

**NUCLEAR ENERGY AGENCY  
COMMITTEE ON DECOMMISSIONING OF NUCLEAR INSTALLATIONS AND  
LEGACY MANAGEMENT**

**Application of the International Structure for Decommissioning Costing (ISDC)  
2012 to Complex and Legacy Sites**

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## *Foreword*

The International Structure for Decommissioning Costing (ISDC) is a hierarchical cost structure of decommissioning activities that are generally relevant for decommissioning projects (NEA, 2012). The ISDC cost structure may be applied to the decommissioning of any type of nuclear facility, such as nuclear power plants, research reactors, fuel cycle facilities and other nuclear facilities. The ISDC aims to include all costs within the planned scope of the decommissioning project. The 2012 report on the *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations* (NEA, 2012), hereafter referred to as “ISDC 2012”, is borne from a joint trilateral collaboration between the Nuclear Energy Agency (NEA), the International Atomic Energy Agency (IAEA) and the European Commission. However, several issues were excluded from or only marginally addressed in the publication such as post-accident decommissioning, legacy management and site remediation.

The Nuclear Energy Agency (NEA) Expert Group on Costing for Decommissioning of Nuclear Installations and Legacy Management (EGCDL) addresses costing issues as an expert group of the NEA Working Party on Management and Organisational Aspects (WPMO) of the NEA Committee on Decommissioning of Nuclear Installations and Legacy Management (CDLM).

In response to the increased focus being placed on decommissioning situations that are more complex than those addressed in the ISDC 2012, the EGCDL established a task group to evaluate the application of the ISDC to complex and legacy sites. The report captures the outcome of this analysis and sets out recommendations proposed to facilitate the application of the ISDC cost structure to complex and legacy sites.

This report was approved by the EGCDL Bureau on 18 April 2024 (NEA/DLM/M(2024)3, not publicly accessible) and incorporates comments received through written procedure from the EGCDL and WPMO members from September 2023 to January 2024, as appropriate.

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## *List of abbreviations and acronyms*

AAEC	Australian Atomic Energy Commission
ANSTO	Australian Nuclear Science and Technology Organisation
BIM	Building information models
CDLM	Committee on Decommissioning of Nuclear Installations and Legacy Management (NEA)
DGR	Deep geological repositories
DOE	Department of Energy (United States)
EC	European Commission
EGCDL	Expert Group on Costing for Decommissioning of Nuclear Installations and Legacy Management (NEA)
EPA	Environmental Protection Agency (United States)
ERDF	Environmental Restoration Disposal Facility
ESC	Environmental safety case
EW	Exempt waste
DNFs	Damaged nuclear facilities
FDHA	Federal Department of Home Affairs
FOPH	Federal Office of Public Health (Switzerland)
HAB	Hanford Advisory Board
HLW	High-level waste
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILW	Intermediate-level waste
ISDC	International Structure for Decommissioning Costing
ISPRA	Institute for Environmental Protection and Research (Italy)
LFLS	Little Forest Legacy Site
LLW	Low-level waste
LLWR	Low Level Radioactive Waste Repository (United Kingdom)
MTIF	Ministry of Trade, Industry and Fisheries (Norway)
Nb	Niobium
NEA	Nuclear Energy Agency
NFS	Nuclear fuel services
NRC	Nuclear Regulatory Commission (United States)
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and maintenance
PCM	Plutonium contaminated materials
PSL	Proposed standardised list of items for costing purposes
R&D	Research and development
RIC	Ranstad industri centrum AB
RSLs	International Working Forum on Regulatory Supervision of Legacy Sites
SFL	Long-lived radioactive waste
SSM	Swedish Radiation Safety Authority
TVRP	Target values for remedial parameters
UMTRA	Uranium mill tailings remedial action
USGS	US geological survey
VLLW	Very low-level waste
VSLW	Very short-lived waste
WNYNSC	Western New York Nuclear Service Center
WPMO	Working Party on Management and Organisational Aspects of Decommissioning and Legacy Management (NEA)

WTP	Waste treatment plant
WVDP	West Valley Demonstration Project
YB	Yellow Book

### Units of measure

Bq/g	becquerel per gram
Bq/kg	becquerel per kilogram
Bq/m <sup>3</sup>	becquerel per cubic metre
Cm	centimetre
Gal	gallon
GBq	gigabecquerel
km	kilometre
km <sup>2</sup>	square kilometre
kt	kilotonne
L	litres
L/min	litres per minute
m	metre
m <sup>3</sup>	cubic metre
mSv	milliSievert
t	tonne
TBq	terabecquerel
μGy/h	microgray per hour
μSv/y	microSievert per year

## *Executive summary*

The *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations* (the “ISDC 2012”) was developed and issued jointly by the NEA, the IAEA and the European Commission in 2012 as the harmonised structure for presenting costs for decommissioning projects (NEA, 2012).

The ISDC cost structure can be applied to decommissioning of any type of nuclear facility, such as nuclear power plants, research reactors, fuel cycle facilities and other nuclear facilities. The ISDC is intended to cover all types of activities identified in any decommissioning project for any type of nuclear installation, regardless of size, composition/complexity of systems and structures, and radiological conditions. The guidance on application of the ISDC follows the internationally accepted decommissioning strategies, describes typical decommissioning activities, and considers the various phases of decommissioning projects, including planning, the transition from operation to decommissioning, and the end points of decommissioning projects. The ISDC 2012 presents a hierarchical structure of typical decommissioning activities in three levels, where these levels present decommissioning activities in increasing degrees of detail and specificity. It also provides detailed examples of cost items normally included in each of the typical activities at ISDC Level 3.

A number of issues were excluded from or only marginally addressed in the ISDC 2012, such as post-accident decommissioning, legacy management and site remediation. There is increased focus on decommissioning facilities and the legacy management of sites where the history, complexity of the situation on site, and potential interactions with other facilities may have a significant impact on decommissioning and the associated costs. As a consequence of these challenges, additional aspects of end states should also be considered.

The NEA Expert Group on Costing for Decommissioning of Nuclear Installations and Legacy Management (EGCDL) evaluated the applicability of the ISDC cost structure to legacy and complex sites according to the NEA Committee on Decommissioning of Nuclear Installations and Legacy Management’s (CDLM’s) understanding of these types of nuclear sites. The EGCDL also extended its evaluation to consider the impacts of accidents and activities for site remediation. This report presents the EGCDL’s findings on the application of the ISDC to legacy and post-accident situations, and for complex sites (gap analysis). It identifies additional activities which could be included in the ISDC cost structure in order to better represent these situations and contexts.

This report allocates the additional activities identified by the EGCDL to the existing ISDC cost structure. The approach followed is to maintain the existing ISDC structure by adding the identified proposed activities only at the end of ISDC Level 2 and Level 3. In order to reflect this additional content, modifications of some existing titles for ISDC Levels 1, 2 and 3 were proposed. This approach ensures the conservation of the ISDC cost structure while providing the possibility to introduce the additional activities identified by the EGCDL.

## 1. Introduction

The NEA Expert Group on Costing for Decommissioning of Nuclear Installations and Legacy Management (EGCDL) addresses costing issues for the decommissioning of nuclear installations and legacy management as an expert group of the Working Party on Management and Organisational Aspects (WPMO) of the Committee on Decommissioning of Nuclear Installations and Legacy Management (CDLM). In this context, the EGCDL:

- i. fosters the exchange of information, knowledge and experience between its members on issues concerned with cost estimation, with a view to promoting collective learning and to enhancing the credibility, reliability and auditability of the cost estimation process, and thus to enhancing stakeholder confidence in the process of managing liabilities;
- ii. describes good practices in the field of cost estimation for decommissioning and legacy management projects, including understanding of the risks associated with financial consequences in regard to cost estimation and financing; and planning for uncertainties, with an overall aim to assist organisation members to develop robust and efficient project management processes, and to examine the scope for achieving consensus on overall objectives and for developing common approaches;
- iii. advises the Working Party on Management and Organisational Aspects of Decommissioning and Legacy Management (WPMO) on major and emerging issues in the area of cost estimation for decommissioning and legacy management, and provides appraisals of the state of the art with a view to consolidating knowledge and making it transferable to a variety of audiences;
- iv. defines, conducts and oversees studies aimed at improving the transparency and reproducibility of cost estimates, including approaches to presentation and reporting estimates;
- v. where necessary, organises topical sessions or workshops on specific topics of interest to the expert group and to the WPMO.

The ad hoc meeting on costing held in September 2019 identified “adapting the International Structure for Decommissioning Costing (ISDC) to extend its applicability” as one of the recommended priority topics of work for a future costing group.

The ISDC cost structure can be applied to the decommissioning of any type of nuclear facility, such as nuclear power plants, research reactors, fuel cycle facilities and other nuclear facilities. However, uranium mining sites are not addressed by the ISDC 2012, and a number of issues were excluded from or only marginally addressed in the ISDC 2012, such as post-accident decommissioning, legacy management and site remediation. Although the ISDC 2012 does consider post-accident decommissioning to some extent, the ISDC does not include decommissioning and remediation following a severe accident such as those at Fukushima Daiichi or Chernobyl.

The EGCDL established a task group to evaluate the application of the ISDC to complex and legacy sites (NEA, 2012). This report presents the outcome of this evaluation.

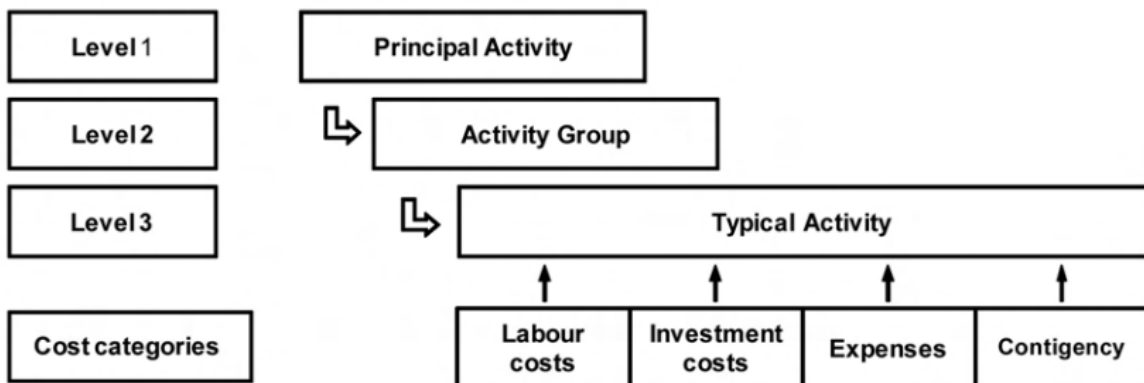
## 2. International Structure Decommissioning Costing (ISDC) of Nuclear Installations (ISDC 2012)

The ISDC 2012 report presents the ISDC cost structure. The ISDC is a hierarchical cost structure of typical decommissioning activities in three levels (see Figure 2.1).

Principal ISDC activities at Level 1 are as follows:

1. Pre-decommissioning actions
2. Facility shutdown activities
3. Additional activities for safe enclosure or entombment
4. Dismantling activities within the controlled area
5. Waste processing, storage and disposal
6. Site infrastructure and operation
7. Conventional dismantling, demolition and site restoration
8. Project management, engineering and support
9. Research and development
10. Fuel and nuclear material
11. Miscellaneous expenditures

**Figure 2.1. Hierarchical structure of the ISDC including Levels 1,2 and 3**



Source: NEA, 2017.

An example of the hierarchical ISDC structure for part of ISDC 04 at ISDC Level 1, 2 and 3 is presented in Figure 2.2 (NEA, 2012). A similar structure is applied to all of the typical decommissioning activities 1 through 11.

Figure 2.2. Example of structure used in ISDC 04

Principal Activity	04 Dismantling activities within the controlled area
Activity Group	04.0500 Dismantling of main process systems, structures and components
Typical Activity	04.0501 Dismantling of reactor internals
	04.0502 Dismantling of reactor vessel and core components
	04.0503 Dismantling of other primary loop components
	04.0504 Dismantling of main process systems in fuel cycle facilities
	04.0505 Dismantling of main process systems in other nuclear facilities
	04.0506 Dismantling of external thermal/biological shields

One of the key issues in decommissioning costing is the comparability and understanding of cost items for decommissioning projects. This is complicated due to many factors:

- a) there are various and mutually non-compatible national specific cost formats for presenting the cost for decommissioning projects;
- b) the meaning of individual cost items in various national specific cost structures may be different;
- c) the scopes of decommissioning projects are defined in various and inconsistent manners.

As a result, cost items presented in national formats are not mutually consistent and the content may not be understood to the needed level of details for comparison of the cost items. Cost estimates depend fundamentally on the decommissioning plans adopted, the assumed end state, and differences in basic assumptions as well as the context in which, and purpose for which, the estimates were prepared. These differences can make cost comparisons arduous and can hinder transparency and, consequently, may impact stakeholder confidence.

In the mid-1980s, the NEA and the European Commission (EC), began to explore ways to standardise the cost presentation structure. In 1999, the NEA, EC and IAEA published a document, “A Proposed Standardized List of Items for Costing Purposes” (PSL), known as “Yellow Book” (YB), which was the predecessor of the ISDC (NEA, 1999). The PSL document set out a preliminary proposed standardised systematic structure of decommissioning cost items, defined in three hierarchical levels. Some European countries started to implement this PSL document at various levels of detail. There were also IAEA and NEA projects for implementation of the standardised PSL decommissioning cost structure (IAEA, 2022; NEA, 2003).

Based on accumulated experience with the use of the standardised PSL structure, the IAEA, the NEA and the EC decided in 2008 to further develop the decommissioning cost structure. The new document was published in 2012 as the “International Structure for Decommissioning Costing (ISDC) of Nuclear Installations” (NEA, 2012).

The ISDC 2012 has proved to be an effective tool for comparison and benchmarking of cost<sup>1</sup> for decommissioning projects, which is the key purpose of the ISDC 2012 (NEA, 2019). At the international level, the ISDC has been applied in the IAEA project on decommissioning costing for research reactors, the DACCORD project (IAEA, 2021a, 2017). In this project, costing cases for various types of research reactors were developed and compared (i.e. benchmarked) with the aim of identifying key cost drivers and developing a platform to support the IAEA member states to develop their own costing cases.

The ISDC 2012 is also used for cost reporting of the EU funded decommissioning activities in Bulgaria<sup>2</sup>, Lithuania<sup>3</sup> and the Slovak Republic, (Council of the European Union, 2013a, 2013b).

The ISDC was also used to report costs for nuclear power plant decommissioning projects in the NEA project (NEA, 2016). The cost for various European nuclear power plant decommissioning projects (originally developed in national/corporate specific cost formats) were provided in the ISDC format and selected US nuclear power plant decommissioning projects were transformed to the ISDC format.

The NEA and the IAEA developed guidance on addressing uncertainties in decommissioning cost estimation (NEA, 2017). This guidance is intended to be used together with that set out in the ISDC 2012 to provide a more complete understanding of decommissioning project costs. Together these two publications form the core international guidance for developing and presenting nuclear facility decommissioning cost estimates. The NEA has recently republished the core of both publications together as the *Handbook for Nuclear Decommissioning Cost Estimation* (NEA, 2024).

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<sup>1</sup> The EGCDL Global Task 3 group is currently developing a cost benchmarking guidance with the recommendation to use the ISDC 2012 cost presentation format as the platform for performing cost benchmarking.

<sup>2</sup> Item 13 of the Council Regulation (Euratom) No 1368/2013 of 13 December 2013 on Union support for the nuclear decommissioning assistance programmes in Bulgaria and Slovakia states: “The costs should be established according to internationally recognised standards for the estimation of decommissioning costs, such as, for example, the International Structure for Decommissioning Costing jointly published by the Nuclear Energy Agency, the International Atomic Energy Agency and the European Commission”.

<sup>3</sup> For Lithuania, item 11 of the Council Regulation (EURATOM) No 1369/2013 of 13 December 2013 on Union support for the nuclear decommissioning assistance programme in Lithuania, and repealing Regulation states: “The costs should be established according to internationally recognised standards for the estimation of decommissioning costs, such as, for example, the International Structure for Decommissioning Costing jointly published by the Nuclear Energy Agency, the International Atomic Energy Agency and the European Commission”.

### 3. Application of the ISDC to legacy and complex sites

The ISDC is a hierarchical cost structure of decommissioning activities that are generally relevant for decommissioning projects. A typical decommissioning project considered in the ISDC 2012 includes a preparation phase, transition phase, the implementation of decommissioning and final site release. A smooth transition from operation is assumed, and the possibility of a deferral period considered.

The ISDC 2012 is related to typical decommissioning projects. A decommissioning project in the ISDC 2012 is considered more or less an independent project with a well-defined scope, with allocated buildings and a site, and related physical and radiological properties. Ownership, responsibilities, regulatory aspects and end states of decommissioning projects are well-defined as part of the assumptions and boundary conditions to be applied for costing purposes.

This ISDC 2012 includes consideration of some aspects that may differ to a certain extent from the above assumptions, such as decommissioning following accidents, the impact of improper operation of a facility, aspects of the end state or interactions with other projects or facilities. However, it does not fully consider the implications of such considerations, such as decommissioning and remediation following a severe nuclear accident.

There is increased focus on decommissioning facilities and legacy management of sites where the history, complexity of the situation on site and possible interactions with other facilities may have a significant impact on decommissioning. Additional types of end states of decommissioning projects and remediation activities have emerged in the context of these challenges (e.g. converting a legacy site to permanent disposal). This report is intended to provide new information on cost estimation for such projects.

The IAEA defines remediation as any measures that may be carried out to reduce the radiation exposure due to existing contamination of land areas through actions applied to the contamination itself (the source) or to the exposure pathways to humans (IAEA, 2022a, para 1.2). Complete removal of the contamination is not implied.

Remediation can entail activities that are similar to decommissioning. Abandoned and currently unauthorised industrial sites, such as former uranium mines and mills and former radium processing facilities, may have buildings and structures to be taken down by actions consistent with the decommissioning process (e.g. decontamination and dismantling); however, such activities at abandoned or unauthorised sites are considered a part of site remediation and would typically be carried out as part of a site-specific remediation plan. In the context of this report, it is appropriate to evaluate activities typical for remediation projects and identify whether these activities are addressed in the ISDC 2012. In doing so, it is necessary to compare the scope of the ISDC 2012 with the understanding of legacy and complex sites from the point of view of the extent of typical decommissioning activities.

#### 3.1. Legacy sites

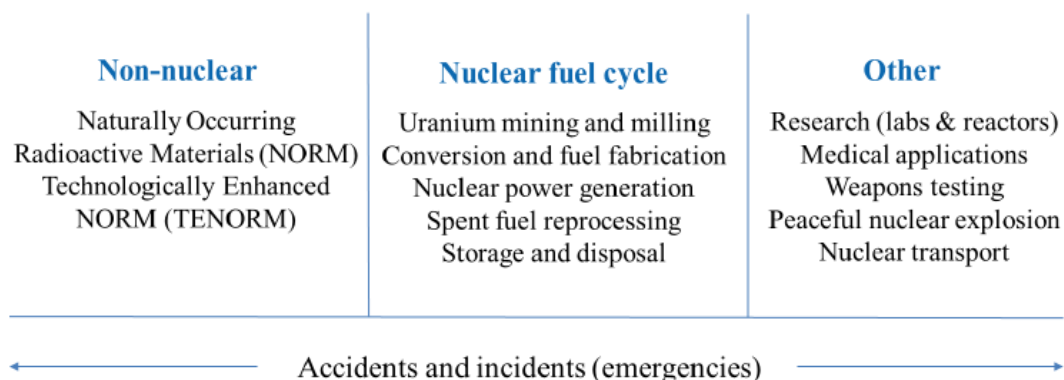
The CDLM has set out its understanding of key issues, which includes elements to consider related to legacy sites. These include:

- facilities and sites on which radioactive materials or contamination remain from past practices, and for which there may be a need to consider remedial actions, are generally considered “legacies”;
- cases where ownership or responsibility is clear, and where the facilities or sites are managed based on established procedures, are generally not considered as “legacies”.

The CDLM understanding includes key phases, legacies, management of materials, end states and end points, stakeholders, and optimisation. It also presents characteristics which are often associated with the general description of “legacy”:

- there is residual radioactive material or contamination that is of concern to the regulator or stakeholders (radiological protection, safety, security and environment), and it is necessary to evaluate the potential need to undertake additional remediation and clean-up;
- a legacy situation may present a complex combination of radiological, chemical and physical hazards, along with other operational challenges, that are not initially well understood (characterised);
- regulatory circumstances are complex because a facility or site was not operated in line with current standards, recommendations and guidance; the current regulatory framework is not designed to address the particular circumstances presented by the “legacy” situation;
- records and knowledge may be limited (e.g. appropriate and adequate records may have been lost or were never kept; former site operators with knowledge of the site are unavailable). Where available, historical records and knowledge may not provide the necessary information for decision making according to the current regulatory framework;
- the present ownership or responsibility for a facility or site may be unclear or complex. This may arise, for example, when there is no identifiable owner, a previous owner no longer exists, or site ownership has changed hands several times. In addition, there may be legacy situations where the known owner cannot perform or complete required remediation works for the sites, facilities, materials, and wastes (“orphans”), so the chain of ownership/responsibility has been broken.

Examples of categories of facilities and events potentially giving rise to legacy sites are presented in Figure 3.1. Military-related facilities and sites are excluded from the scope of this report.

**Figure 3.1. Examples of facilities and events potentially giving rise to legacies**

Source: NEA (2020b), “Understanding of Key Issues for the Committee on Decommissioning of Nuclear Installations and Legacy Management”. (Internal document only)

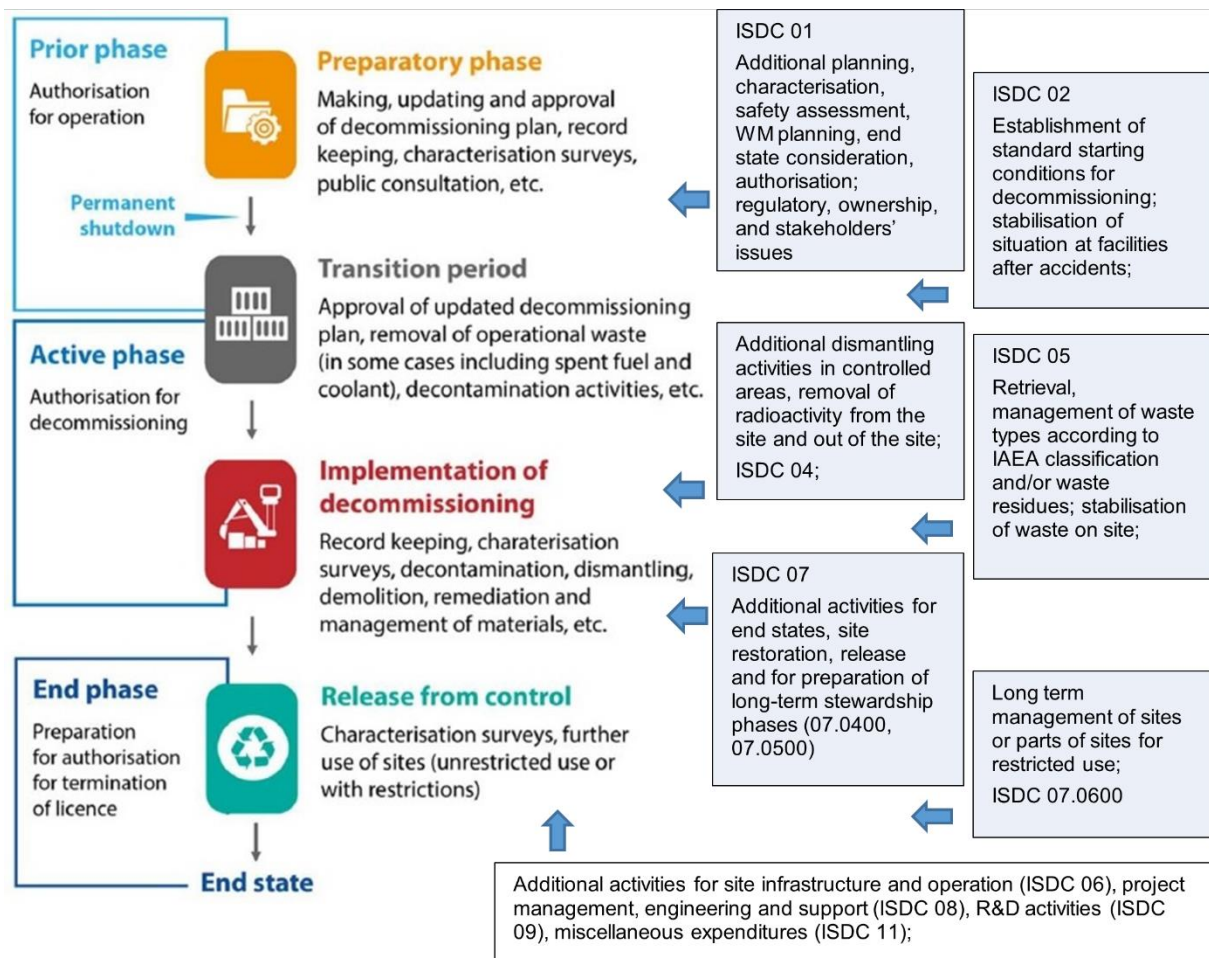
Activities additional to the ISDC 2012 may be identified for managing decommissioning/remediation projects related to legacy sites where:

- regulatory/ownership/stakeholders/initial knowledge issues are specific/limited and non-standard;
- starting situations for decommissioning/remediation projects require specific additional arrangements, e.g. situations after accidents;
- removal of radioactivity from legacy sites or conservation of radioactivity on legacy sites requires specific procedures;
- waste residues in various forms on site, NORM, TENORM may be involved;
- end state types of specific projects may be different from end state types of standard decommissioning projects; for example, for legacy sites, free site release may not be achievable due to the remaining level of residues of radionuclides.

An illustration of the overall path for an immediate decommissioning strategy for a standard decommissioning project is presented in the left part of Figure 3.2. This and other typical decommissioning situations, such as a deferred decommissioning strategy, are well-covered by the ISDC 2012. Decommissioning of legacy sites may require activities additional to those identified in the ISDC 2012. The allocation of the principal ISDC activities in the overall decommissioning path and preliminary identification of potential additional decommissioning activities is presented on the right side of Figure 3.2.

The principal ISDC activities presented in Figure 3.2 are the subject of a further detailed identification of activities that are additional to the ISDC 2012 activities, as presented in Appendix B.

**Figure 3.2. Potential allocation of existing and/or additional principal ISDC activities to the overall decommissioning path reflecting the activities related to legacy sites.**



Source: Adapted from NEA (2020b), "Understanding of Key Issues for the Committee on Decommissioning of Nuclear Installations and Legacy Management". (Internal document only)

### 3.1.1. Understanding of legacy sites in IAEA documents

Legacy sites can arise for many different reasons, but some of the more common causes seen in member states include the following (IAEA, 2022b):

- an absence of effective regulatory supervision over at least some of the history of the site;
- the lack of a long-term strategy for the management and future use of the site;
- weak or missing regulatory requirements and guidance necessary to address decommissioning and closure when operations ended;
- lack of funding for facility decommissioning and closure, or remediation of the site;
- lack of facilities and other arrangements for the management of radioactive waste produced at the site while it was operating.

Common characteristics of legacy sites may include:

- unsatisfactory or unsafe radiological conditions;

- b) poor characterisation of the current radiological condition and a lack of records or knowledge on the history of the site to ascertain what risks and hazards are present;
- c) radioactive contamination affecting the off-site environment, or the threat that it may be released at some time;
- d) other physical and chemical hazards present at the site, particularly because the sites have not been maintained;
- e) unclear ownership and responsibility for management and remediation activities;
- f) insufficient funds to carry out the responsibilities mentioned above.

Frequently, legacy sites are in a poor condition due to the loss of physical and/or regulatory control over the radioactive material for at least some portion of the site's history or because they were subject to regulatory control not in accordance with current IAEA standards. Such loss of regulatory control has often resulted in a degradation of physical control measures, leading to contamination of the environment.

Control measures may include both physical containment and institutional controls, such as land use restrictions and security measures to prevent access to the site. From a regulatory perspective, the key issue is that the levels of contamination, and/or the degraded state of the control measures, lead to concerns about the physical, chemical, nuclear and/or radiation safety and security at the site.

The International Working Forum on Regulatory Supervision of Legacy Sites (RSLs) considers the following types of legacy sites (IAEA, 2022b):

- Interim storage sites and facilities for radioactive waste.

At these sites, waste is stored prior to it being managed at a permanent disposal facility. This can involve many types of radioactive waste. However, if many years pass without a permanent disposal solution, the interim storage facilities may become the "de facto" final disposal sites. Since the interim storage facilities were not designed to be permanent, radiological hazards may develop over time. If regulatory oversight is lax or if there is only slow progress being made in developing adequate permanent disposal capacity, interim storage sites themselves may become legacy sites.

- NORM sites.

NORM is defined as "Radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides" (IAEA, 2019a). A distinguishing feature of NORM industries is that the radionuclides are naturally occurring in the raw material and are concentrated by an industrial process. The residues and/or wastes associated with processing NORM are frequently the by-product of industrial activity and may pose a risk of contamination of sites. Examples include radioactive residues and contamination created from phosphate industries (e.g. phosphogypsum stacks), or scales and sludges from oil and natural gas drilling. Radiological contamination and subsequent risks may develop if these materials are not appropriately managed. Some member states define uranium mining and milling as a NORM activity because it also concentrates the naturally occurring uranium in the ore, while others consider it as part of the nuclear fuel cycle. Uranium or other radioactive materials (e.g. thorium) are sometimes also recovered at mines developed primarily for other ores (e.g. copper, niobium, mineral sands).

- Nuclear technology and development centres.

These facilities may have been abandoned in a contaminated condition and environmental releases may have occurred. Also, there can be more than one degraded facility on the same

site requiring remediation or refurbishment. Chemical and industrial hazards may occur at these sites as well. These facilities are sometimes located adjacent to other, conventional, industrial operations that may still be operating, posing a risk to current workers and their environment.

- Sites and facilities affected by accidents and incidents.

Radiological accidents have the potential to affect large areas and could become legacy sites if there is inadequate regulatory oversight. A significant issue in managing radioactive contamination from such events is that they may create significant stress and social disturbance among interested parties over extended periods of time.

### 3.2. Complex sites

For the purposes of this report, the understanding of “complex sites” is that currently being developed by the CDLM Expert Group on a Holistic Process for Decision Making on Decommissioning and Management of Complex Sites (HDCS). Complex sites include:

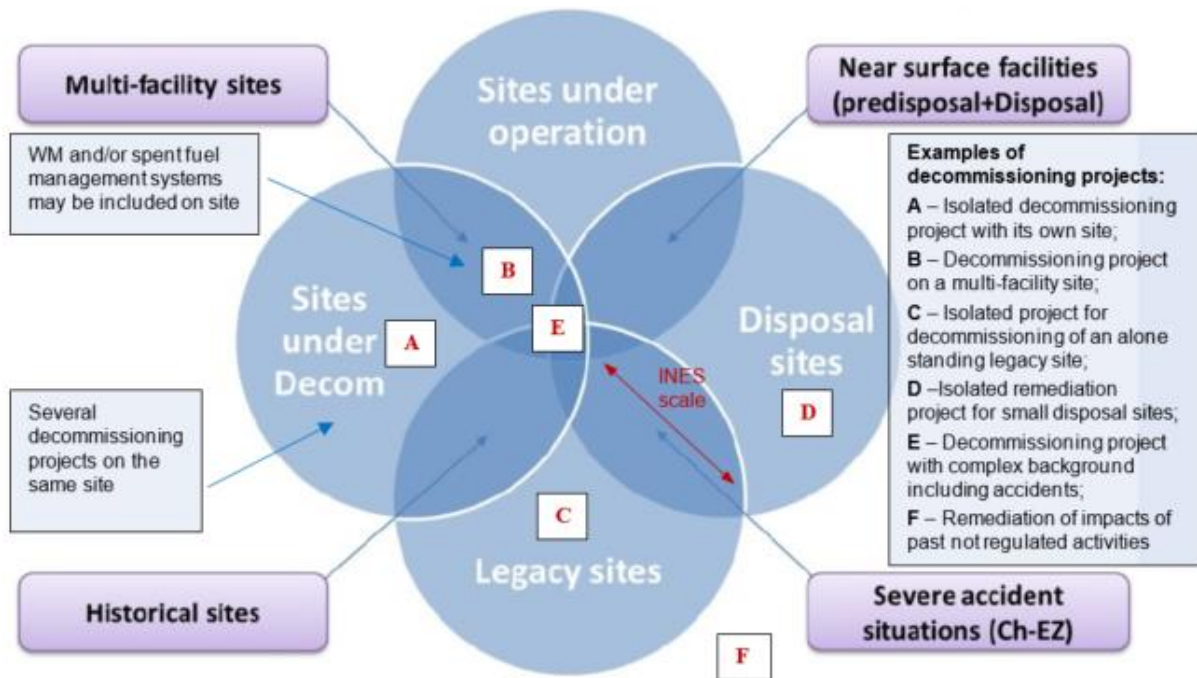
- multi-facility sites where nuclear facilities can be at the same time under operation and/or under decommissioning (the same as multi-unit sites);
- sites under operation with both predisposal (for conditioning, treatment, storage) and disposal facilities;
- historical sites having both nuclear facilities under decommissioning and legacy situations to be considered (former nuclear facilities pending for final decommissioning actions or soils needing specific remediation works);
- nuclear sites subject to severe accident situations where the recovery actions after an accident needed to create on-site disposal facilities and where the former nuclear facilities are still in place pending a lasting solution (decommissioning or remediation actions).

This understanding is consistent with descriptions used at the IAEA (IAEA, 2022c), where multi-facility sites (any type of facility that can be co-located with any other type at a given location) include:

- multi-reactor nuclear power plant sites;
- mixed sites housing nuclear fuel cycle facilities and/or non-power reactors and/or industrial and support facilities;
- mineral processing sites.

The ISDC cost structure is intended for presenting the costs of standalone decommissioning projects. In some cases, as presented in the Figure 3.3, a decommissioning project may be realised within a multi-facility site where several other nuclear facilities of various types may be present. There may be interactions between the decommissioning project and other nuclear facilities on site, potentially giving rise to decommissioning activities that may not have been addressed in the ISDC 2012.

Figure 3.3. Nuclear site overview with examples of positions of decommissioning projects



Source: Adapted from NEA (forthcoming), “Holistic Process for Decision Making on Decommissioning and Management of Complex Sites”.

The complexities described in Figure 3.3 may support the identification of potential interactions and activities in addition to those included in the ISDC 2012. The following situations are described in the figure:

- A. isolated decommissioning project on its own site;
- B. decommissioning project of a nuclear power plant unit located on a site with operating nuclear power plant unit(s) and waste management/spent fuel management facilities;
- C. isolated project for decommissioning/remediation of a legacy site that stands alone and was previously subject to a long-term period of limited surveillance and/or maintenance;
- D. isolated remediation project for a small, well-managed and closed disposal site when an urban or industrial area is near the disposal site;
- E. decommissioning project for a nuclear power plant after an accident where, in parallel, the decommissioning of a nuclear power plant after standard shutdown is being realised, both facilities use the same waste management facility for management of operational and decommissioning waste; where a nuclear power plant in operation is located at the site in close contact with the site of the nuclear power plants in decommissioning;
- F. remediation of the effects of past activities that used radioactive materials in cases with no controlled areas.

Other examples of potentially complex sites could be uranium mining and ore processing facilities, including underground structures, facilities for mining and ore processing, where various waste residues, NORM and TENORM materials may occur.

Complex sites may include nuclear and non-nuclear facilities located in a common site which may share or have overlapping site services, management, ownership and regulatory oversight, with potential impacts on safety, limitations for operations, cost aspects and other issues. These interactions may have some implications for a decommissioning project on multi-facility sites.

In the context of this report, such interactions may require consideration of activities additional to the ISDC 2012 (e.g. when considering the safety within the project or safety of nuclear facilities next to decommissioned facility). The potential interactions of a decommissioning project with other facilities on site are:

- fleet effects;
- investments used across several projects (mostly cost allocating issues);
- site functions like security, fire protection or O&M of shared support systems.

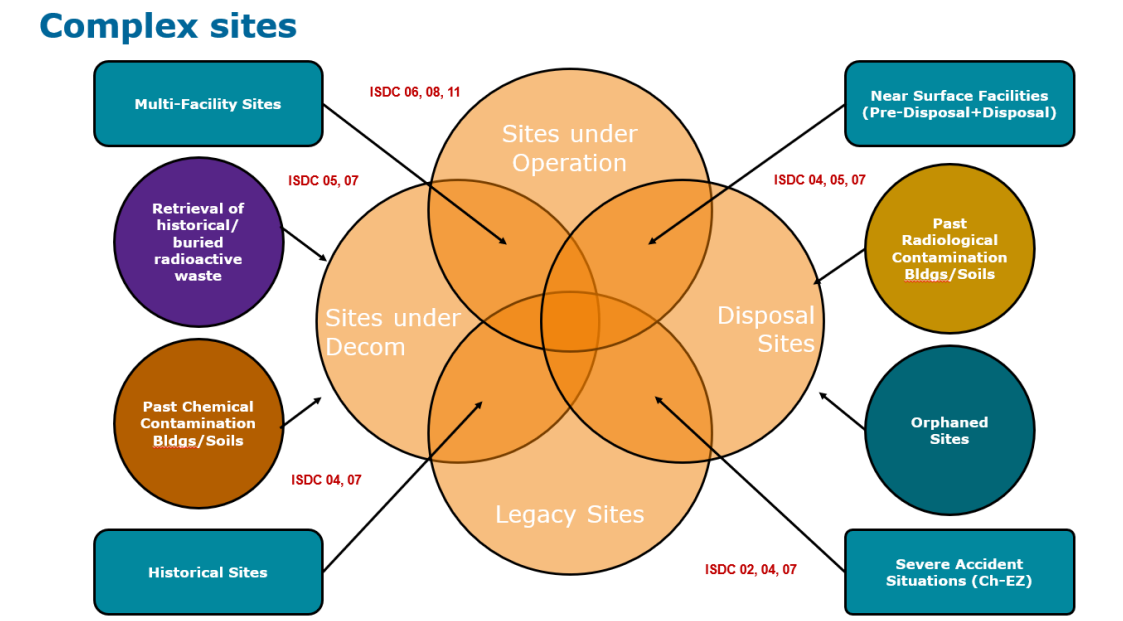
Activities not directly related to physical inventories (i.e. systems, structures and components) preliminary considered as affected by complex site aspects (e.g. activities that may be affected by other on-site activities such as operation of nuclear power plants, other decommissioning project, or waste management facilities for operational and decommissioning waste) are addressed in:

- ISDC 06 “Site infrastructure and operation”
- ISDC 08 “Project management, engineering and support”
- ISDC 11 “Miscellaneous” cost (owner cost, taxes, insurance, collateral projects due to shutdown, etc.)

Preliminary analysis shows that the ISDC may already address to a great extent activities related to complex sites. On this basis, the ISDC 2012 is a solid platform that could be applied to complex sites.

There are other potential situations at complex sites which may further increase the complexity of activities, for example where there may be some legacy or remediation situations needed on a complex site. Those situations are summarised in Figure 3.4. For these situations of additional complexity, further analysis of the ISDC 2012 principal activities 02, 04, 05, 06, 07, 08 and 11 may be needed.

**Figure 3.4. Examples of additional situations which may contribute to increase of complexity with indicated corresponding ISDC principal activities.**



Source: Adapted from NEA (forthcoming), “Holistic Process for Decision Making on Decommissioning and Management of Complex Sites”.

Another analysis of situations at complex multi-facility sites is presented in the IAEA document *Decommissioning at a Multifacility Site: An Integrated Approach* (IAEA, 2022c). Several aspects are presented that were used in the identification of potential activities additional to those considered in the ISDC 2012.

Technical aspects:

- site layout;
- shared infrastructure, including utilities and structures, systems and components;
- waste management facilities and provision;
- development and deployment of decommissioning technologies;
- ground contamination;
- site clean-up;
- area and component reutilisation;
- compliance with end state requirements;
- safety assessment and emergency preparedness;
- environmental monitoring during decommissioning.

Organisational and managerial aspects:

- human resources;
- organisational structures and systems;
- regulatory approaches;

- nuclear security considerations;
- safety and environmental impact assessment;
- emergency preparedness;
- independent owners/operators;
- knowledge management, learning from experience and record keeping;
- human factors;
- asset management, including post-decommissioning site reuse;
- stakeholder engagement;
- supply chain engagement and commercial arrangements.

Financial aspects and integrated planning as listed in the IAEA document are typical decommissioning activities already included in ISDC 01.0100 and 08.0200 (IAEA, 2022c).

## 4. Sources analysed in the identification of gaps in relation to legacy/complex sites

Several sources were used to complete the gap analysis to identify the need for additional activities to those included in the ISDC 2012. These are briefly summarised below.

- The following case studies are from the NEA publication *Challenges in Nuclear and Radiological Legacy Site Management: Towards a Common Regulatory Framework* (NEA, 2020a). These cases were selected based on the diversity of situations and availability of comprehensive data to perform the analysis.
  - Case Study 1. Little Forest Legacy Site, Australia
  - Case Study 2. The Low Level Radioactive Waste Repository (LLWR), United Kingdom
  - Case Study 3. Ranstad uranium mining and milling plant, Sweden
  - Case Study 4. The Sjøve, a former niobium mine, Norway
  - Case Study 5. Stráž Pod Ralskem and Rožná legacy sites, Czechia
  - Case Study 6. Shiprock disposal site in New Mexico, United States
  - Case Study 7. Radium Action Plan 2015 to 2019, Switzerland
  - Case Study 8. Capriano del Colle special waste dump, Italy
  - Case Study 9. Clean-up approaches and strategies for public engagement and participation at Hanford, United States
  - Case Study 10. Western New York Nuclear Service Center and West Valley Demonstration Project, United States
- The IAEA document *Management of Residues Containing Naturally Occurring Radioactive Material from Uranium Production and Other Activities* was used to evaluate if management of NORM materials would require the introduction of new ISDC activities (IAEA, 2021b).
- The IAEA document *Decommissioning at a Multifacility Site: An Integrated Approach* was reviewed to identify if existing ISDC 2012 cover the technical and organisational aspects of complex sites or if new ISDC items should be proposed (IAEA, 2022c).
- The IAEA documents *Managing the Decommissioning and Remediation of Damaged Nuclear Facilities* and *Decommissioning after a Nuclear Accident: Approaches, Techniques, Practices and Implementation Considerations* were used to evaluate if additional ISDC activities should be proposed to address post-accident decommissioning activities (IAEA, 2021c, 2019b).

The detailed analysis of the cases is presented in Appendix B. The summary of the results is presented in Chapter 5.

## 5. Presentation of activities additional to the ISDC cost structure

### 5.1. General comments

The ISDC cost structure is a list of typical decommissioning activities for nuclear facilities where the activities are conducted within projects of a defined scope. The buildings, systems, structure and components, site, radiological situations and materials involved are typically well-defined for these decommissioning projects. The IAEA radioactive waste classification is used in the ISDC 2012. Ownership, responsibilities, regulatory aspects and end states of decommissioning projects are well-defined, as part of the assumptions and boundary conditions for costing purposes to be applied.

This section of the report provides an analysis of features related to legacy situations, complex sites and post-accident facilities and sites as a gap analysis for the ISDC 2012. Considerations include that:

- large site areas may include many different sub-areas;
- waste forms may be very different than in the decommissioning of typical nuclear facilities, e.g. residues at legacy sites or waste forms as the consequence of accidents;
- large quantities of materials may need to be processed;
- some areas were abandoned for a period of time;
- ownership/regulatory/stakeholder aspects may play an important and specific role;
- the impact on the environment may be project-specific and may require specific solutions;
- various options of end states may exist;
- some cases may last a long time, possibly requiring several individually licensed projects and plans over the course of individual decommissioning projects;
- complex sites involving several types of nuclear facilities may require additional activities due to the interactions of individual decommissioning projects with the complex site;
- post-accident situations require in general a phase(s) for the stabilisation of the situation at the facility, depending on the impact of the accident.

Modifying the ISDC to reflect the above situations could make the costs associated with such activities “more easily identifiable” in cost estimates.

### 5.2. Presenting the proposed potential additions to ISDC

In line with the ISDC structure described in Chapter 2, the following approach was used to describe proposed additions to the ISDC:

- keep the existing ISDC Level 1, ISDC principal activities 1 through 11, modifying the descriptor if necessary;
- keep existing ISDC Level 2, Activity Groups, modifying the descriptor of a group if necessary;

- add proposed additions at ISDC Level 2, where relevant, only at the end of the existing activity groups;
- keep existing definitions at ISDC Level 3, Typical Activities, extending/modifying the descriptor of an activity where necessary;
- add any proposed new activities at ISDC Level 3, where necessary, only at the end of existing typical activities.

This approach was chosen to ensure the existing ISDC cost structure can be maintained and provide the possibility to clearly introduce proposed new additional activities.

In potential changes to the ISDC 2012:

- new items are highlighted in red;
- modifications to existing items are highlighted in yellow;
- the ISDC segments for which no modifications are suggested are not presented in the analysis.

A full integrated list of ISDC decommissioning activities with these potential changes is presented in Appendix A.

Additional specific cost items could be added below the third ISDC hierarchical level and could be used to further differentiate detailed sub-activities within defined activities. ISDC defines only three levels for the ISDC cost structure and considers additional numbering below the third level as optional.

### 5.3. Principal Activity ISDC 01 “Pre-decommissioning actions”

ISDC 01 includes the activities until obtaining the licence for the decommissioning project. Identified additional activities for legacy/complex and post-accident sites:

- planning at the programme level; some individual projects may require reflecting the relation of complex sites at the programme level; long-term programmes and relations to individual decommissioning/remediation projects, programme vs. project levels;
- post-accident planning for the period of termination of operation; specific planning is needed for the period of termination of operation due to long-term period and non-standard situation in the facility after accidents;
- survey and analysis of waste forms may require additional/specific procedures;
- information models are one of the recent trends in developing/optimisation of facility data for supporting decommissioning;
- safety, security and environmental aspects may require procedures additional to standard decommissioning cases;
- due to various options of end states of legacy sites, the characterisation and modelling of end states should be included;
- changes in ownership may represent additional cost in specific cases, additional to typical stakeholder activities.

**Table 5.1. Potential modification of ISDC 01 (item 01.0600 remains)**

01	Pre-decommissioning actions
<b>01.0100</b>	<b>Decommissioning and remediation planning</b>
01.0101	Strategic planning
01.0102	Preliminary planning
01.0103	Final planning
01.0104	Planning at the programme level
01.0105	Post-accident planning for the period of termination of operation
<b>01.0200</b>	<b>Facility/site characterisation and information models</b>
01.0201	Detailed facility/site characterisation and historical site assessment
01.0202	Hazardous-material surveys and analyses
01.0203	Establishing a facility inventory database
01.0204	Survey and analyses of residues specific for legacy/complex and post-accident sites
01.0205	Establishment of integrated information systems
<b>01.0300</b>	<b>Safety-, security- and environmental studies</b>
01.0301	Decommissioning/remediation safety analysis
01.0302	Environmental impact assessment and environmental protection plans
01.0303	Safety-, security and emergency planning for site operations
01.0304	Additional safety analysis for legacy/complex and post-accident sites
<b>01.0400</b>	<b>Waste management and site end state planning</b>
01.0401	Establishing waste management and clearance criteria
01.0402	Develop a waste management plan
01.0403	Site end state consideration, criteria, planning and modelling
<b>01.0500</b>	<b>Authorisation</b>
01.0501	Licence applications and licence approvals
01.0502	Stakeholder involvement
01.0503	Regulatory and ownership aspects for legacy/complex and post-accident sites

**Summary:**

- potential modification of some existing titles was included;
- specific aspects of planning were included;
- new trends – information models, were reflected under 01.0200 (item 01.0205);
- remediation of legacy sites may include extensive characterisation; complex examples are presented in the “European Radiation Survey and Site Execution Manual” (EURSSEM, 2009);
- end state planning should be included; in order not to open a new item at Level 2, a new item at the Level 3 could be included under 01.0400;
- waste management techniques specific for legacy sites are reflected in ISDC 05;
- the cost of changing ownership in the planning phase which is allocated to the decommissioning project is reflected in 01.0503; additional costs related to changing ownership during the decommissioning project may be allocated to ISDC 11.0100.

**5.4. Principal Activity ISDC 02 “Facility shutdown activities”**

ISDC 02 includes the activities of the transition period before obtaining the decommissioning licence and the start of decommissioning activities of a decommissioning

project. Original items from the ISDC 2012 remain; there are two potential modifications and two new items:

- modification of text in 02.0102 to highlight that this item is related to reactors;
- adding new item 02.0509 related to the removal of materials requiring specific procedures.

New activities were identified as follows:

- a new item at Level 2, 02.0600, and a set of activities at Level 3 related to management of post-accident situations to enable the start of decommissioning, as proposed and presented in Appendix B;
- a new item at Level 2, 02.0700 and a set of activities at Level 3 for preparation of an abandoned or poorly managed legacy site for decommissioning/remediation; abandoned legacy sites or sites with limited control will need to establish or restore the controlled area prior to obtaining the licence for decommissioning/remediation.

**Table 5.2. Type Potential modification of ISDC 02 (items 02.0200 to 02.0400 remained unchanged)**

<b>02</b>	<b>Facility shutdown activities and/or preparation for decommissioning/remediation</b>
<b>02.0100</b>	<b>Plant shutdown and inspection</b>
02.0101	Termination of operation, plant stabilisation, isolation and inspection
02.0102	Defueling and transfer of fuel to spent-fuel storage <i>in reactor buildings</i>
02.0103	Cooling down of spent fuel
02.0104	Management of fuel, fissile and other nuclear materials
02.0105	Isolation of power equipment
02.0106	Facility reuse
<b>02.0500</b>	<b>Removal of system fluids, operational waste and redundant material</b>
02.0501	Removal of combustible material
02.0502	Removal of system fluids (water, oils, etc.)
02.0503	Removal of special process fluids
02.0504	Removal of waste from decontamination
02.0505	Removal of spent resins
02.0506	Removal of specific operational waste from fuel cycle facilities
02.0507	Removal of other waste from facility operations
02.0508	Removal of redundant equipment and materials
02.0509	Removal of materials requiring specific procedures (e.g. explosives)
<b>02.0600</b>	<b>Specific post-accident actions for the period of termination of operation</b>
02.0601	Procurement of specific equipment for the period of termination of operation
02.0602	Physical, radiological and hazards characterisation
02.0603	Monitoring, sampling, and measurement of affected systems and structures
02.0604	Management of impacts of accidents on systems and structures; additional confinement systems, shielding
02.0605	Management of safety systems affected by accidents and/or additional safety systems; operation of systems
02.0606	Management of impact of accidents on the environment and groundwater; exclusion zones
02.0607	Management of fuel, fissile and other nuclear materials affected by accidents; criticality safety
02.0608	Dismantling/removal activities to enable start of decommissioning
02.0609	Decontamination activities to enable start of decommissioning
02.0610	Other activities during the period of termination of operation in post-accident sites
<b>02.0700</b>	<b>Preparation of legacy sites for decommissioning/remediation</b>
02.0701	Re-arrangement and/or establishment of controlled areas for legacy sites
02.0702	Measures for legacy sites without controlled areas
02.0703	Other actions for preparation of legacy sites for decommissioning/remediation

Summary:

- modification of the title of Principal Activity ISDC 02; one existing title at Level 2 and addition of one new item to 02.0500 were included;
- a new set of activities for post-accident situations according to the *Managing the Decommissioning and Remediation of Damaged Nuclear Facilities* were included (IAEA, 2021c) (See Appendix B, Chapter 4)
- new activities for establishment/restoration of the controlled areas at legacy sites were included.

## 5.5. Principal Activity ISDC 03 “Additional activities for safe enclosure or entombment”

ISDC 03 includes the activities to ensure long-term safety during safe enclosure and/or activities to achieve the status of the facility relevant to the entombment decommissioning strategy.

Two items could be added for post-accident facilities. It is assumed that decommissioning and remediation of legacy sites, once started, will not implement the deferred strategy. If some periods of deferring are included into decommissioning/remediation projects, the items ISDC 03, 06, 11 (existing and new proposed) can be used properly.

**Table 5.3. Potential modification of ISDC 03 (item 03.0300 remains)**

03	Additional activities for safe enclosure or entombment
<b>03.0100</b>	<b>Preparation for safe enclosure</b>
03.0101	Decontamination of selected components and areas to facilitate safe enclosure
03.0102	Zoning for long-term storage
03.0103	Removal of inventory not suitable for safe enclosure
03.0104	Dismantling and transfer of contaminated equipment and material to containment structure for long-term storage
03.0105	Radiological inventory characterisation for safe enclosure
03.0106	Other activities for safe enclosure for post-accident sites
<b>03.0200</b>	<b>Site boundary reconfiguration, isolating and securing structures</b>
03.0201	Modification of auxiliary systems
03.0202	Site boundary reconfiguration
03.0203	Construction of temporary enclosures, stores, structural enhancement, etc.
03.0204	Stabilisation of radioactive and hazardous waste pending remediation
03.0205	Facility controlled area hardening and isolation for safe enclosure
03.0206	Other site related activities for post-accident sites

Summary:

- Items for safe enclosure for post-accident cases were identified under items 03.0106 and 03.02.06.

## 5.6. Principal Activity ISDC 04 “Dismantling activities within the controlled area”:

ISDC 04 includes the activities for removal of the radioactivity from components and buildings in the controlled area to the level of releasing the buildings from the regulatory control prior to its industrial demolition and the removal of the radioactivity from the site to the level of releasing the site. Any generated waste is managed in ISDC 05.

Text modifications in titles are identified for 04.0203, 04.0800, 04.0802. Minor additional activities are identified for ISDC 04.0100, 04.0400, 04.0800; no additional activities are identified for ISDC 04.0300, 04.0500 to 04.0700.

New item 04.0803 would represent activities for the removal of contaminated items out of the site boundary. An example is the contamination of water discharge systems as the consequence of accidents.

The ISDC 04 does not involve removal of radioactivity from large, contaminated areas typical for some types of legacy sites (former mines and ore processing areas, for example). These waste types are considered residues from past activities; management of these residues is in ISDC 05.

An additional specific item at the ISDC Level 2 is for the 04.1000 to include sub-items at Level 3, identified for decommissioning of underground structures.

**Table 5.4. Potential modification of ISDC 04 (items 04.0300, 04.0500, 04.0600, 04.0700 and 04.0900 remained unchanged)**

<b>04</b>	<b>Dismantling activities within the controlled area</b>
<b>04.0100</b>	<b>Procurement of equipment for decontamination and ...</b>
04.0101	Procurement for general site-dismantling equipment
04.0102	Procurement of equipment for decontamination of personnel and tools
04.0103	Procurement of special tools for dismantling the reactor systems
04.0104	Procurement of special tools for dismantling in fuel cycle facilities
04.0105	Procurement of special tools for dismantling of other components or structures
04.0106	Procurement of special tools for decommissioning/remediation at legacy/complex and post-accident sites
<b>04.0200</b>	<b>Preparations and support for dismantling</b>
04.0201	Reconfiguration of existing services, facilities and site to support dismantling
04.0202	Preparation of infrastructure and logistics for dismantling
04.0203	On-going radiological characterisation during dismantling/remediation
<b>04.0400</b>	<b>Removal of materials requiring specific procedures</b>
04.0401	Removal of thermal insulation
04.0402	Removal of asbestos
04.0403	Removal of other hazardous materials
04.0404	Removal of specific and/or mixed waste forms
<b>04.0800</b>	<b>Removal of contamination from areas outside buildings and sites</b>
04.0801	Removal of underground contaminated pipes and structures
04.0802	Removal of contaminated soil, subsoil and other contaminated items
04.0803	Removal of contaminated items out of the site area due to leakages and/or accidents
<b>04.1000</b>	<b>Decommissioning of underground structures</b>
04.1001	Decontamination in underground structures
04.1002	Dismantling in underground structures
04.1003	Final survey of underground structure and release of structures
04.1004	Declassification of underground structures
04.1005	Other activities for decommissioning of underground structures

Summary:

- modification of some existing titles was included;
- minor items related specifically to legacy sites were included;
- removal of radioactivity out of the site is included (consequence of leakages, accidents, incorrect discharges, etc.);
- a new item is proposed on the decommissioning of underground structures with the aim to achieve the status equivalent to 04.0900, i.e. a status with the declaration that radioactivity content in underground structures is below the legal limits;
- after the declaration that the radioactivity is below limits, industrial techniques for the closure of underground structures (physical barriers, backfilling...) can be implemented, 07.0304.

### 5.7. Principal Activity ISDC 05 “Waste processing, storage and disposal”

ISDC 05 (2012) includes overall waste management in a decommissioning project, including the establishment, operation and decommissioning of the waste management (WM) system for a decommissioning project. The waste classification is made according to the IAEA waste classification, i.e. ILW, LLW, VLLW, VSLW, EW and non-radiological waste. Various WM options are envisaged – an own WM system, a shared system, or just external WM services.

Grouping of existing (2012) ISDC 05 items is as follows:

- Item 05.0100 deals with the establishment, operation and decommissioning of the WM system for the decommissioning project; some specific aspects can be identified for legacy site projects;
- Items 05.0200 to 05.0600 deal with historical/legacy waste according to the IAEA waste classification, involved in the decommissioning project (IAEA, 2009);
- Items 05.0700 to 05.1200 deal with waste from decommissioning activities involved in the decommissioning project, according to the IAEA waste classification (IAEA, 2009);
- Item 05.1300 deals with the radioactive waste generated out of the controlled area, i.e. non-radioactive waste.

General comments to ISDC 05 in relation to legacy sites:

- Waste from decommissioning of buildings, systems, components and structures at legacy sites can be managed in existing items 05.0700 to 05.1300. The items 05.0200 to 05.0600 can be used for retrieval/management of waste in former designed structures such as underground tanks.
- Waste items typical for legacy sites related to former mining and or processing are large volumes of solid and/or liquid waste with specific chemical, physical and radiological properties; waste types and properties are presented in IAEA document *Management of Residues Containing Naturally Occurring Radioactive Material from Uranium Production and Other Activities* (IAEA, 2021b).
- Typical techniques for managing these waste types are presented in the IAEA document (IAEA, 2021b); these techniques were proposed for the new item at the Level 2, 04.1400 for management of residues from legacy sites.

- It is assumed that the post-accident waste will be managed within existing ISDC 05 items; possible modifications of the titles 05.0200 to 05.0600 are included.
- In case of conversion of legacy sites to the final disposal site, a new item at Level 2, 05.1500, is included. The item would include approaches/techniques for long-term stabilisation of the waste on site and/or additional engineering barriers.
- Management of underground water is identified as a possible new item at Level 2, 05.1600.

**Table 5.5. Potential modification of ISDC 05 (items 05.0200 to 05.0600 with modification of titles related to post-accident cases; items 05.0700 to 05.1100 remained unchanged)**

05	Waste processing, storage and disposal
<b>05.0100</b>	<b>Waste management system</b>
05.0101	Establishing the waste management system
05.0102	Reconstruction of existing facilities for decommissioning waste management system
05.0103	Procurement of additional equipment for management of historical/legacy waste
05.0104	Maintenance, surveillance and operational support for waste management system
05.0105	Demobilisation/decommissioning of waste management system
05.0106	Specific arrangements for waste management system related to legacy/complex and post-accident sites
<b>05.1200</b>	<b>Management of decommissioning exempt waste and materials</b>
05.1201	Treatment and packaging
05.1202	Clearance measurement of exempt waste and materials
05.1203	Transport of hazardous/mixed waste
05.1204	Disposal of hazardous/mixed waste at dedicated waste dumps
05.1205	Transport of conventional waste and materials
05.1206	Disposal of conventional waste at conventional dumps
<b>05.1300</b>	<b>Management of decommissioning waste generated outside ...</b>
05.1301	Recycling of concrete
05.1302	Treatment and packaging of hazardous/mixed materials
05.1303	Treatment and recycling of other materials
05.1304	Transport of hazardous/mixed waste
05.1305	Disposal of hazardous/mixed waste at dedicated waste dumps
05.1306	Transport of conventional waste and materials
05.1307	Disposal of conventional waste at conventional waste dumps
<b>05.1400</b>	<b>Management of residues at legacy sites</b>
05.1401	Preparatory actions for management of residues
05.1402	Pretreatment of residues
05.1403	Treatment of residues
05.1404	Conditioning and disposal of residues
05.1405	Clearance, reuse and recycling of residues
05.1406	Storage and retrieval of residues
05.1407	Long-term management of residues
05.1408	Other actions for management of residues
<b>05.1500</b>	<b>Long-term stabilisation of waste at legacy sites</b>
05.1501	Establishment of additional engineering barriers on site
05.1502	Stabilisation of existing waste on site
05.1503	Other actions for stabilisation of waste forms at legacy sites
05.1504	Converting the site or its part to permanent disposal site
<b>05.1600</b>	<b>Management of underground waters</b>
05.1601	Pumping of underground waters
05.1602	Treatment of underground waters
05.1603	Other actions for management of underground waters

Summary:

- Modification of some existing titles was included.
- Titles of items 05.0200, 05.0300, 05.0400, 05.0500 and 05.0600 were extended to cover also post-accident waste (see Appendix A).
- The ISDC 2012 was proposed for extension for management of residues from legacy sites, for long-term stabilisation of waste on site and for management of underground waters.
- Sealed/other radiation sources can be allocated to existing ISDC 05.0300 or 05.0400.
- Examples of techniques for 05.1400, 05.1500 and 05.1600 are presented in the “European Radiation Survey and Site Execution Manual” (EURSSEM, 2009).
- Final remediation of areas after removal of residues is in ISDC 07.

## 5.8. Principal Activity ISDC 06 “Site infrastructure and operation”

ISDC 06 includes the on-site activities for supporting the decommissioning/remediation activities at the site level. Items ISDC 06.0100 to 06.0300 represent standard site supporting activities.

In some cases, especially for cases related to accidents during operation, additional activities may be considered in case of ISDC 06.0400, for example additional safety measures or modified emergency preparedness.

In standard decommissioning cases, the site infrastructure and operation for decommissioning is the modified infrastructure from the operational period. In case of partially/fully abandoned cases, the site infrastructure should be established and/or reconstructed.

**Table 5.6. Potential modification of ISDC 06 (items 06.0100 to 06.0300 remained unchanged)**

06	Site infrastructure and operation
<b>06.0400</b>	<b>Radiation and environmental safety monitoring and safety measures</b>
06.0401	Procurement and maintenance of equipment for radiation protection and environmental monitoring
06.0402	Radiation protection and monitoring
06.0403	Environmental protection and radiation environmental monitoring
06.0404	Safety measures on site including emergency preparedness for legacy and post-accident sites
06.0405	Safety measures out of the site including emergency preparedness for legacy and post-accident sites
<b>06.0500</b>	<b>Establishment/reconstruction of infrastructure at legacy, complex sites and post-accident sites</b>
06.0501	Establishment/reconstruction of infrastructure at legacy/complex sites
06.0502	Reconstruction of infrastructure for decommissioning projects at post-accident sites

Summary:

- possible extension of ISDC 06.0400 when considering legacy and post-accident cases is included;
- possible new item 06.0500 to re-establish infrastructure at legacy, complex and post-accident sites is included.

## 5.9. Principal Activity ISDC 07 “Conventional dismantling and demolition and site restoration”

ISDC 07 includes the activities for the dismantling/demolition of non-radioactive components/systems/buildings (non-active), demolition of former buildings in the controlled area after releasing the buildings to industrial demolition in ISDC 04.0900, site remediation and site release activities and future management/options of those parts of the sites which will remain under regulatory control.

Possible new items identified for legacy/complex sites as additional to the ISDC 2012 cover:

- site remediation according to the planned end state;
- management of selected parts of the site after the site release.

**Table 5.7. Potential modification of ISDC 07 (items 07.0100 to 07.0200 remained unchanged)**

07	<b>Conventional dismantling and demolition and site restoration/surveillance</b>
<b>07.0300</b>	<b>Demolition of buildings and structures</b>
07.0301	Demolition of buildings and structures from the formerly controlled area
07.0302	Demolition of buildings and structures from outside the formerly controlled area
07.0303	Dismantling of the stack
07.0304	Closure of underground structures
<b>07.0400</b>	<b>Final cleanup and landscaping and preparation for long-term stewardship</b>
07.0401	Earthworks, landworks
07.0402	Landscaping and other site finishing activities
07.0403	Refurbishment of buildings and site
07.0404	Specific post-remediation activities for legacy and post-accident sites
07.0405	Preparation for short-term and long-term stewardship
<b>07.0500</b>	<b>Final radioactivity survey of site</b>
07.0501	Final survey and release of the site
07.0502	Independent verification of the final survey
<b>07.0600</b>	<b>Perpetuity funding/surveillance for limited or restricted release of property</b>
07.0601	Routine maintenance
07.0602	Surveillance, monitoring and stewardship of areas remaining under control
07.0603	Integrating the site to national monitoring programmes

### Summary:

- modification of the ISDC 07 Principal Activity and one item at Level 2 was included;
- remediation of areas may include various techniques including techniques for covering the areas of legacy sites;
- definition of end states is the key issue;
- stewardship at various levels for parts of the sites which remain under regulatory control; examples of stewardship approaches and activities are presented in “European Radiation Survey and Site Execution Manual” (EURSSEM, 2009);
- large areas of legacy sites compared with a standard decommissioning project for a reactor nuclear facility; accessibility, transport options to the site may represent significant cost;

- site release activities may be more complex and may include specific/additional approaches.

Examples for final site remediation:

- multi-layers covering systems for recovered areas with grass;
- forest-based approach;
- protective covering foils (Case Study 8. Capriano del Colle special waste dump, Italy).

## 5.10. Principal Activity ISDC 08 “Project management, engineering and support”

ISDC 08 includes the activities for project management, engineering and other project support activities within the scope of a decommissioning project; mobilisation/demobilisation activities are included. Existing typical ISDC 08 activities 08.0200, 08.0300 and 08.0400 for the licensee owner and the contractor(s) activities 08.0700, 08.0800 and 08.090, seem to be sufficient.

Specific aspects related to legacy/complex and post-accident sites may include:

- mobilisation and demobilisation activities may include additional specific activities and extents, both for the segment of the licensee owner and for the contractor(s);
- various options of sharing the project management, supporting and health and safety activities in case of complex sites and multi-projects approaches may be implemented.

**Table 5.8. Potential modification of ISDC 08 (items 08.0200 to 08.0400 and 08.0600 to 08.0900 remained unchanged)**

08	Project management, engineering and support
<b>08.0100</b>	<b><i>Mobilisation and preparatory work</i></b>
08.0101	Mobilisation of personnel
08.0102	Establishment of general supporting infrastructure for decommissioning project
08.0103	Specific mobilisation activities related to legacy/complex and post-accident sites
<b>08.0500</b>	<b><i>Demobilisation</i></b>
08.0501	Demobilisation of project infrastructure for decommissioning
08.0502	Demobilisation of personnel
08.0503	Specific demobilisation activities related to legacy/complex and post-accident sites
<b>08.0600</b>	<b><i>Mobilisation and preparatory work by contractors (if needed)</i></b>
08.0601	Mobilisation of personnel
08.0602	Establishment of general supporting infrastructure for decommissioning project
08.0603	Specific mobilisation activities related to legacy/complex and post-accident sites
<b>08.1000</b>	<b><i>Demobilisation by contractors (if needed)</i></b>
08.1001	Demobilisation of project infrastructure for decommissioning
08.1002	Demobilisation of personnel
08.1003	Specific demobilisation activities related to legacy/complex and post-accident sites

## Summary:

- Only mobilisation/demobilisation activities may require additional specific activities.

### 5.11. Principal Activity ISDC 09 “Research and development (R&D)”

ISDC 09 includes the R&D activities for new techniques/processes/simulations/information systems which are not available at the planning stage of the decommissioning project. Recently, a new area for building information models (BIM) for decommissioning has been emerging.

ISDC 09.0100 covers any R&D activities, development of equipment, techniques and procedures for characterisation, decontamination, dismantling and waste management; this extent covers also legacy/complex and post-accident cases.

Specific aspects related to legacy/complex and post-accident sites may include:

- additional/specific R&D activities for new techniques/processes/simulations specific to legacy/complex sites; these are covered by 09.0204;
- modelling of end states of decommissioning/remediation is proposed that may be relevant also for standard decommissioning cases;
- possible new item 09.0300 with its sub-items is proposed as the general item resulting from recent trends in R&D support in decommissioning.

**Table 5.9. Possible modification of ISDC 09 (item 09.0100 remained unchanged)**

09	Research and development
<b>09.0200</b>	<b><i>Simulation of complicated works and computer modelling</i></b>
09.0201	Physical mock-ups and training
09.0202	Test or demonstration programmes
09.0203	Computer simulations, visualisations and 3D modelling
09.0204	Other <b>simulation</b> activities
09.0205	<b>Modelling of site end states of decommissioning/remediation</b>
<b>09.0300</b>	<b><i>Integrated information models</i></b>
09.0301	<b>Operation and updating of integrated information models</b>
09.0302	<b>Use of integrated information models in specific areas (planning, costing, protection...)</b>
09.0303	<b>Other activities related to information models</b>

## Summary:

- ISDC 09 covers in principle also aspects of legacy/complex and post-accident cases;
- 09.0205 could be extended to cover the modelling of site end states of decommissioning/remediation in general;
- proposed new items for ISDC 09.0300 and its sub-items were included. (See Appendix B, Chapter 4)

## 5.12. Principal Activity ISDC 10 “Fuel and nuclear material”:

ISDC 10 includes the activities for fuel and nuclear material management, within the scope of a decommissioning project, after transport of fuel and nuclear material out of the controlled area of the nuclear facility.

Management of fuel and nuclear materials at legacy/complex and post-accident sites may include:

- additional activities related to specific nuclear materials, e.g. plutonium-contaminated materials (PCM);
- transport of damaged fuel, fuel debris and nuclear materials from post-accident sites.

In standard decommissioning activities of nuclear power plants, spent fuel that is transported out of the facility to a centralised long-term interim storage (at a national level or corporate level), is managed under spent fuel management projects.

ISDC 2012 items 10.0200 “Dedicated buffer storage for fuel and/or nuclear material” and ISDC 10.0300 “Decommissioning of buffer storage” were assumed only for research reactors, where the buffer spent fuel storage is needed for short-term storage to enable the start of decommissioning activities (spent fuel should be removed from the facility to be decommissioned prior to the start of decommissioning).

However, there are countries where the interim storage of spent fuel is part of licensing and funding of the decommissioning project due to the lack of a centralised or out-of-the-site interim spent fuel storage.

In order to account for such situations, ISDC 10 “Fuel and nuclear material” could be extended to also cover interim on-site spent fuel storages as part of decommissioning projects.

**Table 5.10. Potential modification of ISDC 10 (items 10.0200, 10.0300 remained with modified titles)**

10	Fuel and nuclear material
10.0100	<b>Removal of fuel or nuclear materials from facility to be decommissioned</b>
10.0101	Transfer of fuel or nuclear materials to external storage or to treatment facilities
10.0102	Transfer of fuel or nuclear materials to dedicated buffer store
10.0103	Transport of damaged fuel, fuel debris and nuclear materials from post-accident sites
10.0104	Management of plutonium contaminated materials and/or other specific nuclear materials
<b>10.0200</b>	<b>Dedicated buffer/interim storage for fuel and/or nuclear materials</b>
10.0201	Construction of buffer/interim storage
10.0202	Operation of buffer/interim storage
10.0203	Transfer of fuel and/or nuclear materials away from the buffer/interim storage
<b>10.0300</b>	<b>Decommissioning of buffer/interim storage</b>
10.0301	Decommissioning of buffer/interim storage
10.0302	Management of waste from decommissioning of buffer/interim storage

Summary:

- potential additional spent fuel management activities for legacy/complex and post-accident sites were included;
- in order to ensure the cost presentation format also includes cost for on-site storage of spent fuel from nuclear power plants, potential title modifications to items 10.0200 and 10.0300 were included.

### 5.13. Principal Activity ISDC 11 “Miscellaneous costs”

The ISDC 11 includes the activities which cannot be allocated directly to ISDC items 01 to 10.

Specifics of management of legacy/complex sites may include:

- involvement of specific stakeholders or transition period related activities, sub-projects; 11.0101, 11.0102, 11.0104;
- changes of ownership that may require additional periodical or permanent payments, to authorities; 11.0103;
- long-term management of selected parts of legacy sites or decommissioning projects that require specific funding arrangements; potential new item 11.0105 is proposed;
- specific payments, taxes, insurances; 11.0200, 11.0300;
- assets from sale of the land.

**Table 5.11. Potential modification of ISDC 11 (items 11.0200 to 11.0400 remained unchanged)**

11	Miscellaneous expenditures
<b>11.0100</b>	<b>Owner costs</b>
11.0101	Implementation of transition plans
11.0102	External project to be performed as a consequence of decommissioning, <b>remediation and/or accidents</b>
11.0103	Payments (fees) to authorities
11.0104	Specific external services and payments
<b>11.0105</b>	<b>Establishment of funds for short-term and long-term stewardship of legacy sites</b>

Summary:

- existing items of the ISDC 2012 can be effectively used;
- potential new item for ISDC 11.0105 is proposed which represents establishment of funds for future short-term and long-term stewardship of legacy site activities after the decommissioning/remediation project is completed.

## 6. Conclusions

This report presents the results of the gap analysis and preliminary identification of activities of decommissioning projects for legacy situations, complex sites and certain post-accident facilities and sites. It suggests how these costs could be made more explicit by potential additions and modifications to the ISDC cost hierarchy.

The EGCDL task group used cases for legacy and complex sites and selected IAEA documents in the context of the gap analysis of the ISDC cost structure. The report presents the summary of the results in Chapter 5 and the full analysis in Appendix B. The approach used for presenting additional activities for potential inclusion in the ISDC cost structure maintains the existing ISDC cost structure. A full list of original ISDC 2012 items with potential extensions and/or modifications of existing items from ISDC 2012 identified through this analysis is presented in Appendix A.

## 7. References

- Council of the European Union (2013a), Council Regulation (Euratom) No 1368/2013 of 13 December 2013 on Union support for the nuclear decommissioning assistance programmes in Bulgaria and the Slovak Republic, and repealing Regulations (Euratom) No 549/2007 and (Euratom) No 647/2010, Official Journal of the European Union, L346/1, <https://eur-lex.europa.eu/eli/reg/2013/1368/>. (Accessed on 29 April 2024)
- Council of the European Union (2013b), Council Regulation (EURATOM) No 1369/2013 of 13 December 2013 on Union support for the nuclear decommissioning assistance programme in Lithuania, and repealing Regulation (EC) No 1990/2006, Official Journal of the European Union, L346/7, <https://eur-lex.europa.eu/eli/reg/2013/1369/>. (Accessed on 29 April 2024)
- Council of the European Union (2009), *European Radiation Survey and Site Execution Manual (EURSEEM)*, Co-ordinated Network on Decommissioning, <https://cordis.europa.eu/docs/projects/files/508/508855/cndwp4eurssemfinalreport.pdf>. (Accessed on 29 April 2024)
- Daniska, V. (2022), “International guidance on decommissioning cost structure and its practical implementation”, in *Fundamental Issues Critical to the Success of Nuclear Projects*, Boucau J. (ed.), Woodhead Publishing Series in Energy, <https://doi.org/10.1016/B978-0-08-102472-0.00003-4>. (Accessed on 29 April 2024)
- Daniska, V. and Zachar, M. (2017), “Lessons learned from implementation of International Structure for Decommissioning Costing (ISDC) of Nuclear Installations”, paper 17198, WM2017 Conference, Phoenix.
- DOE (1980), West Valley Demonstration Project Act, Pub. L. No. 96-368, 94 Stat. 1357, US Department of Energy, [www.nrc.gov/waste/incidental-waste/wir-wvdpa.html](http://www.nrc.gov/waste/incidental-waste/wir-wvdpa.html). (Accessed on 29 April 2024)
- Electronic Code of Federal Regulations (eCFR), (n.d), Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, part 192, Washington, D.C., [www.ecfr.gov/current/title-40/chapter-I/subchapter-F/part-192](http://www.ecfr.gov/current/title-40/chapter-I/subchapter-F/part-192). (Accessed on 29 April 2024)
- Electronic Code of Federal Regulations (eCFR), (n.d), Domestic Licensing of Source Material, as amended, Washington, D.C., part 40, para 40.27, 40.28, [www.ecfr.gov/current/title-10/part-40](http://www.ecfr.gov/current/title-10/part-40). (Accessed on 29 April 2024)
- IAEA (2023), *Application of the Concept of Clearance*, IAEA Safety Standards Series No. GSG-18, International Atomic Energy Agency, Vienna.
- IAEA (2022a), *Remediation Strategy and Process for Areas Affected by Past Activities or Events*, IAEA Safety Standards Series, No. GSG-15, International Atomic Energy Agency, Vienna.
- IAEA (2022b), *The International Working Forum on the Regulatory Supervision of Legacy Sites*, IAEA-TECDOC-2016, International Atomic Energy Agency, Vienna.
- IAEA (2022c), *Decommissioning at a Multifacility Site: An Integrated Approach*, IAEA Nuclear Energy Series No. NW-T-2.13, International Atomic Energy Agency, Vienna.
- IAEA (2021a), *Data Analysis and Collection for Costing of Research Reactor Decommissioning: Final Report of the DACCORD Collaborative Project*, IAEA Nuclear Energy Series, No. NW-T-2.12, International Atomic Energy Agency, Vienna.
- IAEA (2021b), *Management of Residues Containing Naturally Occurring Radioactive Material from Uranium Production and Other Activities*, IAEA Safety Standards Series No. SSG-60, International Atomic Energy Agency, Vienna.

- IAEA (2021c), *Managing the Decommissioning and Remediation of Damaged Nuclear Facilities*, IAEA-TECDOC-1989, International Atomic Energy Agency, Vienna.
- IAEA (2021d), *Research Reactor Spent Fuel Management: Options and Support to Decision Making*, IAEA Nuclear Energy Series No. NF-T-3.9, International Atomic Energy Agency, Vienna.
- IAEA (2019a), *IAEA Safety Glossary: 2018 Edition*, Non-serial Publications, International Atomic Energy Agency, Vienna.
- IAEA (2019b), *Decommissioning after a Nuclear Accident: Approaches, Techniques, Practices and Implementation Considerations*, IAEA Nuclear Energy Series No. NW-T-2.10, International Atomic Energy Agency, Vienna.
- IAEA (2018), *Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities*, IAEA Safety Standards Series No. SSG-47, International Atomic Energy Agency, Vienna.
- IAEA (2017), *Data Analysis and Collection for Costing of Research Reactor Decommissioning: Report of the DACCORD Collaborative Project*, IAEA-TECDOC-1832, International Atomic Energy Agency, Vienna.
- IAEA (2016), *Considerations on the Application of the IAEA Safety Requirements for the Design of Nuclear Power Plants*, IAEA-TECDOC-1791, International Atomic Energy Agency, Vienna.
- IAEA (2014), *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards*, IAEA Safety Standards Series No. GSR Part 3, International Atomic Energy Agency, Vienna.
- IAEA (2009), *Classification of Radioactive Waste*, IAEA Safety Standards Series No. GSG-1, International Atomic Energy Agency, Vienna.
- IAEA (2004), *Transition from Operation to Decommissioning of Nuclear Installations*, Technical Reports Series No. 420, International Atomic Energy Agency, Vienna.
- IAEA (2002), *Decommissioning Costs of WWER-440 Nuclear Power Plants*, IAEA-TECDOC-1322, International Atomic Energy Agency, Vienna.
- NEA (forthcoming), “Holistic Process for Decision Making on Decommissioning and Management of Complex Sites”, OECD Publishing, Paris.
- NEA (2024), *Handbook Nuclear Decommissioning Cost Estimation*, OECD Publishing, Paris, [www.oecd-nea.org/jcms/pl\\_90297](http://www.oecd-nea.org/jcms/pl_90297). (Accessed on 29 April 2024)
- NEA (2020a), *Challenges in Nuclear and Radiological Legacy Site Management: Towards a Common Regulatory Framework*, OECD Publishing, Paris, [www.oecd-nea.org/jcms/pl\\_40359](http://www.oecd-nea.org/jcms/pl_40359). (Accessed on 29 April 2024)
- NEA, (2020b), “Understanding of Key Issues for the Committee on Decommissioning of Nuclear Installations and Legacy Management”, NEA/DLM(2020)2/FINAL. (Internal document only)
- NEA (2019), *Cost Benchmarking for Nuclear Power Plant Decommissioning*, OECD Publishing, Paris, [www.oecd-nea.org/jcms/pl\\_15132](http://www.oecd-nea.org/jcms/pl_15132). (Accessed on 29 April 2024)
- NEA (2017), *Addressing Uncertainties in Cost Estimates for Decommissioning Nuclear Facilities*, OECD Publishing, Paris, [www.oecd-nea.org/jcms/pl\\_15036](http://www.oecd-nea.org/jcms/pl_15036). (Accessed on 29 April 2024)
- NEA (2016), *Costs of Decommissioning Nuclear Power Plants*, OECD Publishing, Paris, [www.oecd-nea.org/jcms/pl\\_14910](http://www.oecd-nea.org/jcms/pl_14910). (Accessed on 29 April 2024)
- NEA (2012), *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations*, OECD Publishing, Paris, [www.oecd-nea.org/jcms/pl\\_14804](http://www.oecd-nea.org/jcms/pl_14804). (Accessed on 29 April 2024)

NEA (2003), *Decommissioning Nuclear Power Plants: Policies, Strategies and Costs, Nuclear Development*, OECD Publishing, Paris, [www.oecd-nea.org/jcms/pl\\_13608](http://www.oecd-nea.org/jcms/pl_13608). (Accessed on 29 April 2024)

NEA (1999), *A Proposed Standardised List of Items for Costing Purposes in the Decommissioning of Nuclear Installations*, OECD Publishing, Paris, [www.oecd-nea.org/jcms/pl\\_13260](http://www.oecd-nea.org/jcms/pl_13260). (Accessed on 29 April 2024)

Swiss Federal Council (1991), Radiological Protection Act, Art. 9, [www.fedlex.admin.ch/filestore/fedlex.data.admin.ch/eli/cc/2017/502/20210101/en/pdf-a/fedlex-data-admin-ch-eli-cc-2017-502-20210101-en-pdf-a-1.pdf](http://www.fedlex.admin.ch/filestore/fedlex.data.admin.ch/eli/cc/2017/502/20210101/en/pdf-a/fedlex-data-admin-ch-eli-cc-2017-502-20210101-en-pdf-a-1.pdf). (Accessed on 29 April 2024)

## Appendix A: Full list of original ISDC 2012 items with proposed extensions and/or modifications

**Appendix A Table 1. Full list of original ISDC 2012 items with proposed extensions and/or modifications**

No.	Summary of identified activities additional to ISDC 2013 and/or modification of existing ISDC titles
	Modification of the title
	New proposed item, additional to the ISDC 2012
<b>01</b>	<b>Pre-decommissioning actions</b>
<b>01.0100</b>	<b>Decommissioning and remediation planning</b>
01.0101	Strategic planning
01.0102	Preliminary planning
01.0103	Final planning
01.0104	Planning at the programme level
01.0105	Post-accident planning for the period of termination of operation
<b>01.0200</b>	<b>Facility/site characterisation and information models</b>
01.0201	Detailed facility/site characterisation and historical site assessment
01.0202	Hazardous-material surveys and analyses
01.0203	Establishing a facility inventory database
01.0204	Survey and analyses of residues specific for legacy/complex and post-accident sites
01.0205	Establishment of integrated information systems
<b>01.0300</b>	<b>Safety-, security- and environmental studies</b>
01.0301	Decommissioning/remediation safety analysis
01.0302	Environmental impact assessment and environmental protection plans
01.0303	Safety-, security and emergency planning for site operations
01.0304	Additional safety analysis for legacy/complex and post-accident sites
<b>01.0400</b>	<b>Waste management and site end state planning</b>
01.0401	Establishing waste management and clearance criteria
01.0402	Develop a waste management plan
01.0403	Site end state consideration, criteria, planning and modelling
<b>01.0500</b>	<b>Authorisation</b>
01.0501	Licence applications and licence approvals
01.0502	Stakeholder involvement
01.0503	Regulatory and ownership aspects for legacy/complex and post-accident sites
<b>01.0600</b>	<b>Preparing management group and contracting</b>
01.0601	Management team activities
01.0602	Contracting activities
<b>02</b>	<b>Facility shutdown activities and/or preparation for decommissioning/remediation</b>
<b>02.0100</b>	<b>Plant shutdown and inspection</b>
02.0101	Termination of operation, plant stabilisation, isolation and inspection
02.0102	Defueling and transfer of fuel to spent-fuel storage in reactor buildings
02.0103	Cooling down of spent fuel
02.0104	Management of fuel, fissile and other nuclear materials
02.0105	Isolation of power equipment
02.0106	Facility reuse
<b>02.0200</b>	<b>Drainage and drying of systems</b>
02.0201	Drainage and drying of closed systems not in operation
02.0202	Drainage of spent-fuel pool and other open systems not in operation
02.0203	Removal of sludge and products from open systems
02.0204	Drainage of special process fluids
<b>02.0300</b>	<b>Decontamination of closed systems for dose reduction</b>

No.	Summary of identified activities additional to ISDC 2013 and/or modification of existing ISDC titles
02.0301	Decontamination of process installations using operational procedures
02.0302	Decontamination of process installations using additional procedures
<b>02.0400</b>	<b>Radiological inventory characterisation to support detailed planning</b>
02.0401	Radiological inventory characterisation
02.0402	Underground water monitoring
<b>02.0500</b>	<b>Removal of system fluids, operational waste and redundant material</b>
02.0501	Removal of combustible material
02.0502	Removal of system fluids (water, oils, etc.)
02.0503	Removal of special process fluids
02.0504	Removal of waste from decontamination
02.0505	Removal of spent resins
02.0506	Removal of specific operational waste from fuel cycle facilities
02.0507	Removal of other waste from facility operations
02.0508	Removal of redundant equipment and materials
02.0509	Removal of materials requiring specific procedures (e.g. explosives)
<b>02.0600</b>	<b>Specific post-accident actions for the period of termination of operation</b>
02.0601	Procurement of specific equipment for the period of termination of operation
02.0602	Physical, radiological and hazards characterisation
02.0603	Monitoring, sampling, and measurement of affected systems and structures
02.0604	Management of impacts of accidents on systems and structures; additional confinement systems, shielding
02.0605	Management of safety systems affected by accidents and/or additional safety systems; operation of systems
02.0606	Management of impact of accidents on the environment and groundwater; exclusion zones
02.0607	Management of fuel, fissile and other nuclear materials affected by accidents; criticality safety
02.0608	Dismantling/removal activities to enable start of decommissioning
02.0609	Decontamination activities to enable start of decommissioning
02.0610	Other activities during the period of termination of operation in post-accident sites
<b>02.0700</b>	<b>Preparation of legacy sites for decommissioning/remediation</b>
02.0701	Re-arrangement and/or establishment of controlled areas for legacy sites
02.0702	Measures for legacy sites without controlled areas
02.0703	Other actions for preparation of legacy sites for decommissioning/remediation
<b>03</b>	<b>Additional activities for safe enclosure or entombment</b>
<b>03.0100</b>	<b>Preparation for safe enclosure</b>
03.0101	Decontamination of selected components and areas to facilitate safe enclosure
03.0102	Zoning for long-term storage
03.0103	Removal of inventory not suitable for safe enclosure
03.0104	Dismantling and transfer of contaminated equipment and material to containment structure for long-term storage
03.0105	Radiological inventory characterisation for safe enclosure
03.0106	Other activities for safe enclosure for post-accident sites
<b>03.0200</b>	<b>Site boundary reconfiguration, isolating and securing structures</b>
03.0201	Modification of auxiliary systems
03.0202	Site boundary reconfiguration
03.0203	Construction of temporary enclosures, stores, structural enhancement, etc.
03.0204	Stabilisation of radioactive and hazardous waste pending remediation
03.0205	Facility controlled area hardening and isolation for safe enclosure
03.0206	Other site related activities for post-accident sites
<b>03.0300</b>	<b>Facility entombment</b>
03.0301	Facility entombment as end state of decommissioning strategy
03.0302	Institutional control and monitoring of the entombment end state
<b>04</b>	<b>Dismantling activities within the controlled area</b>
<b>04.0100</b>	<b>Procurement of equipment for decontamination and ...</b>
04.0101	Procurement for general site-dismantling equipment
04.0102	Procurement of equipment for decontamination of personnel and tools

No.	Summary of identified activities additional to ISDC 2013 and/or modification of existing ISDC titles
04.0103	Procurement of special tools for dismantling the reactor systems
04.0104	Procurement of special tools for dismantling in fuel cycle facilities
04.0105	Procurement of special tools for dismantling of other components or structures
04.0106	Procurement of special tools for decommissioning/remediation at legacy/complex and post-accident sites
<b>04.0200</b>	<b>Preparations and support for dismantling</b>
04.0201	Reconfiguration of existing services, facilities and site to support dismantling
04.0202	Preparation of infrastructure and logistics for dismantling
04.0203	On-going radiological characterisation during dismantling/remediation
<b>04.0300</b>	<b>Pre-dismantling decontamination</b>
04.0301	Drainage of remaining systems
04.0302	Removal of sludge and products from remaining systems
04.0303	Decontamination of remaining systems
04.0304	Decontamination of areas in buildings
<b>04.0400</b>	<b>Removal of materials requiring specific procedures</b>
04.0401	Removal of thermal insulation
04.0402	Removal of asbestos
04.0403	Removal of other hazardous materials
04.0404	Removal of specific and/or mixed waste forms
<b>04.0500</b>	<b>Dismantling of main process systems, structures and components</b>
04.0501	Dismantling of reactor internals
04.0502	Dismantling of reactor vessel and core components
04.0503	Dismantling of other primary loop components
04.0504	Dismantling of main process systems in fuel cycle facilities
04.0505	Dismantling of main process systems in other nuclear facilities
04.0506	Dismantling of external thermal/biological shields
<b>04.0600</b>	<b>Dismantling of other systems and components</b>
04.0601	Dismantling of auxiliary systems
04.0602	Dismantling of remaining components
<b>04.0700</b>	<b>Removal contamination from building structures</b>
04.0701	Dismantling of embedded elements in buildings
04.0702	Removal of contaminated structures
04.0703	Decontamination of buildings
<b>04.0800</b>	<b>Removal of contamination from areas outside buildings and sites</b>
04.0801	Removal of underground contaminated pipes and structures
04.0802	Removal of contaminated soil, subsoil and other contaminated items
04.0803	Removal of contaminated items out of the site area due to leakages and/or accidents
<b>04.0900</b>	<b>Final radioactivity survey for release of buildings</b>
04.0901	Final radioactivity survey in buildings
04.0902	Declassification of buildings
<b>04.1000</b>	<b>Decommissioning of underground structures</b>
04.1001	Decontamination in underground structures
04.1002	Dismantling in underground structures
04.1003	Final survey of underground structure and release of structures
04.1004	Declassification of underground structures
04.1005	Other activities for decommissioning of underground structures
<b>05</b>	<b>Waste processing, storage and disposal</b>
<b>05.0100</b>	<b>Waste management system</b>
05.0101	Establishing the waste management system
05.0102	Reconstruction of existing facilities for decommissioning waste management system
05.0103	Procurement of additional equipment for management of historical/legacy waste
05.0104	Maintenance, surveillance and operational support for waste management system
05.0105	Demobilisation/decommissioning of waste management system

No.	Summary of identified activities additional to ISDC 2013 and/or modification of existing ISDC titles
05.0106	Specific arrangements for waste management system related to legacy/complex and post-accident sites
<b>05.0200</b>	<b>Management of historical/legacy and post-accident high-level waste</b>
05.0201	Characterisation
05.0202	Retrieval and processing
05.0203	Final conditioning
05.0204	Storage
05.0205	Transport
05.0206	Disposal
05.0207	Containers
<b>05.0300</b>	<b>Management of historical/legacy and post-accident intermediate level waste</b>
05.0301	Characterisation
05.0302	Retrieval and processing
05.0303	Final conditioning
05.0304	Storage
05.0305	Transport
05.0306	Disposal
05.0307	Containers
<b>05.0400</b>	<b>Management of historical/legacy and post-accident low-level waste</b>
05.0401	Characterisation
05.0402	Retrieval and processing
05.0403	Final conditioning
05.0404	Storage
05.0405	Transport
05.0406	Disposal
05.0407	Containers
<b>05.0500</b>	<b>Management of historical/legacy and post-accident very low-level waste</b>
05.0501	Characterisation
05.0502	Retrieval, treatment and packaging
05.0503	Transport
05.0504	Disposal
<b>05.0600</b>	<b>Management of historical/legacy and post-accident exempt waste and materials</b>
05.0601	Retrieval, treatment and packaging
05.0602	Clearance measurement of exempt waste and materials
05.0603	Transport of hazardous waste
05.0604	Disposal of hazardous waste at dedicated waste dumps
05.0605	Transport of conventional waste and materials
05.0606	Disposal of conventional waste at conventional dumps
<b>05.0700</b>	<b>Management of decommissioning high-level waste</b>
05.0701	Characterisation
05.0702	Retrieval and processing
05.0703	Final conditioning
05.0704	Storage
05.0705	Transport
05.0706	Disposal
05.0707	Containers
<b>05.0800</b>	<b>Management of decommissioning intermediate level waste</b>
05.0801	Characterisation
05.0802	Retrieval and processing
05.0803	Final conditioning
05.0804	Storage
05.0805	Transport
05.0806	Disposal

No.	Summary of identified activities additional to ISDC 2013 and/or modification of existing ISDC titles
05.0807	Containers
<b>05.0900</b>	<b>Management of decommissioning low-level waste</b>
05.0901	Characterisation
05.0902	Retrieval and processing
05.0903	Final conditioning
05.0904	Storage
05.0905	Transport
05.0906	Disposal
05.0907	Containers
<b>05.1000</b>	<b>Management of decommissioning very low-level waste</b>
05.1001	Characterisation
05.1002	Treatment and packaging
05.1003	Transport
05.1004	Disposal
<b>05.1100</b>	<b>Management of decommissioning very short lived waste</b>
05.1101	Characterisation
05.1102	Treatment, storage, handling and packaging
05.1103	Final management of decommissioning very short lived waste
<b>05.1200</b>	<b>Management of decommissioning exempt waste and materials</b>
05.1201	Treatment and packaging
05.1202	Clearance measurement of exempt waste and materials
05.1203	Transport of hazardous/mixed waste
05.1204	Disposal of hazardous/mixed waste at dedicated waste dumps
05.1205	Transport of conventional waste and materials
05.1206	Disposal of conventional waste at conventional dumps
<b>05.1300</b>	<b>Management of decommissioning waste generated outside ...</b>
05.1301	Recycling of concrete
05.1302	Treatment and packaging of hazardous/mixed materials
05.1303	Treatment and recycling of other materials
05.1304	Transport of hazardous/mixed waste
05.1305	Disposal of hazardous/mixed waste at dedicated waste dumps
05.1306	Transport of conventional waste and materials
05.1307	Disposal of conventional waste at conventional waste dumps
<b>05.1400</b>	<b>Management of residues at legacy sites</b>
05.1401	Preparatory actions for management of residues
05.1402	Pretreatment of residues
05.1403	Treatment of residues
05.1404	Conditioning and disposal of residues
05.1405	Clearance, reuse and recycling of residues
05.1406	Storage and retrieval of residues
05.1407	Long-term management of residues
05.1408	Other actions for management of residues
<b>05.1500</b>	<b>Long-term stabilisation of waste at legacy sites</b>
05.1501	Establishment of additional engineering barriers on site
05.1502	Stabilisation of existing waste on site
05.1503	Other actions for stabilisation of waste forms at legacy sites
05.1504	Converting the site or its part to permanent disposal site
<b>05.1600</b>	<b>Management of underground waters</b>
05.1601	Pumping of underground waters
05.1602	Treatment of underground waters
05.1603	Other actions for management of underground waters
<b>06</b>	<b>Site infrastructure and operation</b>

No.	Summary of identified activities additional to ISDC 2013 and/or modification of existing ISDC titles
<b>06.0100</b>	<b>Site security and surveillance</b>
06.0101	Procurement of general security equipment
06.0102	Operation and maintenance of automated access control systems, monitoring systems and alarms
06.0103	Security fencing and protection of remaining entrances against trespassing
06.0104	Deployment of guards/security forces
<b>06.0200</b>	<b>Site operation and maintenance</b>
06.0201	Inspection and maintenance of buildings and systems
06.0202	Site upkeep activities
<b>06.0300</b>	<b>Operation of support systems</b>
06.0301	Electricity supply systems
06.0302	Ventilation systems
06.0303	Heating, steam and lighting systems
06.0304	Water supply systems
06.0305	Sewage/waste water systems
06.0306	Compressed air/nitrogen systems
06.0307	Other systems
<b>06.0400</b>	<b>Radiation and environmental safety monitoring and safety measures</b>
06.0401	Procurement and maintenance of equipment for radiation protection and environmental monitoring
06.0402	Radiation protection and monitoring
06.0403	Environmental protection and radiation environmental monitoring
06.0404	Safety measures on site including emergency preparedness for legacy and post-accident sites
06.0405	Safety measures out of the site including emergency preparedness for legacy and post-accident sites
<b>06.0500</b>	<b>Establishment/reconstruction of infrastructure at legacy, complex sites and post-accident sites</b>
06.0501	Establishment/reconstruction of infrastructure at legacy/complex sites
06.0502	Reconstruction of infrastructure for decommissioning projects at post-accident sites
07	<b>Conventional dismantling and demolition and site restoration/surveillance</b>
<b>07.0100</b>	<b>Procurement of equipment for conventional dismantling and demolition</b>
07.0101	Procurement of equipment for conventional dismantling and demolition
<b>07.0200</b>	<b>Dismantling of systems and building components outside of controlled area</b>
07.0201	Electricity generating system
07.0202	Cooling system components
07.0203	Other auxiliary systems
<b>07.0300</b>	<b>Demolition of buildings and structures</b>
07.0301	Demolition of buildings and structures from the formerly controlled area
07.0302	Demolition of buildings and structures from outside the formerly controlled area
07.0303	Dismantling of the stack
07.0304	Closure of underground structures
<b>07.0400</b>	<b>Final cleanup and landscaping and preparation for long-term stewardship</b>
07.0401	Earthworks, landworks
07.0402	Landscaping and other site finishing activities
07.0403	Refurbishment of buildings and site
07.0404	Specific post-remediation activities for legacy and post-accident sites
07.0405	Preparation for short-term and long-term stewardship
<b>07.0500</b>	<b>Final radioactivity survey of site</b>
07.0501	Final survey and release of the site
07.0502	Independent verification of the final survey
<b>07.0600</b>	<b>Perpetuity funding/surveillance for limited or restricted release of property</b>
07.0601	Routine maintenance
07.0602	Surveillance, monitoring and stewardship of areas remaining under control
07.0603	Integrating the site to national monitoring programmes
08	<b>Project management, engineering and support</b>
<b>08.0100</b>	<b>Mobilisation and preparatory work</b>

No.	Summary of identified activities additional to ISDC 2013 and/or modification of existing ISDC titles
08.0101	Mobilisation of personnel
08.0102	Establishment of general supporting infrastructure for decommissioning project
08.0103	Specific mobilisation activities related to legacy/complex and post-accident sites
<b>08.0200</b>	<b>Project management</b>
08.0201	Core management group
08.0202	Project implementation planning, detailed on-going planning
08.0203	Scheduling and cost control
08.0204	Safety and environmental analysis, on-going studies
08.0205	Quality assurance and quality surveillance
08.0206	General administration and accounting
08.0207	Public relations and stakeholders involvement
<b>08.0300</b>	<b>Support services</b>
08.0301	Engineering support
08.0302	Information system and computer support
08.0303	Waste management support
08.0304	Decommissioning support including chemistry, decontamination
08.0305	Personal management and training
08.0306	Documentation and records control
08.0307	Procurement, warehousing and materials handling
08.0308	Housing, office equipment, support services
<b>08.0400</b>	<b>Health and safety</b>
08.0401	Health physics
08.0402	Industrial safety
<b>08.0500</b>	<b>Demobilisation</b>
08.0501	Demobilisation of project infrastructure for decommissioning
08.0502	Demobilisation of personnel
08.0503	Specific demobilisation activities related to legacy/complex and post-accident sites
<b>08.0600</b>	<b>Mobilisation and preparatory work by contractors (if needed)</b>
08.0601	Mobilisation of personnel
08.0602	Establishment of general supporting infrastructure for decommissioning project
08.0603	Specific mobilisation activities related to legacy/complex and post-accident sites
<b>08.0700</b>	<b>Project management by contractors (if needed)</b>
08.0701	Core management group
08.0702	Project implementation planning, detailed on-going planning
08.0703	Scheduling and cost control
08.0704	Safety and environmental analysis, on-going studies
08.0705	Quality assurance and quality surveillance
08.0706	General administration and accounting
08.0707	Public relations and stakeholders involvement
<b>08.0800</b>	<b>Support services by contractors (if needed)</b>
08.0801	Engineering support
08.0802	Information system and computer support
08.0803	Waste management support
08.0804	Decommissioning support including chemistry, decontamination
08.0805	Personal management and training
08.0806	Documentation and records control
08.0807	Procurement, warehousing and materials handling
08.0808	Housing, office equipment, support services
<b>08.0900</b>	<b>Health and safety by contractors (if needed)</b>
08.0901	Health physics
08.0902	Industrial safety
<b>08.1000</b>	<b>Demobilisation by contractors (if needed)</b>

No.	Summary of identified activities additional to ISDC 2013 and/or modification of existing ISDC titles
08.1001	Demobilisation of project infrastructure for decommissioning
08.1002	Demobilisation of personnel
08.1003	Specific demobilisation activities related to legacy/complex and post-accident sites
<b>09</b>	<b>Research and development</b>
<b>09.0100</b>	<b>Research and development of equipment, techniques and procedures</b>
09.0101	Equipment, techniques and procedures for characterisation
09.0102	Equipment, techniques and procedures for decontamination
09.0103	Equipment, techniques and procedures for dismantling
09.0104	Equipment, techniques and procedures for waste management
09.0105	Other research and development activities
<b>09.0200</b>	<b>Simulation of complicated works and computer modelling</b>
09.0201	Physical mock-ups and training
09.0202	Test or demonstration programmes
09.0203	Computer simulations, visualisations and 3D modelling
09.0204	Other simulation activities
09.0205	Modelling of site end states of decommissioning/remediation
<b>09.0300</b>	<b>Integrated information models</b>
09.0301	Operation and updating of integrated information models
09.0302	Use of integrated information models in specific areas (planning, costing, protection...)
09.0303	Other activities related to information models
<b>10</b>	<b>Fuel and nuclear material</b>
10.0100	<b>Removal of fuel or nuclear materials from facility to be decommissioned</b>
10.0101	Transfer of fuel or nuclear materials to external storage or to treatment facilities
10.0102	Transfer of fuel or nuclear materials to dedicated buffer store
10.0103	Transport of damaged fuel, fuel debris and nuclear materials from post-accident sites
10.0104	Management of plutonium contaminated materials and/or other specific nuclear materials
<b>10.0200</b>	<b>Dedicated buffer/interim storage for fuel and/or nuclear materials</b>
10.0201	Construction of buffer/interim storage
10.0202	Operation of buffer/interim storage
10.0203	Transfer of fuel and/or nuclear materials away from the buffer/interim storage
<b>10.0300</b>	<b>Decommissioning of buffer/interim storage</b>
10.0301	Decommissioning of buffer/interim storage
10.0302	Management of waste from decommissioning of buffer/interim storage
<b>11</b>	<b>Miscellaneous expenditures</b>
<b>11.0100</b>	<b>Owner costs</b>
11.0101	Implementation of transition plans
11.0102	External project to be performed as a consequence of decommissioning, remediation and/or accidents
11.0103	Payments (fees) to authorities
11.0104	Specific external services and payments
11.0105	Establishment of funds for short-term and long-term stewardship of legacy sites
<b>11.0200</b>	<b>Taxes</b>
11.0201	Value added taxes
11.0202	Local, community, federal taxes
11.0203	Environmental taxes
11.0204	Taxes on industrial activities
11.0205	Other taxes
<b>11.0300</b>	<b>Insurances</b>
11.0301	Nuclear related insurances
11.0302	Other insurances
<b>11.0400</b>	<b>Asset recovery</b>
11.0401	Asset recovery related to redundant equipment
11.0402	Asset recovery related to released materials

No.	Summary of identified activities additional to ISDC 2013 and/or modification of existing ISDC titles
11.0403	Asset recovery related to material and equipment from conv. ...
11.0404	Asset recovery related to buildings and site
11.0405	Other asset recovery

## **Appendix B: Analysis of activities typical to legacy, complex and post-accident sites additional to the ISDC 2012**

Appendix B presents the analysis of decommissioning activities additional to the ISDC 2012 in the following sections:

- case studies presented in the NEA document (NEA 2020);
- analysis of management of NORM materials and sites in IAEA documents (IAEA 2021b);
- analysis of complex sites in IAEA documents (IAEA, 2022c);
- analysis of post-accident decommissioning projects in IAEA document (IAEA, 2021c, 2019b, 2018).

## 1. Analysis of Cases presented in “Challenges in Nuclear and Radiological Legacy Site Management; Towards a Common Regulatory Framework (NEA, 2020a)”

### Case Study 1. Little Forest Legacy Site, Australia

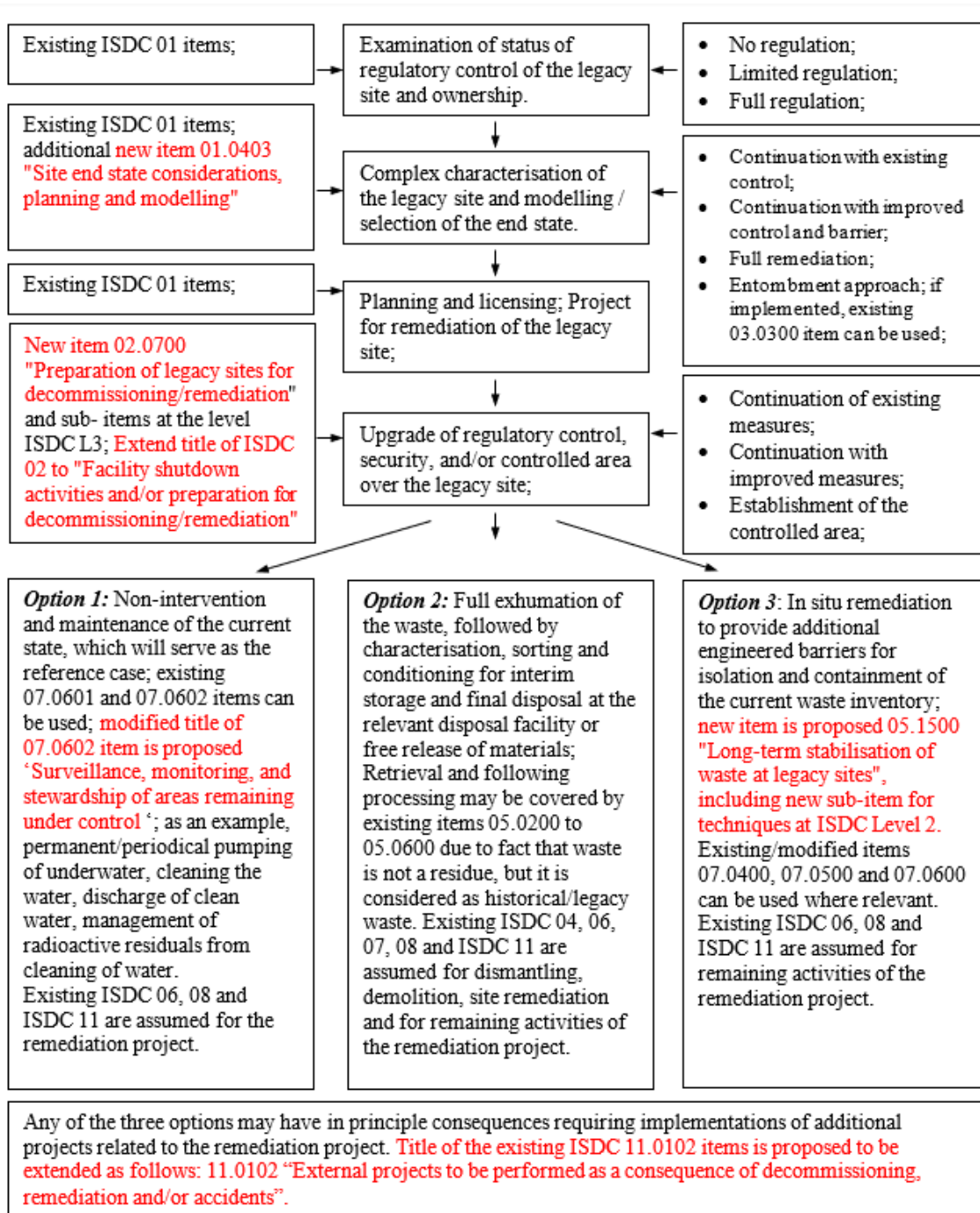
From 1960 to 1968, the former Australian Atomic Energy Commission (AAEC) disposed of radioactive waste in trenches at Little Forest, near its research facility on the southern periphery of Sydney (now a campus of the Australian Nuclear Science and Technology Organisation, ANSTO). The waste was disposed of in a series of trenches, following the international practices which were used at that time for the disposal of low-level solid and liquid wastes.

The Little Forest Legacy Site (LFLS) is situated inside the ANSTO buffer zone. It occupies a section of land where the buffer zone juts out from the 1.6 km radius circle around the former HIFAR reactor at Lucas Heights. The nearest residential area to the LFLS is the suburb of Barden Ridge, located 2.5 km to the east. The western parts of the suburb of Menai are about 3 km north-east of the LFLS. The LFLS consisted originally of a rectangular area approximately 350 m long and 115 m wide surrounded by a cyclone wire fence, which on the eastern side was close to the trenches.

Three options for solutions of the situation at the Little Forest Legacy Site were analysed. Procedure of the analysis and results of the analysis are summarised in the Figure B.1 with the identification of activities identified as additional to the ISDC 2012. The example of LFLS site provides a systematic solution for former disposal sites in three options, which may be applicable to similar situations:

- Option 1: Non-intervention and maintenance of the current state, the case can be used as the reference case;
- Option 2: Full exhumation of the waste, followed by characterisation, sorting and conditioning for interim storage and final disposal at the disposal facility or free release of materials;
- Option 3: In situ remediation of the disposed waste to provide additional engineered barriers for isolation and containment of the waste inventory.

Appendix Figure B.1. Diagram of the systematic solution for the Little Forest Legacy Site



Specific features of Case Study 1, allocation of existing ISDC 2012 items, identification of items additional to the ISDC 2012, and potential modification of existing ISDC 2012 items are listed below:

- site end state in various options should be analysed, new item is proposed, the 01.0403 Site end state considerations, planning and modelling;

- site should be prepared to activities for the systematic solution for the former disposal sites, new item to the ISDC 02 Principal Activity at the Level 2 is proposed, the ISDC 02.0700 Preparation of legacy sites for decommissioning/remediation, with new sub-items presented in the Appendix A;
- due to extension of the ISDC 02 at the Level 2, modification of the title of ISDC 02 is proposed as ISDC 02 Facility shutdown activities and/or preparation for decommissioning/remediation;
- in Option 1, the site will be under the long-term stewardship, the existing 07.0601 and 07.0602 items can be used; modification of the title of 07.0602 item is proposed as ISDC 07.0602 Surveillance, monitoring and stewardship of areas remaining under control;
- in Option 2, the retrieved waste is considered as historical waste (not a residue from past activities on site), existing items ISDC 05 to 06 can be used;
- in Option 3, for stabilisation of the waste on site and for conversion of the site to permanent disposal site, new item to the ISDC 05 Principal Activity at the Level 2 is proposed, the 05.1500 Long-term stabilisation of waste at legacy sites, with new sub-items presented in the Appendix A.

Note: Case Study 1 is the example of three principal solutions for old legacy waste sites. Underground water pumping presented in Option 1 is part of the stewardship of the site.

## Case Study 2. The Low Level Radioactive Waste Repository (LLWR), United Kingdom

The Low Level Radioactive Waste Repository (LLWR) is located on the coastal plain of West Cumbria about 0.5 km from the Irish Sea coast. The Case Study 2 presents the activities for improvement of the performance of the LLWR repository. The activities are related to the improvement of the operation of the LLWR; not to the decommissioning. The upgrading activities were undertaken with the principal aims of:

- improving management practices;
- utilising the disposal space efficiently;
- reducing the visual impact of the disposal operations;
- implementing a variety of improvements to the barrier system for containment.

The presented activities can be in principle also implemented in any decommissioning/remediation projects. The above changes were supported by new safety assessments, accounting for new site information and updated safety criteria and regulatory guidance. For activities listed below in the time sequence, existing ISDC 2012 items are allocated, or new items identified as additional to the ISDC 2012 are presented.

Specific features of Case Study 1, allocation of existing ISDC 2012 items, identification of items additional to the ISDC 2012, and potential modification of existing ISDC 2012 items are listed below:

- 1988: commencement of vault disposal operations (ISDC 05.0100 and sub-items).

- 1991: commissioning of the Marine Holding Tanks and a new marine discharge pipeline; new item is proposed, the ISDC 06.0501 Establishment/reconstruction of infrastructure at legacy, complex sites and post-accident sites.
- 1993: revised Authorisation issued under the Radioactive Substances Act 1993 (ISDC 08.0200);
- 1995: completion of Trench 7 cap and extension of cut-off wall to limit underground release of leachate from the trench disposal area; new item 05.1500 Long-term stabilisation of waste at legacy sites, with new sub-items presented in Appendix 2 can be used;
- mid-1990s: installation of temporary on-site waste treatment capabilities and LLWR waste grouting facility (ISDC 05.0100 and sub-items);
- new programme for management of PCM (plutonium contaminated materials) at LLWR from 1997; new item is proposed, the ISDC 10.0104 Management of plutonium contaminated materials and other specific nuclear materials from the legacy sites;
- 2002: updated safety case (ISDC 08.0200 and sub-items);
- 2006-10: a range of regulatory developments and revised guidance on near-surface waste disposal (ISDC 08.0200 and sub-items);
- from 2010: latest engineering developments, no allocation of ISDC items;
- 2011: updated Environmental Safety Case (ESC) and regulatory review (08.0200 and sub-items if there is no re-licensing).

Note: The Low Level Radioactive Waste Repository (LLWR) in Cumbria is not the legacy site according to definitions in Chapter 3.1 because it is a “well-managed” site. The Case Study 2 for the LLWR in Cumbria is also not the decommissioning or remediation project; it is a project for improvement of the performance of a “legacy-like” case. However, it can be used for identification of typical decommissioning/remediation activities additional to the ISDC 2012. Additionally, Case Study 2 can be used also as an example for implementation of ISDC 2012 principal activities as presented in Appendix D.1. “Additional considerations relating to legacy management (‘well-managed legacies’)”.

### Case Study 3. Ranstad uranium mining and milling plant, Sweden

The Ranstad uranium mining and milling plant (“Ranstadverket” in Swedish) was established as a pilot plant in 1960 under the state-owned company AB Atomenergi. It has changed ownership a couple of times through the years, and since 1987 it belongs to Ranstad Industri Centrum AB (RIC). The plant was originally licensed under the Coal Mining Law (from 1886) and the Atomic Energy Law (from 1956) and during its main operational phase 1965-69, about 200 tonnes of uranium were produced from the surrounding alum shale ore.

The tails were deposited close to the Ranstad industrial area. Due to the low uranium content in the ore (0.03%), combined with the then low uranium market price, all major operations were terminated in 1969.

During the 1970s, the Ranstad facility was used for R&D projects. Apart from uranium extraction, there were also studies for production of other substances (e.g. molybdenum, vanadium, phosphate, oil and sulphur); however, this work was phased out in 1982 due to

low industry interest. The same year, uranium recovery was initiated from waste from nuclear fuel fabrication. Additional requirements from the authorities forced this work to be sized down significantly from 2000-03 and the facility finally closed down at the end of 2009, in conjunction with the end-date for the operational licence.

The Ranstad site is contaminated with uranium and other heavy metals originating from alum shale and operation of the plant. In 1990, the County Administration Board approved some remediation plans proposed by Studsvik Nuclear AB, the original owner, which still had a responsibility for the remediation. Between 1990 and 1994, these remediation actions comprised dismantling/demolition of several buildings, isolating and covering the mill tailings and water filling of the open quarry.

There were no actions for a period of time. Then, in 2006, the County Administration Board, with support from the Environmental Code, issued an injunction requiring further remediation of the site, which was understood to pose a hazard for human and environmental health. Therefore, between 2007 and 2009, further remediation of soil, equipment and facilities (only loose material) was performed by SVAFO AB.

Regarding radiological contamination, the leaching/extraction facility and the sorting facility were considered to be contaminated, with only minor contamination found in other parts of the plant. The highest amounts of radioactivity were present in the leaching/extraction plant and consisted of:

- natural uranium in alum shale;
- leached shale (tailings);
- uranium concentrates, both natural and low-enriched;
- contaminated equipment, spots of uranium at walls and floors;
- sludge and contaminated materials from the leaching pools.

The following alternative waste routes were proposed by the licensee, based on a 10  $\mu\text{Sv/y}$  dose criterion:

- B1: clearance for recycling or reuse of equipment, materials, buildings and offices;
- B4: clearance of offices and buildings for demolition – demolition waste to be used inside the industrial site of Ranstad;
- B7: clearance of materials and equipment for disposal at a disposal site for hazardous waste;
- B8: final disposal of radioactive materials (nuclear waste) in a repository for long-lived radioactive waste (SFL), for waste that could not be cleared.

In 2011, the Swedish Radiation Safety Authority (SSM) issued an injunction requiring specific documents and actions to be developed prior to the decommissioning of the Ranstad site.

These include (existing ISDC 01 Principal Activities can be used, and where relevant, new items are proposed):

- a safety analysis report, including descriptions of management of nuclear materials and waste, management systems, radiological protection, physical protection, safety analysis; new item related to legacy sites is proposed, 01.0304 Additional safety analysis for legacy/complex and post-accidental site;
- an established radioactive waste management plan;

- an established management system;
- plans for each stage of decontamination and dismantling of the sorting and leaching/extraction facilities;
- applications for exemptions from requirements that RIC did not consider necessary.

The end state of the Ranstad decommissioning project is to enable future industrial use of the industrial area. The mill tailings will probably be declared as a closed disposal site, with conditions concerning monitoring, surveillance and restrictions on future use. Discussions were performed between the County Administration Board and the SSM regarding how to solve the problem of long-term protection and monitoring of the mill tailings area.

The ongoing control performed by SVAFO AB was assumed to be finished and there were questions needing to be answered as to who should have the responsibility for monitoring and for the financing of a monitoring programme.

As the result of this and other discussions with the SSM, RIC has also submitted, and the SSM has approved, the set of documents, approaches and end state related to the Ranstad decommissioning project listed below, including the time sequence.

Specific features of Case Study 3, allocation of existing ISDC 2012 items, identification of items additional to the ISDC 2012, and potential modification of existing ISDC 2012 items are listed below:

- general decommissioning plan for the Ranstad site (2014), (ISDC 01.0100);
- decommissioning waste management plan (2013), extension of the title of the item 01.0400 is proposed, the ISDC 01.0400 Waste management and site end state planning;
- mapping of radioactive contamination and dose assessment for workers and the population (2012); new item related to characterisation of legacy sites is proposed, the ISDC 01.0204 Survey and analyses of residues specific for legacy/complex and post-accidental sites and modification of the title of the item 01.0200, the ISDC 01.0200 Facility/site characterisation and information models;
- for implementation of the 10  $\mu\text{Sv}/\text{y}$  dose criterion, additional safety analysis was performed; new item is proposed, the ISDC 01.0304 Additional safety analysis for legacy/complex and post-accidental sites;
- exemptions from some requirements for decommissioning and dismantling of the leaching plant and sorting facility (2012 and 2013; note, special conditions were set for these activities); new item is proposed, the ISDC 01.0403 Site end state consideration, criteria, planning and modelling;
- clearance of wastes to be deposited in a facility for disposal of hazardous waste (loose materials, dismantled components, remainders of alum shale, floors, etc.; 2012); title of the item 01.0401 is proposed for modification, the ISDC 01.0401 Establishing waste management and clearance criteria;
- clearance of uranium-contaminated waste for incineration in a facility for treatment and disposal of hazardous waste (2015), modified item 01.0401 as above can be used;
- decisions on clearance of buildings (existing 04.0900), with subsequent use of building rubble as filling material within the Ranstad industrial area (2013 and 2016), existing items 07.0300 and 07.0400 can be used;

- mill tailings will probably be declared as a closed disposal site, new ISDC items is proposed, the 05.1504 Converting the site or its parts to permanent disposal site;
- responsibility for monitoring and for the financing of a future monitoring programme can covered by existing ISDC 07.0601 and 07.0602 items; modification of the title 07.0602 is proposed, the ISDC 07.0602 Surveillance, monitoring, and stewardship of areas remaining under control, and new item 11.0105 is proposed, the ISDC 11.0105 Establishment of funds for short-term and long-term stewardship of legacy sites.

Note: The Ranstad case is an example of the complexity of possible solutions for legacy sites with various residues.

#### Case Study 4. The Søvte, a former Niobium mine, Norway

The state-owned mining company Norsk Bergverk was responsible for Søvte, a niobium mine, between 1953 and 1965 in the Norwegian county of Telemark, in the geologically well-known Fen complex. Here, rock compositions include considerable quantities of thorium (Th-232) ore as well as enhanced quantities of rare earth elements and iron. In the western part of the Fen complex, where the Søvte mine is located, the predominant bedrock is the mineral søvte, which consists of calcium carbonate and minerals such as pyrochlore, columbite and fersmite rich in Nb and naturally occurring radionuclides, specifically Th-232 and uranium (U-238) (though to a lesser degree than Nb). The main Nb-bearing mineral, pyrochlore, was identified early and vastly exploited commercially. In total, it is estimated that 1.15 million tonnes of søvte were extracted and then passed through subsequent extraction processes.

The former Søvte mining site was decommissioned in the 1960s. Waste from the Søvte mine, as both crushed stone and slag, was left in an area just outside of the processing plant. Primary hazard areas, identified as a sludge disposal site, a wash-house and a slagheap, are now accessible to the public in a local recreation area close to Nordsjø Lake. Additionally, a mechanical engineering shop is located on part of the prior mine site. When the mine was active, worker protection was regulated at the site, but waste management and discharge of radioactive materials was not. After decommissioning the site for economic reasons, remediation began in the form of overlaying numerous parts of the site with sand.

Measurements over the last decade have consistently confirmed the presence of NORM pollution in this area. Gamma dose rates and hot spots of U-238 and Th-232 and their progeny contamination have been identified. More recently, new site characterisation efforts have been undertaken, along with impact and risk assessments and an evaluation of options for waste management.

The current estimated amount of slag is 825 t or 236 m<sup>3</sup>. Estimated amounts of crushed stone are close to 23 000 m<sup>3</sup>. The highest level of radiological activity is typically found in the slag. The maximum measured gamma dose rate in the air was most recently 20 µGy/h. Maximum values of Rn-220 were also high (1.200 Bq/m<sup>3</sup>).

NORM activity concentrations in soil and waste material at different sub-sites were also found to be higher than exemption levels provided by legislation for radioactive waste. The majority of NORM concentrations in waste were in excess of 1 Bq/g.

However, only a limited transfer to biota of Th-232 and U-238 series radionuclides was observed; this was not a sufficient amount to induce population-level effects. For humans, terrestrial gamma radiation was the main contributor to outdoor exposure with annual doses

of up to 30 mSv, being estimated in “worst case” scenarios. The difficulty and significant uncertainty associated with the inclusion of high Rn-220 in the dose assessment was seen.

In the same year, state responsibility for this site was made clear (2011); the NRPA (Norwegian Regulatory Body) officially ordered the MTIF (Ministry of Trade, Industry and Fisheries) to deliver full site characterisation and proposals for clean-up solutions. This decision was taken in order to stop further contamination to the environment and to diminish the risk to both human populations and biota in the area. An action plan with clean-up measures, proposed by the MTIF was approved by the NRPA in 2013 and the deadline for action was set for the end of 2014. However, to be able to deposit the radioactive masses from Søve mine, additional investigations of behaviours of radionuclides Th-232, U-238 and their progeny are required from the proposed disposal sites. Leaking tests are currently ongoing to show the mobility potential of radionuclides through soil phases and into the water. This kind of information will help to estimate the stability of radioactive waste in future and will support a decision concerning where the waste should be disposed. Therefore, the NRPA prolonged the time requirements allotted for final clean-up of the Søve site.

The end state of the former mining site Søve is to enable common unlimited use of the area that is now partly a mechanic-engineering shop and partly on the shores of the lake and near a settlement area. The main objective is to finish clean-up of the area according to the agreed solution to dispose the waste in the proper repository with complete recover that will be monitored with predefined environmental requirements to ensure long-term protection.

The Case Study 4, the former niobium mine in Norway is the example for managing of large quantities of remaining NORM waste and how to define and achieve the end state for this type of legacy sites. New items proposed and/or modifications of existing ISDC titles as presented in Cases Studies 1 to 3 can be used accordingly.

Specific features of Case Study 4, allocation of existing ISDC 2012 items, identification of items additional to the ISDC 2012, and potential modification of existing ISDC 2012 items are listed below:

- new items proposed and/or modifications of existing ISDC titles as presented in above Case Studies 3 be used accordingly;
- management of residues up to its disposal at the proper repository, new item is proposed, the ISDC 05.1400 Management of residues at legacy sites, with new sub-items presented in Appendix 2 can be used;
- for site remediation in the form of overlaying numerous parts of the site with sand, new item is proposed, the ISDC 07.0404 Specific post-remediation activities for legacy and post-accident sites;
- future monitoring with predefined environmental requirements to ensure long-term protection can be allocated to existing 07.0601 or when performed at higher national level, new item can be allocated, the ISDC 07.0603 Integrating the site to national monitoring programmes.

## Case Study 5. Stráž pod Ralskem and Rožná legacy sites, Czechia

Czechia was the birthplace of wide-scale uranium mining, which started in the 1890s on an industrial scale in and near the town of Jáchymov, in particular to produce the green colour

requested by glass and porcelain manufacturers. In the early 1900s, Marie Curie discovered radium within the uranium at the Jáchymov mines and until World War I this was the only known source of radium production in the world. Pre-Cold War uranium production has been estimated to be around 1 000 t, but starting from 1947 Czechia produced uranium for the former Soviet Union.

Including the early mining sites, such as Jáchymov, Horní Slavkov and Příbram, Czechia is estimated to have produced 110 000 t of uranium from 64 uranium deposits. This case study focuses on two of these sites, Stráž pod Ralskem and Rožná.

Mining took place at the Stráž pod Ralskem (Straz) site in the Liberec region from 1967 until 1996, by which 15 562 tonnes of uranium has been extracted. The site's mining area covers 24.1 km<sup>2</sup> and reaches a depth of 220 m beneath the surface. Even though mining has stopped in the traditional sense, uranium has continued to be exploited as a by-product of the remediation of the Straz uranium deposit. More than 2 200 research boreholes and almost 7 700 mining boreholes have been drilled into this deposit. The majority of activity up to today has been chemical uranium mining using in situ acid leaching processes with H<sub>2</sub>SO<sub>4</sub> and HNO<sub>3</sub>. Thirty-five leaching fields were established, covering an area of 700 hectares.

Fifty-five kilometres north-west of Brno, is the Rožná (Rozna) underground facility in the Vysočina region, where a uranium mine operated since 1958. A chemical processing plant and two tailings' impoundments have been in operation there since 1968, where 11 shafts and approximately 580 km of mine tunnels have been dug over 8.76 km<sup>2</sup>. Mining is conducted to a depth of between 950-1 100 m beneath the surface. Annual uranium extraction at Rozna was around 200 t between 2000 and 2016, with around 18 370 tonnes of extracted material over the life of the site. Specific activities at Rozna have consisted of gradual wall slicing under a man-made ceiling, with backfill, the selective method for multi-level tunnels. There also exists a chemical uranium ore processing plant (alkaline leaching) and storage of sludge at the tailings impoundments. Extraction of uranium ore ceased in April 2017.

Due to chemical processing of uranium at Straz approximately 186 million m<sup>3</sup> of contaminated groundwater exists in the Cenomanian aquifer, and another 80 million m<sup>3</sup> in the Turonian aquifer. There are additional challenges with the soil surrounding both aquifers. The groundwater contamination at Cenomanian and Turonian leaves residual technological fluids in the ground. During mining operations, the underground was subject to 4 100 kt of H<sub>2</sub>SO<sub>4</sub> (of this, 80% reacted with the ore and 800 kt remained in the form of loose H<sub>2</sub>SO<sub>4</sub>), as well as 312 kt HNO<sub>3</sub>, 112 kt NH<sub>3</sub>, 26 kt HF and 1.5 kt HCl.

At the Rozna site, there has been continuous outflow of contaminated mine water. This water undergoes regulated out-pumping and treatment, and the treated water is later released into the Nedvědička stream. This treatment of mine water was specifically carried out in localities where mining activities had been discontinued under the framework of reducing such activities. Since the end of mining, close to 6.5 million m<sup>3</sup> of water has been released to streams from the mine and mining facility through the main outputs (where cleaned water is released to the stream), including already-treated additional sludge water from the Rozna deposit. A higher level of treatment is required for runoff from the tailings impoundments.

Liquidation and rehabilitation of the extraction fields at Straz are underway, as well as a broader remediation of the mining area with an aim to:

- remove the uranium enriched solutions from underground water; and
- revitalise the district's environment wherever affected by chemical mining.

The remediation activities include pumping out and treating the water at both the desalination plant and the neutralisation and decontamination plant. This evaporation technology works is followed by crystallisation, re-crystallisation (crystal sulphate of ammonium aluminate) and the removal of salts and metals; the results of which are further processed into both usable and non-usable products. The treated water is released into the Ploučnice River. New item is proposed: 05.1600 Management of underground waters, including 3 sub-items at the ISDC Level 3, presented in Appendix A.

A number of milestones have been important throughout the remediation process. In 2011, target values for remedial parameters (TVRP) were set on the basis of an original risk analysis and the TVRP was subsequently approved by the Czech authorities (Ministry of Environment, Ministry of Industry, State Office for Nuclear Safety) with a final goal to reach TVRP by 2037.

In 2012, all necessary remedial surface technologies (neutralisation stations) were completed and the necessary storage was constructed for residual materials from technological processes. In 2014, the TVRP risk analysis was updated and the first steps of the TVRP were confirmed as completed. It was decided (Ministry of Environment) then that this confirmation and update process will be performed every five years. The ultimate objective is to achieve liquidation of the in situ leaching area, evaporators and other surface objects, and full landscape revitalisation by 2042. The total costs for remediation process are expected to be on the level of EUR 2 billion.

At the Rozna site, site dismantling and gradual rehabilitation are underway (mine tunnels, dumps, the tailings impoundment, unusable structures). Based on a decision by the State Office for Nuclear Safety, the entry points of deserted major mines, dismantled after the completion of prospecting and/or uranium mining, are regularly monitored by the organisation that will oversee the site's remediation. Restoration works include planting of forest trees, and replacement of damaged forest trees on reclaimed dumps, as well as specific fence repairs.

An important part of the mining, dismantling and clean-up processes is continuous monitoring of environmental impacts, for which conditions are currently under review as part of a national monitoring plan. A number of conclusions were drawn and practical implementations carried out based on a specific investigation programme for disposal and remediation at Rozna (approved by the Czech authorities). Primarily, these include the construction of new separators for inner dams and the deposition of sludge under the water level reaching the centre of the tailing pond. As a preliminary step of technical restoration, methods should be considered for covering (with non-sorted fresh tailings) the finest tailings that have been deposited in the centre of the tailing pond.

Decommissioning/remediation activities at Straz and Rozna, Czechia are examples of a complex, long-term and costly programme at the national level with specific features presented below.

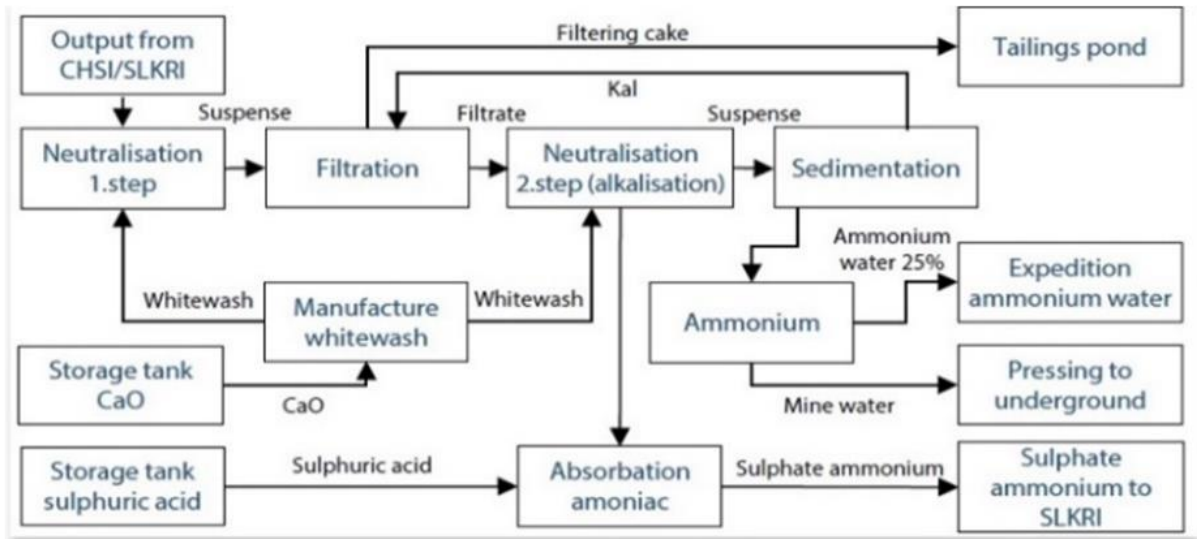
Specific features of Case Study 5, allocation of existing ISDC 2012 items, identification of items additional to the ISDC 2012, and potential modification of existing ISDC 2012 items are listed below:

- Long-term processes (1989-2042) with cost over billion EUR; for managing of long-term processes, tens of years (up to 50 years) and high-cost processes, the relations programme – projects should be considered, new item is proposed, the ISDC 01.0104 Planning at the programme level.

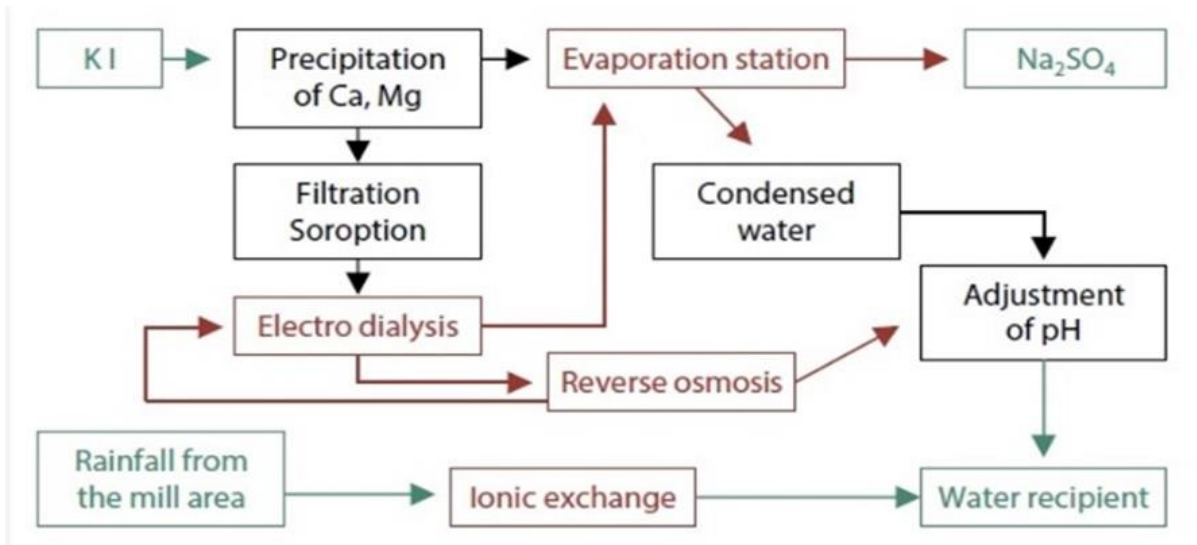
- State company responsible for remediation project as the solely state organisation which took over responsibilities of previous state companies; clear responsibilities, no additional items identified.
- Uranium mines, surface mining structures and underground mining structures; decommissioning of underground mining structures is not included in the ISDC 2012, i.e. decommissioning activities up to release of these structures from regulatory control; new item is proposed, the ISDC 04.1000 Decommissioning of underground structures, with sub-items presented in Appendix A; this item is the equivalent of 04.0900 for buildings on site.
- New item is proposed for industrial activities for closing, fillings, encapsulations, rehabilitation of underground tunnels, etc. for underground structures, the ISDC 07.0304 Closure of underground structures.
- Contaminated groundwater in aquifers (186 million m<sup>3</sup> and 80 million m<sup>3</sup>);, removal of the uranium enriched solutions from underground water, pumping out and treating the water by desalination plant and neutralisation/decontamination/crystallisation, removal of salts and metals which are further processed into both usable and non-usable products; new item is proposed for underground water cleaning, the ISDC 05.1600 Management of underground waters, with subitem presented in Appendix A, examples of treatment of liquid waste in management of underground waters are presented in Appendix Figure B.2-B.4.
- Liquidation and rehabilitation of the extraction fields; management of soils surrounding the aquifers; new proposed item can be used, the ISDC 05.1400 Management of residues at legacy sites, with subitem presented in Appendix A.
- For revitalisation of the environment wherever affected by chemical mining, remediation and reclamation work with focus in the future on the development of tourism and its infrastructure, types of surface barriers for tailings area; new item is proposed, the ISDC 07.0404 Specific post-remediation activities for legacy and post-accident sites, examples may include planting of forest trees, and replacement of damaged forest trees on reclaimed dumps, as well as specific fence repairs as examples, examples of final solutions for tailing ponds are presented in Appendix Figure B.2-B.4.
- Societal aspects – for payment of social and health benefits to the former and current employees, existing items ISDC 11.0104 can be used.
- Continuous monitoring of environmental impacts in the frame of a national monitoring plan; new item is proposed, the ISDC 07.0603 Integrating the site to national monitoring programmes, as the option for long-term stewardship.

Note: Case Study 5 is the example of a long-term national remediation programme with several individual projects. Some examples of treatment of liquid waste and examples of final solutions for tailing ponds are presented in the Appendix Figure B.2-B.4.

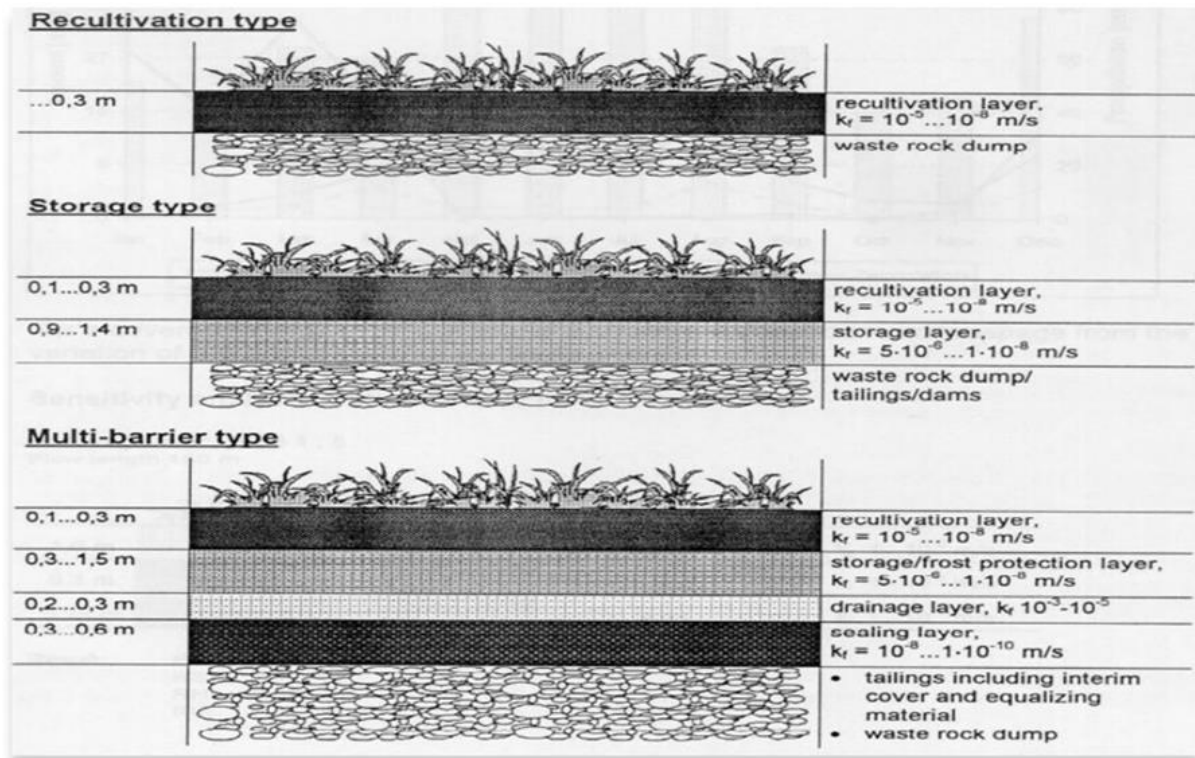
Appendix Figure B.2. Technologies for remediation in situ leaching area



Appendix Figure B.3. Underground water treatment at Rozna site



Appendix Figure B.4. Ending overlap sludge beds (tailing ponds)



### Case Study 6. Shiprock disposal site in New Mexico, United States

The Shiprock disposal site is a former uranium- and vanadium-ore processing facility located within the Navajo Nation in the north-west corner of New Mexico, near the town of Shiprock. The former Navajo Mill at the Shiprock site was constructed and operated from 1954 to 1963 by Kerr-McGee Oil Industries, Inc., and from 1963 to 1968 by Vanadium Corporation of America, which merged with Foote Mineral Company in 1967. Former milling operations at the site created process-related wastes and radioactive tailings.

Most of the waste generated during operation of the mill is managed on site. The site is managed by the US Department of Energy (DOE) Office of Legacy Management. In 1983, the DOE and the Navajo Nation entered into an agreement for site clean-up. By September 1986, all tailings and associated materials (including contaminated materials from off-site vicinity properties) were encapsulated in a disposal cell. Remediation of contaminated groundwater from past milling operations is ongoing.

The Shiprock site consists of two distinct, hydrogeologic systems: the terrace and floodplain systems. In general, the geologic profile of the region consists of alluvial deposits of Quaternary age, which overlie Cretaceous age Mancos Shale. Underlying the Mancos Shale is the Cretaceous age Dakota Sandstone and the Jurassic age Morrison Formation. Groundwater occurs under confined conditions in the Dakota Sandstone and Morrison Formation. A free-flowing artesian well, constructed near the site approximately 460 to 580 m below land surface, discharges at a rate of 200 L/min into Bob Lee Wash, a drainage dissecting the terrace northwest of the disposal cell.

Contaminated groundwater, from milling operations, exists in terrace alluvium and weathered Mancos Shale near the former mill site. During mill operations, an estimated  $3.2 \times 10^9$  L of water was discharged into the terrace system, producing a significant

groundwater mound above the alluvium-Mancos Shale interface. Impacted water is not expected to migrate to the lower aquifer given confinement of the deeper aquifer and upward gradient.

In addition to losses from the San Juan River, seepage and discharge of groundwater from the terrace groundwater system are sources of groundwater to the floodplain. At the north-east edge of the terrace, a steep escarpment 15 to 20 m high forms the boundary between the San Juan River floodplain and the terrace area. Seeps at the edge of the escarpment and on Bob Lee Wash were activated and contributed to the lingering contamination of the floodplain.

The Shiprock disposal site is managed by the DOE Office of Legacy Management. In 1983, the DOE entered into an agreement for clean-up of the site with the Navajo Nation, resulting in the encapsulation of tailings piles, which was completed in September 1986. A long-term surveillance plan was prepared for the disposal site in 1994. After the long-term surveillance plan was approved, the US Nuclear Regulatory Commission (NRC) included Shiprock under a general licence in September 1996. Site ground water clean-up was deferred to the UMTRA (Uranium Mill Tailings Remedial Action) Ground Water Project. Ongoing groundwater restoration activities include active groundwater extraction, as well as use of Environmental Protection Agency's (EPA) supplemental standard provisions provided in the "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings" (eCRF, part 192).

After remediation is complete, the NRC will oversee the DOE in its role as a licensee and long-term custodian of UMTRCA sites. NRC regulations in "General license for custody and long-term care of residual radioactive material disposal sites" and "General license for custody and long-term care of uranium or thorium by-product materials disposal sites" provide general licence requirements for custody and long-term care of Title I and II sites, respectively (eCRF, part 40, para 40.27, 40.28).

The compliance standards for nitrate, selenium and uranium are listed in the EPA's Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings" (eCRF, part 192). An alternative Safe Drinking Water Act limit of 0.05 mg/L for selenium has been proposed. Regulatory standards are not available for ammonia, manganese, sulphate and strontium. A clean-up goal of 2.74 mg/L was established for manganese based on measured background concentrations at the time, although recent background measurements have been as high as 7.2 mg/L. Historically, sulphate concentrations have been elevated in groundwater entering the floodplain from the flowing artesian well, where levels have ranged from 1 810 to 2 340 mg/L (average of 2019 mg/L). Because of these elevated levels from a natural source, the DOE proposed a clean-up goal for sulphate of 2 000 mg/L for the floodplain, which is conservative as nearly half (46%) of the 68 samples collected were above this level (e.g. in background well 0797, sulphate concentrations have ranged from 2 690 to 5 000 mg/L since 2010). No standards are available for strontium, a constituent not typically associated with uranium milling sites, though it was selected as a constituent of concern in the DOE's Baseline Risk Assessment. The EPA's Regional Screening Level for stable strontium in drinking (tap) water is 12 mg/L (NEA, 2020a).

Remediation of the site was initially hampered by an incomplete understanding of the hydrogeological system and sources of contaminants in groundwater. Reducing hydrogeological conceptual model uncertainties has led to better informed remedial decision-making and increased effectiveness of selected technologies.

A significant challenge for remediation of the Shiprock disposal site has been determining the source of elevated concentrations of constituents of concern in groundwater, and determining whether those sources are naturally occurring. A study conducted by the US

Geological Survey (USGS) for the Navajo Nation presented multiple lines of evidence to support a conclusion that the source of water beneath the “Many Devils Wash” is likely focused recharge of precipitation and is not likely sourced from groundwater impacted by former milling operations or from the disposal cell (NEA, 2020a). This evidence includes:

- the lack of a hydraulic gradient from the disposal cell to “Many Devils Wash”;
- visible observations of near-surface, erosion processes such as piping and sapping in and near the channel;
- review of geochemical data to differentiate between terrace impacted and naturally occurring waters, including sodium-sulphate, nitrate and selenium concentrations; as well as uranium activity ratios;
- concentration data providing information on the potential age of recharging ground waters (due to differences in atmospheric concentrations of certain constituents over time) including tritium and chlorofluorocarbon concentration data.

Remedial activities have led to a decrease in seepage rates to the floodplain and reduced water levels and contaminant levels in terrace wells. Groundwater remediation has also led to significant mass reductions of legacy groundwater contamination in the floodplain alluvial aquifer. The DOE plans to remove the ageing liner in the evaporation pond once groundwater extraction in the floodplain is terminated and monitor ensuing groundwater concentrations to determine whether to reline the evaporation pond and resume extraction or decommission the evaporation pond and allow natural flushing to proceed. At that time, the DOE will also monitor groundwater conditions around the disposal cell to better understand if it is a continuing source of contamination to the floodplain aquifer.

Alternatives in groundwater compliance strategies have allowed the DOE to focus on mill-related groundwater contamination, rather than areas with widespread ambient contamination where groundwater restoration efforts are ineffective. The DOE continues geochemical investigations in the area surrounding the disposal cell to better define mill-related versus non-mill-related groundwater contamination to support use of supplemental standards for terrace groundwater.

Specific features of Case Study 6, allocation of existing ISDC 2012 items, identification of items additional to the ISDC 2012, and potential modification of existing ISDC 2012 items are listed below:

- former uranium- and vanadium-ore processing facility was converted to the disposal facility by encapsulation of tailings and associated materials from previous activities in a disposal cell, new proposed item can be used, the ISDC 05.1400 Management of residues at legacy sites, with subitem presented in Appendix A;
- former ore processing consisted of crushing, leaching with sulphuric acid, washing and extracting uranium and vanadium with organic solvents; examples of past activities;
- two distinct, hydrogeologic systems - the terrace and floodplain systems; water in the unlined ponds was able to percolate into the underlying soil and rock; contaminants of concern include ammonium, manganese, nitrate, selenium, strontium, sulphate and uranium; understanding of interactions of two hydrogeologic system, list of contaminants and related factors for their management was important;
- remediation of contaminated groundwater is the second key subject of the project; remediation of the site was initially hampered by an incomplete understanding of

the hydrogeological system and sources of contaminants in groundwater; the hydrogeological model for underwater remediation is of key importance; new item is proposed, the ISDC 01.0403 Site end state consideration, criteria, planning and modelling, which includes also hydrogeologic modelling; it is assumed that hydrogeologic modelling will continue during the long-term stewardship period, item 09.0200 can be used;

- changing of ownership from private companies to DOE, due to the long-term risks posed by uranium and thorium wastes, uranium recovery sites are under the long-term care by the DOE; aspects of changing the ownership may have cost impacts, new item is proposed, the ISDC 01.0503 Regulatory and ownership aspects for legacy/complex and post-accidental sites;
- long-term stewardship is one element of a defence-in-depth approach to long-term protection consisting of government ownership/control, NRC licensing that provides independent oversight, robust engineered barriers that provide long-term stability, and financial assurance;
- engineered barriers must be designed to provide stability for up to 1 000 years, and a minimum of 200 years, without reliance on active ongoing maintenance; new proposed item can be used, the ISDC 05.0500 Long-term stabilisation of waste at legacy sites, with subitem presented in Appendix A;
- the DOE will manage the site indefinitely and will monitor the site consistent with the long-term surveillance plan; long-term custodial care of the site helps ensure public health and safety long into the future, but also requires constant input and effort by the DOE and regulators and can therefore be resource intensive, items of ISDC 07.600 can be used, new proposed item can be used accordingly, the ISDC 07.0603 Integrating the site to national monitoring programmes;
- societal aspects - DOE agreed to provide funding to the Navajo Nation to do parallel, independent investigations; DOE formed a working group and organised Navajo Nation Chapter House meetings to inform local stakeholders; effective forums and methods of communication with the Navajo Nation were developed; existing item 11.0104 can be used;
- funding the long-term surveillance and custodial care is by the state organisation DOE.

Note: Case Study 6 is the example of the detailed approach for management of contaminated underground waters on a legacy site and for the long-term stewardship of site with contaminated underground waters.

### Case Study 7. Radium Action Plan 2015 to 2019, Switzerland

In June 2014, the problem of radiological legacies linked to radium resurfaced following the discovery of radium-contaminated waste at a former landfill site in Bienne (A5 motorway construction site). The Federal Office of Public Health (FOPH) carried out a complete analysis of the site in order to evaluate the health risk to the local population. The results of the analysis confirmed the absence of any health risk to persons living in the areas constructed on this old landfill site. Nevertheless, protective measures were put in place for the workers on the construction site.

Radium was used to produce luminescent paint in the watchmaking industry between 1920 and 1960. In spite of the precautions taken to misplace as little radium as possible, given its cost, employees were exposed, and surface contamination occurred in the workshops or

in the private apartments or buildings where work was carried out. At the time, given the limited management of the waste resulting from the use of radium, radium residues were found in household waste, and, in the absence of any particular precautions, this waste was sent to ordinary landfill sites.

With the action plan, the Federal Council wishes to settle this problem definitively.

Having considered the elements presented above, the Federal Department of Home Affairs (FDHA) has requested the FOPH to prepare an action plan to resolve the problem of radium. Its implementation is based on art. 9 of the Radiological Protection Act of 22 March 1991 (Swiss Federal Council, 1991), and on the IAEA International Basic Safety Standards for Protection (IAEA, 2014). These standards and the recommendations of the International Commission on Radiological Protection (ICRP) define the strategy for the management of radiological legacies such as existing exposure situations. The action plan provides for the search for possible radium-contaminated sites, the diagnosis of its presence in buildings and surrounding land, the assessment of the resulting annual exposure for the residents and, in the case that the exposure to the public exceeds the annual limit of 1 mSv, remediation work. Finally, a particular section of the action plan concerns the monitoring of potentially contaminated landfill sites. The overall process has been approved by the Federal Commission for Radiological Protection.

The radium action plan 2015-2019 is made up of four principles having the aim to account for the sites where radium was handled, to diagnose its presence or absence, to plan and to carry out remediation justified from the viewpoint of radiological protection, and to put in place monitoring of the landfill sites in which radioactive waste of this substance was placed. Four principles were implemented:

- searching for potentially contaminated sites;
- survey of the potentially contaminated buildings, accompanying measures;
- remediation of the contaminated buildings;
- surveillance of the landfill sites and other contaminated sites;

End states and long-term protection values:

The proposed course of action consists in searching for potentially contaminated sites, and initially establishing a radium assessment of each site. A strategy for action has been established based on experience gained in the pilot phase and specifying, depending on the measured parameters, the follow-up. Although most cases show no trace of radium, the assessment provides reassurance for concerned inhabitants. In the case that traces are detected, the following options have to be considered:

- the removal of the radioactive sources or contaminated objects (e.g. the soil from contaminated gardens);
- mechanical or chemical decontamination of the contaminated parts of the housing (floors, walls, water discharge pipes);
- the installation of other means of protection on a case-by-case basis.

With regard to the potentially contaminated public landfill sites, monitoring the concentration of radium in the landfill leachate is the chosen option.

The final objective is to guarantee the habitability of the premises without any unacceptable risk to the population from exposure to remaining contaminants, and to ensure the protection of workers and the population faced with the risks involved with contaminated landfill sites. It should be emphasised that this does not mean the achievement of zero

residual activity from radium. Such an objective could involve disproportionate interventions and unacceptable costs. Thus, it is important that each decision for remediation be justified in an optimisation approach that draws a comparison between its advantages and disadvantages.

The objective of the radium action plan is to eliminate the radiological legacies associated with the use of radium in the watchmaking industry. The organisation and the applied technical procedures ensure the progress of the four axes of the radium action plan.

Specific features of Case Study 7, allocation of existing ISDC 2012 items, identification of items additional to the ISDC 2012, and potential modification of existing ISDC 2012 items are listed below:

- when searching for potentially contaminated sites, analysis of historical records at various levels was of key importance; modification of existing 01.0201 is proposed as ISDC 010201 Detailed facility/site characterisation and historical site assessment, to highlight the role of this activity;
- for survey of identified potentially contaminated sites, specific approaches were used, new item is proposed, the ISDC 01.0204 Survey and analyses of residues specific for legacy/complex and post-accidental sites;
- activities were planned, managed and financed by governmental bodies, co-operation with local municipalities and private owners was included, new item is proposed, the ISDC 01.0503 Regulatory and ownership aspects for legacy/complex and post-accidental sites;
- removal of identified radioactive materials, decontamination of buildings is performed in areas, buildings without the controlled areas, new item is proposed, the ISDC 02.0702 Measures for legacy sites without controlled areas; this item is within the new proposed item at the Level 2, the ISDC 02.0700 Preparation of legacy sites for decommissioning/remediation;
- management of residues is within the new proposed item, the ISDC 05.1400 Management of residues at legacy sites, and sub-items presented in Appendix A;
- planning, managing and supporting activities and other non-technical activities can be identified in the ISDC 06 and 08;
- decontamination and survey of buildings, if implemented can be covered by existing ISDC 04.0703 and 07.0900;
- final management of affected areas can be covered by existing 07.0401 and 07.0402 or by new proposed item, the ISDC 07.0404 Specific post-remediation activities for legacy and post-accident sites;
- for post-project monitoring of landfills, item 07.0602 can be used.

Note: Case Study 7 is the example of remediation activities performed in the public area for final remediation of consequences of past activities.

## Case Study 8. Capriano del Colle special waste dump, Italy

The Capriano del Colle special waste dump is located in the Italian province of Brescia, in Lombardy. It is bounded by other communes of Azzano Mella, Bagnolo Mella, Flero, Poncarale, Castel Mella and Dello. It is situated on the eastern slopes of Monte Netto, occupying a total of about three hectares. It is structured in seven tanks placed in two parallel rows for a total disposable volume of approximately 370 000 m<sup>3</sup>. The contaminated material is collocated only in Tank 3, 4, 5 and 6 for a total volume of 200 000 m<sup>3</sup>.

The special waste dump was used only for the disposal of foundry wastes coming from the production of a metal refinery. The municipality of Capriano del Colle is located in a rich and lush countryside with vineyards dotting the hills and the plain, which are part of the ancient tradition of this natural area.

In the second half of 1990, three sites were investigated for radioactive contaminants, namely Ex-Fermeco 80, RaffineriaMetalli Capra and the dump in Capriano del Colle (BS). Radiological characterisation was performed of the entire special waste dump and Cs-137 was discovered, probably due to a melted radioactive source in aluminium scrap metal coming from Eastern Europe. The same investigations revealed the acknowledgement of Cs-137 contamination within company records. After a first evaluation by special committee, including local governments, these three sites were closed, along with Capriano del Colle (BS) special waste dump.

Radiometric characterisation of the waste disposal, performed by collecting surface and subsurface samples, concluded that most of the radioactive contamination (around  $1 \times 10^{12}$  Bq) was confined to a limited area of the landfill. The total volume of wastes contaminated by Cs-137 was found to be in the range of 200 000 m<sup>3</sup>, covering an area of about 30 000 m<sup>2</sup>. The largest amount of contaminated waste, containing around 1.1 TBq, was found in basin three. Into basins five and six, an average Cs-137 radioactive content was estimated to be much lower than that of basin three (for example, 12 GBq of Cs-137 for basin 5). These activity estimates were based on averaged values and in some samples collected from basin three, Cs-137 values were measured at 20 times higher (196 033 Bq/kg) than the averaged values (9 819 Bq/kg), implying a conservative total Cs-137 radioactive inventory of about 20 TBq.

Cs-137 contaminated wastes that were constituted as dust were mixed with soil to around 30% of volume to avoid any air dispersion. As necessary, the basins were waterproofed through layering 40 cm of clay linings throughout the excavation area and covering the excavation walls and bottoms with a geomembrane. Both upper and lower draining systems were installed with the upper linked to a piping system and tank for collecting the percolate.

After several years, additional groundwater investigations were carried out using piezometers, revealing some further Cs-137 contamination. Local authorities declared that only a portion of the landfill had been filled in a controlled manner, while another portion had been filled without confinement barriers. Therefore, both controlled and uncontrolled landfill liquid was present in the network. Monitoring under the first seal revealed chemical-physical characteristics similar to the top leachate (Cs-137 radioactive concentration of about 0.30 Bq/g); but the water samples, collected from environmental piezometers, found some Cs-137 radioactive contamination greater than minimum detectable concentration values.

Only in recent years, the National Institute for Environmental Protection and Research (ISPRA – the competent national regulatory authority in the field of nuclear safety and radiological protection) was requested to participate in a local committee established by the

prefecture to assist with the problem of radioactive contamination. Values of Cs-137 radioactive contamination in percolate were found to be below 1 Bq/g.

The local committee (previously established by the prefecture and Ispra) requested that the owner of the Capriano del Colle site provide specific radiological scenarios for the leachate that is sent to the local purifier. This would demonstrate compliance with the criterion for radioactive discharge of no radiological concern of 10  $\mu\text{Sv}/\text{y}$  and activity concentrations of the Cs-137 discharge  $\leq 1$  Bq/g. For compliance with the above criteria, the following information was specifically requested by the prefecture:

- a) identification of all possible exposure routes for members of the population (critical group), and possibly for workers, also in relation to the leachate destination;
- b) any conservative assumptions used in the evaluations;
- c) the reference mathematical models used for evaluating individual doses to the population.

The operator of the Capriano del Colle site demonstrated compliance with the radiological concern criteria of 10  $\mu\text{Sv}/\text{year}$ . All radiological scenarios were verified independently by the local committee.

The management of radioactive waste in the past, without a consolidated solution, has intensified the situation today, especially since some radioactive traces of Cs-137 have been found in the groundwater. There is no longer a possibility of waste recovery for disposal. Instead, intensive control of the groundwater is ongoing in order to understand the radioactive concentration of Cs-137 and the concentration of other chemical substances.

In general, the removal of radioactive contamination due to Cs-137 seems to be quite difficult because in the past the disposal of radioactive metal scrap involved mixing the same contaminated metal scrap (dust) within the dumping ground. The contaminated powder was mixed with soil at around 30% of the volume in order to prevent wind transport of the same. The stored material in the plant is configured as earthy powder in a matrix, with whole or fragmented salt blocks placed mainly at the edges of the tanks. Comprehensive monitoring and evaluation of contaminated percolate has to be performed regularly through the environmental monitoring network established around the whole area of the special waste dump.

Final solutions:

It was decided that a specific geomembrane will be put on the main basins (basin 3, and basins 5 and 6) to avoid the production of percolate. The special waste dump will continue to be monitored by the environmental monitoring network.

An appropriate decision-making process was available and applied at the time when contamination was confirmed. It was then concluded that the best solution, given the risks in movement, was to leave it where it was and provide containment. However, the provided containment was not fully effective.

Ongoing monitoring is maintained in co-operation with local stakeholders.

Specific features of Case Study 8, allocation of existing ISDC 2012 items, identification of items additional to the ISDC 2012, and potential modification of existing ISDC 2012 items are listed below:

- Cs-137 was discovered in the industrial waste dump and low contamination by Cs-137 was identified in groundwater;

- extensive characterisation of groundwater and disposed waste were realised, new item is proposed, the ISDC 01.0204 Survey and analyses of residues specific for legacy/complex and post-accidental sites;
- conservative models for all exposure pathways were developed to demonstrate the compliance with the general criteria 10  $\mu\text{Sv}/\text{year}$  for public, other identified chemical substances were included; new items are proposed, the ISDC 01.0403 Site end state consideration, criteria, planning and modelling and the ISDC 01.0304 Additional safety analysis for legacy/complex and post-accidental sites to cover also non-radiological risks;
- final solution is based on developing additional surface barriers by geomembranes to avoid the production of percolate, new item is proposed, the ISDC 07.0407 Specific post-remediation activities for legacy and post-accident sites;
- the solutions are limited for the next 25-50 years, final solution is not yet decided, for long-term monitoring of the waste dump, the existing item 07.0602 can be used.

Note: Case Study 8 is the example of remediation activities performed in the public area after an accident in industry with consequences of radiological and chemical contamination in the industrial waste dump. The remediation is temporary with no waste removal, followed by a monitoring period, final solution is assumed after the monitoring period.

### Case Study 9. Clean-up approaches and strategies for public engagement and participation at Hanford, United States

Hanford is primarily known for its plutonium production over the years from World War II through the Cold War. Since 1989, the site has focused on clean-up resulting from plutonium production. In fact, Hanford is known as the largest nuclear clean-up project in the United States. The Hanford Site in Richland, Washington, United States, was chosen due to:

- its abundant source of cold water from the Columbia River;
- its proximity to a massive power source of the Grand Coulee Dam; and
- its isolation from large cities while being far enough inland from the Pacific Ocean.

Construction of the site was rapid, from 1943 to 1945 (the time frame from design to start-up was only 13 months) with 50 000 workers at its peak.

As Hanford seeks to protect the public, workers and the environment, near-term priorities are to:

- complete demolition of the Plutonium Finishing Plant;
- clean-up research waste burial ground and nearby waste site;
- move highly radioactive sludge from storage near river for future treatment/disposal;
- upgrade/replace and optimise Cold-War-era systems to support Central Plateau clean-up;
- complete design of the low-activity waste pre-treatment system, to provide near-term waste feed for treatment at the Waste Treatment Plant (WTP);

- retrieve, manage and treat 56 million gallons of radioactive waste, currently stored in 177 ageing underground tanks to protect the Columbia River.

Recent successes include:

- completion of the vast majority of clean-up in 220-square-mile area near Columbia River (428 facilities demolished, 984 waste sites cleaned up and 6 reactors is safe enclosure);
- near-completion of remediation of highly radioactive waste site near river (Burial Ground).

Opportunities exist to increase efficiencies and accelerate clean-up. The US Department of Energy (DOE) is working with US Environmental Protection Agency (EPA) and states to streamline clean-up regulations so as to get work done more efficiently.

Efficiencies are also being sought by replacing a 70-year-old water reservoir system needing multiple repairs with smaller reservoirs in the centre of Hanford. Also, portions of the decades old electrical distribution system are being updated for long-term mission needs through 2060.

The primary mission at Hanford was plutonium production. Most of the uranium metal shipped to Hanford was prepared at Fernald, Ohio and Weldon Spring, Missouri. Further milling, metal cladding and final fuel preparation were complete in the southern part of Hanford in the 300 area. Nearly 20 million uranium fuel slugs were prepared at Hanford.

The Columbia River was critical to Hanford during its plutonium production mission because river water was used to cool the reactors when operating. Thus all nine reactors were built within close proximity to the Columbia River. All of the above processes left a legacy footprint with clean-up that workers are dealing with today.

As of April 2017, 879 of 1 715 facilities have been demolished since clean-up began. The Plutonium Finishing Plant, which began operation in 1949 and was the last facility to stop plutonium production was among the highest hazard facilities in the DOE waste management inventory. The plant was scheduled to be torn down in 2018.

Groundwater remediation, or “pump and treat” is conducted by pumping ground water to the surface, treating it using specialised processes to remove the contaminants, and then returning the water to the subsurface. Further, clean-up workers are using several methods in the ground itself to stop or slow the movement of contaminants towards groundwater. As of April 2017, 16 billion gallons of groundwater have been treated, with 343 tonnes of contaminants removed.

Societal aspects:

All Hanford site clean-up is governed by federal and state laws, and is overseen by a number of regulatory agencies with involvement of advisory boards. The Hanford Advisory Board (HAB) comprises 32 seats, with members providing advice and recommendations to the Tri-Party agencies (State of Washington, the US EPA, and the US DOE) on selected major policy issues. These issues include clean-up standards, environmental restoration and waste management and disposition, as well as stabilisation and disposition of non-stockpile nuclear materials and future land use and long-term stewardship. Members of the public are engaged through comment periods, public meetings and the Hanford Speakers Bureau.

End state and long-term protection values:

Remedial activities are ongoing at the Hanford site as discussed above. These activities are being conducted with the objective of reducing environmental risk, protecting the Columbia River, and eventually making the land available for other uses. To date over

1 600 acres of land have been transferred for redevelopment, over 800 facilities have been demolished and over 1 300 waste sites have been remediated. The DOE intends to continue to manage the site to ensure protection of public health and safety into the indefinite future.

With respect to waste management, solid low-level waste is taken to the Environmental Restoration Disposal Facility (ERDF) on the Hanford site. The ERDF accepts low-level radioactive, hazardous and mixed wastes that are generated during site clean-up activities. Over 1 300 of 2 032 waste sites have been remediated since clean-up began.

The Waste Treatment Project has been tasked with the mission of immobilising tank waste in glass for environmental protection and long-term storage. Low-activity waste treatment could begin as soon as 2022. Technical issues are still being resolved for the pre-treatment facility.

Specific features of Case Study 9, allocation of existing ISDC 2012 items, identification of items additional to the ISDC 2012, and potential modification of existing ISDC 2012 items are listed below:

- clean-up is comprised of many types of activities; all are governed by federal and state laws and are overseen by numerous regulatory agencies; clean-up is important to stakeholders to reduce environmental risks, to protect the Columbia River, to eventually make the land available for other uses and to meet federal obligations;
- the Hanford Case Study is in principle the mix of activities for decommissioning of contaminated nuclear facilities, retrieval and management of historical/legacy waste and remediation of large areas; specific features, large inventories, specific radioactive sources are typical;
- there is the programme level and many individual decommissioning and remediation projects, planning at the programme level is relevant;
- at the level of individual decommissioning and remediation projects, the items of the ISDC 2012 and new identified items can be implemented;
- use of new items 02.0600 Specific post-accidental actions for the period of termination of operation, 02.0700 Preparation of legacy sites for decommissioning/remediation and 04.1000 Decommissioning of underground structures, seems to be not relevant;
- management of waste includes historical/legacy waste, decommissioning waste (ISDC 2012 Principal Activity 05), and management of residues from remediation activities (new item ISDC 05.1400) and management of underground waters (new item ISDC 05.1600);
- there are activities for long-term stabilisation of waste on site (new item ISDC 05.1500);
- spent fuel management after the storing period is out of the ISDC, storing of the spent fuel from non-research reactors (specific of the ISDC 2012) is proposed to be involved in the ISDC 10 Principal Activity;
- regulatory, ownership, societal and stakeholders' aspects are covered by items from the ISDC 2012 and new proposed items.

Note: Hanford Case Study 9 is the example of the long-term decommissioning programme which is realised via many detailed partial decommissioning projects. ISDC 2012 items and most of the new identified items can be implemented.

### Case Study 10. Western New York Nuclear Service Center and West Valley Demonstration Project, United States

The Western New York Nuclear Service Center (WNYNSC) is a complex decommissioning site located in western New York State, about 50 km (30 miles) south of Buffalo. The New York State Energy Research and Development Authority (NYSERDA) holds the licence and title to the 13 km<sup>2</sup> WNYNSC site. The WNYNSC is the former location of the only commercial spent fuel reprocessing plant to operate in the United States. Nuclear Fuel Services (NFS) operated the spent fuel reprocessing plant and associated waste disposal areas from the years 1966 to 1975.

In 1972, the plant permanently ceased reprocessing operations after NFS determined that it would not be economically viable to continue reprocessing operations. In 1976, the NFS informed New York State that it would not resume reprocessing and would transfer the facility to NYSERDA when the lease expired in 1980. At the time, the NFS said it would withdraw from West Valley, the site contained 750 spent fuel assemblies that had not been reprocessed, 2.3 x 10<sup>6</sup> litre of liquid high-level radioactive waste stored in two steel tanks, a highly contaminated main plant process building, and almost 8.5 x 10<sup>4</sup> m<sup>3</sup> of radioactive waste buried in the two disposal areas. New York State refused to accept the facilities and the waste, and in 1980 the West Valley Demonstration Project (WVDP) Act was passed (DOE, 1980). The WVDP Act allowed the US Department of Energy (DOE) to take exclusive possession of about 0.8 km<sup>2</sup> of the WNYNSC in order to complete the high-level waste (HLW) solidification and decommissioning activities at the site.

The WNYNSC is located on the west shoulder of a steep-sided, glacially-scoured bedrock valley that is filled with a sequence of glacial sediments. These glacial deposits are comprised primarily of clays and silts separated by coarser-grained layers created during periods of glacial retreat. WVDP is bordered by two streams, Franks Creek to the east and Quarry Creek to the north. The WVDP is bisected by Erdman Brook that divides the site into the North Plateau and South Plateau. Franks Creek is a tributary of Buttermilk Creek.

Most of the residual inventory at the site is stored in the HLW tanks and disposal areas. Liquid HLW from spent fuel reprocessing was stored in two tanks, Tank 8D-2, a 2 800 m<sup>3</sup> carbon steel tank, and Tank 8D-4, a 57 m<sup>3</sup> stainless steel tank.

As a result of operations, site soils, groundwater and surface water/sediments are radiologically contaminated. In 1968, leaks of radioactive nitric acid recovered from spent fuel reprocessing operations migrated into soils beneath the south-west corner of the main plant process building creating what is referred to as the North Plateau Groundwater Plume. This plume contains high concentrations of relatively mobile and short-lived Sr-90. The DOE is remediating the groundwater plume with a permeable reactive barrier wall utilising natural zeolite to remove Sr-90 from groundwater prior to its seepage to surface water.

The DOE performs routine on-site and off-site monitoring (air, surface water, groundwater, storm water, soil, sediment and biological samples) to evaluate any impacts from DOE operations and issues an Annual Site Environmental Report documenting the results of the monitoring.

The final decommissioning EIS for WVDP and WNYNSC evaluated the following alternatives:

- site-wide removal;
- site-wide close-in-place;
- phased decision-making; and
- a no action alternative.

The preferred alternative selected was phased decision-making, or remediation of certain portions of the site in Phase 1 of decommissioning, along with the collection of additional information to inform decisions regarding remaining portions of the site in Phase 2 of decommissioning. The option for unrestricted release of the site was preserved under Phase 1 (the DOE is cleaning up areas of the site to unrestricted release standards in the event that the final Phase 2 decision is unrestricted release of the WVDP and WNYNSC).

As indicated above, the final West Valley Policy Statement prescribes the NRC's licence termination rule as the decommissioning criteria for the WVDP, recognising that the NRC licensee, NYSERDA, will also have to meet the licence termination rule, which has provisions for release with and without restrictions, when the DOE relinquishes control of the Project Premises back to the state. The final Policy Statement also provides flexibility to consider alternatives (e.g. perpetual licence for some parts of the site or exemptions from the rule) to the decommissioning criteria provided in the License Termination Rule, if justified, after considering health and safety, as well as the costs-benefits of the various alternatives.

Specific features of Case Study 10, allocation of existing ISDC 2012 items, identification of items additional to ISDC 2012, and potential modification of existing ISDC 2012 items are listed below:

- case Study 10 includes, similarly as in Case Study 9, the decommissioning activities, management of historical/legacy waste, decommissioning waste, remediation activities and management of underground waters;
- there is the programme level and many individual decommissioning and remediation projects, planning at the programme level is relevant;
- the items of ISDC 2012 and new identified items can be implemented;
- use of new items 02.0600 Specific post-accidental actions for the period of termination of operation, 02.0700 Preparation of legacy sites for decommissioning/remediation and 04.1000 Decommissioning of underground structures, seems to be not relevant;
- management of waste includes historical/legacy waste, decommissioning waste (ISDC 2012 Principal Activity 05), and management of residues from remediation activities (new item ISDC 05.1400) and management of underground waters (new item ISDC 05.1600);
- beside the decommissioning and waste management activities for specific waste types, important item is the new items ISDC 05.1500 Long-term stabilisation of waste at legacy sites, by developing engineering hydraulic barriers and low-permeability geomembrane covers to reduce infiltration of precipitation into the disposal trenches and reduce the volume of water that accumulates in the disposal holes and trenches;

- evaluation and selection of options for final solutions are the key planning and research development activities covered by ISDC 01 and ISDC 09 Principal Activities with ISDC 2012 items and new proposed items;
- for site-wide removal, if implemented, ISDC 2012 items and new proposed items can be used, except of ISDC 03, 05.1500 and 07.0600;
- for site-wide close-in-place, if implemented, ISDC 2012 items and new proposed items can be used, except of ISDC 03 under assumption that the buildings will be decommissioned, 05.1500 may have important role, monitoring/surveillance period of the site remaining under control is assumed (07.0600);
- regulatory, ownership, societal and stakeholders' aspects are covered by items ISDC 2012 and new proposed items.

Note: Case Study 10 is the example of the long-term decommissioning and remediation project in several phases where, except of decommissioning and remediation activities, the stabilisation of situation in underground waters is the important issues and where the final solution for the end state is subject of analysis in primary phase to develop solutions for remaining phase.

## 2. NORM materials in IAEA documents and the ISDC

This appendix summarises the analysis of management of NORM materials from the IAEA document *Management of Residues Containing Naturally Occurring Radioactive Material from Uranium Production and Other Activities* (IAEA, 2021b). The Safety Guide is principally directed towards the management of NORM residues as a planned exposure situation (i.e. including the generation, reuse and recycling, long-term management, and disposal of residues). It also applies to residues arising from the decommissioning of NORM facilities.

The document presents the following aspects of management of NORM materials:

**Pre-treatment:** collection, characterisation, segregation, chemical adjustment and decontamination of equipment contaminated with residues, including interim storage, as necessary.

Residues should be segregated on the basis of their physical, chemical and radiological characteristics, with account taken of subsequent options for treatment and the potential for generating further (secondary) residues. Segregation should be designed and implemented to reduce the volume of residues and waste that will need long-term management. Segregation should facilitate the reuse and recycling of residues. In mining and mineral processing, the segregation of non-mineralised or clean waste rock from mineralised waste rock is a pre-treatment activity.

Scrap items such as pipes, valves, process vessels, pumps and machinery that have been contaminated with NORM residues should be decontaminated where practicable, in the interest of reuse and recycling.

**Treatment:** includes operations intended to improve safety by changing the characteristics of the residues. The basic treatment concepts are volume reduction, radionuclide removal and change of composition. Examples of such operations are incineration of combustible waste or compaction of dry solid waste (volume reduction); evaporation, filtration or ion exchange of liquid streams (radionuclide removal); and precipitation or flocculation of chemical species (change of composition). Often, several of these processes are used in combination to provide effective decontamination of a liquid residue stream. This might lead to further types of secondary residue to be managed (e.g. contaminated filters, spent resins, sludge).

**Conditioning/disposal:** involves operations that transform the residues into a form suitable for handling, transportation, storage and long-term management, including disposal. Conditioning operations include immobilisation, stabilisation and packaging. Common immobilisation methods include solidification of liquid residues, for example in cement. Stabilisation methods can include dewatering and chemical adjustment.

**Clearance, reuse, and recycling:** should be subject to suitable criteria, especially clearance criteria, including, as appropriate, clearance for specific situations (IAEA, 2021b).

**Storage:** refers to the placement of the NORM residues in a facility where appropriate containment is provided and with the intention of retrieval of these residues. Storage may take place between or within different residue management steps.

**Long-term management of NORM residues:** options for long-term management can cover wide range of actions. The preferred option for long-term management will depend on the conditions at the facility or the site where the activity is undertaken, and

on the characteristics of the ore body or the process materials, the mining or processing operation, and the residues generated. When no future use of the NORM residues is foreseen, the residues should be processed or otherwise prepared so as to meet acceptance criteria for long-term management established with the approval of the regulatory body (end state criteria, reference levels, clearance criteria). These criteria are required to specify the radiological, mechanical, physical, chemical and biological properties of the residues. In addition, there should be some info about long-term monitoring / institutional controls / monitoring and management of restrictions, etc.

To avoid the need for long-term management of residues, the options of clearance, discharge to the environment, reuse and recycling, and authorised disposal (including disposal in existing landfill sites and other waste disposal facilities) should be used to the maximum extent possible, subject to meeting relevant regulatory requirements.

**Summary:**

The above listed activities are the base for the new proposed item ISDC 05.1400 and its sub-items. Additional activities such as long-term monitoring / institutional controls / monitoring and management of restrictions, etc. are involved in existing ISDC items.

Final solutions could be conversion of the site to the local closed disposal site (new ISDC 05.1504) or to the site for industrial/nuclear reuse with defined restrictions for use. Alternative solutions could be the disposal at relevant disposal site for NORM materials if this is available; this alternative may enable free release of the site.

### 3. Analysis of activities typical to Complex Sites in IAEA documents additional to ISDC 2012

Technical and organisational aspects related to complex sites as presented in Chapter 3.2 based on analysis of the IAEA document *Decommissioning at a Multifacility Site: An Integrated Approach* are further commented on in this chapter in order to identify whether the existing ISDC 2012 covers these aspects or new ISDC items should be proposed (IAEA, 2022c).

Technical aspects and organisational and managerial aspects are discussed in this section. Financial aspects discussed in the IAEA document represent in principle allocation of cost to ISDC items; items of integrated planning can be identified in existing ISDC 08.0200 items.

#### *Technical aspects:*

##### 1. Site layout;

Site layout (buildings, areas and surroundings) is reflected in definition of the scope and perimeter of the decommissioning / remediation project. No additional ISDC items are needed.

##### 2. Shared infrastructure including utilities and structures, systems and components;

Sharing the infrastructure including utilities and structures, systems and components is described in relevant chapters of the decommissioning / remediation plan. Existing items ISDC 06.0100, 06.0200, 06.0300, 06.0400 define the typical site infrastructure which may be defined within an isolated decommissioning / remediation project or can be shared for more decommissioning / remediation projects on a complex site. Extent of sharing and possible impact on projects should be defined in the project description.

New ISDC items on the ISDC Level 3 are proposed related to safety measure for the ISDC item 06.0400 with modification of the title “Radiation and environmental safety monitoring and safety measures”; new ISDC items 06.0404 “Safety measures on site including emergency preparedness” and 06.0405 “Safety measures out of the site including emergency preparedness” are proposed. Safety measures include also modification of the emergency preparedness if needed.

In standard decommissioning cases, the site infrastructure from operation is used after its modification during the transition period. When establishing of a decommissioning / remediation project on a legacy or complex site without a proper transition period, a need may arise to establish or modify the site infrastructure. New item ISDC 06.0500 “Establishment/reconstruction of infrastructure at legacy, complex sites and post-accident sites” is proposed involving two items at the ISDC Level 3.

##### 3. Waste management facilities and provision;

Waste management systems for decommissioning / remediation projects can be established as the full-scale system within the decommissioning / remediation project; alternatively, it can be shared for more decommissioning / remediation projects or the waste management is defined fully as the service provided out of the project. This should be defined in the description of the item ISDC 05.0100 for the decommissioning / remediation project.

In case of legacy sites some specific requirements may arise in definition of the decommissioning project; new item ISDC 05.0106 is proposed “Specific arrangements for waste management system related to legacy/complex and post-accident sites”.

4. Development and deployment of decommissioning technologies;

Development and deployment of decommissioning technologies may be effectively implemented in case of decommissioning of several nuclear installations on the same site. Extent of the techniques and style of sharing should be defined in these projects; no additional ISDC items were identified, ISDC 04.0100 can be used for these purposes.

5. Ground contamination;

6. Site clean-up;

7. Area and component reutilisation;

The above items 5, 6 and 7 may be shared by decommissioning / remediation project on the same site; clear allocation of common site items and responsibilities should be defined for each project for items ISDC 04 and ISDC 07, no additional ISDC are needed for this in the relation to complex sites.

8. Compliance with end state requirements;

The importance of end state requirements was identified already in the planning phase; new item ISDC 01.0403 “Site end state consideration, planning and modelling” was proposed and the extension of the title of ISDC 01.0300 to end state planning. End states requirements for the complex site and the compliance with end state requirements for individual project of site should presented in the decommissioning plan. New item is proposed in ISDC 09, 09.0205, ‘Modelling of site end states of decommissioning’ which is the continuation of the items 01.0403 in the frame of the decommissioning project planning.

9. Safety assessment and emergency preparedness;

Safety assessment and emergency preparedness for complex sites is of key importance for individual project on site. Impact of other projects on site on the given decommissioning project and impact of the given decommissioning project on other decommissioning projects on site will require additional safety analyses and safety measures to be reflected in individual decommissioning projects.

New item ISDC 01.0304 “Additional safety analysis for legacy/complex and post-accident sites” is proposed for the planning phase; in ongoing projects are these activities covered by ISDC 08.0204.

10. Environmental monitoring during decommissioning.

Environmental monitoring during decommissioning for individual decommissioning / remediation projects in case of complex site should respect the overall site requirements for environmental monitoring; clear definitions should be developed and presented for individual project on site. As an example, in the case when the site includes several ventilation chimneys, the rations for effluents should be defined for individual decommissioning project. Similar approach should be defined for water discharge system. Environmental monitoring is involved in 06.0400, new items are not needed.

***Organisational and managerial aspects:***

- Human resources;

Human resources are involved in ISDC 08.0101 in the phase of mobilisation of the decommissioning project; during the decommissioning project in 08.0305, including training. Any aspects related to decommissioning projects on a multi-facility site should be presented in these ISDC items.

- Organisational structures and systems;
- Regulatory approaches;

Organisational structures and systems and regulatory approaches are covered by existing ISDC 08.0200. Impact of complex site on individual projects on site should be reflected in this ISDC item.

- Nuclear security considerations;

Considerations on nuclear security is not involved explicitly in titles of ISDC 2012 items. This should be presented in more details in examples to ISDC 02.0104, i.e. below the Level 3; new item ISDC 10.0104 “Management of plutonium contaminated materials and other specific nuclear materials” is proposed to cover the activities in some specific cases for legacy/complex and post-accident sites and relations to other facilities on site in case of complex sites.

- Safety and environmental impact assessment;
- Emergency preparedness;

Safety and environmental impact assessment and emergency preparedness in the planning phase is involved in ISDC 01.0303. In the case of a complex site, the effect on individual projects should be presented in new proposed ISDC 01.0304, ‘Additional safety analysis for legacy/complex and post-accident sites’.

Technical aspects of safety and environmental monitoring during decommissioning are involved in ISDC 06.0400; it is proposed to include the emergency preparedness in new ISDC 06.0404 “Safety measures on site including emergency preparedness” and ISDC 06.0405 “Safety measures out of site including emergency preparedness”.

Organisational aspects of emergency preparedness during decommissioning are covered by ISDC 08.0204 “Safety and environmental analysis, on-going studies” the emergency preparedness should be presented in examples to ISDC 08.0204.

- Independent owners/operators;

In some countries are the decommissioning projects performed by state-owned companies. In complex site, specific situation involving various owners and operators may arise. For individual project on a complex site, this should be clearly defined in ISDC 01.0500 “Authorisation” and when needed, additional new item ISDC 01.0503 ‘Regulatory and ownership aspects for legacy/complex and post-accident sites’ can be used.

Cost arising from arrangement of specific situation in the planning/authorisation can be allocated to new proposed item ISDC 01.0503, Regulatory and ownership aspects for legacy/complex and post-accident sites’; during the decommissioning to existing ISDC 11.0102, 01.0103 or 11.0104.

- Knowledge management, learning from experience and record keeping;
- Human factors;
- Asset management including post-decommissioning site reuse;
- Stakeholder engagement;

The above listed items 8 to 11 are covered by ISDC 08.0200 and 08.0300.

- Supply chain engagement and commercial arrangements.

Supply chains are reflected in the ISDC 2012 by two identical segments ISDC 08.0100 to 08.0500 and ISDC 08.0600 to ISDC 08.1000; the relation between management / support of a decommissioning project and the suppliers of activities should be reflected in these items.

Mobilisation of a decommissioning project in standard cases is the continuation of shutdown activities of the facility, i.e. many technical and organisational aspects can be used. In some cases of legacy/complex and post-accident sites, new additional activities may be needed. New items in ISDC 08.0100, 08.0500, 08.0600a and 08.1000 are proposed.

## 4. Analysis of post-accident decommissioning projects

The IAEA document *Managing the Decommissioning and Remediation of Damaged Nuclear Facilities* presents experience in managing the consequences of accidents in nuclear power plants (IAEA, 2021c). The DAROD project was based in large measure on the substantial international guidance and experience for decommissioning available from the IAEA, OECD NEA, and European Commission, and on information from case studies concerning damaged nuclear facilities (DNFs) provided by member states, including experience gained at legacy sites. The DAROD project identified specific areas where guidance needs to be strengthened or expanded to provide sufficient information for dealing with DNFs. Some of these areas include the following:

- assessing the integrity of damaged structures, and the stabilisation of damaged plants;
- planning and preparation for the removal of damaged fuel and fuel debris;
- performing radiological characterisations in hostile environments, e.g. in areas with high levels of radiological contamination;
- performing rapid and efficient characterisation of the environmental contamination of water, soils, and biota; and,
- identifying technologies for undertaking decommissioning and remediation of DNFs, for example, decontamination and segregation techniques, and remote handling systems.

The post-accident activities are performed in the period of termination of operation of facilities which is for normal operation covered by ISDC 02 ‘Facility shutdown activities’. For facilities after an accident, two basic activities can be identified:

- stabilisation phase where the emergency measures are implemented;
- preparation of the facility for decommissioning.

Both activities are performed under the operating licence. In the “Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities” the phase of stabilisation is defined for example in para 7.51 as follows “7.51. In case of an unanticipated shutdown owing to an accident, the facility should be brought to a safe condition by applying emergency measures and recovery (stabilisation) actions. After the emergency phase is over, information should be collected as soon as possible about the radiological status and physical status of the facility and the final decommissioning plan should be developed, which should take into account damage caused by the accident”, (IAEA, 2018, para 7.51).

The subject of the second phase are the exiting activities of ISDC 02 (ISDC 2012) and additional activities which are performed with the aim to bring the facility as close as possible to the starting situation as in facilities with standard shutdown, i.e. without any accidents in operation.

The DAROD project summarises the identified activities for the second phase in three groups as follows:

***Regulatory issues and challenges:***

- identifying the nature and extent of changes that may be required to the regulatory approach and regulatory responsibilities in order to address the DNFs;
- determining which nuclear and non-nuclear regulations and standards are applicable to the DNF situation at hand, and which, if any, require modification;
- evaluating the effectiveness of the safeguards and nuclear material control practices being considered and/or applied at a DNF;
- determining the most effective approach for applying the safety principles, requirements and guidance provided by the IAEA Safety Standards, the NEA, and the European Commission; and,
- evaluating the applicability of the clearance concept.

***Technical issues and challenges:***

- identifying the issues affecting the ability to characterise physical and radiological hazards, and developing methods by which to carry out the characterisations;
- developing methods for the monitoring of affected facilities;
- identifying the issues affecting the ability to perform structural assessments, and developing methods by which to perform the assessments;
- identifying and evaluating the functionality and availability of safety systems, e.g. fire, ventilation, criticality control, shielding;
- developing an approach for the provision or replacement of safety related systems, e.g. fire, ventilation, criticality control, shielding;
- evaluating the requirement for environmental monitoring including groundwater;
- implementing the required environmental monitoring programmes;
- identifying the radioactive waste management infrastructure and technical capabilities required to manage circumstances wherein waste streams may arrive sooner than expected, and that these waste streams may be greater in volume and different in nature than previously planned for;
- identifying the requirements for waste management treatment methods, e.g. volume reduction;
- identifying the unique aspects of, and methods for, managing damaged fuel and fuel debris;
- identifying new technologies that could assist in decommissioning; and,
- identifying the methods required for providing adequate protection of workers.

***Institutional framework and strategic planning issues and challenges:***

- reviewing and evaluating the assignment of responsibilities of the owner, operator, licensee, regulator, decision makers, and both national and local governments;
- identifying and reviewing existing organisational structures, and determining the need for any required changes to existing organisations, or for the establishment of new organisations;

- evaluating, and if necessary, developing risk management and cost estimation methodologies that are suited to dealing with non-standard inputs of information and conditions characterised by a high degree of uncertainty;
- identifying possible financing mechanisms that might be employed for funding the decommissioning and remediation of DNFs;
- identifying and developing an effective process for interacting and communicating with stakeholders;
- evaluating the current decision-making processes, and determining the need for possible changes to those processes;
- determining if the original planned final end state for decommissioning remains appropriate, and providing the rationale used in the decisions concerning that determination (including considerations concerning the use of entombment and safe enclosure);
- developing a systematic methodology that can be used in selecting an optimum strategy for managing the DNF that takes into consideration such factors as cost, time, public perception, waste volume, safety;
- identifying those factors that could have an impact on meeting the remediation and decommissioning project objectives for the DNF, e.g. high levels of complexity and uncertainty, high levels of risk, requirements for hold points, uncertainties about public concerns, international considerations; and,
- determining the extent of any requirements for additional infrastructure, e.g. replacing buildings, safety systems, liquid and waste treatment systems, waste management facilities.

For the first and the majority of the third group of activities, the existing and proposed ISDC items of ISDC 01 and 08 can be used. New item for planning is proposed:

ISDC 01.0105 ‘Post-accident planning for the period of termination of operation’.

The technical activities of the second group are in the DAROD project summarised as (IAEA, 2021c):

- physical, radiological and hazards characterisation;
- monitoring, sampling, and measurement;
- structural assessments;
- methodology used to specify, provide or replace safety systems;
- safety system availability and functionality;
- management and monitoring of environmental contamination;
- waste infrastructure and technical capabilities;
- waste management;
- damaged fuel and fuel debris management;
- relevant technologies for remediation and decommissioning – remote technology;
- decontamination technology; and,
- protection of workers.

Based on the technical activities described in the DAROD project and referenced above, new subgroup of ISDC activities, which are performed during the period of termination of operation, is proposed for the ISDC 02 for extending the “Facility shutdown activities” at the Level 2 and Level 3 as follows:

- 02.0600 Specific post-accident actions for the period of termination of operation;
- 02.0601 Procurement of specific equipment for the period of termination of operation;
- 02.0602 Physical, radiological and hazards characterisation;
- 02.0603 Monitoring, sampling, and measurement of affected systems and structures;
- 02.0604 Management of impacts of accidents on systems and structures; additional confinement systems, shielding;
- 02.0605 Management of safety systems affected by accidents and/or additional safety systems, operation of systems;
- 02.0606 Management of impact of accidents on the environment and groundwater; exclusion zones;
- 02.0607 Management of damaged fuel and fuel debris, maintaining and monitoring sub-criticality;
- 02.0608 Dismantling/removal activities to enable start of decommissioning;
- 02.0609 Decontamination activities to enable start of decommissioning;
- 02.0610 Other activities during the period of termination of operation in post-accident sites.

It is assumed that the above listed activities will be performed during the period of termination of operation after the period of implementation of planned and/or ad hoc developed emergency actions. Key purpose of the period of emergency actions is to restore the nuclear safety in the facility.

These activities performed during the period of termination of operation will bring the facility to the position, when the fuel and fuel debris are transported in specific containers out of the site, and the systems and structures will be stabilised and characterised to the level enabling to develop the decommissioning plan and related documents.

Remotely operated techniques are used for management of damaged fuel and fuel debris and also for characterisation, decontamination and dismantling. Procurement of remote-controlled techniques is allocated to ISDC 04.0100; related R&D, training and simulation activities are allocated to ISDC 09 (09.0300).

The planning of post-accident decommissioning may have in principle several planned phases which are covered by a programme planning.

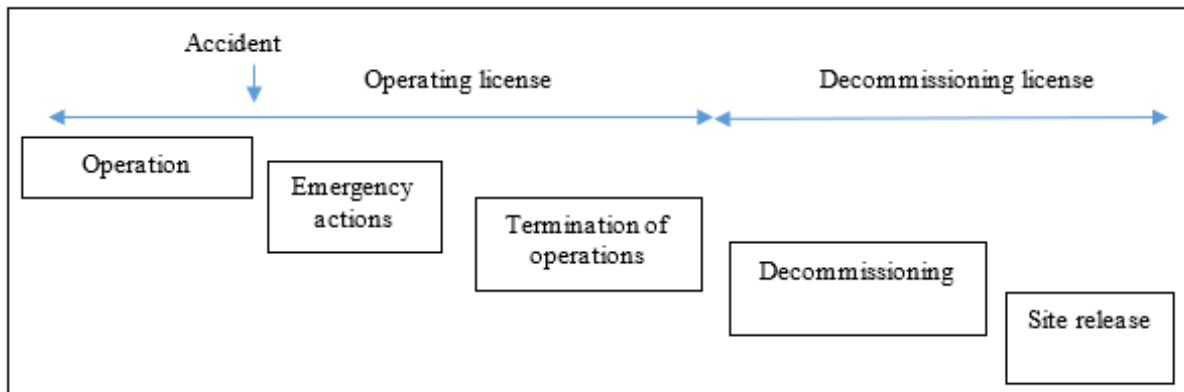
The activities for decommissioning and site release, following the period of termination of operation, for nuclear installations affected by accidents will include some specific activities additional to standard-like decommissioning; these activities have been identified in this report.

It is also assumed that waste generated during the emergency period and during the period of termination of operation will be managed in ISDC 05.0200 to 05.0600 items. Any

specific waste techniques and/or waste management facilities can be allocated to ISDC 05.0100.

Principal timing of actions after the accident in a nuclear facility is presented in the Appendix Figure B.5.

**Appendix Figure B.5. Principal timing of actions after the accident in a nuclear facility**



As an example of timing of post-accident decommissioning is the case of A1 nuclear power plant (INES 4), the emergency period was relatively short (less than 2 years), the period of termination of operation was 20 years, decommissioning period in 5 separately licensed phases is 33 years, and the site release planned as an additional licensed phase is assumed to be 6 years. For each phase, the ISDC is used for planning and costing of decommissioning activities. For comparison, the termination of operation for standard case is less than 10 years (depending single-unit or twin-units design) and standard decommissioning is less than 20 years.

In addition to the new ISDC items that have been proposed above, the IAEA document *Decommissioning after a Nuclear Accident: Approaches, Techniques, Practices and Implementation Considerations* presents ISDC principal activities that are relevant during these periods; within the document is an example how to implement the ISDC to post-accident decommissioning projects (IAEA 2019b).

## Appendix C: Scope of ISDC 2012

The cost structure described in ISDC 2012 may be used for estimating the costs of decommissioning of any type of nuclear facility.

The ISDC provides a hierarchical structure of standard decommissioning activities which is intended to cover all types of activities identified in any decommissioning project for any type of nuclear installation, regardless of size, composition/complexity of systems and structures and radiological conditions. As noted in the body of the report, uranium mining sites with typical large areas, tailings and similar features are not considered. A number of issues were excluded from or only marginally addressed in ISDC 2012, such as post-accident decommissioning, legacy management and site remediation.

The guidance on application of the ISDC follows the internationally accepted decommissioning strategies, describes typical decommissioning activities, and considers the various phases of decommissioning projects, including planning, the transition from operation to decommissioning and the end points of decommissioning projects. The ISDC 2012 presents a hierarchical structure of typical decommissioning activities in three levels, where these levels present decommissioning activities in increasing degrees of detail and specificity. It also provides detailed examples of cost items normally included in each of the typical activities at ISDC Level 3.

Pre-decommissioning activities performed close to the end of operation and during the transition period are identified; a smooth transition from operation to decommissioning is assumed.

During the transition period, under the licence for operation, the activities are performed which prepare the nuclear power plant for decommissioning; experienced operational personnel is used dominantly for these activities. Typical activities of the transition period are well-defined in international documents (IAEA, 2004).

The extent and operation of the controlled area in nuclear power plants from the operational period is preserved also during the transition period and at the start of the decommissioning project. The extent of the controlled area is later gradually decreased as the decommissioning activities progress.

The basic decommissioning strategies were considered:

- immediate dismantling;
- deferred dismantling;
- entombment.

Entombment strategy is implemented only in very specific cases. It is limited to selected parts of former nuclear buildings. This strategy can be effectively implemented for example in cases when the entombed facility will remain under the regulatory control for a long period, for example hundreds of years.

Dismantling activities within the controlled area were identified reflecting the level of knowledge of dismantling techniques and experience at the time of development of the PSL or ISDC. The key purpose of these activities was to remove the radioactivity from buildings to the level of release of buildings for industrial dismantling and to remove the radioactivity

from the site to the level of release of the site. These activities are limited to the extent of the site. Off-site activities are not considered.

Cost items related to the waste management are structures primarily according to the IAEA waste classification, as follows (IAEA, 2009):

- HLW
- ILW
- LLW
- VLLW
- VSLW
- EW
- Waste generated out of controlled areas.

Hazardous waste (asbestos, PCB's, lead, etc.) is considered only in the case of exempt waste and non-radioactive waste. Other waste types such as the NORM, TENORM, mixed waste, chemical waste or other types are not considered explicitly.

End states of waste management in decommissioning projects are the disposal sites for radioactive waste, i.e. DGR for ILW and HLW, surface repositories for LLW and trench type repositories for VLLW and repositories for conventional waste and repositories for hazardous waste. Clearance of materials, including reuse and recycling of materials from dismantling/demolition is considered (IAEA, 2023).

Typical activities for industrial dismantling and demolition and for site clean-up, landscaping and final site survey/release were identified.

Situations where the radioactivity is remaining on site or selected parts of site, is considered only from the point of view of maintenance, surveillance and monitoring. End states of sites involving radioactivity on site where additional activities should be performed for stabilisation of waste, are not considered.

Under principal activities 06, 08 and 09, typical site activities supporting the decommissioning projects, managerial and supporting activities for a decommissioning project, and research and development activities were identified.

Spent fuel management is considered up to the point of transfer of the spent fuel out of the perimeter of the decommissioning project. For research reactors decommissioning, additional items are included for transfer of spent fuel to temporary storage in the frame of the decommissioning project.

Other cost items such as various licence owner cost, taxes, insurances, various payments and assets are considered.

As discussed in the main body of this report, there are a number of features of the ISDC 2012, which are relevant to the consideration of its application to legacy and complex sites:

- ISDC 2012 reflects a standalone decommissioning project, i.e. without sharing some activities with other decommissioning projects;
- decommissioning activities are limited to the site of the nuclear facility, i.e. off-site activities are not considered;
- waste management is limited to waste types typical for materials and radiological parameters of systems, structure, components of a well-defined nuclear facility

consisting of buildings and limited extent of sites; ISDC does not fully consider waste types other than those listed in the IAEA radioactive waste classification (IAEA, 2009);

- removal of radioactivity from buildings and site is assumed to be undertaken to the approved release limits; situations where radioactivity is remaining on site is covered marginally;
- the information needed for planning and performing of decommissioning activities is assumed to have been developed and available at any time;
- ISDC consider situations where a nuclear facility prior to start of decommissioning is managed properly;
- activities for preparing of decommissioning of abandoned sites or not properly managed sites are not explicitly covered.

## Appendix D: Possible application of the ISDC in other areas

The original purpose of the ISDC cost structure is to harmonise the presentation of cost for decommissioning projects. This purpose has proven to be effective over the years. The ISDC has also been used to compare the cost of decommissioning projects with different scopes and/or national decommissioning background. The applicability of the ISDC can be further enhanced by including the additional items of typical decommissioning activities related to legacy, complex and post-accident sites that have been analysed and captured within this report.

The alternative effective implementation of the ISDC is its use as the base for cost estimation structures. The ISDC is the open structure below the third generic numbered level for adding other user's defined numbered levels or levels generated according to the content of the facility inventory database, phases or waste management system of the decommissioning project, as typical examples. The upper part (ISDC Levels 1 to 3) of the user's specific ISDC cost estimation structure formats keep the ISDC generic format, i.e. the three generic numbered levels and the lower part corresponds with the user's specific requirements. The upper generic ISDC part of the ISDC based cost estimation structures directly provides the data for ISDC cost presenting format, for ISDC benchmarking and other general purposes just by aggregating the cost data from lower ISDC levels upwards. Principles of this approach are presented in "Lessons learned from implementation of International Structure for Decommissioning Costing (ISDC) of Nuclear Installations", (Daniska, Zachar, 2017). An example of this implementation of the ISDC is the IAEA DACCORD project (IAEA, 2021a).

In addition to the cost estimation purposes, the ISDC, as the list of typical activities, could also be applicable to:

- legacy management (well-managed legacies);
- as a platform for benchmarking of decommissioning cost by developing the benchmarking assumptions and boundary conditions in the ISDC cost format; transformation of cost from non-ISDC cost formats to ISDC cost format is needed for these purposes; these activities are subject of the EGCDL GT3 NEA forthcoming report;
- use of ISDC in other areas (e.g. as a checklist for planning and cost estimation);
- implementation of the ISDC to probabilistic cost estimation;
- as a model to emulate for developing the cost structure of typical activities related to nuclear power plant spent fuel management and/or deep geological repositories. Examples of this are presented in Chapter 4 of Appendix D for research reactors spent fuel management.

These areas could be further evaluated if and when a decision is made to update the ISDC-2012.

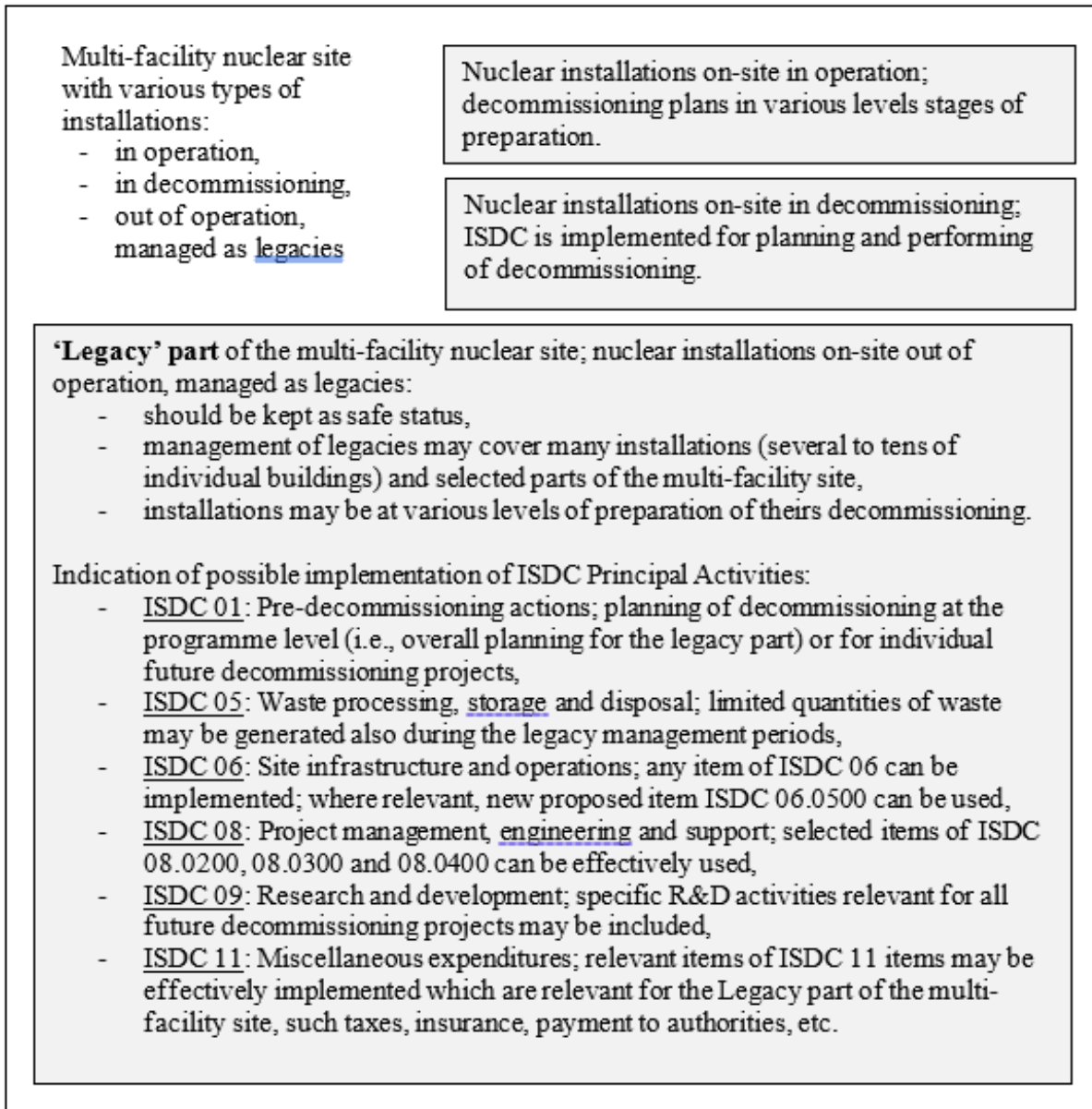
## **D.1. Additional considerations relating to legacy management (“well-managed legacies”)**

Chapter 3.1 of this report presents legacy sites (abandoned or not properly operated sites) with limited knowledge, assumptions and conditions for developing and performing the decommissioning project in order to identify activities additional to ISDC 2012. This section presents the possibility of implementation of the ISDC for management of “well operated” legacy sites prior to their decommissioning.

There are situations worldwide when a non-operating old nuclear facility decommissioning activity is differed with waiting before of up to several tens of years. The facility could be a standalone facility with its own nuclear site, or it could be a part of a multi-facility nuclear site. Such a facility should be kept in a safe status with minimalised impact on the environment and/or other facilities on the same site.

Although the original scope of the ISDC 2012 did not take this situation into account, it can still be successfully implemented for the above-presented nuclear facilities waiting for their decommissioning. If these facilities are considered as “legacies” which should be properly managed, the implementation of the ISDC can be extended also for such situations where management of legacies is the task. An example of this situation is presented in Appendix Figure D.1.

Appendix Figure D.1. Example of implementation of ISDC to “well-managed legacies”



There are two principal implementations of the ISDC for management of legacies:

- standalone (isolated) legacy sites where the preparation of decommissioning can be at various levels of details, selected ISDC 01, 05 (partially), 06, 08, 11 can be used for management of the legacy prior to its decommissioning,
- legacy parts of large multi-facility sites where out-of-operation installations should be kept at safe status respecting the relations on site; the above listed ISDC items can be used.

From the evaluation described here, the ISDC can be used effectively also for management of legacies waiting for their future decommissioning.

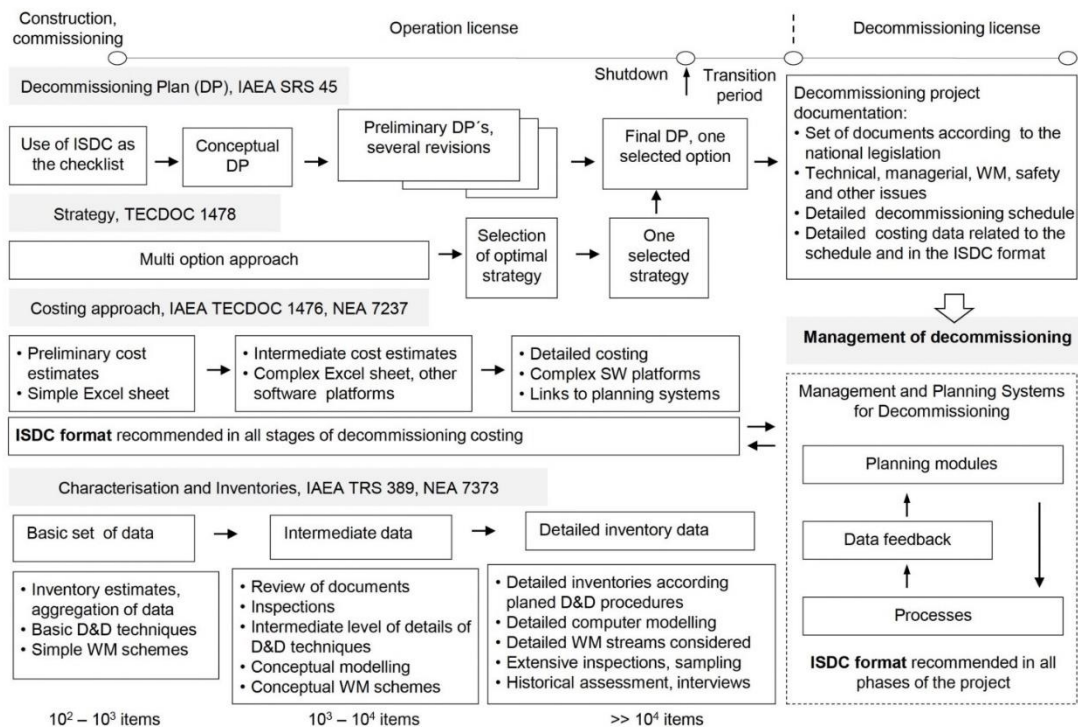
## D.2. Possibilities of use of ISDC in other areas

The ISDC 2012 as the list of typical decommissioning activities has the potential to be used in various applications in addition to presenting the decommissioning cost. Examples for ISDC implementation in areas other than decommissioning costing and related to costing are presented in Appendix Figure D.2, in which are presented parallel long-term activities such as):

- decommissioning planning and strategy;
- characterisation and development of inventories for decommissioning; and
- finally, the performing decommissioning projects (including the feed-back to planning documents).

Except of costing itself (the original purpose of ISDC 2012), the ISDC may be potentially implemented in any of the parallel activities and at any stage.

**Appendix Figure D.2. Typical parallel activities related to preparation and performing decommissioning**



Source: Daniska, 2022.

Examples of additional implementation of the ISDC may be:

- identification of decommissioning activities in the decommissioning plan by ISDC indexes;

- alternatively, organisation of decommissioning activities in the decommissioning plan according to the ISDC;
- indexing of the inventory data by ISDC indexes;
- presenting the results of safety analysis in the ISDC format;
- indexing of items of building information models (BIM) or any modelling by ISDC indexes.

### D.3. Implementation of the ISDC to probabilistic cost estimation

Existing recommended ISDC 2012 cost presentation format is the matrix of typical ISDC 2012 activities at ISDC Level 1, 2, 3 and ISDC cost categories, i.e. labour cost, investment cost, expenses and contingency. Deterministic approach for estimation of contingency is assumed.

Recently, new approach based on Monte Carlo probabilistic method was proposed [NEA uncertainties] for estimation of in-scope uncertainties (equivalent of the ISDC contingency) and out-of-scope uncertainties. Results of this probabilistic approach is different from presentation of deterministic contingency of ISDC 2012. The ISDC was not considered explicitly, for example in preparation of input data for probabilistic cost estimation of uncertainties.

In the frame of the IAEA DACCORD project, the input data were organised in the ISDC format, as an example for implementation of the ISDC for probabilistic cost estimation (IAEA, 2021a).

When the ISDC will be updated, it would be useful to include also a consideration on organisation of input data for probabilistic estimation of uncertainties in the ISDC format and how to organise the joint presentation of results of deterministic and probabilistic cost estimation.

## D.4. Possibilities for other back-end nuclear cycles

The ISDC was developed as the harmonised structure for presentation of cost for decommissioning projects. This approach proved to be effective. There are many cost structures for presentation of decommissioning cost, however it seems that the ISDC is the only one which can be practically used for harmonised presentation of cost for decommissioning projects and for cost benchmarking.

Similar approach, as implemented at development of the ISDC, was used also for presentation of cost for management of spent fuel for research reactors, presented in the IAEA document “Research Reactor Spent Fuel Management: Options and Support to Decision Making” (IAEA, 2021d). The ISDC was used as the model in this project. The developed harmonised structure has following activities at the top level, as equivalents to ISDC principal activities:

1. preparation of spent fuel management options;
2. spent fuel management activities at the reactor building;
3. long-term storage activities;
4. spent fuel return programmes;
5. spent fuel reprocessing;
6. spent fuel conditioning;
7. disposal of the spent fuel and/or fuel related radioactive waste;
8. packaging and transport of spent fuel and/or fuel related radioactive waste;
9. management and support activities;
10. research and development;
11. miscellaneous costs.

The cost categories are the same as in the ISDC, i.e. labour cost, investment cost, expenses and contingency.

The approach aiming to develop harmonised structures for presentation of cost for projects in back-end nuclear cycle could be extended also for other areas such as:

- spent fuel management for nuclear power plants including long-term storage, disposal and reprocessing for various types of fuel,
- Deep Geological Repositories (DGR) and/or surface type repositories.