Canadian Nuclear Safety Commission

Commission canadienne de sûreté nucléaire

Public meeting

Réunion publique

November 9th, 2017

Le 9 novembre 2017

Public Hearing Room
14th floor
280 Slater Street
Ottawa, Ontario

Salle des audiences publiques
14e étage
280, rue Slater
Ottawa (Ontario)

Commission Members present

Dr. Michael Binder
Dr. Sandy McEwan
Dr. Soliman A. Soliman
Dr. Sandor Demeter

Commissaires présents

M. Michael Binder
Dr Sandy McEwan
M. Soliman A. Soliman
Dr Sandor Demeter

Assistant Secretary:

Ms Kelly McGee

Secrétaire-adjointe:

Mme Kelly McGee

General Counsel:

Ms Lisa Thiele

Avocate générale :

Me Lisa Thiele

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Ottawa, Ontario / Ottawa (Ontario)

--- Upon commencing on Thursday, November 9, 2017 at 9:02 a.m. / La réunion publique débute le jeudi 9 novembre 2017 à 9 h 02

Opening Remarks

MME McGEE : Bonjour, Mesdames et Messieurs. Bienvenue à la réunion publique de la Commission canadienne de sûreté nucléaire.

Mon nom est Kelly McGee. Je suis la secrétaire-adjointe de la Commission et j'aimerais aborder certains aspects touchant le déroulement de la réunion.

We have simultaneous interpretation. Please keep the pace of your speech relatively slow so the interpreters are able to keep up.

Des appareils pour l’interprétation sont disponibles à la réception. La version française est au poste 2; the English version is on channel 1.

To make the transcripts as complete as possible, please identify yourself each time before you speak.

La transcription sera disponible sur le site Web de la Commission dès la semaine prochaine.

I would also like to note that this proceeding is being video webcast live and that archives of these proceedings will be available on the CNSC website for a three-month period after the close of the proceedings.

As a courtesy to others, please silence your cell phones and other electronic devices.

Monsieur Binder, président et premier dirigeant de la CCSN, va présider la réunion publique d’aujourd'hui.

President Binder.

THE PRESIDENT: Thank you, Kelly.

Good morning and welcome to the meeting of the Canadian Nuclear Safety Commission.

Mon nom est Michael Binder. Je suis le président de la Commission canadienne de sûreté nucléaire.

Je vous souhaite la bienvenue and welcome to all of you who are joining us via our webcast.

I'm also happy to share with you that today for the first time ever we are experimenting with a new media. We are going to be on YouTube for all you Millennials out there that like to see a proceeding in action.

We will see if the technology will work, so bear with us. I was assured that it's going to work.

Is it on now? Terrific.

I would like to start by introducing the Members of the Commission.

On my right is Dr. Soliman A. Soliman; on my left are Dr. Sandor Demeter and Dr. Sandy McEwan.

We have heard from the Assistant-Secretary Kelly McGee and we also have with us Ms Lisa Thiele, Senior General Counsel to the Commission.

MS McGEE: The *Nuclear Safety and Control Act* authorizes the Commission to hold meetings in the conduct of its business.

Please refer to the revised agenda that was published on November 7th for the complete list of items to be presented today.

The presentation from CNSC staff on Canada's participation at the 7th Review of the Convention on Nuclear Safety that was initially scheduled for today's meeting has been postponed to the Commission's meeting on December 13th and 14th.

In addition to the written documents reviewed by the Commission for this meeting, CNSC staff and other participants will have an opportunity to make presentations and Commission Members will be afforded the opportunity to ask questions on the items before us.

CMD 17-M55.B

Adoption of Agenda

THE PRESIDENT: With this information, I would like to call for the adoption of the agenda by the Commission Members, as outlined in Commission Member Document CMD 17-M55.B.

Do we have concurrence?

For the record, the agenda is adopted.

CMD 17-M41

Approval of Minutes of Commission Meeting held on August 16-17, 2017

THE PRESIDENT: I would now like to call for the approval of the Minutes of the Commission meeting held on August 16-17, 2017, as outlined in CMD 17-M41.

Kelly, any remarks about these proceedings?

MS McGEE: Following the August 16-17, 2017 Commission Meeting, the Commission requested revisions to the proposed text of Regulatory Document 2.2.4. CNSC staff provided a revised version, which is now available under CMD 17-M35.B. After consideration of staff's revised draft document, the Commission approved a revised version of REGDOC-2.2.4 (volume 2): Drug and Alcohol Testing. The final document will be available shortly on the CNSC website. The minutes of August 16-17, 2017, to be approved this morning, provide the details of the process followed and the decisions taken by the Commission to approve Regulatory Document 2.2.4.

I also wish to note that a change will be made to correct an error in paragraph 37 of the draft minutes.

The wording in the sentence of the draft minutes was:

> "CNSC staff added that they do not look specifically to a number but at the trend on a daily basis"

The correct word in that sentence, as presented by CNSC staff and accepted by the Commission, should have been "quarterly basis" instead of "daily basis." So paragraph 37 of the draft minutes for August 16-17, 2017 have been corrected accordingly.

THE PRESIDENT: Thank you.

Are there any other comments, deletions, suggestions?

Okay. So therefore, I seek approval for the minutes.

So for the record, the minutes are approved.

CMD 17-M57

Oral presentation by CNSC staff

THE PRESIDENT: The first item on the agenda for today is the Status Report on Power Reactors, which is under Commission Member Document CMD 17-M57.

I understand we have representatives from Bruce Power, OPG and NB Power available for questioning, either in person or through videoconference or teleconference.

I understand that, Mr. Frappier, you will make the presentation. Over to you.

MR. FRAPPIER: Thank you and good morning, Mr. President and Members of the Commission. I am here to present Commission Member Document 17-M57, the Power Reactor Status Update.

My name is Gerry Frappier and I am the Director General of the Directorate of Power Reactor Regulation.

With me today are the Directors of the Power Reactor Regulatory Program Divisions and technical support staff, who are available to respond to questions.

Also with us, as you mentioned, are Licensee representatives, should there be questions for them.

As you will note, this CMD covers the period up to November the 1st and I am here to present a verbal update to provide you with the most current information.

First off is that Bruce Unit 2 has now returned to full power.

Secondly, New Brunswick Power has submitted the REGDOC-3.1.1 report with regards to the steam burn incident or event. CNSC staff are in the process of reviewing the report and the corrective actions.

This concludes my update. As I said in the opening, CNSC regulatory and technical staff as well as licensees are available to answer any questions you may have.

THE PRESIDENT: I'm told that people from OPG are online. Can you hear us?

MS SMITH: This is Stephanie Smith, Director of Ops and Maintenance from Pickering Nuclear, and

I can hear you, sir.

THE PRESIDENT: Okay, thank you.

Dr. Demeter, do you want to start us off?

MEMBER DEMETER: Sure. Thank you very much. I had a question for the Point Lepreau steam burn incident. There's a comment in here that they will conduct a review looking at greater detail on potential hazards and the personal protective equipment required to mitigate. Is that a broad review of personal protective equipment or is this isolated to this particular incident? Because I'm not sure what personal protective equipment would be required to prevent a steam burn out of the ordinary work equipment you would wear. So is this a broader look? Does this raise a bigger issue?

MR. FRAPPIER: Gerry Frappier for the record. I believe we have New Brunswick Power on the line as well, so I would ask them to describe a bit what is the issue around personal protective equipment associated with this event.

MR. NOUWENS: Jason Nouwens for the record, Director, Regulatory Affairs and Performance Improvement.

Can you hear me okay?

THE PRESIDENT: Yes, we can. Go ahead please.

MR. NOUWENS: Okay, thank you.

So the area or focus on personal protective equipment is specifically related to systems in the station that have saturated liquid, so liquid that could turn to steam upon exiting the system, and the equipment we're looking at is specifically around the foot and leg area that if we're doing work in a particular -- that would prevent that risk, that we could have personal protective equipment available.

In addition, I would like to emphasize that we're also reviewing our operating manual requirements for draining systems, that are the saturated liquid nature, and we're implementing a decay period, from the temperature point of view, of 8 hours. So any future occurrences of draining similar pumps, we've implemented an 8-hour hold point to reduce the temperature to avoid the incident right from the start.

MEMBER DEMETER: Thank you very much. That answers my question.

THE PRESIDENT: Thank you.

Dr. Soliman.

MEMBER SOLIMAN: Thank you very much and good morning. I have a question on Unit 2 Bruce. The leakage location, is it on the primary transport connection to the instrumentation line? I would like also to know the cause of that leak, how we repair it, and if we do any inspection on the repair before we start.

MR. FRAPPIER: Gerry Frappier for the record. Perhaps I'll ask Bruce Power to explain a bit of the instrument line and where the leak was and then have our staff talk about our inspection program on it.

MR. BURTON: Maury Burton for the record.

The instrument line in question was a flow-sensing instrument line for the heat transport system coming off one of the pressure tubes. It's located in the feeder cabinet. The reason for the leak was the line was actually a little loose and it was chafing against the insulation that was installed for the feeder cabinets.

So the repair entails cutting out the leaking section of the tube and replacing it. This is tested before the reactor is put back to power in accordance with our Pressure Boundary Program to ensure that there is no additional leakage. The line was -- there was some additional supports put in to ensure that the line was not going to contact the installed insulation again and we did do some additional inspections in the feeder cabinets to ensure that other instrument lines were not contacting the insulation.

Now, we do also have plans because of the refurbishment on Unit 1 as well to go in and do some similar inspections during the Unit 1 outage that is occurring in the winter of 2018.

MS SIMIC: Sanja Simic for the record. I'm the Acting Director for Bruce Regulatory Program.

This is just to confirm that the leak was smaller than the OPNP limit. So Bruce Power proactively shut down the unit and decided to perform the repair. And as part of our regulatory oversight we will be conducting a focused inspection.

MEMBER SOLIMAN: Okay. Is this an inspection -- is this a repair, you reweld the pipe again or...?

MR. BURTON: Maury Burton for the record.

The actual fix is using Swagelok repairs. So we do Swagelok fittings on each end of the tube and then use those fittings to connect. It's very difficult to do tube welding in these areas. Therefore, we use the Swagelok. It's an approved procedure that we do for these types of leaks.

MEMBER SOLIMAN: Thank you.

THE PRESIDENT: Thank you.

Dr. McEwan?

MEMBER McEWAN: No question.

THE PRESIDENT: Dr. Demeter?

MEMBER DEMETER: I'm good, thank you.

THE PRESIDENT: More questions?

MEMBER SOLIMAN: Yes.

THE PRESIDENT: Go ahead.

MEMBER SOLIMAN: Unit 1 Darlington. I would like just more explanation about this control issue and why we shut down the reactor.

MS RIENDEAU: This is subsequent to a routine test on Turbine 1 that occurred on September 1st. There was -- OPG determined that they needed to conduct a further in-depth investigation and so it was planned and they shut down the unit on October 27 and they actually -- I believe it was a pressure switch that they needed to either test or confirm the condition and then the unit was returned to service following the shutdown.

MEMBER SOLIMAN: Okay. Do you have any concern about putting the reactor in complete thermal cycle from normal operation to cool down, to shut down again, to heat up and start up and all this full cycle in less than one day?

MR. FRAPPIER: Gerry Frappier for the record.

I think all the procedures were followed. Those procedures have been reviewed by various safety analysis and operational personnel, so we don't have a concern with the procedure that they used.

MEMBER SOLIMAN: Thank you.

THE PRESIDENT: But, you know, again, I imagine you need a little bit more explanation. When you use language to investigate possible control issues without telling me what control issues you're concerned with raises a red flag to me.

MR. FRAPPIER: Gerry Frappier for the record.

So the turbine side of course we don't pay as much attention to given that there's no nuclear systems on it. It is very important obviously since that's where the electricity gets generated, so they operationally are very concerned about it. There's various control aspects to the steam going in and ensuring that the turbines are spinning in a proper way. All of those have to work properly from an operational perspective or else they will have some serious concerns.

We don't have somebody from OPG on the line right now who can respond to the Darlington thing, but if needed we can certainly get a bit more clarification.

THE PRESIDENT: I'm just asking for a little bit more text when you use language like that to explain any safety issue, possible safety issue, et cetera. Some of the things you just said should have been articulated in the text.

MR. FRAPPIER: Good point and we'll make sure it's like that in the future.

THE PRESIDENT: Any other questions?

Okay. Thank you. Thank you very much.

CMD 17-M50.1/17-M50.1A

Oral presentation by the

Nuclear Waste Management Organization

THE PRESIDENT: The next item on the agenda is an information item to provide an update on the Long-term Management of Canada's Used Nuclear Fuel.

The Nuclear Waste Management Organization will make a presentation on the implementation of the Adaptive Phased Management program, after which CNSC staff will also present an update on their early role.

We also have participation from Natural Resources Canada, David McCauley. Is he here? Okay, good.

Welcome.

So let me turn the floor to Ms Swami for the presentation. Over to you.

MS SWAMI: Good morning, President Binder and Commissioners. My name is Laurie Swami and I am the President and CEO of the Nuclear Waste Management Organization, that I'll refer to as the NWMO in this presentation.

I'd like to begin by recognizing that we are making this presentation today in Algonquin Traditional Territory.

We are very pleased to have this opportunity to share with you an overview of the important national infrastructure project we are implementing on behalf of Canadians.

We will showcase our work in this presentation in four distinct sections.

Following my introductory comments, Dr. Paul Gierszewski, Director, Safety & Licensing, will provide the background of our program.

Dr. Mahrez Ben Belfadhel, Vice President, Site Selection, will provide an overview of our siting activities.

And finally, Mr. Derek Wilson, our Chief

Engineer and VP Contract Management, will discuss our technical program.

We also have Ms. Lisa Frizzell, VP Stakeholder Relations, and Mr Robert Watts, VP Indigenous Relations, as well as staff on the phone available to assist in answering any of your questions.

As we present the information, I am confident that you will see how much this organization has accomplished through hard work and dedication, both from highly skilled staff and from regular people, people in communities across this province and beyond who see the importance of what we're doing and have stepped forward to learn more, to share their thoughts, and to play a role in the project's success. They have made the Used Fuel Management program in Canada a reality.

To begin, I'd like to give you an overview of the NWMO.

We were formed in 2002 as a requirement of the *Nuclear Fuel Waste Act*. This Act required Canada's nuclear energy corporations to establish a waste management organization.

In response, Ontario Power Generation, New Brunswick Power Corporation, and Hydro-Québec formed the NWMO, a not-for-profit corporation with an independent board of directors. These companies, along with Atomic Energy of Canada Limited, fund the NWMO's operations.

The NWMO's mission is to develop and implement collaboratively with Canadians a management approach for the long-term care of Canada's nuclear fuel waste that is socially acceptable, technically sound, environmentally responsible and economically feasible.

It is an important mandate and an ambitious mission and we couldn't be more proud to be delivering a solution for Canada's used nuclear fuel, one that provides safe and environmentally responsible closure to the nuclear fuel cycle.

I think it's fair to say that one of the most important lessons we've learned so far is that this project is as much about people as it is about process, science and technology. We are honoured and humbled by the relationships we have built with people in municipal, First Nation and Métis communities, all of those individuals who are guiding our work, asking important questions and actively exploring how this project might fit in their area.

The solution that Canada has selected is known as Adaptive Phased Management, or APM. APM provides a clear path forward for the long-term management of used nuclear fuel.

There are some fundamental features about this project. First, it is a national infrastructure project with an investment of $16 billion to $24 billion over the next hundred years or so. It will protect health, safety, and the environment.

The technical end point of this approach is a deep geological repository. The final design will meet all regulatory requirements.

It will require a long-term partnership with communities, including First Nation and Métis people. And importantly, funding is in place to support our work.

The Act established how Canada would develop and implement its used fuel management plan. Key elements are listed on this slide, and throughout this presentation, we will provide more details on how the Act is being met.

Under the Act, the NWMO has broad accountabilities. The most important are listed here.

Right now we have a number of critical activities underway. One, of course, is selecting a site to host a DGR. Practically speaking, we can only achieve this partnership with local communities.

We are also developing technical programs and capabilities to be ready to meet all regulatory requirements, including those for environmental approvals and the CNSC licences.

To help make sure we are well positioned to address all requirements when we become a licensee, we have a special project arrangement with the CNSC staff. This arrangement allows us to keep CNSC staff informed and to seek guidance on regulatory requirements.

We started as an organization of four people in 2002. Since then, we've built a team with deep expertise across a range of functions. We have grown to an organization of 160 people. We have developed expert capabilities in engagement, Indigenous and stakeholder relations, geoscience, engineering, transportation, and safety and licensing.

Our headquarters is in Toronto, but we also have small field offices in seven communities. These offices are open to the public to come and learn about our work. We also have an industrial facility in Oakville where we do testing of prototype equipment.

The *Nuclear Fuel Waste Act* establishes oversight of the NWMO program through our reporting to the Federal Minister of Natural Resources and through the legislated advisory council. Beyond that, we have a number of other important committees and groups listed on this slide that provide advice and guidance on how best to execute our project. They provide us with invaluable insights and help continuously strengthen our program.

Included is a Council of Elders and Youth who advise us about respectful engagement of Indigenous people and how to interweave Indigenous knowledge into our work.

I will now turn the presentation over to Dr. Paul Gierszewski to provide some further background on the NWMO.

DR. GIERSZEWSKI: Good morning. For the record, my name is Paul Gierszewski. I am director of Safety and Licensing at the NWMO.

I would like to give you a brief history of planning for used fuel management in Canada.

From the start of the nuclear program in Canada, the long-term hazard of nuclear fuel waste was recognized. Interim storage facilities were established, with the expectation that a long-term solution would be implemented, probably based in part on geological disposal. There was early research on this approach.

In 1978, the governments of Canada and Ontario established the Canadian Nuclear Fuel Waste

Management Program to specifically advance the technology for the disposal of Canada's nuclear fuel waste. This initiated a significant research and development program in Canada, primarily by Atomic Energy of Canada Limited (or AECL) and Ontario Hydro. This effort was in parallel with similar efforts internationally.

Starting 1989, the concept of geological disposal itself, without any specific site, was reviewed by a federal environmental assessment panel chaired by Dr. Blair Seaborn. In 1998, the panel concluded that:

> "from a technical perspective, the safety of the AECL concept had been on balance adequately demonstrated for a conceptual stage of development, but from a social perspective, it had not."

The panel further made a number of recommendations. In response to this panel report and its recommendations, the federal government passed the *Nuclear Fuel Waste Act* in 2002 and the NWMO was formed.

The *Nuclear Fuel Waste Act* required the NWMO to seek input from Canadians on possible approaches to managing Canada's used nuclear fuel over the long term and to recommend an approach to the Minister of Natural

Resources.

In response, the NWMO led a three-year national consultation from 2002 to 2005. This dialogue involved thousands of citizens, specialists, and Aboriginal peoples in every province and territory in Canada.

During this engagement, Canadians told us that:

- a long-term plan was needed;
- safety and security must be the top priority;
- this generation has a responsibility to take action on the waste we have produced; we should not defer a solution;
- the approach must be consistent with best international practice; and
- the approach must be adaptable to changes in circumstances and technologies.

The Act required that at least three specific methods be included in the study. These were:

- deep geological disposal in the Canadian Shield;
- storage at nuclear reactor sites; and
- centralized storage, either above or below ground, anywhere in Canada.

Other options were also considered as raised by the general public and technical experts. These included reprocessing followed by recycling or reusing nuclear fuel, with an aim to reduce the volume and toxicity of the high-level waste to be managed. However, there were technical, social, and economic issues, and there were -- and are -- no plans to reprocess used fuel in Canada. The NWMO continues to monitor developments in this area.

Over the course of the three-year study, it was clear that each of the approaches had unique strengths and limitations. This led Canadians involved in the study to look for an approach that would better meet the objectives Canadians said were important. Adaptive Phased Management is the approach that emerged from the engagement of citizens over the course of the study.

Adaptive Phased Management or APM was therefore the approach recommended by the NWMO to the government. It is both a technical method and a management system.

The technical end point is the containment and isolation of used nuclear fuel in a deep geological repository, or DGR, in a suitable rock formation.

APM is also a management system. it is an approach that is deliberately flexible and phased. It is responsive to new developments. It is a process that engages people to find an informed and willing host.

After its review, the federal government selected APM as the approach for long-term management of Canada's nuclear fuel. This was a Cabinet-level decision and is documented in the Order in Council as included in our CMD.

Furthermore, the government directed NWMO to implement this approach, starting with developing a siting process. The NWMO consulted with Canadians over two years regarding this process. We proposed a process to the Minister of Natural Resources, and in 2010 the Minister concurred that this was a reasonable approach. We are now implementing this approach.

The *Nuclear Fuel Waste Act* is clear that the responsibility for funding the long-term management of used fuel rests with the nuclear waste owners. The NWMO was also required to propose a funding formula to the Minister of Natural Resources to determine how much the waste owners need to pay to implement the plan. In 2009, the Minister of Natural Resources approved the formula the NWMO proposed. Under this formula, waste owners make annual payments into trust funds. These funds can only be accessed by NWMO once it has received a licence to construct a repository.

The NWMO has prepared cost estimates for the implementation of APM. The estimated lifecycle cost to site, design, build, operate, and close the APM DGR is about $24 billion in as-spent dollars for a capacity of 5.2 million used fuel bundles. The cost estimate can vary, depending on the location, rock type, and the final used fuel capacity requirement.

This cost estimate has been benchmarked against similar estimates of other national waste management programs. The estimate is updated at a minimum every five years to reflect the state of technology and current planning timeframes.

The present value of this lifecycle cost is about $9 billion in 2017 dollars. This cost is presently covered by existing trust funds, existing provincial guarantees, and through funding provided annually by the nuclear waste owners. Funding details are provided in our annual and triennial reports. And our 2014 to 2016 triennial report was published earlier this year.

This slide provides a high-level timeline of NWMO's future plans.

We are currently in the preliminary assessment stage of site selection, as will be described in more detail by the next speaker. We are in a narrowing-down process, evaluating alternative sties in progressively more detail. We anticipate selecting a preferred site around 2023.

Subsequently, we will initiate a detailed program to develop and present the information required to obtain regulatory approvals to initiate site preparation and construction at the site. This work will include detailed characterization of the site, preparation of safety reports, and environmental assessment. It will include the construction of a centre of expertise in the vicinity of the site.

For planning purposes, we anticipate that we will formally indicate our intent to apply for environmental approval and licence after selection of a preferred site, and subsequently we would provide our complete documentation to support the application decision in 2028. And for planning purposes, we have assumed that these applications will be successful and the relevant permits and licences would be granted around 2032.

Assuming that we have licence to proceed in 2032, we would initiate the final detailed design and start site preparation and, in due course, construction at the site. We anticipate that it would take about 10 years to complete these activities and to receive an operating licence such that operations could begin about 2043.

I will now pass the presentation to my colleague, Dr. Mahrez Ben Belfadhel.

DR. BEN BELFADHEL: Bonjour, mon nom est Mahrez Ben Belfadhel. Je suis le vice-président de la sélection de site à la SGDN.

This presentation provides an overview of the site selection process we are implementing with the involvement of people in our siting areas.

I will briefly describe the main steps in the process and the criteria being used to assess the suitability of siting areas, the type of field studies being conducted to advance understanding of the suitability of siting areas, and the community engagement program, focussing on how we are working with municipalities and Indigenous communities to advance the siting process.

The site selection process was developed collaboratively with a cross-section of Canadians. This was to ensure that this important decision -- where to site the repository -- was made in a way that reflects the values, principles, objectives, and concerns of Canadians.

The siting process was developed through two years of public dialogue in 2008 and 2009. The process was initiated in 2010, after it was reviewed and acknowledged by the Minister of Natural Resources as a reasonable approach. And by 2012, 22 communities had expressed interest in learning more about the project and entered the siting process.

APM requires an informed and willing host with a suitable geology. This means that safety is paramount and would not be compromised for any considerations, and the project will not be imposed on any community. It is a community-driven process where communities express interest in entering the siting process and they can also choose to leave at any time during that process.

From an implementation perspective, the siting process involves a step-wise approach, with progressively more detailed technical, socio-economic, and cultural studies conducted as the work advances over time.

Consistent with our approach and commitment to collaboratively work with communities, the siting process is implemented through an inclusive and broad engagement program, and the NWMO is committed to implementing the project with the involvement of municipalities, First Nations, and Métis communities working in partnership to implement it.

The siting process includes three main evaluation steps to assess the suitability of siting areas and ultimately select a preferred site. These include an initial screening that was completed over a few months for all 22 communities that entered the site selection process. And this was to assess whether there were any obvious conditions that would exclude them from the process, using readily available information and five initial criteria.

The initial screening was followed by the preliminary assessment, which is conducted in two phases over multiple years. The first phase was a desktop study conducted for all communities passing the initial screening. The second phase involved a series of field studies for a subset of communities. All communities currently remaining in the process are at the Phase 2 assessment. This is where we are with the site selection process.

The ultimate objective of the preliminary assessment is to select a preferred site for the third and final site evaluation step, which is the detailed site characterization designed to further develop and assemble a robust safety case. This step will take three to five years.

The suitability of sites is being assessed for safety against a set of detailed criteria that reflect international guidance and best practice. These criteria address six safety functions:

- First, safe containment and isolation of used nuclear fuel for a long period of time, which requires favourable geological characteristics.

- Second, resilience to geological processes and climate change, such as earthquakes, glacial cycles, and land movements. We want a site that is stable today and will remain stable in the long term.

- Third, isolation of used nuclear fuel from future human intrusion, mainly through staying away from areas containing exploitable natural resources.

- Fourth, amenable to site characterization and data interpretation activities, meaning that we will be staying away from complex geologies, geologies that are difficult to understand.

- Fifth, safe construction, operation, and closure of the repository, which requires favourable geomechanical characteristics of the rock.

- And finally, safe and secure transportation of used fuel from interim storage facilities to the repository.

Beyond ensuring safety, the NWMO is

committed to implementing the project in a manner that will foster the well-being and quality of life of people in the siting areas. The NWMO also understands that well-being can only be defined by communities themselves as they are best positioned to assess their long-term interests, based on the vision they have for their area. In order to ensure that a holistic approach is taken to exploring the potential effect of the project, the NWMO encourages communities to explore the project through the many different lenses of long-term sustainability that are shown on the slide.

The NWMO is also committed to work together with Aboriginal people to respectfully interweave Indigenous knowledge of the natural environment and traditional lands and cultural and spiritual values that they may wish to share to guide the assessments. This commitment is anchored in our 2016 traditional knowledge policy that was developed with the guidance and support of the Council of Elders and Youth. This is something we are very proud of as an organization.

There are a number of ways we are working with Indigenous communities. Field studies are planned, executed, and interpreted jointly with local Indigenous communities, which provides opportunities for input and exchange of knowledge; ceremonies and offerings are led by communities prior to field work; and NWMO staff and contractors are provided with cultural training.

This map shows the location of the 22 communities that initially expressed interest in learning about the APM project. Initially there were three communities in northern Saskatchewan, 13 communities in northern Ontario, and six communities in southern Ontario.

As a result of the various alternative site evaluations and the narrowing down of the number of communities completed to date, seven siting areas remain in the siting process as marked in blue on the map. They are all in Ontario.

I would like to note that this map only shows the communities which initially expressed interest in learning more about the project in their areas. As the engagement broadens, many First Nations and Métis communities and other municipalities in these areas are now involved in learning as a necessary part of the siting process.

For geographic reference, this map shows the location of the remaining siting areas in relation to the location of the seven used nuclear fuel interim storage facilities across the country, as shown in purple. The map shows that transportation of used nuclear fuel is an important part of APM and the siting process, irrespective of which siting area is selected at the end.

In terms of geological settings, five of the seven remaining siting areas are on crystalline rocks of the Canadian Shield in northern Ontario. The two other siting areas are on sedimentary rock in southern Ontario.

Moving forward with the site evaluations, our planning assumption is to continue with the preliminary assessment and the narrowing-down process. We intend to select a preferred site in 2023 and begin detailed site characterization in '24. At that time, we will also expect that we would formally indicate our intent to apply for a CNSC site preparation and construction licence.

This slide shows the three criteria that will be used to select a preferred site. First and foremost is safety. We would need confidence that a robust safety case can be developed at the preferred location. Second is the confidence that a safe, secure, and socially acceptable transportation plan can be developed to transport used nuclear fuel. Third is the confidence that a strong and sustainable partnership can be developed in the siting areas.

With the next few slides, I would like to provide an overview of the technical site evaluation process to assess the suitability of siting areas, and I will focus on field studies.

The technical site evaluation process includes a series of multidisciplinary technical studies to assess whether it is possible to find sites that have the potential to meet NWMO safety criteria. The key disciplines include geoscience, environment, engineering, and safety assessment.

Given the importance of the geology at this stage of the assessment, the NWMO established an international geoscientific review group to provide advice and review of the approaches, methods, criteria that are used to conduct the geoscientific studies.

For those sites on the crystalline rocks of the Canadian Shield, initial field studies include non-intrusive high-resolution airborne surveys followed by geological and environmental mapping.

These initial field studies were designed to identify potential repository sites for more intensive field studies, including deep borehole drilling and testing.

In the case of those sites on the sedimentary rocks of southern Ontario, the first step of field work will be deep borehole drilling at potential repository sites. Due to the nature of sedimentary rocks and the amount of existing geological information, airborne surveys and geological mapping are not needed at this stage of the assessment.

Airborne geophysical surveys included high-resolution magnetic and gravity surveys over the siting areas. These new airborne surveys greatly advanced our understanding of the geology, including the interpretation of faults and fractures, which allowed us to improve the quality and resolution of available geological maps for the areas of interest.

For example, the image that you see on the slide illustrates the significant difference in resolution between the historic magnetic surveys in the background labelled as 'before' and the new surveys we acquired over one of our siting areas labelled as 'after'.

Geological mapping allowed us to learn more about the rock types and structures, ground-truth the faults and fractures that were interpreted from airborne surveys and collect surficial information such as topography and extent of soil cover.

On the environment side, field studies included ecological land classification and identifying significant wildlife habitats.

Field mapping was done in close collaboration with local Indigenous communities. The technical teams and the local knowledge experts walked the land together which provided opportunities for sharing observations and learning from each other.

Deep borehole drilling is a significant milestone from both the technical and engagement perspectives. On the technical side, it is an important activity to advance understanding of the geology at depth. On the engagement side, it is a significant step forward as boreholes will be drilled on potential safe and socially acceptable repository sites.

For example, the location of our first borehole in one of the communities was selected based on geological stability, but also after extensive engagement and consultation with people in the area, including First Nation and Métis people.

Each borehole will be drilled to a depth of about 1,000 metres and it will be subject to a comprehensive testing program to advance understanding of the geological, hydrogeological and geochemical conditions of the site.

This slide shows the status of initial

field studies for the communities remaining in the process.

In the Ignace/Wabigoon area in northern Ontario, initial field studies were completed and borehole drilling was initiated. We actually started drilling our first borehole this week.

In the other communities in northern Ontario, all initial studies were recently completed. We are in the process of identifying potential repository sites. In southern Ontario, the next step is to consider borehole drilling.

An important aspect of our process is the involvement of people from both municipal and Indigenous communities in the planning and execution of field studies. Community involvement included field visits, planning meetings and workshops with community members, local knowledge holders, Elders and youth and others. Involvement also includes discussions and exchanges around findings from technical field studies conducted by the NWMO, and also findings from Indigenous knowledge and land use studies conducted by the communities themselves.

All findings to date have been shared with communities, documented and published on our website. We have published over a hundred study reports in addition to a wide range of information materials, some translated into

French and Aboriginal languages.

This leads me to the next topic which is community engagement.

The NWMO has a broad and inclusive engagement program with municipalities and Indigenous communities.

The main goals of the engagement programs are to be present in the communities and to build awareness and understanding of the project by reaching out to communities and people in the area, to work in collaboration with people in the area to identify potential repository sites that are socially acceptable and respectful of social, cultural and spiritual values.

Another goal is to explore the potential to foster the well-being in the area through the implementation of the project and, finally, to explore with communities the potential to come together in a supportive partnership to implement the project in the area.

Engagement with municipalities is achieved through a wide range of activities that are organized with the community. These include monthly public meetings of CLCs in each municipality, open houses and open office events to share work plans, findings and get input from community members, and also participation in local and regional community events.

An important component of the engagement program is to encourage and support learning opportunities, such as visits to interim used fuel storage facilities at nuclear power stations and participation in conferences, including opportunities to meet with members from other communities elsewhere in the world that are considering hosting used fuel repositories.

In 2017 alone we conducted 11 open houses, 84 engagement events on transportation and over 80 youth initiatives. We organized 16 community tours of used fuel dry storage facilities and participated in hundreds of community events and presentations.

The community liaison committees, or CLCs, play an important role and critical role in the design and delivery of the engagement program. CLC members are selected by the municipalities, they are independent of the NWMO. CLC members are actively involved in representing the needs and interests of communities and providing guidance to NWMO in this community-driven process. They also facilitate learning in their communities; for example, through seeking external expert speakers for the community.

Our engagement with Indigenous communities is built on NWMO's Aboriginal policy and continued advice from the council of Elders and youth. It is premised on respect for Aboriginal treaty rights and the recognition of the positive contributions that First Nations and Métis people can and will make.

NWMO engages Indigenous people at many levels, from local communities and treaty organizations to national organizations. Engagement activities include capacity-building activities and a wide range of information sharing and learning and gathering activities.

A key area of engagement is the establishment of funding of multi-year programs designed to incorporate local Indigenous knowledge and land use as an input to assessment activities in the area.

Guided by people in the area, and in respect of spiritual and cultural practices, field activities are often preceded by ceremonies.

This completes my overview of the siting process.

In closing, I would like to acknowledge the strong leadership being shown by the communities involved in the process to pave the way for advancing Canada's plan for the long-term management of used nuclear fuel.

As we move forward with the siting

process, we continue to learn from our communities and adapt.

I will now pass the presentation to my colleague, Derek Wilson, for the final part of today's briefing.

MR. WILSON: Good morning.

For the record, my name is Derek Wilson and I'm the Chief Engineer and Vice-President of Contract Management at the NWMO.

The NWMO has made significant progress in the development of conceptual designs and technical solutions for the implementation of this first-of-a-kind project in Canada. We have developed a highly qualified team of professionals, as well as strong industry and academic partners to deliver our technical program.

The technical end-point for the project is the used fuel being deposited in a deep geological repository.

Our paramount objective of safety, and our approach to safety assessments will be discussed.

The NWMO's design and demonstration activities, as well as a brief discussion on the technical developments related to transportation will be provided.

Our on-going research and development

activities, including our collaboration with academic and international partners will be the end.

This slide summarizes the deep geological repository concept and its key safety features.

First, the deep location means that the used fuel is isolated from events that will happen at surface. This includes both human and natural events.

Second, there are multiple barriers to contain the radioactivity. These include the durable waste form, the robust corrosion-resistant container, the bentonite clay seal around the containers, and a thick barrier of low-permeability rock.

The rock also provides a stable and predictable environment to support the engineered barriers. This is ensured through the selection of a rock formation that is ancient, has low seismicity, has old groundwaters at depth and shows minimal glacial disturbance at the repository level.

There is international consensus that long-term isolation of used fuel through deep geologic disposal is a safe and responsible approach. It is the approach adopted by all countries with a defined end-point for their used fuel wastes, whether those are direct disposal of used fuel or the high-level wastes from reprocessing of used fuel.

The status of several countries is listed in this slide. They all plan for geological repositories.

Finland, Sweden and France have sites identified. Finland is the most advanced, having received their construction licence in 2015.

The NWMO has prepared conceptual designs of the repository facilities, both surface and underground, building on the knowledge gained through international experience and the NWMO's technical program.

The latest conceptual design's update was published in 2016. Since then, further design optimizations of the underground layout have been completed considering the need to be adaptive to a fractured rock environment as we would expect in a crystalline rock formation.

A potential surface facility design is shown here. The surface facilities would include the used fuel packaging plant, the shaft headframes and hoists, the sealing materials fabrication plant, and support services ranging from ventilation, to water management and radiation protection.

The underground repository, which is not shown on this slide, would consist of the access shafts from the surface, an underground services area near those shafts, which includes an underground demonstration facility, and the emplacement rooms for the used fuel containers.

As the NWMO progresses with more detailed site assessments and gains information on the subsurface conditions at the potential repository locations, site-specific conceptual and preliminary designs will be prepared.

Safety is paramount in all aspects of the NWMO operation and planning, including our current siting stage.

But two unique aspects of the APM from a CNSC licensing perspective are the safe operations of the facility prior to closure, and the safety of the facility after closure. The next few slides make some more general points on these topics.

During the operations or 'preclosure' phase, the DGR will be a licensed nuclear facility. Used fuel will be transported to the site in certified transportation packages. At the site, the used fuel will be removed from these packages and transferred into final repository container. Once each container is filled, it is closed and sealed and encased in a bentonite clay over-pack. This package is moved underground and put into an emplacement room.

Some of the key safety features of this include:

First, the fuel is basically transferred between robust containers. CANDU fuel bundles are a durable solid material, and there is no need for any processing of the fuel at the DGR site.

Second, by the time these fuel bundles are transferred to the DGR, they will not require active water cooling. Passive air cooling is sufficient.

And third, all the handling will be in shielded rooms or hot cells using remote equipment and the ventilation for these would be monitored and filtered.

The really unique aspect of a DGR is its long-term or 'postclosure' safety approach.

The repository would first have an extended monitoring period following the operations phase, with the shafts and underground access tunnels open. Based on some 40 years of operating experience, and after several decades of extended monitoring, there would be a decision by future society that they had sufficient information and confidence to close the repository. Tunnels and access shafts would be sealed and surface facilities removed.

The repository site would then be placed under institutional control. We expect that the repository site would continue to be monitored.

After closure, the repository is intended to remain passively safe, while the radioactivity naturally decays. This post-closure safety is provided through several key aspects as noted here and previously mentioned.

Ultimately, the NWMO will present a safety case for its proposed repository and site to support its licence application.

A safety case is defined as an integrated collection of arguments and evidence to demonstrate safety and meet all the regulatory requirements for a given facility.

The approach that we will take will be guided by CNSC criteria and regulatory documents, notably CNSC G-320. It will be supported by safety assessments.

Typically we assume that people are living on-site in future after some period, and we examine the impacts on these people from a variety of future scenarios. These scenarios range from likely to unlikely. These include the impacts of future glaciation of the site.

In addition to quantitative safety analyses, the safety case will also include arguments and evidence based on measured features of the site, such as the age of the deep groundwaters. It will also include information drawn from natural analogs, such as the existence of natural copper deposits that are millions of years old.

This approach is consistent with international practice.

We do not presently have a site. However, we have applied this methodology to conceptual designs in different geological settings.

These safety case studies provide us with an opportunity to improve our methodology, to discuss approaches and expectations with the regulator, and to improve our understanding of the key factors for safety to help guide siting and design.

As mentioned earlier, the repository concept is a combination of natural geologic barrier in conjunction with multiple engineered barriers within the system. The waste form itself is comprised of high-density, low-solubility ceramic fuel pellets encased in strong, corrosion-resistant Zircaloy sheaths.

Most of the radionuclides are trapped where they are formed, in the middle of the uranium oxide pellet.

Over the past five years, the NWMO has designed a used fuel container, optimized specifically for used CANDU fuel. The container uses a steel shell for strength and a copper coating to provide corrosion protection. The NWMO has optimized copper coating technologies to apply the appropriate copper thickness to provide long-term protection of the container.

The last of the engineered barriers is the bentonite clay surrounding the container. This bentonite clay provides a self-sealing water barrier around the container that can also absorb many of the radionuclides.

The NWMO engineered barrier system allows for an efficient arrangement of the used fuel in the repository. In this design, the used fuel is placed horizontally in the emplacement room inside prefabricated blocks. In doing this, the emplacement is simplified and the overall excavation requirements for the repository are minimized.

The design of the engineered barriers, including the use of prefabricated bentonite over-packs, also allows for the packaging of the used fuel container on surface in a controlled environment. The used fuel container and bentonite over-pack, or buffer box, is then shielded and transported into the emplacement room for automated placement.

The NWMO engineered barrier design and emplacement concept incorporates several innovations in design, material application and fabrication processes.

A large focus of our technical design work is executing our engineered system's proof-testing program. The NWMO has developed detailed designs of many of our engineered system components. We have also developed, with industry partners, the technologies required for the fabrication and inspection of these engineered barrier components. These include the hybrid laser-arc welding technology for sealing the used fuel containers, the electrodeposition and cold spray copper coating processes, the technology to make large dense bentonite blocks, and the bentonite back-fill placement equipment.

We are fabricating prototypes in order to ensure that we understand their performance and how to handle the components, the fabrication process tolerances, and the techniques for inspection and verification.

We have pressure tested our prototype containers for performance against our design requirements, and beyond.

The NWMO has established a test facility where we undertake prototype testing and have designed and commissioned equipment required to support the initiation of used fuel container serial production trials. The facility also supports our on-going engagement activities with interested municipal and Indigenous communities and other stakeholders.

We are presently constructing a full-scale, partial-length emplacement room at the facility. We will fabricate a series of containers and buffer boxes to test the fabrication and repeatability of the process, and then demonstrate emplacement in this full-scale mock-up.

An important aspect of APM is the ability to safely move the used fuel from its existing interim storage facilities, at or near the reactor sites, to the repository site.

We are considering road and/or rail as preferred modes of transport in Canada.

The transportation would be based on a robust package design. This design, and the certification of it, are based on international standards and testing.

Transportation of radioactive materials in general, and used fuel in particular, is highly regulated and has an excellent safety record.

At this point, I would like to note that in our CMD 17-M50.1, in Section 5.2 on page 23, the first sentence of the second paragraph should read:

> "The NWMO has a mobile exhibit featuring an actual container that is certified as a transport package for used nuclear fuel."

We are often asked about the safety of our used fuel transport packages. As part of the certification of such a package, it must pass a series of tests as shown on this slide.

These tests are comprised of a drop test, which is shown in the picture on the left of this slide, a penetration test, which is not shown, a thermal test as illustrated in the picture on the right side of this slide, and a water immersion test.

While the NWMO moves into technical implementation, we maintain broad-based technical research activities in the areas of geoscience, safety and corrosion.

The NWMO partners with Canadian and international universities, as well as industry partners in the execution of our work.

In 2017, the NWMO sponsored studies at 17 universities and we have also worked closely with the

Federal Natural Sciences and Engineering Research Council in supporting and building on research excellence at Canadian universities.

In 2017, we supported seven collaborative research and development grants and two industrial research chairs.

The results of the work done by NWMO staff and by our industry and research partners is published as technical reports, conference papers and journal articles in order to ensure it is widely considered and reviewed.

The NWMO is also participating in joint projects at international underground research laboratories, with recent projects in Sweden and Switzerland.

The NWMO also collaborates with other national and international agencies.

For example, our development of copper coating technologies has drawn interest from international partners, with four countries providing participant funding to NWMO-led development programs.

We are presently active in technical working groups within the Nuclear Energy Agency of the OECD, and with the IAEA. We also work closely with other waste management groups, including EDRAM, and other international organizations.

MS SWAMI: Laurie Swami, for the record.

I would like to mention that one of the many things that gives me confidence that the NWMO will succeed in its mandate, it is the culture of dedication, passion and recognition of just how important our work is to Canadians. I hope you’ve seen a glimmer of that today in the passion and dedication from my staff.

You've also heard about the substantive, highly skilled work our technical experts have progressed over the past 15 years.

Canada can stand proud that we are advancing an internationally recognized, technically sound solution for our used nuclear fuel. We are taking accountability now and for future generations.

We will build a deep geological repository to isolate the waste and it will protect people and the environment. Further, we have the funding. The waste owners have set aside the funds for the future.

And finally, the true strength of the Canadian plan is that we are implementing it collaboratively with people; first through the initial dialogue that took place across this country to define what we should do and how we should do it, and now through working together to build partnerships with municipalities and indigenous communities.

The fact is, people have stepped forward to guide this project. They’ve contributed their time and their knowledge. They’ve asked questions, important ones that have made us think and rethink and that have made the project better. They’ve participated and learned.
And we’ve learned, too. We’re still learning. And it is that constant process of learning together that will see this project through.

Thank you, and we are happy to answer any questions you may have.

THE PRESIDENT: Thank you.

Before I get into the question session, we would like to turn the floor to CNSC Staff for their presentation as outlined in CMD 17-M50.

I understand that Ms Tadros will make the presentation.

Over to you.

CMD 17-M50

Oral presentation by CNSC Staff

MS TADROS: Thank you, and good morning.

Mr. President, Members of the Commission, for the record, my name is Haidy Tadros. I am the Director General of the Directorate of Nuclear Cycle and Facilities Regulation.

With me today, on my left, is Ms Julie Mecke, Senior Project Officer of the Wastes and Decommissioning Division. On her left, Dr. Julie Brown, Geoscience Assessment Officer of the Environmental Risk Assessment Division.

And behind us in the second row, Ms Karine Glenn, Director of the Wastes and Decommissioning Division, and Ms Kim Noble, Team Leader, Aboriginal Consultation and Participant Funding.

We are also joined by other CNSC specialists who are familiar with this file.

The objective of CNSC Staff's presentation today is to provide Commission Members with an update on CNSC Staff's early involvement in the initiative for a Deep Geological Repository for Canada's used nuclear fuel. Specifically, we will highlight Staff's pre-licensing activities, Staff's international and research activities as well as the outreach activities, including indigenous engagement.

I'll now turn the presentation over to Ms Julie Mecke to walk through the details.

MS MECKE: Thank you.

Good morning. My name is Julie Mecke.

This slide shows the previous times that CNSC Staff have presented to the Commission regarding CNSC's early involvement in the NWMO's APM approach.

CNSC updated the Commission in December of 2016 as part of the 2015 Regulatory Oversight Report for Waste Management, Storage and Processing in Canada, which is filed as CMD 16-M50.

The following is background information and has already been presented in detail by NWMO staff, so I will not repeat the slide again.

This slide provides the stages of CNSC licensing for Class I nuclear facility and will put into context the stage of NWMO's APM approach.

As shown on the slide, the APM approach is currently at phase zero, pre-licensing phase, where no licence application has been submitted to the CNSC. As discussed previously and according to NWMO's proposed schedule, the earliest an application would be submitted is in 2028.

Although a licence application has not been submitted, early engagement of the CNSC can provide valuable input at this point in the process to the future applicant, to the public and indigenous groups.

This approach is in line with international consensus that the active, independent involvement of a knowledgeable and competent regulator involved early in the process is important.

The objectives of the pre-licensing involvement of the CNSC are to build independent, in-house knowledge to be prepared for review of a future licence application. This includes conducting our own independent research.

Initiate a dialogue with the future applicant, the NWMO.

Provide information on our role as the regulator to interested communities, First Nations and Métis communities.

Provide guidance on regulatory requirements. Focus on key safety aspects.

Maximize national and international collaboration and, finally, review key research publications from the future applicant, the NWMO.

To formalize the early involvement with the NWMO prior to submission of a licence, there is a service arrangement between the NWMO and CNSC.

This is currently the second service

arrangement with the NWMO and is in effect until March 31st, 2019.

Under the service arrangement, CNSC Staff provide regulatory guidance prior to submission of a licence. For example, CNSC Staff has conducted pre-licensing reviews of conceptual designs. In addition, the Service Agreement is posted on the CNSC web site.

As part of the service arrangement, CNSC Staff conduct outreach activities to provide information on CNSC's role as the independent nuclear regulator.

At these outreach activities, staff share information on the science and research being used in regulatory decision-making.

The following slides illustrate the in-house expertise that the CNSC currently have who are contributing to CNSC's work being conducted under the Service Arrangement.

CNSC Staff have professional and technical staff in various disciplines, such as project management, licensing, environmental protection, geoscience, corrosion, radiation protection, management system, packaging and transport, emergency preparedness, security Safeguards and, finally, communication and media relations.

Team members are involved in outreach

activities, technical pre-licensing reviews, conducting and coordinating research and contributing to the development of international guidance documents.

As the APM approach moves forward, the roles of these specialist will expand to ensure CNSC Staff is ready to review a future application.

Now I will discuss CNSC's international and research activities which are being done in order to prepare for a future review of a licence application.

First, CNSC's independent research on deep geological repositories started in 1978.
CNSC's independent DGR research is one of the key outputs into CNSC research strategy on waste management.

A comprehensive list of CNSC research papers is available on our web site.
In addition, there is a detailed interactive timeline outlining the decades of research on the science behind the disposal of radioactive waste.

Examples include mathematical modeling on the impacts of glaciation on sedimentary rock, and second, experimental and theoretical studies on the long-term performance of bentonite seals. And this is done in collaboration with the French technical support organization, the IRSN.

Second, CNSC Staff participate in international projects to maintain knowledge and competence by keeping up to date with international state-of-the-art science, practices and regulations.

These collaborations are one way to share knowledge and to pool resources on a global scale.

For example, Staff are involved in the International Atomic Energy Agency's groups, and also and the European Union's Sustainable network of Independent Technical expertise, or SITEX, in relation to radioactive waste disposal. This is a group of regulators and technical support organizations, and CNSC was invited to join by the IRSN.

Finally, Staff continue to share and exchange information with other regulators.
An example of this is CNSC have established a Deep Geological Regulator's Forum, or DGRRF, which includes regulators from Finland, France, Sweden, Switzerland and the United States. The group is to learn more about their DGR licensing process.

CNSC Staff have hosted the first workshop, which occurred in Ottawa in March 2016. And recently, Staff participated in the second workshop which was hosted by the Swedish nuclear regulator in Gimo, Sweden in

September of 2017.

Through these meetings, Staff have received confirmation that, for the most part, our early activities are in line with what other regulators did or are doing in the pre-licensing phase. Perspectives on how those regulators would improve the process have been beneficial to hear, and inform Staff in our daily work in this pre-licensing stage, but also for future stages.

There are also areas where CNSC has been able to share our strengths such as our broad approach to conducting outreach activities, our comprehensive web site, specifically outreach to youth, public hearing process and our participant funding program and our approach to indigenous engagement.

Another way CNSC Staff are seeking advice is through CNSC's Independent Advisory Group, or the IAG.

The IAG was founded in 2015 to provide objective, independent advice to Staff on the geoscience aspects of the DGR initiative for the long-term management of Canada's used nuclear fuel. The IAG consists of six Canadian geoscientists, experts from five Canadian universities, and one consultant.

IAG members are all independent researchers at Canadian universities and internationally-recognized experts in their respective disciplines with long histories of scientific excellence.

Examples of areas include hydrogeology, groundwater flow and contaminant transport, isotope geochemistry, tectonics and the geology of the Canadian shield, engineering material and structural materials, and also international experience in developing relevant safety guides and standards.

Activities of the IAG include reviewing the NWMO's documents related to their research and development program, including NWMO technical reports, attend NWMO's annual geoscience seminar and, finally, the review of CNSC's independent research program on DGRs.

CNSC Staff continue to conduct outreach activities. At this early stage before an application has been submitted, our outreach activities serve to explain our regulatory role as the independent nuclear regulator and to build relationships.

At the request of community representatives, CNSC Staff conduct outreach activities.

As part of the planning, CNSC Staff discuss with the community representatives on the format of outreach activity and if there are specific topics of interest; for example radiation protection or indigenous engagement.

Regarding the format, CNSC can host a day-long meeting in Ottawa, present in the community, and these meetings open to the public.

Also, CNSC can host a CNSC open house in the community. And open houses are informal gatherings with posters set up to provide information, and members of the public, First Nations and Métis communities can ask questions to CNSC Staff in a one-on-one setting.

CNSC Staff have also met with First Nation and Métis communities, and I'll discuss that more in the next slide.

Furthermore, Staff have also received outreach requests from neighbouring communities.

Since May of 2010, Staff have conducted 54 meetings with communities and 16 CNSC open houses. CNSC Staff continue to build and expand these relationships.

Regarding indigenous groups, CNSC Staff are working on developing a structured, transparent, formalized approach to ongoing engagement with indigenous communities.

Building relationships with First Nation and Métis communities who may have an interest in learning more about the initiative for a DGR for Canada's used nuclear fuel is a priority to the CNSC. As building strong relationships based on trust and mutual respect takes time, CNSC Staff has begun to do this early in the pre-licensing phase.

To date, if an outreach event is planned in a given area, the CNSC has reached out directly to nearby First Nations and Métis communities to let those communities know that an independent nuclear regulator exists and is available to meet and to provide communities with information about the CNSC and its regulatory role.

In our meetings, Staff also provide CNSC published REGDOC-3.2.2, Aboriginal Engagement, which sets out requirements and guidance for licence applicants whose proposed projects may raise the Crown's duty to consult to help understand the role of the licence applicant.

The following is a list of outreach activities that CNSC Staff conducted from April 1st, 2016 to October 30th of 2017.

Highlights include CNSC Open House in Hornepayne, Ontario, where a local school attended. CNSC Staff provided information on radiation protection and also explained how we protect the environment.

CNSC Staff were invited to present at the Wabigoon Lake Ojibway First Nation Gathering and Learning workshop to explain our role and our approach to Aboriginal engagement and consultation.

Staff were also invited to present at the Métis Nation of Ontario pre-annual General Assembly meeting.

And finally, not specifically included in this slide, but in connection with CNSC Open Houses, Staff have also reached out to local schools in Elliot Lake and Blind River to provide information on the fundamentals of radiation protection.

The following are CNSC staff key messages when we are conducting outreach.

First, CNSC is the independent regulator. No licence application, and it's early in the process.

CNSC does not promote the APM project or nuclear energy. And finally, CNSC is not responsible for national energy policy.

The following are examples of common topics raised during outreach activities.

First, explaining the role of the CNSC, the CNSC licensing process and how the public, First Nation and Métis communities can participate. Questions on how CNSC conducts safety checks by inspections and enforcement, and also questions on the independence of the Commission.

Second, the importance of clarifying roles; for example, explaining that the CNSC is the independent regulator and that we are not the NWMO and that we are not industry.

In order for members of the public to have an understanding of radiation, CNSC Staff explain what radiation is and how workers are protected.

Members of the public will ask about repository safety, for example, what if something goes wrong and how will safety be assured.

They will also ask about benchmarking, specifically what are other countries doing and how does Canada align.

Finally, there are questions on the transportation of used nuclear fuel, emergency preparedness and security.

The following are examples of what we have learned from talking to communities for the past seven years.

Overall, feedback has been positive. People are happy to hear that there is an independent nuclear regulator who is looking after safety and that CNSC is here for the entire lifecycle of a DGR facility. They like to know that if a licence is issued there are safety checks and rules that need to be followed.

The benefit of being involved early is that CNSC can clarify our role as Canada's independent nuclear regulator and that we are not the NWMO.

Staff have also found it helpful to explain the science and how CNSC collaborate on international research that is being performed in order to make sound regulatory decisions.

The importance of starting early to establish relationships with people in communities, First Nation and Métis communities, as it takes time to build relationships.

CNSC Staff have received feedback that the public and indigenous communities that they appreciated meeting CNSC subject matter experts such as a geologist, a CNSC inspector, radiation protection specialist. For example, a CNSC inspector can explain firsthand how they conduct safety checks and enforcement tools. They also like to hear that CNSC inspectors can conduct unannounced inspections.

Finally, CNSC Staff, we get to learn about the communities.

To assist the public, CNSC Staff have included information on talking to communities on our external web site. The site will be updated as the APM approach proceeds.

There is information on CNSC's regulatory role and early involvement in the APM approach, community meetings with the CNSC, regulating Canada's Geological Repositories, including a fact sheet, CNSC research on Geological Repositories, and CNSC interactive timeline outlining the decades of research on the science behind the disposal of radioactive waste.

Thank you. Now I'll turn it over to Ms Tadros.

MS TADROS: Thank you.

So on this slide, we've identified a few next steps for CNSC Staff with regards to this project.

We plan to update the Commission in 2020, as this will align with the next anticipated triennial report on activities by the NWMO.

We plan to continue the independent research programs, international collaboration and regulatory exchange and site visits. This includes sharing regulatory operational experience, or OPEX.

We also continue on international benchmarking. For example, CNSC early involvement in the APM approach will be internationally peer reviewed. This will occur at the next review meeting of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management in May of 2018.

We will continue outreach and engagement activities in the communities impacted. And we will also continue to provide regulatory guidance such as conducting pre-licensing reviews when requested by the NWMO.

To conclude, early involvement of the regulator in DGR initiatives is international best practice. Communities have requested CNSC Staff help in understanding how the CNSC regulates the nuclear sector and how the public can get involved if an application were submitted in the future.

CNSC Staff are available to meet with communities, First Nations and Métis communities and will continue to build and expand these relationships in a formalized, structured approach.

CNSC Staff participation in international projects allows best use of resources and benchmarking by keeping up to date with state-of-the-art science, practices and regulations.

This concludes our presentation. We are available for any questions the Commissioners may have.

THE PRESIDENT: Okay. Thank you.

I think we need a 10, 15-minute break. Make it 10:50.

Thank you.

--- Upon recessing at 10:35 a.m. /
Suspension à 10 h 35

--- Upon resuming at 10:52 a.m. /
Reprise à 10 h 52

THE PRESIDENT: Okay, we're back, and we'll jump right into the question period. Starting with Dr. Soliman.

MEMBER SOLIMAN: Thank you very much. The presentation is very good really, and that covers all the issues. I have some questions. The first one is, among many assessments which have been done, the cultural assessment is one of them. I would like to know how you assess the culture, and whether it is questions answered or observations, or something else, as well as how you apply the culture assessment into the site selection.

DR. BEN BELFADHEL: Ben Belfadhel, for the record. So the culture is assessed in the context of the community well-being assessment. Meaning an assessment to determine how the project is going to enhance the well-being of the communities in the future.

So this assessment of community well-being is really driven by the communities themselves, because they are the ones who know what they want from themselves. We can't really tell the communities, this is how you should evolve from a cultural perspective or a socioeconomic perspective.

So when we initiated the site selection process and communities started coming in the assessments, in the site process the first thing we did is we provided them support. Most communities they did what we call the visioning exercise. So that visioning exercise included all the lenses that I presented on the slide. They looked at their future through those lenses, and they did that without considering the project.

So they did it really how do we see ourselves in the future from a social, cultural and economic perspective? So that's on the municipal side.

On the Aboriginal side, I will ask my colleague, Bob Watts, to expand a little bit more on that.

MR. WATTS: For the record, my name is Bob Watts. Thank you, Ben, and thank you for the question.

We've been working with Aboriginal communities providing resources to First Nation and Métis communities in the siting areas to provide resources so that they can do traditional land use studies to be able to understand the potential impact of our project on land use, both from the past, present and into the future.

Combining that with ceremony, with assessment tools that the communities have developed themselves, even in the slide that we presented here that looked at the many aspects of well-being.

We had started off with some of our own sense of what well-being might look like a number of years ago, and developed assessment tools around that. That's changed by input from community, both Indigenous and non-Indigenous communities, and will continue to evolve.

In fact, in about three weeks' time we're meeting a number of experts to go over again what well-being might look like from both an Indigenous and non-Indigenous point of view. So communities have the opportunity to assess a project in light of what's important to them from a cultural and a social point of view.

MEMBER SOLIMAN: Okay. Did you find any difference with respect to Indigenous communities? Did you find any differences in culture between them, and how this is reflected on the site? Because you are choosing the site based on the culture.

So did you find any differences between different community cultures, or did you find the culture is different from one community to another?

MR. WATTS: For the record, Bob Watts. I think, in terms of the depth of studies that we've done at this point, it may be too difficult to be able to say what differences might happen from one community to another.

But we do know that there are differences. We do know in terms of relationship with the land and history on the land that there's differences between the Indigenous and non-Indigenous community, particularly over time and the types of uses that those communities may have had of the land.

But we also know that in some cases if you take Indigenous people and you take trappers who may be Indigenous and non-Indigenous, there's a lot that they're going to have in common in terms of their view of the land and relationship with the land.

So it's not easy at this point to say, you know, this is the way one group thinks and the way another group thinks. For a lot of the studies we've done to date, it's been more about practices on the land and how a particular project might impact on both traditional and future and present land use.

MEMBER SOLIMAN: Thank you.

DR. BEN BELFADHEL: Ben Belfadhel, for the record. Just to set the context for the assessment, Dr. Soliman. You mentioned how we select a site and how culture is included in that site selection.

So in order for us to select a site really need three -- we look at three criteria. One, as I mentioned in my presentation, is safety, safety has to be there. Then the second most important thing is to assess the potential for partnership with the municipalities, with First Nations, and Métis people.

That partnership is anchored in two main things. One of them is a demonstration that the project is going to enhance the well-being of the communities, and culture is one component of that well-being. So we have to ensure that the project is not going to be detrimental for cultural aspirations of the communities, that it is going to enhance that. The other anchor is the demonstration of willingness of course. People have to be willing to host the project.

THE PRESIDENT: Okay. I understand the soft words that go with this. But what is a willing community? Have you defined...? Is it a municipal council, is it a region, is it the municipality with all the communities? I can see a situation where a municipality agrees and a neighbouring municipality does not.

So have you now defined how you're going to assess a willing community, and is it by a poll, is it by a vote, is it by you coming and telling us they are willing community? How is it going to be decided?

DR. BEN BELFADHEL: Ben Belfadhel, for the record. So what we say in our site selection process is that before we select a site we would like to see a compelling demonstration of willingness in the siting area.

Because we are very early in the process, we haven't defined what that compelling demonstration of willingness is. But when we have conversations with people we tell them compelling demonstration of willingness means the majority of people in the siting areas, people who are affected by the project have to be on board.

The reason we haven't defined it, like saying you have to do a poll or a survey or all the tools that are used, it's because there is not cookie cutter approach, because it depends on what siting areas we are.

If you look at the seven siting areas that we have, they have different social fabrics, different geographies, so we have non-Aboriginal people, Aboriginal people, First Nations, Métis people. So we want to leave it up to the communities themselves to define how they would like to express that compelling demonstration of willingness.

But having said that, we have to do our homework as well. We have to be satisfied that people who are affected by the project are willing to host it.

THE PRESIDENT: That's why I'm asking the question. I just don't know how you're going to do it, and it's kind of going to be a difficult situation.

You need this demonstration of willing community that'll also be good for 10 years, until you get a licence application, et cetera, et cetera. You know how things change. So I'm just trying to figure out whether you thought about what you're going to do about this.

DR. BEN BELFADHEL: So the good thing with this is we have time. We have time, we still have -- before we select the community, we have at least five years. Where we are today with the communities, we are at the learning stage. So we haven't -- all the communities that we are working with, none of them has committed to the project, so they are learning about the process, we are learning about the communities from a geology point of view and environment.

So we are building relationships. When we get to the time where we need to select a community, we will then use the tools that are appropriate at the time to -- in order to have the compelling demonstration of willingness.

But I fully agree with your point that even if let's say in five days we select a community that is willing, it doesn't stop there, because we will still have many years of detailed site characterization and licensing. So our engagement will continue and we will work very closely with the communities because our objective of doing this together with the communities is forever. Even after we get a licence, engagement is still alive, it will continue.

THE PRESIDENT: Thank you.

Dr. McEwan?

MEMBER McEWAN: Thank you, Mr. President.

So sort of following this train of thought. It seems to me that whatever community is selected, there is going to be a massive dislocation of their life: how many people will be involved in the construction phase; how many people will be involved in the long-term operation phase; and, how does an organization like NWMO or the province or the region plan for that huge increase over the base?

MR. WILSON: Derek Wilson, for the record. You're correct. There’s going to be, in the communities that we’re looking at, there’ll be a degree of which the impact will be felt depending on the size of the population and the demographics that are there.

For the construction period -- and again, when we look at it, and as Ben mentioned, we have some time between now and the time that there’s going to be construction. But one of the key considerations is the resources and the capacity within the communities now, and looking forward to be able to support it. Those are considerations that we have to take into account as well when we’re looking at a site selection decision.

You know, the construction staffing could be in the range of two and a half to 3,000 people, you know, so whether it’s a combination of increasing infrastructure within the communities, siting a camp for that phase, and then we get into the operations phase, you know, in that five to 700 employee type range.

So, you know, there’s time now to build and we’re working with the communities now. We’re looking at partnership opportunities, we’re looking at capacity building, and looking to see their own vision of the project and how we would be able to accommodate the infrastructure. But again, we have time and we're starting those conversations in the community now.

MEMBER McEWAN: Just a question. How many Aboriginal employees does NWMO have?

DR. BEN BELFADHEL: Mahrez Ben Belfadhel, for the record. I believe we have around 15 people.

THE PRESIDENT: Dr. Demeter?

MEMBER DEMETER: Thank you for the presentation. As a new Commissioner, it's the first time I've had the opportunity to be briefed on this topic in this detail, so I appreciate that.

My first question is fairly technical. It seems that the funding model is largely based on nuclear power plants and their entities funding this into seed funding and trust funding. All the technical diagrams show sort of CANDU fuel bundles. How are you going to manage potentially non-CANDU fuel from research reactors?

I'm not sure if -- part of this is I'm not sure if like the SLOWPOKE Saskatchewan or the McMaster reactor, whether they use a CANDU fuel bundle or a different configuration, and how you'll fit that into your model, and the funding for those smaller institutions. How are you planning for the future when there might be totally new technologies, modular reactors that use a very different fuel configuration for their reactors?

MR. WILSON: Derek Wilson, for the record. So you are correct, the design is focused around a CANDU fuel bundle or what we consider a CANDU fuel bundle equivalent. So we have a waste acceptance criteria that stipulates the type of fuel offering that we would receive to be able to put through the facility. That would include some of those non-CANDU type fuel sources, as you said, whether they be research reactor fuels and so on.

So there’s a responsibility of the waste owner to be able to provide the fuel in a form that we can use. So we have, as part of our current lifecycle cost estimate, what we consider the CANDU fuel bundle equivalent, so we assume it receives in that form.

Your comment with respect to perhaps new market entrants or SMRs or those types of fuels. At this point, we assume that that would be within our responsibility to manage in the long-term, whether it be an SMR fuel. But at this point we don’t know the form or the composition of such a fuel.

So we would, at the time that that would become a realization, we would have to assess the financial implications of that, and then the trust funds and the funding formulas may have to be adjusted at that time to account.

THE PRESIDENT: Okay. This is a time when I my normal question to NRCan. Are you planning to do anything about this very narrow definition of what NWMO site’s supposed to accommodate?

I have no idea why it was decided to use this language of fuel bundles removed from commercial research facilities, rather than high-level waste. Because there’s going to be high-level waste and, NRCan, what’s your plan for high-level waste which is not fuel?

MR. McCAULEY: Thank you. Dave McCauley, for the record. So you're right, the definition in the legislation is quite narrow, it refers to irradiated fuel bundles removed from a commercial or research nuclear fission reactor.

We recognize that there are other fuels similar to -- coming from research reactors that are bundle-like or fuel-like materials, and the NWMO has taken the approach of being willing to accommodate these fuels in their facility.

Now, in terms of other fuels that might be resulting from SMRs, et cetera, I think that that would be a decision for the NWMO to make. But the legislation provides that it’s an obligation of the nuclear energy operators to be part of the Nuclear Waste Management Organization. If they fit within the definition of a nuclear energy corporation, and then their fuel would be hosted by the NWMO.

The alternative is where research reactor fuels are produced and then the NWMO provides a service to them by accommodating their fuels. So that’s basically the scope of the legislation.

There’s no plan to change the definition of nuclear fuel waste. The NWMO is able to accommodate other fuels that it considers would be appropriate for its facility. But at this time, there are no fuels that we’ve identified that would require -- that would not be accommodated by the NWMO.

THE PRESIDENT: Well, I was talking about non-fuel high-level waste. Like calandria fuel channels, things of that nature, where are they going to end up?

MR. McCAULEY: So we do an inventory of radioactive waste. We survey the waste producers every three years to identify other high-level wastes, and they have not been identifying other high-level wastes. The wastes that they’ve been identifying are included as used nuclear fuel or nuclear fuel waste in their inventories.

So some of these materials might be considered intermediate-level waste, for example. That’s how they characterize them. But at the end of the day, it’s up for the operators to determine how they’re going to be managing their wastes.

THE PRESIDENT: So as the expert then, NWMO, you don’t believe that -- you believe that you don’t need to change legislation? You can accommodate all waste in Canada with the existing legislation?

MS SWAMI: Laurie Swami for the record.

Our mandate is to manage the long-term management of used nuclear fuel, so the discussion today has been around SMR technology or new advances in technology. We see that as part of our responsibility. We have the responsibility for the existing CANDU fuel and any that's generated by the operators today. If there were new entrants into Canada's nuclear energy sector, we would look at what the funding formula would be for those new entrants and we would accommodate that on a fee-for-service basis for example.

I think when you're referring to high-level waste and the calandria, those types of materials that are from the operating facilities, that would typically be classified as intermediate-level waste and the program in Canada addresses that through the policy level, through NRCan, which says that the owners of those wastes are responsible for dealing with the long-term disposal of those materials. And the organizations that are responsible obviously are members of the NWMO as well. They have developed programs in their own right and I think that for them the decisions will come through their own processes. But for NWMO we feel satisfied that the Act meets the needs of the used fuel for Canada.

THE PRESIDENT: Okay, thank you.

Dr. Soliman?

MEMBER SOLIMAN: Thank you. My next question is about climate change. We mention in the report that it has been taken into the design, long-term resilience to climate change. What technical steps have been taken or are going to be taken in order to accommodate the change on the climate?

MR. WILSON: Derek Wilson for the record.

When we made reference to climate change in the presentation, it was more with respect to the long-term climate change impacts for the post-closure safety assessment and that being, you know, as we mentioned, the potential for future glaciation and to ensure that the impact of that glaciation does not extend down to the repository level and impact it, which influences the depth that we may consider depending on the rock formation and the location within the Canadian Shield or even in Southern Ontario. So that was in the context of that.

With respect to the impact of the more -- you know, the pre-closure phase impact of climate change, the level of design that we're at at the conceptual level, not knowing where the ultimate siting location is going to be, we haven't taken into consideration the potential for those nearer-term climate change impacts currently in the design and that would be something that we work forward to. So we're looking at the long-term prediction around climate change impacts around water and those sorts of activities, but it's too early right now to say how we're impacting the design of the facility for those considerations.

MEMBER SOLIMAN: Okay. We know that the climate is changing and some of the items, tornados for example or flooding, this will affect the design and I think if you have a preliminary design these items have to go into consideration. I don't know if this has been taken or not.

MR. WILSON: Derek Wilson for the record.

Indeed we do consider the potential for

changes in climate that could impact our siting for instance. So we would not site the repository in a depressed area that has -- you know, in a valley where there's a potential for flooding and future flooding that would not be able to be managed within the design. So those types of considerations are taken into siting. You know, the containers are in robust forms now. They come to us in a robust form. The consideration is that the facility would take those into account. But again, the specific design elements, at this point it's too early for us to say exactly what those are, but of course those are considered.

THE PRESIDENT: Dr. McEwan?

MEMBER McEWAN: Thank you, Mr. President.

Slide 29 of the NWMO presentation, as you were making the presentation I kept hoping you'd go into an explanation of what we're looking at a little bit more. I presume those are contiguous areas. Can somebody just provide an explanation of what opportunities for increased understanding, safety, the improved resolution does, and perhaps the difference in the contiguous areas of what we're looking at?

DR. BEN BELFADHEL: So just maybe to -- Ben Belfadhel for the record -- to explain the reason why we even started with these high-resolution surveys.

When we started, when communities came into the process, especially in Northern Ontario, most of the communities were in areas that were not studied in the past because our interest was focused on granitic rocks and those granitic rocks have not been surveyed, for example, by mining companies. Most of the work focused on areas where there is a potential for natural resources like volcanic rocks. So when we looked at the data that we had to work with, the resolution was pretty low. Just to give you an idea, the resolution that we worked with, for example, what you see in the background there, the resolution is 800 metres, so the flight lines of the plane were each 800 metres.

The resolution that we did is 100 metres. So it's -- you can see, I can explain that slide. Like if you look at the background, the magnetic surveys, we conducted them mainly to understand the distribution of structures like faults and fractures. If you look at the background you can't see much, but if you look at the triangular form that we have there, you can see long lines and you can clearly see that those long lines are potential fractures. So that's the type of improvement that we got.

And the other thing that these surveys

allowed us to do is to have a better resolution of the different rock types that exist within the areas. The maps that we worked with were developed in the '40s and '50s. They used very coarse mapping. But with this type of surveys we were able to really refine the contours of the different geological formations. And so these surveys allowed us to go from very large areas -- like in some areas we had over 100-by-100-kilometre areas that we had to assess. So with these surveys we were able to narrow down the areas that we focused on.

MEMBER McEWAN: So just again out of interest, if I look at the -- there's almost a junction in the middle of that almost arrow shape that you've outlined and you go from sort of green with yellow and red shadings to an area that is blue with red shadings. What is that telling us?

DR. BEN BELFADHEL: So what you see, like the area in the middle is a different rock type. These are the volcanic rocks and, as you can see, they are heavily fractured, and those rocks, we excluded them from the site selection process even at the screening stage because we identify them as not suitable.

So in this case when we continued the studies we focused on the areas -- for example, if you look to the left there is an area that is green. So that area, what you see there, I can say in plain language it's clean. There aren't many lines going through it and that's a sign that the area is homogeneous, no fractures, the potential for fractures there is low. So this is exactly what we were looking for with these -- so it was a very good guide for us to focus on areas.

MEMBER McEWAN: So, effectively, it's a screening tool?

DR. BEN BELFADHEL: Yes.

THE PRESIDENT: Thank you.

Dr. Demeter?

MEMBER DEMETER: Thank you. I know it's a long time in the future but this is more a question for CNSC staff.

Under the current regulatory -- under the Act and the Regs, with onsite storage of high-level waste which is fuel or other high-level waste, it's currently under the sort of *Class I Facilities Regs*. When all this gets moved to offsite storage, do you anticipate that a new set of regulations will be required to contain this very particular activity? And do you also see that -- obviously, the nuclear power plants who have paid a lot into this will want their waste stored there, but for other licensees who may have high-level waste or nuclear fuel waste who haven't paid into this, do you see that as an obligatory storage option for them or voluntary?

MS TADROS: So thank you for the question. Haidy Tadros for the record.

I believe your first question was with regards to our regulatory framework and how sort of the Act and the Regulations as they currently exist, will they be meaningful -- if I may paraphrase -- into the future with these waste facilities?

So with that regard, I believe our regulatory framework as it currently exists with the set of regulatory documents as defined by our safety and control areas are sufficient to regulate what currently exists and well into the future in terms of the waste that is being categorized for the Class I facility waste that the NWMO will be seeing.

With regards to your second question on the potential for high-level waste producers, seeing them more obligatory to use this waste facility or a potential other option, as was stated, it is up to them to decide in terms of what choice they have to make.

Maybe I'll pass this over to Ms Karine Glenn who may have finer detail in terms of our current regulatory structure and the requirements and into the future with regards to waste producers.

MS GLENN: Karine Glenn for the record. I'm the Director of the Wastes and Decommissioning Division at the Canadian Nuclear Safety Commission.

As Ms Tadros stated, the current Act and Regulations would be -- would enable us to license a facility such as a repository for high-level waste. It is the framework under which OPG DGR for instance is being proposed and licensed. There may be some specific requirements when we look at records retention and how long we go into monitoring for long term, and those can all be addressed through licensing or licence conditions. We are in the process of modernizing our regulatory documents that pertain to waste and we had a discussion paper in 2016 with some questions surrounding repositories and those kinds of questions, and so we will be coming forward with updated and revised guidance documents, but the actual regulatory framework in terms of requirements does not require modification today.

With respect to your question about whether obligatory or optional with respect to the high-level waste, the current waste policy that NRCan has put in place -- and maybe Mr. McCauley can add on that --

is that the waste producers are responsible, and the CNSC does not dictate where the waste goes as long as the proposal that is put forward is assessed as being safe and protective of the environment and of people.

MEMBER DEMETER: Thank you very much.

THE PRESIDENT: So again, I'm going to go back to that. So I want to hear from CNSC. We heard from NWMO and from NRCan that no legislative changes are required, we can handle any waste in Canada. Do you agree? So I'm talking about, I don't know, Cobalt-60, Cesium, things that I don't know where they're going to end up. Everybody is happy that the legislative framework now will allow us to -- you're going to the Joint Convention on Nuclear Waste Management. Will Canada present a view that we know exactly where everything is going to end up?

MS TADROS: Thank you for the question, sir. I think this was one of the ones we were anticipating. Haidy Tadros for the record.

Correct, we are going into the Joint Convention and our position will be that Canada's regulatory framework is robust to provide clarity of expectations with regards to waste and waste management.

With that, and as Ms Glenn has identified, we take opportunities to look at improving the clarity of expectations, we introduce more guidance, we introduce more clarify of information that is currently found not only in international standards but, as mentioned, we also use Canadian standards, CSA standards.

So at this point maybe Ms Karine Glenn can provide the details with regards to the framework not just with the CNSC but the framework, the national framework that exists for waste management and waste categorization.

MS GLENN: Karine Glenn for the record.

Currently the number of disposal facilities in Canada is not extensive, but there are many proposed projects that are coming before the Commission or are currently before the Commission for licensing action or for assessment.

When it comes to do we have a solution for all types of waste, I will start by saying that all wastes are currently stored in a safe manner and through oversight we continue to verify that that is the case. All of the facilities that store the waste are licensed by the CNSC and come before the Commission on a regular basis for relicensing. And so that's one aspect of it.

In terms of disposal, we are aware that industry is currently working together at finding solutions for the remainder of the waste that doesn't have a home, if you'd like, and we continue to follow up with them on the progress that is being made. And as facilities approach decommissioning end-of-life, these questions will become much more important to be resolved. Right now we still have time on our side, but we continue to undergo peer review of that every three years by the Joint Convention contracting parties and at the time we have committed as a country, Canada, that we are looking to those solutions. These solutions take time, as you've seen with many other projects for waste disposal, and so industry is working towards concrete solutions for the remainder of the waste.

THE PRESIDENT: Okay, thank you.

Back to Dr. Soliman.

MEMBER SOLIMAN: Thank you. My next question is about the used fuel containers. One of the proof test plans is non-destructive testing. Could you elaborate on the plan for non-destructive testing?

MR. WILSON: Derek Wilson for the record.

So as we've been developing the design and the prototyping, looking at the manufacturing and fabrication technologies and so on that we've incorporated into our container design, obviously we have the need to be able to identify the non-destructive examination requirements for those, and so we've been over the last two years developing the NDE processes and equipment requirements to be able to analyze the condition of the welds, the thickness and the purity of the copper, coatings and so on.

So right now we're looking at a series of both eddy current and ultrasonic. We've just gone through the process of identifying the needs. We're actually commissioning right now prototype equipment for us to be able to do that non-destructive examination in-house at our Oakville facility. So we're just in the process now of working through setting ourselves up internally to be able to do that.

MEMBER SOLIMAN: Is the test only on the weld for flaw indications or it includes something else?

MR. WILSON: Derek Wilson for the record.

So right now what we're doing for the welds specifically is we're looking for flaws and we're looking for microcracking within the structure of the weld. And on the copper coating we're looking at flaw detect and essentially the adhesion to the metal substrate of the copper coating.

THE PRESIDENT: Thank you.

Dr. McEwan?

MEMBER McEWAN: Thank you. I'm just

quickly looking -- I think it's Slide 52 where you talk about the timeframe of expectation of the safety containers. As I was thinking, it just seemed slightly incongruous, but forgive a naïve question. So in the water immersion test, you say that 200 metres has to be robust and intact for one hour. If you drop something at 200 metres, it's going to take a lot more than one hour to recover it, so how do you actually ensure that there is a safety element built into that one-hour testing? Does that question make sense?

MR. WILSON: Derek Wilson for the record. I believe I understand the question.

These are international testing requirements for the certification of transport packages and these are standard pretty much internationally for that. The immersion test is to demonstrate the integrity of the container under pressure, and again, so it's the eight hours at 15 metres or the one hour at 200 metres.

And again, these are intended to be bounding scenarios for the integrity of the container in various aspects. I know there is the expectation that the container -- you know, the container performance is expected to be beyond that for the purposes of retrieval and so on. So again, these are international standards that we have to adhere to, and in this particular case this is actually done through numerical modelling and model assessments as opposed to a physical placement of the container at 200 metres.

THE PRESIDENT: Dr. Demeter? Sorry.

MS TADROS: That's fine. Haidy Tadros, for the record, just to maybe complement a little bit with regards to the standards that are used.

So on Slide 52 the progression that is identified is sort of a typical scenario of an extreme event that would happen to the package, so something gets dropped, potentially punctured, flames, and then water that is poured to put the fire out, and the standards in terms of the temperatures used, the timeframes that are used, again, as explained, are intended to be to mimic what would the container be under in terms of stress and how the container should survive, if you will, the different phases of the accident.

Ms Karine Glenn can elaborate specifically on the water immersion tests and the standards if that's worthwhile.

MS GLENN: Karine Glenn for the record.

I'll just clarify that the water immersion test is not a cumulative test, it's done separately from the other three, and it looks at the actual transport container integrity itself, so for leakage at that point and making sure it doesn't collapse. However, it's important to note that this type of container has multiple barriers and that the fuel itself is actually in a solid form. The pellets are in a welded pencil, if you'd like, in bundle. And so that actual test, what they're looking at is the actual external flask and does not actually take into account all the multiple barriers that are included in the container.

MEMBER McEWAN: So if I'm right, 200 metres is 20 atmospheres?

MS GLENN: Yes, that is correct, and that takes actual -- what we call maximum operating pressure, so it would assume that internally there are additionally certain conditions at the onset.

These, as Mr. Wilson pointed out, are standardized test conditions, hypothetical accident conditions as dictated through the International Atomic Energy Agency Regulations, which Canada has adopted in its integrity, and it is used worldwide. And in over 55 years of the transportation of radioactive materials there has never been an accident that has resulted in significant environmental or radiological contamination from a transport accident.

And there have been multiple very severe accidents such as fires, crashes of -- with very severe consequences. And in all cases, the packages performed as expected.

THE PRESIDENT: I think somebody -- somebody want to add something to this?

MR. GARG: Yeah. This is Raj Garg here. I'm the transport specialist at the CNSC.

I would just like to add that these tests shown on this slide 52, they're very basic requirement written there. They are not elaborative, really.

There's much more requirement on these tests when they're done like the drop test or the thermal test. There are certain requirements imposed before you can do that.

There is to be engulfing fire, it has to be controlled air circulation there. So when the water test -- water immersion test is done, the studies haven't been done how long it's going to take the package, how far it will be from the ground level, depending on that.

And again, I think the last 50 years there have been one or two cases where they've not been able to take the package out from the deep water level from more than 200 metres.

So there's a number of studies done after this test have come there but, again, there's much more requirement behind that. This is just in simple terms these requirements are put there.

THE PRESIDENT: Thank you.

Dr. Demeter?

MEMBER DEMETER: thank you. This is just an observation, maybe, for clarification.

CNSC Staff have talked about the countries involved in their DGR regulatory forum, and then there was a slide from NWMO, slide 54, which looks like international cooperation -- signed cooperation agreements.

The one disparity between the two lists is that the U.S.A. is not one of the signed cooperation agreements. And given their history and long road to where they've gotten, I just was curious why the U.S. is not part of that group that's signed cooperation agreement but is part of the DGR forum group.

MR. WILSON: Derek Wilson, for the record.

These cooperation agreements are set in such a way that the technical research and development that's ongoing between these various organizations is shared freely.

There's -- we have ongoing coordination and cooperation with the United States through various other forums, but these particular cooperation agreements, because of the Department of Energy, we're not able to form a similar type of agreement with them just from a sharing perspective for the DOE.

So the Department of Energy doesn't have the same mechanism to form such a free-flowing agreement of information back and forth as compared to the other waste management organizations that have a very similar mandate to the NWMO.

MEMBER DEMETER: Just as a follow-up to that for staff, do you have any form of signed cooperation agreements with NRC, for example, or EPA, or is it just a DOE issue in the U.S.?

MS MECKE: Julie Mecke, for the record.

Just to be clear that CNSC as a regulator will enter into Memorandums of Understanding with other countries, and they may not be the same countries as NWMO, just so that's clear.

On the DGRF is the U.S. NRC and the CNSC does have a Memorandum of Understanding with them and as another fellow nuclear regulator, we have the ability to share information and do technical exchanges with them, so it's an add-on to that existing MOU that we have with them.

THE PRESIDENT: But if I understand correctly, you bonded with the WIPP people once they -- you know, the event happened over there. And they have -- it's DOE oversight, but they have an external body that you can actually -- the technical managers that, I assume, you are in constant discussion.

MR. WILSON: Derek Wilson, for the record.

You're correct. As I mentioned, we do have -- we do have coordination with the Department of Energy, the WIPP facility, for instance, in terms of being able to gain access to that facility and share information, similarly with Yukka Mountain and the work that was done there.

So there's avenues for us to be able to leverage the U.S. experience. It's just not through a similar agreement as we have in this particular area.

So we have an engagement. You know, the EDRAM group is another example where, you know, the U.S. participates, as does Canada.

So there are multiple forums that we have connection to the U.S. program. It's just not through this type of mechanism; that's all.

THE PRESIDENT: Thank you.

Dr. Soliman.

MEMBER SOLIMAN: Thank you.

I have a question about the safety assessments, specifically operational safety.

What -- I know this question may be ahead of time, but I would like to know your expectations or what factors, what thought has been put in place with respect to operational safety.

DR. GIERSZEWSKI: Paul Gierszewski, for the record.

So we have conceptual designs at this point, and we are looking at them from an early stage to understand the operational safety aspects as a guide back to the design at this stage.

We've looked at a variety of topics at this point. We've taken, for example, an ALARA perspective looking at the planned operations to see what that would imply, and so does that suggest way s to optimize the design when you understand what contributes to the worker dose.

We've -- in fact, recently -- currently doing some work on the accident assessment during the pre-closure phase looking at possible accidents from both internal events looking at how we're handling the fuels and how that might lead to an accident as well as external events and doing an assessment on that based on the conceptual design.

So we're looking at it now with an early stage to understand what are the key drivers on that from both input to the design and input to our understanding of what we need to do as part of a future safety assessment for an actual facility.

THE PRESIDENT: Thank you.

Dr. McEwan?

MEMBER McEWAN: Just a couple of simple questions.

Do you make your annual and triennial reports public or are they private to the Minister?

MS FRIZZELL: Good morning. For the record, my name is Lisa Frizzell, and I am the Vice-President of Stakeholder Relations at the Nuclear Waste Management Organization.

Thank you for your question.

Yes, we make our annual and triennial reports public. We publish them on our web site at the same time we submit them to the Minister of Natural Resources.

We also distribute them to a mailing list of people who have expressed interest in being updated on our work.

MEMBER McEWAN: And in terms of the agreements that you've entered into with communities for sort of the educational process that you describe in the CMD, what do they look like? How structured are they, how -- what sort of commitment do you make to those communities to provide resources?

DR. BEN BELFADHEL: Ben Belfadhel, for the record.

So we have a wide range of agreements with communities, funding agreements, and the principle of that is -- for many of the agreements is our principle is we don't want the communities to be out of pocket by participating in the project, so what we try to do is to cover their expenses and their learning activities. We cover all that because, as you can imagine, that takes a lot of effort and energy, so we want to help them with that.

So the agreements are very simple, so the communities, they express desires in terms of what they want to do in terms of learning and things like that, and we just look at that and sign an agreement. And --

THE PRESIDENT: Are they public, the

agreement? The fact that you enter into an agreement and all that.

DR. BEN BELFADHEL: So all the agreements that we have are on our web site, so we have pamphlets that describe all the fundings that we give to our communities. And in addition to that, all these agreements are discussed at CLC meetings, at Chief and Council meetings or at Mayor and Council meetings that are public.

THE PRESIDENT: Speaking of public, you know, by the way, I really like the -- all the references in there.

So this is going to be such a long project, so what's your game plan, both CNSC and NWMO, about keeping references of all the work that's been done?

You have advisory committees, you have geoscientific review group, you have the IAG review. Are all this material classified and publicly available somewhere?

MS FRIZZELL: This is Lisa Frizzell, for the record.

Yes, we have a comprehensive set of materials posted on our web site, including background about the work that we do, the program information that's available to communities, technical reports, questions and answers and so on.

MS TADROS: It's Haidy Tadros, for the record.

Thank you for the question, sir. It's a very important one.

Yes, we currently have executive summaries of the AEG (sic) reports, and I believe it was just posted today, the most recent that the IAG was involved in.

As staff -- and we conduct our outreach activities. We have opportunities to, obviously, communicate with the public, but we have our regulatory oversight reports and our status updates, sessions such as these with the Commission through Commission Member Documents that are publicly available.

All of these is kept in reference and is intended to be a living history of the decisions made, the steps taken, the communities and the individuals we've seen and discussed as the life cycle of this project goes forward.

THE PRESIDENT: Thank you.

Dr. Demeter.

Dr. Soliman.

MEMBER SOLIMAN: On slide number 12, technical method, the last bullet under technical method, optional is stable shallow underground storage.

Could you please elaborate on that? What does that mean?

MR. WILSON: Derek Wilson, for the record.

As part of the original studies that were conducted in the -- in the period of developing APM, there was a consideration for an option for an interim storage facility, either shallow -- at shallow depth or at surface to facilitate the fuel given the uncertainty around the times because the original plan was it could have been anywhere from 2035 to 2065.

That option, while it was maintained, we are not -- no longer carrying that option as one that we're considering in terms of both cost and design considerations, but it was an original option of the APM program at the time in 2005 when it was proposed to the federal government.

THE PRESIDENT: Is that why the asterisk is in there? There's an asterisk.

Every time I seen an asterisk, I'm looking for a note.

MR. WILSON: Derek Wilson, for the record.

That is correct. There's -- if you -- this is an extract from a larger slide that we're actually condensed and, unfortunately, we missed the asterisk, but that's -- what the asterisk says is that that's no longer under active consideration at this time.

THE PRESIDENT: Thank you.

Dr. McEwan?

MEMBER McEWAN: Thank you, Mr. President.

Staff slide 15, you were talking about outreach and some of the sort of key topics and key questions.

So the fourth bullet, "Safety: What if something goes wrong?" how do you answer that?

MS MECKE: Julie Mecke, for the record.

So when someone -- a member of the public does come and ask this question, we try to first put where we are in the context.

We explain who we are as the regulator and it's NWMO who's going out now looking for a site, and it's early in the process. But this is a question that we will ask ourselves, and we say that this is a question that the Commission -- we're independent of them, but they will also ask this question, too.

We explain the concept of a safety case and how you'll have information at the beginning, but again, it's up to the applicant to demonstrate safety. And that we have specialists in environment, radiation protection, geologists who will answer and look at all the aspects of a future application in order to make a recommendation to the Commission so that they can make a decision on the application in the future.

MEMBER McEWAN: So I guess, NWMO, how would you answer it?

DR. GIERSZEWSKI: Paul Gierszewski, for the record.

So there's a couple of points that I would make.

First, again, just drawing back to the nature of the design, the multiple barriers, the reliance on the geosphere and the safety case, we would also have the evidence to support those arguments, which is not just that -- the computer models, but the evidence you would have from the site, the age of the ground waters, the age of the rocks. So that's part of it.

Secondly, then, in the safety assessment part of it, we don't just look at the case where everything works as expected. We also do look at what goes wrong. And indeed, one of the -- our standard analysis cases is what if all the containers fail, and that is then part of the cases that would be presented. Here's the range of scenarios from the likely to the unlikely, here's the range of consequences that then go into making the decision about our preferred site and then, ultimately, a decision about whether the site is suitable to receive a licence.

I guess the last point I would just draw on this is that we will have something on the order of 40 years of operational experience with the repository and then decades of extended monitoring before we choose to close it, so you know, there will be 100 years from now before actually making the decision that we're comfortable with the evidence that we have behind us, not just in front of us, that this is a -- this is safe to close this repository and go into the post-closure phase where there would still be monitoring and institutional control around the site.

MR. WILSON: Derek Wilson, for the record.

And I think the safety from the post-closure side is something that people sometimes have a difficulty understanding. I think more importantly is some of the nearer term safety issues that they'd be looking at. And we have a great record in Canada to be able to point to in terms of how, you know, fuel is currently stored, assuring them about the transportation, the integrity of the transportation packages, looking at the operational components as we understand them today, you know, again being not very complex and using robust containers and using the existing safety framework from which we can work.

So I think that gives a lot of confidence that, you know, we can point to an industry that's safe in Canada and we can point to the types of activities that we'd be doing in this facility, specifically on the surface.

Once it goes underground, I think while the long-term concern is there, people feel that once it's underground it's safer than it was on surface, so.

THE PRESIDENT: It's strange that nobody mentioned emergency management, in particular during construction, during, you know, putting in the material in there. There will be emergency provision somewhat.

But I have to tell you, and this is just from my gratuitous advice, I don't like the word "closure". It conjured the idea of abandonment, and we are getting into many, many other projects. You mean you're going to walk away from that?

I don't think you need the concept of a closure. It's a long management process that has a different intensity of intervention. And I keep -- when people say that we cannot predict what's going to happen in three years, let alone in 3,000 years my answer is as long as there's going to be Canada, there's going to be a regulator and this is forever.

And I don't know why -- why you need to come up with this "closure" concept that nobody understands and really feel anxious about. Not only with your project. Practically every project that we hear.

And again, I don't like that in our legislation the notion of abandonment gets the same kind of thinking. You notice we haven't used that term quite a bit.

So the institutional transfer normally is something that people understand a different modus operandi, but it's always under somebody's oversight.

MS SWAMI: Laurie Swami, for the record.

I understand what you're saying with respect to closure, and when we're talking about closure, we're not talking about abandonment at all. We're talking that the facility at some point will have received all of the used fuel and it will be time to actually close its operation and close off the shafts or other components that will be open to the surface.

So we actually will proceed with an engineered barrier that includes closure.

So I think that your point is taken, though, that the words "closure" may suggest a different way of looking at our facility, and so we'll take that under advisement and perhaps we'll come back with better words that would be more suitable.

THE PRESIDENT: Dr. Demeter?

Dr. Soliman.

MEMBER SOLIMAN: On slide 41, I have a very simple question. The slide 41 shows the DGR concept which is deep, about 500 metre.

How big it is the other two dimensions?

MR. WILSON: Derek Wilson, for the record.

If we look at that from a very symmetrical configuration in the underground given the inventory of about 5.2 million fuel bundles, the underground footprint would be about six square kilometres, or two kilometres by three kilometres, in lateral dimension.

MEMBER SOLIMAN: Thank you.

THE PRESIDENT: Dr. McEwan?

Dr. Demeter?

So I have a question I've been asking now for quite a while.

In your document you show that you're looking for -- in 2023, you would like to come to us with one site. You're putting all your eggs in one site.

Why won't you -- have you ever considered the Swedish model where they came up with two sites? And there was almost like kind of a competition to make sure that one of those two would be selected rather than betting only on one particular site.

MS SWAMI: Laurie Swami, for the record.

So the site selection process that was submitted by the Nuclear Waste Management Organization and was reviewed by the Minister involved us going through the site selection process and identifying a site that we would take through for detailed site characterization.

As you can imagine, the detailed site characterization is quite an extensive piece of work, so once the site is selected, we then have to do the detailed site investigation, the environmental studies and all of the work that would prepare us for the detailed licence application that would be required in about 2028.

So it's a significant in time and effort to investigate that site, so that's one of the reasons that we're looking at it from that perspective.

We also are recognizing what the communities will be interested in, so the communities that are going to continue through this process -- and I think you rightly said it earlier. It is a long process for any one community to go through because of the work that would be required, the external pressure we can imagine in terms of finally accepting a particular site and the region around that site, so we need to be assured that we can maintain that community interested in our work and interested in continuing to host a Deep Geologic Repository.

So we need to balance where the risks are, and certainly one of the risks that we would look to is what if, at the end of the day, the community that does put their hand up looks to a change in their perspective on the project or if there was a change in the general societal expectations. We'll certainly have to consider what that would look like.

So we handle that more through a risk management perspective, so we have one path that takes us one direction with risk management around that.

THE PRESIDENT: Just to clarify, if I understand what the Swedish -- Sweden has done, they eventually selected one, but all the way till the end, there were two communities were in the running and they were both geologically acceptable and they both wanted it.

It was at the end to select the best of

the two, but the dynamics was that -- that the two would counter each other to make sure that nobody bails out, if you know what I’m saying.

They were both -- they were both compensated for their work, et cetera.

I'm just worried about, you know, at the final -- the eleventh hour even the selected community will say no.

MS SWAMI: Laurie Swami, for the record.

I believe that the work that this organization has done in developing the relationships with communities would limit that risk to be almost non-existent. Today we have seven communities that want to be with us, and we're continuing to build with -- the relationship with them.

And as we enter into partnership discussions, I think it becomes clearer and clearer that these communities want to be here. And if you think that two creates tension in terms of continuing through, seven also creates that tension. And as we narrow down over the number of years to get to 2023, I think that tension will grow and we'll be in a very similar position as -- at the end of the day when the selection is made.

THE PRESIDENT: Okay. Thank you.

Any final words you want to share with us?

MS SWAMI: Laurie Swami.

I really appreciate your attention this morning. I know that we've provided a very detailed overview of our program. I think we're very proud of the work that we do, and we look forward to coming forward before the Commission in future, probably in 2020, or when we're ready to submit our applications.

THE PRESIDENT: Okay. Thank you.

We will break out for lunch now, coming back at 1 o'clock. Thank you.

--- Upon recessing at 12:01 p.m. /
Suspension à 12 h 01

--- Upon resuming at 1:06 p.m. /
Reprise à 13 h 06

THE PRESIDENT: The next item on the agenda is an information item to provide an update on the implementation of recommendations from the Tritium Studies Project Synthesis Report. This is outlined in CMDs 17-M48 and M48.A.

So I understand we have some representatives here from CNL, Canadian Nuclear

Laboratories, and were available to help. But in the meantime, I understand that Mr. Rinker, you will make the presentation. Over to you.

CMD 17-M48/17-M48.A

Oral presentation by CNSC Staff

MR. RINKER: Good afternoon President Binder and Members of the Commission. My name is Michael Rinker and I am the director general for the Directorate of Environmental and Radiation Protection and Assessment.

With me today are Dr. Nana Kwamena, an environmental protection officer with the Health Sciences and Environmental Compliance division, Ms Julie Burtt, a radiation and health science officer of the same division, Dr. Nadereh St.-Amant, a senior analyst from the Laboratory Services division, and Mr. Elias Dagher from the Environmental Risk Assessment division. We will be sharing today's presentation.

We also have other CNSC staff available to answer any questions.

The purpose of today's presentation is to summarize CNSC staff's work on the Tritium Studies Project. Based on the research that CNSC staff have conducted to meet the objectives of the project, staff conclude that adequate provisions have been made through existing regulatory mechanisms for the protection of Canadians from exposure to tritium releases. CNSC staff is requesting that the Commission endorse staff's conclusion that the intent of the Tritium Studies Project has now been fulfilled.

Please note that there is an error in the title of Table B.2 of Appendix B of CMD 17-M48. The title of Table B-2 should read "Total estimated dose to a child receptor," not "an infant receptor."

The total HTO dose summed from all pathways should be corrected in Tables B.2, B.3, and B.4 of Appendix B. Specifically:

- For Table B.2, the total HTO dose considering all pathways should read 3.41×10^{-2} mSv per year

- For Table B.3, the total HTO dose considering all pathways should read 3.45×10^{-2} mSv per year

- For Table B.4, the total HTO dose considering all pathways should read 2.87×10^{-2} mSv per year

Dr. Kwamena will now continue with today's presentation.

DR. KWAMENA: Good afternoon, members of the Commission.

For the record, my name is Dr. Nana Kwamena and I am an environmental protection officer here at the Canadian Nuclear Safety Commission.

To begin the presentation, we will present a brief history of the CNSC's Tritium Studies Project. This will be followed by a description of the main chemical forums, sources, and uses of tritium in Canada to provide context for why the CNSC regulates tritium-releasing facilities and activities.

The main part of the presentation will summarize the research studies and initiatives that CNSC staff have undertaken in implementing the recommendations of the Tritium Studies Project. Staff will also present the achievements of other CNSC tritium-related initiatives that staff have been involved in to date. We conclude the presentation by outlining how the work completed by staff has met the objectives of the project.

In January 2007, the Commission directed CNSC staff to initiate a series of research studies on tritium releases in Canada. This directive was documented in the Record of Proceeding, Including Reasons for Decision for SRB Technologies' relicensing hearing for the renewal of a Class 1B operating licence. At that time, tritium levels in the environmental were at levels that were not expected due to the operation of the facility. It was determined that the facility was not doing enough to control its emissions.

The Commission concluded that the regulatory framework in place was sufficient to protect people living around nuclear facilities. The Commission also concluded that additional research on tritium releases in Canada was needed to increase current knowledge and improve the regulatory oversight of tritium-releasing facilities in Canada.

It should be noted that since the initiation of the project, SRB Technologies has implemented a number of control measures and best practices to reduce their airborne emissions of tritium.

Following the request from the Commission, CNSC staff initiated the Tritium Studies Project later in 2007. Between 2007 and 2010, CNSC staff engaged in a number of research studies to address the objectives of the Tritium Studies Project. In June 2010, CNSC staff presented the results of the project to the Commission as part of the Tritium Studies Project Synthesis Report. The Synthesis Report included a summary of staff's research along with staff's recommendations to improve environmental protection aspects of the CNSC's regulatory framework.

In January 2013, CNSC staff provided the Commission with an update on the work that CNSC staff have been involved in in implementing the recommendations of the project since the publication of the Synthesis Report in 2010. None of the recommendations of the project were closed at the 2013 update. CNSC staff indicated that it would provide an update to the Commission once the remaining research initiatives had been completed.

Today's presentation summarizes the work that CNSC staff have carried out or funded to date to address the objectives of the Tritium Studies Project. The purpose of today's presentation is to demonstrate that through staff's work the objectives of the project have been met.

The following set of slides provides background information on the chemical forms, sources, and uses of tritium to provide context for why the CNSC regulates tritium-releasing facilities.

Tritium occurs in the atmosphere in the same chemical forms as hydrogen. The radiological half-life of tritium is 12.5 years.

Tritium in the gaseous form is referred to as tritiated gas or HT. Once it is in the air, HT rapidly mixes with air moisture to form water molecules known as tritiated water or HTO. HTO can mix with water in the body and other environmental media such as soil, plants, and animals. HT is less harmful to people than HTO because it is only weakly absorbed by the body.

Organically-bound tritium, or OBT, is another form of tritium that is found in biological systems. OBT is formed from the exchange of hydrogen with carbon-based molecules through different metabolic processes.

The different forms of tritium can also be distinguished based on the time spent in the body. HTO clears from the body four times faster than OBT. In an adult, HTO has a biological half-life of 10 days, while OBT's biological half-life is 40 days. The biological half-life of HT is also 10 days, as this accounts for the 0.1 percent of HT that is converted to HTO. As a result of this different in the biological half-lives, OBT has a greater dose consequence compared to HTO.

In general, tritium is one of the major contributors to radiological dose at nuclear power plants and tritium processing facilities.

Tritium is mainly produced as a by-product of the operation of CANDU and research reactors. CANDU reactors use heavy water as a moderator. The operation of the reactor results in the formation of tritium.

Tritium removal facilities, such as the one at the Darlington facility, recover the tritium produced by the reactors. Some of the recovered tritium is used at tritium processing facilities such as SRB Technologies to produce non-electrical self-luminescent military and aviation products.

The operation of CANDU reactors along with the industry chain of using tritium to make non-electrical self-luminescent lights is unique to Canada. These are some of the main reasons why CNSC staff are leading experts in the fields of tritium regulation, the behaviour of tritium in the terrestrial environment, and tritium radiobiology and dosimetry.

The CNSC regulates and monitors environmental releases of tritium from nuclear reactors and tritium processing facilities. Staff also undertake independent environmental monitoring to ensure that the public and the environment are protected.

Environmental protection at nuclear

facilities is conducted in accordance with the *Nuclear Safety and Control Act* and its associated regulations. The environmental protection regulatory framework ensures that nuclear facilities are operating to protect the health and safety of people and the environmental. The CNSC's regulatory framework is informed by research studies as well as national and international guidance and standards.

Doses to members of the public are often estimated because they are too low to be measured. The doses are estimated using measured concentrations of nuclear substances like tritium in environmental samples.

HTO is measured directly in environmental samples. In contrast, OBT is often modelled rather than measured due to its complexity of analysis. Specifically, an OBT:HTO ratio of 0.7 as recommended by CSA Group Standard N228.1, Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities, is used in dose calculations. This value represents the mean of the values previously observed in the literature.

Doses to members of the public from tritium releases are between 0.0001 and 0.01 mSv per year, which is a small fraction of the public dose limit of 1 mSv per year.

The figure on this slide illustrates how doses to members of the public living around nuclear facilities that emit tritium, as represented by the blue cube, are a small fraction of the public dose limit, as represented by the orange cube, and natural background, as denoted by the larger green cube. The dose to a member of the public was calculated by CNSC staff using data from the CNSC's Independent Environmental Monitoring Program. Further details regarding the data and the assumptions used in staff's calculation will be provided later in the presentation.

Staff will now provide an update on the status of the recommendations from the Tritium Studies Project.

The Tritium Studies Project identified certain areas related to environmental protection as requiring further study. Therefore, CNSC staff made recommendations to enhance the environmental protection with respect to tritium within the existing regulatory framework.

The first recommendation included continuing to investigate the environmental behaviour of tritium, especially organically-bound tritium, and to determine the resulting dose consequences.

In order to address the lack of precision in tritium levels in air using active and passive air samplers, CNSC staff recommended that work be undertaken to identify the factors that are needed for adequate calibration of active and passive tritium in air samplers.

CNSC staff recommended that groundwater protection principles at Class 1 facilities be addressed. This arose because, although regulatory requirements protect human health, past practices have not provided a sufficient level of protection of groundwater resources outside the licensed boundary of certain nuclear facilities.

Lastly, as part of the Tritium Studies Project, staff recommended that additional studies in radiobiology and dosimetry be conducted to reduce uncertainty.

The follow slides will demonstrate how staff have addressed the recommendations of the project.

The Environmental Fate of Tritium in Soil and Vegetation Study was carried out to address the recommendation on the variability in the OBT:HTO ratios that had been observed in environmental samples.

Research for the Environmental Fate Study was conducted near the Darlington and Gentilly-2 nuclear power plants and two tritium processing facilities, SRB Technologies and Shield Source Incorporated. The work was conducted during the 2008 and 2009 growing seasons. The green dots on the map represent the nuclear facilities around which the sampling took place. These sites were selected due to the differing nature of their operations and the availability of locally grown vegetation.

Environmental samples of soil, garden produce, animal fodder, and animal products were obtained and analyzed for HTO and OBT.

The OBT:HTO ratios observed in this work were greater than the recommended ratio in the CSA Group Standard N288.1. CNSC staff compared the ingestion dose for a member of the public consuming vegetation with the recommended ratio and using the maximum OBT:HTO ratio observed in this work. The dose from the higher OBT ratio was approximately five times higher. From a regulatory perspective, the calculated doses in both cases was a small fraction of the public dose limit and below doses known to cause health effects.

The results of the Environmental Fate of Tritium in Soil and Vegetation Study were published in the *Journal of Environmental Radioactivity* in an article co-authored by CNSC and University of Ottawa staff.

In 2012, CNSC funded and actively participated in a follow-up project entitled Tritium Transport in the Terrestrial Environment. The follow-up project was carried out during the 2012 growing season near SRB Technologies, a tritium processing facility in Pembroke, Ontario. The objectives of the project were twofold: first, to understand the conditions that led to the high-than-expected ratios using an experimental approach with more environmental monitoring; and secondly, to increase the CNSC's laboratory's analytical capabilities by conducting parallel tritium analysis using split samples and to provide quality assurance.

The result of the Tritium Transport in the Terrestrial Environmental study confirmed the elevated OBT:HTO ratios that had been observed in staff's previous work and in the literature. The results of this work were presented by CNSC staff at the Third International Conference on Radioecology and Environmental Radioactivity and were also published in the *Journal of Environmental Radioactivity*.

The results of these two studies support the growing body of evidence thabt OBT:HTO ratios in environmental samples may be higher than those used in environmental transfer models.

Existing environmental transfer models may not take into account less-studied environmental transfer processes or account for the non-equilibrium state of actual operations.

Further research is needed in different environmental media, as well as in different locations on the factors that lead to the higher than expected ratio in order to reach a scientific consensus. This consensus, if reached, may lead to the revision of transfer models.

CSA Group Standard N28.1 is reviewed on a five-year cycle. CNSC staff sit on the technical committee and will ensure that OBT-related matters are appropriately addressed.

The result obtained from both studies do not impact the overall risk to health, since doses to members of the public from tritium-releasing facilities are low.

CNSC staff have also been involved in other research studies and initiatives to address staff's recommendation on the variability of the OBT to HTO ratios in environmental samples.

CNSC staff have participated in the International Atomic Energy Agency's Modelling and Data for Radiological Impact Assessment, or the MODARIA Program.

CNSC staff have been actively participating in the MODARIA's working group that develops, tests and compares models for tritium releases.

As part of the MODARIA Program, CNSC staff collaborated with staff from the Japanese Atomic Energy Agency, as well as staff from the Canadian Nuclear Laboratories on a modelling inter-comparison to understand the role of HTO transfer from the soil to the leaf and its effect on the OBT to HTO ratio in vegetation.

The results of this collaborative research were published in their peer reviewed literature.

In another initiative, CNSC staff hosted a three-day tritium workshop in April, 2016. The workshop brought together scientists from the CNSC, the Canadian Nuclear Laboratories,
L'Institut de Radioprotection et de Sûreté Nucléaire, or IRSN, and the University of Ottawa.

As part of the workshop, the participants shared results and information on the various research projects underway at their respective institutes and discussed topics of mutual interest.

Active and passive air samplers are used by CNSC licensees for measuring tritium in air. The results from both samplers can differ significantly. As a result, there are questions regarding the accuracy and the precision of the two methods.

A comparison of active and passive tritium-in-air sampling was included as an objective of the Tritium Transport in the Terrestrial Environment research project. The University of Ottawa developed a tritium-in-air sampler, as shown by the photo in the middle of the slide. This was validated using an Atomic Energy of Canada Limited air sampler in the photo shown on the right. The data that was collected was fit for purpose and used for research that was published in the peer reviewed literature.

The CANDU Owners Group has also investigated this research topic.

The work in this area has quantified the uncertainties with respect to tritium-in-air sampling and no further work on this area is planned.

Tritium-in-air monitoring is conducted by the licensee, other federal and provincial departments, such as Health Canada and the Ontario Ministry of Labour, as well as by CNSC staff as part of the Independent Environmental Monitoring Program and this provides verification of the concentrations of tritium in air around nuclear facilities.

From a regulatory perspective, people living around nuclear facilities that emit tritium are protected since the inhalation dose estimated, using either type of tritium-in-air sampler method, is a small fraction of the public dose.

As part of the tritium studies projects, CNSC staff were directed to enhance the regulatory framework for groundwater protection.

CNSC staff provided an update to the Commission in January, 2013 on two discussion papers that incorporated principles for groundwater protection.

The first discussion paper entitled, "Protection of Groundwater at Nuclear Facilities in Canada", addressed the integration of groundwater protection within the CNSC's overall environmental protection framework. The key aspects of this document were formalized as guidance as part of the CSA Group Standard N288.7, Groundwater Protection at Class 1 Nuclear Facilities and Uranium Mines and Mills.

These principles were also incorporated in CNSC Regulatory Document-2.9.1, Environmental Protection: Environmental Principles, Assessment and Protection Measures.

The second discussion paper is entitled, "Process for Establishing Release Limits and Action Levels at Nuclear Facilities". It addressed establishing release limits, action levels and effluent design objectives for radionuclides and hazardous substances released from nuclear facilities. It also recognized that groundwater is a valued ecosystem component that should be protected and considered when designing nuclear facilities.

Requirements and guidance for controlling releases to the environment, which includes consideration of groundwater at an end use to be protected, will be incorporated as part of a future CNSC Regulatory Document.

I will now turn over the presentation to Ms Julie Burtt to address the recommendation for additional studies in radiobiology and dosimetry.

MS BURTT: Thank you. Julie Burtt, for the record.

I am a Radiation and Health Sciences Officer and the CNSC's point of contact for the studies discussed on the next four slides.

The CNSC's Tritium Studies Project published in 2010 included an independent, comprehensive review and assessment of radiation protection principles and practices related to tritium.

The results and conclusions of this work was previously reported to the Commission. The recommendations from this project were that, although doses from exposures to tritium are low, further research may be beneficial for epidemiological studies and for individual dosimetry to confirm that bio-kinetic models are adequate and to reduce uncertainties.

In response to staff's recommendation, the studies on the Toxicity of Tritium: Effects of Low-Dose Tritium and Gamma Radiation Project was developed and led by Canadian Nuclear Laboratories, or CNL. The project will be referred to as the Toxicity of Tritium Project for the remainder of this presentation.

The CNL project is a multi-year collaboration between CNL, the CANDU Owners Group, IRSN and the CNSC. CNSC's role in the project included providing funding, as well as providing input and project design and data analysis for certain tasks.

The main purpose of the CNL project was to provide an in-depth analysis of the toxicity of tritium by investigating the relative toxicity of low-energy beta and gamma radiation.

The project consisted of six project tasks. Five of the tasks evaluated the toxicity of tritium by looking at cell and tissue responses in mice. An additional task evaluated the toxicity of tritium by considering the development of cancer over the entire lifespan of mice.

The lifespan study includes exposing 3,600 mice to different doses and forms of tritium and gamma radiation. This study is ongoing as it is a long-range study, as the average mouse lifespan is two and a half years.

ICRP bio-kinetic models state that HTO and OBT behave differently once taken into the body. Specifically, the ICRP bio-kinetic model predicts that HTO behaves like water and, therefore, HTO is homogenously distributed throughout the body. This same model predicts that OBT is distributed heterogeneously in body tissues and has a longer retention time.

The results obtained by CNL were in contrast to the existing ICRP bio-kinetic model for OBT.

The CNL toxicity of tritium study found that HTO and OBT had similar uptake, retention and excretion patterns; in other words, OBT behaved like ingested water. The significance of these results may influence the way a tritium dose is calculated. Additional studies are needed to confirm the results obtained by CNL.

From a regulatory perspective, these

results are unlikely to impact overall risk to health, since doses from tritium-releasing facilities are a small fraction of a person's total dose and are very low.

As mentioned previously, the ongoing work of the toxicity of tritium study is looking at the development of cancer over the entire lifespan of mice that are exposed to HTO, OBT and gamma radiation. The results from this study, once completed, in conjunction with the other tasks, will contribute to defining the RBE for tritium.

The RBE is a concept used to compare different types of radiation in terms of the same biological effect. There are many RBE values published in the literature. The variation exists because the RBE of tritium depends on whether x-rays or gamma rays are used as the reference. All of the studies inform the appropriate choice of eradiation rating factor that permits the calculation of the special unit of dose called the millisievert. The millisievert can be used for protection from all types of radiation, not just beta radiation from tritium. If requested, CNSC staff can provide an update to the Commission on the results of the Toxicity of Tritium Project, once the entire project is complete.

As a result of the work carried out by

staff, the recommendations of the project have been addressed. Specifically, research has been conducted investigating the variability in the OBT/HTO ratios in environmental samples. Studies have identified uncertainties in tritium-in-air sampling using both active and passive samplers. Groundwater protection principles have been incorporated in CNSC Regulatory Documents and CSA Group Standards. Studies have been conducted to provide an in-depth analysis of the toxicity of tritium.

CNSC staff conclude that the work that has been carried out to date has met the intention of the recommendations and that the objectives of the project have been met.

I will now pass the presentation to Dr. Nadereh St.-Amant.

DR. ST.-AMANT: Thank you.

Good afternoon, Members of the Commission. My name is Dr. Nadereh St.-Amant and I'm a Senior Analyst at the CNSC.

The following section provides an overview of CNSC Laboratory's activities for the analysis of different forms of tritium in environmental samples.

As part of the Tritium Terrestrial Environmental Project which was completed in 2012, the CNSC

Laboratory developed methodologies and acquired equipment for the analysis and processing of OBT in environmental samples.

OBT samples are typically prepared by combusting a dry portion of an environmental sample in an oxygen chamber, as shown here, followed by liquid scintillation counting of the collected sample. The image on the left of this slide is the Parr Oxygen Chamber that was implemented at the CNSC Laboratory in 2012. The image on the right is a new type of oxygen chamber that the CNSC Laboratory acquired in 2015.

As the first case study of the new equipment, the CNSC staff and the manufacturer of the equipment collaborated and recently published an article in the peer reviewed journal on the use and implementation of the new equipment.

With the expansion of the analytical capability, since 2012 the CNSC Laboratory has analysed the two major forms of tritium in over 2,500 samples in support of CNSC funded research projects, national and international inter-comparison exercises and the CNSC's independent environmental monitoring program.

CNSC staff remain up to date with the current methods and techniques for tritium analysis by participating in national and international working groups.

Since 2012, the CNSC staff has participated in an international OBT analysis working group. The group includes members from different countries including Canada, France, United Kingdom, Romania, South Korea, China and Japan. The working group meets annually to discuss the improvements in the analysis of OBT and to organize inter-comparison exercises. A member of the CNSC Laboratory has been part of the working group since its inception and has served as a member of the scientific committee since 2014.

The CNSC Laboratory has successfully participated in all inter-comparison exercises organized by the group since 2012.

The results of the first inter-comparison exercise was published in the Journal of Environmental Radioactivity, co-authored by CNSC staff.

CNSC staff also participated in an inter-comparison field study campaign with the IRSN staff. This study was carried out near SRB Technologies in Pembroke, Ontario for a two-week period during the summer of 2013.

The objective of the field campaign was to compare the methods used for sampling and measuring different forms of tritium. The results obtained by IRSN and CNSC were in good agreement for HTO measurements for tritium in air and in grass samples. Differences in OBT activity concentration results of some of the grass samples were noted and investigated.

The two laboratories concluded that the differences found were due to the inhomogeneity of the split samples, and not the analytical measurements.

The research collaborative work for the field campaign was published in peer reviewed journal co-authored by the CNSC staff.

As a result of CNSC Laboratory's active participation in the area of OBT analysis, in September, 2016 CNSC Laboratory was invited to host a practical training workshop as part of the IAEA's Analytical Laboratories for the Measurement of Environmental Radioactivity, or ALMERA. ALMERA is the world-wide network of analytical laboratories that are coordinated by the IAEA's environmental laboratories.

The CNSC hosted a workshop focused on sample preparation methods and on the analysis of OBT in food samples using liquid scintillation counting.

Participants from 14 countries attended the hands-on training. The comprehensive training provided would enable the participants to implement the acquired techniques and methodologies in their countries' analytical laboratories.

I will now pass the presentation to Mr. Elias Dagher.

MR. DAGHER: Good afternoon. My name is Elias Dagher and I am in the Environmental Risk Assessment Division of the Canadian Nuclear Safety Commission.

Tritium is monitored in different environmental media as part of licensees' environmental monitoring programs.

Tritium in the form of HTO is routinely monitored in air, water and food around facilities that release tritium. However, the concentration of OBT in the environment is traditionally estimated from the amount of HTO measured using the OBT to HTO ratio. OBT is being monitored in some environmental media at a number of CNSC regulated facilities.

The CNSC has been monitoring tritium in the form of HTO and OBT around nuclear facilities as part of CNSC's Independent Environmental Monitoring Program, or IEMP. The IEMP is a regulatory tool that complements the CNSC's ongoing compliance verification program.

The IEMP involves taking samples from

publicly accessible areas around nuclear facilities and measuring and analysing the amount of radiological and hazardous substances in those samples.

The sampling and analysis is conducted independently by CNSC staff with the results posted on CNSC's external website.

Since 2012, IEMP sampling campaigns have been completed around facilities that release tritium, such as research and tritium processing facilities, as well as nuclear power plants.

Samples analysed include air, soil and food, such as meat and vegetables. In all cases, the IEMP results confirm that people and the environment around these facilities are protected.

This figure displays an environmental transport and multi-pathway exposure model. It shows the many pathways that humans may be exposed to tritium in the environment. This exposure may be from natural background, or due to releases from the facility through the atmosphere, surface water and the ground.

For example, an exposure pathway to tritium may be from the inhalation of air or from the consumption of fish.

Using the data collected as part of the

IEMP, CNSC staff calculated the public dose due to multiple exposure pathways to a hypothetical infant, child and adult receptor. The objective of this dose calculation was to demonstrate that doses due to tritium exposure to members of the public living around tritium-releasing facilities are low and below the public dose limits of 1 mSv per year.

Furthermore, the dose calculation was based on the maximum tritium concentration measured for each environmental media and food analysed throughout the IEMP to date. It is, therefore, not specific to any nuclear facility. This approach allows for the simplistic high-level and conservative dose estimates.

This slide provides the results of the dose assessment. As we can see, the highest dose was received by the adult receptor. This was a result of the higher rate of consumption of water and higher inhalation rates by an adult. Due to the very conservative consumptions used, these results are about three times higher than the estimated doses to public reported annually by the licensees. This represents a very conservative dose estimate.

This figure shows the per cent contribution of each exposure pathway to the total tritium dose to an adult receptor of 0.035 mSv per year. Exposure from air immersion and inhalation were found to be the major contributors to the total tritium dose at about 70 per cent. The second highest contributor to dose was ingestion of water at about 28.5 per cent. Ingestion of food contributed to only about 1.5 per cent of the total tritium dose and only .5 per cent of the total tritium dose came from OBT through the food ingestion pathway.

Even at higher OBT to HTO ratios, the dose is not expected to change significantly as the total contribution from OBT in food is a small percentage of the overall dose.

In summary, the research projects conducted as part of the tritium studies report have expanded the CNSC's laboratory capabilities in the analysis of tritium in environmental samples. This has allowed the lab to support CNSC funded research projects, participate in national and international inter-comparisons and analyse samples as part of the CNSC's Independent Environmental Monitoring Program.

CNSC staff collect and analyse environmental samples around facilities that emit tritium. The results were used to calculate the dose to a hypothetical member of the public using conservative assumptions and the calculated dose supports the conclusion that members of the public exposed to tritium releases are protected, as doses are a fraction of the public dose limits and are below doses known to cause health effects.

I will now pass the presentation back to Mr. Rinker to conclude this afternoon's presentation.

MR. RINKER: Michael Rinker, for the record. I will now conclude staff's presentation.

Key aspects of the work that has been conducted as part of the tritium studies project, and other related studies, have been communicated to members of the public and the scientific community.

The project has communicated during two public information sessions and through eight CNSC information documents.

CNSC staff have also published seven articles in the peer reviewed literature and one chapter in the Encyclopaedia of Sustainability Science & Technology. Additional publications are still expected from ongoing work.

Abstracts from staff's research and summaries of different initiatives are posted on the CNSC's external web page.

Results of the IEMP around tritium-releasing facilities are also up to date with the

2016 sampling campaign results posted on the CNSC's external web page.

In addition to the publications that were produced as a result of the tritium studies project, CNSC staff have also contributed to international documents on the tritium science. For example, most recently CNSC staff were acknowledged by the United Nations Scientific Committee on the Effects of Atomic Radiation, or UNSCEAR, 2016 report for their work in preparing the first draft of the annex on the biological effects of selected internal emitters, including tritium.

The CNSC information documents and peer reviewed publications are evidence of the CNSC staff's decade-long engagement in research regarding the behaviour of tritium in the environment, as well as the radiobiology and dosimetry of tritium.

Based on the work presented here and previously to the Commission, CNSC Staff maintain that adequate provisions have been made through existing regulatory mechanisms for the protection of Canadians from exposure to tritium releases.

CNSC Staff are of the opinion that the project has met its overall objectives of increasing the information available regarding tritium releases and enhancing the regulatory oversight of tritium releasing facilities.

CNSC Staff will continue to remain abreast of the latest developments in tritium science in support of the regulatory oversight of tritium releasing facilities.

CNSC Staff request that the Commission endorse CNSC Staff’s conclusion that the intent of the project has been fulfilled.

This concludes CNSC Staff’s presentation. We are now available to answer any questions. Thank you.

THE PRESIDENT: Thank you. So let’s proceed to the question session, starting with Dr. Demeter.

MEMBER DEMETER: Thank you for that presentation. I have to commend the Staff on this large body of research, publications, and reports, which I’ve had a chance in my past and other -- that I’ve had time to review, read, and reference a lot. So thank you for that.

As some of my other colleagues may have found, the one study which found that HTO and OBT had similar uptake retention and excretion patterns in contradistinction to biokinetic models from the ICRP. I found that very interesting because it phenomenally changes the dose considerations, because the effective dose is what you calculate the committed dose from a person. If they have the same as water, then it has a very different effective halftime versus OBT.

I looked at the original reference which you put in there, which linked it to three amino acids; alanine, glycine and proline, I think.

But the question is, how do you square the circle where the international literature says that they're different, they have different retention periods, which affect effective dose? This says that it acts like water. That's the question I had.

MR. RINKER: Mike Rinker for the record. So this research is the result of research that is conducted by CNL, who are here today and can answer some of those technical questions for you.

I would like to say though that the CNSC is still relying on the international body of knowledge. While this is a very interesting study that we're going to look and pursue, we are not altering how we would expect the dose consequences of tritium exposure to be calculated.

THE PRESIDENT: Why don't we invite the CNL people to join us?

DR. KLOKOV: Hello everybody. My name is Dimitry Klokov, I'm a scientist, trained radiobiologist. I'm the head of the section of Radiation Biology at CNL.

Regarding the biokinetics of OBT and, in similarity to HTO, as correctly was pointed, we tested three amino acids, and these are the results that we found. Their kinetics were very similar. I think there are other studies that examine other forms of OBT which are not necessarily amino acids, that might be the reason.

So although we found their biokinetics is similar, we found some differences in their biological effects, which was not covered by this presentation probably because the data is still under processing and analyzing. But we found that OBT had more effects -- led to more biological effects than HTO. That can be an expression of internal differences, how those different forms of tritium behave in cells and outside the cells in these different forms.

But as to why they have similar kinetics, in our studies we have no scientific answers for that.

MEMBER DEMETER: The one thing I wondered -- thank you for the answer -- is that the specific forms of OBT found in nature might be linked to more complex molecules that are much more difficult for the body to manage, versus a more simplified OBT with a single amino acid. But I'm speculating as well, because I couldn't figure out the answer.

DR. KLOKOV: Yes, you can only speculate on that. I think that the spectrum of OBT, different forms of OBT that are found in the environment, is huge and it's definitely different, it's not three amino acids that we studied, that might be the reason. But that's probably an interesting point to address in future studies.

THE PRESIDENT: But is it only one study that found this or was it replicated by a few other studies?

DR. KLOKOV: No, we're reporting results of our own study, that was one study, but it was a large study and robustly done.

THE PRESIDENT: Thank you. Dr. Soliman.

MEMBER SOLIMAN: Thank you very much for the presentation. I have a question about the active and passive air sampling of tritium. Every method, as indicated, has its own uncertainty and approximation.

Again, every method has its own approximation and uncertainty, and I would like to know from your point of view which method is suited, our sampling?

The reason I'm asking this question is because the open literature is -- some of the literature is preferring the active, and some others are preferring the passive. So from our point of view, which one we support more?

MR. RINKER: Mike Rinker, for the record. So an excellent question, it's the question that we were working on for several years. I would say, first of all, the first observation when we did a comparison, actually a CANDU Owners Group conducted the comparison, they found that active samplers around the Bruce site reported lower values than -- sorry, the passive samplers were lower than the active samplers, suggesting that active samplers might be more conservative.

However, the contrary was found at the Pickering nuclear site and the Darlington site. So to find out which one gives precisely the real answer, it's unclear. What was found though is the active samplers have more reproducible measurements, and so there's a reliance factor there that is important.

A disadvantage of an active sampler is it requires power, it requires the use of pumps. So for a facility like a nuclear power plant where you can frequently go out and survey, the emissions are constant. It's a reasonable preference to rely on active samplers and indeed the nuclear power plants have shifted over to that type of monitoring methods.

In contrast, there is a tritium processing facility in Pembroke, it releases tritium up the stack, but not continuously, it's in pulses. So one day with an active sampler you could go out and take a measurement, it may be very different than if you went two days later. It depends on when you go.

That speaks to the advantage of a passive sampler, which you could hang throughout the community on telephone poles and other areas and get an average value that was calculated over the course of a month.

So there are advantages and disadvantages over the two methodologies.

I think what we have now is a reasonable measurement of tritium in the environment that we can go out and confirm through our own independent environmental monitoring program the power reactors have shifted to an active system. SRB Technologies in Pembroke relies on the passive, we feel that their programs are both substantial and provide us with the information we require for compliance.

THE PRESIDENT: So you're not worried about your using one methodology and the licensee using another methodology, because you can reconcile them or how does it work?

MR. RINKER: Mike Rinker, for the record. Sometimes it’s good to have different methodologies to look at the same parameter so you’re aware of if there are any biases that occur. In the case of the nuclear power plants, they do have some passive samplers around in communities and they have active samplers, so we se that comparison.

With the Independent Environmental Monitoring Program we go out to Pembroke to the SRB facility with our active samplers, and they have a compliance program based on passive. So we see the two results and we have an good understanding of what the tritium concentrations are.

THE PRESIDENT: Thank you. Dr. McEwan.

MEMBER McEWAN: Thanks, Mr. President. Again, congratulations, just a great paper and presentation, thank you.

On page 9, sort of going back to OBT and HTO, I was interested in the variability that you got with the exposure pathway, and the change in ratios, particularly the anomalous results you got with air.

Does that have any implications for the way in which you would build an inspection on a regulatory regime in terms of long-term review of monitoring parameters and analysis of that?

MR. RINKER: Mike Rinker, for the record. So I'll start and I'll ask my subject matter experts if they can add something.

So I think, fundamentally, the issue with the ratios is in lab experiments it's fairly precise, 0.7 seems to be a reasonable ratio. Lab experiments allowed the system to reach equilibrium. In nature, that's not occurring and I think that, fundamentally, that's the issue. Is you have releases of tritium that could be in pulses, wind direction changes, and tritium is mobile as HTO is water, so you get evapotranspiration, and OBT is not as mobile as HTO.

So we're rarely seeing equilibrium get reached. So we are doing surveys to try to get an understanding. So what's a reasonable method to bound what the ratios could be? We have done a fair amount of work, and when we come for our licence renewal hearing, for example, while the licensee has followed the standard as appropriate and has done some extra calculations, we do our own calculations of what if the ratio is as high as 10 or 15, to make sure that those consequences to members of the public are quite low.

So by doing that, I think we're assured that all of the facilities are providing us with the information that allows us to conclude that the dose consequences around those facilities is very low and protective.

So we are comfortable with waiting for the next revision of that standard, which will be in 2019, where the CANDU Owners Group is conducting a nation-wide survey of OBT ratios, and all of that science can be brought in over the next couple of years to revise the standard. We don’t feel that there’s a reason to react now.

THE PRESIDENT: So what is the bottom line? Let’s assume it’s revised fundamentally. I’m looking at the bottom line with respect to impact on health or impact on the environment.

MR. RINKER: Mike Rinker, for the record. So the impact is not that substantial. If we could bring up slide 34, I believe. This slide illustrates the contribution of OBT towards the total dose that a person would receive. What’s important is in the blue area the majority of dose that comes to a person is the air you breathe, and OBT does not exist in the air.

A large proportion in red is the water you drink, and OBT does not exist in that water. So OBT only exists in that sliver at 3 o’clock in that slide, and that’s the component for which the ratio matters.

So coming up with the appropriate ratio, while it's critical that from a scientifically-based organization we know what we're talking about, overall it doesn't have a huge impact.

THE PRESIDENT: Okay, thank you. Dr. Demeter. Oh, you want to follow-up on this? Go ahead.

MEMBER McEWAN: So I just want to follow-up on this, because I remember an intervener, I think at Bruce, who made a comment about pregnancy and tritium, which I thought was perhaps less helpfully constructive than it might have been.

Does any of the work you've done over the last 10 years on this project, and particularly recently, provide any reassurance that he was perhaps overstating the problem or understating it? Do you remember that?

MR. RINKER: Mike Rinker, for the record. I remember it at Pembroke for the SRBT hearing, if that could be it? So there was a fair amount of misinformation in that presentation, and we did try to explain the science.

But the only way to really approach that is the type of outreach that we're doing to try to meaningfully engage with the public who hear that. It's hard to combat when a medical doctor explains something that is important to health of a pregnant woman, the public reacts to that.

We do have, in general, the science related to -- at least the most advanced internationally, the science related to the biokinetics of tritium in the human and what people are actually exposed to, and there is no credence to the fact that pregnant people are at risk and their infants are at risk to tritium exposures around any of those facilities.

MEMBER McEWAN: Just one final comment. I really liked that last slide you just showed, the distribution of input. That was a really nice slide.

THE PRESIDENT: I also like the cubes. So pictorially it tells a story, which is good, thank you.

Dr. Demeter.

MEMBER DEMETER: Just a question on your international OBT analysis work group. I'm not trying to make this a theme, but it lists the number of countries you're involved with; France, United Kingdom, Romania, South Korea, and Japan.

The NCRP in the U.S. has published extensively on tritium as well and they've got a large body of expertise at Oak Ridge and Tennessee. Are you involved with them at all, tapping into their experience?

DR. KWAMENA: Dr. Nana Kwamena, for the record. So I can't speak to the analysis group, but as part of the MODARIA program that I mentioned during the presentation I have been able to be in touch with someone from the U.S. DOE who has put me in touch with their Tritium Working Group, I believe it's called. So I have made that link and so we have made that connection. So we haven't fully explored it, but at least we've made that initial link if we want to explore any future initiatives.

MEMBER DEMETER: I raise it not to be North American centric, but given the impact on the Great Lakes and the impact of the Canadian nuclear power industry on the Great Lakes relative to the tritium concentrations, I think there's a lot of interest across the border given that heavy water reactors produce a lot more environmental tritium than light water reactors. So that's the only reason I made that connection. Thank you.

MR. RINKER: Mike Rinker, for the record. If I could comment on that, I think it's an important statement, that the Great Lakes matter, particularly with relation to tritium.

We're doing a body of work about how impacted the Great Lakes have been to radionuclides in the nuclear industry. What is interesting to note about tritium in the Great Lakes is the concentrations of tritium peaked in the mid-1960s, late-1960s, where Lake Ontario was close to 40 B q/L, similar with Lake Ontario, even Lake Superior was closer to 20 Bq/L, as a result of bomb testing that occurred above ground up until around 1960.

The tritium concentrations have been decreasing ever since, despite the fact that a nuclear power industry has been constructed and operating during that same period.

THE PRESIDENT: In addition, weren't you and your staff invited to testify about tritium post-Yankee shutdown, which they discovered some tritium leakage and you were invited, I think, by the U.S. NRC to testify, were you not?

MR. RINKER: Mike Rinker, for the record. So that's correct. They did have some problems with aging reactors and they had tritium releases that were in groundwater. The releases were quite low because, as Commissioner Demeter had mentioned, the reactors are designed different, they're tritium content are less.

Nevertheless, they had concerns because in the U.S. a tritium plume may mean there's something else coming, such as strontium. So I was invited to provide information to the Commission at the NRC about what tritium -- what our understanding is, what are the groundwater drinking standards, and how appropriate they are and other facts like that.

THE PRESIDENT: Thank you. Dr. Soliman.

MEMBER SOLIMAN: Thank you. I have questions about the issue of OBT to HTO. I understand from your write-up/presentation that tritium exists in three forms; HT, HTO and OBT. Why do we emphasize on the OBT over HTO ratio? Each one of them can be large, but the ratio can be very small. So what is the reason for concentrating on OBT over HTO? That’s the first part of the question.

The second part, if it exists in three forms, is the equation supposed to be OBT over HTO, plus HT?

MR. RINKER: Mike Rinker for the record. Very good question, why are we doing all of this is not something that we have stated. Organically-bound tritium, OBT, is not something that is very easily measured in the environment. So a licensee may have many data points regarding HTO, but less regarding organically-bound tritium. So one way to get around that is to model its behaviour, and so a ratio is used so that you know if you have measured HTO, then by default you can calculate what your OBT concentration is.

So that ratio is a factor that's used in the model to determine what is the OBT value in the absence of data.

MEMBER SOLIMAN: My question is, yes, you are assuming that OBT is 100 per cent -- is a product of OBT or function of OBT alone. But there is HTO also, then the equation has to be adjusted, OBT over HTO, plus HT also, if it exists.

So if you get the ratio, the ratio means that OBTs were used only by HTO. But HT in there can have contribution, isn't it...?

MR. RINKER: Mike Rinker, for the record. So HT is often released from nuclear facilities, but it would then be oxidized to HTO if it comes down in rainwater or cycles through food. HT gas, in general, is not cycled through the soil, where HTO is. OBT is converted from HTO to OBT by micro organisms that exist in soils and brought up in through plants.

I'll ask Dr. Kwamena to provide more information about the relationship between HTO and OBT.

DR. KWAMENA: This is Dr. Nana Kwamena for the record.

So the current understanding is that the OBT is formed from the HTO and so that is why the focus is on this OBT to HTO ratio. As Mr. Rinker said, HT is released from facilities, but generally its dose consequence is almost negligible. Therefore, the impact has to be from its oxidation to HTO. That can happen in the soil but that's a very small percentage, it's almost like 2 percent. So the real contributor to the formation of OBT is from HTO. If you wanted to have the ratio as you suggest, which would be OBT over HTO plus HT, because that HTO contribution is so small, it's negligible, in a sense it goes to zero and essentially you're left with this OBT over HTO, which is where most of the scientific research has been focusing.

MEMBER SOLIMAN: Okay. The leaves -- if there is an HT, the leaves do not absorb that through the leaves, it's not necessary to go from the soil?

DR. KWAMENA: Dr. Nana Kwamena for the record.

That is correct, you can have foliar deposition of HT onto the leaves. There could be oxidation of those because microbes that oxidize to HTO could also exist, but again, that contribution is very small. The main driver is the HTO more so coming up through the root system than through foliar deposition.

But you're right, this is also a

mechanism, but the main focus of the scientific literature has focused on the contribution of HTO. In fact, CNSC staff, using the results from our 2008 and 2009 study, are looking at the impact of the HTO pathway into a contribution in OBT formation, but in the greater scientific community this is believed to be a pathway of somewhat minor importance.

THE PRESIDENT: Thank you.

Dr. McEwan.

MEMBER McEWAN: Thank you, Mr. President.

A couple of use of English. I'm just helping interpreting data.

For Table 2 and Table 3, because these are like to be used standalone and I found myself having to flip backwards and forwards, it would be helpful to have CRL and SSI and SRBT just -- I know you've mentioned it before but I think in the table itself it would be helpful.

On page 22 of -- again, it was just it clashed a little bit with me. In the first paragraph in 3.2.2 you say:

> "The purpose of this dose calculation was to demonstrate..."

It seems to me you've made an *a priori* decision there and it might be better to modulate that just a little.

And then on page 16, on the bottom line on page 16, "has achieved very good results." I have no idea what that means. It would be helpful "namely that" or something just to help clarify.

And then on -- I'm sorry, I'm not doing very well with slides here. You have one slide where you summarize the outcomes of the project and in one of the statements you say that there has been -- you've found a difference between passive air sampling and active air sampling and leave it at that. I mean I think that begs the question of: Is it important, what do we need to do about it, does it have implications, as we discussed earlier. I just think it clarifies what is otherwise an excellent document.

THE PRESIDENT: Okay. Dr. Demeter.

MEMBER DEMETER: Thank you. Just a technical point. Slide 23 of your presentation, the second bullet says:

> "The RBE of tritium varies depending on whether x-rays or gamma radiation was used as the reference"

From a technical point of view it would be helpful to actually say the energy differences, because x-rays and gamma rays are the same, they're both photon drive radiation sources, so it depends whether it's the nuclear source of the photon or an electron shell source. So somebody reading this would say, is that a 250 kV or a... That's the only -- it's just a technical observation to give the standard reference source.

THE PRESIDENT: Thank you.

Dr. Soliman?

Dr. McEwan?

Okay. Well, I've got a couple of observations at least.

First of all, on your chart on page 8, you show the university laboratory versus CNSC laboratory. What are the units we are -- what are we mentioning here? And slope is .99 (NS). Can somebody explain to me what NS is?

--- Pause

MR. RINKER: Mike Rinker for the record.

So the units are becquerels per litre, and not significant is the NS.

THE PRESIDENT: I don't know why those things catch my eye. On page 7 you talk about the mean OBT over HTO ratios. So I want to understand, "1.0±1.7". Plus or minus what? Is it the percentage?

MR. RINKER: Mike Rinker for the record.

Since it's a ratio, it's unitless.

THE PRESIDENT: But how can it be a minus? Okay, I'm missing something here.

DR. KWAMENA: This is Dr. Nana Kwamena for the record.

So it's providing the mean plus the standard deviation. So the ratio is unitless, but then it provides the standard deviation.

THE PRESIDENT: Oh, the negative one. Okay. I just want to make sure it's clear and, you know, what do we mean by that.

And one more. On your table in the Annex, what I was wondering is why there were no measurements for Pickering on some of the IEMP data. You didn't do one or where is all the information? I'm looking at page 21 and all the N/A's, you know.

MR. DAGHER: Elias Dagher for the record.

The reason -- so we do see -- we did measure fish. Around tritium we try to find local produce and that was not very easy to do because it is within a big city. So for Darlington for instance, when we conducted the IEMP sampling campaigns there, there was an abundance of local vegetation and food, not so much around Pickering.

THE PRESIDENT: But you know that Pickering, in fact Pickering has to get authorization on fish from DFO, and with the licence renewal coming up, that's why I was surprised that this data was not available on Pickering. It may become available, I don't know.

MR. DAGHER: Elias Dagher for the record.

So we have sampled fish in the past at other nuclear facilities such as Bruce, but we do that when it is available, when we are able to actually get fish from that location.

MR. RINKER: Mike Rinker for the record.

So we don't have a boat and so we have to rely on others to collect the fish for us.

THE PRESIDENT: Not a good answer. I think -- you want to add anything to this?

MS SAUVÉ: Kiza Sauvé, I'm the Director of Sciences and Environmental Compliance Division.

So we did sample in 2017 for the independent environmental monitoring program at Pickering and those results will be available before the upcoming relicensing. Fish was not done in 2017. We do look for local farms as much as possible. It is difficult in Pickering. It's hard to get local foodstuffs, it's hard to get local fish. Moving forward we're going to be working more with indigenous groups and local communities when we're making the sampling plans to be able to respond to those questions. So we are hearing you.

THE PRESIDENT: Okay. Well, you know that it will be an issue in the Pickering licensing renewal.

On your page 24 when you talk about control of releases to the environment, you're talking about the requirement of controlling releases will be coming. I thought we -- when is that? I mean are we developing something new in a regulatory document on that?

MR. RINKER: Mike Rinker for the record.

Yes, we are. There is Regulatory Document 2.9.1 Part II, and that is going to deal specifically with releases and setting release limits, and it will incorporate also environmental action levels. There was a CSA standard for the development of action levels for releases to the environment that was published earlier this year and that will be incorporated into our Reg framework as well.

THE PRESIDENT: Do you have any timelines on this? When is it going to happen?

MR. RINKER: Mike Rinker for the record.

We have a draft developed for internal review and we hope to go out to the public in the spring I believe of 2018. I will have to confirm with our Regulatory Affairs Branch. They have a list of priorities that they are trying to get out and this is not on their top 10.

THE PRESIDENT: Okay, thank you.

My final question is I don't think any study on tritium can be complete without treating our drinking water and tritium. What's new on that front and the debate about 7,000 Bq/L versus 10 Bq/L? So where is all of this going to be discussed or resolved?

MR. RINKER: Mike Rinker for the record.

So the Health Canada guideline is 7,000 Bq/L and that remains the standard in Ontario, 7,000 Bq/L. Many years ago, I think we're approaching 10 years ago now, there was a committee that recommended 20 Bq/L and in fact they calculated a range between 15 and 117. If they were going to go that route, we had recommended 100 Bq/L. That is what is being achieved by the industry in wells that are located at the perimeter of licensed facilities. However, Ontario has a list of maybe 15 radionuclides that have standards that do not follow the approach that was taken to recommend 20 Bq/L. So I think internally the province is struggling with a way forward on this recommendation and for now it remains stalled with the province.

THE PRESIDENT: So is it still a work-in-progress or are you still in dialogue with them, are they looking for any help in this or suggestions?

MR. RINKER: Mike Rinker for the record.

So we do periodically discuss the topic. They have our advice in writing with them. We've asked for updates on whether they're proceeding and it does not look like -- they have not stopped -- they have not decided against the recommendation, but they have not made any progress moving forward.

THE PRESIDENT: Thank you.

Any final question?

Okay, thank you. Thank you very much.

We'll take a 10-minute break, 15-minute break -- 2:40.

--- Upon recessing at 2:26 p.m. /
Suspension à 14 h 26

--- Upon resuming at 2:42 p.m. /
Reprise à 14 h 42

CMD 17-M46/17-M46.A

Oral presentation by CNSC staff

THE PRESIDENT: The next item on the agenda today is an information item on the biological mechanisms acting at low doses of radiation. This is outlined in CMDs 17-M46 and 17-M46.A.

I understand, Mr. Rinker, you still have the floor. Over to you.

MR. RINKER: Thank you, Mr. President and Members of the Commission. My name is Michael Rinker, Director General of the Directorate of Environmental and Radiation Protection and Assessment.

I am accompanied by staff members of the Health Sciences and Environmental Compliance Division, Mrs. Julie Burtt and Dr. Julie Leblanc, both Radiation and Health Sciences Officers in that Division, as well as Dr. Rachel Lane and several other subject matter experts to help address any questions.

We are also accompanied by Dr. Patsy Thompson, who serves as the CNSC's Technical Advisor, as well as Vice Chair of the United Nations Scientific Committee on the Effects of Atomic Radiation, or UNSCEAR.

We are here today to present CMD 17-M46 in response to a request from the Commission following a public meeting in Ottawa on April 6th, 2016. The Commission requested that staff present the current science on the effects of low doses of radiation.

I will ask Dr. Leblanc to begin the staff's presentation.

MS LEBLANC: Thank you.

For the record, my name is Julie Leblanc. As mentioned, I am a Radiation and Health Sciences Officer.

Before I begin with the presentation, I’d like to draw your attention to the picture of the cell on this slide. It is here as a reminder that today’s presentation will be focused on radiation biology, the field of study that looks at the effects of radiation on living things. Typically, experiments in this field are performed on cells, parts of the cell or on whole animals.

Radiation biology complements epidemiology. The latter is the study of the factors affecting health and illness of human populations and how disease is distributed.

Until recently, epidemiological studies

could not provide firm conclusions as to the health effects from the low doses of radiation, nor can they offer any explanation of what is going on inside the human body following radiation exposure. Radiation biology experiments are useful as they can offer a biological basis for what occurs within the low dose range.

To understand the effects of radiation, we will first review some fundamental concepts in radiation biology.

Within the radiation protection framework, there are three different, but related, types of dose often discussed.

The first, on the top of the screen, the absorbed dose, is expressed in a unit called the gray, but more commonly referred to as milligray, which is 1,000 times smaller. It describes the energy deposited by radiation in a kilogram of substance, like tissue. When discussing human health studies or radiation biology studies of cells or animals, this is the unit typically being used as it is a physical unit.

The next two units are radiation protection quantities. This means that judgment has entered the equation since both terms include weighting factors grounded in science but determined by scientific committees.

The equivalent dose, expressed in sieverts, or more commonly milliSieverts, is the absorbed dose weighted for the different types of radiation. This weighting factor accounts for the fact that for the same dose some types of radiation are more biologically damaging than others. The example on the middle of the screen shows that alpha radiation is 20 times more biologically damaging than both beta or gamma radiation for the same dose.

At the bottom of the screen, the effective dose, also expressed in milliSieverts, is the equivalent dose weighted for the sensitivity to radiation of the organ or tissue exposed. Some tissues and organs are considered to be more sensitive to radiation, that is, radiation can be more harmful to certain tissues or organs. This occurs because the cells that make up those tissues divide more frequently. You can see in the diagram three different examples of weighting factors are listed: one for the testes, one for the lungs, and another for the bladder, demonstrating that the testes have a larger weighting factor and are thus considered to be more sensitive to radiation.

The figure on this slide is providing context for the term "low dose." The grey box symbolizes

100 mSv. This is the value we tried to limit our review of the literature for the purposes of the CMD and today's presentation. At times, greater doses were considered, but our work focused on radiation biology experiments where the doses were in the low dose range, that is, 100 mSv or less.

To put this value in context, we can compare the grey box to several other values.

First, the green box represents the nuclear energy worker dose limit of 50 mSv in one year. The 100 mSv over 5 years component of the dose limit is not shown on this figure.

Second, the blue box represents the annual average natural background in Canada of 1.8 mSv.

Third, the orange box symbolizes the annual public dose limit of 1 mSv.

Workers typically receive a small fraction of the CNSC dose limits year after year. The doses discussed throughout this presentation, which are 100 mSv and below, are particularly relevant as they are in line with that -- with what nuclear energy workers actually receive over their lifetime. The doses to members of the public are 100 to 1,000 times lower than the CNSC public dose limits and are thus relevant to today's discussion, as they are significantly lower than the doses used in experimental radiation biology studies.

Another concept to understand before we move on to the biological effects of radiation is radiation quality. Radiation quality is a measure of energy that is transferred from the radiation to the exposed matter, or the tissue, over a given distance. This is referred to as the linear energy transfer, or L-E-T.

The L-E-T can impact the type of damage that may happen to the cell as a result of the exposure to radiation. Therefore, it is important when comparing experimental results from different studies to know which type of radiation was used.

As you can see at the top of the diagram, low L-E-T types of radiation, like beta radiation, transfer their energy to the tissue or organ in a sparsely ionizing pattern over a large distance, whereas high L-E-T types of radiation, like alpha radiation, transfer their energy in a dense ionizing pattern over a comparatively small distance.

The implication here is that high L-E-T radiation could cause damage to the cell that is more difficult to repair than low L-E-T radiation.

Although radiation can pass through and deposit its energy in any part of the cell, nuclear DNA has classically been considered the most critical molecule because it is the set of instructions or genetic code that dictates how your cells will grow, divide and function.

This set of instructions is passed from cell generation to cell generation. Damage to DNA could result in an adverse biological effect, like a mutation, which in theory could increase the risk of developing cancer.

After radiation exposure, the cell will mount a response to maintain the integrity of the genome, which is the sum total of an organism's DNA, to minimize any adverse effects or biological damage caused by the radiation. Many parts of the cell like the cytoplasm, mitochondrion and cell membrane, as shown on this image, all have important roles to play when a cell responds to radiation.

The figure on this slide shows a cartoon version of DNA where the two sides of the molecule are linked and together form what is called a double helix.

If radiation does deposit its energy in the nucleus of the cell where the DNA is housed, it can cause damage either through direct or indirect action. This means that radiation either interacts directly with the DNA or the radiation interacts with atoms in the surrounding environment, creating molecules called free radicals, which in turn interact with the DNA.

The important take-away from this picture is that both direct and indirect actions of radiation can result in the same type of DNA damage.

The type of DNA damage we are most interested in is called a double strand break. As you can see in the image on this slide, a double strand break is where both sides of the DNA double helix are severed or cut. There are many different types of DNA damage that exist, and we will not go over all of the different types but focus on double strand breaks, as they are considered to be the most severe form of DNA damage since they are the most difficult to repair.

Furthermore, DNA damage is strongly associated with the development of cancer.

Double strand breaks can occur via normal processes -- cell processes, excuse me, such as DNA replication or cell division. They can also occur due to environmental stressors such as radiation, ultraviolet rays, natural or synthetic chemical agents.

As stated on the previous slide, double strand breaks can occur as a result of natural cell processes or by some environmental stressor. To put this into context, cells can sustain and repair a relatively high rate of naturally-occurring DNA damage. Approximately 50,000 sites of different types of DNA damage occurs per cell per day. Approximately 10 of these naturally-occurring events are double strand breaks.

Thus, if cells can adequately deal with this level of naturally-occurring DNA damage, then a small number of additional radiation-induced double strand breaks would be of little consequence for cancer risk. Again, the amount of DNA damage at a cellular level is proportional to dose.

For example, a dose of five milliGray of low L-E-T photons or electrons would result, on average, in 0.25 double strand breaks per cell per day.
The fraction of a double strand break, or the 0.25 number, is a reflection of probability that at such low doses some cells will be traversed by radiation and develop a double strand break, while others will not.

As we've been discussing, if radiation passes through a cell causing damage like a double strand break, the cell will then mount a response to maintain the integrity of the genome. This response will either lead to proper repair of the damage resulting in no increased cancer risk or there will be misrepair or a lack of repair leading to an increased cancer risk as indicated by the pink cell.

However, an increase in the risk of cancer is just that, an increase in risk; it does not mean that a cancer will necessarily arise. This is demonstrated by the possibility that the cell highlighted in pink can either become cancerous or not indicated by the black and blue cells, respectively.

What I would like for you to take away from the fundamentals of radiation biology section is that, first, ionizing radiation can damage DNA, but this damage is most often repaired.

Second, double strand breaks are the most severe type of damage since it is the most difficult to repair.

Third, improperly repaired damage can contribute to cancer development.

And fourth, environmental exposures of radiation produce a small fraction of damage compared to what occurs in our bodies every day.

I will now pass the presentation to Mrs. Julie Burtt.

MS BURTT: Thank you Dr. Leblanc. For the record, my name is Julie Burtt, and I am a Radiation and Health Sciences Officer with a background in radiation biology.

Next we will discuss how epidemiological studies of people who have been exposed to radiation have helped us understand the risk of developing radiation-induced cancer. This risk is described by a dose-response model.

A dose-response model is a theoretical model that describes how the risk of cancer varies with radiation exposure.

The risks from radiation have largely been derived from epidemiological studies of the atomic bomb survivors. Where there was data, typically above 100 milliGray, the dose response was linear, meaning that as dose increased, so did cancer risk. However, in the low dose range, the natural incidence of the disease masked any effects that may have been caused solely by radiation. Because of this, the linear-non-threshold model, shown on this diagram in red, assumes that the cancer risk at low doses can be linearly extrapolated from the risk observed at higher doses. Recent chronic low dose epidemiological studies of nuclear energy workers have provided additional support for the LNT model.

Also featured on this diagram in blue is a dose-response model called the linear quadratic model, which assumes an upward curvature between dose and cancer risk. Of note, the linear quadratic model best describes the risk of developing leukemia due to radiation exposure.

Overall, the data from epidemiological studies is typically consistent with either a linear or linear quadratic dose-response model.

As the nuclear regulator, we use the LNT model for radiation protection purposes, that is, to inform the choice of appropriate dose limits.

The international radiation protection community understands that the LNT and linear quadratic models cannot explain all experimental data. There is epidemiological evidence supporting some non-linear dose-response models, but this largely stems from high dose epidemiological studies.

For comparisons' sake, the LNT model is shown in red on all three images on this slide.

The first image on the screen describes a threshold dose-response model, shown in yellow, which assumes that there is no risk incurred until a certain dose is exceeded. For example, a threshold dose of a few thousand milliGray has been observed for select cancers, like bone cancer.

The middle image on the screen shows a

supralinear dose-response model, shown in blue, which assumes a greater risk than predicted by the LNT model. This model best describes extremely radiosensitive patients suffering from certain rare genetic disorders.

The third image on the screen shows a hormetic dose-response model, shown in purple, which assumes that the risk from radiation is not only lower than predicted by the LNT model but could, in fact, lead to stimulatory and beneficial effects which at larger doses become detrimental. Although there is support for the hormesis model in animal studies, there is no human epidemiological evidence supporting this model to date.

The figure on this slide is an exaggerated representation of how both low dose radiation biology and epidemiological studies support the five different types of dose-response model, each with their own curve. The colours of each line are consistent with the previous two slides, that is, the supralinear model is in light blue, the LNT model is in red, the linear-quadratic model is in dark blue, the hormesis model is in purple, and the threshold model is in yellow.

In epidemiological studies, the outcome of interest is typically cancer development in people exposed to radiation. In radiation biology studies, the outcome of interest is a particular biological effect, like DNA damage, for example, which can be observed in a cell or from an animal exposed to radiation. The level of DNA damage and subsequent repair is often used to draw conclusions about cancer risk in people.

What I would like for you to take away from the dose-response models section is that, first, the LNT model cannot explain all scientific data. This model is practical from a regulatory perspective and conservative from a health perspective.

And two, the international regulatory community, including the CNSC, continues to use the LNT model for regulatory purposes. The CNSC regulates based on the best available scientific data and continues to monitor developments in the scientific literature. Presently, epidemiological evidence cannot confirm any dose-response model below approximately 100 mSv. This is where experimental radiation biology studies of different biological mechanisms can help explain each dose-response model by providing insights as to what may be occurring in living organisms at low doses. Four different biological mechanisms will be defined and explained in the following slides.

As we've discussed earlier, when radiation passes through a cell, the cell is going to mount a response. A biological mechanism encompasses the steps between a stress response to radiation and a resulting biological effect. The effect of interest is typically DNA damage.

It should be noted that each of the four biological mechanisms discussed can be induced by other stressors, like chemicals, for example.

The reason we are discussing the different biological mechanisms is because, in theory, each one could influence the shape of the dose response curve, and we are interested in what is going on at the cellular level in the low dose range.

To review, the first biological mechanism that we will discuss today is the bystander effect. This mechanism was presented to the Commission in April of 2016.

Bystander effects are radiation-like effects that are observed in unirradiated cells that are responding to communication signals from directly irradiated neighbouring cells. The nature of these signals is not fully understood at this time, but reactive oxygen species are thought to play a major role.

This figure shows how the ionizing radiation only interacted with one cell, highlighted by the red nucleus in panel A, and that red nucleus has sent communication signals to the pink nuclei as highlighted in panel B. As far as the cell can tell, whether it has a pink or red nucleus, they will both act as if the radiation passed right through each and every pink and red nucleus despite the fact that it only passed through the cell highlighted with a red nucleus.

Importantly, the identification of the bystander effect confirms that energy does not need to be deposited in a cell to produce a biological effect and, therefore, the whole cell, tissue or organ can respond to radiation exposure.

The bystander effect could be either a protective mechanism or a mechanism that leads to detriment. For example, if communication signals were to lead to the destruction of bad or unhealthy cells, this mechanism could be considered as protective. However, if communications signals were to create adverse effects in neighbouring healthy cells, like inflicting DNA damage upon them, this biological mechanism could be considered as detrimental.

The second biological mechanism, also discussed before the Commission in 2016, is genomic instability. Genomic instability is described by the accumulation of new genetic alterations, or changes, observed in the progeny of irradiated cells, even multiple cellular generations after the initial hit by radiation. A cellular generation is the result of a cell dividing to produce two identical daughter cells. Each new cell generation is indicated by a downward pointing arrow.

As you can see in the figure on this slide, different types of changes like mutations shown in green or different types of damage to whole chromosomes called chromosomal abnormalities shown in purple and red can be observed multiple cell generations after the initial hit by radiation. These alterations or changes appear to be random in nature and timing.

Genomic instability is a hallmark of cancer and thus is considered to be a biological mechanism that solely leads to detriment.

The third biological mechanism is considered to be a protective mechanism. As you can see in the figure on this slide, the adaptive response is where a small priming dose of radiation, indicated by the purple bar, serves to increase the resistance of the cell to a subsequent larger challenge dose, indicated by the blue bar, typically given several hours later. Importantly, less DNA damage, indicated by the red arrow, is observed when you combine a priming and challenge dose compared to when the challenge dose is delivered alone.

The adaptive response is the best studied mechanism that supports a hormesis dose-response model.

The last biological mechanism is referred to as hyper-radiosensitivity increased radioresistance, or HRS/IRR. This biological mechanism is defined by an increase in sensitivity to radiation between 10 and 300 milliGray, followed by an increase in radioresistance between approximately 300 and 1,000 milliGray.

HRS/IRR is best described using the induced repair model, a model derived from the linear quadratic model. The induced repair model, shown here in blue, differs from the linear quadratic model, shown in red, as it theoretically accounts for the induction of DNA repair machinery. In other words, the induced repair model describes the HRS/IRR mechanism because it accounts for the induced radioresistance, hence its name.

The molecular basis for the hyper-radiosensitivity increased radioresistance phenomenon is that lower doses are less capable of triggering DNA repair or other radioprotective mechanisms because there is not sufficient DNA damage to induce these mechanisms, resulting in cell death, observed as hyper-radiosensitivity, and that higher doses inflict more DNA damage, subsequently triggering the repair mechanisms, resulting in an increase in cell survival, observed as increased radioresistance, which eventually reaches the cell survival rate approximated by the linear quadratic model.

The mechanisms presented in this section provide an overview of the possibilities of what may be occurring at the cellular level following very low, low and moderate doses of radiation. These terms are defined by the United Nations Scientific Committee on the Effects of Atomic Radiation, or UNSCEAR, are indicated on the slide where very low doses refer to doses lower than 10 milliGray, low doses refer to doses lower than 100 milliGray, and moderate doses refer to doses between 100 and 1,000 milliGray.

The figure on this slide provides a breakdown of the broad range of doses at which each individual biological mechanism has been observed in vitro in the literature. As you can see in red, genomic instability is observed as low as 10 milliGray, but generally between 100 and even over 1,000 milliGray.

In purple, the bystander effect has been observed as low as five milliGray, but generally between 10 milliGray and 1,000 milliGray.

In yellow, the priming component of adaptive response has been observed at low as one milliGray, but generally between one and 200 milliGray.

In green, increased radioresistance, or IRR, is typically observed above 300 milliGray.

In blue, hyper radiosensitivity, or HRS, has been observed as low as 10 milliGray, but generally below 300 milliGray.

For IRR and HRS, there is a grey zone for where the cell transitions from a state of sensitivity to a state of resistance.

While these mechanisms have been observed over a broad range of doses, we are interested in them because they occur both at -- they occur in the low dose range. What’s more, they'll all generally occur at an optimal dose of approximately 100 milliGray, demonstrating that they can be active at the same time.

What I would like for you to take away from the biological mechanisms section is that low doses of ionizing radiation induces many biological changes, and these changes can be explained by the following biological mechanisms: the bystander effect; genomic instability; the adaptive response, and hyper-radiosensitivity increased radioresistance.

Further, to better understand the contribution of these mechanisms on human health, the study of the interaction between these mechanisms will undoubtedly be a source of important information.

The relationship between the different radiation-induced biological mechanisms has been reviewed in the literature, but few studies have directly considered multiple mechanisms at once.

Several key proteins active in several molecular pathways are known to be involved in all four of the biological mechanisms discussed in this presentation shown in white at the top of each column. This table highlights the role of select proteins in three different molecular pathways important for cancer development shown in black listed in each row.

The first row refers to DNA repair. Radiation induces DNA damage. In response, the cell activates DNA repair. The successful repair depends heavily on the levels of key proteins involved in DNA repair.

The second row refers to the Cell Cycle Regulation. In order for new cells to be generated, cells naturally go through a process of duplication and division known as the cell cycle. The regulation of the cell cycle helps facilitate the repair of any DNA damage, including radiation-induced DNA damage.

The third row refers to Oxidative Stress. Reactive Oxygen Species, or ROS, are produced in the course of normal cellular processes such as during energy production in the mitochondria. Typically, mitochondria are equipped to reduce ROS levels when needed. However, if levels of ROS become too elevated, oxidative stress could occur which could lead to DNA damage. Radiation can also lead to oxidative stress.

Of note, while all of the biological mechanisms listed in this table have each of the molecular pathways in common, each biological mechanism may lead to the activation or inhibition of the particular molecular pathway. For example, oxidative stress is increased during the bystander effect but decreased during the adaptive response.

The similarities with regards to the shared molecular pathways discussed on the previous slide may help explain some of the other common features of the four biological mechanisms.

Recent studies have stressed that the four biological mechanisms discussed here are not mutually exclusive. However, exactly how these mechanisms interact remains an important research question.

Biological mechanisms could be affected by the activity of other mechanisms, perhaps even acting together or against one another.

This slide highlights the need to better understand the individual biological mechanisms, but also if and how they act in concert. The answers to these questions will improve our understanding of the contribution of each biological mechanism to any potential health outcomes.

So what does all of this mean?

Are there any potential health implications from the biological mechanisms that we've discussed? In other words does the radiation exposure under consideration that is causing changes at the cellular level lead to an increase, a decrease or no change in cancer risk at the individual level?

The potential health implications depend on whether or not DNA damage is successfully repaired. Persistent DNA damage could compromise the integrity of the genome. Genomic integrity, which forms the base of the figure on this slide, is the maintenance of our genetic code. It ensures proper function of not only our cells, but our tissues, our organs and our body as a whole.

The loss of genomic integrity can lead to an increase in cancer risk. As the figure on this slide demonstrates, the maintenance of genomic integrity is a delicate balance between radiosensitivity and radioresistance.

Radiosensitivity could result from a combination of biological mechanisms that are driven by factors such as lack of DNA repair or an increase in oxidative stress.

Radioresistance could be -- could be the result from a combination of different biological mechanisms that are driven by factors such as an increase in DNA repair or a decrease in oxidative stress.

At this time, there is not enough evidence to demonstrate the impact of the biological mechanisms on radiation-induced cancer risk at low doses. More research on the interaction between of all of the biological mechanisms is needed before we can determine under what circumstances the scale will tip towards radiosensitivity or radioresistance.

Going forward, the careful consideration of the limitations of radiation biology studies and a better understanding of the low dose DNA damage response will be critical in assessing radiation-induced cancer risk. It's difficult to take experimental cell studies or animal studies in an attempt to extrapolate what that means for the risk of cancer in humans.

For example, careful considerations could include whether cell or tissue-specific effects observed in *in vitro* experiments reflect the true response in the body as a whole, whether uniform animal who have the same age, sex, diet, lifestyle, and genetic background can represent diverse human populations, and whether experimental dose and dose rates are representative of environmental exposures.

Of note, it is also possible that the different biological mechanisms impact an organism at the cellular level only and may not impact overall cancer risk.

I’d like to pass the presentation back to Mr. Rinker to conclude with Staff thoughts on where the science is, where it's going and how it impacts our regulatory oversight.

MR. RINKER: Thank you.

Michael Rinker, for the record.

To conclude, cells respond to radiation exposure in a multitude of ways.

The biological mechanisms discussed here depend on cell type, some of which have different radiosensitivities, radiation quality, as an example high L-E-T alpha radiation induces more complex types of DNA damage than low L-E-T beta or gamma radiation, and biological endpoint, what was the observed or measured experimental outcome. Today we've discussed DNA damage as an example in some detail.

The balance between positive, negative or neutral effects at the cellular level may or may not impact overall health.

Given the outstanding uncertainties in the low dose range, there is not enough scientifically sound evidence to warrant a change from the current radiation protection framework which bases its dose limits found in the Radiation Protection Regulations, in part, on the LNT dose-response model. Any uncertainties in risk estimates are further minimized by the use of the ALARA, As Low As Reasonably Achievable, principle.

Together, the dose limits and the ALARA principle effectively minimize worker and public exposures to safe levels.

Given all of the information presented today, it is staff's conclusion that the current Canadian radiation protection framework is robust and protects workers and members of the public.

With regards to the next steps for the subject matter presented to you today, staff intend to publish a technical summary of this work in the peer-reviewed literature.

In order to continue to regulate based on the best available science, CNSC Staff will continue to monitor developments in the scientific literature.

Staff have also identified areas where potential research projects could be initiated. For example, future studies should focus on how biological mechanisms can influence cancer development in humans. Notably, these studies should consider all biological mechanisms and not focus solely on one mechanism, and both *in vivo* and *in vitro* studies that elucidate the signalling pathways are also warranted.

Thank you. That concludes our presentation today, and we are available to respond to any of your questions.

THE PRESIDENT: Thank you.

So let's jump into the questions starting with Dr. McEwan.

MEMBER McEWAN: Thank you, Mr. President.

So again, congratulations. Excellent,

excellent paper.

And having said that, I'm just going to start off with two minor criticisms.

The Hanahan and Weinberg paper that you quote on page 17, they updated that in 2010, and it's a very significant update, so you should be using that as your reference. And it would actually change a little bit, I think, of the way in which the text in that paragraph reads as well, but I think that's important.

My second comment, I guess, is when you talk about the way in which -- so this is on page 19, response to DNA damage. You don't discuss cell death, either apoptotic or necrotic. And again, I think in the context of what you're trying to achieve with this paper, that's probably an oversight that could be corrected easily and usefully.

So a question. And in fact, it's a question that struck me a number of times.

So in the discussion, you talk about nuclear DNA and nuclear DNA damage. What is the impact to the cell of mitochondrial DNA damage?

MS BURTT: Julie Burtt, for the record.

So out of the papers that we read for the literature review to put this work together, mitochondrial

DNA and the 37 genes that it impacts were not highlighted in the literature. The most common topic areas were mitosis and how DNA damage would impact that process.

So to answer your question, I'm not sure how mitochondrial DNA would come into play there, but the focus of our literature review definitely focused on nuclear DNA.

MEMBER McEWAN: Okay. And maybe just while doing one more troll of the literature, I seem to remember one or two papers which at least discussed it.

And again, I think, as this is becoming a public document, it's important, even if you find nothing, to say that you found nothing, I think.

THE PRESIDENT: Dr. Demeter?

MEMBER DEMETER: Thank you again.

It's an excellent piece of work. It's a complicated story to tell in one session.

I wanted to concur with Dr. McEwan that for like slide 10, which is talking about radiation-induced cancer risk, that cell death is important because it means that there's no harm to the individual.

And same with the bystander effect on page 17, if there is an induced bystander effect where the cells have shorter survival versus becoming genomically unstable, and that is also of no significant necessary consequence to future division to that cell.

The question I have is more philosophical from a regulatory point of view.

As there's an evolution and challenge to LNT as a model for low-dose radiation response and ALARA is based strongly on LNT, there's going to be considerable increased attention paid to the other parts of ALARA, the economically and socially acceptable, where putting the bar so low where the model is competing with a bunch of other models may have -- you might find licensees saying putting another inch of lead in that water -- millimetre of lead or -- there's going to be some potential pushback because there might be difficulty in demonstrating effects at that very low dose level, way below dose limits, we're talking.

So that -- when the licensee hears we gotta do X, Y and Z unless economically -- an economic hardship, how do we decide where to draw that line based on these evolving models of harm and low dose effects?

MR. RINKER: Mike Rinker, for the record.

So I'd like to pick up on the example you used about that one more millimetre of shielding as an example.

So that would be a direct capital cost

that would reduce a dose field, as an example.

I've attended a number of workshops where industry are discussing amongst themselves about ALARA, and I think ALARA's a very important program to us and to the industry. And what they've really looking at and under the definition of ALARA is to optimize their processes, so they're not necessarily looking at the purchase of a new mitigation measure. They're talking about lessons learned, how could they do their work in a -- procedurally in a way that could minimize worker exposure.

And I think in general, whether it's radiation or whether it's any other chemical exposure, for a company that's continually thinking about can they do the same work in a manner that minimizes the exposures to people and to the environment other ways is a really positive aspect.

And I think that's where the majority of the efforts are going, and we have not received very much pushback on that issue to date.

THE PRESIDENT: Thank you.

Dr. Soliman.

MEMBER SOLIMAN: Thank you.

It's a very good presentation. I enjoyed reading it. But I don't deny that it is very scary, too, really.

I have question. This is not the field I read a lot about it now, so my questions will be maybe in the basics, depending on my knowledge, also.

My question here will be about gamma and x-ray.

These are rays. That means it's a wave. The wave has two stressors. From continental mechanics, the wave has two stressors.

The wavelengths which share the frequency of the wave and the amplitude, which is the energy content, so these two sometimes, depending on their receptor structure, the frequency play a bigger role than the energy. And in some other structures, the damage can happen by the load, which is energy in this case. This is what we do in quantum mechanics.

Is this exactly the same here or different? Does the frequency have any effect or damaging effect on the cell? Knowing that the cell has a frequency, the cell has -- okay, let me just --

MR. RINKER: It's a really interesting --

MEMBER SOLIMAN: I didn't complete my question.

The frequency content of the load, that's number one.

Number two, any structure has a material property, has a boundary condition, and it has a shape, and it has a mass. It has a frequency also. But the frequency of the receptor is hidden inside the -- it doesn't show. So if the frequency of the load content will match the frequency of -- what we call natural frequency of the structure, you will have a resonance, and maybe I was thinking from the standard model that the effect of frequency, yes, the load which is the energy is hitting one cell, but because of the frequency, the damage will be more to other cells.

So would you please elaborate on that.

MR. RINKER: Mike Rinker for the record.

So I'll start just to make sure we understand the question. You're asking a biologist to answer a physics question. But to make --

--- Laughter / Rires

MR. RINKER: I think the second part is regarding the --

MEMBER SOLIMAN: I think --

MR. RINKER: -- regarding the frequency of the --

MEMBER SOLIMAN: Just a second please.

I think there is no difference between all the science. For example, the quantum mechanics is a branch of science which is -- can explain any phenomena on fluid mechanics, solid mechanics, heat transfer, physics. So because this is not my area, but I can see some resemblance between what is here and what is -- quantum mechanics says.

MR. RINKER: Thank you. Thank you for that clarification.

So the question on the frequency of the receptor, by analogy, I believe you're referring to, as an example, the frequency of microwaves are chosen in a way that link to the frequency of the receptor being water in food particles, and that enables the food in your microwave to heat up. There's a relationship between the frequency of the wave and the frequency of the receptor.

And you're asking from a radiation perspective is the frequency of the radiation induced and the damage it caused impacting on the frequency of the receptor, being the cell or the DNA in this case.

I'll ask Dr. Du Sautoy to answer that question.

MR. DU SAUTOY: I just want to clarify a little bit about your view about waves. And you're right, the answer lies in the quantum mechanical explanations of what's going on. So at these sort of very small sizes and relatively high energies, then what appears to be waves actually show themselves as particles. So instead of looking at the amplitude and frequency of a wave, you actually get properties relating to particles, in particular the number of photons and the energy of photons. And the certain energy of a photon will cause ionization in atoms. And the ionization of the atoms cause the radicals and the molecular effects that are going on.

So the wave view of what's going on is actually really replaced by a particle view through quantum mechanics. And then you look at the particle interaction. So in fact, a better view of what's going on is more like billiard balls. So electrons and photons behaving like billiard balls interacting with atoms, and that's what's causing the ionizing radiation and so forth that go on to produce these effects at a molecular level, if that helps you.

MS BURTT: If I could just add to the second part of your question was with regards to the receptor. So for the cell, one thing that the bystander did teach us is that the receptor doesn't really matter. The fact the nuclear DNA is the end point doesn't really matter -- the energy could be deposited anywhere in the cell, in the cytoplasm, near the mitochondria, in the nucleus -- the adverse effects can occur in cells even if the radiation didn't pass directly through them. So the receptor at the end of the day isn't the whole story, if that helps.

MEMBER SOLIMAN: Yes, it helped. The capability of gamma ray and X-ray to penetrate, is it that this is maybe function of the frequency to penetrate the skin?

MR. DU SAUTOY: I think the penetration ability is simply the interaction cross-section for certain particles. So you imagine the electrons as particles was the apparent cross-section, and that tells you the probability of penetration to a certain area. It's not really related to the width of the wave.

THE PRESIDENT: Okay. Thank you.

Dr. McEwan.

MEMBER McEWAN: Thank you Mr. President.

So a couple of again suggestions, if I may.

I think it would be very helpful to put in probably a diagram of the repair mechanism path from ATM down. I think it would help some of the text as you read it, particularly again given the fact that this will be a public document. And you can then show where each of the different elements arises in that. Just a thought.

The other suggestion, I think it's important also in your text to recognize that the bystander effect is seen in other biological phenomena. So for example, transplant rejection, the bystander effect is seen. So this is not a biological effect that is entirely limited to a radiation effect and it needs to be put in that, again, sort of almost evolutionary context.

So a question. Is there any evidence, do you have any thoughts on whether or not the dose-rate at which radiation is delivered is important? Or is it simply a secondary component of your thoughts on dose?

MS BURTT: Julie Burtt for the record.

In all of the literature that we've reviewed for this work, the factor that would change the outcome of the experiment was definitely cell type, the type of radiation and quality, so high LET or low LET.

And there were very few studies that within the same study and same experimental conditions used a high dose-rate and compared it to a lower dose-rate within the same study. So if I do comment, my comment would be comparing different studies.

So it seems like it does have an impact, but because that wasn't performed within the same study, it's difficult to draw firm conclusions. But dose-rate does seem to have an impact on the outcome measured.

MEMBER McEWAN: You should probably look for Brian Marples' "Inverse Dose-Rate Effect." I think it's an important emerging element of this area that again I -- it may be overly ambitious to try and include it in this review, but I think you at least need to acknowledge it.

MS BURTT: It is a paper that we've read and noted. It's just not something that is evaluated across all the different biological mechanisms by each. But there are select people who are leading in the field that are looking at that, so I definitely appreciate that comment.

THE PRESIDENT: Dr. Demeter.

MEMBER DEMETER: Thank you.

I like the inclusion of impact on the individual cell, the bystander effect. You talked about various differences in background radiation between different countries and some very high background countries, which have had some epidemiological effect.

In your glossary you have, under the

bystander effect, you talk about it's not to be confused with two other -- cohort effect or abscopal effect. And it would be nice in the text somewhere to describe the abscopal effect, because it has historical reference for people receiving radiation therapy in one part of their body and having effects totally distant from any radiation field. So it's an interesting phenomenon and adds to the body of the radiation biology.

The question I have is there's a growing literature looking at individual susceptibility to radiation -- beyond the people that have extreme genetic disorders that have extreme sensitivities -- but amongst the regular population, and the impact that may have in tailoring exposures to individuals -- patients, in my case. Is there -- do you have any comments on individual variability and how that may impact going forward in a radiation biology point of view?

MS BURTT: Julie Burtt for the record.

One phenomenon that is plagued by individual variability is adaptive response. So that's a reason why people cite that that phenomenon has not been able to be reproduced in just if you change the cell line or different experimental conditions. It's particular. So it's one where you see that being raised over and over.

For the other biological mechanisms, it's not something as noted in the literature, but it's -- it's definitely an emerging phenomenon, and to extrapolate what we're seeing in cell studies to individual sensitivities to radiation needs more research.

THE PRESIDENT: Thank you.

Dr. Soliman.

MEMBER SOLIMAN: I have a question about cells' resistance or cell -- what makes a cell more or less responsive to radiation? If I had the same dose and -- there is many cells representing many tissues in the body and they are different, as you explain here -- for the same dose the response will be the same for all of them or the harm for the cell will be the same? Or it will be different? Like I can -- okay, I can give a dose. It will kill one cell, but it might not kill another. So what is the reason for that and why?

MS BURTT: Julie Burtt for the record.

So probably the main reason would be where the cell would be in its cell cycle. So there are different phases of the cell cycle. So if the cell is in a resting phase, getting ready for DNA synthesis, resting again, or getting ready for DNA division -- or cell division, pardon me, depending on what stage the cell is at in that cycle will make it more or less sensitive to the effects of radiation.

MEMBER SOLIMAN: Is this regardless of the dose amount?

MS BURTT: Julie Burtt for the record.

Are you asking if it is a dose-rate effect?

MEMBER SOLIMAN: If the dose is high, it can kill one cell but maybe will not kill another cell. So whether it is on the transformation phase or not, is this true, and what is the reason for that.

MS BURTT: Julie Burtt for the record.

We have to be careful about when we're talking about low doses versus high doses. So if you do have a dose of, say, several grays, you are going to most likely induce death in a large group of cells. If you were talking about doses in the low-dose range, then the stage of the cell cycle would probably be more of a determinant of would it be detrimental or not. Does that help?

MEMBER SOLIMAN: Yeah, okay. Thanks.

THE PRESIDENT: Thank you.

Dr. McEwan.

MEMBER McEWAN: Thank you.

So again, maybe you could just go through a 101 explanation of genomic instability again. Because as I've listened to the conversation and as I read your document, again thinking of the target of publication as a public document. And you've really got two targets, because you've got the peer-reviewed literature and then you have this as, you know, the 101 guide to it. And I think they're both really, really important.

Can you just take me through it one more time so that I'm clear that I understand what you're saying, please.

MS BURTT: Julie Burtt for the record.

So I won't go over my speaker's notes in -- exactly, but I will reread the definition. We can talk about the definition.

So genomic instability is described by the accumulation of new genetic alterations or changes observed in the progeny of irradiated cells, even multiple cellular generations after the initial hit by radiation.

So if we're looking at accumulation of new genetic alterations, if we're looking at the figure on slide 18, please. Thank you. If we're looking at the accumulation of new genetic alterations, we have examples at the bottom of the slide. Micronucleus is written in blue, mutation in green, cell death in black, mititotic failure in blue, and two different types of chromosome aberrations or abnormalities in chromosomes in purple and red. So we're adding different types of changes or alterations as you go along, as the cell generation divides and continues to divide across multiple generations.

So when I say a "generation," if you put a pen along the line and then you have an arrow going down, that's a new generation, and then arrows going down another new generation as cells divided. So as you go along from cell generation to cell generation, you're adding changes or adverse effects. And they're accumulating in number. And this can be several generations after the initial hit of radiation. And the experimental evidence for this has shown that it can go over 20 cell generations, you're still accumulating changes.

I think the last thing that I wanted to mention was depending on whether the cell turns a colour to mark a change or stays beige, it's random in timing and in nature.

Does that help?

MEMBER McEWAN: I needed you -- thank you -- to go through it again.

I think you need to discuss the implications of the change in colour. What are the issues that are likely to develop because of that? I don't think it needs to be a lot of text, but I think there needs to be a brief description. Because as you said it, it's all accurate, it's all right, but there's sort of that next step of explanation.

The other piece in the text that I think can be made a little more -- given a little more clarity is where you discuss chronic inflammation and epigenetics. Again, I think you need to make it clear that we're talking about different mechanisms, not this as a combination of mechanisms -- could be a combination of mechanisms. But I think you need to sort of just again make that a little bit clearer. Because you're talking about radiation, and then suddenly epigenetics pops up and chronic inflammation pops up -- just in terms of clarity.

But within the context, it's well explained, so again, thank you.

MS BURTT: Julie Burtt for the record.

So I'll just comment. The context that I will add is that a cancer is not going to develop based on one little green circle. Many changes and alterations need to occur before an unhealthy cell will turn into a full-blown malignant cancer. So that's the point that I'm making and I will highlight. Thank you.

THE PRESIDENT: Thank you.

Dr. Demeter.

MEMBER DEMETER: Thank you.

I wanted to strongly concur with a statement you put in 1.3 of your page 10 of your document that "the LNT model should not be used for individual or population-based cancer risk assessment," as is done commonly in the literature and leads to all kinds of issues with trying to communicate, especially to patients when those kinds of things get published. I really appreciate that.

THE PRESIDENT: Not only in the literature, in the press and some of your colleagues --

--- Laughter / Rires

THE PRESIDENT: -- should know better. They use it quite often.

MEMBER DEMETER: Yeah, I bellow that every day.

The one question is did you come across any literature that -- we talk about radiation safety as time-dose shielding or time-distance shielding. I use dose as well, because if you lower dose, you lower -- the fifth one is ameliorating factors. Have you come across any evidence or literature that patients can modify their risk -- or people, public, workers, patients -- by antioxidants or any other form of biological intervention that might reduce their sensitivity?

MR. RINKER: Mike Rinker for the record.

Other than of course iodine, we're not aware of any.

MEMBER DEMETER: Thank you.

THE PRESIDENT: Dr. Soliman.

MEMBER SOLIMAN: I have a question in CMD 17-M46. On page 35 it says "higher doses of radiation resulted in a slower rate of repair than lower doses."

And in page 33, item number 2, just above the Figure 15, under HRS IRR it says "high doses inflict more DNA damage ... triggering the repair mechanisms, resulting in an increase in cell survival."

How is these two statements is -- can we elaborate on these two statements, because it looks like they are talking about different things.

MS BURTT: Julie Burtt for the record.

One thing that was very difficult to harmonize for this work was every time you find a paper that states one thing, you will most certainly find a paper that states the opposite.

So in each of the respective papers that you are pointing to, they did find results that seem contradictory. But again, their experimental design and set-up was not the same. And you have to take into account which type of radiation was used in each one. Was it a high LET or low LET, and are you comparing apples to oranges.

MEMBER SOLIMAN: Yeah, well, both of them are talking about higher doses. "Higher doses of radiation resulted in a slower rate of repair than lower doses." The second one, it say "higher doses inflict more DNA damage ... triggering the repair mechanisms, resulting in an increase in cell survival."

So both of them are talking about the higher dose.

MS BURTT: Julie Burtt for the record.

So for one of the papers, we are talking about high LET, and for the other we're talking about high doses. So that is different words that are trying to explain very different concepts. So the Neumaier paper on page 35 that you're referring to were talking about doses about a gray. And then the previous paper is lower doses but delivered at a higher rate.

MEMBER SOLIMAN: Okay.

MEMBER McEWAN: I think it's also

important to recognize that the dose that induces the radioresistance is not a particularly high dose. It's simply higher than the hyper-radiosensitivity dose.

THE PRESIDENT: Okay. We're back to the top. Dr. McEwan.

MEMBER McEWAN: So I just have two comments. Slide 23 I really, really like the blue box. In a field dominated by physicists, I think it's nice to see the biologist recognized. Although I do have a colleague who says that all biology is simply applied physics.

--- Laughter / Rires

MEMBER McEWAN: Another colleague.

And slide, if I can find it, 25, I really like also because I think it weighs the different risks. And I think if, you know, the text around that -- polish it a little bit. It's a really, really good slide.

THE PRESIDENT: I actually like the whole slide deck. It's really -- whoever put those diagrams and photos, I think if you can actually -- I hope at least the deck will go into the public. I'm not sure that anybody in the general public will read the details of the document itself, but the deck and some of the animation, if you can animate some of those things in it, should be almost a bestseller in trying to explain those complicated issues.

So congratulations on that one.

MS BURTT: Thank you.

THE PRESIDENT: Dr. Demeter.

MEMBER DEMETER: I have no questions.

THE PRESIDENT: Okay, so just so we know how complicated this is, I don't know if you have any comment, have you been watching the Americans now tie themselves in knots one more time to try to get epidemiological study or whatever study on low radiation? It's again coming up in Congress. They're trying to force DOE to continue on what they've started many years ago. And the Americans -- I understand American expert society or -- I can't remember which society it was -- couldn't agree on methodology that can actually measure the true impact of low-dose radiation. So any comments on that?

And maybe while we got an honourable ex-member here -- Dr. Thompson, welcome -- you can tell us about whether UNSCEAR or ICRP ever will acknowledge that they are different dose reaction and maybe venture into the difference between regulatory requirement, regulatory limits, and health limits. So it's a mouthful. Who wants to go?

MS BURTT: Julie Burtt for the record.

So my colleague Dr. Julie Leblanc and I

saw that in the media clippings and watched the hour and 41 minutes of riveting discussion.

So on November 1st what happened was the United States House Subcommittee on Science, Space, and Technology held a hearing on the future of low-dose radiation research. Because if you'll remember, the USDOE, or Department of Energy, defunded the program for low dose research and a lot of great things came out of that program.

The hearing didn't include any DOE employees, but it did call upon experts to give their opinion of how important low-dose radiation research was, and how taking money away from that program to fund biomass fuels may not have been in the best interests of the country.

But the conclusion of the whole hearing process was that the hearing committee highly encouraged the DOE, who were not present, to undertake a leadership role to increase the inter-agency collaboration to improve information on radiation-induced health effects.

Without the USDOE program it doesn't mean that the Americans are not moving forward. There are many academics there who love their work and are passionate about it and are getting together in other forums. One of them is called -- it's the ideas workshop, the Dose Alliance group. And they want to formalize together a methodology for studying the effects of low doses. And they're borrowing a page out of the chemical toxicity chapter and looking at how people who study chemicals and cancer development have done so. They're trying to apply that framework to all low-dose radiation research.

So the Americans are trying very hard to get back their low-dose research. And I'll ask Dr. Patsy Thompson to elaborate on UNSCEAR's position as well as ICRP's position.

DR. THOMPSON: Patsy Thompson for the record.

Essentially what I can say is that UNSCEAR has for the last number of years done work to better be able to extrapolate -- so do scientific documents the way UNSCEAR has traditionally done scientific documents with good literature reviews and a strong peer review process before the documents are published.

But there is also much of an effort that's going on to provide guidance on when we can use scientific studies, such as epidemiological studies, to draw conclusions on individual's risks or population risks after exposures, especially to very low doses -- low doses of radiation.

It's been, as was mentioned earlier by Dr. Binder, the use of the LNT to make estimates of the number of cancers in populations exposed to very low doses of radiation. I think it's been recognized that it's -- it may be a useful tool following an accident for public health planning, for example, and medical surveillance planning so that you can sort of have an idea of what types of budgets you would be looking at and how many people you may need to care for. But even then, that use has limitations. But it's certainly not appropriate in terms of doing individual risk assessments.

And so UNSCEAR has done a lot of work to clarify those concepts and go from essentially risk estimates to extrapolation and conclusions on who would be at risk and not.

The other thing that is being done as well is recognizing the limitations of epidemiology for doses below 100 mSv for the large number of exposed individuals that would be needed, where there's a project now going on looking at radiobiology as we've been discussing today but in a context where looking at the -- essentially the processes, the genes that are either up-regulated or down-regulated in the context that is specific to cancer risk estimate assessments. So that eventually the hope is to be able to bridge the gap between what epidemiology can provide as evidence and using biology, essentially, to be able to make better estimates of cancer risk at doses between 10 and 100 mSv. And so that work is going on.

The document on -- the biology document is expected to be ready for publication in 2019. And that work is going on. There's a number of Canadians involved in that work as well as Americans and colleagues from other countries.

In terms of ICRP, they do focus on regulation. UNSCEAR's role is really in terms of the science and providing the best scientific documents for use by the IAEA and the ICRP. ICRP has indicated that they will continue to use the LNT and other framework because it has proven useful for regulation, recognizing that it does have its limitations. But I don't think it'll change any time soon.

THE PRESIDENT: Yeah, but there is a dilemma here. There's a real dilemma which Fukushima really brought forth that for regulatory reasons we use the LNT model and we set up the ALARA and we came up with the 1 mSv dose for the public. But then for recovery and all of a sudden people are talking about 20 mSv as being okay to come back to your home. And people say, What happened to the 1 mSv? Because they look at the 1 mSv as a health limit.

So I think there's a misunderstanding about what the 1 mSv is and how it's related to actually health effects where -- so are we talking about there's no real perceived impact below 100 mSv, yet we are imposing a 1 mSv, and you keep talking about protect the environment and the health.

So there is -- do you see -- am I seeing a problem here for a regulator, particularly post-accident, about the recovery?

DR. THOMPSON: Patsy Thompson for the record.

You're right. The use of the ICRP framework for accident and post-accident situations -- the documents are relatively clear. The issue is in terms of having ingrained in people that 1 mSv is a safe level.

And ICRP has documented -- it's written in black and white -- that 1 mSv is what they find borderline acceptable risk of cancer. And so when you put something like that in, it's not a big step after that for people to say, well, you know, anything above that is unsafe. But borderline acceptable means that the cancer risk if, you know, one in a million or one in a hundred thousand, essentially they've assigned something that they find -- society has found acceptable. And 1 mSv is really approaching what would not be acceptable for other risks in society.

But it was never designed to deal with contaminated sites and post-accident situations.

THE PRESIDENT: So my second question on my -- I don't know -- my rant, really, is so we all know about background radiation; right? We evolved as a species with radiation. So you know, you see a range between 1.8 here in Canada and maybe go all the way up to -- in fact you mentioned a couple of places -- Kerala, India and China, which I think it's all the way up to almost -- I don't know if you know what the number is, but they're high numbers; right?

So we have some interveners came to us and say, We're all dying slowly out of -- from background radiation. Or the other that they say that with background radiation there is a limit. There is kind of a thing that you don't see any impact on health because otherwise we would actually all slowly die from background radiation.

So how do you reconcile those observations and the health impacts? Somebody help me with this.

DR. THOMPSON: Patsy Thompson.

I think the issue is developing a framework to regulate industries that are controlled by humans and that are controllable, where on the other hand you have a natural situation where essentially it's not controllable, it's not -- what ICRP would say -- amenable to control. And in that case, then, higher doses are acceptable.

And perhaps Dr. Lane can speak to some of the studies that have been done in Kerala, India and Iran and China from a radiobiology point of view. The studies that have been done, unfortunately, are not always clear-cut. There's some studies that show evidence of greater DNA damage in these populations. Other studies don't.

Some studies have shown that, you know, from an epidemiological point of view, in some cases it looks like you may have an increased risk, but not a significant one; and in other cases not. So, it's not that clear-cut.

THE PRESIDENT: But the one we're familiar with is the one -- the Colorado. I think they've studied the Colorado intensively and I don't think there was any differentiation between, you know, the various country and the mortality.

So to me that reads like there is a threshold, at least at the background level there should be a threshold. So, what am I missing and why is the ICRP and all the rest of the people are not saying there is a threshold?

MS LANE: Rachel Lane, for the record.

I'm going to talk to you about the Kerala Study. Now, the Kerala Study is a very high background radiation area and it's not uncommon to have cumulative exposures over 200 milligray which is quite -- is high.

When this has been -- the best study of this population basically indicated that the dose response was flat, okay, implying that there's no dose response relationship in this population.

However, there are problems with this study because of the accuracy of the dosimetry, the migration of the population, the ascertainment of cancers, and so on. So, what needs to be done in this community is to have better dosimetry and better ascertainment of cancers to really understand the effect.

It's not a perfect study and more research is being done on it, but this is a good example of a very high background community.

One thing I do want to point out is, when you do epidemiological studies you have confidence intervals and you have a point estimate. And what you see in studies is, although you have low doses, you may not have a statistically significant increase in risk, but what you do have is your confidence intervals that can be quite high and quite low. They basically cancel out, but that does not mean to say that we do not see people at low doses with increased risk, okay, even though the risk is low, the risk does exist, and I think that's something that you need to consider.

Thank you.

THE PRESIDENT: Okay. I don't think we're going to resolve it here, but I think the take-away for everybody is that a lot more research needs to be done and I think there are many, many organizations that would like to see more research done on this.

So, any final question?

So, thank you. Thank you very much for this. And I really hope that this will find its way to some sort of publication, both in the scientific community which will get into the details, but also in the public which is a little bit more simpler in trying to understand it.

So, thank you for that.

This concludes the public meeting of the Commission. Thank you for your participation.

MS McGEE: If you borrowed interpretation devices, please remember to return them to the reception and claim your identification card.

Thank you. Bonne fin de journée.

--- Whereupon the meeting concluded at 4:04 p.m. / La reunion s'est terminée à 16 h 04