Planning for a Safer Future in Northwest Russia: Clean-up of the Cold War Legacy

By Jim Honeywill and Taras Pryymak

VT Nuclear Services Ltd

Introduction

At the end of the cold war in the mid-1990s, a large scale withdrawal from service of nuclear submarines, ships and their associated coastal infrastructure commenced in Northwest Russia. However, a period of deep economic recession in Russia led to a delay in the decommissioning of the various vessels and support facilities. As a result, the environmental threat to the region began to increase as the technical condition of vessels and support facilities continued to deteriorate.

It became clear that in order to accelerate the reduction of radioactive and other environmental hazards in the region, international cooperation and funding was necessary. The decision of the Group 8 Leaders at the Kananaskis Summit (2002) to establish the Global Partnership Program was a real break through in this respect. One of the major initiatives undertaken as a result of this agreement was the formation of the Northern Dimension Environmental Partnership (NDEP) Support Fund, administered by the European Bank for Reconstruction and Development (EBRD). Of high priority under the NDEP was the development of a Strategic Master Plan (SMP) to accelerate the reduction in the environmental hazards associated with the Cold War nuclear legacy in Northwest Russia.

The SMP was developed as a living document [1] by an International Consultant (IC) comprising VT Nuclear Services Ltd (formerly British Nuclear Group Project Services Ltd) and Fluor Ltd in partnership with various Russian Institutes. This collaboration included developing integrated plans for nuclear decommissioning, environmental rehabilitation and safety and security improvements and preparing for strategic decisions on how to tackle bottlenecks for existing and future projects.

This was the first time that a nuclear partnership between the Russian Federation and the West had been undertaken on such a scale in order to develop a plan that addresses not only the elimination of the near-term hazards but also sets the long-term goals for environmental rehabilitation in the whole region. In the process, unlike prior efforts, all the sites at which obsolete vessels and facilities were located were considered as a single system, thus ensuring a consistent approach to common problems and avoiding unnecessary duplication. The SMP completed in September 2007 specifies the regional and individual site strategies required to achieve this goal.

Fig.1 The scope of the SMP:
Retired nuclear submarines and vessels: the Floating Maintenance Base *Lepse*, (A) and a Floating Radiation Control Station, (B); obsolete Dry Storage Facilities for Spent Nuclear Fuel and radioactive waste at Andreyeva Bay (C, D) and corroded Spent Nuclear Fuel containers at Gremikha (E)

Cold War Legacy

At the peak of the Cold War the Russian Federation had 250 submarines, warships and icebreakers, containing over 450 naval nuclear reactors. Two thirds of all these vessels were located in the Northwest of Russia, forming part of the Northern fleet. The aged condition of many vessels and their supporting coastal infrastructure is of major environmental concern. Significant technical challenges need to be overcome to alleviate the growing environmental threat to the region and its neighbours. In addition, the scope of the hazard reduction programme is large and varied and requires a range of solutions, some unique, to collectively address problems that have accumulated over many years.

Phase One of the SMP, completed in 2004, collated the most current technical data for the retired naval fleet and infrastructure of Northwest Russia. Eight 'strategic studies' were undertaken to address specific information gaps as part of Phase Two of the SMP and collectively the data gathered underpinned the development of the SMP strategic objectives.

The SMP characterised the broad nature of the problems in the region. Over 120 naval vessels await defuelling and decommissioning, with decisions needing to be taken regarding the future of a sunken nuclear submarine (fig.2) still containing Spent Nuclear Fuel (SNF). As a result of past accidents[1], dismantling of some highly contaminated submarines will require unique solutions, while bespoke defuelling and dismantling techniques will be necessary for one non-standard Papa-class submarine.
Other incidents in which Northern Fleet submarines have been involved include collisions with other submarines; fires at naval bases and shipyards; submarines that have become entangled in trawler nets; accidents during test launches of submarine launched missiles; collisions with icebergs and so forth [2].
In addition, bespoke storage and processing capabilities need to be developed for spent fuel from liquid-metal (lead-bismuth) coolant reactors from Alpha-class submarines.

[1] Submarine accidents have been caused by fires that have resulted in sinking; by loss of reactor coolant resulting in severe overheating and damage of reactor cores; and a number of smaller incidents in which radioactivity has leaked.

Fig.2 Decommissioned submarine K-159 in Gremikha Bay two days before sinking whilst being towed to Sayda Bay on 30/08/2003 (www.bellona.org)

Significant challenges are also faced in the defuelling and dismantling of other obsolete naval vessels. Some service vessels such as the Floating Maintenance Base *Lepse* (fig 1A) still contain damaged spent fuel and are themselves highly contaminated. *Lepse* itself poses one of the highest nuclear and radiation risks in the region. 639 Fuel assemblies are stored on board, many of which are badly damaged. One retired nuclear powered surface ship is suffering from corrosion and insufficient maintenance and is nearing the end of its design life for storage afloat with SNF on board. Structural deterioration of several of these floating vessels is so advanced that a significant risk of sinking exists.

Arguably the greatest hazards exist at two former submarine Coastal Maintenance Bases located at Gremikha and Andreyeva Bay. The large areas of contaminated buildings, land and coastal areas at both bases are a potential source of radioactive material release to the environment.

Spent fuel, equivalent to more than 100 submarine reactor cores, is currently being stored in unsatisfactory conditions on both sites. Solid radioactive waste, including high-level waste, SNF and Spent Removable Cores (SRC) all exist in deteriorating storage conditions and present a major hazard at Gremikha, while the site at Andreyeva Bay has more than 3,000 SNF assemblies, 20% of which are estimated to be damaged.

Radioactive waste and SNF stored at Andreyeva Bay is in badly corroded containers and within dry storage facilities that have suffered water ingress. Corroding waste and SNF containers are also stored on open air pads at both bases (fig.1D and E).

In order to fully quantify the scope of the remediation works, an analysis was also made of both the current and the required infrastructure throughout the region. This identified the following key problems and bottlenecks that must be solved in order to implement the SMP in a timely manner.

- further development of defuelling and dismantling infrastructure for *Lepse*, Papa-class nuclear submarine and nuclear-powered cruisers.[2]
- provision of the infrastructure and equipment at Gremikha and Andreyeva Bay to support SNF preparation for removal;
- insufficient outer and inner containers for SNF transportation in Northwest Russia;
- construction of a dedicated container ship for SNF transportation;
- no facility to process high-level and liquid intermediate-level radioactive waste;
- capital upgrade of roads, facilities and infrastructural equipment
- loss of skilled personnel;
- requirements for special handling and processing of damaged spent nuclear fuel;
- medium or long term storage for some non-reprocessible SNF;
- construction of a regional centre for radioactive waste conditioning and storage; and,
- absence of an integrated processing, elimination and disposal infrastructure for toxic waste in the region.

Clearly the technical challenges, each with different characteristics, hazards and degrees of complexity are far reaching and involve the analysis and coordination of many complex interactions across a large geographical area.

---

[2] This includes a protective containment equipped with auxiliary systems for safe SNF removal from the hull of *Lepse*; upgrade and construction of new hoisting capabilities; design and manufacture of shrouds for SNF assemblies; and the construction of a temporary SNF storage facility.

Framework for the SMP

A multi-disciplinary Programme Development Team (PDT) was established under the Foundation for Environmental Safety of Power Engineering (FESPE) at the Institute for the Safe Development of Atomic Energy (IBRAE RAS). This team comprised the full range of experience and knowledge necessary to propose appropriate solutions to the challenges and in total included 40 principle experts representing leading Russian research and industrial organisations such as RRC KI, NIKIET and NIPTB "Onega".

The International Consultant (IC) comprised representatives of Fluor Ltd and VT Nuclear Services Ltd who were integrated into the PDT in Moscow for the duration of the project. In-field personnel were supported by a team of UK experts based in the VT Nuclear Services Ltd home office. Thus, the IC was able to transfer up-to-date Western experience on a broad range of issues related to the SMP in the most efficient way, and crucially, provided the strategic overview necessary to effectively integrate the many elements of the SMP.

Development of the Plan

The information gathered during Phase One of the SMP formed the basis for the implementation of the strategic planning process used in Phase Two for the detailed development of the SMP. From the definition of a "vision" for the programme and the "mission" of the PDT team, the high-level objectives of the plan were developed and quantitative goals for the programme set.

Vision

A vision was established to guide the development of the SMP. This vision was defined in terms of a global end-state:

"Northwest Russia (and neighbouring countries) are no longer threatened by radiological or toxicological releases that may exceed regulatory criteria from retired nuclear powered vessels, the former military bases, or the retired maintenance vessels. Also, the coastal maintenance bases have been remediated to a condition that is protective of human health and the environment for prospective land use."

Execution of the SMP will result in the accomplishment of this vision.

Mission

Among the many organisations and teams associated with achieving the vision for Northwest Russia, the PDT had a unique mission:

"The PDT mission is to develop an integrated SMP and management system that will enable efficiently achieving the vision and objectives for Northwest Russia. This plan addresses nuclear powered vessels, nuclear maintenance vessels, former maintenance bases, spent fuel, radioactive waste, and toxic waste within the scope determined in the SMP Terms of Reference."

Strategic objectives

Effective planning requires a clear understanding of what works are required for each retired naval vessel or facility, and for associated land and marine areas. During the development of the SMP, each type of facility or vessel had an "end-state" developed such that they would ensure that each of the pieces when added together would support achieving the overall vision of reduced hazard in Northwest Russia.

Development of any complex strategy like the SMP can take many different paths. Based on the information gathered in Phase One and the defined end-states for each group of facilities, strategic objectives were established to provide clear milestones for success in accelerating hazard reduction. These strategic milestones serve as benchmarks for evaluating alternative approaches now and in the future:

- reprocessible spent nuclear fuel is removed from the region by 2018 and shipped to the Mayak facility in the Russian Federation;
- non-reprocessible spent fuel is in safe, interim storage by 2015;
- by 2025, Andreyeva Bay and Gremikha have been remediated to an end state protective of human health and the environment;
- radioactive waste is properly packaged and placed in interim storage suitable for at least 50 years;
- toxic waste has been treated as required and properly disposed or recycled for re-use;
- a programme management information system (PMIS) is developed and implemented; and,

- facilities, sites, and other equipment have been upgraded to ensure the work can be performed safely and securely.

Strategic Guiding Principles

Key to the initial development of strategic options was the development of seven Guiding Principles. These guided selection of cost-effective alternatives from amongst the wide range of possible strategic approaches that could be employed.

Based on Western experience, the guiding principles developed by VT Nuclear Services provided reasonable assurance that strategic alternatives would be selected that provide lower costs when measured over the entire lifecycle of the programme. The following were referred to throughout the course of the SMP development:

- common technical approaches applied across all sites;
- tried and tested solutions applied where possible and feasible;
- maximise use of existing industrial capability and infrastructure;
- minimise construction of duplicate infrastructure facilities;
- locate new spent nuclear fuel and radioactive waste management facilities at locations of their greatest concentration;
- consolidate storage locations for single-type materials, for example, spent nuclear fuel and radioactive waste; and,
- dispose of very low-level radioactive waste at the source site.

The IC was also instrumental in providing guidance and advice to the PDT so that a robust quality framework underpinned the SMP. Development was performed within a quality assurance programme consistent with ISO 9001:2000, Quality Management Systems - Requirements.

Strategic Planning Process

With a framework in place, the SMP was developed using a top-down planning approach to ensure that the strategic objectives were achieved or modified where necessary to reflect programme issues in ongoing projects.

Coordination of effort was critical to the success of the SMP. The IC led the integration of the separate technical solutions for individual facilities and sub-programmes developed by the various Russian institutes at the functional level of the plan and with the identification of individual project objectives.

An iterative review approach was taken (fig. 3) to rationalise the number and scope of detailed projects under development, to exploit synergies, remove duplication and to resolve potential conflicts between projects, ensuring consistency with the vision of the SMP and helping to achieve the strategic objectives.

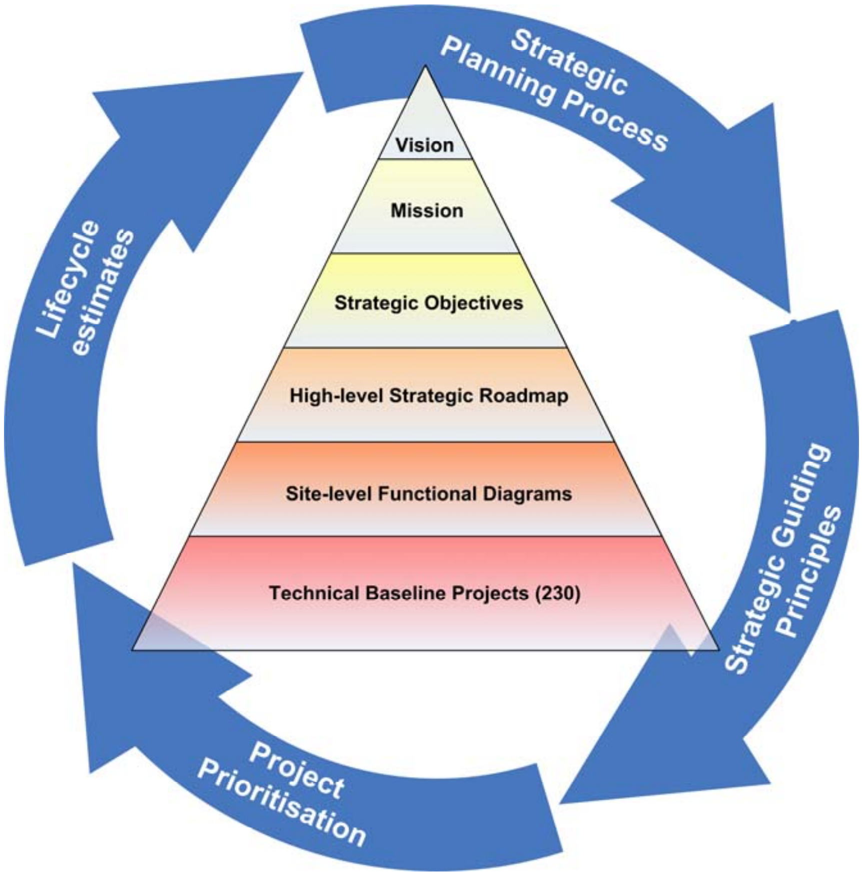

Fig. 3 The SMP strategic planning process and SMP framework

As component project scopes matured, the IC provided the necessary guidance and Western experience to underpin the plan with lifecycle cost and resource estimates. Specifically, this drew on the experience of VT Nuclear Services in the UK and European decommissioning markets with their development of Technical Baseline Plans for reactor decommissioning and with the analysis of the costs of decommissioning fuel cycle, waste management and other infrastructural facilities.

The results of these efforts were multiple layers of strategic planning within the SMP each with increasing degrees of detail. A top-level integrated strategy for the entire region was developed – the Strategic Roadmap.

A simplified version of the high-level Roadmap is given in fig.4. This depicts the sources of waste and SNF (yellow boxes) at the coastal maintenance bases (Gremikha and Andreyeva Bay), on-board retired naval vessels and at shipyards in the region. All active waste generated within the region will be processed at source, or by using mobile facilities, before eventual storage at facilities to be built at Sayda Bay. In addition, two processing facilities have been proposed to handle toxic waste across the region. Naval vessels will be dismantled at a number of possible shipyard locations. Dismantled submarine units (Reactor Units, RU) will be towed to Sayda Bay for storage. Recovered SNF (including some damaged assemblies) that can be reprocessed will be sent to the Russian Federation reprocessing facility at Mayak. SNF which cannot be reprocessed will be transported to the Atomflot facility at Murmansk for temporary storage (50 years).[3]

[3] Lead-Bismuth liquid metal spent removable cores from Alpha-class submarines currently cannot be processed and will be the subject of a future feasibility study.

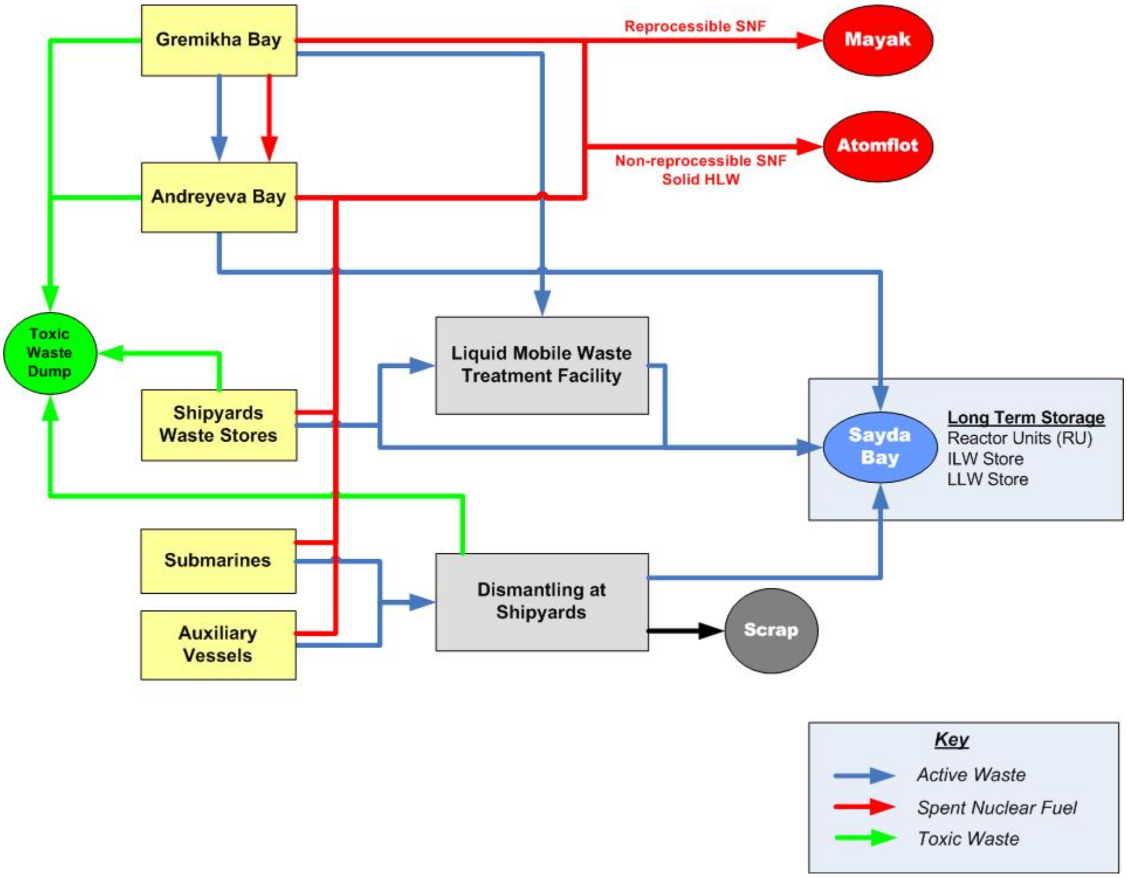

Fig. 4 The Simplified Strategic Roadmap for Northwest Russia

Beneath this top level, site-specific strategies were developed for Andreyeva Bay and Gremikha. Issue-specific strategies were also developed for SNF, radioactive waste, and toxic waste.

Beneath this functional layer of the plan, individual projects were established (230 in total) that will implement these strategies. These were prioritised to identify those projects that are most beneficial to achieving the overall SMP vision of hazard reduction. The IC modelled this process after the approach used in the UK by the Nuclear Decommissioning Authority (NDA). Eight criteria were established (fig.5) and a team of 14 experts tasked to evaluate projects by ranking them using these assigned criteria and weighting factors that were developed. The highest priority projects (approximately 70) that are ready to be initiated in the first few years of the SMP programme were grouped into a Priority Project Plan.

Fig. 5 Eight criteria used in the project prioritisation exercise

Main Outcomes of the SMP

A roadmap for Northwest Russia has been created that identifies key targets that need to be delivered in order to accelerate the cleanup of the region. Importantly, it specifies:

- the earliest completion date for the cleanup of Gremikha in order to address the growing social issues[4] with maintaining a work force at this site;
- that all submarine reactor compartments, reactor rooms and storage units of other retired naval vessels will be placed in the long term storage facility at Sayda Bay near Murmansk;
- that the movement of high-level wastes and spent fuel will be minimised by siting facilities at Andreyeva Bay where the vast majority of spent fuel and radioactive waste exist;
- that mobile, modular facilities will be used for the treatment of the more difficult high level and intermediate level liquid radioactive wastes; and,

[4] The skilled workforce at Gremikha is reducing due to job availability; the remoteness of the base with limited transport infrastructure between the nearest major cities; inadequate financial support from the state, and the absence of strategic development plans for the region.

- that very low level radioactive waste arising from the remediation of Andreyeva Bay and Gremikha will be disposed of on-site in new engineered waste disposal facilities.

The projects that underpin the above strategies are all included in the SMP schedule so as to facilitate effective programme management throughout the lifecycle of the SMP. This will help to ensure that activities are completed to time and to budget. Cost and resource data loaded into the SMP schedule will enable:

- effective cost management of individual projects and the programme as a whole;
- effective resource management;
- predictions for internal resource demands that will inform transition decisions regarding recruitment, general resource loading, accommodation on sites etc;
- effective programme monitoring and overview; and,
- identification of critical path activities.

The cost to implement the SMP is currently estimated to be about €2 Billion and represents a major international commitment of funds. As work on the various projects proceeds, further experience and knowledge may come available that may affect the direction of the SMP. It is imperative therefore that the SMP is a dynamic plan that matures through a process of regular review within a controlled and integrated framework. To provide such a framework, the IC established a Programme Management Information System (PMIS), developed by Fluor Ltd based on their extensive experience on similar projects worldwide.

Conclusions: How Will the SMP be used?

There is a major distinction between the SMP and other federal programmes aimed at decommissioning which are directly funded by the Russian Federation. The SMP is not a direct action programme for the allocation of state funding by Russian federal agencies, but is rather a strategic framework developed for the state nuclear corporation Rosatom to help implement and manage near and mid-term investment programmes.

The SMP will therefore be used to guide the development of both near and mid-term operational plans and higher level federal programmes. As a guiding framework, the SMP will form a live document that will evolve as further studies are undertaken and as a greater detail of information becomes available.

The SMP has been developed in an integrated manner so as to ensure that the vision for Northwest Russia is achieved while reducing lifecycle costs wherever practicable. As a result, the SMP represents key progress to securing the objectives for the NDEP established in 2002 [3].

As a benchmark and technical baseline, the SMP will be the reference point for the development of short-term and long-term programmes by both Rosatom and foreign investors, will provide the foundation for long-term strategic decisions for the region and will facilitate the continuous evaluation of progress against objectives.

With the SMP established, the first priority projects can now commence. In June 2008, Rosatom and the EBRD signed a grant agreement to allocate €70 million for funding a number of priority projects in accordance with the SMP. Tendering for the contract for the decommissioning of *Lepse*, a project estimated to cost €40 million, is due to start before the end of the year.

References

[1] The ethos behind the SMP as a 'living plan' is described at: http://www.ebrd.com/country/sector/nuclear/overview/funds/ndep.htm

[2] Nuclear ship accidents description and analysis, Øigaard, P.L., March 1993 (www.bellona.org)

[3] Working on behalf of the EBRD, the independent Expert Advisory Group comments regarding the SMP's *"breakthrough in strategic approach"* can be found at www.ndep.org