



NUCLEAR WASTE
MANAGEMENT
ORGANIZATION

SOCIÉTÉ DE GESTION
DES DÉCHETS
NUCLÉAIRES

Preliminary transportation plan

December 2021

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Introduction to the NWMO

For more than 50 years, Canada has been using nuclear power as a reliable energy source to power our homes, businesses, schools, and hospitals. The Nuclear Waste Management Organization (NWMO) plays an important role that completes the fuel cycle. We are responsible for implementing, collaboratively with Canadians and Indigenous peoples (First Nations, Métis and Inuit), Canada's plan for the safe, long-term management of used nuclear fuel, in a manner that protects both people and the environment.

Canadian used nuclear fuel – a byproduct of nuclear power – is a stable solid that comes in the form of a fuel bundle and is not flammable or explosive. Currently, used nuclear fuel is stored at licensed interim storage facilities in Canada. This is a safe, but temporary solution. Canadians have made it clear that it is important to implement a long-term approach – and not leave it for future generations.

Canada's plan, also known as Adaptive Phased Management, calls for used nuclear fuel to be contained and isolated in a deep geological repository, a system of naturally occurring and engineered barriers, in an area with informed and willing hosts. A deep geological repository is a national environmental infrastructure project, aligns with international best practice, and benefits from the best available science and research, including Indigenous Knowledge.

After gradually narrowing our focus based on social and technical studies, there are currently two remaining potential siting areas involved in the NWMO's site selection process: the Ignace area in northwestern Ontario, and South Bruce in southern Ontario. We expect to select a single, preferred site in 2023.

A key component of Canada's plan is transporting used nuclear fuel to the deep geological repository site. Transportation will begin in the 2040s – once the repository is operational.

Globally, the transportation of used nuclear fuel has a strong record of safety. Over 50 years, there have been more than 20,000 shipments worldwide of used nuclear fuel, and none have caused harm to people or the environment because of the release of radioactive materials. There is also a strong regulatory framework for the transportation of used nuclear fuel. Transportation of used nuclear fuel in Canada is regulated by the Canadian Nuclear Safety Commission (CNSC) and Transport Canada. Shipments will also meet the International Atomic Energy Agency (IAEA) safeguard requirements to ensure they are safe and secure.

The NWMO's highest priority as we plan for transportation is safety. Safety is at the core of everything we do at the NWMO, as our overriding objective is the protection of people and the environment. Based on conversations with thousands of Canadians and Indigenous peoples, we understand that people have questions and concerns about the transportation of used nuclear fuel. The NWMO is committed to an ongoing dialogue with Canadians and Indigenous peoples as we refine our transportation plans. Public input is invaluable to this process. Together, we are setting priorities, principles and objectives for transportation planning, which can be found on our website at www.nwmo.ca/transportationplanning. This plan is an early step in the NWMO's Transportation Planning Framework. The goal of this document is to begin to answer the questions we are hearing about transporting used nuclear fuel in the 2040s. It outlines the multiple layers of safety that are required through the regulatory framework and additional measures that the NWMO plans to put in place.

This transportation plan is preliminary in nature given a few factors, including:

- » Two siting areas remain in the NWMO's voluntary site selection process;
- » The NWMO is considering two modes of transportation – an all-road system and a road/rail system; and
- » Technology, infrastructure, best practices, and societal priorities are expected to evolve over the 20-year planning time frame.

We recognize that this preliminary plan will evolve and become more detailed over the next 20 years. Future work planned for upcoming years will be included in subsequent iterations of this plan. This plan has three sections:

Section 1: Overview of the transportation program. This section provides information about the NWMO's preliminary transportation system designs and answers commonly asked questions about how the NWMO plans to transport used nuclear fuel.

Section 2: Safety and security. This section describes commonly raised concerns about transportation safety, regulatory requirements for safely transporting used nuclear fuel, as well as the multiple layers of safety the NWMO will apply to our transportation program.

Section 3: The road ahead. This section describes planned work over the upcoming years to further inform and refine our transportation planning.

1. Overview of the transportation program

People have asked us many questions about how the NWMO plans to transport used nuclear fuel. The map below shows the locations of interim storage facilities and the two potential sites, providing a sense of the scope of this transportation program and understanding that the used nuclear fuel must be transported through communities and traditional territories to whichever site is selected. The transportation program is expected to begin in the early 2040s once the deep geological repository is operational and take up to 50 years to complete.

Acknowledging the preliminary nature of this plan, the following section outlines the NWMO's current thinking on how this transportation program will be approached. We are looking at two options for each site, either:

- 1) An all-road used fuel transportation system; or
- 2) A road/rail used fuel transportation system.

For planning purposes, the all-road used fuel transportation system is referred to as the NWMO's reference case. This is the option that is considered for lifecycle cost estimates to ensure accountability and transparency as we implement Canada's plan. The road/rail used fuel transportation system is referred to as the alternative case. Both transportation mode options can be safely implemented to either potential repository site. The designs for these two systems have been established and consider the following: regulatory requirements; the use of various transportation packages; potential vehicles (e.g., trucks/rail cars); associated fleet requirements for transport packages; representative routes; nuclear security and escort arrangements; emergency management, including response and recovery; logistics and scheduling of shipments; as well as operational aspects such as communication, monitoring and tracking of shipments.

Once a site is selected, the NWMO, in collaboration with Canadians and Indigenous peoples, will confirm the NWMO's used fuel transportation system, which will include finalizing key decisions such as the selection of transport mode(s) and packages. Based on these decisions, the design of a used fuel transportation system will be refined and provide the foundation for future work.



1.1 How many used fuel bundles will there be?

As of June 30, 2021, there are approximately 3.1 million used fuel bundles in storage at the eight interim storage facilities in Canada. By the end of the operating life of each of Canada's existing nuclear reactors, it is anticipated that there will be 5.5 million used fuel bundles. The table below outlines how much used nuclear fuel is stored at each interim storage facility and the projected number of packages that would be transported from each facility over the 50-year time frame over which operations will be ongoing. It is important to note that while Whiteshell is identified as an interim storage facility on the previous map, the NWMO anticipates that the used fuel bundles at this facility will be consolidated with the used fuel bundles at Chalk River, based on current decommissioning plans for the Whiteshell facility.

Interim storage facility	Origin site	Projected number of used fuel bundles to be transported	Projected number of transportation packages to be transported (all road)	Projected number of transportation packages to be transported (road/rail)
Bruce	Bruce	2,907,650	15,147	7,573
Pickering	Pickering	902,148	4,699	2,350
Darlington	Darlington	1,268,801	6,610	3,305
Chalk River	Chalk River	7,187	90	90
Douglas Point	Bruce	22,256	207	207
Gentilly-1	Gentilly	3,213	43	43
Gentilly-2	Gentilly	129,925	1,083	1,083
Point Lepreau	Point Lepreau	258,820	2,157	2,157
Totals:		5,500,000	30,036	16,808

Q&A

Will the NWMO be responsible for used fuel from small modular reactors? Will this increase the amount of used fuel? If so, how will those be transported?

As mandated in the *Nuclear Fuel Waste Act*, the NWMO is responsible for all Canada's used nuclear fuel – including that created using new or emerging technologies like small modular reactors. This means that used fuel could be transported from any province that chooses to pursue the use of small modular reactors, including those west of Manitoba. Canada's plan will be implemented over several decades, and a fundamental tenet is incorporating new knowledge and technical advancements. The NWMO has outlined criteria that any fuel waste will need to meet to ensure it be accepted, and this includes transportation requirements. Regardless of the type of used fuel we are transporting (conventional reactors or small modular reactors), the stringent regulatory requirements for transportation will be applied to the NWMO's transportation program – see the following pages for more information. For more information about Canada's Small Modular Reactor Action Plan, please go to www.nrcan.gc.ca/our-natural-resources/energy-sources-distribution/nuclear-energy-uranium/canadas-small-nuclear-reactor-action-plan/21183.

1.2 How will it be transported?

Transportation packages

Safety of transporting used nuclear fuel begins with transportation package design. Transportation of used nuclear fuel will occur in a certified package that adheres to stringent Canadian regulations and international standards. Used nuclear fuel transportation packages are designed and tested to ensure protection of people and the environment during normal operations, as well as during severe accident conditions – even though unlikely.

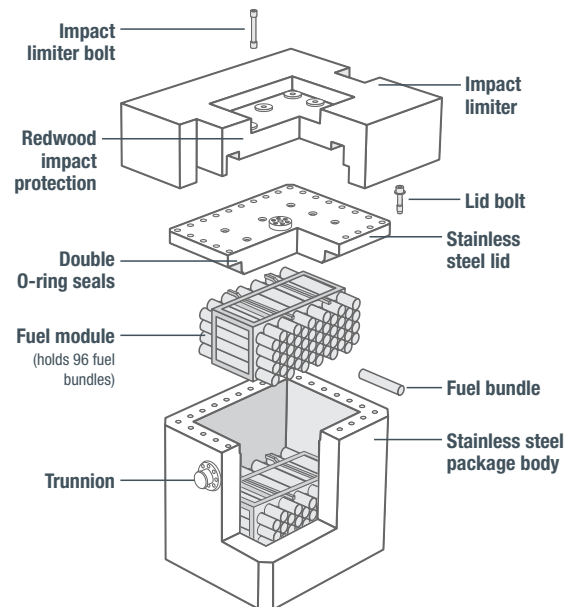
The CNSC regulations are aligned with international standards, and the CNSC is responsible for evaluating transportation packages and certifying designs. Before a used nuclear fuel transportation package can be used in Canada, the design must be reviewed and certified by the CNSC.

The NWMO is assessing different package designs for transporting used nuclear fuel. Final designs will be selected based on a number of factors such as how the used fuel is currently stored, transportation modes, and efficiency. To minimize handling during the transfer from interim storage to the transportation package, the NWMO is looking at using transportation packages that accommodate the current storage method.

Used fuel from Ontario Power Generation (OPG)-owned sites (Bruce, Pickering and Darlington) is currently stored in rectangular fuel modules (see diagrams that follow) contained in dry storage containers. For fuel that uses this storage method, there are two existing transportation package designs that the NWMO is exploring:

Used Fuel Transportation Package

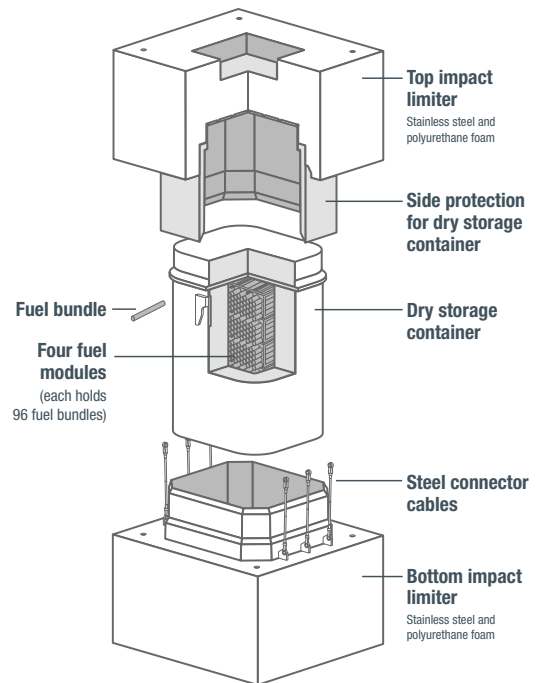
The Used Fuel Transportation Package (UFTP) consists of three main components: the body, lid and impact limiter. The body and lid are made of solid stainless steel with walls nearly 30 centimetres thick. The lid is attached to the body by 32 bolts. The impact limiter consists of a redwood core encased in a stainless steel skin. The stainless steel body and lid provide containment, shielding and impact resistance. The impact limiter is designed to protect the body and lid closure in the event of an accident. The reusable package can carry 192 used fuel bundles (two modules) and weighs almost 35 tonnes when loaded.



Dry Storage Container Transportation Package

Used nuclear fuel is currently stored on an interim basis in dry storage containers (DSC) at OPG Waste Management Facilities. The Dry Storage Container Transportation Package (DSC-TP) consists of a DSC fitted with impact limiters on each end.

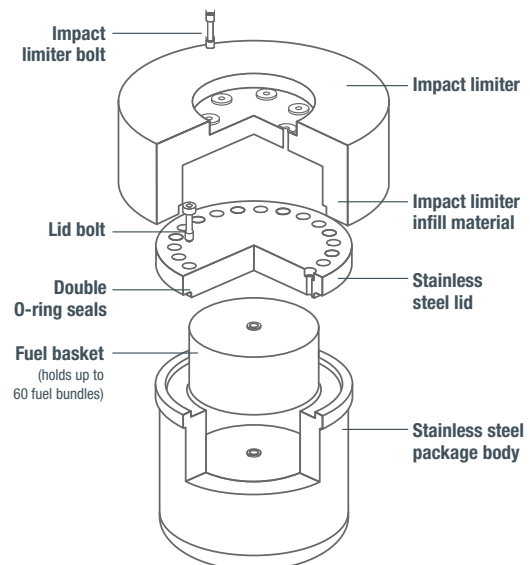
The DSC consists of a body and lid made of high-density concrete encased in a carbon steel skin. The DSC body and lid are welded closed after being filled with used fuel. The reusable impact limiters consist of stainless steel shells filled with rigid polyurethane foam. The impact limiters are fastened together using steel cables. The DSC provides containment and shielding, and the impact limiters are designed to protect the DSC in the event of an accident. The DSC can carry 384 used fuel bundles (four modules) and weighs approximately 100 tonnes when loaded.



All other used fuel (Point Lepreau, Gentilly, Chalk River, Whiteshell, and Douglas Point) is currently stored in dry storage baskets. For fuel that currently uses this storage method, the NWMO is exploring the development of the following transportation package design:

Basket Transportation Package

The Basket Transportation Package (BTP) is under development and designed to move used fuel that is currently stored in dry storage baskets. The BTP consists of the following main components: body, lid, and one or two impact limiter(s). The image on the right shows the BTP concept with one impact limiter. Impact limiters are designed to protect the BTP in the event of an accident. This reusable package can carry up to 120 used fuel bundles (two baskets) and is anticipated to weigh 28 tonnes when loaded.

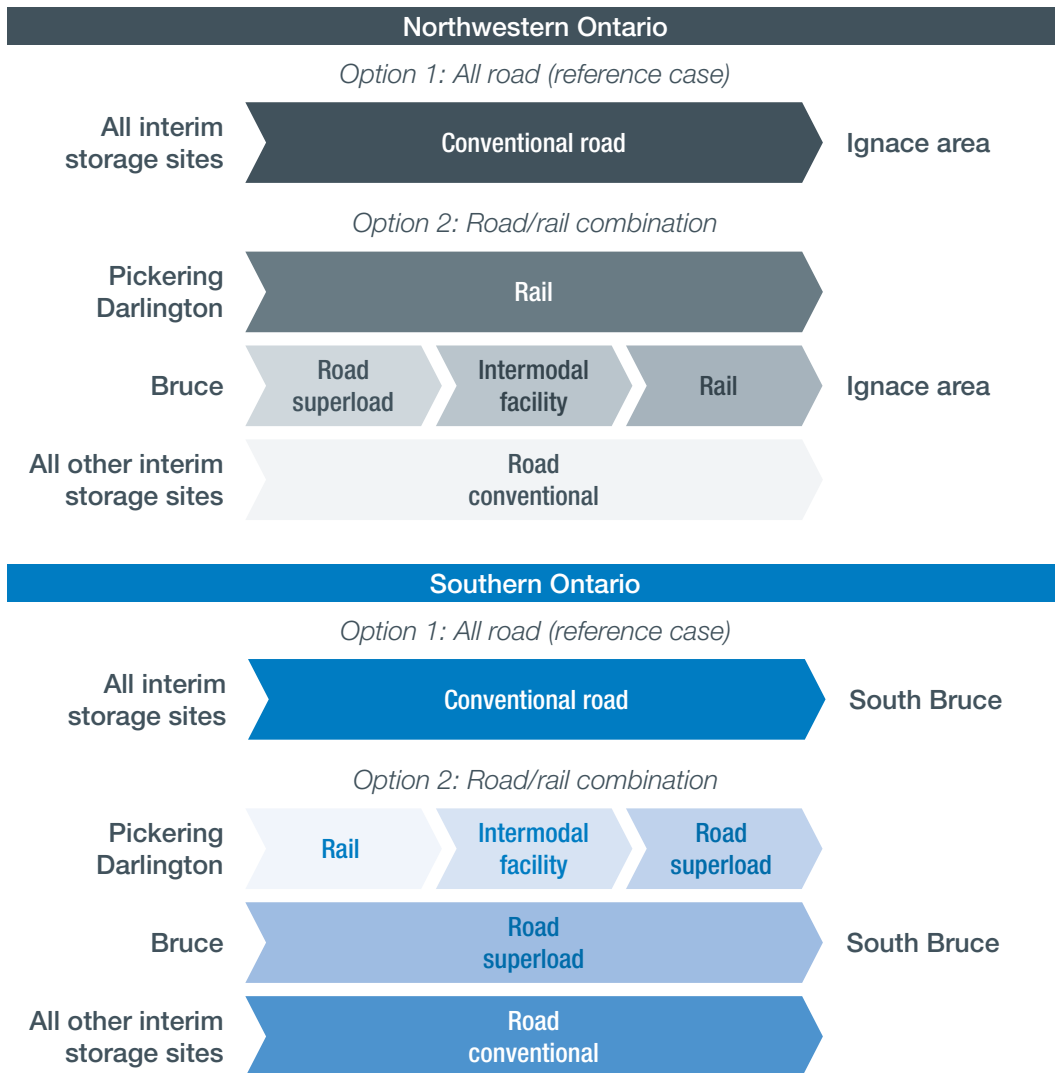



Transportation modes

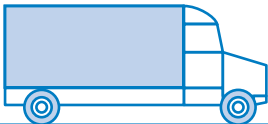
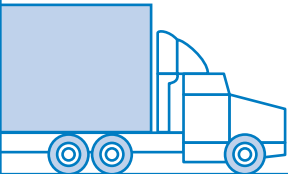
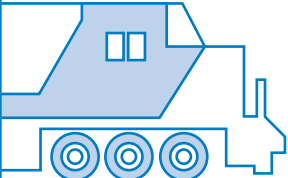
The transportation systems being considered assume the predominant use of existing infrastructure; however, some local site infrastructure will be required. As described above, the NWMO's two systems under consideration include an all-road option and a road/rail option to each potential host site.

Defining these options helps the NWMO develop preliminary routes, make early assumptions about infrastructure that will be needed to support the transportation program and assist in resource planning. For example, road/rail options to each site will require superload shipments and the development of an intermodal facility. Superload shipments are heavy haul shipments that require special permits to transport because of their weight. This would involve the movement of an entire Dry Storage Container (100 tonnes) a relatively short distance (e.g., from Bruce Power to the South Bruce site, or from Bruce Power to a rail line for the Ignace area site). An intermodal facility would allow for the safe and secure transfer of used fuel from truck to train or vice versa. The diagrams that follow describe these options in more detail, as well as what transportation package designs would be used in each mode.

Although the all-road and road/rail systems are shown for each potential siting area, the road/rail option may not make sense for both sites. For example, there is no existing rail infrastructure to the South Bruce site, which makes Option 2 for southern Ontario, in particular, an unlikely choice. For this reason, our preliminary planning has focused predominantly on the all-road options, known as the reference case.



All road (reference case)	Both sites
Truck	
	576 UFTPs/year – 1 package/truck 78 BTPs/year – 1 package/truck
Total: 654 shipments/year	

Road/rail alternative	South Bruce	Ignace area
Truck		
	78 BTPs/year 1 package/truck	78 BTPs/year 1 package/truck
Superloads		
	288 DSC-TPs/year 1 package/truck	165 DSC-TPs/year 1 package/truck
Rail		
	25 DSC-TPs/year 5 packages/train	22 DSC-TPs/year 14 packages/train
Total: 391 shipments/year		Total: 265 shipments/year

Why is the NWMO looking at two transportation mode options – either an all-road system, or a road/rail combination system?

There are a number of factors to consider when it comes to transportation mode selection. Both transportation mode options – an all-road system or a road/rail combination system – can be safely implemented to either potential repository site. Other factors that will be taken into account include transportation package designs, existing infrastructure, and operational elements like scheduling and routing. As identified above, and based on these factors, the all-road system is the NWMO's reference case, and a road/rail system is an unlikely option for the South Bruce site.

For current planning purposes, the all-road transportation system (reference case) makes use of two package designs – the UFTP and BTP – both of which are suitable for transport over existing highway networks using conventional tractor-trailers based on approximate weights and dimensions.

The all-road transportation system uses existing highway networks and provides more flexibility in terms of scheduling and routing. This option would result in a higher number of overall shipments per year because the UFTP and BTP are transported individually (one per tractor-trailer), while multiple packages can be transported at once by rail.

The road/rail combination system also uses two package designs – the DSC-TP and the BTP. While the BTP can be transported over existing highway networks in a conventional tractor-trailer, the DSC-TP requires a specialized superload truck and is subject to additional restrictions due to its weight and overall dimensions. These may include lower speed limits, use of additional escort vehicles, and lower scheduling flexibility.

Because of these restrictions, it is more efficient to transport multiple DSC-TPs at a time using rail rather than individually over road, whenever possible. This option would result in a lower number of overall shipments per year, with each shipment carrying a higher number of used fuel bundles when compared to the all-road system.

Are all transportation packages (the UFTP, DSC-TP and BTP) currently certified in Canada?

The NWMO currently holds a design approval certificate for the UFTP. If the DSC-TP is used, it may need some additional work to ensure that it is certified for road and rail transport. The BTP would need to go through the certification process if the NWMO decides to proceed with this design.

Why doesn't the NWMO just use the UFTP – especially if it is already certified?

Used fuel bundles are packaged in different ways at different interim storage facilities. To minimize handling, the NWMO is proposing to use certified transportation packages that accommodate the current storage method.

How would the NWMO transport a superload and why?

The use of superloads is being considered for relatively short distances (typically less than 125 kilometres) as part of the road/rail alternative due to the weight of the package. A superload would involve the movement of a full DSC, which can carry 384 used fuel bundles (compared to the 192 bundles held by the UFTP). Superloads would be used to minimize the number of times used fuel bundles are handled because the used fuel can be moved in the package in which it is currently stored at interim storage facilities.

1.3 What distances will be travelled?

The distances from the interim storage facilities to each potential repository site are described below. For road shipments from all locations, transport teams consisting of two drivers in the vehicle (one off-duty, one on-duty) are assumed for the entire round trip. There are exceptions to the two-driver teams where distances are relatively short. The asterisks in the table below indicate shipments that would be completed by a single driver.

Potential deep geological repository location	Interim storage facility/ Projected used fuel bundles	All road (reference case)	Road/rail alternative	
		One-way road distance (km) ¹	Road distance (km)	Rail distance (km)
Northwestern Ontario (Crystalline – Ignace area)	Bruce (2,907,650)	1,775	125*	1,750
	Pickering (902,148)	1,725	-	1,600
	Darlington (1,268,801)	1,725	-	1,625
	Point Lepreau (258,820)	2,900	2,900	-
	Chalk River (7,187)	1,600	1,600	-
	Gentilly-1 (3,213)	2,150	2,150	-
	Gentilly-2 (129,925)	2,150	2,150	-
	Douglas Point (22,256)	1,775	1,775	-
Southern Ontario (Sedimentary – South Bruce)	Bruce (2,907,650)	50*	50*	-
	Pickering (902,148)	275*	75*	225
	Darlington (1,268,801)	300*	75*	250
	Point Lepreau (258,820)	1,725	1,725	-
	Chalk River (7,187)	600	600	-
	Gentilly-1 (3,213)	950	950	-
	Gentilly-2 (129,925)	950	950	-
	Douglas Point (22,256)	50*	50*	-

¹ Distances are rounded to the nearest multiple of 25 kilometres.

* Shipments completed by a single driver.

The northwestern Ontario site is obviously farther from the interim storage facilities – why is the NWMO considering a site that is so far away – doesn't this increase the risk of transportation accidents?

For a site to be selected, the NWMO will need to demonstrate the following:

- 1) A deep geological repository can be safely implemented with a strong technical safety case;
- 2) The project can be implemented in partnership with informed and willing hosts; and
- 3) Confidence that a safe, secure and socially acceptable transportation plan can be developed.

Section 2 of this document describes the safety controls the NWMO will implement to ensure safe transportation of used nuclear fuel regardless of the location of the repository site. These controls have enabled countries around the world to safely transport used nuclear fuel for over 50 years without an accident leading to human or environmental harm because of radioactive release.

The NWMO is confident in the safety of transportation to either site.

1.4 What are the time frames for transporting used fuel?

The transportation program is expected to take up to 50 years to complete. This will involve transportation of the used nuclear fuel from different interim storage facilities at different times.

The timing of the shipments will be based on the site's ability to receive and repackage the used fuel and place it into the deep geological repository. The table below describes approximate time frames for moving the used nuclear fuel from the interim storage sites to whichever host site is selected. Transport from some interim storage facilities will overlap. The time frames below consider that transportation year-round is not always feasible due to weather, potential road restrictions and other unknowns (e.g., equipment downtime, maintenance, etc.).

At this early conceptual design stage and for costing purposes, the time frames assume that shipments will occur six days per week for about nine to 11 months of the year. These assumptions depend on which site is selected.

Interim storage facility	Time frames (approximate years)
Bruce	35-50
Pickering	5-20
Darlington	20-45
Point Lepreau	10-15
Chalk River	1
Gentilly-1	1
Gentilly-2	1-5
Douglas Point	1-5

If there is more used fuel than is currently anticipated, does this mean there will be more shipments per year?

No. The pace of shipments is determined by the rate that the NWMO can repackage the used fuel bundles and place them in the repository, not the total number of used fuel bundles. Annual shipments would only increase if operational efficiencies are found in the repackaging process at the deep geological repository site.

Has the NWMO determined the order in which it will remove the used fuel from the interim storage facilities? Which interim storage facility will be first?

The order of shipments has not been finalized. This will be based on considerations such as the number of used fuel bundles in each location, the age of the used fuel being stored, and the operational status of the interim storage facility.

You say that you assume that shipments will run about nine to 11 months of the year. Does that mean that you won't run shipments between January and March?

No. Shipments will be dependent on the conditions identified above (weather, road restrictions and unscheduled maintenance). In this conceptual design phase, we are conservatively assuming that for about 30 to 90 days of the year, we may not be able to transport used fuel due to these conditions.

1.5 What equipment will we need?

Whichever type of transportation package is required, specialized equipment will be needed to transport these packages.

Road transport: Transport trucks will include various features to ensure the safe and secure movement of used nuclear fuel. The transport tractor must have an engine capable of pulling a combined load of the trailer and when fully loaded – for conventional trucks, weights are similar to that of a logging truck. In addition to the engine power requirements, trucks or trains will have many other equipment features. The NWMO will continue to investigate new and evolving best practices in equipment and technology over the next 20 years. At this point in time, example equipment features could include:

- » Extended cab with an integrated sleeper berth;
- » Speed limiters to meet provincial regulations;
- » Radar-based collision mitigation system to assist drivers with avoiding collisions;
- » Anti-theft electronic immobilizer system (e.g., biometric or handprint scanner);
- » Passenger mounted LCD touch screen computer with GPS interface for communications with the Transportation Communication & Control Centre (C&CC);
- » Fire extinguishing/suppression equipment to meet the National Fire Code;
- » Cellular and/or satellite phone;
- » Event recorders and onboard video cameras;
- » Anti-lock braking system (ABS) brakes;
- » Ride and stability control with self-steering axles;
- » Custom-designed mounting frame to spread the load of the transportation package evenly across the axles;
- » Transportation package tie-down system;
- » GPS units for remote real-time tracking of the vehicle location (one on the tractor and one on the transportation package carried within the trailer); and
- » Emergency response personal protective equipment.

Rail transport: Transport by rail is expected to include the following features:

- » LCD touch screen computer with GPS interface for communications with repository site central logistics team;
- » Fire extinguishing/suppression equipment to meet the National Fire Code;
- » Cellular and/or satellite phone;
- » Event recorders and onboard video cameras;
- » GPS units on each locomotive and railcar for remote real-time tracking of the vehicle location; and
- » Emergency Response Personal Protective Equipment.

Canadian regulations established by the CNSC and Transport Canada require the maintenance, testing and inspection programs and associated schedules for performing repairs and maintenance activities on transportation security systems, technical devices and equipment.

2. Safety and security

There is a strong regulatory framework for the transportation of radioactive materials at both a national and international level. Transportation of used nuclear fuel in Canada is regulated by the CNSC and Transport Canada. Shipments will also meet the IAEA safeguard requirements to ensure they are safe and secure. Transportation operations will meet federal, provincial and local safety legal requirements, and will be inspected for compliance. The NWMO will need to demonstrate to regulatory authorities the safety and security of a transportation system before the shipments of used fuel can begin.

The section below describes aspects of the regulatory framework that focus on safety and security, as well as the NWMO's multi-layered approach to transportation safety. That said, the NWMO recognizes and acknowledges that people have had different lived experiences with transportation and may have additional questions about safety. We recognize there is a difference between regulatory safety and social safety. We will begin this section with a discussion of social safety.

2.1 Public priorities – Social safety

First and foremost, it is the NWMO's responsibility to protect people and the environment. This begins with understanding what people are concerned about and considering whether and how our program addresses these concerns. We have heard from the public that they are concerned about the risks associated with transportation. These concerns are often expressed in the description of potential accident scenarios and questions about whether the transportation packages could withstand those specific accident scenarios. To address common concerns raised, some of these accident scenarios are described in the table below. Next to each scenario is a reference to the section of this plan that describes how the NWMO will either mitigate or respond to such scenarios, along with a description of how the NWMO plans to protect people and the environment from all accident scenarios.

	Scenarios	Section reference
1	Accident involving the release of solid used fuel bundles into water	Sections 2.3.1 and 2.3.3
2	Road or rail accidents involving multiple points of impact (e.g., package rolls down a rockface into a river)	Sections 2.3.1 and 2.3.3
3	Road or rail accidents due to bad weather (e.g., snow, freezing rain)	Sections 2.3.2 and 2.3.3
4	Natural disaster events along transportation routes (e.g., flood, fire, rockslide)	Sections 2.3.2 and 2.3.3
5	Road or rail accidents requiring volunteer first responders	Section 2.3.3
6	Train derailments in remote areas	Section 2.3.3
7	Transportation package being the target for terrorist activity	Section 2.3.3

2.2 Regulatory safety

As previously mentioned, there is a strong regulatory framework for the transportation of used nuclear fuel in Canada.

Consistent with this framework of regulation and oversight, the NWMO's transportation program will need to meet the CNSC's and Transport Canada's requirements to be approved. Below is an overview of different aspects of our program and specific regulations.

Transportation package: Used nuclear fuel transportation packages are designed and tested to ensure protection of the public during normal operations, as well as during accident conditions. The CNSC, using internationally recognized standards that have been in existence for over 60 years, has the responsibility for evaluating the transportation package and certifying its design, the registration of the use of individual packages, and monitoring the package maintenance process. These standards are set by the IAEA under *Regulations for the Safe Transport of Radioactive Material – Specific Safety Requirements* (No. SSR-6).

Prior to transporting used nuclear fuel in Canada, the CNSC's comprehensive regulatory framework requires a certificate for the transport package and a licence to transport. The CNSC evaluates applications to ensure that safety and security measures are technically and scientifically sound, that all requirements are met, and that the appropriate safety and security provisions are in place to protect people and the environment. Packages used to transport used nuclear fuel from interim storage facilities to the repository must be certified by the CNSC.

Radiological safety: Packages used to transport used nuclear fuel must meet radiation level requirements prescribed by the CNSC's *Packaging and Transport of Nuclear Substances Regulations, 2015*. Regulatory requirements for the package ensure the public and workers are safe. The package is designed and tested to ensure that in the event of an accident, any radiological release will not exceed the regulatory limits. The CNSC's *Radiation Protection Regulations* have set an annual radiation dose limit for members of the public to limit exposure from nuclear-related activities, using the ALARA principle (As Low As Reasonably Achievable).

Emergency response and training: Transport Canada's *Transportation of Dangerous Goods Regulations* establish requirements for worker and driver training, emergency planning, safety marks (e.g., placards), and documentation. Emergency response planning will be required through the CNSC licence conditions as well. Transportation planning needs to address these aspects and ensure that all equipment, packages and activities for road and rail shipments meet regulatory requirements. The NWMO will need to demonstrate that all activities will be conducted by trained personnel, including emergency responders. The NWMO will also need to develop an emergency response plan and ensure workers and emergency responders are trained before shipments can begin.

Security: Security provisions during transportation need to ensure CNSC regulatory requirements are met. Security measures are aimed at preventing diversion or sabotage of the transportation package, and include a combination of engineered, physical and monitoring measures to protect the cargo, and provide for detection, alarm, recording, and communication, in the event of an occurrence.

2.3 The NWMO's safety program

Based on the strong regulatory framework described above, the NWMO's program has multiple layers of safety.



2.3.1 The transportation package

Scenario 1

Cumulative effects testing addresses concerns about multiple impact accident scenarios.

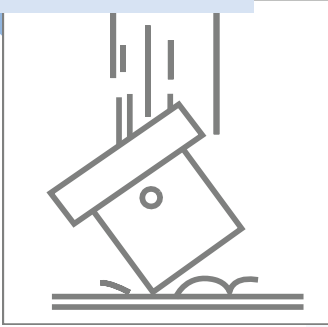
Safety is built into every element of the NWMO's transportation program, beginning with the transportation package design. Used nuclear fuel transportation packages are designed and tested to ensure protection of the public during normal operations, as well as during accident conditions.

Before a used fuel transportation package can be used in Canada, the design must be certified by the CNSC to meet regulatory requirements, which incorporate international safety standards. The requirements include tests designed to demonstrate the ability of the package to withstand severe impact, fire and immersion in water. These are extreme tests to demonstrate how durable packages are.

When all the requirements for design and testing are met, the CNSC issues a certificate for the package design. The certificate specifies instructions for the operation and maintenance of the transportation package. It also defines the authorized contents that may be carried in the package. The certificate is typically valid for five years. At the end of this period, the NWMO will have to reapply to re-certify the package.

To gauge the cumulative effects on the transportation package design, the first two tests described below are conducted in the sequence that would result in the most damage to the package, followed by the thermal test. For more information about transportation package testing and regulations, go to www.nwmo.ca/transportation.

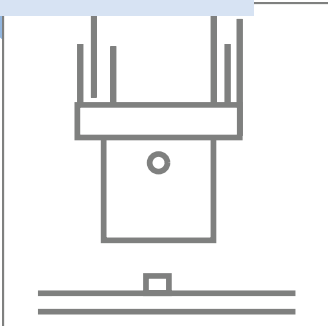
Free-drop test



The package is dropped from nine metres (30 feet) onto a flat, unyielding surface (such as a steel-reinforced concrete pad), striking the surface in the orientation that will result in the most damage to the package.

This test determines the performance of the package when it experiences loads comparable to the most severe potential transportation collision. The loads associated with this test are many times higher than those experienced when a train travelling at 160 kilometres an hour collides with the transportation package. A detailed analysis is available in the NWMO technical report: *Why the Nine Metre Drop Test Bounds the Impacts from Most Severe Accidents* (NWMO TR-2014-04).

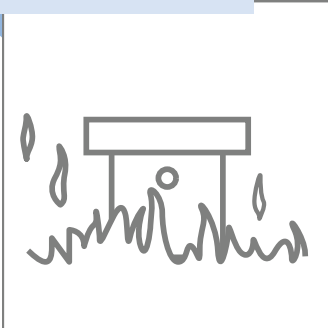
Puncture test



After the drop test, the same package is subjected to a one-metre (40-inch) free drop onto a 15-centimetre (six-inch) diameter steel bar at least 20 centimetres (eight inches) long.

While the free-drop test simulates an impact that is spread over a larger area, this test looks at what would happen in a collision with a sharp object. The test demonstrates that the container will not puncture.

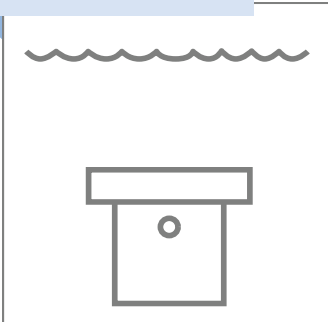
Thermal test



Using either computer analysis or physical testing methods, the same package used in the drop and puncture tests is then subjected to a fully engulfing petroleum fire. The fire temperature must reach 800 degrees Celsius (1,475 degrees Fahrenheit) for 30 minutes.

This test mimics the conditions of a potential severe accident involving flammable liquids near a package. The fire must fully engulf the package for the entire test. The flame must reach 800 degrees Celsius, which is typical of a hydrocarbon fire. In real accidents, fires involving flammable liquids generally do not burn for 30 minutes because the supply of fuel dwindles and the fire location shifts.

Immersion test



Using either computer analysis or physical testing methods, the package is subjected to external pressure that is the same as if it were immersed under 15 metres (50 feet) of water for at least eight hours to test for leakage. The package is also subjected to an enhanced water immersion test at 200 metres (650 feet) to test its ability to withstand extreme external pressures.

Water bodies near most bridges, roadways or harbours are less than 15 metres deep. The eight-hour period is sufficient to allow the submerged package to come to a state where its conditions will not change, regardless of the length of time required to remove it. The enhanced immersion test (200 metres) considers the unlikely possibility of a package sinking at particularly deep locations, such as some points on the continental shelf. It subjects the package to maximum pressure.

Scenario 2

This Q&A addresses concerns about release of package contents into water.

What if the transportation package opens and a fuel bundle or pellet gets into the water?

Firstly, in the over 50-year history of transporting used nuclear fuel internationally and in Canada, there has never been a transportation package damaged to the point where radiological release has resulted in human or environmental harm. This is because of the stringent regulations in place and the robust package design.

Transportation packages are designed and tested to withstand severe accident conditions, and offer a very high degree of assurance that a package cannot be breached. The tests required by the CNSC are described on p. 20. Additional examples of extreme accident scenarios (e.g., a train running into a package at 160 km/hr or a propane tank rail car exploding beside a package) can be found on our YouTube channel at www.youtube.com/NWMOCanada.

In any accident scenario, procedures outlined in the transportation emergency response plan would be followed. The plan would detail the response actions that should take place, resources available to mitigate the situation, and ultimately, how to return the accident site to normal.

If there was an accident and the package fell into water, the most likely result would be no release of radioactivity. Even so, the NWMO has heard that people are interested in understanding more about the implications of these types of extreme accident scenarios. As described in Section 3, the NWMO's future work will include more detailed studies of accident scenarios, including assessing potential radiological doses to members of the public and workers in these very unlikely events.

It is important to note that used nuclear fuel is a stable solid – not a liquid or a gas, and it is not flammable or explosive. Because of this, it also does not readily react or break down in water. This means that even in the virtually impossible scenario that a container was somehow breached, widespread contamination would also be very unlikely.

2.3.2 Operational safety

The next layer of safety applied to the transportation system is the operational controls layer. These are the actions the NWMO will take to prevent accidents and manage risks, including route selection, communications, and real-time monitoring and tracking. Most importantly, if an event is detected along the transportation route in advance of a transportation shipment, such as bad weather or a highway closure, the shipment will not go out or an alternate route will be used (depending on the situation).

Route selection

Safety will be the top factor when it comes to transportation route selection. Other priorities such as fastest routes and highest quality infrastructure will also be considered. Route assessments will be guided by:

- » Minimizing the total time that the nuclear material remains in transport;
- » Minimizing the number and duration of any transfers of the nuclear material from one vehicle to another;
- » Avoiding fixed transport schedules for the movement of the nuclear material;
- » Varying the routes used to transport the nuclear material, considering applicable regulations and ordinances regarding transport routes for radioactive and hazardous materials; and
- » Choosing routes that consider any obvious hazards such as rockslides, floods or forest fires that could adversely affect the transport at certain times.

In addition to the regulatory requirements, the NWMO's route selection will also be guided by:

- » Seasonal load capacity restrictions on travelled roadways (for road transport);
- » Load height and weight restrictions (road and rail); and
- » Potential emergency response times (for road and rail).

In addition to the above variables, the NWMO's dialogues with Canadians and Indigenous peoples have provided another set of considerations for routing that the NWMO will continue to review as work progresses. Some of these are covered above. Other considerations include:

- » Proximity to population centres and schools;
- » Proximity to sensitive environmental areas (e.g., for any new infrastructure required);
- » Potential need to improve existing or build new infrastructure (e.g., extension of rail track);
- » Potential for traffic congestion and potential impact on commuters;
- » Assessment of political and social acceptance;
- » Trade-off between a longer route that goes through less densely populated areas versus a shorter route that goes through more densely populated areas; and
- » Indigenous and local knowledge of specific corridors.

The NWMO will continue to work with Canadians and Indigenous peoples to explore priorities and considerations related to route selection as transportation planning evolves and becomes more refined once a site is selected.

What transportation routes are being considered? Why hasn't the NWMO published these?

Current regulations do not allow the public disclosure of security information on the location, routes and timing of shipments, nor any security arrangements or procedures specific to the transportation of used nuclear fuel. This type of information is considered prescribed and is limited to persons who have a legitimate need to know, such as police response forces.

That said, we recognize that many of the potential routes are obvious. Also, we know that people are interested in giving us feedback about factors they think we should consider for route selection. This is valuable information for us. In fact, the considerations that people have given us to date are being included in our ongoing routing analysis.

Because there are still two sites and we are still looking at road, or a combination of road and rail in terms of modes, there are many potential routes that are being considered. These routes would, for the most part, be along transport infrastructure currently in use for the transportation of dangerous goods and the many other radioactive shipments that are being transported in Canada every day. To get a bit more specific, routes will be predominantly along major provincial highways and/or Class 1 rail lines.

We will continue to bring more information about routing considerations as we work through routing analysis, including information that can be shared from a regulatory perspective.

More information about transportation of used nuclear fuel can be found at <https://nuclearsafety.gc.ca/eng/resources/fact-sheets/packaging-and-transport-of-nuclear-substances.cfm#F5>.

Communications

During transportation, the drivers will remain in frequent contact with the shipper, receiver, local authorities, and response forces along the transport route. For security reasons, communication will be by encrypted messages only.

In remote regions, there may be gaps in communications coverage. Where it may not be possible to avoid such “blackout” areas along the transport route, other communication arrangements will be established. Satellite telephones can be used as backup communications in the event of disruption of primary cellular communications.

Additionally, the NWMO will review new communication technologies for use as they are proven reliable. Example equipment:

- » CB radio (on privately licensed frequency);
- » CB antenna;
- » Satellite telephone (encrypted, use to be limited to backup communication if CB radio unavailable); and
- » Cellular telephone with carrier service.

Real-time tracking and monitoring

One mechanism of tracking shipments is the use of a security escort. These escorts would maintain constant surveillance of the shipment. The responsibilities of security escorts are described in section 2.3.4.

Electronic or satellite equipment will also be used to track and monitor shipments. The NWMO will operate a central Transportation Communication & Control Centre (C&CC) located at the repository site that will provide a single point of contact for all agencies involved in transportation-related communications, and that will monitor and track used fuel shipments.

Each escort vehicle, tractor or railcar, and transport package will be equipped with a GPS unit for remote real-time tracking of their location. Additional best practices and available technologies will be reviewed for tracking and monitoring as they are proven reliable.

Scenarios 3 and 4

This responds to people's concerns about natural disasters (floods, fires, snow) and bad weather conditions impacting transportation. Constant communication with a central command centre during transportation will allow the NWMO to change course to avoid these types of events. If an event is detected along the transportation route in advance of a shipment, the shipment will not go out or an alternative route will be used.

2.3.3 Emergency management and security

Emergency management systems and security planning and protocols are the next layer of safety applied to the transportation program. These are systems put in place to prevent, mitigate and manage accidents and/or security threats. It is important to remember that transportation packages are designed to withstand extreme accident scenarios. That said, a road or rail accident can still have a significant impact on the transportation network. It is therefore important that plans are in place to manage these accidents should they occur.

Emergency management

In Canada, the emergency management community has adopted a standard approach for responding to incidents. Federal, provincial and local governments use a comprehensive approach to emergency management, which includes having in place measures for prevention, mitigation, preparedness, and response and restoration activities for all modes of transportation.

The NWMO will provide an emergency response plan to the Canadian regulatory agencies to demonstrate that appropriate emergency measures are in place. The purpose of the emergency response plan is to ensure co-ordination among the NWMO, provincial and local first responders, as well as federal agencies. It should be noted that first responders have general training on response protocol for dangerous goods, and any supplemental training or awareness programs would build on this knowledge base. Additionally, specialized teams with expertise and training in response and recovery would be dispatched by the NWMO in the event of an accident involving a transportation package.

Scenarios 5 and 6

The NWMO's transportation program is designed to prevent accidents; however, if an accident were to occur, the plan would need to address the scenarios identified, including recovery in remote locations and how the NWMO will work with other emergency response organizations, including volunteer responders.

The emergency response plan may include, but is not limited to the following:

- » Description of the emergency response organization and external agencies, as well as their roles, responsibilities, capabilities, and duties, and how they will work together;
- » Agreements on assistance with other facilities and/or other organizations;
- » Plans for mobilizing and deploying resources for response;
- » Description of roles and responsibilities (e.g., driver, escort, NWMO transportation command centre staff, first on the scene team, response team, recovery team, etc.);
- » Training and qualification requirements, as well as drills and joint exercises; and
- » Communication protocols, as well as procedures for alerting and notifying key organizations and personnel, as well as the public.

The NWMO will also need to consider either owning or contracting the following equipment to support emergency management preparedness.

Equipment	Purpose
Excavator	Excavation of trenches or access ways, ability to cut through heavy steel
Rotator tow truck	Ability to lift equipment, truck and trailers
Wheeled dozer	To push debris and away from the site
Wheel loader	To lift and load the debris into haulage vehicles
HiWay tractor	To haul equipment to/from incident locations
Heavy equipment float trailer	To carry equipment to/from incident locations
Mobile crane	Ability to lift transportation packages
Side-boom	Ability to lift equipment in tight area
Track loader/dozer	To push debris away from the site
Hi-rail vacuum truck	To vacuum away unwanted materials

As an additional support, Transport Canada operates Canadian Transport Emergency Centre (CANUTEC) – a national advisory service that assists emergency response personnel in handling dangerous goods emergencies on a 24-7 basis. The emergency centre is staffed by bilingual scientists specializing in chemistry or a related field and trained in emergency response.

The emergency response advisors are experienced in interpreting technical information from various scientific sources to provide pertinent and timely advice.

Security

Security planning must be done prior to transportation, and the NWMO must submit a transportation security plan as part of our application for a licence to transport used nuclear fuel. Like the transportation routes, the security plan is prescribed information and not available to the public. As part of this work, the NWMO must look at normal operations and worst-case scenarios to ensure plans are in place to respond to those scenarios. The security plan must include:

- » A threat assessment that looks at the nature, likelihood and consequences of acts or events that may place information or the used nuclear fuel at risk, along with corresponding mitigation measures, including emergency response;
- » Proposed security measures;
- » Communication arrangements;
- » Arrangements with response forces;
- » Planned and alternate routes;
- » Provisions for the support of response forces along the transport route;
- » Procedures for contacting, during transportation, the response force from any involved jurisdiction or agency;
- » Contingency arrangements to address such events as a mechanical breakdown of a transport or escort vehicle, or failure of a shipment to arrive at its destination at the expected time;
- » Procedures to be followed during an unscheduled stop or unscheduled delay during transport; and
- » Provisions for notifying any response force along the transport route in advance of the actual shipment.

In addition to the security plan, the shipments will be accompanied by one or more escorts. Their responsibilities would involve:

- » Conducting searches of persons, materials, vehicles;
- » Remaining in frequent contact with the shipper, receiver, local authorities, and response forces along the transport route;
- » Inspecting for security breaches and vulnerabilities, and ensuring the secure storage of any transport equipment; and
- » Responding to and assessing incidents and events.

Scenario 7

The transportation security plan addresses the concern about the package being a target for terrorist activities. It includes threat assessments that look specifically at these possibilities.

2.3.4 Management system

The final layer of safety applied to the transportation system is a management system that is focused on quality assurance, learning through experience, training, and auditing. This is one of the ways that the nuclear industry, as a whole, maintains its strong transportation track record. It is a combination of applying Canadian and international regulations and industry best practices.

The regulations described in section 2.2 outline requirements for training, monitoring and auditing. Specifically, the CNSC requires training of workers and emergency responders as part of the application for the licence to transport. The CNSC also performs compliance inspections and is responsible for investigating all incidents and emergency response situations that occur during transport. Transport Canada establishes requirements and undertakes compliance inspections for training and documentation. They also enforce requirements for emergency response planning.

In addition to these training, monitoring and auditing functions, the international nuclear community also has provisions for monitoring and auditing transportation activities and events. For example, the IAEA, which sets the standards for package design and testing, reviews and updates its requirements for transportation packages approximately every six years.

Personnel and training

The nuclear industry has very high standards with respect to driver/operator training. These standards are governed by regulations under the *Transportation of Dangerous Goods Act*, 1992, c.34. Training requirements set out in this act identify that drivers must be certified and have adequate training. Training must cover the following:

- » The type of material the driver/operator is carrying;
- » Safe handling practices, including the characteristics of the dangerous goods;
- » Proper use of equipment;
- » Reasonable emergency measures the person must take to reduce or eliminate any danger to the public;
- » The emergency response plan for that specific shipment; and
- » Documentation and reporting requirements.

Transport Canada ensures that all these training requirements are met prior to issuing a training certificate and will also do spot checks during transportation programs to ensure that training certificates are up-to-date.

3. The road ahead

As discussed, this document is the NWMO's preliminary plan for how we will approach transporting used nuclear fuel from interim storage facilities to the eventual repository site, beginning in the 2040s. Recognizing that this is approximately 20 years away, this work will continue to be expanded on and refined to incorporate emerging technologies and possible changes in infrastructure, as well as public priorities through our collaborative transportation planning process. The following paragraphs describe the work that the NWMO will carry out over the upcoming years as we work towards our ultimate goal of protecting people and the environment. Future iterations of this document will provide updates on this work as it progresses.

Routing

Once a site is selected, detailed routing analyses will be completed to establish primary and alternate routes. Route selection criteria will be established, prioritizing the use of high-quality infrastructure and using shortest route options while also considering potential hazards.

Since transportation is not expected to begin until the 2040s, we recognize that transport infrastructure and networks may evolve over time and while our work is ongoing, influencing final and alternate route selection.

Transportation safety

The NWMO is planning a multi-year work program on transportation safety of used nuclear fuel. Anticipated areas of work include:

- » Gathering information on federal, provincial and route-specific accident data to assess the type, severity and cause of accidents to better understand issues that lead to transport accidents;
- » Based on available accident data:
 - Identifying best available technologies that can be implemented to prevent accidents from occurring such as speed limiters, collision avoidance systems, duress buttons, etc;
 - Identifying best practices and operational programs that can be implemented to mitigate potential accidents (see *Operational best practices* on the next page);
- » Assessing doses to members for the public and workers (crew/escorts) under both routine and normal conditions of transport, as well as accident scenarios, to ensure that they are safe; and
- » Assessing risks associated with a range of transportation accident scenarios.

Emergency management

The NWMO plans to continue work in the area of emergency management and planning. A conceptual level operational plan will be developed in the future. At a minimum, this generic emergency management plan will:

1. Define accidents and hazards the emergency management program will address;
2. Establish a conceptual response plan and describe how a response will be executed; and
3. Ensure that people, equipment and infrastructure will be ready to execute the response plan and procedures.

A more comprehensive emergency management plan will be developed as details about mode, package and routes are finalized.

Security

The NWMO is initiating work in the area of transport security. Specifically, the NWMO is looking to develop a robust transportation security framework to ensure that used nuclear fuel can be transported in a secure manner.

This work will consider regulatory requirements, operational experience and best practices both nationally and internationally. It will also be the basis for the transportation security plan, as well as a threat risk assessment, which are required before any shipments of used fuel can occur.

After site selection and closer to the start of operations, a comprehensive transportation security plan that establishes detailed co-ordination with appropriate municipal, provincial and federal law enforcement agencies and threat risk assessment will be developed.

Operational best practices

The NWMO is committed to continued monitoring of international and Canadian best practices in the area of radioactive material transport. Review of the following is planned:

- » Frequency and level of examination of transportation package inspection and maintenance;
- » Frequency and level of examination of truck or train inspection and maintenance;
- » Training development standards for transport crew and personnel;
- » Frequency and scale of emergency response plan testing;
- » Indicators and metrics during monitoring and tracking of shipments (location, traffic, weather), as well as real-time analytics (speed, brake pressure) of conveyance during transport; and
- » Operational controls and limits, e.g., safety protocols implemented during changing transport conditions, route guidance and control, parking management and protocols in the event of traffic congestion, severe weather, and other external events (such as forest fires, snowstorms, flooding, tornados, etc.).

Transport infrastructure

Following site selection and finalization of decisions on transport modes and routes, it is anticipated that transportation infrastructure improvements or upgrades may be required. Collaboration with transportation system owners will be undertaken to address safety and service gaps along primary and alternative transportation routes.

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