Presentation to ASN

ICRP Task Group 97

APPLICATION OF THE ICRP RECOMMENDATIONS FOR SURFACE AND NEAR SURFACE OF SOLID RADIOACTIVE WASTE

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Paris France

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ICRP TG 97 Member

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ICRP Structure

Main Commission

Scientific Secretariat

Committee 1
Effects

Committee 2
Doses

Committee 3
Medicine

Committee 4
Application

Task Groups

ICRP Task Group (TG) 97 Mandate

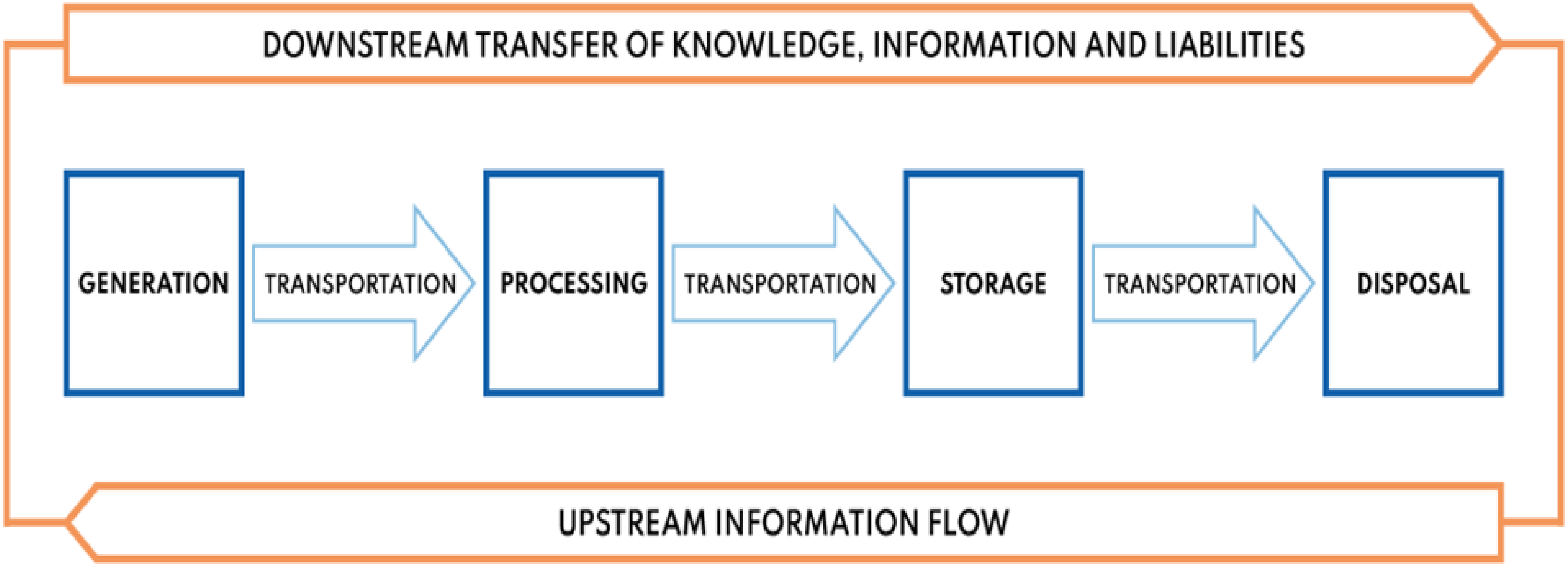
- To prepare a publication that describes and clarifies the application of the Commission's recommendations relevant to surface and near surface disposal of radioactive waste
  - Protection of the public and workers (Publications 101 & 103)
  - Protection of the environment (Publication 124)
- The report will be a companion to Publication 122

Goals and Objectives

- Provide recommendations for how the fundamental radiation protection principles are to be applied over the life cycle of surface and near surface disposal including transition from planned exposure to existing exposure situation in the case of a loss of institutional control
- Explore the application of the graded approach in implementing protection principles and advice in all facets of a facility's life cycle, based on hazard posed and degree of waste isolation
- Consult with regulators, implementers and relevant stakeholder's concerning the practical implementation of the Commission's recommendations
- Creation of a new standalone ICRP Publication that complements Publication 122 without unnecessary duplication
- Consideration of Publications 46, 77, and 81 and recent international experience

Background

- The final management solution for radioactive waste is emplacement of waste in an engineered facility without the intention of retrieval (i.e. disposal)
- Waste management refers to entire process from generation to disposal of solid waste



Scope

- All exposure situations offer the prospect of generating waste
- The management of a (near)surface facility largely follows the principles and practices applicable for a planned exposure situation
- Appropriate consideration for timeframes and uncertainties
- The recommendation applies to the design, construction, operational, closure and post-closure phases of disposal
- Does not consider predisposal management and no specific guidance on siting is provided

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Overview of Radioactive Waste and (Near)Surface Disposal

- Waste types
- Disposal system
- Disposal options
- (Near)Surface facility
- Phases of (Near)Surface facility

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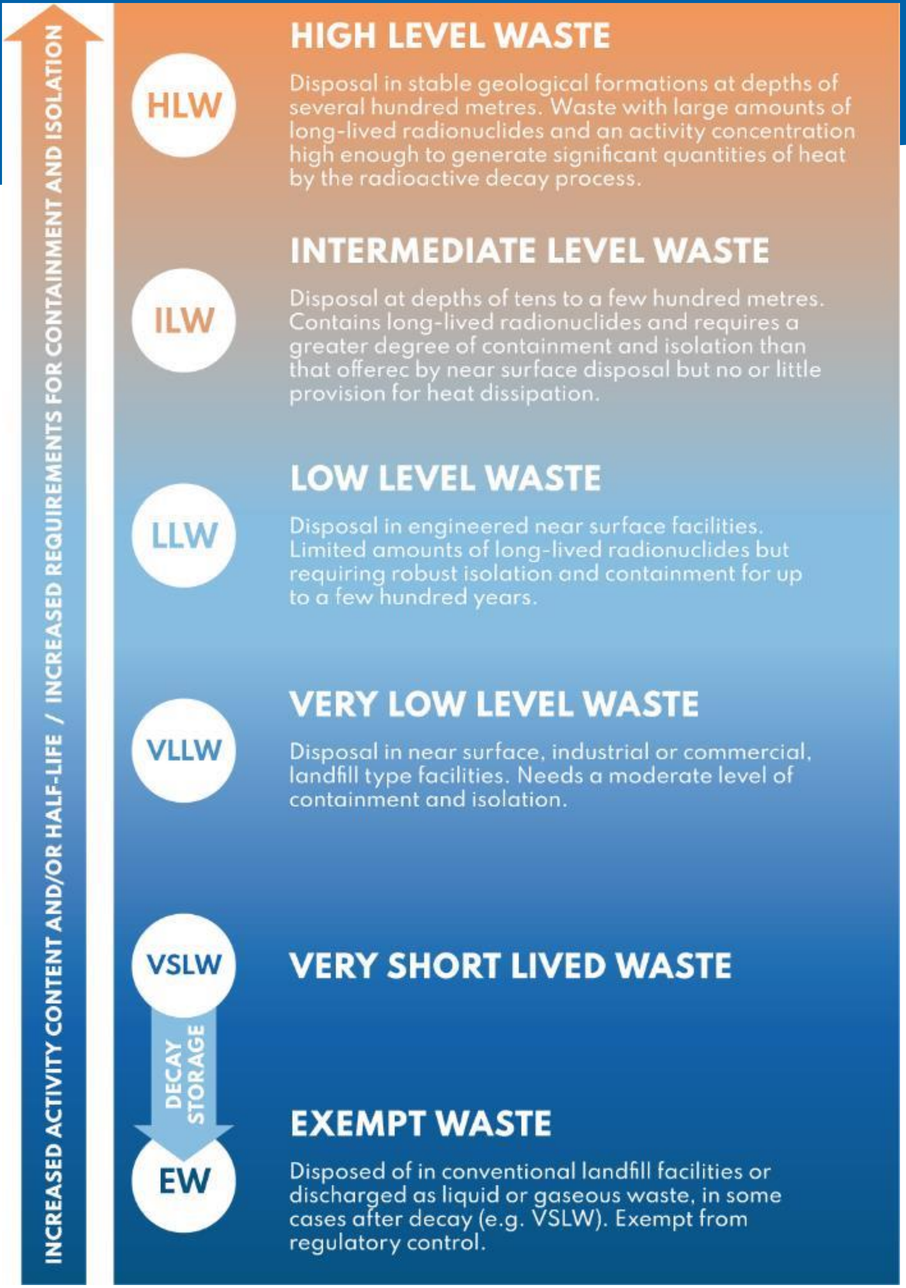
Waste Types

- The waste types most appropriate for (near)surface disposal are LLW and VLLW
- Surface and near surface disposal involve disposal on the surface or to depths of several tens of meters.
- The waste remains in the accessible biosphere



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Disposal System

- **The goal of a disposal system is to provide protection of humans and the environment for a time period in accordance with the waste related hazards**
- **The strategy adopted internationally is to**
  - **Isolate** the waste by placing a safe distance between the waste and the man and environment
  - **Contain** the waste in engineered barriers for a predefined period as well as on engineered and natural barriers after this period, in order to limit the dispersion of radionuclides in the environment and to delay in time

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Disposal Options

- **The principal characteristics of waste that determine the selection of management and disposal options are volume, chemical and physical form and radionuclides content**
- **VLLW and LLW are characterised by large volumes and low radioactivity content more specifically:**
  - Short-lived radionuclides with less than 30-year half-life (Cs-137, Sr-90)
  - Long-lived radionuclides with more than 30-year half-life weak-beta or alpha emitters.

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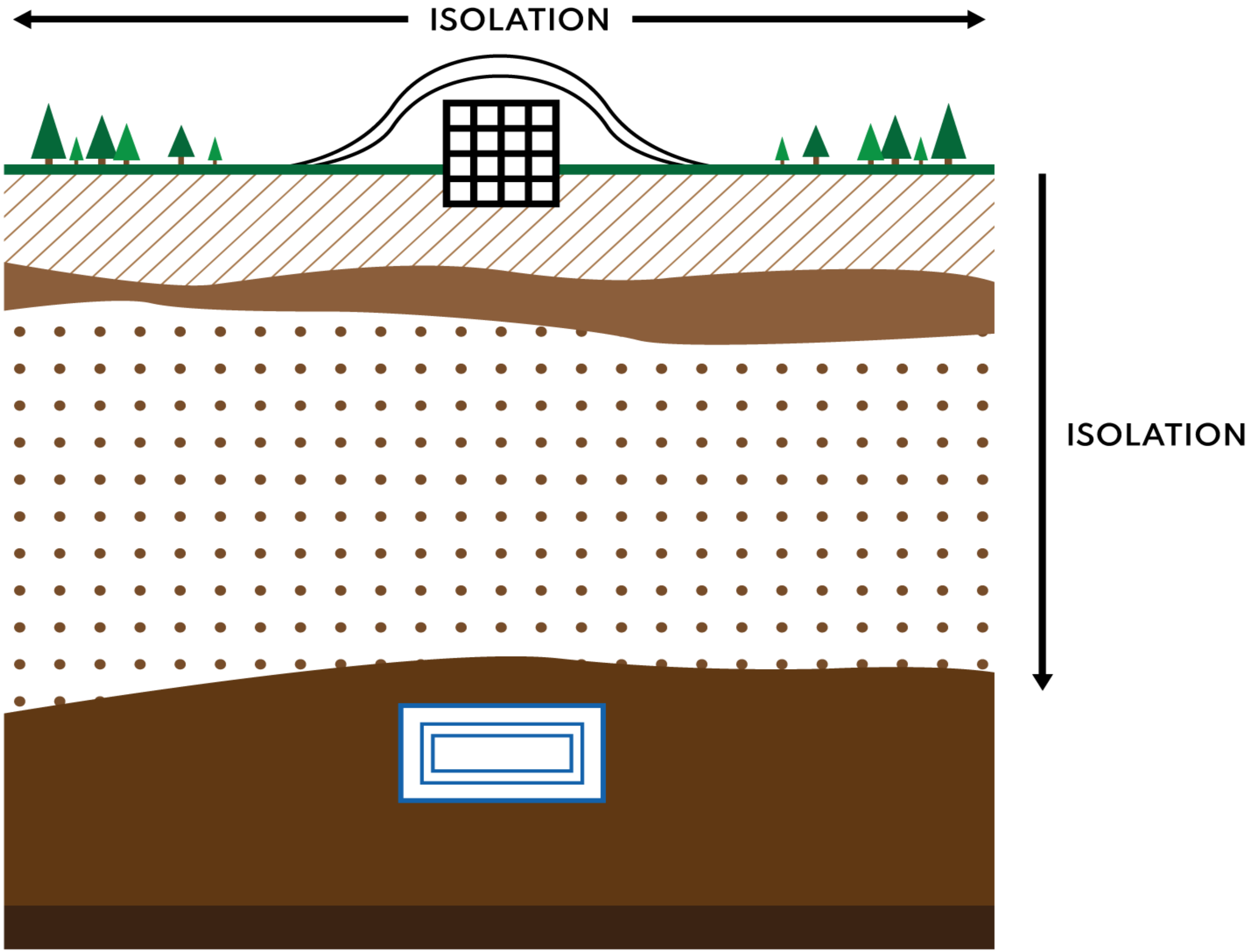
(Near)Surface facility

- **The disposal system must provide isolation and containment**
  - Until the **short-lived radionuclides have decayed** to levels that can not give rise to significant exposure, this will be a period of **several hundred years**, as the degree of the hazard changes, particularly the hazard from inadvertant human intrusion in the decades and centuries following closure. During this period, containement and isolation by a **combination of physical barriers and institutionnal control** (access control, land use restrictions)
  - By **limiting the the activity content of long-lived radionuclides** in the disposed waste to reduce the long-term residual risk.
  - By **avoiding site location with mineral and water resources** to limit the likelihood of deterioration of the barriers by deliberate human intrusion


ISOLATION
ISOLATION

Phases of (Near) Surface Facility

- **Three main phases: pre-operational, operational, post-closure**
  - Activities can **overlap** (i.e., siting and design) or can **occur at the same time** (i.e., construction of disposal units, emplacement in built units, closure of full units)
  - After closure activities are limited to those included in the planned **institutional oversight and controls** : period of regulatory control, monitoring of the cover, preservation of records, monitoring by society

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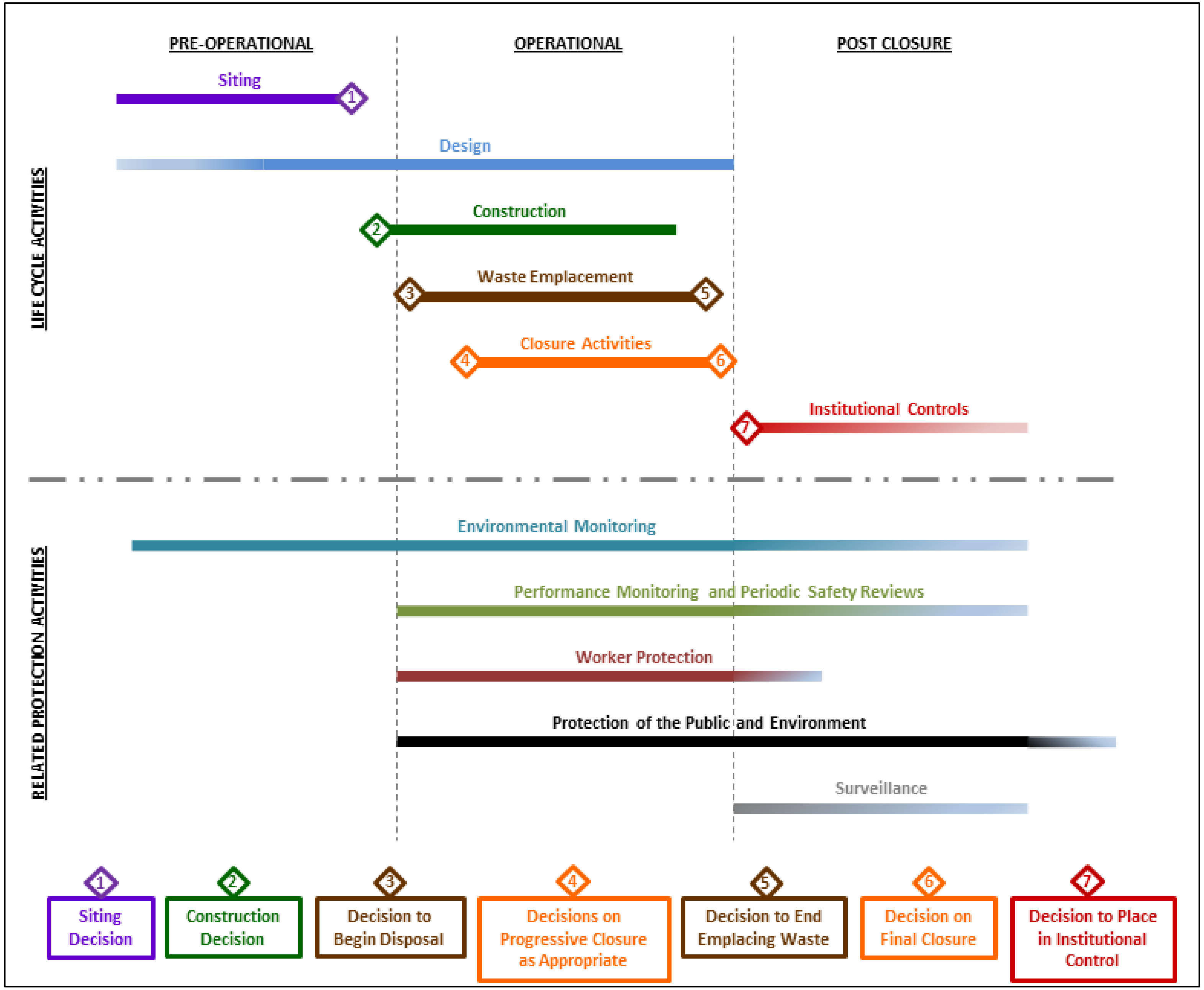
PRE-OPERATIONAL
OPERATIONAL
POST CLOSURE
LIFE CYCLE ACTIVITIES
Siting
Design
Construction
Waste Emplacement
Closure Activities
Institutional Controls
RELATED PROTECTION ACTIVITIES
Environmental Monitoring
Performance Monitoring and Periodic Safety Reviews
Worker Protection
Protection of the Public and Environment
Surveillance
1 Siting Decision
2 Construction Decision
3 Decision to Begin Disposal
4 Decisions on Progressive Closure as Appropriate
5 Decision to End Emplacing Waste
6 Decision on Final Closure
7 Decision to Place in Institutional Control

The application of the System of Radiological Protection to (Near)Surface Disposal of Radioactive Waste

- Principles of RP System and ethical considerations
- Strong ethical foundation
- The Fundamental Principles of RP
  and (Near) Surface Disposal
- Exposure situations
- Dose and risk concepts
- Representative person
- Optimization of protection
- Protection of the environment

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Principles of the RP System and Ethical Considerations

- Three fundamental principles:
  - **Justification**
  - **Optimization**
  - **Dose limits**
- Waste can come from all exposure situations but once the decision is taken to implementing a (near)surface facility the realization is best described as a **planned** exposure situation.
- The goal is to provide optimal levels of protection suitable with the prevailing circumstances; **situation-based approach** provides a way of thinking (i.e., dealing with waste in contaminated territory) without creating rigid boundaries in terms of exposure situations.

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Strong Ethical Foundation

Four core ethical values

- **Beneficence/non-maleficense:**
  Doing good and avoiding doing harm
- **Prudence:**
  Informed choices under uncertainties
- **Justice:**
  Fairness in distribution of advantages and disadvantages
- **Dignity:**
  Unconditional respect that every person deserves

Three procedural values

- **Accountability:**
  of the present generation to future generations
- **Transparency:**
  Access to information
  Enables social oversight
- **Inclusiveness:**
  Stakeholder involvement

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The Fundamental Principles of RP and (Near) Surface Disposal

- **Justification:**
  - Radioactive waste management is an integral part of the practice generating the waste. Therefore, justification of the practice generating the waste includes the management options for the waste including its disposal
- **If the management of the waste was not considered or the practice is no longer in operation, protection should be optimized independently of considering the justification of the past practice**

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- **Optimisation : «** the likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable » (**ALARA**)
- To ensure that the disposal system provides the required level of radiological protection, dose calculations should be complemented by considering its site and engineered features, such as **robustness**, **best available technique, safety margins, and defence in depth**
- Indeed, the uncertain nature of calculated effective dose and risk that is estimated to arise in the very distant future reduces their usefulness for the optimisation process
- Optimisation can be **constrained** by economic and societal factors

- **Dose limitation:**
  - Applies in radioactive waste disposal as it is considered a planned exposure situation
- Individuals and populations in the future should afforded at least the same level of protection as the current generation
- Not only issues of protection have to be considered but also **transfer of knowledge and resources**:
  - Isolation and containment of waste rely more on human protective actions than for geological disposal
  - Transfer of knowledge and resources is important to allow future generation to address protection issues associated with the disposal facility

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Exposure Situations

- **Planned exposure situations** are situations involving the **deliberate** introduction and operation of sources of exposure. Planned exposure situation can give rise to:
    - **Normal exposure situations** that are virtually **certain to occur** and which have a range of magnitude which is **predictable** with the attendant uncertainty
    - **Potential exposure situations** for which there is a potential for exposure but **no certainty** that they will occur (e.g., deviation from normal operation)

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- **Emergency exposure situations** are exposure situations resulting from a loss of control of a planned source (e.g., accident) or from any expected situation (e.g., malevolent event) which requires urgent action to avoid or reduce undesirable exposure
- **Existing exposure situations** are resulting from source that already exist when a decision to control them is taken (natural radiation, past activities or after emergencies)
- The delibarate introduction of a (near)surface facility is a **planned exposure situation** nevertheless exposures are not planned to occur

- The aim is to provide protection
  - During the **operational phase** by reducing exposure as low as reasonably achievable taking economic and societal factors into account.
  - **In the long term**, after closure when the facility is functioning as a **passive system, e.g. after oversight is no longer in place**, there is a possibility for exposure due to the anticipated decrease of the level of containment and isolation or because of natural disruptive events or inadvertent human intrusion

While the range of doses can be estimated the actual outcome cannot be predicted. The commission considers them as **potential exposure.**

- For (near) surface disposal facilities, an actual **emergency situation** is very unlikely even not credible, because of the strong limitation of activity in the waste and the generally inert and immobile form of the waste complemented by the built-in and passive safety features but disturbing events or intrusion could lead to an **existing exposure situation**.
  - For the **operation phase**, normal and potential exposures should be considered; only severe disruptive events could lead to an emergency situation followed by an existing exposure situation.
  - **After closure**, if the disposal facility evolves according expectation, the concept of planned exposure situation continues to apply. Only abrupt and severe perturbation outside the design basis could lead to an emergency situation. Changes in society (breakdown of control, loss of memory) can lead to situation requiring actions not necessary urgently. Those situations could be considered as existing exposure situations.

Dose and Risk Concepts

- Calculation of **effective dose** for workers and the public are used for optimization of protection by comparing with **dose constraints** and reference levels and to demonstrate **compliance with dose limits**
- **In the distant future**, uncertainties grows with time and gives rise to intrinsic difficulties for compliance demonstration with the system of protection including the process of optimization
  - Broader approach needed based on **sound and robust engineering design**
- **Risk** is a function of probability of the event causing dose and the probability of detriment due to that dose
- **Risk constraints** are applied to potential exposure when reasonable estimates of event probabilities can be made or when the probability can be bounded
  - In this case, an **aggregated approach** can be applied

- Dose limit for workers is 20 mSv y^{-1} with the requirement of optimizing protection below dose constraint
- Dose limit for the public is 1 mSv y^{-1} from all sources and a dose constraint of 0.3 mSv y^{-1} for each source
- For potential worker exposure, generic constraint for fatalities is $2x10^{-4}$ y^{-1}
- For potential public exposure, the risk constraint is 10^{-5} y^{-1}
- An optimized system may result in a distribution of dose where **some can be predicted above the applicable dose constraint**
    - These situations should be investigated more in depth e.g. **in the event of human intrusion, isolation and confinement should be enhanced with emphasis on the quality of design and construction**

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<table>
<tr><th>Phase</th><th>Activity/Scenario</th><th>Protective approach</th><th>Criteria</th><th>Planning framework</th></tr>
<tr><td>Pre-operational & Operational</td><td>Site preparation; Design; Construction; Waste emplacement; Closure</td><td rowspan="2">Planned exposure situation, implementing:
• Dose limits
• Constraints (dose and risk)
• Derived Consideration Reference Levels (DCRL)</td><td>Optimisation as for the design and operation of any facility</td><td rowspan="3">Design basis</td></tr>
<tr><td rowspan="3">Post-closure</td><td>Expected evolution of facility and environment including foreseeable disruptive events</td><td>Optimisation guided by constraints of 0.3 mSv y^{-1} (dose); 10^{-5} y^{-1} (risk); and lower end of relevant DCRL</td></tr>
<tr><td>Natural disruptive events or Inadvertent human intrusion</td><td>Existing (and/or Emergency) Exposure Situation, implementing:
• Reference levels
• DCRL</td><td>Optimisation guided by reference levels ≤ 20 mSv and DCRLs</td></tr>
<tr><td>Extreme events; Accidents</td><td>Evaluation against possible consequences; Best Available Technique (BAT)</td><td>Not considered in optimisation</td><td>Beyond design basis</td></tr>
</table>

The Representative Person

- For the purpose of protection of the public, the representative person corresponds to an individual receiving a dose that is representative of the **most highly exposed person** in the population (ICRP, 2006)
- There is limited scientific basis for predicting the nature or probability of future human action, so representative person needs to be hypothetical and stylized
  - Assumed habits and characteristics should be based on **reasonably conservative and plausible assumptions**

Optimization of Protection

- Optimization of RP when applied to development and implementation of a (near)surface disposal system needs to be understood as an **iterative, systematic and transparent evaluation of options** for enhancing its protective capabilities and for reducing its radiological impact
- Optimization should also be considered **holistically** within the context of the national waste management policy and strategy
- Recognized that economic and **societal factors** (e.g., policy decision, risk acceptance issues) can bound optimization process to various extents by defining additional conditions (e.g., site location, retrievability)

- **The greatest opportunity to optimize protection is in the design phase** which should be given a high focus. In the distant future, dose and risk lose their intrinsic meaning, but can provide an enveloping estimate of potential radiological impact
  - As a result, **calculated dose and risk in the future might not be discriminating factors between design options**
- Optimization process supports design but provides less information on protective capability in the distant future, a situation where **sound design and system performance should dominate**
- If several sites are identified and evaluated, selection will be based on a multifactorial decision that uses quantitative and qualitative judgement
  - **Radiological assessment** will be one factor but **will not likely dominate the decision** due to its preliminary nature and associated uncertainties

Protection of the Environment

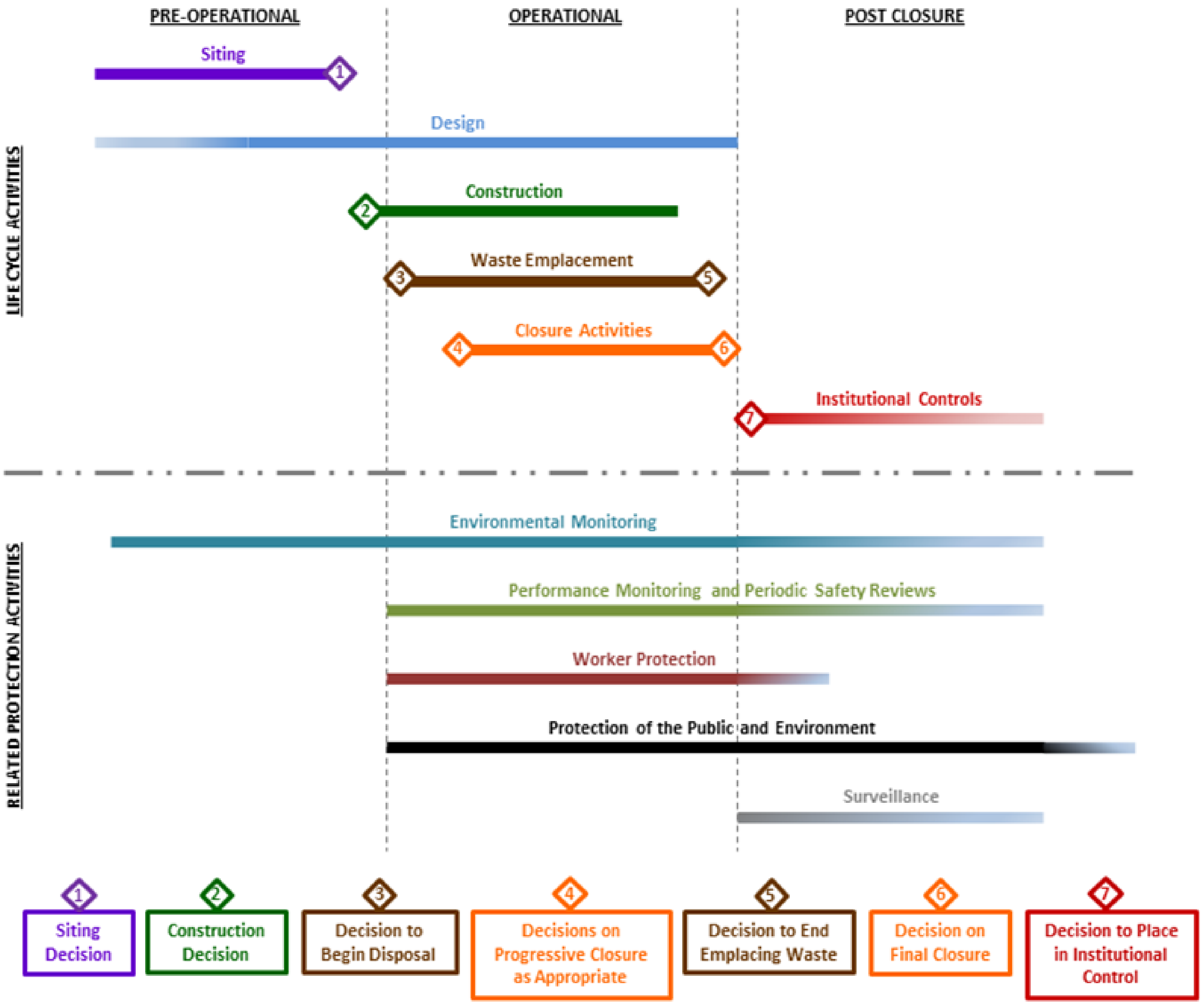
- ICRP considers protection of the environment by virtue of the aim of
    - *"**preventing or reducing the frequency of deleterious effects on fauna and flora** to a level where they would have a negligible impact on the maintenance of biological diversity, the conservation of species, or the health status of natural habitats, communities and ecosystem (ICRP 2007)"*

- Default tool for demonstrating protection and need for protective action should be the set of Reference Animals and Plants (**RAPs**) Derived Consideration Reference levels (**DCRLs**) (ICRP 2008 and 2009c)

Implementation of the System of Radioprotection to the phases of a (Near)Surface Disposal Facility

- Oversight
- Protection during different phases
- Protection of particular circumstances

Disposing of radioactive waste is a planned exposure, so there is an obligation to provide controls during different phases



Oversight

Ensures that an appropriate control system is in place as long as it is required

- **Direct oversight**: active measures carried out by the operator before operation, during construction, waste emplacement, closure and in the immediate post closure phase
  - Example: inspections, monitoring, keeping of records
- **Indirect oversight**: measures in place after the site has been released from regulatory control (depending on the residual activity)
  - Example: restriction of land-use, records keeping, societal memory of the site
- **No oversight**: prudent to assume the memory of the site will be lost; disposal facility needs to be designed not to rely on oversight in the distant future by providing **passive safety** features

Protection during different Phases

- **Pre-operational phase**: facility design is based on sound and proven engineering practices complemented by optimization, assessment of robustness and consideration for defense in depth
  - **Performance of facility in operational and post-closure phases are determined**
  - Dose calculations are undertaken for a range of evolution scenarios and for inadvertent human intrusion
  - Cautious but realistic assumptions should be made for the different uncertainties to avoid underestimation of exposure, but overly conservative assumptions should be minimized to avoid completely unrealistic outcomes
  - **Numerical compliance with dose criteria alone should not compel acceptance or rejection of a (near) surface disposal facility**

- **Protection during the operational phase**: most of the decision regarding long-term safety have been taken during the pre-operational phase and limited opportunity is left for corrective action
  - Dose limits and constraints for planned exposure situation are applied
  - Environmental conditions are monitored and compared with baseline data
  - After final closure, monitoring and access control provisions are put in place
- **Protection during the post closure phase**: monitoring continue to confirm the ongoing performance (containment and isolation) and necessary maintenance is carried on
  - Period of time activities are continued depends on the activity of disposed waste and the degree of confidence in the long-term performance of the facility
  - Need to meet the **reference level for inadvertent intrusion** if it were to happen; the Commission recommends to select a reference level **from 1 to 20 mSv**
  - For situations with **off-site impacts** the **lower range of 1 to 20 mSv** is recommended

Protection in particular circumstances

- **Natural disruptive events** (e.g., earthquake, severe flood)
  - **Events for which it is possible to estimate or bound the probability** and time frames of occurrence **are normally included in the design-basis scenarios**.
    - Commission recommends application of the risk or dose constraint for these **planned exposure situations**
  - **Very-low probability events can be excluded from design-basis** through an agreed and transparent methodology
    - Risk and dose constraint for planned exposure situation does not apply in this case and the situation is treated as an **existing exposure situation** using stylized scenarios to estimate the potential radiological impact
    - Commission recommends using a reference level within the **lower half of the 1 to 20 mSv/y with the objective to progressively reduce the exposure to the lower end of the band or below if possible**

- **Inadvertant human intrusion**
  - Because human intrusion could occur due to the location of the (near) surface facility in the accessible biosphere it should be included **in the design basis** provisions beeing taken to reduce the possibility and the radiological impact.
  - The Commission considers it is prudent to assume intrusion will occur corresponding to an **existing exposure** situation. **Reference levels in the lower half of the 1 mSv to 20 mSv/y with the objective to reduce progressively to the lower end of the band is recommended.**
  - Reasonable **stylised scenarios** may be used noting that extreme practices should not be adopted. The optimum design of a disposal system may result in a distribution of dose where some are above of the reference levels.

Main Points

- The system of radiological protection is applied to the (near) surface disposal of solid radioactive waste in the context of a planned exposure situation with appropriate considerations of the timeframes and related uncertainties
- The potential exposures to humans and the environment associated with the expected evolution of the (near) surface disposal facility included in the design basis, are considered as planned exposure situation

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- **Optimisation of radiological protection**
  - Essential throughout all life phases of a (near) surface disposal facility and **is of particular importance in the design phase** as this will determine the performance of the facility in the operational and post-closure phases
  - Application to the development and implementation of a (near) surface disposal system, has to be understood in the broadest sense as an iterative, systematic, and transparent evaluation of protective options for reducing impacts to humans and the environment

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- **Appropriate mechanisms for formal and structured dialogue between the regulator and operator and with stakeholders should be established as early as possible in the process. The inclusion of ethical values in the dialogue is important and can be a useful at promoting a shared understanding**
- **The uncertainties associated with future exposures must consider both the magnitude and the likelihood of occurrence. Scenarios involving human intrusion require special consideration**

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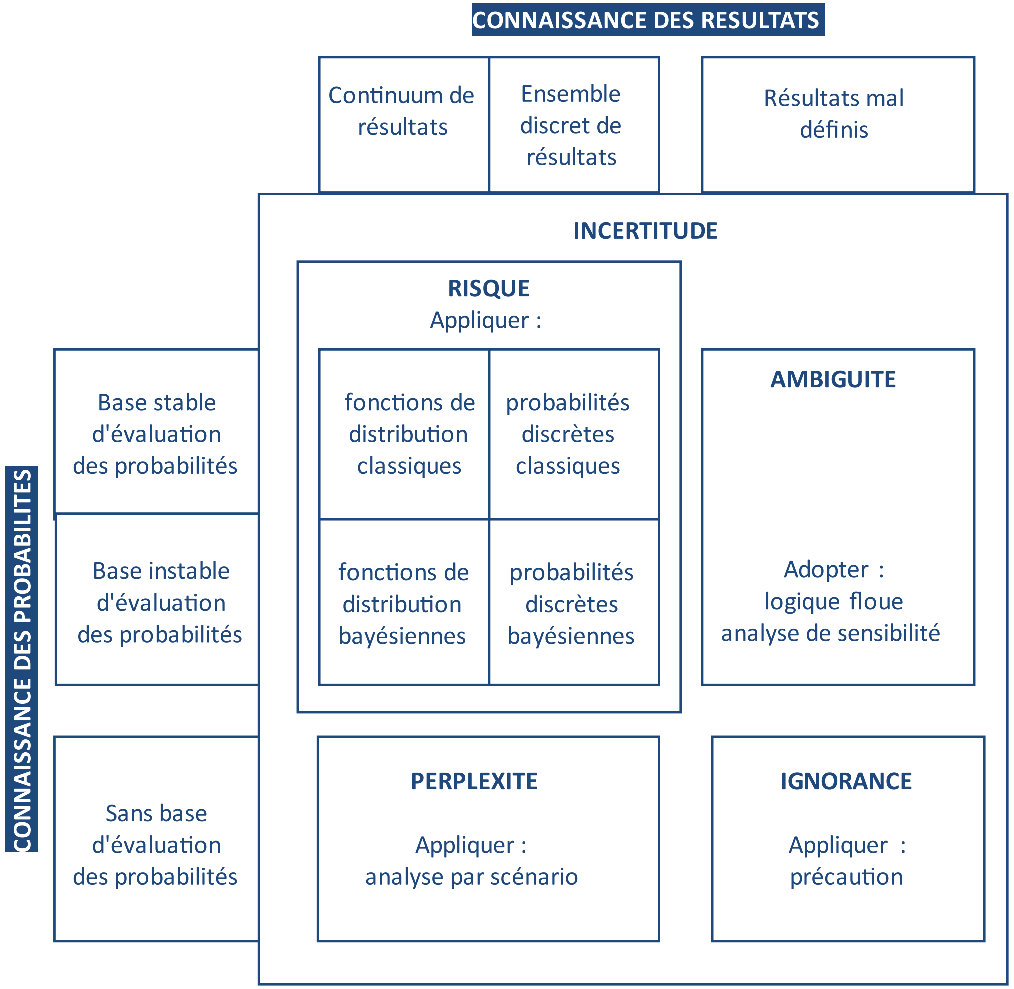
Compléments sur l’approche par risque.

(note personnelle)

Approche par Risque (selon Stirling)



Approche par Risque

Soit un plan dans lequel nous représentons, en abscisse, la connaissance des résultats et, en ordonnée, la connaissance des probabilités. Sur l'abscisse, les résultats apparaissent en trois catégories : continuum, ensemble discret et résultats mal définis. En ordonnée, trois catégories également : une base stable d'évaluation des probabilités, une base instable d'évaluation des probabilités et l'absence de base d'évaluation des probabilités. Le domaine du risque englobe le sous-espace du plan défini par les résultats discrets et continus et l'évaluation des probabilités stable ou instable. Le domaine de la perplexité est défini comme sous-espace du plan correspondant à l'absence de base d'évaluation des probabilités et une connaissance des résultats discrets ou continus. L'ambiguïté est définie sur le domaine constitué des résultats mal définis mais pour lesquels il existe une base (stable ou instable) d'évaluation des probabilités. Enfin, l'ignorance correspond au domaine résiduel restant pour lequel les résultats sont mal définis et les probabilités ne peuvent être évaluées (d'après Stirling, 2000).