – the population of the entire impact area).

Some projects may also cause mild and/or temporary impacts on people and their living environment. These include the adverse effects on comfort caused by noise and odours, which are nevertheless not considered health effects. The impacts of incidents and accidents are addressed separately in Chapters 9.21 and 9.22.

Health effects can be direct or indirect. The path of impact in exposure to a direct health detriment can be the skin, digestion, respiratory tract, sensory organs, circulatory organs, skeletal and muscular structure as well as the internal organs and the nervous system. The path of impact in exposure to an indirect health detriment can be the respiratory air, domestic water, food, housing conditions, working conditions, exercise, rest and recreation as well as leisure activities. Examined from this perspective, "health" is a very broad concept.

Conventional health effects were assessed mainly on the basis of the results of the impact assessments concerning noise, vibration and air quality. The magnitude of the effects was compared to known limit and guideline values as well as other indicators. The limit and guideline values based on studies define the exposure and concentration limits for preventing health detriments. Any exceeding of limit or guideline values is likely to cause health effects in some of the exposed, whereas such effects are unlikely when the values are not exceeded. The review accounted for the effects extending primarily to the closest residences and secondary homes, nearby trails and outdoor routes as well as recreational areas. The impacts related to health were assessed in the form of an expert assessment.

The assessment of the noise impacts' health effects is based on the project's planning data and the results of the noise measurements conducted in the power plant's surroundings previously, in 2013, 2017 and 2020 (see Chapter 9.5), as well as on previous experience of the noise emissions of construction and dismantling work as well as excavations. The results were compared to the limit values specified in the power plant's environmental permit.

In terms of vibration, the assessment accounted for the vibration impacts attributable to the excavating of the L/ILW repository as well as the dismantling activities and transports. The vibration assessment accounts for any nuisance experienced by people. The significance of vibration was assessed in the form of an expert assessment based on similar previous excavation projects and on the knowledge and experience gathered during the L/ILW repository's quarrying.

The impact that air quality may have on any health detriments was assessed on the basis of an expert assessment. In addition, the assessment covered various emission sources, and the probable physical and chemical properties of their emissions from the perspective of health effects. The emissions of the power plant's emergency diesel generators and diesel-powered emergency power plant were assessed on the basis of their operating times and estimated fuel consumption. The tailpipe emissions of traffic and the emissions of the quarrying and dismantling activities attributable to decommissioning were also taken into account.

In addition to conventional health detriments, radiation doses were assessed by calculation. The emissions of radioactive substances and radiation are discussed in more detail in Chapter 9.8, and the health effects of radiation are described at a general level in Chapter 7.2. This chapter provides a summary of the theoretical radiation exposure and its health effects, based on the aforementioned chapters. The impact assessment reviews the radiation doses caused by normal operation by comparing them to the limit value for an annual dose of a member of the public (0.1 mSv). Possible incidents and accidents and their adverse effects are assessed separately in Chapters 9.21 and 9.22.

9.20.3 Background information on health effects

9.20.3.1 Noise

Exposure to noise may affect people's health or comfort. The degree to which noise is found disturbing is influenced by the recipient's characteristics: age, gender, morbidity or other sensitivity. Noise that is found disturbing may have negative health effects. Alongside air pollutants, ambient noise is one of Europe's biggest environmental problems, because it is a stressor, and its modes of action are still partly unknown. Exposure to noise is nevertheless known to cause physiological stress which has been linked to the risk factors of cardiovascular diseases and sleep disorders, among other things. While the stress reaction is often unconscious, it can be intensified by a conscious awareness of the nuisance caused by the noise.

According to Government Decision 993/1992, the equivalent continuous sound level pressure (LAeq) of noise in a residential area may not exceed 55 dB during the daytime (7 a.m.–10 p.m.) and 50 dB during the night-time (10 p.m.–7 a.m.). The corresponding LAeqs for secondary homes are 45 dB during the daytime and 40 dB during the night-time. The guideline values for residential areas are considered health-based, given that exposure in such areas is continuous. The lower guideline values applicable to areas of secondary homes are based on the adverse effects on recreational values and the expectations of soundscapes in such areas. According to the permit regulations of Loviisa power plant's environmental permit, the noise caused by the power plant's operation, excluding noise attributable to statutory tests, at sites used for holiday housing may not exceed a daytime level of 45 dB or of 40 dB during the night-time.

9.20.3.2 Vibration

In addition to the mere magnitude of the vibration, the degree to which an individual finds vibration disturbing is influenced by the circumstances in which it is detected. Vibration tends to disturb people more during the night, for example. In addition to the time of day, this is influenced by the fact that vibration is easier to detect in rest and when lying down. Noise experienced simultaneously with vibration may result in a combined impact in which the vibration is perceived to be greater than it would be without the noise. Furthermore, if the vibration has an impact on the surrounding building – by shaking things or rattling windows, etc. – the residents' experience of disturbance increases to a marked extent.

How people experience vibration is individual. While some people find vibration that barely passes the threshold of detection strongly unpleasant, other people are not disturbed by even significant vibration as a result of having grown accustomed to it. Vibration is found disturbing particularly easily when the noise emitted by the source of the vibration is also found disturbing.

9.20.3.3 Air quality

In terms of their properties, air-borne particulates are a mixture of different kinds of particulates of various sizes, the origins of which cover numerous different emission sources. Particulates spreading as air pollutants and/or gaseous compounds end up in the atmosphere due to human activities, including industrial processes, traffic and residential wood combustion. In Finland, more than half of the particulates in the air are derived from long-range transboundary air pollution. The very smallest – ultrafine and nano-sized – particulates, on the other hand, are primarily confined close to their source, such as an incineration process. The limit values for respirable particulates in terms of air quality are provided in Government Decree 79/2017.

Changes in air quality impact primarily the respiratory tract and circulatory system, but they can also contribute to the development or worsening of several diseases. In terms of particulates, the emergence of health detriments is influenced by their concentration, physical and chemical properties, as well as their size. The concentration of particulates in the air, as well as their harmfulness, varies according to season. The principal mechanism by which particulates impact the body is inflammation. Long-term exposure to fine particulate matter is known to increase the risk of heart and respiratory tract diseases as well as lung cancer. Fine particulate matter has also been shown to be linked to the development of several other diseases, such as asthma and neuropathic diseases. In addition, it has been suggested that the combined effect of exposure to particulates and noise may increase the risk of the development of new diseases. The population groups most sensitive to air pollutants are children, senior citizens and individuals with an underlying disease of the respiratory tract or circulatory system.

9.20.3.4 Radiation

Ionising radiation may harm cells. What is significant in terms of cell damage is the magnitude of the radiation dose, and whether the individual receives the radiation dose over a short or long period. The health effects of radiation and the reference data on radiation sources and radiation doses in Finland are discussed in more detail in Chapter 7.2.

Direct effects are unambiguous detrimental effects related to sudden very large single doses of radiation. The direct detrimental effects of radiation include radiation sickness, radiation burns, cataracts and foetal damage.

In principle, random long-term effects can arise from even minor exposure to radiation. Random effects are statistical detrimental effects, and what is typical of them is that the risk of a detrimental effect grows in step with the increase of the radiation dose. The random detrimental effects of radiation include various types of cancer and genetic mutation.

In practice, the cancer risk caused by small doses of radiation cannot be detected in the population, given how common a disease cancer is. The small increase possibly attributable to radiation is lost within statistically natural variation. For example, the fallout from Chernobyl – the total dose of which in a person residing in Finland over an 80-year period is two millisieverts, on average – is expected to cause some cancer deaths in Finland during that time. During the same period, a million people will die of cancer attributable to other causes, however (STUK Guide 2021h).

9.20.4 Present state

The morbidity index of the Sotkanet Indicator Bank, maintained by the National Institute for Health and Welfare (THL), was drawn up to function as an indicator of regional variation in morbidity and changes in the morbidity of individual regions. The index accounts for seven groups of diseases, which include the cerebrovascular and coronary diseases common to Finns, as well as musculoskeletal disorders, accidental injuries and dementia. The greater the value of the index, the more common the morbidity in a particular area is. Based on the last few years, the age-standardised morbidity index for the Loviisa area has been slightly higher than the national average. In 2016, the value of the index in Loviisa was 102.5, whereas in the entire country, it was 100. The index has declined in recent years; as recently as 2012, for example, it was 111.8. The age-standardised cancer index for the Loviisa area in 2016 was 110.7. Morbidity in Loviisa is therefore slightly higher than on average in Finland. While the higher-than-average morbidity may be attributable to the population's age structure, there are several possible reasons for the cancer index, including Loviisa's location in an area where the levels of radon in indoor air are higher than average.

Residents in the surroundings of the nuclear power plant are given an opportunity, within the framework of STUK's environmental radiation monitoring programme, to participate in annual measurements which investigate the amount of radioactive substances accumulated in the human body. The invitation is mailed primarily to individuals whose residential address during the year of each measurement lies within a five-kilometre radius of the nuclear power plant. In addition, the group of invitees is supplemented by a random sampling of individuals whose residential address is located within a 5–7-kilometre radius of the nuclear power plant. The gamma emitting radionuclides in the bodies of residents in the area surrounding the nuclear power plant are determined with a direct gamma ray spectrometer measurement outside the body. In 2019, the measurements did not detect radioactive substances originating from the power plant in the residents of Loviisa power plant's surroundings. Nor did the whole-body measurements of previous years detect radioactive substances originating from the power plant.

The environmental radiation monitoring of Loviisa power plant is discussed in Chapter 9.8.3.4. The amounts of radioactive substances originating from the power plant's operation detected in the environment of Loviisa power plant are small enough to be negligible in terms of the environment's or people's radiation exposure. The radiation dose calculated, on the basis of emissions, for the most exposed individual in the environment of Loviisa power plant in 2019 was less than 1% of the constraint set in the Nuclear Energy Decree (161/1988), which is 0.1 millisieverts (STUK Guide 2020c).

Table 9-70 shows the sensitivity of the affected aspect and some factors determining sensitivity (see Chapter 9.1.4).

Table 9-70. Sensitivity of affected aspect: people's health.

Sensitivity of affected aspect: people's health	
The impact area's level of sensitivity is determined on the basis of the residential and living environment's properties, including the area's housing, services, demographics, and the environment's resilience or adaptability. The sensitivity level is influenced by the location of sensitive facilities, the number of residents and any current adverse impacts on humans, for example.	
Minor	The nuclear power plant area is surrounded by a precautionary action zone extending to a distance of five kilometres. This zone may not contain facilities inhabited or visited by a considerable number of people, such as schools, hospitals, care facilities or shops. Nor are there any other sensitive facilities in the zone, including schools or daycare centres. There are no permanent residents up to a distance of one kilometre from the power plant. There are about 40 year-round residents up to a distance of five kilometres from the power plant. Approximately 12,400 people live within a distance of 20 kilometres of the power plant. There are plenty of recreational settlements in the vicinity of the area. The air quality of the Loviisa area is good. The calculated dose of the individual most exposed in the environment due to the power plant's operation in Loviisa has remained significantly below 1% of the 0.1 mSv constraint set in the Nuclear Energy Decree (161/1988) (STUK 2021e). In 2019, the measurements did not detect radioactive substances originating from the power plant in the residents of Loviisa power plant's surroundings.

9.20.5 Environmental impact of extended operation

Impact formation

The impact of extended operation on air quality would consist of the emissions (carbon dioxide, nitrogen oxide, sulphur oxide and particulate emissions, dust) of the emergency diesel generators and the diesel-powered emergency power plant, as well as traffic. Noise is generated by the power plant's operation, traffic and machinery. The sole source of vibration is traffic. The nuclear power plant generates radioactive substances during its operation. These substances are treated by way of filtering and are delayed so that their radiation impact on the environment is very small. The impacts would remain primarily unchanged, but they would continue for another 20 years.

The conventional health effects resulting from extended operation would be primarily related to the noise and air emissions as well as the vibration generated by the activity. Given that the operations would continue in their current form, exposure to conventional health effects would be minor. The impacts would be confined primarily to the power plant area, but residents of the residential and holiday buildings on nearby islands and the mainland could be exposed to occasional noise.

Given that the operations would continue in their current form, there would be no changes to the noise levels. Modification and construction work could result in limit values being exceeded occasionally. The related noise would nevertheless be temporary and would therefore not lead to health detriments. Given that the operations would continue in their current form, the noise is not expected to generate health detriments. Temporary vibration impacts could occur in connection with the construction of additional buildings and traffic, but they would be confined to the power plant area and the immediate vicinity of roads, and are not expected to cause health detriments.

Extended operation would have a slight impact on air quality. The emissions into the air would consist primarily of the short-term tests of the emergency diesel generators and the diesel-powered emergency power plant. The impact of the local traffic emissions would remain in the vicinity of the roads. The amount of tailpipe emissions will decline in the future as cars are electrified, due to which traffic-based emissions would consist mainly of road, tyre and brake dust. The impact of this dust would be confined primarily to the immediate vicinity of roads. In terms of emissions into air, extended operation is not expected to cause direct health detriment in areas beyond the power plant and the roads.

The radioactive substances detectable in the environment of Loviisa power plant originate primarily from nature or have migrated from elsewhere; only a minor amount originates from the power plant. In extended operation, the impact that radioactive emissions resulting from the normal operation of Loviisa nuclear power plant would have on the radiation load of the surrounding nature is expected to remain very low, as in the current situation (see Chapter 9.8.3). In Finland, the radiation dose caused to residents in the areas surrounding nuclear power plants has been significantly below one per cent of the dose constraint set by the government, which is 0.1 mSv a year (STUK 2021a).

The power plant's extended operation is not expected to result in changes to the plant's current health effects, but the impacts would continue for another 20 years.

9.20.6 Environmental impact of decommissioning

Impact formation

The excavation of the L/ILW repository and the power plant's dismantling activities will generate occasional noise and vibration. In addition, traffic will generate tailpipe emissions and dust. The vibration impacts will be generated by the underground blasting work related to the expansion of the L/ILW repository, the possible dismantling of buildings and the increased transports carried out by heavy vehicles.

Dust emissions related to the L/ILW repository's expansion will be generated by the underground blasting work, for example, and by transports and the stacking of the quarry material. The underground blasting will also involve emissions of nitrogen oxides and sulphur oxides. Furthermore, some emissions will be generated in the tests of the diesel generators during the operational phase of the plant parts to be made independent. Dismantling activities during decommissioning will result in controlled radioactive discharges into the air and waterways as well as in the radiation exposure of mainly personnel participating in the dismantling work and waste handling. The emissions and radiation doses will remain below the limit values, and will not result in health effects.

Noise during decommissioning will be generated by the excavation of the L/ILW repository and the dismantling measures in the power plant area. The noise will be occasional in nature and may, in suitable conditions, be audible on the nearby islands and the mainland. Nevertheless, the most significant noise will be confined to the power plant area or its vicinity. The impacts of the noise are expected to remain minor, when accounting for their confinement primarily to the power plant area and for their temporary nature. This is not expected to have detrimental effects on health.

The vibration generated by the excavation of the L/ILW repository and the dismantling activities will be mild in nature and confined to the vicinity of the source of the vibration. The transports related to the decommissioning may cause traffic-based vibration of a longer duration, but it will be confined to the vicinity of the transport routes. The vibration is not expected to cause health detriments at the residential and holiday buildings in nearby areas.

The impacts on air quality are related to the excavation of the L/ILW repository and the resulting dust emissions, as well as to the emissions of nitrogen and sulphur oxides generated by the blasting. Dust can also be generated in connection with the crushing of the quarry material or any concrete, and by traffic. Traffic will also generate tailpipe emissions. Some emissions will be generated in the tests of the diesel generators during the operational phase of the plant parts to be made independent. The conventional emissions into the air (consisting of, among others, carbon dioxide, nitrogen oxides and particulate emissions) will be mainly local and occasional, and will be confined to the vicinity of the power plant area and transport routes. According to the assessment, the impact of the decommissioning operations will not cause the limit or guideline values for air quality in the environment to be exceeded. However, in suitable weather conditions, traffic emissions could cause temporary increases in concentrations. However, this is not expected to cause health effects, given that the situations in question are probably transient in nature and short in duration. The spread of the impacts on the air is influenced by the size of the particulates generated by the operation. The particulates generated in the decommissioning and the excavation of the L/ILW repository's expansion are mostly larger than fine particulate matter, i.e. more than 2.5 μm in diameter, due to which they fall earlier and closer. The greatest concentrations comparable to the limit and guideline values are found near the source of the emission, such as a crusher or transport route.

When the operation of Loviisa power plant ends, it will no longer generate emissions of radioactive substances in the current manner. Momentary controlled radioactive discharges into the air and waterways may nevertheless take place during the decommissioning phase. The targets and emission limits for radioactive emissions during the decommissioning phase will be defined as the decommissioning plans progress. The methods to be used in the decommissioning will be selected so that the emission limits subsequently confirmed by the authority are not exceeded, meaning that there will be no health effects. The Nuclear Energy Decree sets the limit for the annual dose to which a member of the public is exposed in connection with the decommissioning of a nuclear power plant, or other nuclear facility with a nuclear reactor, at 0.01 mSv (section 22 b 161/1988).

9.20.7 Radioactive waste generated elsewhere in Finland and its impact

The reception, handling, interim storage and final disposal of radioactive waste generated elsewhere in Finland at the power plant is not expected to cause conventional health effects. Radiation exposure would be confined solely to the personnel handling waste, and the radiation doses would remain significantly below the set dose limits.

9.20.8 Comparison of options and Significance of impacts

Table 9-71 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (see Chapter 9.1.4).

Table 9-71. Significance of impacts: people's health

Significance of impacts: people's health			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	**Minor**	**No change**	**No impact.** Noise, vibration, tailpipe emissions and dust, among other things, would be generated during extended operation in the same manner as during the power plant's current operation. The operations occurring in the power plant area are not expected to be detrimental to the health of residents in the nearby area. The tailpipe emissions and dust caused by road traffic will be confined to the vicinity of the road network, in terms of which exposure to conventional health detriments is minor. The impact that radioactive emissions resulting from normal operation would have on the radiation load of the surrounding nature is expected to remain very low, as it currently is. Extended operation is not expected to effect changes to the plant's current operation and the resulting impacts.
Decommissioning	**Minor**	**No change**	**No impact.** Noise, vibration, tailpipe emissions and dust, among other things, will be generated during the decommissioning. Some emissions will be generated in the tests of the diesel generators during the operational phase of the plant parts to be made independent. The operations occurring in the power plant area are not expected to be detrimental to the health of residents in the nearby area. The tailpipe emissions and dust caused by road traffic will be confined to the vicinity of the road network, in terms of which exposure to conventional health detriments is minor. The dismantling methods to be used in decommissioning are selected so that the emission limits for radioactive substances confirmed by the authorities will not be exceeded, which means that health detriments will not be formed.
Radioactive waste generated elsewhere in Finland	**Minor**	**No change**	**No impact.** The handling and transport of radioactive waste generated elsewhere in Finland is not expected to cause health detriments. Radiation exposure would be confined solely to the personnel handling waste, and the radiation doses would remain significantly below the set dose limits.

9.20.9 Mitigation of adverse impacts

Means by which to mitigate adverse effects are presented in the following chapters:

- traffic (see Chapter 9.4)
- noise (see Chapter 9.5)
- vibration (see Chapter 9.6)
- air quality (see Chapter 9.7)
- emissions of radioactive substances and radiation exposure (see Chapter 9.8).

9.20.10 Uncertainties

The uncertainties in the assessment of health effects are principally related to the uncertainties described in the sections on impact assessments. Differences between individuals also introduce uncertainties to the assessment of health effects.

9.21 SEVERE REACTOR ACCIDENT

In the event of a nuclear power plant accident, radioactive substances detrimental to health could end up in the environment. This chapter discusses a severe reactor accident in which the amount of radioactive substances ending up in the environment is significant. Milder cases are discussed in Chapter 9.22.

A severe reactor accident at the power plant is a highly unlikely extreme event, the materialisation of which would require several failures in the plant's systems and problems in the plant's control. Various incidents and accidents, including a severe reactor accident, have been prepared for in the plant's design and operation so that their consequences can be minimised. Chapter 7.5–7.8 contains a more detailed discussion of nuclear safety.

9.21.1 Methods of assessment

This chapter presents the calculation method for and assumptions concerning an environmental emission caused by a severe reactor accident.

The assessment of a severe reactor accident is based on the assumption that an amount of radioactive substance equivalent to the limit value for a severe accident pursuant to section 22 b of the Nuclear Energy Decree is released into the environment. The emission would contain 100 terabecquerels (TBq) of the caesium-137 (Cs-137) nuclide and other radionuclides in equal proportion to how much of them would be expected to be released in proportion to caesium-137 in the accident. Based on the activity released in the emission, the reviewed fictitious severe reactor accident corresponds with an INES level 6 accident on the International Nuclear and Radiological Event Scale. The impact of the release's dispersion in the accident was studied over a distance of 1,000 km from the power plant.

The modelling results are compared to the civil protection-related action limits pertaining to evacuation and seeking shelter indoors presented in STUK's preparedness guideline VAL 1 (STUK 2020a). In addition, the assessment covers the impacts of the radioactive fallout and radiation doses resulting from a severe reactor accident. The accident's follow-up as well as social and socioeconomic impacts are discussed on a general level.

9.21.1.1 Emission and dose limits

According to section 22 b of the Nuclear Energy Decree (161/1988), the emission of radioactive substances resulting from a severe nuclear power plant accident may not necessitate large-scale protective measures for the population nor any long-term restrictions to the use of extensive areas of land and water. To limit long-term effects, the limit value for a Cs-137 emission into the ambient air is 100 TBq. The possibility of the limit value being exceeded must be extremely small. The possibility of an emission requiring protective action in terms of the population in an early phase of the accident must likewise be extremely small.

Guideline VAL 1 provides orders of magnitude for the civil protection-related action limits and indicative levels (STUK 2020a). The dose criteria for seeking shelter indoors and evacuation, the areas, and the action levels regarding a fallout's strong gamma and beta emitters related to guidelines VAL 1 (STUK 2020a) and YVL C.3 (STUK 2019a) are summarised in Table 9-72. The five-kilometre precautionary action zone and the 20-kilometre emergency planning zone mentioned in Table 9-72 are shown, in terms of Loviisa power plant, in Figure 9-66.

9.21.1.2 Emission and its release into the atmosphere

The radiation doses and fallout resulting from a severe reactor accident were modelled on the basis of analyses performed for Loviisa power plant which allow for estimating the amount of radionuclides which would be released into the environment. The radiation dose assessments were based on a fictitious accident in which the activity of a total of 200 radionuclides or states is released into the environment.

In this fictitious severe reactor accident, 100 TBq of the Cs-137 nuclide and other radionuclides in equal proportion to how much of them would be expected to be released in proportion to caesium-137 in the accident. In a severe reactor accident, iodine is one of the key radioactive substances from which radiation doses arise. Given that the various states of iodine have dose coefficients that differ from each other, the dispersion calculation generally accounts for the different states of iodine to prepare a more precise dose estimate. In the dispersion calculation, iodine's state for all isotopes of iodine contained by the emission is assumed to divide as follows: 95% of the iodine is released as aerosols (particulate), 4.85% in element form and 0.15% as organic iodine (European utility requirements for LWR nuclear power plants 2016).

In the severe reactor accident under review, the power plant is producing electricity for the national grid at full capacity when a pipe of the primary system breaks. As a result of several failures, the reactor's water level drops, due to which the fuel is damaged, and radioactivity is released into the containment building. The accident is also assumed to include a leak from the containment building, as a result of which the activity is provided with a leakage route from the containment building to the atmosphere. The emission is assumed to begin some 2.5 hours after the reactor's shutdown (reactor trip) and it will be released into the atmosphere, unfiltered, at a height of approximately 31 m above ground level. The impacts of the emission were modelled by employing 22 hours as the duration of the emission in the dose calculation.

Table 9-72. Actions to protect the population, dose criteria and area delimitations, as well as action levels related to fallout.

Action	Dose criterion (VAL 1)	Greatest distance from power plant to which the action may extend (YVL C.3)	Indicative action level (VAL 1)
Seeking shelter indoors	> 10 mSv over a period of two days	Power plant's emergency planning zone (20 km)	The fallout of the fallout's beta and gamma emitters exceeds 10,000,000 Bq/m² for longer than two days
Evacuation	> 20 mSv during the first week for an unsheltered individual	Power plant's precautionary action zone (5 km)	The fallout of the fallout's beta and gamma emitters exceeds 10,000 000 Bq/m² for longer than two days

9.21.1.3 Dispersal calculation

The modelling of the radiation doses and the radioactive fallout was performed with the Tuulet programme developed by Fortum Power and Heat Oy. The program has been approved by STUK for use in the calculation of the radiation doses of the residents of nearby areas. The modelling is based on the Tuulet 2.0.0 program version, which has been modified for the purpose of the environmental impact assessment to allow for an assessment of the emission up to a distance of 1,000 km from the power plant. The results provided by the modified version of the program were compared, in terms of external doses, to the HYSPLIT model published by the National Oceanic and Atmospheric Administration (NOAA) of the United States (NOAA 2020). The comparisons show that the external radiation doses modelled with the Tuulet program are of the same magnitude as those of the HYSPLIT model.

The Tuulet program accounts for the effect that the power plant's buildings would have on the wind field and, thereby, the impact that the emission's release height would have on the dispersion. The emission cloud's vertical dispersion accounted for reflection from the ground and the atmosphere's inversion layers, the height of which depends on the atmosphere's stability.

In the Tuulet program, the dispersion of the emission cloud is described with the Gaussian trail model, which accounts for the decay of radioactive substances and their deposition on the ground as dry and wet fallout. To enable the statistical processing of the results, the modelling employed the weather data of three years retrieved from Loviisa power plant's weather observation system. The weather data was selected so that they represented the climate in the power plant's nearby areas in a diverse manner. The calculation of the effective whole-body radiation dose accounted for direct gamma radiation from the emission cloud, the gamma and beta radiation from the fallout and lake water, and the internal dose resulting from radioactive substances that enter the body through breathing and food. The emergence and migration of daughter nuclides was not modelled separately, but their dose impact was taken into account in the parent nuclides' dose coefficients and in the average gamma energies.

The accumulation and migration of radioactive substances in the biosphere has been modelled in the Tuulet program. The nuclides' deposition directly on the surfaces of plants and their migration from the soil to a plant's inner parts via root uptake was taken into account. Activity can also run off the surfaces of plants. Whether the activity ends up in plants depends on whether the emission occurs in the summer, during the growing season, or during another season. Harvest time has an impact on the migration of radioactivity from pasture grass and forage to cows. From cows, the activity ends up in humans through beef and milk. Radioactivity may also end up in game animals through forest meadows, and finally in humans who eat the game. In winter, the emission is initially deposited on top of ice and snow, meaning that the activity ends up in the food web with a delay, once the snows have melted. Activity deposited in lakes is initially mixed into the lake's water volume, finally ending up in the freshwater fish and ultimately, the humans who eat the fish. The radiation dose that accumulates through food over a year can be divided into the period of use of fresh food and stored food.

At distances of more than 100 km, it was conservatively postulated that radiation doses would accumulate at each calculation point through all dose pathways, although in reality, the doses accumulating in sea areas originate solely from the direct radiation emitted by an emission cloud passing overhead and from radioactive substances entering the body through breathing. The fallout and radiation doses estimated with the Tuulet program are therefore conservative.

No protective action was postulated when modelling the radiation doses, meaning that any decreasing effect that seeking shelter indoors and making changes in the food ingested would have on radiation doses was not taken into account. The fallout and radiation doses are presented according to a 5% exceeding probability. This means that there is a 95% probability that the fallout or radiation dose would remain smaller than the result presented here.

9.21.4 Age groups and the integration times of radiation doses

According to the International Commission on Radiological Protection (ICRP), it is advisable to account for different age groups when modelling radiation doses, given that the groups have different types of consumption pattern when it comes to nutrition. In accordance with the ICRP's recommendations (ICRP 2006), this modelling covered the age groups of one-year-olds, 10-year-olds and adults. Of these age groups, an adult is what is referred to as a representative person for the radiation doses in the environment of Loviisa power plant. The radiation dose accumulated throughout a lifetime was assessed by applying a 70-year exposure period (integration time) for one-year-olds, a 60-year exposure period for 10-year-olds and a 50-year exposure period for adults. The amount of nutrition typically ingested by each age group, based on Finnish consumption patterns, was accounted for in each age group. When assessing the radiation doses in terms of children, the individual's growth and the way of life and nutrition that change as a result of the growth were taken into account.

Both seeking shelter indoors and evacuation should be observed when modelling the potential actions for protecting the population attributable to a severe reactor accident. According to the VAL 1 guideline (STUK 2020a), seeking shelter indoors must be examined in terms of the radiation dose received over two days, and in terms of evacuation, the radiation dose received during the first week must be reviewed. The radiation dose caused by a severe reactor accident during the first year and throughout an individual's entire life can also be reviewed.

Table 9-73. The radiation doses caused by a severe reactor accident to a one-year-old, 10-year-old and an adult at a distance of 1–1,000 km from the emission's release point over two days, seven days, one year and the person's lifetime.

	Estimated dose of the one-year-old [mSv]				Estimated dose of the 10-year-old [mSv]				Estimated dose of the adult [mSv]			
Distance (km)	2 d	7 d	1 a	70 a	2 d	7 d	1 a	60 a	2 d	7 d	1 a	50 a
1	24.1	26.1	121.0	267.0	25.2	27.4	105.0	292.0	19.5	21.6	88.8	320.0
5	4.4	4.8	26.1	60.1	4.5	4.9	22.9	65.7	3.8	4.1	20.1	73.1
10	2.0	2.2	15.0	27.7	2.1	2.2	10.6	30.0	1.8	1.9	10.0	34.1
15	1.3	1.4	11.7	21.3	1.4	1.5	7.9	20.1	1.2	1.3	7.0	22.1
20	1.0	1.1	8.0	14.5	1.0	1.1	5.4	13.9	0.9	1.0	4.8	15.2
50	0.35	0.37	2.08	3.91	0.36	0.38	1.49	3.78	0.32	0.35	1.35	4.26
100	0.23	0.23	0.31	0.41	0.23	0.23	0.28	0.40	0.22	0.23	0.27	0.43
300	0.07	0.07	0.11	0.16	0.07	0.07	0.10	0.16	0.07	0.07	0.09	0.17
500	0.04	0.04	0.06	0.09	0.04	0.04	0.05	0.09	0.04	0.04	0.05	0.10
700	0.02	0.02	0.04	0.06	0.02	0.02	0.03	0.06	0.02	0.02	0.05	0.06
1,000	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.04

9.21.2 Radiation doses and fallout

The radiation doses resulting from a severe reactor accident are shown in Table 9-73. The radiation doses have been estimated for children aged one and 10, and for an adult, at a 1–1,000 km distance from Loviisa power plant. For the assessment of civil protection actions, the radiation doses are shown according to two-day and seven-day exposure periods. In addition, the radiation doses were assessed in terms of a year's and an entire lifetime's exposure periods.

According to the modelling (Table 9-73), the radiation dose that an adult living 20 km from the emission's release point would be subject to as a result of a severe reactor accident would be around 4.8 mSv with a one-year exposure period. The radiation dose caused by a severe reactor accident during an exposure period of one year outside Loviisa power plant's emergency planning zone of 20 km would remain smaller than the average annual radiation dose of an individual residing in Finland. The estimated magnitude of the annual radiation dose of an individual residing in Finland is 5.9 mSv (STUK 2020b).

The radiation doses of the children aged one and 10 would typically be greater than the adult's radiation doses in the vicinity of the power plant. This is due to different nutrition, for instance, in which the consumption of milk, among other things, is more pronounced than in adults. Although the lifelong exposure of the one-year-old and 10-year-old would be longer than the adult's, this would not automatically translate into a greater lifelong radiation dose, given that the accumulation of the radiation dose would be at its greatest in the moments following the accident.

Estimates of the fallout resulting from a severe reactor accident are presented in Table 9-74 for those caesium (Cs), iodine (I) and tellurium (Te) nuclides which, according to the radiation dose analysis, cause the greatest dose through the fallout during a one-year exposure period. In terms of the iodine isotopes I-131 and I-132, fallouts are shown for the three states of iodine (aerosol, organic and element), because these have different deposition rates from the air to the ground. The table also accounts for the long-lived strontium-90 (Sr) nuclide.

9.21.2.1 Effects of radiation doses

The health effects of radiation at a general level are described in Chapter 7.2.

Based on the modelling, the greatest radiation dose at a distance of one kilometre, accounting for all age groups, is approximately 25 mSv during the first two days, and approximately 27 mSv during the first week. Radiation doses of this magnitude do not have direct radiation effects on humans or cause developmental impairment in foetuses. A roughly 30-mSv radiation dose is equivalent to three whole-body CAT scans (STUK 2021i). A change in complete blood counts within a few days requires a radiation dose of approximately

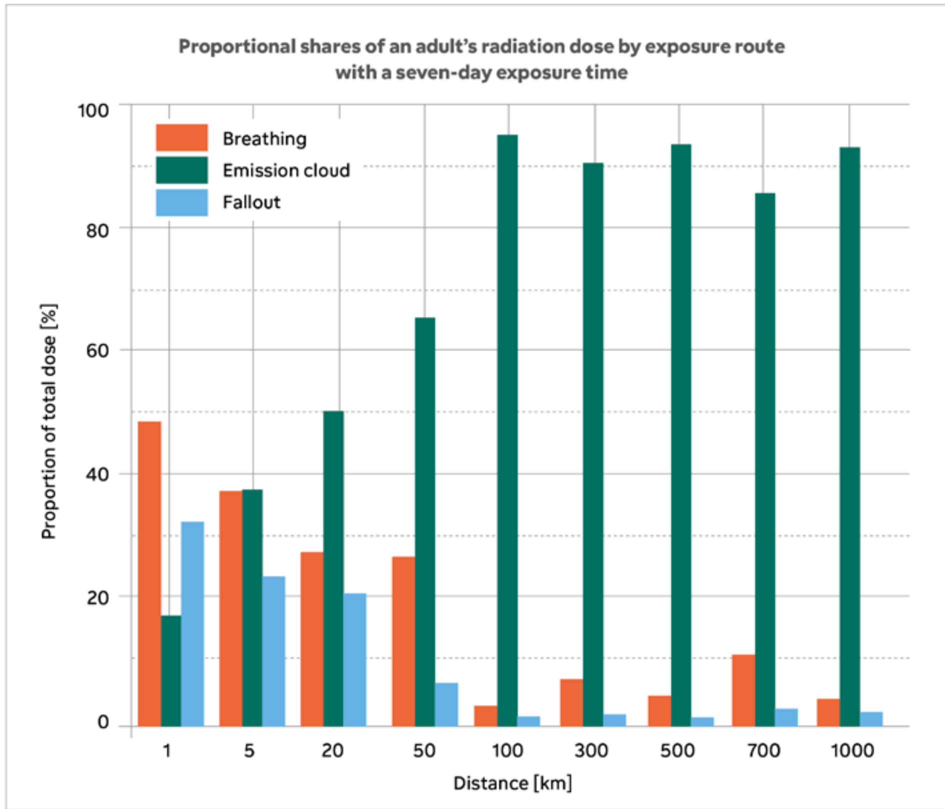

Figure 9-82. The relative proportions of an adult's radiation dose per exposure pathway during a seven-day radiation dose exposure period.

500 mSv. Sudden radiation doses of more than 100 mSV when a foetus is at a sensitive developmental stage may lead to developmental disorders (STUK 2019b).

By comparing the results of the modelled radiation dose estimates (Table 9-73) to the dose criteria in Table 9-72, the dose criteria for both seeking shelter indoors and evacuation are exceeded in the zone located at a distance of less than five kilometres from the power plant. In other words, at a distance of more than five kilometres from the power plant, the dose criteria for seeking shelter indoors or evacuation are not exceeded.

When examining the radiation dose at the outer limit of the power plant's precautionary action zone – i.e. at a distance of five kilometres from the power plant – the estimated radiation doses caused by a severe reactor accident throughout an entire lifetime are roughly 60 mSV for a child aged one (70-year exposure period), roughly 66 mSv for a child aged 10 (60-year exposure period) and roughly 73 mSv for an adult (50-year exposure period). At a distance of 20 km from the power plant, the radiation doses are in the range of 1 mSv during the first days, regardless of age group. The radiation doses estimated for entire lifetimes are, at a 20-kilometre distance, in the range of 15 mSv at maximum.

In the case of the adult, the radiation dose was also estimated for a fisherman. The fisherman is assumed to live five kilometres away from the power plant and to use local fish for food around eight times as much during a year than an average person residing in Finland does. Due to the impact of the pronounced consumption of local fish, the lifelong radiation dose was expected to be 164 mSv at most (50-year exposure period).

When the results of the modelling are compared to the annual average radiation dose of a person residing in Finland, which is around 5.9 mSv a year (STUK 2020b), one can conclude that the amount of radiation accumulated by a person residing in Finland from other sources over 50 years is approximately 295 mSv. In addition, a person living in a block of flats in a location in which they are exposed to abundant radon through domestic water or indoor air may be subject to a maximum radiation dose in excess of 1,500 mSV over a period of 50 years (STUK Guide 2020b).

When reviewing the results of the modelling, one should note that in the event of a severe reactor accident, the authorities would initiate action to protect the population, such as seeking shelter indoors, at a very rapid schedule – a factor not accounted for in the dose estimates presented. This being the case, the results presented are also conservative in this sense. Actions protecting the population implemented at an early stage can significantly reduce the greatest radiation doses received during the initial stage of the accident, which are attributable to activity entering the body through respiration as well as direct external radiation caused by an emission cloud travelling in the air stream and to deposition on the ground.

The relative proportions of the seven-day exposure period of an adult person presented in Table 9-73 are illustrated in Figure 9-82 as a function of distance. The nutrition dose pathway is not shown in the figure, because practically no radiation dose is received through this exposure pathway during a seven-day exposure period (as opposed to a one-year exposure period, for example). The figure shows that during the first week, respiration and deposition cause most of the radiation dose in the power plant's nearby areas. However, when the distance grows the radiation emitted by an emission cloud begins to dominate. A direct radiation dose attributable to an emission cloud can be efficiently limited by seeking shelter indoors (see Chapter 9.21.3), which is also relatively effective in sheltering a person from radiation doses received through respiration and deposition.

In longer periods of exposure, the effects of the deposition and particularly food intake begin to dominate the radiation dose. By avoiding the consumption of food products from the polluted areas, it is also possible to at least partly avoid the radiation dose attributable to food.

9.21.2.2 Effects of radioactive fallout

Fallout refers to the airborne radioactive particles originating from an accident deposited from an emission cloud on the ground or water as a result of both gravity (dry fallout) and rain (wet fallout). The fallout may remain above ground and cause a radiation dose via direct radiation, or it can migrate more deeply into the soil and transfer, in part or in full, through complex mechanisms, to plants, fungi and animals. Radioactivity can also end up in humans through food. It is also possible for the fallout to return from the ground into the air due to wind, for example. In waterways, part of the fallout mixes with the water, while part ends up in the sediment at the bottom, where it can also be remixed into the water as a result of currents.

When reviewing the effects of the fallout, one should especially account for the long-lived Cs-137 nuclide (with a half-life of some 30 years) and for the Cs-134 nuclide, with a slightly shorter half-life (a half-life of approximately two years). The shorter-lived isotopes of iodine in their different states are also often examined in connection with fallout (the half-life of I-131, for instance, is around eight days), as is the Sr-90 nuclide (with a half-life of approximately 29 years). In addition, the review included the nuclides Te-132 (with a half-life of roughly three days) and the short-lived I-132 (with a half-life of approximately 2.3 hours), which is the radioactive decay product of the Te-132 nuclide. Noble gases are not discussed in this context, given that they do not cause fallout.

By comparing the results of the modelled fallout estimates (Table 9-74) with the action levels in Table 9-72, the action levels for both seeking shelter indoors and evacuation are exceeded in the zone located at a distance of less than five kilometres from the power plant. In other words, at a distance of more than five kilometres from the power plant, the dose criteria for seeking shelter indoors or evacuation are not exceeded.

According to the modelling, when reviewed according to criteria in line with STUK's VAL 1 guideline, the area at a distance of less than one kilometre from the power plant is extremely contaminated, meaning that the area contains abundant radioactivity on all surfaces. The area at the outer limit of the power plant's precautionary action zone (at a distance of five kilometres from the plant) is heavily contaminated. The area at a distance of 15 kilometres is contaminated, and starting from a distance of 80 kilometres, the area is mildly contaminated or nearly clean.

Of the nuclides reviewed, the isotopes of iodine have the greatest impact immediately after an accident. In a human, iodine tends to be stored in the thyroid gland, but its effects can be mitigated with the timely intake of iodine tablets, which make the thyroid store stable iodine instead of radioactive iodine. Of the nuclides with a long half-life, Cs-134 and particularly Cs-137 and Sr-90 cause a radiation dose for years in the form of fallout. Caesium typically accumulates in the muscles and strontium in the bones of a human body. The biological half-life is often significantly shorter than the physical half-life, meaning that the Cs-137 ending up in a human body, for example, leaves the body more quickly than with the help of physical decay alone.

Radioactive fallout may demand either short-term (e.g. iodines) or long-term (e.g. caesiums and strontium) restrictions in the use of land or water areas as well as restrictions related to the use of foodstuffs. By comparing the fallout estimates in Table 9-74 and the VAL 1 guideline, the modelled severe reactor accident would result, among other things, in the clean-up of the built environment, restrictions related to the recreational use of natural areas and the organising of measurements and purification of humans living within a radius of less than 15 kilometres from the power plant. The use of built-up recreational areas should also be restricted up to a distance of 80 kilometres. The authorities would also impose restrictions on products used as food, such as berries, mushrooms, fish, game and dairy products, based on their activity concentrations (VAL 1 guideline).

9.21.3 Mitigation of impacts

The impact of an emission resulting from a severe reactor accident can be mitigated by various actions that aim to protect the population, such as the administration of iodine tablets and seeking shelter indoors, by evacuating the population before the emission reaches a particular area or by evacuating the population at a later stage, if the radiation situation requires this.

If the population is evacuated before the emission reaches an area, the radiation dose caused by the accident can even be avoided completely. In some cases, such as when the population, for one reason or another, cannot be evacuated in time before the emission cloud reaches an area, seeking shelter indoors is a good way to reduce the radiation exposure attributable to a radioactive cloud.

Table 9-74. The depositions [kBq/m²] of the nuclides causing the greatest radiation doses through fallout at different distances from the power plant in a severe reactor accident.

	Deposition [kBq/m²]									
Distance (km)	**Cs-134**	**Cs-137**	**I-131 (aerosol)**	**I-131 (organic)**	**I-131 (element)**	**I-132 (aerosol)**	**I-132 (organic)**	**I-132 (element)**	**Te-132**	**Sr-90**
1	706	441	4353	0,5	1,472	5,424	0,6	1,828	4,983	1.1
5	126	79	779	0.07	181	970	0.09	225	892	0.2
10	56	35	344	0.03	65	429	0.04	81	394	0.09
15	33	21	205	0.02	35	256	0.02	43	235	0.05
20	23	21	141	0.01	22	176	0.02	28	162	0.04
50	6.3	4.0	39	0.005	4.8	49	0.006	6.0	45	0.01
100	0.4	0.3	2,6	0.0004	0.2	3.3	0.0005	0.3	3.0	0.0007
300	0.2	0.1	1,1	0.0003	0.07	1.4	0.0004	0.09	1.2	0.0003
500	0.1	0.07	0,7	0.0003	0.04	0.8	0.0003	0.05	0.8	0.0002
700	0.08	0.05	0,5	0.0002	0.03	0.6	0.0003	0.04	0,.05	0.0001
1,000	0.05	0.03	0,3	0.0002	0.02	0.4	0.0002	0.03	0.03	0.0001

Among other things, the effectiveness of seeking shelter indoors depends on the material used in the building and the location of the space used as a shelter within it. STUK has estimated (STUK 2020a) that even at its minimum, seeking shelter indoors, when carried out in an orthodox manner, can reduce the radiation dose to one-third of what it would be without seeking shelter indoors. Seeking shelter indoors is at its most effective when the building's ventilation has been stopped, and when the space used for the sheltering is the civil defence or air-raid shelter of an apartment building, for example. In such cases, the radiation dose is estimated to remain as low as one five-hundredth of the dose received without the shelter (STUK 2020a).

The impacts of the fallout can be mitigated in several ways, depending on the area in question. Paved urban environments, for instance, can be washed, which means that significant portions of the fallout can be removed with water. Land areas can also be modified so that the soil material on their surface containing the most fallout is removed and transported to a controlled storage location. In a fallout situation, the principal clean-up measures target living environments in which people spend a large part of their time (including housing) or with a high population density (urban areas).

STUK's VAL 1 guideline (STUK 2020a) provides guidelines for the protective actions that aim to protect the population in the early and intermediate stages of an emergency exposure situation. The guideline reviews the content of and grounds for the protective actions, and provides various dose criteria and indicative action levels which, if exceeded, necessitate the initiation of protective action. In an emergency exposure situation, STUK assesses the situation's safety significance in accordance with the Rescue Act (379/2011) and gives recommendations on protective action to the authorities which decide on such action. In an emergency exposure situation, a nuclear power plant's licence holder works in close cooperation with STUK, ensuring the safety of the power plant and its environment in the best possible way. The key responsibilities for the protective action in an emergency exposure situation are compiled in Appendix 4 to

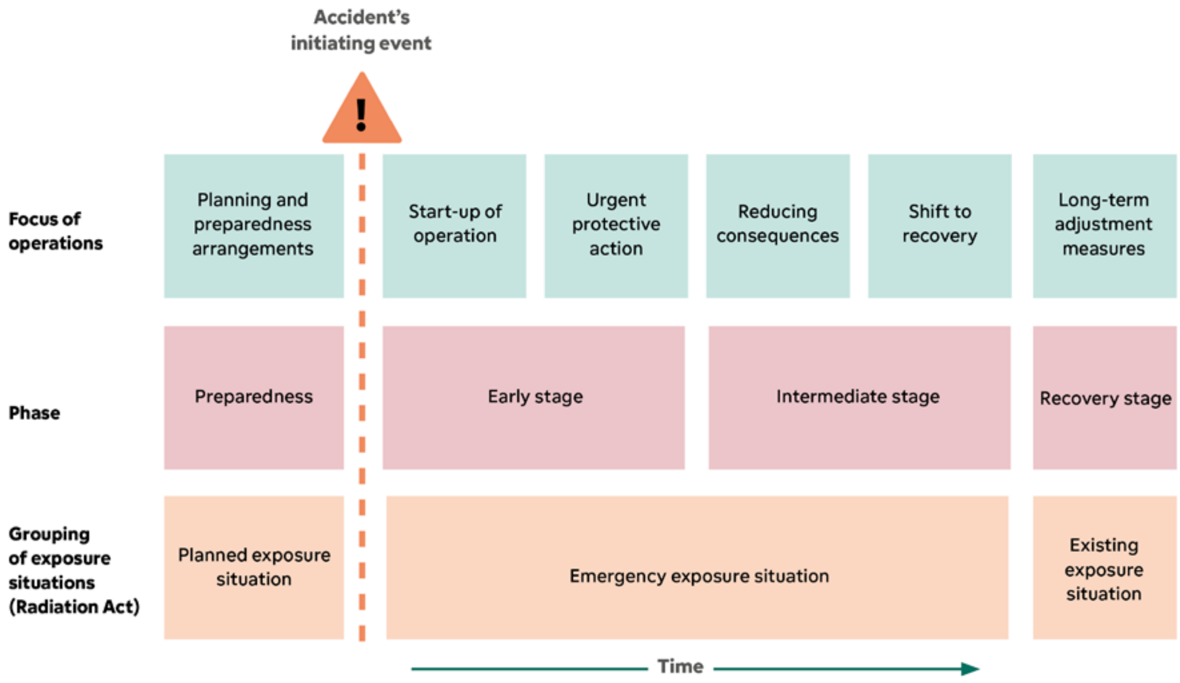

Figure 9-83. Development and stages of an emergency exposure (STUK 2020a).

the VAL 1 guideline. The radiation situation manual published by the Ministry of the Interior (Ministry of the Interior 2016) provides instructions for the authorities' measures in an emergency exposure situation. Figure 9-83 shows the focal points of the protective action during the various stages of an emergency exposure situation.

Preparing in advance for a potential accident is an important principle of protective action. It enables the rapid initiation of the planned action as soon as the accident has occurred.

During the early stage of the accident, the focus of the protective action is on initiating the action and urgent protective action. The protective actions during the early stage focus particularly on people and production, with the aim of both protecting people as well as facilitating and mitigating the action required during the intermediate stage. Urgent protective action concerning the population and the people working in the hazardous area includes seeking shelter indoors or curfews, taking iodine tablets, isolating the area and access restrictions, the population's evacuation and protecting the people working in the hazardous area. Action will also be taken to shield foodstuffs, the primary production of animal feed and domestic water, the raw materials of foodstuffs, finished products and production facilities. If necessary, restrictions on food and the trade of goods will also be imposed (STUK 2020a).

The focus of the protective action during the intermediate stage of an accident is on reducing the consequences and the transition to recovery from the accident. During the intermediate stage, the protective action focuses on the living environment and on restoring society's activities, in addition to people and production. In terms of the population and people working in a contaminated area, the protective actions are similar to those during the accident's early stage. Additional actions include the measurement and purification of humans as well as the removal of radioactive substances and the reduction of their migration. Other possible actions include potential restrictions to land use as well as the use of foodstuffs, food production and water supply (STUK 2020a).

The recovery stage is the final stage of the protective actions, during which the focus is on the long-term adjustment measures (STUK 2020a).

9.21.4 Social and socioeconomic impacts

A severe reactor accident's impacts on society are varied and of a long-term nature. Among other things, the impacts on society and its activities depend on the place of residence (urban environment or rural areas) and the actions imposed by the authorities that aim to protect the population (evacuation and the applicable limit values related to the dose rate and fallout). Managing the aftereffects of the accident, long-term healthcare and mental wellbeing, as well as supporting society in many other ways, should also be paid attention to as a countermeasures.

Areas contaminated as a result of the accident, including food production areas, may have to be removed from use for a long time or even permanently. Settled urban areas can be cleaned up much more easily than croplands or forests, for example. In some areas, this could lead to a significantly steeper drop in the areas' value than elsewhere, even if the level of contamination is identical.

The impacts of a severe reactor accident concern both built infrastructure and nature, but they also have psychological effects on humans. The large-scale contamination of the environment resulting from a severe reactor accident may lead to job losses, and thereby impact people's livelihoods and result in chronic anxiety and various well-founded or unfounded fears related to radiation in the environment. Furthermore, the mere large-scale evacuation of the population may lead to significant problems in mental wellbeing, even if the direct impacts of radiation could be completely avoided with timely evacuation. The people exposed to radiation in the accident may also be subject to discrimination.

The social and socioeconomic impacts of the Chernobyl accident have been studied extensively (see Chernobyl Forum 2005). Some 116,000 residents were evacuated soon after the accident, and overall, the number of residents evacuated over the years amounts to more than 330,000. Although relocation reduced the population's radiation dose, many considered it a traumatic experience, even after material compensation (such as new housing) (Chernobyl Forum 2005).

The social and socioeconomic impacts of the accident include large-scale restrictions to land use in previously arable land areas and consumers still shunning products grown in areas which have already been categorised as safe. This has had an impact on the total economy in areas which experienced the greatest radioactive fallout from the accident at Chernobyl (Chernobyl Forum 2005).

The population structure has also undergone significant changes, given that in the areas which suffered most from the accident, the elderly are abnormally overrepresented in the age distribution. Among other things, this is the result of migration, during which the younger population has gravitated elsewhere on their own initiative. In addition to an abnormal age distribution, this has also had psychological effects. In the areas in question, the mortality rate is higher than the birth rate, and various industries have difficulties finding a professional workforce. This has had an impact on many sectors, including social services. The people living in areas most contaminated by the accident have a more negative attitude towards their own health than people living in other areas. A certain type of victimisation and a culture which leans increasingly heavily on government-paid subsidies have also take hold (Chernobyl Forum 2005).

According to a study of the Fukushima accident (Hasegawa et al. 2016), the accident has caused mental problems such as post-traumatic stress disorder, chronic anxiety and feelings of guilt, an indeterminate feeling of loss, emotions related to families or communities set apart as well as feelings of shame. Increased deaths were observed particularly among the evacuated senior citizens in need of care. It has been suggested that these deaths are the result of the constant changes in nutrition, hygiene as well as medical and general care resulting from the multiple evacuations. In addition, the Fukushima accident caused what are referred to as lifestyle-related changes, given that many of the evacuees experienced changes in their eating habits, amount of exercise as well as the consumption of tobacco and alcohol. The changes are expected to lead to an increase in diseases related to these lifestyles, such as obesity (Hasegawa et al. 2016).

9.21.5 Comparison with the Fukushima accident

The Fukushima accident was well documented from the start, and the fallout and radiation doses, for instance, have been mapped across a large area right up to the present day. The Fukushima accident led to the meltdown of the reactor core of three power plant units and consequently, a significant release of radioactive substances and the resulting action aiming to protect the population. The Fukushima accident was categorised as an INES level 7 accident on the International Nuclear and Radiological Event Scale. Based on the activity released in the emission, the modelled fictitious severe reactor accident of Loviisa power plant is an INES level 6 accident.

Table 9-75. Comparison between the Fukushima accident and Loviisa power plant's modelled severe reactor accident (Extension Site of Distribution Map of Radiation Dose 2021; Unscear 2013; Unscear 2015).

	The Fukushima nuclear power plant accident		Loviisa power plant – modelled severe reactor accident	
Emission into air [TBq]				
I-131	151,000		1,040	
Cs-137	14,500		100	
The fallout in an area within approximately 100 km of the power plant [kBq/m^2]				
I-131, min	0,4[a] (1340)		1.07	
I-131, max	7,400[b]		14,681	
Cs-137, min	< 300		0.1	
Cs-137, max	3,000 - 14,700		1,090	
Radiation dose [mSv]				
	One-year exposure period[c]	Lifelong exposure period[c]	One-year exposure period[d]	Lifelong exposure period[d]
One-year-old	2.0 - 7.5	2.1 - 18.0	0.3 - 8.0	0.4 - 14.5
10-year-old	1.2 - 5.9	1.4 - 16.0	0.3 - 5.4	0.4 - 13.9
Adult	1.0 - 4.3	1.1 - 11.0	0.3 - 4.8	0.4 - 15.2

a: The fallout in the direction of the emission trail approximately three months after the accident, when the half-life of I-131 has had a significant effect on the value. The value in parentheses has been scaled to the date of the accident, 12 March 2011, when the radiation levels were first detected as rising (Unscear 2013). The scaling factor 3357.341 is based on the half-life of I-131 (8.0252 d) and a 94-day period.
b: In the city of Namie, in the days following the accident.
c: The radiation doses reported in terms of the Fukushima accident correspond with the range estimated for the dose in the areas of Fukushima Prefecture in which the population was not evacuated, given in the reference (Unscear 2013)a. Initially, the evacuated area extended to a distance of 20 km from the power plant. Later, the area was expanded, particularly due northwest.
d: For the sake of comparison, the range of the radiation doses at a distance of 20–100 km from the power plant is shown in terms of Loviisa power plant's fictitious severe reactor accident.

Table 9-75 shows reference data on the Fukushima accident and the modelled Loviisa power plant's severe reactor accident. Based on the table, the emission of the Fukushima accident was approximately 150 times greater, in terms of both iodine and caesium, than the severe reactor accident of Loviisa power plant in the case example would be. Despite this, the modelled I-131 fallout resulting from Loviisa power plant's severe reactor accident in the case example is, in places, up to twice that of the data published on the Fukushima accident, which is itself an indication of the calculation model's conservative nature. However, in terms of the Cs-137 radionuclide, the fallout observed in the Fukushima area is significantly greater. The radiation doses are in the same range of magnitude, and in places, even extremely close to each other in all age groups.

In the assessment concerning a severe reactor accident at Loviisa power plant, the estimates of the fallout and the radiation doses were conservative, and the modelling did not account for the impact of protective actions as a factor reducing radiation doses. In a genuine accident situation, the protective actions would be implemented on a scale instructed by the authorities. Extensive protective action aiming to protect the population was taken in the Fukushima accident. In addition, some of the emissions resulting from the Fukushima accident were carried east, towards the sea, meaning that the emission as a whole did not result in a deposition over land areas. This means that the fallout deposited on the ground and measured from the environment of Fukushima does not, as a whole, correspond with the amount of activity released into the atmosphere in the accident. The comparison between a severe reactor accident at Loviisa power plant and the Fukushima accident is therefore not straightforward in every respect.

9.22 OTHER INCIDENTS AND ACCIDENTS

9.22.1 Baseline data and assessment methods

Incidents and accidents and their environmental impacts were reviewed on the basis of the requirement for nuclear facilities set by the authorities and on the investigations carried out. Among other things, the existing safety and risk analyses drawn up for Loviisa power plant were reviewed to identify incidents and accidents.

The incidents and accidents discussed are related to the power plant's internal and external events in which there is no need to initiate safety measures involving the reactor and the storages for spent fuel, or in which they work as planned. In other words, the event does not directly cause an incident or accident pursuant to the Nuclear Energy Decree (161/1988), or the approval criteria in accordance with the event category are met. Incidents and accidents could have an impact on functions and safety functions during normal operation and thereby impair the power plant's safety level. The categorisation of a nuclear power plant's incidents and accidents, preparing for them as well as their management and emergency preparedness operations are described in Chapter 7.

Some external events could lead to the power plant's temporary shutdown, at which point commercial electricity production would be suspended and the power plant would be shifted to a shutdown state. Work would also be stopped if necessary. Examples of such events include an oil accident in the sea area, a high air or seawater temperature, or a high or low level of seawater. The power plant's shut down would aim to ensure that the power plant's state was as safe as possible, should the situation be exacerbated for some reason.

In disturbances of the electricity network, the electricity produced by the plant cannot be transmitted to the national grid, due to which the power plant would be left at houseload operation power or be shut down, in which case the diesel generators in the power plant area would be used for the production of the electricity needed in the area.

If the measures related to the management of incidents and accidents fail, or if the systems needed for their performance are out of order, the situation could deteriorate. The measures and systems are presented in more detail in Chapter 7.5.2. At its most extreme, the situation could, as a result of numerous failures and errors, escalate into a severe reactor accident, the consequences and impacts of which are discussed in Chapter 9.21. Nevertheless, the probability of such a situation is extremely low.

In extended operation, the estimate concerning the radiation doses was prepared for a milder case, in which the safety functions worked as planned. The case pertains to a major leak from the primary system to the secondary system during operation. The case covers a broad group of various incidents and accidents of a nuclear power plant in the majority of which the impacts are significantly milder than in the case presented here, or in some cases, of the same magnitude. In accordance with the categorisation of the Nuclear Energy Decree (161/1988), the accident falls under the event category B – design extension condition. Based on the activity released in the emission, the event is an INES level 4 event according to the international categorisation.

In addition, the review in terms of extended operation and decommissioning covers other potential incidents and accidents in which a small quantity of radioactive substances could spread into the environment. Such situations have been deemed possible in the plant's safety analyses when, for example, handling spent nuclear fuel or radioactive waste, or if there is a leak in a system containing radioactive substances. Situations causing minor radioactive emissions may occur at all stages of the plant's lifecycle until the plant has been decommissioned. For example, fires may cause a radioactive emission, but also an impairment of the safety level by damaging part of the safety system.

The estimates on the radiation doses were prepared with the Tuulet programme. Instead of 1,000 km, the impacts of the emissions' dispersal are reviewed up to a distance of 1–100 km from the power plant, because the emissions are significantly smaller than the emission of a severe reactor accident would be, due to which the impact area of the emissions would not extend as far. The assessment employed conservative postulations, and the doses were estimated by employing an overshoot probability of 0.5% over a one-year integration period.

The impact assessment also reviewed conventional incidents and accidents which have no material impacts on the plant's safety level in principle. Such incidents and accidents do not cause radioactive emissions, and they are related to the transports, loading and unloading, storage and use of oils and other chemicals, for example. The reasons for the accidents could include equipment failure and human error.

9.22.2 Extended operation

9.22.2.1 Radioactive emissions

The worst-case scenario in terms of radiation doses would be a severe reactor accident at Loviisa power plant, which is discussed in Chapter 9.21. This chapter deals with an accident which would involve a major leak from the primary system to the secondary system. The case covers a broad group of various incidents and accidents of a nuclear power plant in the majority of which the impacts are significantly milder than in the case presented here, or in some cases, of the same magnitude. These also include fires and explosions occurring in the power plant's premises, which could result in radioactive emissions into the environment.

It is possible in pressurised-water plants, such as Loviisa power plant, for the water cooling the reactor to enter the secondary system as a result of damage occurring in the steam generators. Should such a leak be big, some of the water and steam would be blown into the atmosphere until the pressures of the systems level off. The primary system's water contains radioactive substances. At its greatest, such an accident would cause residents in the power plant's environment (at a distance of one kilometre from the power plant) a radiation dose of 3.3. mSv at a one-year exposure period. Of this dose, 1.5 mSv would be the result of an emission into the air and 1.8 mSv of a discharge into the sea.

The radiation dose resulting from this accident would be around 55% of the average annual radiation dose of a person residing in Finland, 5.9 mSv. Table 9-76 shows the estimated radiation doses resulting from an emission into the air at different distances from Loviisa power plant.

The systems of Loviisa power plant contain radioactive substances during normal operation. Leaks from the systems lead to only minor radioactive emissions. Such an event would cause residents in the power plant's environment (at a distance of one kilometre from the power plant) a radiation dose significantly below 0.1 mSv at a one-year radiation dose exposure period. This radiation dose would be around 1 % of the average annual radiation dose of a person residing in Finland, 5.9 mSv. An emission from a system containing radioactive substances could occur as a result of some of the events presented in Chapter 9.22.2.2 or an earthquake.

Incidents and accidents related to the handling and storage of waste, including spent nuclear fuel, are discussed in Chapter 9.22.4.

9.22.2.2 Fires, explosions, oil and chemical accidents

The reasons for the accidents discussed in this chapter include equipment failures, human error and earthquakes. Table 9-77 shows in more detail how fires, explosions and oil and chemical accidents are prepared for, and the impacts they may have. In some cases, they could also result in radioactive substances spreading into the environment. The events are prepared for in the power plant's design and instructions. The impacts of individual events are limited to a small area, and the emissions of radioactive substances are minor. In events of a larger scale, which could occur if some of the preparedness measures fail, the emission could be greater. Even in this case, the emission and its impacts are nevertheless expected to remain significantly below category B of the postulated accident's design extension condition. The radiation doses specified above in Chapter 9.22.2.1 therefore also cover the radiation doses of residents in the power plant's environment in the events covered in this chapter.

In addition to fire protection, the tasks of the plant fire brigade include protection against chemical and oil accidents. The plant fire brigade maintains firefighting equipment and machinery and material preparedness of the kind that allow it to handle small incidents and start damage control in big events before the regional fire service arrives.

9.22.2.3 Preparing for climate change

Climate change has an impact on the intensity of external events and the probability of powerful phenomena. As a result of climate change, the average temperatures of seawater and air close to the surface of the earth will increase in the future, for example, and heatwaves in air and seawater will become more common. Precipitation is also likely to increase. The sequestration of heat and carbon dioxide in seas will change the stratification and pH conditions of seawater, while increasing precipitation will dilute the salinity of seawater directly through precipitation, but also through run-off. Changes in these physical quantities of the environment will form complex feedback loops between each other, which makes assessments of the magnitude of the changes difficult and sensitive to error (Bolle et al. 2015).

In accordance with what is presented in Chapter 7.5.6, one of the threats posed by climate change from the perspective of the operation of Loviisa power plant is a rise in sea levels. According to the Intergovernmental Panel on Climate Change (IPCC 2018), the global rise in sea levels would be roughly 0.3 m in 2050 compared to the average level in 1986–2005, even according to the worst climate change scenario. At the location of the power plant, the impact would be less than half of this due to the rising landmass. The temporarily high level of seawater is attributable to weather phenomena, which are monitored and forecast continuously at Loviisa power plant. In the event of a high level of seawater, the plant will be shut down at an early stage, and flood control will be installed for some systems.

In the future, the increase in the temperature of the air and seawater may result in power restrictions or the need for temporary shutdowns at the power plant due to the conditions of the environmental permit and the requirements imposed on the equipment's cooling capacity. Increasing violent storms may cause disruptions in the main grid, which the plant has prepared for in the form of numerous sources of backup power.

Studies related to climate change are monitored continuously, and modifications are carried out as necessary on the basis of the assessed effects, as explained in Chapter 7.8.

Table 9-76. The greatest distance-specific radiation doses [mSv] of an adult at a distance of 1–100 km from Loviisa power plant, resulting from an emission into air that forms in the secondary system due to a major leak in the primary system.

Distance [km]	Radiation dose estimated for an adult [mSv]
1	1.5
5	0.78
15	0.16
20	0.11
50	0.02
100	0.005

Table 9-77. Impacts of incidents and preparing for them.

Incident	Impact	Preparedness
Fires and explosions	- Property damage and bodily injury - Damage to structures - In a major fire, the spread of combustion gases into the environment - In a major fire, the run off of firewater into the environment - Minor spread of radioactive substances into the environment possible	- Structural fireproofing (the separation and location of systems to be protected as well as fire compartmentalising). - Instructing the plant's controllers in how to manage the situation. - Minimising fire loads and appropriate storage. - The appropriate treatment of flammable gases generated in the process systems. - The pressure relief devices of pressure vessels. - The application of ATEX equipment and condition regulations. - Fire detection system. - Fire extinguishing systems. - Hydrogen leak alarms. - The plant's own fire brigade with 24-hour standby readiness. - The personnel's training and qualification requirements. - The fire and rescue plan, and cooperation with other operators and the authorities. - Filtered ventilation system.
Transport accident or spill of light fuel oil	- Oil spill into the soil or waterway	- Transports are carried out according to regulations applicable to the transport of dangerous goods. - Transports within the power plant area are carried out along guided and paved transport routes. - The fuelling of the diesel generators' engines relies on the plant area's distribution pipes. - Unloading areas are paved, and the rainwaters of the unloading places of the diesel buildings, in which the largest oil stock is located, are treated in the oil separator before the cooling water is conducted into the discharge tunnel. - All storage tanks are equipped with level meters and overfill prevention devices, and unloading events are supervised by both the driver of the tank truck and a representative of the power plant. - The storage tanks for fuel oil are located in their own separate rooms, the volume of which is at least equal to the volume of the storage tank. The rooms are not equipped with drainage. The day and usage tanks, which are smaller than the storage tanks, are located in spaces with drainage either to a collector tray or the cooling water discharge tunnel, via oil separation. - The storage and day tanks are monitored daily for the detection of any leaks. The condition of the tanks is also covered by regular inspections. - All oil separators are equipped with oil sensors which, when oil is detected, close the separator's discharge valve and send an alert to the control room. The condition and functioning of the oil separators and sensors are covered by regular inspections, and records are kept on the inspections. - Absorbents for spills are available in the plant area. - The security personnel monitor the surrounding waterbody, the mouths of drainage pipes and drainage ditches for any signs of oil. - An action plan has been drawn up for any oil spills. - The plant fire brigade is responsible for the oil pollution response.
Oil spill in the yard area	- Oil spill into the soil or waterway	- Absorbents for spills from machinery are available in the plant area. - Any oil spills occurring in the generator transformer area are collected in the collector for drain oil under the transformers. A collector under each transformer can hold the transformer's entire volume of oil. - The emergency generator transformer is located in the catchment basin, which collects smallish oil spills.
Chemical ransport accident or chemical spills	- Bodily injuries (e.g. corrosive chemical splashes) - Chemical spill into the soil or waterway	- Transports are carried out according to regulations applicable to the transport of dangerous goods. - Transports within the power plant area are carried out along guided and paved transport routes. - Chemical spills occurring indoors are directed into a collector system. - The chemical's entry into the environment is prevented according to separate spill instructions. - The transfers of chemicals within the power plant comply with the applicable safety guidelines and regulations. A manual for the transport of hydrazine barrels has been drawn up, for example.

9.22.3 Decommissioning

During the preparation phase of decommissioning, the power plant will still be in operation or in a shutdown state. The actual dismantling operations can be started once the spent nuclear fuel has been moved from the reactor buildings to the storages for spent fuel. At the same time, a great many of the power plant's systems will become obsolete, given that there will longer be a risk of an accident involving the reactor or the reactor building's fuel pools. Any extra chemicals, fuel oil and oil will be removed, after which the risks related to them will also disappear.

The dismantling, packing and transport of the systems and structures will create risks which are prepared for in largely the same way as during the power plant's operation. This is discussed in Chapter 9.22.2. Incidents and accidents related to the transport, handling and storage of waste, including spent nuclear fuel, are discussed in Chapters 9.22.4 and 9.22.5. The nature and scale of the operations will nevertheless differ from what they are during the plant's operation. The prevention and extinguishing of fires, for example, plays an important role in managing these risks.

Special attention will be paid to the personnel's radiation protection when planning the dismantling measures and other decommissioning phases. The careful selection of individual ways of working and the tools used has a significant impact on the personnel's radiation doses. A radiological protection plan, which will be further specified before the dismantling work begins, has been drawn up for the dismantling of each piece of equipment or set of systems. Some of the radiological protection measures employed in the implementation of the decommissioning are listed below:

- the radiological protection measures already employed during electricity production and annual outages;
  - active monitoring of radiation and contamination levels;
  - minimising the duration of radiation work with good planning;
  - orthodox use of personal protective equipment (respirator, gloves, etc.);
  - the construction of temporary radiation shelters;
  - decontamination of equipment;
  - the dismantling and packing of strongly radiating waste under water;
- optimising the order of the work phases in the decommissioning;
- optimising work methods, such as the cutting of pipes;
- the use of remote-controlled chipping and sawing robots;
- sawing concrete structures under water;
- filtered local exhaust ventilation (local suction/dust removal) to be installed at individual work sites;
- barriers preventing the spread of dust to be installed at individual work sites or a larger area;
- a dimensioned radiation shield around the reactor pressure vessel's core zone;
- a radiation protection cylinder modified for the transport of the reactor's inner parts during decommissioning;
- control of the crane from a separate radiation-shielded control location;
- manual remote control of the crane from outside the reactor building with the help of a video link;
- additional radiation shielding to be installed in the vehicle transporting the most active waste.

Despite the measures listed above, situations in which a small quantity of radioactive substances end up in the environment may occur during decommissioning. The dose estimate of 0.1 mSv presented in Chapter 9.22.2.1 also applies to these situations.

In addition to what is presented above, the dismantling activities related to the decommissioning involve risks similar to those involved in any kind of dismantling activity. These risks are life and health risks, which are prepared for with good planning and execution. No possible incidents will have an impact on the environment. Part of the work, such as asbestos removal, complies with the required protective measures.

9.22.4 Spent nuclear fuel as well as low and intermediate-level waste generated at the power plant

9.22.4.1 Handling, storage and transport of spent nuclear fuel

Situations causing minor radioactive emissions may occur during the operation of the fuel storages in the same manner as during the power plant's operation, which is discussed in Chapter 9.22.2.1. Even so, there are only a few systems, which means that the likelihood of such situations is also smaller than it is in connection to the power plant units. The 0.1 mSv specified in Chapter 9.22.2.1 also covers the loss of the recovery of the residual heat of the spent fuel stored in the interim storages for spent nuclear fuel.

The transports of spent fuel between the reactor buildings and the storages for spent fuel are not subject to the IAEA's safety requirements (IAEA 2018) or the Act on the Transport of Dangerous Goods (719/1994), because the transports take place within the power plant area. For all intents and purposes, the requirements are nevertheless accounted for; for example, the dose rate of the radiation on the surface of a transfer cask meets the requirements set for transports outside the power plant area. Several of these transfers take place each year during operation – and will take place during the initial phase of decommissioning – in a transfer cask designed for the purpose. No disruptions or accidents occurring during transfer are expected to cause radioactive emissions, given that the cask will be transported at a low height, which means that even if the cask topples over, it will not break. Thus an exceptional incident would result in radiation doses for the personnel. The magnitude of the doses would be equal to what it is expected below in connection with an accident occurring in a transport to Olkiluoto, in which the cask does not break.

The transports of spent nuclear fuel for encapsulation and final disposal at Olkiluoto are transports of dangerous goods, subject to, among other things, the IAEA's safety requirements (IAEA 2018) and the Act on the Transport of Dangerous Goods (719/1994). According to these requirements, the transfer cask must be able to withstand a drop from a height of nine metres, fire and submersion in water. The dose rate of external radiation may not exceed the value of 2 mSv per hour on the transport device's (vehicle's) outer surface or the value of 0.1 mSv at a two-metre distance from it. A transport plan and preparedness plan will be drawn up for transports. In the event of an accident, the rescue personnel could be required to work in the vicinity of the transfer cask, in which case eight hours of working at a distance of two metres from the cask would result in a maximum radiation dose of 0.8 mSv. This radiation dose would be around 14% of the average annual radiation dose of a person residing in Finland, 5.9 mSv. At a distance of approximately 30–50 metres from the transfer cask, its radiation dose rate would be equal to natural background radiation. Should the transfer cask's integrity be lost in more serious accidents involving traffic, the consequence could be a radioactive emission formed by noble gases or other volatile substances which would expose an individual to a negligibly small radiation dose (Posiva 2012, Appendix 18).

Table 9-78. The impacts of incidents and accidents related to the handling of operational and decommissioning waste, and preparing for them.

Incident	Impact	Preparedness
Waste handling and transport accidents	- Bodily injuries - Minor spread of radioactive substances into the environment possible	- Lifting and transport plans - Transport equipment and waste packaging methods suitable for the waste type and conditions - Radiation control - Maintenance of passageways and transport routes

9.22.4.2 Handling of operational and decommissioning waste

During the power plant's operation, radioactive waste is handled, transported and stored in relatively small amounts at a time, due to which any incidents or accidents are expected to generate only minor radioactive emissions. During decommissioning, the amounts are larger, but the occurrence of incidents and accidents can be prevented in the detailed planning of the decommissioning by the selection of the methods for handling radioactive waste and packaging as well as logistics arrangements. This also applies to reducing the consequences of any incidents or accidents.

The estimates of the radiation doses (less than 0.1 mSv from the leakage of systems containing radioactive substances and 3.3 mSv from an improbably large fire) also include waste handling accidents. The potential impacts of incidents and accidents related to the handling of operational and decommissioning waste, and the preparedness measures involved, are explained in Table 9-78. The general principles of preparing for fire also apply to the handling of waste. These are dealt with in Table 9-77.

9.22.4.3 L/ILW repository

Emissions of radioactive substances from the L/ILW repository into the environment occur solely as a result of incidents or accidents. The worst-case scenario involves an intense transport vehicle fire, which could result in a maximum radiation dose of 0.2 mSv at a one-year exposure period to a resident in the power plant's environment. This radiation dose would be around 3% of the average annual radiation dose of a person residing in Finland, 5.9 mSv.

Table 9-79. Incidents and accidents identified as possible during the final disposal facility's operational phase.

Incident	Impact	Preparedness
The flooding of the final disposal halls due to a rise in sea level or a failure of the seepage water system.	- The waste containers are exposed to water and radioactive substances could be dissolved in the water. - A minor spread of radioactive substances into the environment in connection with the water being pumped out is possible.	- A rise in sea level to the L/ILW repository's access tunnel and the mouths of the shafts is extremely unlikely, given that the mouth of the access tunnel is at a level of three metres (N2000). - The L/ILW repository has a seepage water tank which collects the seepage water from the bedrock. The seepage water tank can hold roughly a week's worth of seepage water, during which time the system can be repaired, or an alternative pumping method can be arranged.
Fires (e.g. the fire of a transport vehicle)	- Minor spread of radioactive substances into the environment possible	- Fire detection system. - Fire extinguishing systems. - The plant's own fire brigade with 24-hour standby readiness. - The personnel's training and qualification requirements. - The fire and rescue plan, and cooperation with other operators and the authorities. - Filtered ventilation system.
The mechanical damage of waste containers or release barriers.	- No impact on the environment. - Bodily injuries.	- The condition of the bedrock and rock reinforcements is regularly monitored and maintained to avoid rocks falling on top of the containers. - Transports and transfers are planned, and they are implemented according to the instructions provided so that the likelihood of damage is small. - Monitoring the condition of and supporting waste containers when necessary. - The probability of seismic phenomena that could damage the structures or waste containers is extremely low.

Incidents and accidents identified as possible during the L/ILW repository's operational phase are shown in Table 9-79. In most incidents and accidents, the impacts would be confined to the L/ILW repository. The L/ILW repository's long-term safety and situation after closing are discussed in Chapters 7.9.3 and 9.10.5.2.

9.22.5 *Radioactive waste generated elsewhere in Finland and its impact*

The handling and final disposal of radioactive waste generated elsewhere in the Loviisa power plant area is subject to incident and accident measures corresponding to those described in Chapter 9.22.4. Radioactive waste generated elsewhere would not alter the situation to any significant degree.

The only incident or accident identified as specific to radioactive waste generated elsewhere in Finland is a disruption related to the transport of such waste. These transports would be subject to the Act on the Transport of Dangerous Goods (719/1994) and the IAEA's safety requirements (IAEA 2018). Transports in general are described in 9.10.6. The transport safety of a radioactive substance is ensured primarily with the package, which must be protective and sufficiently strong to allow transport in the manner of conventional goods. The package must keep the adverse effects caused by the radioactive substance minor, both during transport and in a possible accident. The packages used in the transport of radioactive substances are subject to various requirements according to the radioactivity and other properties of the transported substance, for example, considering the impacts that the damaging of the packages could have in the event of a traffic accident, for example. Among other things, the regulations specify the activity limits which, if exceeded, require the package to withstand a fall from a height of nine metres onto a hard surface and a 30-minute incineration test at a temperature of +800 °C. The packages must be marked appropriately, and the consignment notes must describe the content of the packages as precisely as necessary in light of the waste's radioactivity and other properties. The party performing the transport must ensure that the driver is sufficiently qualified, and that the standard safety instructions for accidents, for example, are readily available in the cabin.

The aforementioned measures ensure that the driver and rescue authorities can account for the radioactive substance being transported during a disruption or in an accident. The radiation shielding of the radioactive substances being transported must be dimensioned so that it does not restrict any possible rescue measures (STUK 2012).

9.23 COMBINED IMPACTS WITH OTHER PROJECTS

No new projects are being planned or are currently underway in the power plant area or its vicinity that could contribute to a combined impact in the event that Loviisa power plant's operation is extended or the plant is decommissioned.

However, in the future, the project may have an interface with the potential recovery of thermal energy or the further use of transmission lines, but there is still insufficient information about these possibilities, due to which their review is not included in this EIA Procedure. The energy production alternatives at the power plant, such as the utilisation of thermal energy generated in the processes, may become topical in the future. The decision on the further use of the transmission lines in the event of the power plant's decommissioning will be made by Fingrid Oyj, the owner of the transmission lines.

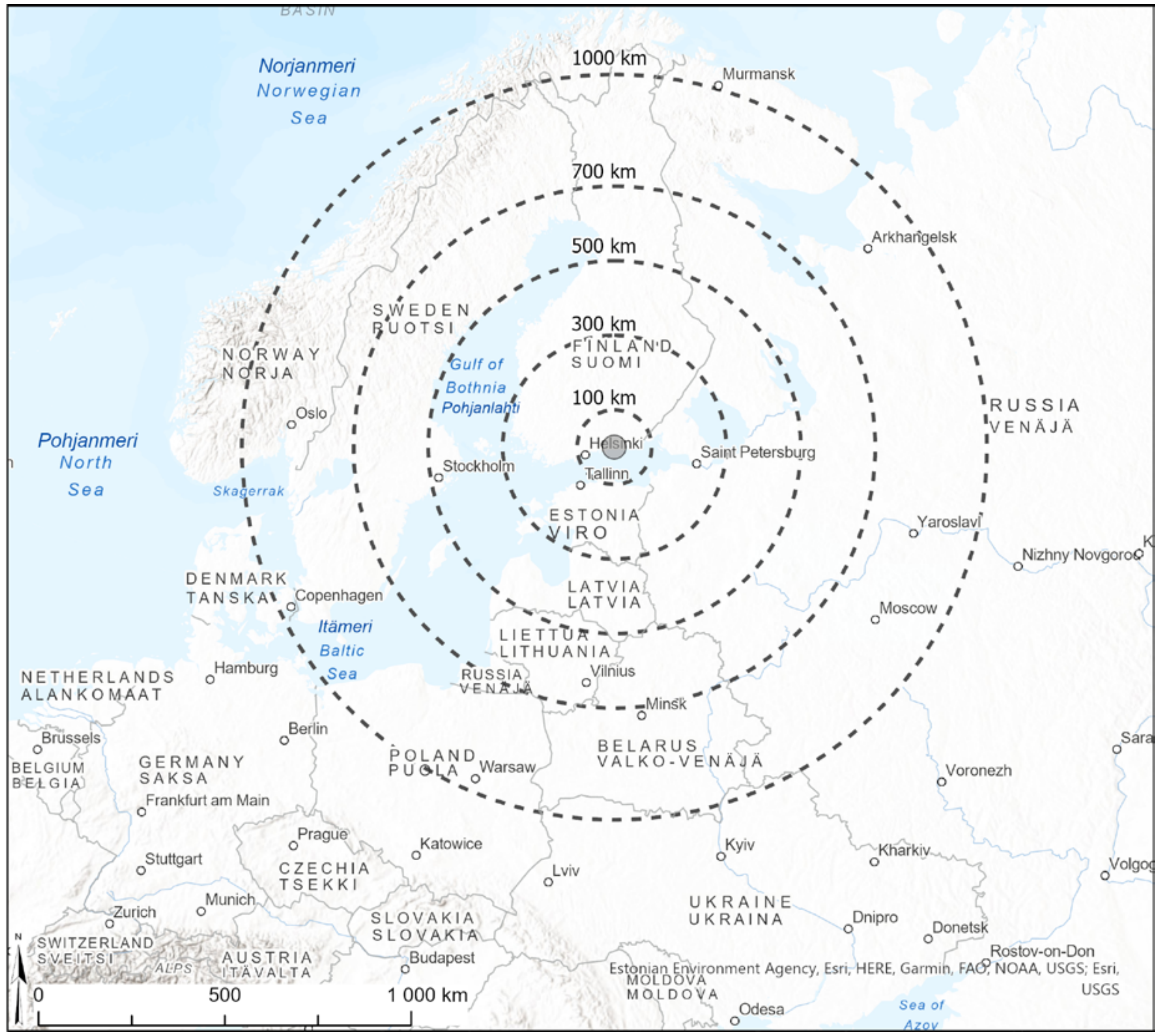

Figure 9-84. Indicative distances from Loviisa nuclear power plant, up to 1,000 km.

9.24 TRANSBOUNDARY IMPACTS

9.24.1 Impacts of a severe reactor accident

The transboundary impacts were assessed by modelling the dispersion of a radioactive emission resulting from a severe reactor accident, the consequential fallout and the population's radiation doses up to a distance of 1,000 kilometres from Loviisa nuclear power plant. The modelling reviewed an extremely improbable severe reactor accident, in which a 100 TBq emission of the radionuclide caesium-137 (Cs-137), corresponding to the limit value provided in section 22 b of the Nuclear Energy Decree (161/1988), and other radionuclides of the reactor inventory to a proportionate degree, are released into the environment. Based on the activity released, the accident would be an INES level 6 accident.

The modelling methods and the impacts of the modelled fictitious reactor accident are described in more detail in Chapter 9.21. The analyses made for Loviisa power plant served as the starting point for the modelling, and the postulations of the modelling ensure the conservative nature of the estimated fallout and radiation doses. The actions aiming to protect the population, for example, and the restrictions on the use of foodstuffs, which would allow the radiation doses to be reduced in both the short and long run, were not accounted for in the modelling.

Figure 9-84 illustrates the distances to other countries up to a distance of 1,000 kilometres from Loviisa nuclear power plant. The distances shown are the counting points employed in the modelling on which the estimate of the fallout and radiation doses caused by a severe reactor accident, including beyond the borders of Finland, is based.

Table 9-80. The estimated magnitudes of the country-specific radiation doses of children and adults resulting from a severe reactor accident. The range of the radiation doses corresponds to the approximate distance to Loviisa power plant from areas within a state's borders.

Country	The approximate distance of the state's areas from Loviisa power plant (maximum, minimum) [km]	Range of one-year-old's lifelong dose [mSv]	Range of 10-year-old's lifelong dose [mSv]	Range of adult's lifelong dose [mSv]
Estonia	300, 100	≤0.16–0.41	≤0.16–0.40	≤0.17–0.43
Russia	1,000, 100	≤0,.03–0.41	≤0.03–0.40	≤0.04–0,.43
Sweden	1,000, 300	0.03–0.16	0.03–0.16	0.04–0.17
Latvia	500, 300	0.09–0.16	0.09–0.16	0.10–0.17
Lithuania	700, 500	≤0.06–0.09	≤0.06–0.09	≤0.06–0.10
Belarus	1,000, 500	≤0.03–0.09	≤0.03–0.09	≤0.04–0.10
Norway, Poland, Ukraine, Denmark	1,000, 700	≤0.03–0.06	≤0.03–0.06	≤0.04–0.06
Germany	1,000	≤0.03	≤0.03	≤0.04

Based on the results of the modelling, a severe reactor accident would not have direct health effects on the residents of the power plant's nearby areas or beyond the borders of Finland. At a distance of five kilometres from the power plant, the radiation dose during two days attributable to the modelled severe reactor accident would be 3.8–4.5 mSv, depending on the group reviewed. Based on the dose criteria set in Finnish legislation and official requirements (Table 9-72), the dose criteria are exceeded in the precautionary action zone extending to a distance of less than five kilometres from the power plant. The need to protect the population is therefore not transboundary.

Table 9-80 shows the country-specific radiation doses resulting from the radioactive emission of a severe reactor accident up to a distance of 1,000 kilometres from Loviisa nuclear power plant. The radiation doses attributable to natural background radiation in the European area are 1.5–6.2 mSv a year (European Commission 2019). Compared to this, the radiation doses attributable to the emission of the severe reactor accident beyond Finland's borders remain small enough to be negligible from a general statistical perspective. Table 9-80 shows the rough level of radiation doses' magnitude in various countries, based on the counting points employed in the modelling and shown in Figure 9-83. The estimated lifelong radiation doses for an adult are a maximum of 0.43 mSv and a minimum of ≤0.04 mSv. Children's estimated lifelong radiation doses are basically of an equivalent size.

The greatest transboundary radiation doses focus on the vicinity of Estonia and Russia, whose borders are, at their shortest, a distance of roughly 100 km from Loviisa nuclear power plant. When the distance grows, the radiation doses decrease. The Swedish coast is around 400 kilometres from Loviisa nuclear power plant. Based on a conservative estimate, the lifelong dose in the area of the state of Sweden is a maximum of 0.16 mSv for children and 0.17 mSv for adults (the doses are shown at the counting point of 300 km). In northern and southern Sweden, at a distance of roughly 1,000 km, the lifelong radiation doses of children and adults are in the region of 0.03–0.04 mSv.

At distances of more than 1,000 km, the radiation doses have not been reviewed in more detail computationally, but based on the results of the modelling and an expert assessment, they are expected to be smaller or no greater than 0.03–0.04 mSv for children and adults in places like eastern/northeast Germany and southern/southwest Poland.

9.24.2 Other impacts

In addition to the impacts of a severe reactor accident, neither extended operation nor decommissioning is expected to have other transboundary impacts.

10. Significance of environmental impacts and comparison of options

10.1 SUMMARY OF THE SIGNIFICANCE OF ENVIRONMENTAL IMPACTS

The operational phases following the current licence periods, which include either extended operation or decommissioning, are compared in Table 10-1. The handling, interim storage and final disposal of radioactive waste generated elsewhere in Finland is also reviewed separately. The review accounted for the significance of the impacts impact-specifically, based on the affected aspects' sensitivity and the magnitude of the change (see Chapter 9.1.4). The table focuses on comparing the operations that would take place in the Loviisa power plant area after the current licence periods and the resulting environmental impacts. The impacts of the operational phase of extended operation were assessed until 2050 at the furthest. In the operational phase of decommissioning, the assessment accounted for the operations falling under its scope (including the expansion of the L/ILW repository, the first and second dismantling phase and the operation of the plant parts to be made independent), all the way up to the closure of the L/ILW repository. The assessment focused on assessing the impacts of normal operation. Incidents and accidents are described in Chapters 9.21, 9.22 and 9.24.

Table 10-1. Summary of the impacts' significance in terms of the different operational phases. The colours indicate the level and nature of the significance (white: no impact; green: positive; red: negative).

Negative impact — Positive impact

Very high	High	Moderate	Minor	No impact	Minor	Moderate	High	Very high

	Extended operation	Decommissioning	Radioactive waste generated elsewhere in Finland
Land use, land use planning and the built environment	Minor negative	Minor positive	No impact
Landscape and cultural environment	Minor negative	Minor positive	No impact
Traffic	Minor negative	Moderate negative	No impact
Noise	No impact	Minor negative	No impact
Vibration	No impact	Minor negative	No impact
Air quality	No impact	Minor negative	No impact
Emissions of radioactive substances and radiation exposure	Minor negative	Minor negative	Minor negative
Use of natural resources	No impact	Minor positive	No impact
Waste and waste handling (Loviisa)	Minor negative	Minor negative	Minor negative
Waste and waste handling (Finland as a whole)	No impact	No impact	Moderate positive
Energy markets and security of supply	High positive	Major negative	No impact
Greenhouse gas emissions and climate change	Moderate positive	Moderate negative	No impact

	Extended operation	Decommissioning	Radioactive waste generated elsewhere in Finland
Regional economy (the Loviisa sub-regional area)	Very high positive	High positive	No impact
Regional economy (Finland as a whole)	Minor positive	Minor positive	No impact
Soil and bedrock	No impact	Minor negative	No impact
Groundwater	No impact	Minor negative	No impact
Surface waters (Hästholmsfjärden, in the Klobbfjärden body of water)	Moderate negative	Moderate positive	No impact
Surface waters (rest of the nearby sea area)	Minor negative	Minor positive	No impact
Surface waters (Lappomträsket lake)	No impact	Minor negative	No impact
Fish fauna	Moderate negative	Moderate positive	No impact
Fishing industry	Minor negative	Minor positive	No impact
Flora, fauna and conservation areas	Minor positive	Minor negative	No impact
People's living conditions and comfort	Minor negative	Moderate negative	Minor negative
Health	No impact	No impact	No impact

10.10.1 Extended operation

10.1.1.1 Positive impacts

In the operational phase of extended operation, the impacts with the greatest positive significance involve the regional economy (Table 10-1). Loviisa power plant's impacts on the regional economy are extremely high at the level of the Loviisa sub-regional area and also visible at the level of the entire country.

The energy markets and security of supply are also expected to be subject to positive impacts of a major significance. The extended operation of Loviisa nuclear power plant would support the security of supply of Finland's energy system and reduce the need to import electricity as its consumption grows in the future.

The impacts on greenhouse gas emissions and climate change are moderate and positive in terms of their significance in the event that operation is extended. The use of nuclear energy in electricity production supports Finland's objective of being carbon neutral by 2035. The operation of the nuclear power plant does not generate greenhouse gas emissions.

The impacts on flora, fauna and conservation areas are expected to be minor and positive, particularly in terms of the avifauna, given that the power plant's cooling water will maintain, in the event of extended operation, Hästholmsfjärden's significance as regionally important wintering grounds for waterfowl.

10.1.1.2 Negative impacts

The thermal effect on surface waters would continue at the current level in the operational phase of extended operation. The potentially warming climate combined with the thermal load of the cooling water could increase the thermal effect in the vicinity of the discharge location. This is expected to have an at most moderate and negative local impact in Hästholmsfjärden. A slight deterioration in the status of the Klobbfjärden body of water resulting from the combined impact of the thermal effect and the point source diffusion of nutrients cannot be ruled out.

The impacts on the icthyofauna are expected to be moderate and negative. The continuation of the power plant's thermal effect maintains a situation in the sea area that favours fish species adapted to warm water, such as pike-perch and cyprinids. The warmer waters may also allow the non-native species round goby to become more abundant in the area, which is nevertheless not expected to have an impact on the area's stock of pike-perch. The impact on fishing is expected to be minor and negative.

The power plant's extended operation is expected to have a negative impact of minor significance on land use, land use planning, the landscape, traffic as well as people's living conditions and comfort. Emissions of radioactive substances, radiation exposure and the accumulation rate of spent nuclear fuel as well as low and intermediate-level waste would remain at their current level, with a minor and negative significance. The radiation dose caused to residents in the surrounding area by Loviisa power plant has been clearly below one per cent of the dose constraint set by the government, which is 0.1 mSv a year.

10.1.2 Decommissioning

10.1.2.1 Positive impacts

Once the power plant is no longer in operation, its very high positive impacts on the regional economy will end (Table 10-1). Regional economy impacts which partly substitute for this will nevertheless be created for different operators and industries during the operational phase of decommissioning. The impacts on the sub-regional area of Loviisa are high and positive in significance. The impacts on the regional economy will come to an end once the decommissioning ends.

The impacts on surface waters will be moderate and positive significance in the Klobbfjärden body of water, when the thermal load in the sea area comes to an end. At this point, the temperature and stratification conditions of the surface water and the length of the growing season will return to the natural state. The positive impacts may appear with a delay. The decommissioning will not weaken the category of the quality factors of the ecological status or prevent the body of water from attaining a good status.

The icthyofauna is expected to be subject to impacts with moderate and positive significance when the thermal load's impact on the marine ecosystem comes to an end. The fishing opportunities in winter will return to a better level, due to which fishing is expected to be impacted in a minor and positive way.

In addition, the decommissioning is expected to have minor and positive impacts on land use, land use planning, the landscape and the use of natural resources.

10.1.2.2 Negative impacts

The power plant's decommissioning will have a major and negative impact on the energy markets and security of supply. The power plant's decommissioning would result in a need to procure electricity free of carbon dioxide emissions for Finland to achieve its carbon neutrality objective. This would require the construction of new electricity production capacity in Finland and the increased electricity imports. The possibilities for exporting electricity from Finland would also reduce.

The impact on greenhouse gas emissions and climate change is expected to be moderate and negative. The decommissioning of Loviisa power plant would lead to a need to increase other emission-free electricity production capacity to an equal degree.

Traffic impacts are expected to be at most moderate and negative. Traffic volumes will temporarily increase during the dismantling phases, possibly impairing the smooth flow of traffic. The increase in traffic volumes could increase road safety risks, particularly on Atomitie and Saaristotie.

The impacts on people's living conditions and comfort are expected to be moderate and negative, given that the power plant's decommissioning will result in a significant and observable change in the operations taking place in the power plant area. The power plant's decommissioning and termination of electricity production may result in changes to the local identity and in both concerns about the effect the change will have on the vitality of the Loviisa region and actual changes. All in all, the various phases of the decommissioning will take several decades.

The decommissioning is also expected to have minor and negative impacts on noise, vibration, air quality and on the flora, fauna and conservation areas.

The impacts on the soil and bedrock as well as groundwater resulting from the expansion of the L/ILW repository will be minor. The dismantling of radioactive parts and waste handling during the decommissioning will result in radiation exposure, which will remain below the dose limits. Following the closure of the L/ILW repository, the final disposal will meet the long-term safety requirements.

10.1.3 Radioactive waste generated elsewhere in Finland

The reception, handling, interim storage and final disposal of any radioactive waste generated elsewhere in Finland within the Loviisa power plant area would not have an impact for the most part (Table 10-1).

Yet the reception of radioactive waste generated elsewhere in Finland is expected to have a moderate and positive impact, at the level of the entire country, on waste and waste handling, given that radioactive waste generated in different sources is provided with a safe and cost-effective final disposal solution at Loviisa power plant. The use of Loviisa power plant's existing functions and facilities applicable to the handling and final disposal of radioactive waste would support the overall social solution and the development of safe waste management at a national level.

The handling of radioactive waste generated elsewhere in Finland will result in minor radiation exposure which will amount, due to the small volume of the waste, to a mere fraction of the already small radiation impact of the operational waste. The waste handling and final disposal will be executed so that their impact on the radiation doses of the personnel and members of the public in the environment will be minor and the long-term safety requirements will be met. Minor negative impacts may still result from the concern raised by the radioactive waste generated elsewhere in Finland.

10.2 COMPARISON OF OPTIONS

10.2.1 Extended operation VE1 and decommissioning VE0/VE0+

When reviewing and comparing the project's options (VE1, VE0 and VE0+), one must take into account that extended operation (VE1) would also include decommissioning to be carried out at a later stage and the reception of radioactive waste generated elsewhere in Finland.

The most significant difference between the options is the time at which the operational phases that would occur in the power plant area would be carried out:

- In extended operation (VE1), the power plant's operation would be extended by roughly 20 years, starting from when the current operating licences expire, in 2027 and 2030. The phases related to decommissioning would be carried out around 2045–2090.
- In the decommissioning option (VE0/VE0+), the power plant's operation will end as the current operating licences expire in 2027 and 2030, in which case preparation for the power plant's decommissioning will be begun in the next few years. The phases related to decommissioning would be carried out around 2025–2065.
- Radioactive waste generated elsewhere in Finland can be received at Loviisa power plant in both the option of extended operation (VE1), until 2090, and in the option of decommissioning (VE0+), until 2065.

The significance of the environmental impacts differs in the different operational phases (Table 10-1). In all options, the final situation will ultimately be the same, in that the current operations in the power plant area will have ended.

In extended operation (VE1), the environmental impacts are in their entirety greater than in the other options, because the option includes the power plant's longer operating time and its decommissioning as well as the reception of radioactive waste generated elsewhere in Finland. The most negative impacts of extended operation will be attributable to the cooling water's thermal load on the sea area. Extended operation would also involve significant positive impacts on the regional economy, energy markets and greenhouse gas emissions.

Once the power plant's operation comes to an end, these impacts will no longer be generated. Positive impacts on the regional economy will still be generated during decommissioning, but they will be smaller than during operation and concern different industries until the impacts end entirely once the decommissioning has concluded. The decommissioning will have its greatest positive impacts on the status of the sea area, given that the thermal load on the sea area attributable to the power plant's cooling water will end. Decommissioning will nevertheless result in negative impacts, particularly in relation to dismantling activities. If the power plant's decommissioning is carried out when the current licence periods end (VE0/VE0+), the positive and negative impacts related to extended operation (VE1) will not materialise.

The reception of radioactive waste generated elsewhere in Finland would not have significant environmental impacts. The power plant has existing competence, technology and spaces for its handling, interim storage and final disposal. The reception of this waste at Loviisa nuclear power plant would be in the interest of the entire society, as radioactive waste generated by various sources would be provided with a safe and cost-effective final disposal solution.

The operations of Fortum Power and Heat Oy's nuclear power plant in Loviisa is highly established and their environmental impacts are well known. The techniques, processes and the means by which to mitigate the impacts are well known. In the option of extended operation, the plant's ageing management is considered; the related measures are presented in Chapter 4.1. These measures serve to ensure the power plant's safe further use. The operations include monitoring the development of the best available technique (BAT), legislation's requirements for the industry and experiences from other nuclear power plants. The decommissioning plan will be updated and specified as the project progresses. The risks of incidents and accidents have been and are prepared for, accounting for any changes in the operating environment or legislation. In option VE1, the risk of accidents would continue for some 20 years longer than in options VE0 and VE0+.

Based on the assessments made, the project's options VE1, VE0 and VE0+ are feasible in terms of their environmental impacts. The means for preventing and mitigating adverse effects presented in the assessment report will allow the potential environmental impacts to be mitigated, provided that they are accounted for in the project's further planning and implementation insofar as possible.

10.2.2 Differences in decommissioning in Options VE1 and VE0/VE0+

In option VE1, decommissioning would be carried out, barring some exceptions (see Chapter 5.9), largely in a manner corresponding to that in option VE0, described in Chapter 5. The environmental impacts of decommissioning, presented in Chapter 9, are largely the same in both options. The most significant difference concerns the time of the decommissioning and the environmental impacts attributable to it. In option VE0, the environmental impacts related to the decommissioning phases would take place around 2025–2065, and in option VE1, around 2045–2090, provided that the power plant's commercial operation is extended by a maximum of 20 years. The most large-scale work related to the decommissioning of the power plant units will take place, for the most part, during the first 10 years following the end of the plant's operation. The differences in the environmental impacts of the decommissioning in options VE1 and VE0 are explained in Table 10-2.

Table 10-2. Differences of decommissioning carried out after extended operation (VE1) compared to the option in which the decommissioning would be carried out after the current licence periods (VE0).

	VE0 decommissioning	VE1 decommissioning	Summary of the differences between the environmental impacts
First dismantling phase of decommissioning	The operation of the power plant units will end in 2027 and 2030. They will be dismantled at different times.	The operation of the power plant units can be ended simultaneously around 2050 or with a shorter delay than in option VE0.	In option VE1, the decommissioning could be carried out simultaneously for both power plant units or with a shorter delay than in option VE0. In this case, the first dismantling phase can be carried out slightly more quickly, which could increase traffic, noise and vibration impacts compared to the overlapping decommissioning in option VE0. Option VE1 would also allow experience of the decommissioning of nuclear power plants from other countries to be accumulated. The techniques used in the decommissioning could also be developed, which could reduce the impacts on the environment.
Low- and intermediate-level operational waste	Low-level waste during operation approximately 2,700 m³ and intermediate-level waste during operation approximately 4,900 m³.	Low-level waste during operation approximately 3,300 m³ and intermediate-level waste during operation approximately 7,300 m³.	In option VE1, the total volume of the low and intermediate-level operational waste to be handled would increase as a result of the 20 additional years of operation. The current expansion plan concerning the L/ILW repository is also expected to be sufficient in option VE1, because the accumulation rate of the operational waste has been successfully reduced, and because the extension of the operating life would not significantly increase the volume of decommissioning waste.
Radioactivity of decommissioning waste	The radioactivity of the decommissioning waste is approximately 22,000 TBq.	The radioactivity of the decommissioning waste is approximately 33,000 TBq.	In option VE1, the amount of radioactivity contained by some types of decommissioning waste will increase as a result of the 20 additional years of operation. Due to the targeted dose constraints set for decommissioning and the effective radiation shielding in the handling of the waste types in question, this would not have a significant impact on the personnel's radiation doses. In both options, the personnel's collective radiation dose accumulated during the decommissioning is estimated to be roughly 10 manSv, while the annual dose of a member of the public will remain below the limit value of 0.01 mSv set for decommissioning. Despite the increase in radioactivity, the long-term safety impacts would remain below the limit values set for them; the radiation dose of the most exposed individuals would remain below 0.1 mSv a year, for example.

	VE0 decommissioning	VE1 decommissioning	Summary of the differences between the environmental impacts
Interim storage of spent nuclear fuel	Total amount approximately 7,700 bundles. Interim storage in the existing storage for spent nuclear fuel within the power plant area.	Total maximum amount approximately 12,800 bundles. Increasing the interim storage capacity within the power plant area.	In option VE1, the total amount of spent nuclear fuel would grow as a result of the 20 additional years of operation, which would increase the need for the power plant area's capacity for the interim storage of spent nuclear fuel. This would be implemented either by placing the fuel more densely within the water pools of the existing storages or by expanding one of the existing interim storages by a maximum of two new pools of water. The possible increase of storage capacity by expanding one of the existing interim storages (KPA2) would nevertheless not increase the volume of decommissioning waste in option VE1. The ways in which the storage capacity would be increased would not have differing impacts on radiation doses. In normal operation, the interim storage and treatment of spent nuclear fuel within the power plant area would not cause abnormal radiation or emission impacts on the environment in either option. Nor would the personnel's legal limit values be exceeded.
Transports of spent nuclear fuel	Roughly 6–8 road transports of spent nuclear fuel a year (one cask at a time) or two transports by sea a year (3–4 casks at a time).	Roughly 6–8 road transports of spent nuclear fuel a year (one cask at a time) or two transports by sea a year (3–4 casks at a time).	In option VE1, the increase in the total volume of operational waste would increase the total number of the transports of nuclear fuel, but at an annual level, the number of transports would be the same in both options. In option VE1, the transports could begin later and be spread over a longer timespan. In both options, the radiation to which humans and the environment would be exposed as a result of the transport of spent nuclear fuel would be very low.
Final disposal of spent nuclear fuel	Eurajoki, Olkiluoto (Posiva Oy). Total amount approximately 7,700 bundles.	Eurajoki, Olkiluoto (Posiva Oy). Total maximum amount approximately 12,800 bundles.	Posiva Oy possesses a decision-in-principle and a building permit for the final disposal of 6,500 tonnes of uranium (tU). The amount of spent nuclear fuel that would be accumulated in option VE1 would be included in this amount and would have no effect on the safety of the final disposal.

10.2.3 Radioactive waste generated elsewhere in Finland in the event of extended operation (VE1) and decommissioning (VE0+)

Options VE1 and VE0+ include the reception of radioactive waste generated elsewhere in Finland at Loviisa nuclear power plant. The difference between the options is the overall schedule of the waste to be received. Radioactive waste originating from elsewhere in Finland can be received at Loviisa power plant during the operation and dismantling of the plant parts to be made independent for as long as the functions needed for the handling and final disposal of waste are available. In extended operation (VE1), this would be possible until around 2090, and in decommissioning (VE0+), until around 2065.

In both options, the maximum volume of the waste to be received would be 2,000 m^3. However, the duration for which the waste is in interim storage could be longer in the option of extended operation (VE1). Even in this case, due to the small volume of the waste, the radiation impact would amount to only a fraction of the already quite small radiation impact of operational waste.

10.3 CONCLUSIONS ON THE MOST SIGNIFICANT ENVIRONMENTAL IMPACTS

All the project's options (VE1, VE0/VE0+) are feasible from the environmental perspective.

10.3.1 Option VE1

The option of extending the operation of Loviisa nuclear power plant (VE1) supports Finland's objective to be carbon neutral by 2035, in line with the Programme of Prime Minister Sanna Marin's Government. Extended operation would create significant economic benefits through the value chain and the multiplier effect, particularly at the local and regional levels. The most significant negative impact up to 2050 in option VE1 is the warming impact that the cooling water discharge side would have on the sea area, the significance of which was deemed at most moderate and negative. The warming impact of the cooling water would be extended by roughly 20 years following the current operating licence period (2027/2030).

In option VE1, the impacts of the cooling water would end in 2050 as a result of the end of commercial operation, as would the major positive impacts on the regional economy resulting from the power plant's extended operation. The major negative impact that the end of the power plant's commercial operation will have on the energy markets and security of supply would also materialise in 2050. During the decommissioning of the power plant, partly substituting regional economy impacts will be generated for different operators and industries, but their impact will remain smaller than the impact of the commercial operation.

In option VE1, the power plant's operation would continue in its current form for the next 20 years, and significant direct impacts on the regional economy would be accumulated during the additional years of operation. In addition, turnover would be generated for other industries in the Loviisa sub-regional area in 2030–2090 (2030–2080 in the regional economy modelling) in excess of EUR 800 million in the form of multiplier effects, while the value added would amount to more than EUR 460 million, and the need for labour to more than 8,900 person-years. Correspondingly, the regional economy's multiplier effects across Finland would amount to more than EUR 5,800 million in turnover, more than EUR 2,900 million in value added and more than 44,200 person-years in need for labour. Significantly more than half the regional economy impacts would concern the period between 2030 and 2050. The regional economy impacts in option VE1 would come to an end around 2090, when the decommissioning concludes.

In option VE1, radioactive waste generated elsewhere in Finland can be received at Loviisa power plant until around 2090. While this will not have a significant environmental impact, the reception of radioactive waste generated elsewhere in Finland will have a moderate positive impact at the level of the entire country. This would benefit the interests of society as a whole by providing a safe and cost-effective final disposal solution for radioactive waste originating from various sources.

10.3.2 Option VE0/VE0+

In the decommissioning option (VE0/VE0+), Loviisa nuclear power plant's commercial operation would end as the current operating licences expire, at which point the at most moderate and negative impact that the cooling water discharge side has by warming the sea area would come to an end, as would the major regional economy impacts during the power plant's operation. The major negative impact on the energy markets and security of supply would furthermore materialise in 2027 and 2030.

In option VE0/VE0+, the power plant's decommissioning, which would take place between the late 2020s and circa 2065, would generate new demand in the form of multiplier effects in the Loviisa sub-regional area to an amount of roughly EUR 300 million and value added in excess of EUR 170 million, and a labour requirement in excess of 3,800 person-years. Correspondingly, the regional economy impacts across Finland would total more than EUR 2,200 million in turnover, more than EUR 1,100 million in value added and more than 17,500 person-years in the labour requirement. In option VE0, the regional economy impacts would be focused on the 2030s.

In option VE0+, radioactive waste generated elsewhere in Finland can be received at Loviisa power plant until around 2065. While this will not have a significant environmental impact, the reception of radioactive waste generated elsewhere in Finland will have a moderate positive impact at the level of the entire country. This would benefit the interests of society as a whole by providing a safe and cost-effective final disposal solution for radioactive waste originating from various sources.

11. Monitoring and observation of impacts

The project owner has various monitoring and observation programmes involving environmental impacts in place. The requirements for the programmes are provided in environmental legislation and in regulations and guidelines issued pursuant to the Nuclear Energy Act. Chapter 11 focuses on regular monitoring and observations.

11.1 OBSERVING RADIOACTIVE EMISSIONS AND RADIATION MONITORING

During extended operation, the operation of the power plant would be similar to its current level, which is why the observation and monitoring is expected to continue in much the same manner as it currently does. The following chapters provide a summary of the monitoring of radioactive emissions and radiation control at Loviisa nuclear power plant in the case of extended operation.

Once the power plant's operations have ended, the environmental radiation monitoring will be carried out in a manner approved by STUK. During and also after the decommissioning, until the end of the interim storage of spent fuel and the closing of the L/ILW repository, the radiation monitoring is likely to continue according to the current materially identical procedures. The impact that a reduction in the emissions of radioactive substances and the change in emission routes and the nuclide breakdown of emissions will have on the monitoring needs will be assessed at a later date. The assessment is likely to lead to some changes to the programme for environmental radiation monitoring.

11.1.1 Emission measurements

The precise emission measurements of radioactive substances ensure that the power plant's combined emissions into the air and discharges into the water do not exceed the emission limits confirmed by STUK, and that the environmental radiation doses remain below the limits specified in section 22 b and section 22 d of the Nuclear Energy Decree. The results are reported to STUK at regular intervals. A nuclear power plant's emissions are monitored specific to power plant units and emission routes and with continuous measurement instruments and by sampling. Emissions into air take place in a controlled manner through the ventilation stack and possibly, to a minor extent, through the turbine building's ventilation. Activity into the sea is discharged in a controlled manner from the inspection tank. If the water is not clean enough, it is returned to treatment. The auxiliary facilities, such as the final disposal facility for operational waste, the storage and the solidification plant for liquid waste are covered by the power plant's emission monitoring.

11.1.2 Environmental radiation monitoring

Fortum monitors the environment of Loviisa power plant in accordance with the environmental radiation control programme. The status of radioactive substances in the surroundings of Loviisa power plant has been monitored for a long time. The baseline studies began as early as 1966, before the construction of the power plant began. The environmental radiation control is based on sampling, the identification of radionuclides in the samples and the determination of their levels. The environmental radiation control aims to ensure that the population's radiation exposure attributable to a nuclear power plant is kept as low as reasonably achievable, and that the limit values specified in regulations are not exceeded.

The environmental radiation control programme of Loviisa focuses on measurements of external radiation, the routes through which people are exposed to radioactivity and the indicator organisms that enrich radioactive substances, such as fern. The current monitoring in the environment of Loviisa power plant in line with the radiation control programme is shown in Figure 11-1.

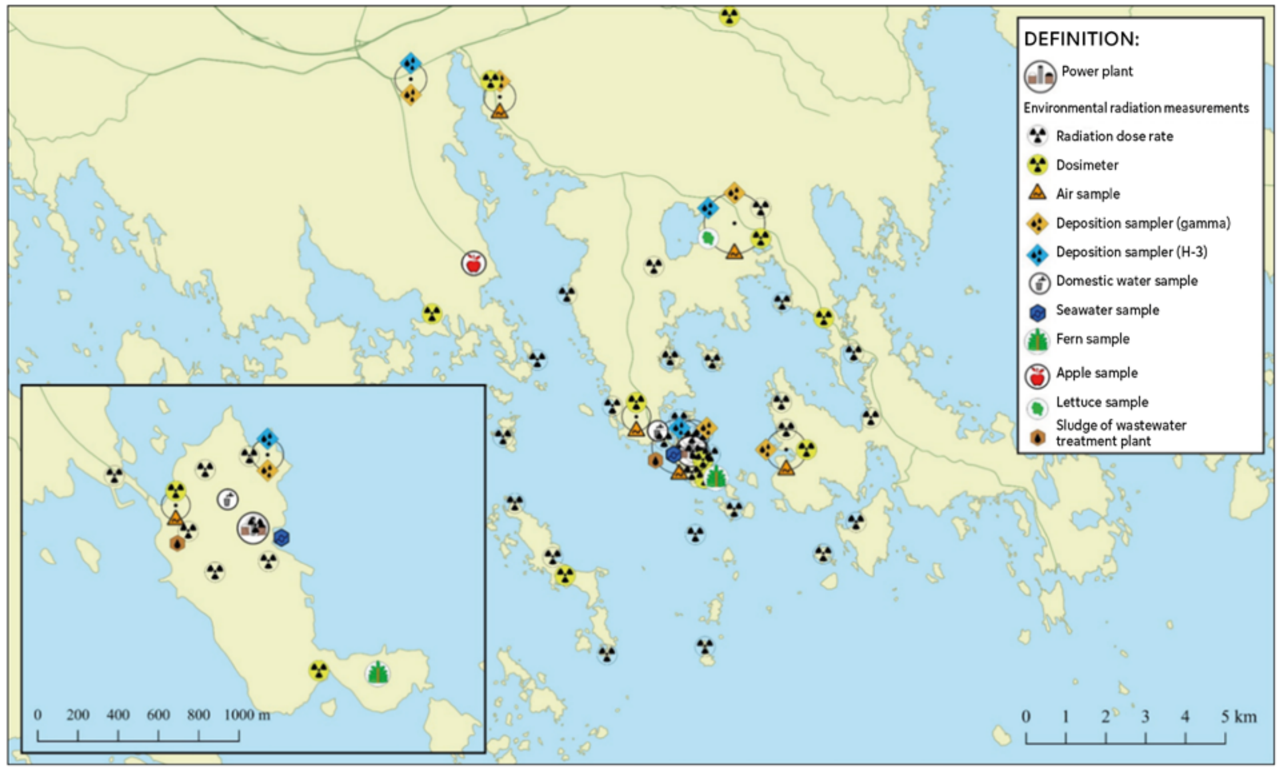

Figure 11-1. The measurement and sampling sites of Loviisa power plant's environmental radiation control programme. If there is more than one monitoring target in a particular location, the location is marked with a black dot, and the monitoring targets are represented with an arc drawn around the dot.

STUK also carries out its own independent monitoring in the environment of Loviisa power plant. STUK regularly takes samples from the air in connection with plants' annual outages and collects samples from the soil and sea environment within the framework of STUK's environmental radiation monitoring programme. The sampling focuses primarily on sample types related to food chains, such as milk, agricultural products, domestic waters, fish, game and other foodstuffs (STUK 2020c; STUK 2021c and STUK 2021d).

External radiation is measured continuously. These measurements yield real-time information on changes in the radiation level in the environment. To measure external radiation, there is a total 21 radiation dose ratemeters at distances of two and five kilometres from, and seven dose ratemeters within, the power plant area (Figure 11-1). The ratemeters are part of the national radiation metering network, and thereby also serve regional monitoring. In addition to the power plant, the results of the measurements are available to the Ministry of the Interior and the Radiation and Nuclear Safety Authority in real time. Ten dosemeter stations have also been placed at 1–10-kilometre distances from the power plant, in the most important directions.

The methods employed in the environmental radiation monitoring detect radioactive substances inherent in nature and even small emissions originating from Finland and beyond, which indicates the system's good detection sensitivity. Extended operation would not result in any material changes to the power plant's operations in relation to radiation monitoring.

11.1.3 Meteorological measurements

The dispersion of radioactive substances released into the air during the power plant's normal operation or a possible accident is assessed with the aid of meteorological measurements. The meteorological data is provided by Loviisa power plant's weather observation system, which includes two measurement locations: the main observation point, located in the power plant's vicinity, and the additional observation point, which is located at a distance of around 12 km from the power plant. Both measurement locations are equipped with a weather mast and a measuring station on the ground. The observations of the weather observation system are available in real time at the power plant, the Finnish Meteorological Institute and STUK. The measured variables include the wind speed and direction, atmospheric pressure, relative humidity, the time and volume of precipitation as well as temperature.

11.1.4 Radiation dose estimates

During the power plant's operation, the population's radiation exposure in the environment is estimated annually on the basis of the meteorological measurements and emissions. The results are reported to STUK. In a possible accident, the radiation doses of people in the environment are estimated in real time on the basis of the meteorological measurements and emission data. The estimates serve the rescue and emergency services, and they are compared to the results provided by the dose ratemeters. The radiation dose calculation software used for the estimates are described in Loviisa power plant's preparedness instructions, approved by STUK.

11.2 MONITORING OF COOLING WATER AND WASTEWATERS

The volume and quality of the cooling water and wastewaters conducted from the power plant to the sea is monitored in a manner approved by the Uusimaa ELY Centre. The volume of cooling water is monitored on the basis of the seawater pumps' operating times and output. The temperature of the cooling water taken from and conducted to the sea is measured continuously. The measurements are used to calculate the rise in the cooling water temperature in the condensers, the flow of the cooling water and the amount of heat conducted into the waterway. The monitoring of the wastewater volume is based on the measurements of the wastewater treatment plant. The wastewater monitoring follows the amounts of nutrients and solids as well as oxygen-consuming substances conducted into the waterway.

During decommissioning, the monitoring of the cooling water and wastewaters will be carried out in a manner approves by the Uusimaa ELY Centre.

11.3 IMPACT MONITORING

The impact monitoring conducted in Loviisa power plant's nearby sea area includes the monitoring of the quality (physico-chemical quality) of the seawater as well as biological and fishery economics monitoring. The biological monitoring covers the phytoplankton, benthic fauna and aquatic vegetation monitoring carried out every three years.

The temperature of the seawater at different sampling depths is measured in connection with the monitoring of the seawater's quality and biological monitoring. In addition to the sea area's temperature monitoring, the forming of the ice cover is monitored in the sea area surrounding Hästholmen approximately once a month, starting from the beginning of December, until the ice cover in the surrounding sea area has melted completely.

Loviisa power plant's monitoring related to fishery economics is composed of the catch accounting and fishing inquiries of commercial fishermen and the fishing inquiries of leisure-time fishermen. In addition, test fishing is conducted in the power plant's nearby sea area during scheduled years.

During decommissioning, waterway monitoring will be carried out in a manner approved by the Uusimaa ELY Centre.

11.4 MONITORING OF FLUE GAS EMISSIONS

The emissions of the emergency diesel generators and the diesel-powered emergency power plant are calculated according to the consumption of light fuel oil, the fuel's quality data and emission factors. The emissions are reported annually to the environmental protection authorities. Given that the emergency diesel generators and diesel-powered emergency power plant serve as the power plant's emergency power supply, their use is limited to test runs and is therefore extremely minor.

The monitoring of carbon dioxide emissions subject to the Emissions Trading Act is carried out according to the conditions of the approved emissions permit. The emissions report verified by an external party and required by the emissions permit is delivered to the Energy Authority every year.

11.5 NOISE MONITORING

Noise measurements in line with the conditions of the environmental permit are conducted in the power plant's environment. These measurements ensure that the noise generated by the power plant complies with the guideline values set by the authorities. The measurements are performed by an external expert in accordance with the relevant instructions issued by the Ministry of the Environment in January 1995 ("Ympäristömelun mittaaminen"). The plans concerning the measurements are submitted to the Uusimaa ELY Centre for approval no later than three months prior to the measurements.

The sound power level (LWA) of fixed sound sources, which have a significant impact on the environment's noise level, is measured by an external expert whenever a piece of equipment is renewed.

During decommissioning, noise measurements will be carried out in a manner approved by the Uusimaa ELY Centre.

11.6 WASTE RECORDS

The formation, volumes, waste types and locations of radioactive and conventional waste are monitored at the power plant both continuously and as larger-scale summaries. The records on radioactive waste detail the activities as well as waste volumes and types of both individual waste packages and storage and final disposal facilities. The records on conventional waste detail the waste types and volumes of the waste batches as well as the recipient and handling method of the waste.

A summary of the radioactive waste is drawn up each year and delivered to STUK for reference. The annual summary of conventional waste is delivered to the ELY Centre.

11.7 MONITORING IMPACTS ON HUMANS

Impacts in people can be monitored by organising discussion events, conducting resident surveys or interviews, and collecting information through electronic feedback channels, for example. Especially during decommissioning, residents and other stakeholders can be shown a contact person from the power plant whom they can contact if they detect any disturbing effects.

The project owner regularly publishes topical information on the plant's operations on its website, and two or three times a year in a supplement delivered to residents of the nearby area in the local paper.

11.8 L/ILW'S REPOSITORY'S MONITORING PROGRAMME

The L/ILW repository is subject to the regular monitoring of rock mechanics, hydrology and groundwater chemistry. These are described in Chapters 9.14 and 9.15. The monitoring programmes were reviewed in the L/ILW repository's periodic safety review drawn up in 2020, in which they were deemed sufficiently extensive and comprehensive. The scope and comprehensiveness of the monitoring programmes is reviewed when necessary, such as before the excavation related to the L/ILW repository's expansion begins.

12. Project's licence and permit process and project's relation to plans and programmes

Once the environmental impact assessment procedure has concluded, the project progresses to the licence and permit phases. The coordinating authority's reasoned conclusion on the EIA Report will be appended to the various licence and permit applications when the applications are submitted. The following provides a general description of the permits, licences and decisions the project's different options may require. It also outlines the project's relation to various plans and programmes pertaining to the use of natural resources and environmental protection.

12.1 DECISIONS AND LICENCES PURSUANT TO THE NUCLEAR ENERGY ACT

The power plant units of Loviisa nuclear power plant have operating licences in accordance with the Nuclear Energy Act which are valid until the end of 2027 and 2030 respectively. The operating licence of the final disposal facility for low and intermediate-level waste (the L/ILW repository) is valid until the end of 2055.

New operating licences must be applied for in terms of the power plant units should the power plant's operation be extended. The decommissioning of the power plant units requires the application of a decommissioning licence. The operating licence and decommissioning licence are issued by the Government.

In the case of both extending the operation and the decommissioning of the power plant, the L/ILW repository is operated longer than the validity of the current operating licence, which is why a new operating licence must be sought for the L/ILW repository. In addition, the current operating licence of the L/ILW repository does not cover all planned purposes of use, and they can be taken into account in the potential licence application. These uses are the final disposal of radioactive waste generated elsewhere in Finland, decommissioning waste and waste containing uranium. The waste containing uranium does not refer to spent nuclear fuel, but rather a measuring instrument containing uranium, for example.

The plant parts to be made independent require a separate operating licence once the operating licence of the power plant units expires, and they will begin to be dismantled as the decommissioning licence takes effect.

The project's implementation may also require other licences in accordance with the Nuclear Energy Act.

12.1.1 Operating licence

The licence to operate a nuclear facility may be issued provided that the prerequisites listed in section 20 of the Nuclear Energy Act are met. The prerequisites include the following:

- the nuclear facility and its operation meet the safety requirements laid down in the Nuclear Energy Act, and appropriate account has been taken for the safety of workers and the population;
- the methods available to the applicant for arranging nuclear waste management, including disposal of nuclear waste and decommissioning of the facility, are sufficient and appropriate;
- the applicant has sufficient expertise available, and especially the competence of the operating staff and the operating organisation of the nuclear facility are appropriate;
- the applicant is considered to have the financial and other prerequisites to engage in operations safely and in accordance with Finland's international contractual obligations.

Operation of the nuclear facility may not be started on the basis of the licence granted for it until the Radiation and Nuclear Safety Authority has ascertained that the nuclear facility meets the safety requirements set, that the security and emergency arrangements are sufficient, that the control necessary to prevent the proliferation of nuclear weapons has been arranged appropriately, and that the nuclear facility operator has arranged, in the manner provided, indemnification regarding liability in the event of nuclear damage. In addition, it is required that the Ministry of Economic Affairs and Employment has ascertained that provision for the cost of nuclear waste management has been arranged in accordance with the provisions of the Act.

12.1.2 Decommissioning licence

When the operation of a nuclear facility has been terminated, the holder of the operating licence is obligated to undertake measures to decommission the nuclear facility in accordance with the plan and the requirements set for decommissioning referred to in section 7g of the Nuclear Energy Act. For this purpose, the holder must apply for a decommissioning licence which will enter into force after the operating licence. The licence must be applied for well in advance so that the authorities have adequate time to assess the application before the termination of the operating licence of the nuclear facility.

A licence for the decommissioning of a nuclear facility may be granted if the prerequisites listed in section 20 a of the Nuclear Energy Act are met. The prerequisites include the following:

- the nuclear facility and its decommissioning meet the requirements related to safety in accordance with the Nuclear Energy Act, and the safety of the employees and the population, as well as environmental protection, have been duly taken into account;
- the methods available to the applicant for the decommissioning of the nuclear facility as well as other nuclear waste management are adequate and appropriate;
- the applicant has the necessary expertise and especially the competence of the nuclear facility personnel and the organisation of the nuclear facility available, and they are appropriate and suitable for decommissioning;

- the applicant has the financial and other necessary requirements to carry out the decommissioning safely and in accordance with Finland's international contractual obligations.

The decommissioning of a nuclear facility may not be started before the granting of the related licence unless otherwise provided in the other licences of the licence holder. The decommissioning of a nuclear facility may not be started on the basis of the licence granted for it until the Radiation and Nuclear Safety Authority has ascertained that the nuclear facility meets the safety requirements for decommissioning, that the security and emergency arrangements are sufficient, that the control necessary to prevent the proliferation of nuclear weapons has been arranged appropriately, and that the nuclear facility operator has arranged, in accordance with the related provisions, indemnification regarding liability in the event of nuclear damage. In addition, it is required that the Ministry of Economic Affairs and Employment has ascertained that provision for the cost of nuclear waste management has been arranged in accordance with the provisions of the Act.

12.1.3. Other licences in accordance with the Nuclear Energy Act

In addition to the operating licence and decommissioning licence, the project options may require other licences in accordance with the Nuclear Energy Act. Section 21 of the Nuclear Energy Act provides the prerequisites for granting a licence for other use of nuclear energy, such as the possession, manufacturing, production, transfer, handling, use, storage, transport and import of nuclear substances and nuclear waste, as well as final disposal on a smaller scale than extensive final disposal (the operating licence). In accordance with section 16 subsection 2 of the Nuclear Energy Act, STUK grants a licence for the aforementioned operations by application.

A licence can be granted for other use of nuclear energy when so required by the operation if the prerequisites set in section 21 of the Nuclear Energy Act are met: The prerequisites include the following:

- the use of nuclear energy meets the safety requirements laid down in the Nuclear Energy Act, and appropriate account has been taken of the safety of the workers and the population, and environmental protection;
- the applicant has possession of the site needed for the use of nuclear energy;
- nuclear waste management has been arranged appropriately, and provision for the cost of nuclear waste management has been made in accordance with the provisions of the Nuclear Energy Act;
- the applicant's arrangements for the implementation of control by the Radiation and Nuclear Safety Authority as referred to in the Nuclear Energy Act are sufficient;
- the applicant has sufficient expertise available, and the operating organisation and competence of the operating staff are appropriate;
- the applicant is considered to have the financial and other prerequisites to engage in operations safely and in accordance with Finland's international contractual obligations;
- the authorisations required under the Council Directive on the supervision and control of shipments of radioactive waste and spent fuel (2006/117/Euratom) have been obtained from foreign states, and the said
- provisions can also be observed in other respects;
- the use of nuclear energy otherwise meets the principles laid down in Sections 5–7 of the Nuclear Energy Act and does not conflict with the obligations under the Euratom Treaty.

The use of nuclear energy may not be initiated on the basis of a granted licence until the Radiation and Nuclear Safety Authority has ascertained, when required by the operations, that the use of nuclear energy is in accordance with the safety requirements set, that the security and emergency arrangements are sufficient, that the control necessary to prevent the proliferation of nuclear weapons has been arranged appropriately, and that indemnification regarding liability in the event of nuclear damage in connection with the operations has been arranged in compliance with the relevant provisions.

12.2 LICENCES PURSUANT TO THE RADIATION ACT

Loviisa power plant's radiation practice other than the operation of nuclear energy requires a safety licence pursuant to the Radiation Act. Fortum Power and Heat Oy is the undertaking in the radiation practice pursuant to the safety licence in terms of the use of unsealed sources, X-ray equipment and sealed sources in industry and research.

Unsealed sources used for the performance of radiochemical analyses, for instance, are handled in Loviisa power plant's laboratory. X-ray equipment, such as XRF analysers, are used in materials inspections. Sealed sources are used in the power plant units to check the calibrations of measuring instruments and operational tests, among other things.

The safety licence for radiation practice is valid until further notice. The safety licence is a document that must be kept up-to-date in terms of any amendments, such as the addition of any new radiation sources or their removal from use. The supervisory authority is STUK.

The radiation practice in industry and research will be continued to an extent deemed necessary in the event of both the extended operation of the power plant or its decommissioning. The safety licence will be amended if necessary.

12.3 RADIOACTIVE WASTE GENERATED ELSEWHERE IN FINLAND

Small amounts of radioactive waste originating from some place other than Loviisa power plant may be stored under the L/ILW repository's current operating licence. When a new operating licence for the L/ILW repository is applied for, the amount of the waste generated elsewhere in Finland will be specified. An account on the quality and maximum quantity of nuclear materials or nuclear waste manufactured, produced, handled, used or stored in the nuclear facility, including radioactive waste generated elsewhere in Finland, will be included in the power plant's and L/ILW repository's applications for a licence.

VTT's FiR 1 research reactor has an operating licence pursuant to the Nuclear Energy Act which will remain valid until the end of 2023. VTT Technical Research Centre of Finland Ltd has submitted an application addressed to the government with which VTT applied for a licence referred to in section 20 of the Nuclear Energy Act for decommissioning the FiR 1 research reactor in such a way that the amount of radioactive substances remaining in facility's area, located in Otaniemi, Espoo, meets the requirements issued by virtue of the Nuclear Energy Act. The applied for licence would be valid until the end of 2038. As part of the licence process, VTT carried out an environmental impact assessment on the decommissioning of the FiR 1 research reactor. VTT has a safety licence pursuant to the Radiation Act for the decommissioning of the Otakaari 3 research laboratory.

VTT has made an agreement with Fortum Power and Heat Oy on the decommissioning services and nuclear waste management of the FiR 1 research reactor and the Otakaari 3 research laboratory. VTT has noted to the ministry that the services under the agreement between Fortum and VTT meet the VTT's nuclear waste management needs. As the licence holder of a nuclear power plant, Fortum has the expertise and operating system required to fulfil the contractual obligations. The same agreement also applies to the management of the OK3 laboratory's radioactive decommissioning waste in its entirety. The agreement's implementation is conditional upon Fortum being able to secure the permits and licences required for handling the waste at Loviisa power plant and placing it in final disposal in the L/ILW repository.

12.4 LICENCES REQUIRED FOR THE TRANSPORT OF RADIOACTIVE SUBSTANCES

Transports of radioactive substances and waste are subject to the Act on the Transport of Dangerous Goods (719/1994), the Radiation Act (859/2018) and, in terms of nuclear materials and waste, the Nuclear Energy Act (990/1987), and the regulation issued pursuant to the above.

The transport of nuclear fuel requires a transport licence pursuant to the Nuclear Energy Act. The prerequisites for such a licence include a transport plan, safety plan and, in some cases, a preparedness plan. The permit authority in transport licence matters is STUK. In the event of extended operation, fresh fuel will continue to arrive to the power plant and in terms of this, the licence process will remain the same as it currently is. Posiva is responsible for the transports of spent fuel for encapsulation and final disposal in Eurajoki, Olkiluoto. The transports require a transport licence pursuant to the Nuclear Energy Act.

The radioactive waste generated elsewhere in Finland which may be handled at Loviisa power plant or be deposited in final disposal in Loviisa's L/ILW repository is either nuclear waste as referred to in the Nuclear Energy Act or radioactive waste as referred to in the Radiation Act, depending on whether the practice in which it was generated is subject to the Nuclear Energy Act or the Radiation Act. The decommissioning waste of VTT's research reactor is an example of nuclear waste pursuant to the Nuclear Energy Act, whereas the waste of VTT's materials research lab is primarily radioactive waste as referred to in the Radiation Act, as is any waste generated elsewhere in industry, research facilities and in healthcare.

While the transport of nuclear waste is basically subject to a transport licence, the Nuclear Energy Decree states that the transport licence is not required in the event that the maximum activity of nuclear waste not containing nuclear material and to be transported at one time is 1 TBq. Preliminary estimates suggest that the decommissioning waste of VTT's research reactor will need a maximum of two transports requiring a licence. Other transports are reported to STUK.

A safety licence pursuant to the Radiation Act is not required for the transport of radioactive substances, with the exception of the transport of high-activity sealed sources by road or by rail. Even the transports which do not require a safety licence must nevertheless be reported to STUK. The activity of most of the future transports of radioactive waste generated elsewhere in Finland is likely to be of the kind which does not require a safety licence. The transport are nevertheless reviewed case-specifically, and the procedure is determined according to the radioactivity of the substance to be transported.

To summarise, one can conclude that all transports of nuclear waste or radioactive substances are subject either to a notification to STUK or the application of a transport or safety licence in the manner required by the valid law. Regardless of the notification or permit procedure, the transports are subject to the aforementioned acts and any other regulations issued by virtue of them, such regulations including orders pertaining to transport packages, their marking, the equipment of the means of transport, the driver's qualifications and transport documents.

12.5 LAND USE PLANNING

The valid local detailed plan makes it possible to carry out modification work in the power plant area, construct additional structures and buildings, and decommission the power plant. Needs to change land use plans may become topical after decommissioning if existing limitations to the use of land in the power plant area and its surroundings caused by the power plant's operation are lifted. The local detailed plan contains information on the L/ILW repository's location. In respect of this, it must be ensured that the plan notations are also retained in the future. Any changes to the local detailed plan are approved by the Loviisa town council. Information about the restrictions pertaining to the area's further use can also be included in the land use registers, if necessary.

12.6 PERMITS IN ACCORDANCE WITH TH LAND USE AND BUILDING ACT

In accordance with the Land Use and Building Act (132/1999), the construction of power plant buildings related to the required modification work, the necessary infrastructure and facilities requires a building permit. In Loviisa, the town's building and environmental board is responsible for the duties and decision- making of the building inspection authorities.

In areas covered by a local detailed plan, a building permit is granted under the following conditions:

- the building project is in keeping with the valid local detailed plan;
- construction meets the requirements laid down in the Act and other requirements prescribed in or under the Act;
- the building is appropriate for the location concerned;
- a serviceable access road to the building site exists or can be arranged;
- water supply and wastewater management can be organised satisfactorily and without causing environmental harm; and
- the building will not be located or constructed in a way that causes unwarranted harm to neighbours or hinders appropriate building on a neighbouring property.

Separate action permits may be required for smaller structures, such as containers of temporary warehouses if they are not included in the building permit application. The dismantling permits required by the Land Use and Building Act are applied for in connection to the decommissioning and the dismantling of buildings. The necessary notifications are also filed at this point.

12.7 ENVIRONMENTAL AND WATER PERMIT

The operation of a nuclear power plant requires an environmental permit in accordance with the Environmental Protection Act (527/2014) (annex 1 Activities subject to a permit, Table 2 Other installations, section 3 Energy production, b) nuclear power plant).

Loviisa power plant has an environmental permit and a water permit granted by the environmental permit agency of Western Finland on 8 April 2009 (decision numbers 23/2009/2 and 24/2009/2). The permit became legally valid by the decision issued by the Supreme Administrative Court on 19 June 2012. The permit applies to the operation of the power plant, cooling water intake, emissions of the power plant and monitoring. The power plant has a service water abstraction permit in accordance with the Water Act, granted by the Water Rights Court by its decision on 27 December 1976, for the abstraction of raw water from Lappomträsket lake. The said permit applies to leading water from the Lappomträsket lake and the regulation of the water level.

A permit is required for any change in an activity that increases emissions or their impact, or for any other substantial change in an activity requiring an environmental permit. However, no permit is required if the change does not increase the environmental impact or risks, and if the change in the activity does not require the permit to be reviewed (section 29 of the Environmental Protection Act). The need for changes to the existing environmental and water permits will be assessed in cooperation with the authorities if an operating licence for continuing operations after 2027/2030 is applied for (and issued). According to the current assessment, the impacts of Loviisa nuclear power plant will remain much the same as they are today.

The operator must inform the environmental protection authority without delay of the termination of the activity. The authority issuing the environmental permit may issue orders on the termination of the activity, if necessary.

The issue of a new environmental permit requires that the operations, considering the permit provisions to be set and the location of the activity, do not alone or together with other functions:

- cause harm to health;
- cause other
    - harm to the environment and its functions;
    - prevent or materially hinder the use of natural resources;
    - cause a loss of general amenity of the environment or of special cultural values;
    - reduce the suitability of the environment for general recreational use;
    - cause damage or harm to property or impairment of use;
    - constitute a comparable violation of the public or private interest;
- result in the violation of the prohibition of soil or groundwater contamination;
- cause the deterioration of special natural conditions, present a risk to the water supply or affect other potential uses important to the public interest within the area impacted by the activity;
- create the unreasonable burden referred to in the Adjoining Properties Act.

Permit provisions that prevent and limit emissions are set for the operations in the permit by considering the nature of the operations and local environmental conditions.

The water abstraction and discharge structures require a permit pursuant to the Water Act (587/2011). If water abstraction from Lappomträsket lake is discontinued, the removal of the structures made for the abstraction requires that a permit pursuant to the Water Act be applied for.

Should the undertaking apply for a new water permit, the application should include a project description and a report on the impact of the project in accordance with the Government Decree on the management of water resources (1560/2011). A permit for a water resources management project will be granted if:

- the project does not significantly violate public or private interests;
- the benefit gained from the project to public or private interests is considerable compared with the losses incurred for public or private interests.

The water resources management project may not jeopardise public health or safety, cause considerable detrimental changes in the natural state of the environment or the aquatic environment and its functions, or cause considerable deterioration in the local living or economic conditions.

The environmental permit authority is either the Southern Finland Regional State Administrative Agency or the environmental protection authority of the town of Loviisa, depending on the operation subject to the permit application. In water permit matters, the permit authority is the Southern Finland Regional State Administrative Agency. The environmental permit application and the permit application in accordance with the Water Act concerning the same operation shall be processed jointly and decided by a single decision unless this is considered unnecessary for a specific reason.

The ELY Centre must generally be notified of the groundwater pumped out of the repository, if the minimum water volume is 100 m^3 a day. If the volume of water pumped is 250 m^3 a day or more, the activity is subject to a permit in accordance with the Water Act. If a concrete crushing plant or a crushing plant for the quarry material with a minimum total operating time of 50 days is established in the area for the decommissioning and dismantling activities, the activity requires an environmental permit.

12.8 PERMITS AND DOCUMENTS IN ACCORDANCE WITH THE CHEMICALS ACT

Facilities engaged in extensive industrial handling and storage of chemicals require a permit granted by the Finnish Safety and Chemicals Agency (Tukes). The extent of the industrial handling and storage of chemicals is determined based on the quantity and dangers of the chemicals stored in the facility. The permit sets conditions for the activities, and a commissioning inspection is conducted at the facility after the permit is granted. Fortum's Loviisa power plant has a valid permit for the extensive industrial handling and storage of chemicals, and the power plant is an institution subject to a safety assessment regulated by Tukes.

The Act on the Safe Handling of Dangerous Chemicals and Explosives (390/2005, the "Act on Chemical Safety") excludes radioactive substances and products containing radioactive substances from its area of application. Changes in the handling, storage and quantities of radioactive materials do not therefore as a rule result in changes to the chemicals permit.

However, changes in the operation may, in accordance with the Act on Chemical Safety, invoke an obligation to apply in writing for a permit for a production facility change if the planned change is an expansion comparable to the establishment of a production facility or another essential change. Changes categorised as essential include a significant increase in the quantity of hazardous chemicals, a significant change in the hazardous chemicals being handled or stored, or in their properties or state, a significant change in the manufacturing or handling method, or another change that may significantly affect the accident risk. The notification of the change in the operation submitted to Tukes should include the essential information on the change and a report on the safety impact of the change. The institutions subject to a safety assessment should also update the essential parts of the safety assessment.

The Tukes regulatory authority should be notified of the decommissioning of Loviisa power plant in accordance with the Act on Chemical Safety. The notification concerning the decommissioning of the operation must include a plan for how the structures and areas of the production facility and its parts to be decommissioned are cleaned if required after the operations are discontinued, and the measures that are taken to ensure that hazardous chemicals and explosives do not cause personal injuries or damage to the environment or property.

12.9 OTHER PERMITS AND PLANS

The Government Decree on areas restricted for aviation (VNa 930/2014) has defined the surroundings of the power plant as a no-fly zone. The no-fly zone covers the power plant surroundings within a four-kilometre radius and at an altitude of up to 2,000 metres. On a general level, the Aviation Act (864/2014) requires a permit for air navigation obstacles to set up a facility, building, structure or sign of a certain height. The party responsible for maintaining the air navigation obstacle must notify the Finnish Transport and Communications Agency Traficom or an instance designated by it of any changes concerning the obstacle (such as the removal of the air navigation obstacle) and its contact information.

Conventional dismantling requires a dismantling plan. In this connection, a contractor who has a work permit for asbestos demolition granted by the permit authority carries out the required survey concerning asbestos and harmful substances. The demolition method, protection and reuse possibilities of waste are determined based on the survey.

If there is reason to expect the noise or vibration to be particularly disturbing, the undertaking must notify the local environmental protection authority of a measure causing temporary noise or vibration (section 118 of the Environmental Protection Act).