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WASTE ACCEPTANCE CRITERIA

NEAR SURFACE DISPOSAL FACILITY WASTE ACCEPTANCE CRITERIA

NEAR SURFACE DISPOSAL FACILITY (NSDF)

232-508600-WAC-003

Revision 4

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1. SCOPE AND APPLICABILITY

The Near Surface Disposal Facility (NSDF) is a planned Engineered Containment Mound for solid Low Level Radioactive Waste that will be located at the Chalk River Laboratories (CRL), located in the town of Deep River Ontario. All waste that will be placed for disposal in the NSDF will be Low-Level Waste (LLW) as defined by the Canadian Standard Association (CSA) N292.0:19 [1].

This Waste Acceptance Criteria (WAC) specifies all of the requirements that Canadian Nuclear Laboratories (CNL) will use as decision limits for accepting/rejecting LLW for disposal. The NSDF WAC also informs waste generators, both CNL and external, of the criteria for accepting waste, aiding them to make decisions on how to manage their waste.

This revision of the NSDF WAC is subject to change based on licensing approvals by the responsible authority, the Canadian Nuclear Safety Commission (CNSC).

1.1 Exclusions

The NSDF will not contain high-level radioactive wastes such as used nuclear fuels nor intermediate level waste such as irradiated reactor core components.

The requirements for interim storage prior to placement in the NSDF are outside of scope of this document and are documented in the Waste Management Areas Waste Acceptance Criteria [2].

Requirements for the transportation of waste to the NSDF Facility are outside of scope of this document; refer to CNL's Transportation of Dangerous Goods Program [3] and [4].

2. PURPOSE

This document defines the criteria for the acceptance of LLW at CNL's NSDF. The NSDF WAC ensures CNL meets its responsibility as the licensee; all waste received for disposal is in compliance with the design and licensing basis for the Facility. Specific safety criteria are provided in the Design [5], the Environmental Impact Statement [6], the Post-Closure Safety Assessment [7], the Safety Analysis Report [8] and the Criticality Safety Document [9]. Compliance with the NSDF safety criteria ensures the short-term and long-term protection of the public, the environment and workers.

Waste shall comply with all of the criteria listed in the WAC to be considered acceptable for disposal in the NSDF.

The criteria are separated into four sections in this document. Specifically:

- The limits and controls for the physical properties of waste, including packaging limits and controls (Section 3);
- The limits and controls for the chemical properties of waste (Section 4);
- The limits and controls for the radiological properties of waste (Section 5);
- Administrative processes and quality controls that provide assurance that waste placed in the NSDF complies with the NSDF WAC as well as the Infrequently Performed Operations (Section 6.4).

The basis for the limits and controls are provided in Appendix A.

3. PHYSICAL PROPERTIES OF WASTE

Wastes being disposed in the NSDF are organized into six physical waste types defined by material type. The NSDF Waste Types are:

Type 1 Waste – Soil and soil-like wastes. Includes contaminated soils and other waste materials with characteristics similar to soil that can be placed within the mound with what would be required for the disposal of soil.

Type 2 Waste – Comingled radioactive waste, debris, refuse, soil, and soil-like waste. Includes wastes that are anticipated to be at least 50% soil or soil-like in nature.

Type 3 Waste – Non-soil-like waste. Includes materials that can be excavated and handled as bulk materials but do not have the physical characteristics of soil and soil-like materials. These include process wastes, highly organic wastes, highly compressible wastes, flowing wastes and similar waste types.

Type 4 Waste – Decommissioning and Demolition (D&D) waste. Includes typical materials used in construction, such as: concrete, asphalt, brick, lumber, structural steel, process equipment, piping, wood and other building materials produced by D&D activities.

Type 5 Waste – Packaged Waste, refers to wastes contained in rigid packages. There are two types of rigid waste packages: Non-Leachate Controlled Waste Packages and Leachate Controlled Waste Packages. Liners and soft-sided packages are not considered Type 5 Waste.

Non-Leachate Controlled Waste Packages include intermodal containers (e.g., 20 foot ISO container), steel waste boxes (e.g., B-25 boxes) and drums (e.g., 205 L drum).

Leachate Controlled Waste Packages are packages that provide containment of the waste during the time that the disposal cell is not covered with the final cover. Containment can also be provided using approved overpacks or waste processing methods.

Type 6 Waste – Oversize debris, includes waste that does not fall within the definition of waste Types 1 through 5, primarily by its size or shape. The Infrequently Performed Operations process (Section 6.4), is used to approve placement of Type 6 wastes.

3.1 Bulk Waste Physical Properties

Bulk wastes are identified as Type 1, 2, 3, 4, and 6 wastes. The physical requirements for waste Types 1 through 4 are listed here; whereas the physical requirements for Type 6 waste is covered in Section 3.2:

- Bulk Waste must be size reduced to 0.3 m or less in at least one dimension and sized to fit within the bulk waste packaging/transportation vehicle;
- Bulk Waste can be reduced to rubble;
- Rebar in concrete debris shall be cut flush;
- Bulk waste that is not easily compacted by standard landfill equipment, in the ECM shall limit void space to a maximum of 10%. The waste generator is responsible to ensure the waste is processed to meet this requirement (e.g., waste may need to be cut, crushed or have void space filled).
- As necessary, the use of bags, plastic wrap or fixatives are permitted to address As Low As Reasonably Achievable (ALARA) principles [10].

3.1.1 Bulk Waste Packaging/Transportation Vehicles

Bulk waste is placed in either bulk waste packaging or a transportation vehicle for shipment to the NSDF. Approved bulk waste packaging includes:

- Soft sided packages (of various sizes);
- Intermodal waste containers, 6.1 metres (20 foot), equipment with a single or double-end-doors. Various duty rated options are available including Type A, IP-1 and IP-2 Industrial Containers.
- Roll-off containers with a single or double end-doors.

Bulk waste packaging/transportation vehicles must meet the following requirements:

- The waste container is compatible with the chemical and physical properties of the waste;
- The container must be free of damage that could compromises its integrity;

Additionally, re-usable waste containers and transportation vehicles shall:

- Be packaged such that unloading the bulk waste can be performed without creating safety hazards for NSDF personnel, including binding;
- Use a liner, or ensure the waste is wrapped in plastic to minimize container contamination during the unloading process.

3.2 Type 6 Oversized Debris

Type 6 waste is bulk waste that cannot be reasonably expected to be processed to meet the physical requirements listed in Section 3.1. As oversized debris adds constraints during the waste placement process, including special handling to offload oversize debris, preparing placement plans, processing (e.g., grouting) in the cells or preparing special instructions, all Type 6 waste shall go through the Infrequently Performed Operations process (see Section 6.4).

Note; transportation requirements may be a limiting factor for Type 6 waste; however as noted in Section 1.1, are not covered in this document.

3.3 Type 5 Packaged Waste

Type 5 Packaged Waste refers to wastes contained in rigid packages prepared for disposal. All Type 5 waste must comply with the following requirements:

- The waste container is compatible with the chemical and physical properties of the waste; and
- Internal void space of the waste package is limited to a maximum of 10%. When the internal void space is greater than 10%, the waste generator is responsible for ensuring that the void space is filled with non-compactable waste or grouting the contents so that grout flows throughout and fills the interstitial voids.

3.3.1 Non-Leachate Controlled Waste Packages

Non-Leachate Controlled Waste Packages are waste packages that must be able to contain the waste until placement in the NSDF. Pre-approved non-leachate controlled waste packages include:

- Drums which may be galvanized, stainless, carbon steel, or plastic; up to 386 litres, and have a mass up to 450 kg.
- Waste Boxes which may be galvanized steel, stainless steel or carbon steel, up to 2.7 m3, and have a mass of up to 5,000 kg.
- Intermodal waste containers, 6.1 metres (20 foot). Various duty rated options are available including Type A, IP-1 and IP-2 Industrial Containers. Gross weight up to 36,000 kg.

3.3.2 Leachate Controlled Waste Packages

Leachate Controlled Waste Packages are waste packages that are able to provide containment of the waste during the time the disposal cell is not covered with the final cover (approximately 5-10 years). Containment of the waste can be provided by the final waste form itself, or having the waste in a package or overpacked package such that the waste package complies with the following guidance [11]:

- The package shall maintain structural integrity when subjected to the maximum NSDF overburden pressure (vertical pressure) of 350 kPa. This vertical pressure bounds the maximum anticipated live loads (e.g., compaction and vehicle loads).
- The package shall maintain structural integrity when subjected to the maximum NSDF soil pressure (lateral pressure) of 200 kPa. This lateral horizontal pressure bounds the maximum anticipated live loads (e.g., compaction and vehicle loads).
- The design of the packaging shall prevent the infiltration and/or exfiltration of water when the package is subjected to the above disposal pressures.
- The exterior of the packaging shall be chemically compatible with the expected NSDF disposal environment.
- The package shall include gas venting if deemed a gas generation hazard exists.

Examples of acceptable leachate controlled waste packages include, but are not limited to, high integrity containers or macroencapsulation.

3.3.3 Shielded Waste Packages

Waste packages that include shielding are subject to the following additional requirements:

- The use of shielded packages must be pre-approved by NSDF Facility Authority (Waste Profile and Waste Management Plan); and
- The physical characteristics of the shielding, including material type, mass and thickness are documented.

3.4 Asbestos Waste

The NSDF will accept radiologically contaminated asbestos waste. Asbestos Waste includes:

- Asbestos Containing Material (ACM), material that contains 0.5 per cent or more asbestos by dry weight; and
- Waste that results from the removal or handling of ACM, including personal protective equipment, tools that cannot be decontaminated and cleaning materials.

Asbestos Waste shall:

- Be placed in an impermeable container, bag or liner of sufficient strength (minimum thickness is 0.15 mm [6 mil]) to accommodate the weight and nature of the waste;
  - The container, bag or liner must be sealed;
  - The container, bag or liner must be free from punctures, tears or leaks;
  - The external surfaces of the container, bag or liner must be free from asbestos waste;
- Every container, bag or liner must display thereon in large, easily legible letters that contrast in colour with the background the word “CAUTION” in letters not less than ten centimetres in height and the words:
  - CONTAINS ASBESTOS FIBRES
    Avoid Creating Dust and Spillage
    Asbestos May be Harmful to Your Health
    Wear Approved Protective Equipment.
- Asbestos Waste shall be segregated from other waste streams;
- The quantity of friable and non-friable asbestos waste (in kilograms) is to be reported.

3.5 Free Standing Liquids

Free standing liquids are not permitted in NSDF waste (i.e., equal to or greater than 1% free standing liquids by volume). Wastes that are suspect to contain free liquids (e.g., high moisture content) can be tested using:

- SW-846 Test Method 9095B: Paint Filter Liquids Test [12]; or
- Test Method for the Determination of Liquid Waste (slump test) [13]. Note waste is defined as “Liquid Waste” if it slumps more than 150 mm.

Wastes that have been rendered solid via stabilization (e.g., cementation) or pre-treatment are required to meet this performance objective.

The use of inorganic absorbents is acceptable for small, incidental amounts of free liquid or to prevent the presence of condensate upon delivery to NSDF. Examples of acceptable absorbents are:

- Aquaset (including Aquaset II-H and Aquaset II-G);
- Petroset (including Petroset-II);
- Bentonite, and
- Nochar (including A610 Petro Bond; A611 Petro Bond and A660 Acid Bond).

The use of organic (i.e., carbon-based) absorbents is not acceptable.

3.6 Pressurized Containers

Pressurized containers are not permitted for disposal in the NSDF. Pressurized containers that are radioactively contaminated and cannot be decontaminated are acceptable for disposal in NSDF if they have been permanently vented and comply with all requirements of the NSDF WAC (e.g., Bulk Waste Physical Properties, Section 3.1).

Acceptable vented pressurized containers are to be segregated from other waste streams and clearly labelled.

4. CHEMICAL PROPERTIES OF WASTE

Waste characterization plans must be designed to provide chemical properties that are representative of the waste stream(s) being sampled and characterized.

4.1 Hazardous Waste

Waste that, notwithstanding of its radioactive component, is classified as hazardous waste is not permitted for disposal in the NSDF. Specifically:

1. Listed Waste:

   As defined in Ontario Regulation 347 [13], including: hazardous industrial waste; acute hazardous waste chemical; hazardous waste chemical; or severely toxic waste, unless the Listed Waste has been treated using methods for land disposal described in Ontario Regulation 347 (see Table 1 for guidance).

2. Characteristic Waste:

   As defined in Ontario Regulation 347 [13], including: ignitable waste; corrosive waste; reactive waste; or leachate toxic waste, unless the Characteristic Waste has been treated using methods for land disposal described in Ontario Regulation 347 (see Table 2 for guidance).

3. Polychlorinated Biphenyls (PCB) Waste:
   i. Materials containing PCBs at a concentration equal to, or greater than fifty parts per million by weight whether the material is liquid or not; and
   ii. Materials containing PCBs at concentrations less than fifty parts per million by weight that are leachate toxic waste.

4. Biohazardous Infectious Waste:

   Material or materials contaminated with organisms or toxins that can cause diseases in people or animals, unless the material has been treated and no longer has the characteristics of biohazardous infectious waste.

Table 1
Guidance on Listed Waste [13]

Listed Waste	Abridged Ontario Reg. 347 Definition (for convenience purposes only)	Ontario Reg. 347 Section that Defines Land Disposal Treatment Methods
Hazardous industrial waste	A waste [mixture of a waste or waste derived from a waste] listed as a hazardous industrial waste in Schedule 1, other than a waste described in Schedule 1.1 […]	75, 82 & 83
Acute hazardous waste chemical	A commercial waste [mixture of a waste or waste derived from a waste] chemical listed as an acute hazardous waste chemical in Part A of Schedule 2, other than a waste described in Schedule 2.1 […]	76, 82 & 83
Hazardous waste chemical	A commercial waste [mixture of a waste or waste derived from a waste] chemical listed as a hazardous waste chemical in Part B of Schedule 2, other than a waste described in Schedule 2.2 […]	77, 82 & 83

Listed Waste	Abridged Ontario Reg. 347 Definition (for convenience purposes only)	Ontario Reg. 347 Section that Defines Land Disposal Treatment Methods
Severely toxic waste	A waste [mixture of a waste or waste derived from a waste] that contains a contaminant listed as a severely toxic contaminant in Schedule 3 at a concentration greater than one part per million […]	78, 82 & 83

Table 2
Guidance on Characteristic Waste [13]

Characteristic Waste	Abridged Ontario Reg. 347 Definition (for convenience purposes only)	Ontario Reg. 347 Section that Defines Land Disposal Treatment Methods
Ignitable waste	(a) is a liquid, other than an aqueous solution containing less than 24 per cent alcohol by volume and has a flash point less than 61° Celsius, as determined by the Tag Closed Cup Tester (ASTM D-56-79), the Setaflash Closed Cup Tester (ASTM D-3243-77 or ASTM D-3278-78), the Pensky-Martens Closed Cup Tester (ASTM D-93-79), […], (b) is a solid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a danger, (c) is a Class 2.1 Flammable Gas within the meaning of paragraph 2.14(a) of the [Transportation of Dangerous Goods Regulations] [14], (d) is a Class 5.1 Oxidizing Substance within the meaning of paragraph 2.24(a) of the [Transportation of Dangerous Goods Regulations] [14], or (e) is a Class 5.2 Organic Peroxide within the meaning of paragraph 2.24(b) of the [Transportation of Dangerous Goods Regulations] [14];	79, 82 & 83
Corrosive waste	(a) a waste that is aqueous and has a pH less than or equal to two or greater than or equal to 12.5 as determined by a pH meter, (b) a waste that is a liquid and corrodes steel (SAE 1020) at a rate greater than 6.35 millimetres per year at a test temperature of 55° Celsius using test NACE TM-01-69 […], or (c) a waste that is a solid and, when prepared in a mixture or solution with distilled water that is 50 per cent waste by weight, has a pH less than or equal to two or greater than or equal to 12.5 as determined by a pH meter, […]	79, 82 & 83

Characteristic Waste	Abridged Ontario Reg. 347 Definition (for convenience purposes only)	Ontario Reg. 347 Section that Defines Land Disposal Treatment Methods
Reactive waste	(a) is normally unstable and readily undergoes violent change without detonating, (b) reacts violently with water, (c) forms potentially explosive mixtures with water, (d) when mixed with water, generates toxic gases, vapours or fumes in a quantity sufficient to present danger to human health or the environment, (e) is a cyanide or sulphide bearing waste which, when exposed to pH conditions between two and 12.5, can generate toxic gases, vapours or fumes in a quantity sufficient to present danger to human health or the environment, (f) is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement, (g) is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure, (h) is a Class 1 Explosive within the meaning of Section 2.9 of the [Transportation of Dangerous Goods Regulations] [14];	79, 82 & 83
Leachate toxic waste	A waste producing leachate containing any of the contaminants listed in Schedule 4 [Ontario Regulation 347] at a concentration equal to or in excess of the concentration specified for that contaminant in Schedule 4 [Ontario Regulation 347] using the Toxicity Characteristic Leaching Procedure;	79, 82 & 83

4.2 Key Constituents of Potential Concern

Key Constituents of Potential Concern (COPC) are chemicals of interest if CNL were to emplace the constituent at its maximum leachable concentration [15]. The COPC were used for NSDF leachate modelling purposes and the total quantity of COPCs in the waste must be tracked; therefore, when the Key COPC listed in Table 3 are present in the waste and/or are part of the waste container, the concentration or quantity and the uncertainty shall be reported.

Table 3
Key Constituents of Potential Concern [15]

Chemical Name	Chemical Abstracts Service (CAS) Number
1,1,2,2-Tetrachloroethane	79-34-5
1,1,2-Trichloroethane	79-00-5
1,4-Dichlorobenzene	106-46-7
Acetone	67-64-1
Aluminum	7429-90-5
Anthracene	120-12-7
Antimony	7440-36-0
Arsenic	7440-38-2
Barium	7440-39-3
Benzene	71-43-2

Chemical Name	Chemical Abstracts Service (CAS) Number
Benzo[a]pyrene	50-32-8
Beryllium	7440-41-7
Bis(2-ethylhexyl)phthalate	117-81-7
Boron	7440-42-8
Cadmium	7440-43-9
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroform	67-66-3
Chromium (Total)	7440-47-3
Chromium VI (same as total)	18540-29-9
Chrysene	218-01-9
Cobalt	7440-48-4
Copper	7440-50-8
Dioxin (Toxic Equivalency)	9014-42-0
Ethylene dibromide	106-93-4
Fluoranthene	206-44-0
Fluorene	86-73-7
Fluoride (aqueous)	16984-48-8
Furan (Toxic Equivalency)	110-00-9
Iron	7439-89-6
Lead	7439-92-1
Mercury	7439-97-6
Methylene Chloride	75-09-2
Molybdenum	7439-98-7
Nickel	7440-02-0
Nitrate	14797-55-8
Nitrite	14797-65-00
Phenol	108-95-2
Phenolic compounds, nonchlorinated	
Phosphate (Phosphorus)	14265-44-2
Polychlorinated Biphenyls (PCB)	1336-36-3
Selenium	7782-49-2
Silver	7440-22-4
Sodium	7440-23-5
Tetrachloroethylene	127-18-4
Thallium	7440-28-0
Tin	7440-31-5
Vanadium	7440-62-2
Zinc	7440-66-6

4.2.1 Estimated Quantity of Metals and Organics

The estimated quantity of discrete metals (including metal waste and packages) and organics in the NSDF at closure, has been included in the Post-closure Safety Assessment [7] model primarily for its potential effects on release rates of radiological constituents from the Facility. As such, tracking of actual mass (plus the

uncertainty) of metal and organics received as waste or as part of the waste package shall be recorded. Table 11 and Table 12 in Appendix B provide the estimated quantities of Metals and Organics.

4.3 Chemical Properties of Waste for Criticality Safety

Moderators, reflectors and chelating agents are limited and restricted in the NSDF to ensure compliance with nuclear criticality safety requirements [9]. Note the Criticality Safety Document restricts averaging of compounds over a maximum of one waste unit, which is defined as 1,500 kg.

- The Nuclear Criticality Control Officer (NCCO) shall approve all shipments of waste containing moderators, reflectors and chelating agents to the NSDF prior to shipment.
- Compounds of carbon, fluorine, magnesium and bismuth are restricted to ≤20% by mass over a single waste unit (i.e., 1,500 kg).
- Beryllium, deuterium and graphite are restricted to ≤ 0.1% by mass combined over a single waste unit (i.e., 1,500 kg).
- Chelating agents in waste shall be restricted to less than 0.1% by mass over a single waste unit (i.e., 1,500 kg).
    - Chelating agents are chemical compounds (usually organic compounds) that form complexes with metal ions or other substrates, often modifying the solubility of metal ions or other substrates. Examples of chelating agents are: ethylenediaminetetraacidic acid (EDTA), citric acid, oxalic acid and tri-butyl phosphate.
- Highly water soluble forms of Special Fissionable Material shall not be accepted for disposal at the NSDF.
    - Highly water-soluble Special Fissionable Material compounds are defined as uranyl nitrate, uranyl fluoride, uranyl sulfate, uranyl acetate, uranyl chloride, uranyl formate, uranyl potassium carbonate, uranyl sulfate plutonium fluoride and plutonium nitrate.

4.4 Special Waste and Waste Electrical and Electronic Equipment

Radiologically contaminated Special Waste (also known as municipal hazardous waste) and Waste Electrical and Electronic Equipment (WEEE) may be accepted in the NSDF. Existing mixed waste processing routes are to be utilized before considering Special Waste and WEEE for the NSDF.

Special Waste and WEEE will likely require additional processing to ensure compliance with land disposal requirements (Section 4.1) prior to placement; therefore, all Special Waste and WEEE is to be segregated from other waste streams and clearly labelled.

Special Waste includes:

- Batteries (all types, spent or not);
- Pressurized and aerosol containers (empty or not);
- Portable Fire extinguishers (used or not);
- Containers that contained hazardous waste;
- Used oil filters;
- Fluorescent light bulbs (or tubes);
- Sharps (e.g., syringes);
- Equipment that may contain residual mercury (switches, thermostats, thermometers).

Waste Electrical and Electronic Equipment includes:

- Appliances;
- Information Technology Equipment (computers, monitors and peripherals);
- Telecommunications Equipment;
- Audio-Visual Equipment;
- Any other electronic tools or equipment.

5. RADIOLOGICAL PROPERTIES OF WASTE

The radiological properties of waste acceptable for NSDF disposal are presented in this section. As noted previously, all requirements within this document must be met for waste to be accepted. For example, the radionuclide concentration limits in Section 5.2, plus external dose limits in Section 5.6, must both be satisfied.

5.1 Minimum Reporting Requirements

Waste characterization plans must be designed to provide radionuclide concentrations that are representative of the waste stream(s) being sampled and characterized. The Waste Generator must report at a minimum:

- The activity and identity of radionuclides that contribute to 95 % of the total activity and the uncertainty of those radionuclides;
- For significant radionuclides (Section 5.4):
  - The activity and identity of the significant radionuclides and the uncertainty of the activity of those radionuclides; or
  - When a significant radionuclide was not detected in the waste, the detection limit for the analysis; or
  - When the activity of a significant radionuclide was added using scaling factors, justification of the scaling factors; or
  - When a significant radionuclide was not analysed, justification is required; and
- The activity and identity of radionuclides with half-lives greater than five years that were identified during the waste characterization process shall also be reported along with their uncertainties. This is particularly important for radionuclides that decay to significant radionuclides (e.g., Cm-244, Pu-238, U-236).

5.2 Radionuclide Concentration Limits

The radionuclide concentration limits for waste are provided in Table 4 for a single radionuclide; or in the case of a mixture of radionuclides, the sum of the component radionuclide limit fractions must not exceed 1 to demonstrate compliance and referred to as the “Sum of Fractions” rule. The calculation of the concentration limits shall exclude the mass of packaging and shielding.

$$\sum_{i=1}^{n} \frac{Concentration\ of\ Radionuclide\ i}{WAC\ Limit\ for\ Radionuclide\ i} \leq 1$$

Table 4
Radionuclide Concentration Limits in NSDF Waste

Limits for Bulk Waste & Non-Leachate Controlled Packaged Waste	100 Bq/g for α emitting radionuclides 1,000 Bq/g for long-lived βϒ emitting radionuclides ($t_{1/2}$ > Cs-137) 10,000 Bq/g for short-lived βϒ emitting radionuclides ($t_{1/2}$ ≤ Cs-137) 100,000 Bq/g for H-3
Limits for Leachate Controlled Packaged Waste	400 Bq/g for α emitting radionuclides 10,000 Bq/g for long-lived βϒ emitting radionuclides ($t_{1/2}$ >Cs-137) 10,000 Bq/g for Cs-137 10,000 Bq/g for Sr-90 10,000,000 Bq/g for H-3

5.3 Criticality Safety Limits and Restrictions

Quantities of Special Fissionable Material (SFM) exist in residual, unrecoverable amounts, predominately as contaminants on waste equipment, demolished structures and in soil as a result of nuclear fuel cycle activities (e.g., operation of National Research Experimental, National Research Universal and other research and development activities), and must be limited in the NSDF to ensure nuclear criticality safety. The NSDF Criticality Safety Document [9] defines the following limits and restrictions:

- The NCCO shall approve all shipments of waste containing SFM to the NSDF prior to shipment.
- Emplacements of waste containing SFM[1] shall comply with the mass fraction limits shown in Table 5. Natural and depleted uranium and thorium are not included in any limit set. The U-235 component of uranium enrichments above natural (i.e., 0.71 wt%) is counted in the U-235 SFM category.
    - Homogeneously distributed SFM shall meet the mass fraction limits listed in Table 5. Waste containing non-homogeneously distributed SFM shall meet the limits in Table 5 by averaging over a maximum of one waste unit (i.e., 1,500 kg).
- Recoverable quantities of SFM are not accepted for disposal in NSDF. That is, nuclear material that requires accounting or inventory management and reporting through CNL's Nuclear Materials and Safeguards Management Program (i.e., transfers on INMAS) [16], shall not be accepted for disposal in NSDF.

Table 5
Limits for Special Fissionable Material in Waste Placement [9]

Special Fissionable Material Type	Limit for Sum-of-Fractions Rule (mass fraction)(1)
U-235 (enrichments above natural, 0.71 wt%)	0.35 g U-235/kg waste
U-233	0.3 g U-233/kg waste
Pu-239 +Pu-240 + Pu-241	0.14 g (Pu-239 + Pu-240 + Pu-241)/kg waste

Note 1: For combinations of SFM types, the sum-of-fractions rule shall be satisfied:

$$\frac{U\text{-}235\ value}{U\text{-}235\ limit} + \frac{U\text{-}233\ value}{U\text{-}233\ limit} + \frac{(Pu\text{-}239 + Pu\text{-}240 + Pu\text{-}241)\ value}{(Pu\text{-}239 + Pu\text{-}240 + Pu\text{-}241)\ limit} \leq 1$$

5.4 Significant Radionuclides

Significant radionuclides (Table 6), are the radionuclides that were identified in the Reference Inventory [17] and were included as part of the Post-Closure Safety Assessment [7] for calculating dose to future receptors. The Post Closure Safety Assessment identified radionuclides that exceeded safety criteria; therefore a modified Reference Inventory, known as the Licensed Inventory represents the maximum activity of significant radionuclides that can be place in the NSDF [8]. Significant radionuclides are required to be tracked by NSDF, the maximum activity of the Licensed Inventory at closure are provided in Appendix B, Table 13. For guidance purposes, the maximum activity at placement and the average concentrations of the Licensed Inventory are also provided in Appendix B, Table 13.

[1] Fissionable material that can be arranged into a critical assembly outside a nuclear reactor, including material containing uranium enriched in the isotope ^{235}U in excess of natural abundance and/or isotopes of Pu and/or the isotope ^{239}Np which decays to ^{239}Pu and/or the isotope ^{233}U and/or the isotope ^{233}Pa which decays to ^{233}U [18].

Table 6
NSDF Significant Radionuclides

Radionuclide	Element Name	Half Life (years)[(a)]	Predominant Decay Emissions[(b)]
Ag-108m	Silver	4.38E+02	gamma
Am-241	Americium	4.33E+02	alpha/gamma
Am-243	Americium	7.36E+03	alpha
C-14	Carbon	5.70E+03	beta
Cl-36	Chlorine	3.01E+05	beta
Co-60	Cobalt	5.27E+00	beta/gamma
Cs-135	Cesium	2.30E+06	beta
Cs-137	Cesium	3.01E+01	beta/gamma
H-3	Hydrogen	1.23E+01	beta
I-129	Iodine	1.57E+07	beta/gamma/x-ray
Mo-93	Molybdenum	4.00E+03	x-ray
Nb-94	Niobium	2.03E+04	beta/gamma
Ni-59	Nickel	7.60E+04	x-ray
Ni-63	Nickel	1.01E+02	beta
Np-237	Neptunium	2.14E+06	alpha/gamma
Pu-239/240	Plutonium	2.41E+04/6.56E+03	alpha
Pu-241	Plutonium	1.43E+01	beta
Pu-242	Plutonium	3.75E+05	alpha
Ra-226	Radium	1.60E+03	alpha/gamma
Se-79	Selenium	3.27E+05	beta
Sn-126	Tin	2.30E+05	beta/gamma
Sr-90	Strontium	2.88E+01	beta
Tc-99	Technetium	2.11E+05	beta
Th-230	Thorium	7.54E+04	alpha
Th-232	Thorium	1.40E+10	alpha
U-233	Uranium	1.59E+05	alpha
U-234	Uranium	2.46E+05	alpha
U-235	Uranium	7.04E+08	alpha/gamma
U-238	Uranium	4.47E+09	alpha/gamma
Zr-93	Zirconium	1.61E+06	beta

Note a: Half-life value are source from the IAEA Live Chart of Nuclides [19].

Note b: Predominant Decay Emissions from the IAEA Live Chart of Nuclides [19]. Radionuclides with predominant decay emissions of alpha/gamma are to be treated as α emitters for limits in Table 4. Radionuclides with predominant decay emissions of x-ray (or that include x-ray) are to be treated as βγ emitters for the radionuclides concentration limits in Table 4.

5.5 External Surface Contamination on Waste Packages

The maximum non-fixed surface contamination on the accessible surfaces of waste package or transportation vehicles, averaged over 300 cm^2, must be less than 3.7 Bq/cm^2 for β,Υ-emitters, and less than 0.37 Bq/cm^2 for α-emitters.

5.6 Dose Rate Limits and Means of Handling and Transferring

The dose rate limits and the means of handling and transferring that shall be applied to the bulk and packaged waste at the NSDF are presented in Table 7, and are derived from the Safety Analysis Report [8].

Table 7
Dose Rate Limits and Means of Handling and Transferring

Radiation Type	Dose Rates	Means of Handling and Transferring
Total gamma and neutron	≤0.5 mSv/h near contact **and** ≤0.01 mSv/h at a distance of 1 metre	Manual handling or mechanical means
Total gamma and neutron	>0.5 mSv/h to ≤2 mSv/h near contact **and** >0.01 mSv/h to ≤0.1 mSv/h at a distance of 1 metre	Mechanical means
Total gamma and neutron	>2 mSv/h near contact **or** >0.1 mSv/h at a distance of 1 metre	Handling and transferring is subject to Radiation Protection Programs controls, Infrequently Performed Operations (Section 6.4) and assessment approval by the NSDF Facility Authority.
Beta	<10 mSv/h near contact	Based on total gamma and neutron dose rates

5.7 Disused Sources

The NSDF requires that all disused sources being considered for disposal at NSDF are evaluated through the Infrequently Performed Operations (Section 6.4). The evaluation shall follow the International Atomic Energy Agency (IAEA) guidelines [20] and [21].

All disused sources and/or equipment that contains sources, shall be segregated from other waste streams and clearly labelled.

For registered sources, the registration number shall be included in the accompanying disposal documentation.

6. ADMINISTRATIVE REQUIREMENTS

6.1 Waste Certification

Waste Generators shall be approved through CNL's Waste Certification process [22] prior to waste acceptance for disposal at CNL's NSDF.

6.2 Waste Acceptance Documentation

Management Control Procedures (MCPs) and Standards (STDs), provide quality controls and govern the waste management process [23], [24] and [25]. Prior to waste being received and accepted for disposal in the NSDF, the following documents are required and must be formally accepted by the waste receiver:

- Waste Profile Form [26] and [27].
- Waste Management Plan or equivalent [28] and [27].
- Waste Package Data Form [29] and [30].

The following documents are used to support the completion of the aforementioned documents and the completion of any of these documents may be required prior to the acceptance of waste for disposal:

- Waste Assessment Form [31] and [27].
- Waste Characterization Plan [32] and [24].
- Waste Characterization Report [23].
- Waste Container Inventory Form [33] and [30].

6.2.1 Waste Marking and Labelling

Every waste package and/or bulk waste shipment is required to have a unique identifier linking the waste back to the waste acceptance documentation. The label on waste packages shall be:

a) Clearly and legibly printed;
b) Readable by people and, where required, by scanning devices;
c) Conspicuously located;
d) Securely fixed; and
e) Made of material sufficiently durable to retain its physical characteristics through handling and storage.

Additional marking or labelling to meet other requirements such as Radiation Protection or Transportation of Dangerous Goods may be required, however these requirements are covered in other CNL Management Systems documents [34], [3] and [4].

6.3 Waste Verification

Canadian Nuclear Laboratories, as the NSDF licence holder, is responsible for the conformance of all waste that will be placed in the NSDF against the requirements of the WAC. As part of the waste acceptance process, waste generators and their waste shall be subject to the NSDF verification process. This verification can occur at any step of the waste disposition process (and can occur at multiple steps) including:

- Prior to generation;
- During generation;
- Prior to shipment;
- Upon receipt;
- Approval of waste for disposal; and
- Upon disposal.

The verification of NSDF waste can be completed by NSDF personnel or other support personnel (e.g., Waste Programs, Waste Characterization Services). Verification of waste being received at the NSDF includes at a minimum:

- Visual inspection of waste packages and/or bulk waste transportation vehicles against:
  - waste packaging requirements (Sections 3.1.1 & 3.3);
  - the supporting waste acceptance documentation (Section 6.2); and
  - waste marking and labelling requirements (Section 6.2.1);
- Visual inspection of bulk waste against the bulk waste physical requirements (Section 3.1);
- Measurements of dose rates against:
  - the external dose rate limits (Section 5.6); and
  - the supporting waste acceptance documentation (Section 6.2);

Additionally, verification of waste against all of the requirements of the WAC may include:

- Physical inspection of waste;
- Non-destructive assays;
- Destructive sampling and analysis.

The frequency of verification uses a graded approach and depends on the waste certification requirements. Waste Acceptance Criteria non-conformances identified through the verification process as well as discrepancies between waste acceptance documentation and verification results are managed through the Waste Certification process [22].

6.4 Infrequently Performed Operations

Waste that does not meet all of the criteria listed in the WAC (including Type 6 Waste, Oversized Debris), may be considered for disposal on a case-by-case basis only after receiving the documented authorization from the NSDF Facility Authority following the *Infrequently Performed Operations* process [35]. Authorization must comply with the *Facility Authorization for the Operation of the Near Surface Disposal Facility at the Chalk River Laboratories* [35]. This may be supported by the *Operational Decision Making* process [37] or *Problem Validation & Technical Operability Evaluation* [38] as applicable.

Waste that is acceptable for disposal after going through the Infrequently Performed Operations process, requires the documented decision to be attached with the waste's documentation (Section 6.2).

6.5 Waste Data Records

Waste records for all waste generated or accepted at CNL operated sites, are managed in a manner that preserves information including location, characteristics, and inventories. Waste Management records are controlled to prevent loss, destruction or alteration of the waste records, and conform to a standardized format.

Information on the storage, preservation, turnover and retention requirements for waste data records are provided in *Waste Data* [25].

7. REFERENCES

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[4] *Off-Site Transportation of Dangerous Goods,* 900-508520-STD-004.

[5] *Design Description*, 232-503212-DD-001.

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[9] *Criticality Safety Document,* 232-503230-CSD-001.

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[22] *Waste Certification,* 900-508600-MCP-003.

[23] *Management of Waste,* 900-508600-MCP-004.

[24] *Waste Characterization,* 900-508600-STD-003.

[25] *Waste Data*, 900-508600-STD-004, 50962683.

[26] *Waste Profile Form*, 900-508600-FM-003.

[27] *Waste Management Plan,* 900-508600-FID-001.

[28] *Waste Management Plan Template,* 900-508600-TMP-001.

[29] *Waste Package Data Form,* 900-508600-FM-004.

[30] *Waste Data Forms,* 900-508600-FID-003.

[31] *Waste Assessment Form,* 900-508600-FM-002.

[32] *Waste Characterization Plan Template*, 900-508600-TMP-002.

[33] *Waste Container Inventory Form,* 900-508600-FM-005.

[34] *Radiation Protection* (PRD), 900-508740-PRD-001.

[35] *Infrequently Performed Operations*, 900-508200-MCP-008.

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[37] *Operational Decision Making*, 900-508200-MCP-002.

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[40] *Near Surface Disposal Facility Geomembrane Relative Performance Report – Public Version (Redacted)*, 232-503212-REPT-024.

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APPENDIX A BASIS OF THE NSDF WAC

The NSDF WAC has been developed to ensure that the wastes placed in the NSDF are within the bounds of the specific design and safety criteria and are commensurate with international experience in near surface disposal of radioactive waste.

This section provides the basis of the WAC requirements. The NSDF WAC was developed using multiple criteria, including:

- Federal and Provincial Regulations;
- International Standards and Guidance;
- Benchmarking similar facilities; and
- The design and safety basis for NSDF including the Design [5], the Environmental Impact Statement [6], the Post-Closure Safety Assessment [7], the Safety Analysis Report [8] and the Criticality Safety Document [9].

Note, the numbering of the appendix sections is adjusted to align with the corresponding sections on WAC requirements.

A.3 PHYSICAL PROPERTIES OF WASTE

The utilization of an ECM design was appropriate for NSDF given the volumes of LLW as well as the vast majority of the waste stream is contaminated soils and demolition debris. Placement of this material as bulk waste (not in packages), enables appropriate compaction rates to ensure the Facility's design basis is met. The design basis ensures the Facility's robustness to survive environmental events commensurate with the timeframe assessment. For example, the Facility's predicted performance in the event of a significant seismic event (i.e., 1 in 10,000 year return period), is reliant on the waste compaction rates.

As the NSDF will only contain LLW, the waste requires isolation and containment for periods of up to a few hundred years as per IAEA requirements [39]. The design of the NSDF, addresses this requirement through the design life of the ECM which is 550 years. The design life is accomplished through use of both natural materials as well as engineered components where confidence has been demonstrated through the geomembrane testing program [40]. Anthropogenic analogues exist which provide supporting evidence that mounds constructed out of earthen materials are robust enough to survive thousands of years (e.g., Monks Mound) [41].

An ECM is also a common design for LLW disposal, supporting cleanup missions where the significant portion of the waste stream is contaminated soils and demolition debris. Table 8 provides a list of LLW disposal facilities that are designed with similar physical WAC.

Table 8
Attributes of Selected Near Surface Facilities in Canada and the United States for Long Term Management of Low Level Radioactive Waste [6]

Facility	Location	Built	Status	Capacity (m3)	Waste Type	Climate	Annual Precipitation	Terrain	Distance to Nearest Surface Water Body
Proposed CNL Near Surface Disposal Facility	Ontario, Canada	Proposed	Proposed	1,000,000	LLW from past operations, environmental remediation and decommissioning	Wet	87 cm	On a ridge	~0.35 km to Perch Creek, 1.1 km to Ottawa River
Port Granby Long Term Waste Management Facility	Ontario, Canada	2017	In Operation	300,000	LLW and mixed waste from uranium processing	Wet	83 cm	Flat	0.7 km Lake Ontario
Port Hope Long Term Waste Management Facility	Ontario, Canada	2017	In Operation	1,200,000	LLW, hazardous and mixed waste from uranium processing	Wet	83 cm	Flat	0.1 km to Brand Creek, 3 km to Lake Ontario
Oakridge National Laboratories, Environmental Management Waste Management Facility	Tennessee, USA	2002	In Operation	1,300,000	LLW, hazardous waste from environmental remediation and decommissioning	Wet	140 cm	On a ridge	0.5 km to Bear Creek & Clinch River
Hanford Environmental Restoration Disposal Facility	Washington, USA	1996	In Operation	16,800,000	LLW, hazardous and mixed waste from environmental remediation and decommissioning	Arid	16 cm	Flat	12 km to Columbia River
Portsmouth On-site Waste Disposal Facility	Ohio, USA	Under Construction	Under Construction	1,000,000	LLW, hazardous and mixed waste from uranium processing	Wet	102 cm	On a ridge	2.4 km to Sciota River
Fernald On-site Disposal Facility	Ohio, USA	1996	Closed	2,250,000	LLW and mixed waste from uranium processing	Wet	105 cm	Flat	~1 km to Great Miami River

A.3.1 BULK WASTE PHYSICAL PROPERTIES

The requirements for the physical properties of bulk waste are set to ensure the waste can be safely and compliantly placed as set out by the requirements of the Waste Placement and Compaction Plan [42]. Disposal cell lifts have been designed to be approximately 0.3 to 0.5 m; therefore, the size restrictions on material are in place to ensure bulk waste can be contained within those lifts. Rebar in concrete is required to be cut flush as protruding objects create operational issues for compaction equipment and industrial safety hazards for the employees operating that equipment. Lastly, the requirement to reduce void space is in place to minimize potential for future differential settlement of the waste which could affect the cover and/or the seismic stability of the ECM.

A.3.1.1 Bulk Waste Packaging/Transportation Vehicles

Bulk waste packaging and transportation vehicles must be compatible with the chemical and physical properties of the waste to prevent damage to the package during handling and placement processes. This requirement complies with CSA N292.0:19 [1].

It is also important that waste that contains debris is loaded into the waste package/transport vehicle such that the unloading process does not create conventional safety hazards in the disposal cell. A stuck load could lead to industrial safety hazards such as an extended truck tipping over while unloading [8].

The requirement to plastic wrap or utilize liners is in place to minimize the radiological contamination of re-usable containers and/or transportation vehicles.

A.3.2 TYPE 6 OVERSIZED DEBRIS

Type 6 waste, oversized debris, is bulk waste that cannot reasonably be processed to meet the physical requirements of other bulk waste types. The rationale for this waste stream is primarily based on the limits of operational practicality; thus, it may result from a cost-benefit decision or even an ALARA analysis [10].

Oversized debris shall go through the Infrequently Performed Operations process (see Section 6.4) because without proper planning, oversized debris could present conventional hazards to employees placing the waste. Special instructions for transporting the waste within the NSDF, off-loading the waste, handling and placing the oversize debris and processing (e.g., reduction of void space) the waste are to be prepared. Additionally, waste placement plans are to be prepared as improperly placed oversized debris could impact the integrity and long-term performance of the ECM (e.g., void space greater than 10%).

A.3.3 TYPE 5 PACKAGED WASTE

A.3.3.1 NON-LEACHATE CONTROLLED WASTE PACKAGES

For non-leachate controlled waste packages, it is required that the chemical and physical properties of the waste do not impact the integrity of the waste package during handling and placement processes. This requirement complies with CSA N292.0:19 [1]. Damaged packages could lead to the exposure of workers to radiological or conventional hazards. No credit for packaging is retained as part of the Post-Closure Safety Assessment [7].

The requirement to maximize density and reduce void space, is to minimize potential for future differential settlement of the waste which could affect the cover and/or the seismic stability of the ECM [42].

To aid in planning and the placement of waste, non-leachate controlled waste packages are standardized as drums, waste boxes and intermodal containers.

A.3.3.2 Leachate Controlled Waste Packages

The NSDF radionuclide concentration limits in Table 4 apply a graded approach to control leachate radionuclide concentrations during placement of waste. There will be a small portion of waste which will be required to use robust packaging to prevent the spread of contamination. Specifically, leachate controlled waste packages are intended to provide short-term barriers for wastes with higher radionuclides concentrations during the time the disposal cell is not covered with the final cover system (approximately 5-10 years); thus more mobile radionuclides, such as tritium, are kept isolated from the environment minimizing radionuclide concentrations in the liquid effluent during the operations phase. This principle has been incorporated into the design basis of the Wastewater Treatment Plant (WWTP) [43]. Specifically the WWTP has been designed for certain influent leachate concentrations and while the design offers flexibility, leachate controlled waste packages assist with managing the influent concentration.

For leachate-controlled waste packaged waste, it is required that the chemical and physical properties of the waste do not impact the integrity of the package during handling, placement and until the disposal cell is closed and the final cover is constructed. Packages that are damaged could expose employees to radiological or industrial hazards. No credit for packaging is retained as part of the Post-Closure Safety Assessment [7].

It is also important to maximize density and reduce void space, to minimize potential for future differential settlement of the waste which could affect the final cover and/or the seismic stability of the ECM [42].

A.3.3.3 Shielded Waste Packages

As per the Safety Analysis Report [8], the NSDF limits external exposure rates on waste packages to protect workers handling and placing waste (Section 5.6). Shielded Waste Packages could be used to ensure waste complies with the dose rate limit in Table 7.

Depending on the type of shielding material used, particular attention must be made to ensure requirements around hazardous waste are still met (e.g., lead shielding).

A.3.4 ASBESTOS WASTE

Asbestos waste is a hazardous material as loose asbestos fibres are an inhalation hazard that can cause cancer and other diseases. Asbestos waste requires strict controls to protect workers that are handling and placing asbestos waste. The requirements on asbestos waste are derived from Ontario Regulation 347 [13] and Ontario Regulation 278/05 [44].

The requirement to track the quantity of asbestos waste received in the NSDF is to report to Environment and Climate Change Canada’s National Pollutant Release Inventory [45].

A.3.5 FREE STANDING LIQUIDS

The NSDF is a solid waste disposal facility thus, will not receive free standing liquids. Limiting the amount of liquids in waste reduces the risk of contamination spread as well it reduces the amount of leachate that will be generated. Minimizing free liquids in the waste complies also with CSA 292.0:19 [1].

The use of absorbents is permitted for incidental liquids however, the absorbents must be inorganic. The use of organic absorbents increases the risks of fire, particularly if oxidizers were inadvertently also present in the waste.

A.3.6 PRESSURIZED CONTAINERS

Pressurized containers or other vials would likely be ruptured during waste placement activities leading to several industrial hazards:

- This rupture would release the contents, exposing workers to potentially hazardous substances;
- Damaged containers can also become missiles and may lead to injuries or equipment damage, and
- Depending on the type of gas and the pressure of the pressurized container this could lead to an explosion and/or fire.

Requiring that vented pressurized containers are segregated from other waste stream allows the workers that are placing waste to verify that vented pressurized containers comply with the NSDF requirement of being permanently vented.

A.4 CHEMICAL PROPERTIES OF WASTE

A.4.1 HAZARDOUS WASTE

Although the NSDF is located on land own by a Federal crown corporation and that the nuclear industry is regulated by the Nuclear Safety and Control Act; CNL looks to comply with the intent of provincial regulations in the absence of federal legislation. As there are no federal legislations governing land disposal, NSDF proposed that the restrictions around chemical constituents of waste would be modelled after Ontario's Regulation 347:

> *"Waste placed in the NSDF will meet the intent of land disposal and leachate requirements specified in the Ontario Environmental Protection Act, Regulation 347 [13]. This is a requirement of the WAC; thus, limiting the chemical characteristics within the waste. Hazardous waste will not be acceptable for disposal in the NSDF and will not be placed in the NSDF." [6].*

Chemical constituents in wastes require special controls to reduce adverse effects to human health and the environment. Chemical constituents are controlled by:

1. Definitions that set criteria and thresholds for hazardous waste; and
2. By establishing land disposal treatment requirement.

The key principle of hazardous waste legislation is to prohibit and discourage activities that involve placing untreated hazardous wastes in or on the land when better treatment or destruction alternatives exist. Hazardous wastes cannot be disposed on land until the waste meets specific land disposal treatment requirements to reduce the mobility or toxicity of its hazardous components.

The land disposal treatment requirements in Ontario are consistent with the land disposal treatment requirements established by the United States Environmental Protection Agency [46].

A.4.2 KEY CONSTITUENTS OF POTENTIAL CONCERN

Key COPC (Table 3) [15], are required to be tracked as they are placed in the NSDF to stay within the design basis of the WWTP [43]. Specifically, the WWTP has been designed for certain influent leachate

concentrations, and reporting constituents within Table 3, will assist operations in dispositioning anomalies observed within the influent leachate.

Note, technical note on COPC also investigated compatibility with geomembrane performance; however some additional analysis has demonstrated that as long as the quantity of these COPCs are below the land disposal regulation, the effect on geomembrane performance should be negligible [47].

It is important that the concentration of COPCs remains below the land disposal regulation so that the geomembrane is not damaged [47]. The COPCs which are constrained by the Ontario Regulation 347 limit [13], are considered not to affect the Post-Closure Safety of the NSDF [7].

A.4.2.1 ESTIMATED QUANTITY OF METALS AND ORGANICS

The objective of reporting the quantity of discrete metals and organics in the NSDF at closure, is to ensure compliance with the Post-Closure Safety Assessment assumptions for non-radiological inventory [7]. Specifically, the inventory is included in the Post-Closure Safety Assessment model primarily for its potential effects on the release rates of radiological constituents from the Facility. Tracking the mass of metal and organics received is required to remain within the safety basis.

The non-radiological inventory, such as metals and organics, also has the potential to generate landfill gases. Landfill gas generation rates have been evaluated based on the radiological and non-radiological inventory, and it was determined that only a passive landfill gas venting system was required [48]; however, reporting of the metal and organic inventory is necessary to remain within the design basis.

Total quantity estimates of metals and organics are provided in Appendix B.

A.4.3 CHEMICAL PROPERTIES OF WASTE FOR CRITICALITY SAFETY

Chemical properties of waste in the NSDF must be restricted to ensure compliance with nuclear criticality safety requirements defined in the NSDF Criticality Safety Document [9]. This includes moderators, reflectors, chelating agents as well as the chemical forms of fissionable material.

A.4.4 SPECIAL WASTE AND WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT

As a best practice, NSDF WAC requires that Special Waste and WEEE be segregated for future treatment, as there are hazards (e.g., chemical and heavy metal) associated with Special Waste and WEEE. The proper segregation ensures that Special Waste and WEEE is tested for compliance with land disposal requirement for hazardous waste [13] and if required, properly treated to meet those requirements.

A.5 RADIOLOGICAL PROPERTIES OF WASTE

A.5.1 MINIMUM REPORTING REQUIREMENTS

The minimum reporting requirements are in place to ensure that significant radionuclides (A.5.4) are being reported and tracked to meet design requirements and safety basis [7].

By reporting a minimum of 95 percent of total radioactivity and the significant radionuclides, radionuclides that are contributing to short-term dose and long-term performance are captured. The minimum reporting requirements complies with the CSA N292.0:19 requirements [1].

Uncertainties in the calculations also need to be reported, as they can represent the theoretical maximum activity present in the waste.

A.5.2 RADIONUCLIDE CONCENTRATION LIMITS

The WAC radionuclide concentration limits are derived from the guidance of both IAEA GSG-1 [49] and CSA N292.0:19 [1], and their respective definitions of LLW as noted in Table 9 below.

Table 9
IAEA and CSA Guidance on Low Level Waste

IAEA GSG-1	*"The regulatory body should establish limits for the disposal of long lived radionuclides on the basis of the safety assessment for the particular disposal facility. A limit of 400 Bq/g on average (and up to 4000 Bq/g for individual packages) for long lived alpha emitting radionuclides has been adopted in some States […]. For long lived beta and/or gamma emitting radionuclides, such as ^{14}C, ^{36}Cl, ^{63}Ni, ^{93}Zr, ^{94}Nb, ^{99}Tc and ^{129}I, the allowable average activity concentrations may be considerably higher (up to tens of kilobecquerels per gram) and may be specific to the site and disposal facility."*
CSA N292.0:19	*"Low-level radioactive waste (LLW) contains material with radionuclide content above established clearance levels and exemption quantities, but generally has limited amounts of long-lived activity. For orientation purposes only, a limit of 400 Bq/g on the average (and up to 4000 Bq/g for individual waste packages) for long-lived alpha emitting radionuclides can be considered in the classification process. For long-lived beta and/or gamma emitting radionuclides, such as ^{14}C, ^{36}Cl, ^{63}Ni, ^{93}Zr, ^{94}Nb, ^{99}Tc and ^{129}I, the allowable average activity concentrations can be considerably higher (up to tens of kBq/g) and can be specific to the site and disposal facility. However, detailed classification should be distinguished using the characteristics specified in Clause B.3. LLW requires isolation and containment for periods of up to a few hundred years."*

Using an iterative approach, the upper range of radioactivity was tested within early Post-Closure Safety Assessment models (i.e., alpha activity up to 4000 Bq/g and long-lived beta/gamma up to 50,000 Bq/g) and then the inventory adjusted to ensure a suitable safety margin for the NSDF design. Therefore, as part of the iterative process, the limit for alpha was set at 400 Bq/g and the limit for long-lived beta-gamma was set at 10 000 Bq/g. The limits for bulk waste and non-leachate controlled waste packages are more restrictive based on worker protection and leachate modelling.

As noted in Section A.3.3.2, the NSDF radionuclide concentration limits in Table 4 assist in controlling the radionuclide concentrations in generated leachate. Higher radioactivity of more mobile radionuclides, such as tritium, are controlled and isolated from the environment to minimize liquid effluent releases during the operations phase and respect the design basis of the WWTP [43]. The graded approach of the radionuclide concentrations ensures that the effluent discharge targets are achievable.

For short-lived radionuclides; the limits for bulk waste and non-leachate controlled waste packages are based on worker protection and leachate modelling [8].

The radionuclide concentration limits are also restricted by the sum of fractions rule for waste that contains a mixture of radionuclides. This approach is benchmarked from the United States Nuclear Regulatory

Commission (§ 61.55 Waste classification) [50]. It is also used in Canada as part of the CNSC Nuclear Substances and Radiation Devices Regulations when determining exemption quantity [51].

A NSDF is a suitable and technically feasible means of disposing low-level radioactive waste. The effectiveness of such facilities has been demonstrated as illustrated through the following similar facilities currently in operation list in Table 10.

Table 10
Benchmarked radionuclide concentration limits

Disposal Facility or Reference	long-lived β-ϒ Bq/g	α Bq/g	Comment
LLW bulk disposal facility Clive, UT USA	Semi-Nuclide Specific, NRC Class A Greater than 10,000	370	Transuranic alpha-emitting transuranic nuclides with half-life greater than five years and in concentrations up to 10 nCi/g (Class A).
Idaho CERCLA Disposal Facility INL, US	Nuclide Specific greater than 10,000	370	Transuranic alpha-emitting transuranic nuclides with half-lives greater than 20 years and concentrations greater than 10 nCi/g are prohibited for disposal
Low Level Waste Repository Drigg, Cumbria UK	All beta emitters 12,000	4,000	Nuclide-specific annual activity limits for acceptance in addition to concentrations. Defined as LLW.
LLW disposal facility at Andrews, TX USA	Semi-Nuclide Specific, Up to NRC Class C. greater than 100,000	3,700	Transuranic alpha-emitting radionuclides with half-life greater than five years and Radium-226 in concentrations up to 100 nCi/g (Class C). Waste consignments with concentrations of transuranic radionuclides in excess of 10 nCi/g (Class A) must be stabilized and disposed at least 5 metres below the surface.

Other NSDFs operate in the USA, France and elsewhere, but the four examples listed above were chosen to benchmark acceptable levels of long-lived radionuclides based on similarity of low level radioactive waste streams considered for disposal at the NSDF.

A.5.3 CRITICALITY SAFETY LIMITS AND RESTRICTIONS

Quantities of SFM exist in residual, unrecoverable amounts, predominately as contaminants on waste equipment, demolished structures and in soil as a result of nuclear fuel cycle activities (e.g., operation of National Research Experimental, National Research Universal and other research and development activities) and will be safely disposed of in the NSDF based on limiting the concentration of SFM within the ECM. This is achieved using mass fraction limits on SFM for each waste unit placed in the ECM to ensure the amount of SFM in any individual waste unit does not constitute a criticality safety hazard [9]. The Licensed Inventory Table 13 [8], also provides a complementary safety argument as it limits the total fissionable material inventory for the entire NSDF. Restrictions further reduce the potential for any scenarios where criticality is considered to be plausible.

A.5.4 SIGNIFICANT RADIONUCLIDES

A waste inventory for the proposed NSDF was required to complete the long-term safety assessment and inform the Post-Closure Safety Assessment [7]. Since the Post-Closure Safety Assessment supports the claim

that future public doses will be well below the long-term dose acceptance criteria, the Post-Closure Safety Assessment made a recommendation to lower the maximum activity of certain radionuclides in the Reference Inventory. This modified Reference Inventory, known as the Licensed Inventory is part of the safety and licensing basis of NSDF [8]; thus it represents a total inventory limit for NSDF. The requirement for waste generators to report significant radionuclides has been included in the WAC to ensure NSDF operations can track the total inventory for alignment with the Licensed Inventory Table 13.

Further, as a set quantity of these radionuclides were used in the evaluation of the NSDF Design documents, such as the Waste Characterization Report [52], and the Safety Analysis Report [8], it's important to track the total quantity of these radionuclides to ensure the inventory does not exceed the safety basis (see Table 13 in Appendix B).

Uncertainty in measurement or estimates is required such that the upper possible limit of NSDF inventory is known. If a waste generator does not have significant radionuclides within waste stream, justification for not reporting is required.

A.5.5 EXTERNAL SURFACE CONTAMINATION ON WASTE PACKAGES

The external surface contamination requirements are in place to limit spread of contamination during movement of waste on the CRL site and to minimize exposure to workers that are handling and placing the waste and waste packages. The requirements are derived from the IAEA's Regulations for the Safe Transport of Radioactive Material [53].

A.5.6 DOSE RATE LIMITS

The external exposure rate requirements are in place to limit radiation doses to workers that are handling and placing the waste and waste packages.

The gamma and neutron dose limits are based on Movement of Non-Waste Equipment and Material [54] and the beta dose limits are from As Low As Reasonably Achievable (ALARA) Review and Assessment – Planning and Control of Radiation Work [55].

The dose rate limits comply with IAEA's Regulations for the Safe Transport of Radioactive Material [53].

A.5.7 DISUSED SOURCES

As per IAEA guidelines [20] and [21], disused sources (including disused sealed sources) are a waste stream that requires special management because they contain highly concentrated amounts of a single radionuclide. Specifically, the guidance limits that only radioactive sources of a half-life of less than 30 years should be considered for near surface disposal without special requirements.

The NSDF requires that sources are subject to all of the WAC requirements, including radionuclide concentration limits and external exposure rates. As well, sources shall be segregated from other waste streams; thus ensuring that the activity of sealed sources is not diluted by waste that is less radioactive.

The NSDF requirements on sealed sources complies with IAEA guidelines [49].

A.6 ADMINISTRATIVE REQUIREMENTS

A.6.1 WASTE CERTIFICATION

The Waste Certification Requirements ensure wastes transferred to the NSDF meet the WAC and establishes a mechanism to manage verification and non-conformances. The Waste Certification Programs requirements are documented in CNL's Waste Certification Program Management Control Procedure [22].

A.6.2 WASTE ACCEPTANCE DOCUMENTATION

The required Waste Acceptance Documents are in place to ensure that sufficient characteristics of the waste are documented to confirm acceptability with the WAC. Briefly, the purpose of these documents is:

- The Waste Profile Form [26] and [27], summarizes the physical, chemical and radiological characteristics of the waste stream(s) gathered from process knowledge, destructive analysis and non-destructive analysis. The Waste Generator reviews the overall Waste Profile and certifies that waste dispositioned against the Waste Profile conforms to the requirements documented.
- Waste Management Plan [28] and [27]; documents the verification, packaging and handling requirements for all of the waste generators' waste streams. The Waste Management Plan also documents the waste generation process, specific roles and responsibilities, training, waste minimization and waste certification requirements.
- Waste Package Data Form [29] and [30], documents a waste package's specific attributes (i.e., physical, radiological, chemical constituents) and links the Waste Package record to the approved Waste Profile and Waste Management Plan.

The required Waste Acceptance Documentation complies with CSA N292.0:19 [1] requirements.

The Waste Profile Form, Waste Management Plan can be supported by additional documentation. Briefly, the purpose of these documents is:

- Waste Assessment Form [31] and [27], is used as an initial planning tool and documents the types of waste that the facility project is expected to generate, radiological and hazardous constituents gathered from previous characterization efforts.
- Waste Characterization Plan [32] and [24], these are written to document the sampling and analysis needed to identify or confirm waste characteristics that are known and/or missing. The results of the characterization plan are then documented in a Waste Characterization Report [23]; and
- Waste Container Inventory Form [33] and [30], support the Waste Package Data Form and provides a detailed listing of the Waste Container's contents. The Waste Management Plan documents when the Waste Container Inventory Form is required.

A.6.2.1 WASTE MARKING AND LABELLING

The proper identification of waste packages and waste shipments is key to linking the waste acceptance documentation that provides the characteristics of the waste.

The Waste Marking and Labelling requirements are based on CSA N292.0:19 [1].

A.6.3 WASTE VERIFICATION

Waste verification supports waste certification, to ensure wastes transferred to the NSDF and the supporting documentation are accurate and comply with the WAC. This also meets the requirements of CSA N292.0:19 [1].

A.6.4 INFREQUENTLY PERFORMED OPERATIONS

The Infrequently Performed Operations Process is available as an option when a specific waste package or waste stream meets most, but not all of the requirements of the WAC. The Infrequently Performed Operations process is limited by the safety basis provided in the Design Requirements [5], the Environmental Impact Statement [6], the Post-Closure Safety Assessment [7], and the Safety Analysis Report [8] as there is safety margin between the safety basis and the WAC.

The Infrequent Performed Operations [35] complies with CSA N286-12 (Section 7.9.8) [56].

A.6.5 WASTE DATA RECORDS

Canadian Nuclear Laboratories Waste Data Management Control Procedure [25], adheres to the requirements listed in CSA N292.0:19 [1].

APPENDIX B ESTIMATED TOTAL QUANTITY OF IRON, ORGANIC MATERIAL AND RADIONUCLIDES ASSUMED AT CLOSURE OF THE ECM

The following appendix provides the estimated quantity of Metals (Table 11), Organics (Table 12) and Significant Radionuclides (Table 13) at closure of the ECM.

Table 11
Estimated Quantity of Metals in ECM at Closure [15]

Estimated quantities of metal in ECM (kg)				
Waste Metal in NSDF			**Package Metal (13% of volume)**	
Aluminum	32,966		0	
Copper	3,519,725		0	
Iron	1,790,389		8,651,507	
Lead	177,988		0	
	Waste Low Estimate (kg)		**Total Waste + % Packages in the ECM (kg)**	
	-50%		**10%**	**25%**
Aluminum	16,483		16,483	16,483
Copper	1,759,863		1,759,863	1,759,863
Iron	895,194		7,550,200	17,532,709
Lead	88,994		88,994	88,994
	Waste High Estimate (kg)		**Total Waste + % Packages in the ECM (kg)**	
	+100%		**10%**	**25%**
Aluminum	65,932		65,932	65,932
Copper	7,039,450		7,039,450	7,039,450
Iron	3,580,777		10,235,976	20,218,291
Lead	355,976		355,976	355,976

Table 12
Estimated Quantity of Organics in ECM at Closure [15]

Constituent	**Estimated Volume (m^3)**	**Density (kg/m^3)**	**Total Estimated Mass (kg)**	**Estimated Mass Low -50% (kg)**	**Estimated Mass High +100% (kg)**
Wood	83,256	753	62,691,798	31,345,899	125,383,596
Dry Active Waste	36,688	481	17,647,136	8,823,568	35,294,273
Total	**119,944**		**80,338,934**	**40,169,467**	**160,677,869**

Table 13
NSDF Licensed Inventory [8]

	NSDF Licensed Inventory at Placement		NSDF Licensed Inventory at Closure	
Radionuclide	**Maximum Activity (Bq)**	**Averaged Activity Concentration (Bq/g)[(a)]**	**Maximum Activity (Bq)**	**Averaged Activity Concentration (Bq/g)[(a)]**
Ag-108m	2.73E+10	2.86E-02	2.62E+10	2.74E-02
Am-241	6.04E+10	6.32E-02	9.74E+10	1.02E-01
Am-243	5.26E+07	5.49E-05	5.24E+07	5.48E-05
C-14	1.71E+12	1.79E+00	1.70E+12	1.78E+00
Cl-36	3.97E+09	4.15E-03	3.97E+09	4.15E-03
Co-60	9.06E+16	9.47E+04	1.47E+16	1.53E+04
Cs-135	5.19E+08	5.43E-04	5.19E+08	5.43E-04
Cs-137	5.59E+12	5.84E+00	3.17E+12	3.31E+00
H-3	8.91E+14	9.32E+02	2.79E+14	2.91E+02
I-129	1.75E+10	1.83E-02	1.75E+10	1.83E-02
Mo-93	1.47E+05	1.54E-07	1.47E+05	1.53E-07
Nb-94	2.34E+10	2.45E-02	2.34E+10	2.45E-02
Ni-59	1.21E+09	1.26E-03	1.21E+09	1.26E-03
Ni-63	3.11E+11	3.25E-01	2.59E+11	2.70E-01
Np-237	1.74E+07	1.82E-05	1.74E+07	1.82E-05
Pu-239/240[(b)]	5.07E+10	5.29E-02	5.06E+10	5.29E-02
Pu-241	1.67E+12	1.74E+00	5.84E+11	6.10E-01
Pu-242	6.32E+07	6.60E-05	6.32E+07	6.60E-05
Ra-226	3.65E+10	3.81E-02	3.61E+10	3.77E-02
Se-79	9.26E+07	9.68E-05	9.26E+07	9.68E-05
Sn-126	1.24E+08	1.30E-04	1.24E+08	1.30E-04
Sr-90	6.05E+12	6.32E+00	3.35E+12	3.50E+00
Tc-99	3.16E+11	3.31E-01	3.16E+11	3.30E-01
Th-230	5.30E+09	5.54E-03	5.30E+09	5.54E-03
Th-232	2.70E+10	2.82E-02	2.70E+10	2.82E-02
U-233	2.74E+08	2.86E-04	2.74E+08	2.86E-04
U-234	6.88E+10	7.19E-02	6.88E+10	7.19E-02
U-235	2.96E+09	3.10E-03	2.96E+09	3.10E-03
U-238	7.57E+10	7.91E-02	7.57E+10	7.91E-02
Zr-93	4.92E+11	5.14E-01	4.92E+11	5.14E-01

Note a: Average activity concentrations calculated using the ECM total waste mass of 9.57E+08 kg [17].
Note b: Decayed using the half-life of Pu-239.