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Supplier Document

Building Condition Assessment In-situ Decommissioning of Whiteshell Reactor 1 (WR-1)

WLDP-26000-REPT-011

Revision 1

Accepted by:	Jeff Miller Project Engineer	2022-05-26 Date
Accepted by:	Syed Khan Section Head, Civil	2022-05-30 Date

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REPORT

Building Condition Assessment

In-situ Decommissioning of Whiteshell Reactor 1 (WR-1)

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Project No. 18101723 (3000) Rev 1

May 26, 2022

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Record of Issue

Date	Revision	Prepared by	Approved by
March 27, 2019	0	MR/MPN	MLJM
March 25, 2022	0A	MR/MPN	MLJM
April 14, 2022	0B	MR/MPN	MLJM
May 26, 2022	1	MR/MPN	MLJM

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Canadian Nuclear Laboratories (CNL) to carry out a building condition assessment of the Whiteshell Reactor 1 (WR-1) facility located at the Whiteshell Laboratories (WL) near Pinawa, Manitoba. The building condition assessment is part of an In-situ Decommissioning (ISD) program to evaluate the integrity of the existing subsurface concrete foundation and bottom slab of WR-1 prior to grouting the existing structure of the reactor building (Building 100). The scope of this component was a condition assessment of the exposed and accessible concrete elements of the substructure, supplemented with laboratory testing of recovered cores to establish the condition and properties of the concrete. This report presents a factual record of the current structure condition based on a visual inspection, core sampling and laboratory testing.

The visual inspection of the Building 100 foundation walls was carried out from October 10 to October 12, 2018, while the core sampling was carried out from October 29 to November 5, 2018.

The laboratory testing of the concrete cores extracted from the structure of Building 100 was completed in November and December of 2018 and January 2019 in Golder laboratories located in Whitby, Mississauga, and Vancouver.

2.0 DESCRIPTION OF THE STRUCTURE

Building 100 is a seven-storey structure, five floors of which are below-grade (Level 500 to Level 100). Exterior and interior structural members of the building are made of cast-in-place reinforced concrete. The building dimensions in plan are approximately 26 m by 27 m and the building is approximately 18 m high for the portion below ground. The thickness of the concrete foundation walls ranges from 0.45 m to 0.90 m, while the thickness of the sub-basement slab is approximately 0.90 m. The building was originally constructed in 1963-1965.

3.0 SCOPE OF WORK

The building condition assessment program included the following tasks:

- Review of available WR-1 facility construction documentation and hydrogeological data.
- Visual assessment of the exposed portions of internal subsurface concrete foundation walls and the related concrete floor structure. The visual assessment included surface deterioration mapping and a delamination survey.
- Concrete coring investigation of the concrete foundation walls and concrete floor from the inside of the structure.
- Laboratory testing on the extracted concrete core samples.
- Preparation of a report describing the factual results of the investigation and providing recommendations for potential repairs for any condition issues which could affect the long term integrity of the structure that were identified during the investigation.

4.0 SUMMARY OF SIGNIFICANT FINDINGS

4.1 Visual Assessment and Delamination Survey

Members of Golder's Materials Engineering Group carried out surface deterioration mapping and delamination surveys of the exposed and accessible portions of internal subsurface concrete foundation walls at Levels 100 to 500 and of the concrete floor slab at sub-basement Level 100. The field investigation was carried out on October 10 to October 12, 2018. Portions of some walls and slabs were not surveyed due to access restrictions to rooms on occupational health and safety grounds with contamination present.

It should be noted that the visual detection of previously repaired areas, as well as some types of concrete deterioration, such as efflorescence or rust staining on the surface of the walls and floor was difficult due to the presence of paint coating.

According to the Ministry of Transportation Ontario's (MTO's) Ontario Structure Inspection Manual and the MTO's Structure Rehabilitation manual, cracking in concrete structures is defined as follows:

- Hairline cracks – less than 0.1 mm wide
- Narrow cracks – 0.1 mm to 0.3 mm wide
- Medium cracks – 0.3 mm to 1.0 mm wide
- Wide cracks – greater than 1.0 mm wide

The cracking in this report will also use this classification system.

It should be noted that the exact origins of the observed cracks have not been established during this building condition assessment. Such a task entails analysis of the evolution of the cracks including data on the time of occurrence of cracks and their development in time. Golder was not provided with any previous studies on the cracks observed in WR-1. As shown later in this report, some possible causes of cracks, such as alkali-silica reaction or ettringite deposition (sulphate attack), have been ruled out based on the tests performed.

The results of the surface deterioration mapping and delamination surveys are summarized in Sections 4.1.1 to 4.1.6. and are shown on Figures 1 to 6 in Appendix E.

4.1.1 North Wall

The north foundation wall was generally in good to fair condition. Deterioration observed on the north foundation wall included mainly narrow cracking with only one medium width crack located on Level 100 of the building. The visual assessment and delamination survey were carried out on a total north wall area of 337 m^2. The total length of the observed cracks (all vertical) was 30.8 m. The total length of the observed cold joints was 15.9 m. It should be noted, that areas of the north wall which were not inspected by Golder due to restricted access to some of the rooms should still be assessed prior to grouting when arrangements can be made for safe entry. No delamination was detected. No evidence of ground water ingress through cracks and cold joints was found. The surface deterioration mapping of the north wall is shown on Figure E-1 in Appendix E.

4.1.2 East Wall and Stair 2

The east foundation wall was generally in good to fair condition. Narrow vertical and horizontal cracking was observed on the east foundation wall of the building with the exception of one medium horizontal crack located at Stair 2, on Level 100. The visual assessment and delamination survey were carried out on a total east wall and Stair 2 area of 296 m^2. The total length of the observed cracks was 61.1 m, comprising 51.4 m of vertical cracks and 9.7 m of horizontal cracks. The total length of the observed cold joints was 10.3 m. No delamination was detected. No evidence of ground water ingress through cracks and cold joints was found. The surface deterioration mapping of the east wall is shown on Figure E-2 in Appendix E.

4.1.3 South Wall and Stair 2

The south foundation wall was generally in good to fair condition. The distresses observed on the south wall included narrow vertical and horizontal cracking as well as a 0.5 m by 0.6 m concrete patch in Room 107 on Level 100. The visual assessment and delamination survey were carried out on a total south wall and Stair 2 area of 443 m^2. The total length of the observed cracks was 33.7 m, comprising 18.5 m of vertical cracks and 15.2 m of horizontal cracks. The total length of the observed cold joints was 27.0 m. No delamination was detected. No evidence of ground water ingress through cracks and cold joints was found. The surface deterioration mapping of the south wall is shown on Figure E-3 in Appendix E.

4.1.4 West Wall

The west foundation wall was generally in good condition. Deterioration found on the west wall included narrow cracking on Level 100 and Level 500. The visual assessment and delamination survey were carried out on a total west wall area of 243 m^2. The total length of the observed cracks was 26.0 m, comprising 15.2 m of vertical cracks and 10.8 m of horizontal cracks. The total length of the observed cold joints was 6.2 m. It should be noted, that areas of the west wall which were not inspected by Golder due to restricted access to some of the rooms should still be assessed prior to grouting when safe access can be arranged. No delamination was detected. No evidence of ground water ingress through cracks and cold joints was found. The surface deterioration mapping of the west wall is shown on Figure E-4 in Appendix E.

4.1.5 Stair 1

The Stair 1 foundation walls were generally in good to fair condition. Narrow vertical and horizontal cracking was observed on all three (north, east and west) outer walls of Stair 1. The visual assessment and delamination survey were carried out on a total Stair 1 area of 231 m^2. The total length of the observed cracks was 42.1 m, comprising of 15.5 m of vertical cracks and 26.6 m of horizontal cracks. Most of the observed cracks were located on the north wall of Stair 1 from Level 100 to Level 400. The total length of the observed cold joints was 48.3 m. Two localized areas of concrete delamination were detected on the north wall of Stair 1 at Level 400. No evidence of ground water ingress through cracks and cold joints was found. The surface deterioration mapping of the Stair 1 walls is shown on Figure E-5 in Appendix E.

4.1.6 Floor Slab

The basement floor slab on Level 100 was generally in good condition. Deterioration found on the floor included narrow cracking. The visual assessment and delamination survey were carried out on a total slab area of 325 m^2. The total length of the observed cracks was 27.5 m. The total length of the observed cold joints was 32.7 m. It should be noted that areas of the floor which were not inspected by Golder due to a restricted access to some of the rooms should still be assessed prior to grouting when safe access can be arranged. No delamination was detected. No evidence of ground water ingress through cracks and cold joints was found. The surface deterioration mapping of the floor slab is shown on Figure E-6 in Appendix E.

4.2 Core Sampling and Testing

4.2.1 Investigation Procedures

The field work for the concrete coring of foundation walls and basement floor slab of Building 100 was carried out from October 29 to November 5, 2018. A total of 35 concrete cores were extracted from walls and the basement floor slab of Building 100 to evaluate the condition of the concrete. Twenty-nine (29) horizontal cores were obtained from the foundation walls, and 6 vertical cores were extracted from basement floor slab.

During the building condition assessment, the core locations were marked out in the field by Golder and agreed upon by CNL staff. Prior to coring, the proposed core locations were scanned with ground penetrating radar (GPR) to determine the presence and location of reinforcing steel and/or embedded utilities to a depth of approximately 250 mm. The scanning service was retained by CNL. The proposed core locations which were in conflict with reinforcing bars and/or embedded utilities were moved accordingly. Site photographs of the proposed core locations after GPR scanning are shown in Appendix A.

The concrete coring was carried out using a hand operated core drill supplied and operated by CNL personnel. Samples of the concrete were obtained using a 100 mm nominal diameter diamond tipped core barrel. The concrete cores were advanced to depths ranging from 170 mm to 430 mm depending of the core locations. Photographs of the cores are provided in Appendix B.

The field work was supervised by a member of Golder's Materials Engineering Group, who located the cores, monitored the coring and sampling operations, and logged and labeled the retrieved core samples. The cores were brought to Golder's (CCIL certified to CSA standards) laboratory in Whitby for visual examination and laboratory testing. Laboratory testing of the cores included: unconfined compressive strength, chloride ion content, porosity, pH value (all carried out in the Golder Whitby laboratory), hydraulic conductivity (Golder Mississauga laboratory), and petrographic analysis (Golder Vancouver laboratory).

Details of the concrete cores (location, diameter, length, etc.), observations made during the visual examination and comments on the core samples, and the results of the laboratory testing carried out on selected cores from Building 100 are presented on the "Core Log for Exposed Concrete Components" sheets in Appendix C.

Details of the core locations and core testing program prepared in accordance with the RFP requirements are provided in the Table 1.

Table 1: Core locations and testing program

Core Number	Structure Component	Room	Test Parameter					
			Compressive Strength	pH Value	Chloride Depth	Porosity Density	Hydraulic Conductivity	Petrographic Analysis
C1	South Wall	107				X		
C2*	South Wall	107						
C3*	East Wall	109						
C4	North Wall	Stairs 1				X		
C5	South Wall	538	X	X				
C6	East Wall	508	X					
C7*	East Wall	508						
C8	East Wall	203					X	
C9	East Wall	203	X					
C10	East Wall	110/111						X
C11	North Wall	Strainer			X			
C12	West Wall	Strainer	X					

Core Number	Structure Component	Room	Test Parameter					
			Compressive Strength	pH Value	Chloride Depth	Porosity Density	Hydraulic Conductivity	Petrographic Analysis
C13	North Wall	103	X	X				
C14	East Wall	Stairs 1	X	X				
C15	East Wall	Stairs 1			X			
C16	West Wall	Stairs 2	X					
C17	North Wall	402	X					
C18	West Wall	505					X	X
C19	West Wall	505	X	X				
C20*	West Wall	536						
C21	North Wall	202	X					
C22	North Wall	202					X	
C23*	Floor	107						
C24*	Floor	107						
C25	Floor	108	X			X		
C26*	Floor	109						
C27	Floor	111	X	X				
C28	Floor	103					X	
C29	South Wall	Stairs 2	X					
C30*	South Wall	Stairs 2						
C31	South Wall	538			X			
C32	North Wall	508	X			X		
C33	North Wall	508					X	
C34	West Wall	107	X					
C35	West Wall	107				X		

*Notes. Cores C2, C3, C7, C23, C24, C26, and C30 were not submitted for laboratory testing were returned to WR1.

4.2.2 Core Visual Examination

The visual examination of the recovered concrete cores was initially carried out on site following extraction, with a more thorough evaluation carried out at Golder's laboratory in Whitby. In general, the foundation walls and basement slab structures at each core location consisted of ordinary (Portland cement) concrete with coarse aggregate ranging in size from 5 mm to 40 mm, with the majority of the aggregate particles ranging in size between 5 and 20 mm. The coarse aggregate particles have a mainly rounded shape with a smooth surface texture. A more detailed description of the aggregate is provided in the petrographic analyses section of the report and in Attachment D.

The concrete at the core locations was generally in good to fair condition. Only four out of twenty-nine horizontal cores from the foundation walls were judged to be in fair condition with the rest of the cores being in good condition. As for the vertical cores obtained from the basement floor slab, one out of six cores were in fair condition, while the remaining five cores were in good condition.

Some of the cores were advanced through surface cracks/cold joints on the walls and the floor slab to determine the depth of those concrete defects. Vertical and horizontal cracks were noted in the following cores: C2, C12, C15, C24, C25, and C30. The full core depth cracks were found at the locations of Cores C2, C15, and C30 (all these cores were extracted from the foundation walls). It was not determined whether those cracks have propagated through the full thickness of the walls. Cores C1, C4, and C23 were advanced through cold joints.

Generally, no defects, such as large voids/cavities or disintegrated concrete were identified in the extracted cores, with the exception of Cores C22 and C23 in which a few larger voids were detected. Some of the cores had entrapped air voids distributed throughout the length of the sample. Most of the fractures observed in the recovered cores looked fresh and were likely mechanical breaks that occurred due to the coring process and extraction.

Details of the concrete core condition and defects observed are presented on the “Core Log for Exposed Concrete Components” sheets in Appendix C.

Some of the extracted cores had a slight difference in colour in comparison to most of the samples. The mortar fraction (cement paste + sand) of concrete in Cores C5, C18, C19, C20, and C31 was visually lighter and had a beige tint in contrast to the grayish colour of the other cores (see Figure 1). The colour difference became very noticeable after the fracturing of the samples during compressive strength testing (Figure 4); however, there was no visual difference in coarse aggregate appearance between cores. It should be noted that all beige coloured cores (C5, C18, C19, C20, and C31) were obtained from the foundation walls at the top of the underground level (Level 500) of Building 100.

Figure 1: Sections of Cores C31 (Room 538, South Wall) and C8 (Room 203, West Wall) showing paste colour difference.

Two core locations (C12 and C29) had evidence of previous repair works. Core C12 had a 10 mm to 20 mm thick layer of patching mortar at the top surface of the core. Core C29 completely consisted of mortar without coarse aggregate, had a lower density compared to the other cores of ordinary concrete and most likely was a repair grout mix. The total depth of repair near C29 was at least 240 mm (the depth of Core C29).

There was no visual evidence of deleterious chemical reactions, such as alkali aggregate reactivity or sulphate attack, occurring in any of the concrete core samples.

In general, it was intended to avoid coring through rebar, however, reinforcing steel bars were encountered in 5 of the 29 core samples extracted from the foundation walls. All rebars were observed to be in clean condition upon extraction. Reinforcing steel bars were not encountered in the floor slab cores.

4.2.3 Compressive Strength

Compressive strength testing was carried out on 15 concrete core samples extracted from the foundation walls and floor of Building 100. The following were considered when determining the appropriate samples for compressive strength testing:

- The tested samples were selected from all four foundation walls (North, East, South and West) and from the floor slab.
- The tested wall cores were representative of the whole elevation of the foundation walls, i.e. they were distributed throughout the levels of the building from the basement floor slab (Level 100) to the Level 500.
- The tested samples were selected to reflect all varieties of concrete type, quality, appearance, etc.

The ends of the saw cut concrete core samples were ground to a smooth, flat surface and were moist conditioned for 24-hours prior to testing. Correction factors, based on the core length to diameter (L/D) ratios were applied to the measured compressive strengths, in accordance with Table 1 of CSA A23.2-14C. The results of the compressive strength testing (with correction factors applied), as well as the densities of the cores, are presented in Attachment D.

The results of the laboratory testing of density and compressive strength carried out on selected cores are summarized in Table 2 and presented in Figure 2 showing the relationships between those parameters.

Table 2: Compressive Strength and Density Test Results

Core Number	Density (Mg/m^3)	Compressive Strength (MPa)
C5	2.294	18.0
C6	2.321	29.0
C9	2.377	31.8
C12	2.429	41.1
C13	2.382	28.6
C14	2.351	32.4
C16	2.390	39.6
C17	2.377	41.3
C19	2.268	14.3
C21	2.325	30.3
C25	2.375	42.5
C27	2.382	30.1
C29	2.262	90.2
C32	2.325	25.0

Core Number	Density (Mg/m^3)	Compressive Strength (MPa)
C34	2.301	40.3

The highest compressive strength result of 90.2 MPa, about three times higher than the average core strength, was obtained for Core C29 extracted from the south wall of Stairwell 2. As mentioned in Section 4.2.2, Core C29 consisted of fine aggregate concrete, which was likely a repair grout mix. The rest of the cores were advanced in ordinary heavy concrete with considerably lower strength properties. Further analysis of strength was conducted on these 14 cores of ordinary concrete.

The compressive strength of the 14 core samples of normal concrete tested ranged from 14.3 MPa to 42.5 MPa., with an average compressive strength of 31.7 MPa. The maximum strength was 3.2 times higher than the minimum compressive strength result, generally indicating non-uniformity of the concrete in terms of mechanical properties. The density of concrete was also characterized by a wide range of values from 2.268 to 2.429 Mg/m^3.

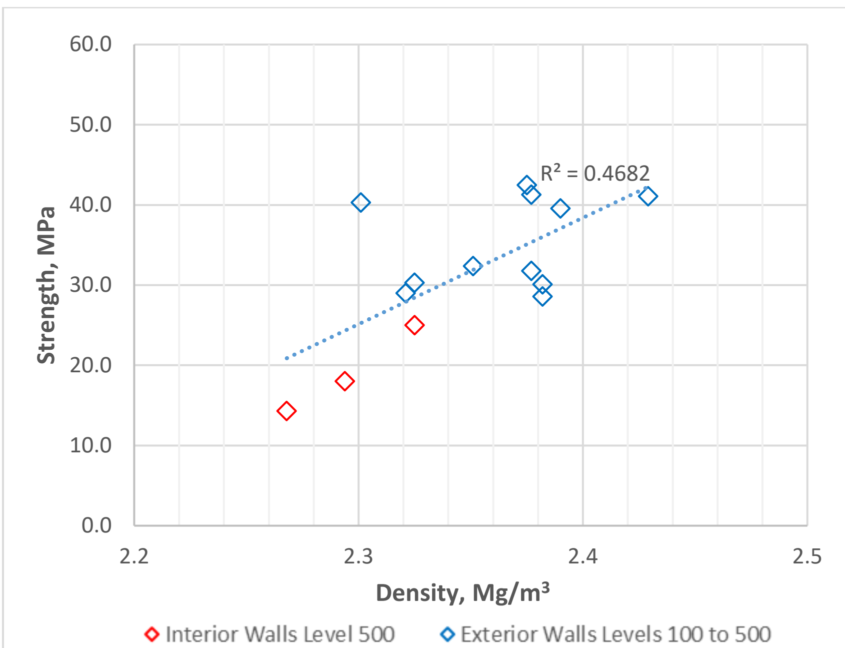


Figure 2: Relationship between Compressive Strength and Density of the tested cores.

The relationship between concrete core density and compressive strength was evaluated (see Figure 2). The R-squared value (R^2=0.468) based on the linear trend-line reflects a clear relationship between the two parameters.

During analysis of strength and density values of the tested cores It was noted that most of the low density/strength results (shown in red in Figure 2) were obtained on samples from locations on Level 500 of Building 100.

According to WR-1 Design Manual DM-201 - Structural Materials, three concrete mixes were used in Building 100. For the exterior structures in contact with soil or rock, concrete with a compressive strength of 3,500 psi (24.1 MPa) and sulphate resistant cement was used. For the interior structures, two types of concrete with specified compressive strength of 3,000 psi (20.7 MPa) were used: normal concrete with a dry unit weight of approximately 150 pcf (~ 2400 kg/m^3) and heavy concrete for radiation shielding purposes with a dry unit weight of not less than 220 pcf (~ 3525 kg/m^3). It also should be noted, that based on the structural drawings and the concrete density values obtained (see Fig. 2) no core was extracted from structure components with heavy concrete. Table 3 provides further evaluation of compressive strength with respect to structure component, location and elevation of extracted cores.

Table 3: Core locations and Compressive Strength

Core Number	Structure Component	Room	Elevation (m)	Height* (m)	Compressive Strength (MPa)
C5	South Wall (Interior)	538	263.3	12.5	18.0
C6	East Wall (Exterior)	508	263.7	12.5	29.0
C9	East Wall (Exterior)	203	254.5	3.7	31.8
C12	West Wall (Exterior)	Strainer	252.4	1.5	41.1
C13	North Wall (Exterior)	103	252.1	1.2	28.6
C14	East Wall (Exterior)	Stairs 1	258.2	7.3	32.4
C16	West Wall (Exterior)	Stairs 2	257.9	7.0	39.6
C17	North Wall (Exterior)	402	260.0	9.1	41.3
C19	West Wall (Interior)	505	263.7	12.8	14.3
C21	North Wall (Exterior)	202	254.2	3.4	30.3
C25	Floor slab (Exterior)	108	250.9	0.0	42.5
C27	Floor slab (Exterior)	111	250.9	0.0	30.1
C32	North Wall (Interior)	508	263.3	12.5	25.0
C34	West Wall (Exterior)	107	252.1	1.2	40.3

Notes. * Height from the top of floor slab Level 100.

Based on the structural drawings and WR-1 Design Manual DM-201, in further analysis, the floor slab, the north, west, and south walls from Level 100 to Level 400, and the east wall from Level 100 to Level 500, were considered as the exterior structures. On the other hand, the north, west, and south walls at Level 500 were considered as interior structures.

The compressive strength results were plotted against elevation of the of the corresponding cores (Figure 3). The average strength of 11 cores representing the exterior structures at Levels 100 to 500 was 35.2 MPa. Each of the 3 cores extracted from the interior walls at the highest Level 500 (Cores C5, C19, and C32) had lower strengths ranging from 14.3 MPa to 25.0 MPa with an average strength of 19.1 MPa. Two cores with the lowest strength, i.e. 14.3 MPa (Core C19, south wall) and 18.0 MPa (Core C5, west wall), had a distinctly different appearance from the other cores (see Figure 4) as described above in Section 4.2.2. For those low strength cores the failure of the core samples under compression took place both at the contact zone between the coarse aggregate and the cement paste and within the mortar fraction of the concrete. For most of the other samples, a fracture crack also passed through the coarse aggregate, indicating a higher strength of cement paste and within the contact zone.

Based on the core visual examination and the compressive strength results, it can be concluded that the concrete of the interior foundation walls of the upper Level 500 (the north, south and west walls) has a different appearance and lower strength than the concrete in the floor slab and Levels 100 to 500 of the exterior foundation walls, confirming that different concrete mixes were used for the interior and exterior structure components.

None of the cores extracted from the floor slab and the exterior walls had a lower strength than the specified compressive strength for sulphate resistant concrete of 24.1 MPa. On the other hand, two out of three cores from the interior walls of Level 500 had lower compressive strength than the specified 20.7 MPa. Cores C5 and C18 had 69% and 87% of the specified strength, respectively. The average compressive strength of the interior wall cores (19.1 MPa) was 92% of the specified strength. In accordance with Clause 4.4.6.6.2.2 of CSA 23.1-14, the compressive strength of the concrete in the area of the structure represented by the core is considered adequate if: 1) the average core strength is equal to at least 85% of the specified strength and 2) no one core is less than 75% of the specified strength. Thus, it can be concluded that the compressive strength of the interior walls at Level 500 does not satisfy the requirements for concrete strength as required in WR-1 Design Manual DM-201 - Structural Materials.

Considering that the interior foundation walls of Rooms 505, 508 and 538, from where Cores C19, C32 and C5 were extracted, are not exposed to the external environment, the lower concrete cannot be linked to extreme exposure conditions during operation of the building, such as cycles of wetting-drying or freezing-thawing. The impact of aggressive substances like sulphates or chlorides should also be excluded for the same reason. However, other factors could explain the lower compressive strength, including inconsistencies in batching, variations in water-cement ratio, entrapped air content variations etc. However, it should be noted that the performance of the concrete during more than 50 years in service, appears to have been satisfactory.

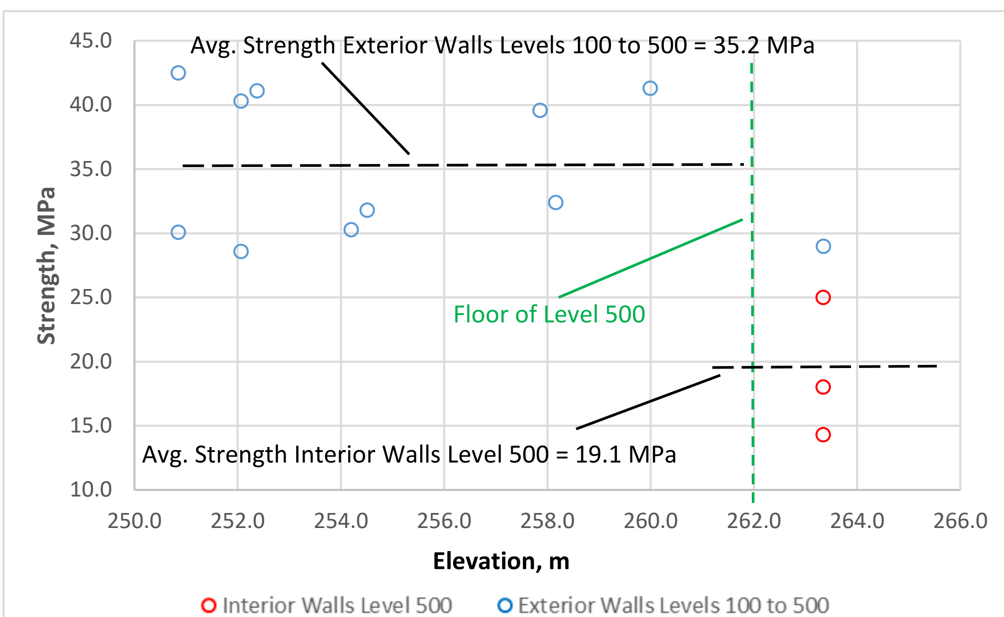


Figure 3: Relationship between Compressive Strength and Elevation of the tested cores.

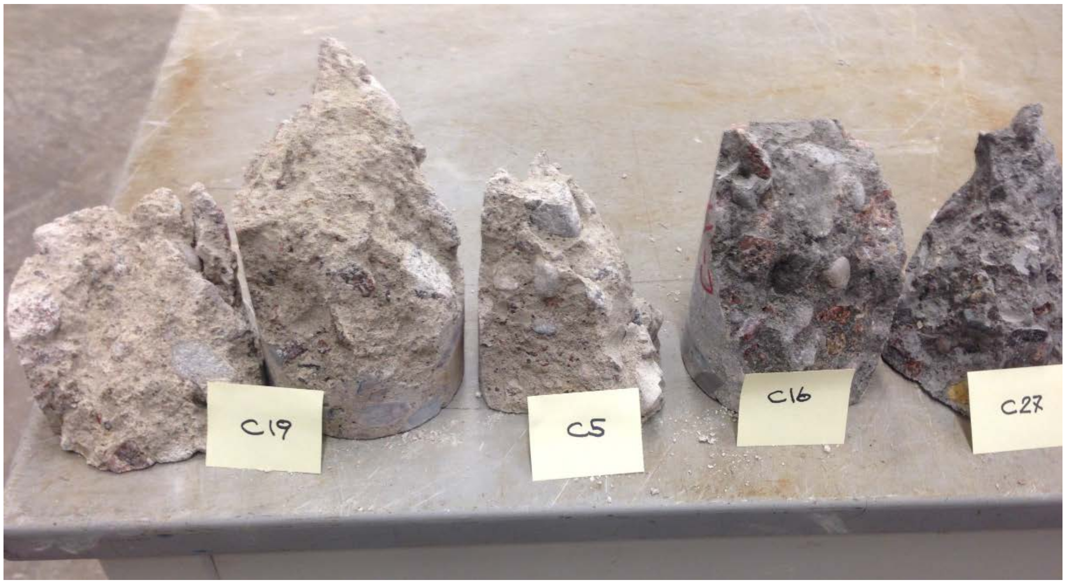


Figure 4: Cores C19 (West Wall, Room 505), C5 (South Wall, Room 538), C16 (West Wall, Stairs 2), and C27 (Floor slab, Room 111). Note: The different concrete colour between Cores C19/C5 and Cores C16/C27.

4.2.4 Chloride Ion Content

Chloride ion content testing was carried out on three core samples extracted from the foundation walls (Cores C15, C11, and C31) as shown on the 'Core Log for Exposed Concrete Components' in Appendix C. The results are shown in Table 4 and also presented in Appendix D.

Table 4: Chloride Ion Content test results

Core Number	Core Location	Chloride Ion Content (% Chloride by Weight of Concrete)					
		0-10 mm	50-60 mm	100-110 mm	150-160 mm	200-210 mm	250-260 mm
C15	Stairs 1, East Wall	0.019	0.010	0.009	0.009	0.006	0.010
C11	Strainer, North Wall	0.016	0.000	0.000	0.000	-	-
C31	Room 538, South Wall	0.014	0.010	0.020	0.014	0.010	0.008

Analysis of test results showed that the chloride ion content did not exceed the commonly accepted threshold for corrosion to occur (0.025 percent by mass of concrete) for all samples. Also, it does not appear that there is any sign of a chloride Ion ingression in the foundation wall structure from inside. Note that we did not recover any samples for testing close to the exterior of the walls.

After examining the data, it may be concluded that a background chloride ion value, i.e. the acid soluble chloride content in the mix ingredients which is measured but does not contribute to corrosion, is between 0.0% and 0.010% by weight of concrete.

As seen from Table 4, the top horizons of the tested cores (i.e. closest to the interior surface of the walls) had a chloride ion content higher than the background values of deeper layers of the structure. A possible explanation for this could be the presence of chloride compounds in the paint applied on the inside surfaces of the foundation walls. For example, methylene chloride, also known as dichloromethane, has been widely used as an industrial solvent in paints. However, based on the results, there is no evidence of external chlorides contaminating the concrete.

4.2.5 pH Value

Measurements of pH value were carried out on five of the core samples, four taken from the foundation walls (Cores C5, C13, C14, C19) and one from the floor slab (Core C27). The testing procedure followed was the use of pH paper and associated pH chart in accordance with ASTM F710-17 (there is no CSA equivalent standard). The pH tests were performed immediately after saw cutting of the cores, i.e. on freshly exposed surfaces of concrete. For Cores C14 and C19 the testing was carried out at the top and bottom of the cores to confirm the consistency of the pH parameter along the walls' thickness. All tests indicated a pH value of 12.0, irrespective of depth, as presented in Table 5 and in Appendix D.

Table 5: pH values for Cores

Core Number	pH Value	
	Top	Bottom
C5	-	12.0
C13	-	12.0
C14	12.0	12.0
C19	12.0	12.0
C27	12.0	-
Average	12.0	12.0

It is known that the alkaline environment of concrete with pH above 11.5 provides chemical protection (passivation) to reinforcing steel bars. The pH values obtained are constant (pH=12) for all locations and throughout the thickness measured of walls and slab. This fact, together with the low chloride ion content measured, allows us to conclude that there is a low risk for steel corrosion in the investigated stricture components of Building 100.

4.2.6 Density, Absorption, and Voids

Density, absorption, and voids in hardened concrete testing was carried out in accordance with the method given in CSA A23.2-11C. Five cores presented in Table 6 were selected for density, absorption, and voids testing. The laboratory test reports are presented in Appendix D.

Table 6: Density, Absorption, and Voids Test Results

Core Number	Absorption After Immersion and Boiling (%)	Bulk Dry Density (Mg/m^3)	Volume of Permeable Pore Space (%)
C1	4.0	2.352	9.5
C4-1	3.9	2.336	9.2
C4-2	7.3	2.111	15.4
C25	5.5	2.253	12.4
C32	4.1	2.330	9.6
C35	5.3	2.235	11.8

The test results presented in Table 6 for the Cores C1, C25, C32, and C35 are the average values of determinations on three specimens. The results for Core C4 are presented as two separate values for the following reasons. Two cores, C1 and C4, were drilled through colds joints, i.e. the joints between two different concrete pours, and each of these cores consisted of two halves. In the case of Core C1, all three specimens needed for the test were taken from one half of the core, representing the same concrete pour, and had a minor scatter in test results (see Appendix D). In the case of Core C4, two specimens (A and B) were taken from one half of the core and one specimen (C) was obtained from the other half. Because the two haves of Core C4 represented two different concrete placements, and demonstrated a noticeable variance in the density, absorption, and voids values, the test results were presented separately for each half of the core as C4-1 (average of specimens A and B) and C4-2 (specimen C).

The absorption and volume of permeable pore values for tested cores ranges from 3.9% to 7.9% and 9.2% to 15.4%, respectively, having generally an inverse relationship with bulk dry density: an increase in density led to lower absorption and lower volume of voids values (Figure 5).

The values and ranges obtained for absorption after immersion and boiling and volume of permeable pore space are considered to be typical values for air entrained ordinary heavy concrete with a compressive strength of about 30 MPa.

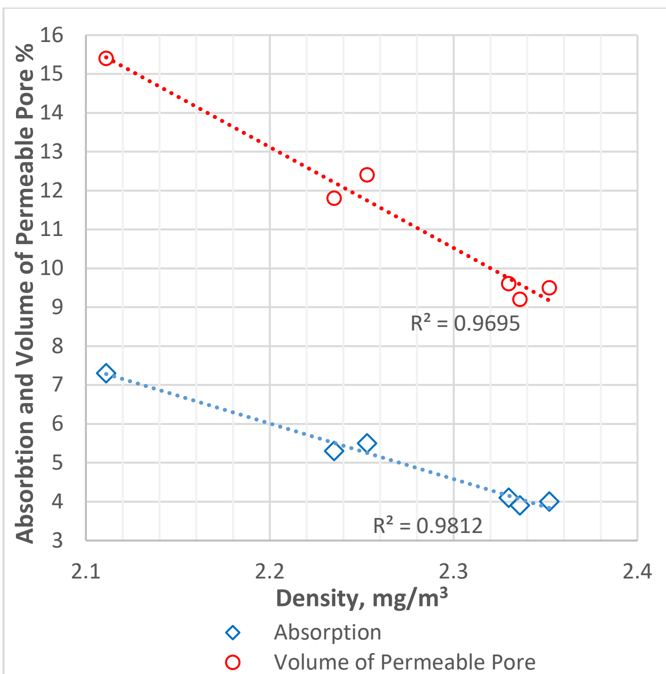


Figure 5: Relationships between Absorption (blue symbols) and Volume of Permeable Pores (red symbols) and Dry Bulk Density.

4.2.7 Hydraulic Conductivity

Hydraulic Conductivity testing of concrete was carried out in accordance with the method given in ASTM D5084-16 (there is no CSA equivalent standard). The five cores presented in Table 7 were selected for Hydraulic Conductivity testing. The laboratory test reports are presented in Appendix D.

Table 7: Hydraulic Conductivity Test Results

Core Number	Hydraulic Conductivity (m/s)
C8	1.62×10^{-11}
C18	9.75×10^{-11}
C22	7.26×10^{-11}
C28	1.16×10^{-11}
C33	4.84×10^{-11}

Hydraulic conductivity for the selected cores ranged from 1.16×10^{-11} to 9.75×10^{-11} m/s. Such a range of hydraulic conductivity values lies within the typical limits for ordinary heavy concrete.

Each of the core locations C8, C18, C22, and C33 had a paired core (correspondingly C9, C19, C21 and C32), i.e. a second core which was extracted from the same area. It is expected that concrete in each pair of cores, i.e. C8-C9, C18-C19, C21-C22, and C32-C33, would have the same properties because of their proximity being only about 0.3 m to 0.5 m apart. Cores C9, C19, C21, and C32 were tested for compressive strength and density in accordance with CSA A23.2-14C (see Table 2). Thus, we can illustrate the relationship between hydraulic conductivity and compressive strength/density using the paired cores. These relationships are illustrated in Figures 6 and 7.

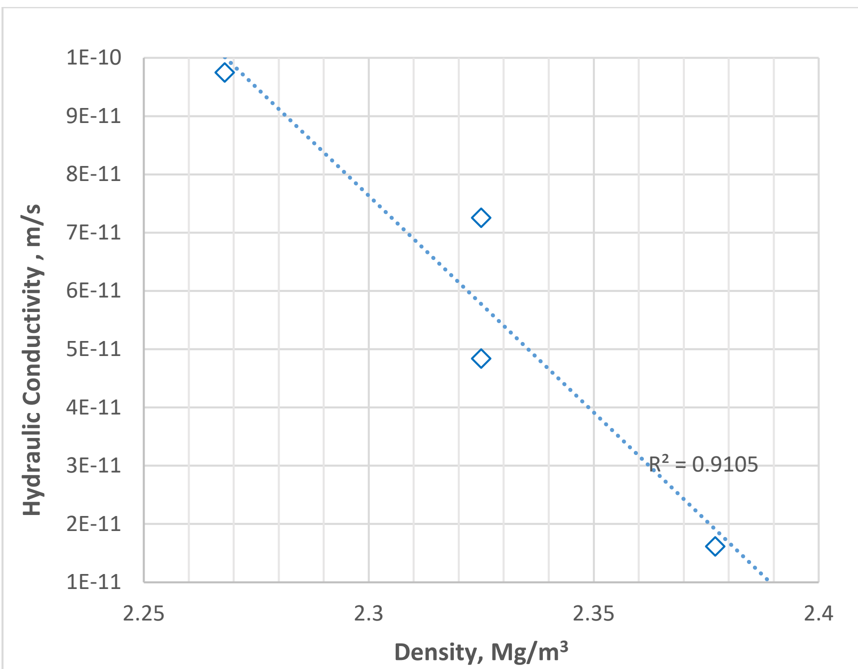


Figure 6: Relationship between hydraulic conductivity and density.

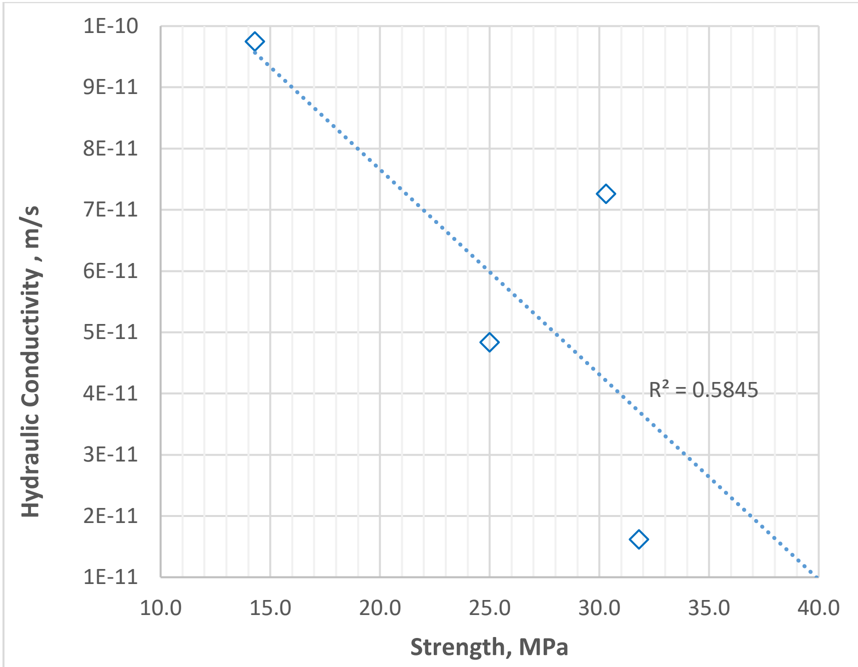


Figure 7: Relationship between hydraulic conductivity and compressive strength.

Hydraulic conductivity plotted against compressive strength and density showed inverse relationships between these parameters. Core C18 with the lowest density and, as a result, with the lowest compressive strength had the highest value of hydraulic conductivity, i.e. had the highest permeability among all cores. On the other hand, the densest microstructure of concrete (found in Core C28 which had the lowest porosity) provided the highest compressive strength and the lowest hydraulic conductivity.

Nevertheless, the measured values of hydraulic conductivity from $1.16x10^{-11}$ to $9.75x10^{-11}$ m/s indicate that the intact concrete of the foundation walls and sub-base slab can provide reasonable resistance to infiltration of liquid substances through the thickness of the concrete structure components which form the exterior envelop of Building 100.

4.2.8 Petrographic Examination

Petrographic examination of hardened concrete were carried out in general accordance with the method given in ASTM C856-17 (there is no CSA equivalent standard). Following the visual examination and review of preliminary laboratory testing results, Cores C10 and C18 were selected for Petrographic Examination. The selection of Core C18 was dictated by it having the highest hydraulic conductivity of $9.08 \cdot 10^{-11}$ m/s and lowest compressive strength (14.3 MPa), as well as the appearance of cores C18 and C19 (see Figure 4 and Section 4.2.2) which represented the west wall at Level 500, Room 505. Core C10 represented higher strength concrete taken from the East Wall in Level 100.

Table 8: Petrographic Analysis Core Sample Locations

Core Number	Structure Component	Room	Elevation (m)
C10	East Wall	110	254.5
C18	West Wall	505	263.7

These samples were submitted to Golder's Materials Engineering Laboratory in Vancouver for preparation work and Petrographic Examination. The individual Petrographic Examination reports for each core are provided in Attachment D; a summary of these data is provided below.

In general, the concrete samples were found to be dense and well consolidated. The concrete was air entrained. The core C18 concrete had an excessive entrained air content (estimated at up to 10%).

The coarse aggregate used in the concrete consisted of a mixture of fluvial (subrounded to rounded) and crushed rock aggregate with a maximum size of about 20 mm. The crushed rock particles were generally granitic while the composition of the fluvial materials aggregate was a mixture of granite, sandstone, quartzite, carbonates, gneiss and metasandstone. Fine aggregate was a natural sand composed of limestone, granite, sandstone, quartz, feldspar, and biotite.

Cement was well hydrated. Estimated water/cementing materials ratio was in the 0.5-0.6 range for Core C10 and in the >0.6 range for Core C18. The paste colour was light beige in hand sample, light grey/beige in the microscope for Core C18 and was medium grey in colour for Core C10. Paste ranged in porosity and stiffness (from firm to soft) in both cores. After wetting, some paste became softer and was easily gouged/removed. Some of the paste appears to be disturbed/weak, and zones of porous/low quality paste were observed.

In both cores the contact zone between cement paste and aggregate contained defects but they were more pronounced in the C18 sample: debonded zones where paste is removed next to coarse aggregates, were just occasionally observed in Core C10 while similar defects were commonly encountered in Core C18.

It should be noted that the findings of the petrographic examination are consistent with the results of other types of testing carried out on the concrete cores. For example, the high content of air voids, zones of disturbed/weak/ porous cement paste, a debonded contact interface between cement paste and aggregate (all defects commonly observed in Core C18) – ultimately resulted in the lower density and compressive strength, as well as the higher values of permeable pore volume, absorption, and hydraulic conductivity obtained on the paired Cores C18 and C19.

Nevertheless, the petrographic analysis showed that the concrete did not exhibit any types of degradation such as alkali-silica reaction or ettringite deposition. The detected carbonation (Core C10 only) was minor. It is anticipated that after grouting of the building's inside space the carbonation process will be impeded and will not impact on durability of concrete in the long-term. The petrographic examination does not identify any significant cause for concern in terms of serviceability or performance of the assessed concrete structure components for use as the formwork for the grout encapsulation of Building 100.

5.0 ADDITIONAL CONSIDERATIONS

As stipulated in WR-1 Design Manual DM-201 - Structural Materials, sulphate resistant cement was to be used for the exterior structure components in contact with soil or rock. Determining whether the sulfate-resistant cement was actually used in the exterior walls during construction was not part of the scope of work of the Building 100 condition assessment; however, based on the results of the petrographic analysis and pH value testing, there were no signs of any sulphate attack occurring in the cores examined. It should be noted, the depth of the recovered cores was limited by the depth of the GPR scanning to avoid hitting any conduit or service line during drilling. As a result, no core was drilled through the full wall thickness and the depth of the cores extracted from inside of the building did not exceed 260 mm for the walls. Sulphate attack is a very slow process, and if it has taken place, it might not have reached the level at which the cores were obtained. Thus, it is not possible to confirm the usage of sulfate-resistant cement based on the absence of signs of sulphate attack in the cores. To confirm the types of binder used in the concrete mixes and to further evaluate their sulphate-resisting properties, two types of tests could be considered:

1) XRD/XRF testing on the cement paste of the exterior and interior concrete mixes; and

2) Optical and electron microscopy on polished thin sections of the cement pastes.

During the Golder visual inspection some of the rooms/areas with restricted access due to radioactive contamination were not surveyed. We recommend carrying out a visual examination of these rooms for the presence of cracks, surface deterioration and other defects, so as to provide confidence regarding the overall concrete structure conditions before starting grouting works. Also, we understand that in some of the inaccessible rooms, the exposed concrete surfaces have been exposed to spillage of an organic liquid coolant. The interaction of this substance with the existing concrete and, especially, with the proposed grout mix, is of concern. The details of the chemical composition of the organic coolant should be determined to evaluate any potential for it to chemically attack the proposed grout. We recommend CNL provide the relevant information about the chemical nature of the above noted organic substance for further consideration.

6.0 NEED FOR A REPAIR WORKS PROGRAM

The concrete of the foundation walls and floor slab have the properties (composition, strength, permeability, passivation, etc.) to continue to provide a durable building structure in the long term. The intact concrete has low permeability and is in generally good condition. It should be confirmed that the measured concrete hydraulic permeability values are consistent with the assumptions that were made when the long term integrity and performance of the decommissioned facility were modelled.

The observed cracking of the structure components is minor, and consists of mostly narrow cracks which do not have signs of efflorescence, rust staining, etc. Thus, it is likely that the detected narrow cracks do not need to undergo any repairs prior to the overall grouting works. Consideration could be given to prior specialty grouting of the few medium cracks and cold joints. We recommend that crack repairs be undertaken using a combination of Sikadur 35, Hi-Mod LV, a high-viscosity and high strength epoxy grout sealer and Sikadur 31, Hi-Mod Gel, a high strength epoxy paste adhesive. These products are suitable for this purpose when applied in strict accordance with the manufacturer's recommendations. It is recommended that all medium cracks wider than 0.3 mm should be sealed.

It should be noted, that there was no evidence of ground water ingress through cold joints which may indicate the effectiveness of the water stops utilized during original construction.

Based on the results of surface deterioration mapping and delamination surveys, as well as testing of the recovered cores for compressive strength, chloride ion content, pH value, density, absorption, and voids in hardened concrete, hydraulic conductivity, and petrographic examination, we believe that the existing concrete is compatible with the proposed decommissioning works, subject to confirmation that the results obtained are compatible with the assumptions made during the previous modelling of the long term performance of the decommissioned facility.

7.0 CLOSING

We trust that this report provides sufficient information regarding the building condition assessment of the Whiteshell Reactor 1 (WR-1) facility to meet your requirements. If you have any questions, or require any additional information, please do not hesitate to contact our office.

Golder Associates Ltd.

Maxim Ryskin, Ph.D.
Concrete Specialist

Michael P. Navarra, M.A.Sc., P.Eng.
Materials and Pavement Engineer

for

Michael L.J. Maher, Ph.D, P.Eng.
Principal

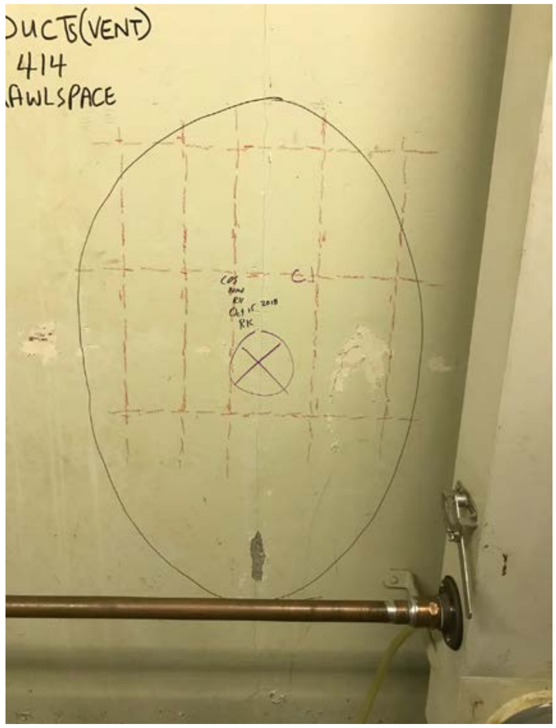
MR/MPN/MLJM/mc

https://golderassociates.sharepoint.com/sites/26836g/technical work/rfi017 response to cnsc comments on testing/building condition assessment/rev 1/18101723 rep cnl wr1 survey whiteshell 04-14-2022 rev 1.docx

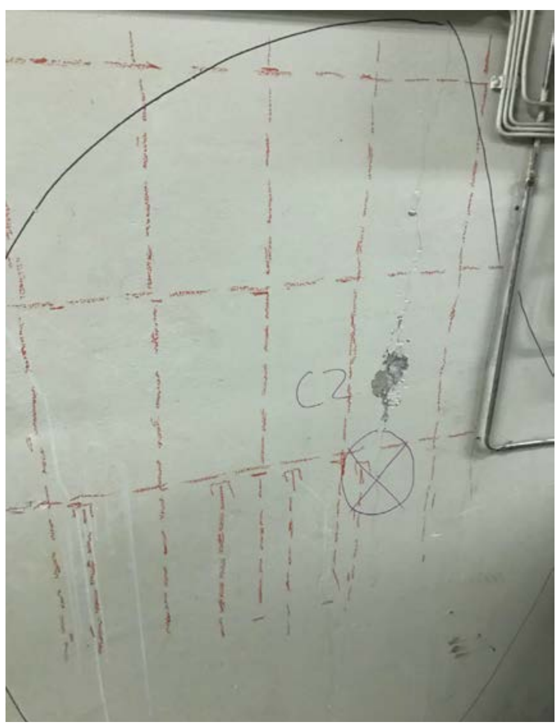
APPENDIX A

Core Location Photographs

Core Location Photographs In-situ Decommissioning of Whiteshell Reactor 1 Pinawa, Manitoba	Figure A-1



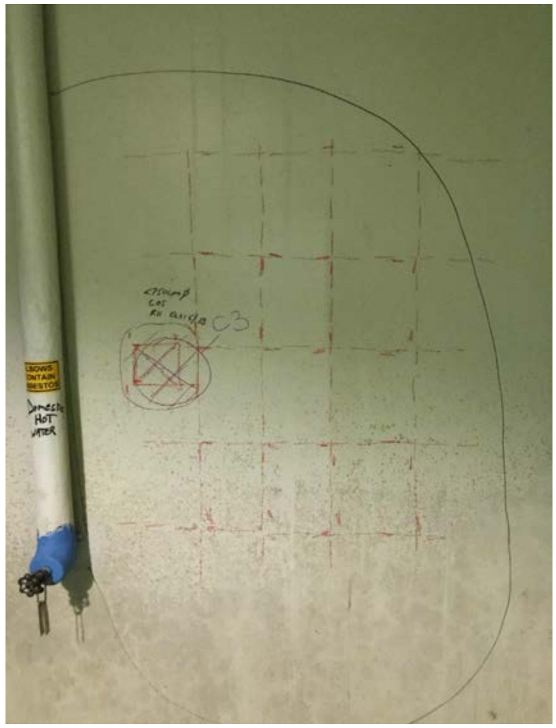
Location of Core C1 after GPR scanning



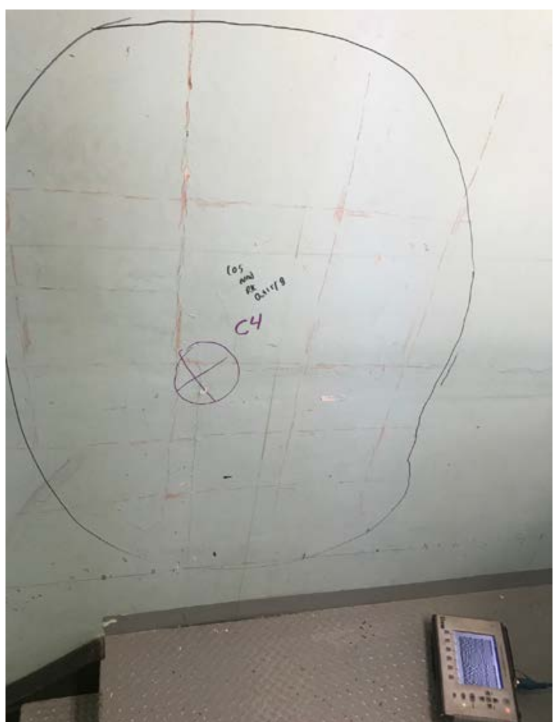
Location of Core C2 after GPR scanning

Date: March 2019	Golder Associates Ltd.	Inputted By:	MR
Project: 18101723		Checked By:	MPN

Core Location Photographs In-situ Decommissioning of Whiteshell Reactor 1 Pinawa, Manitoba	Figure A-2



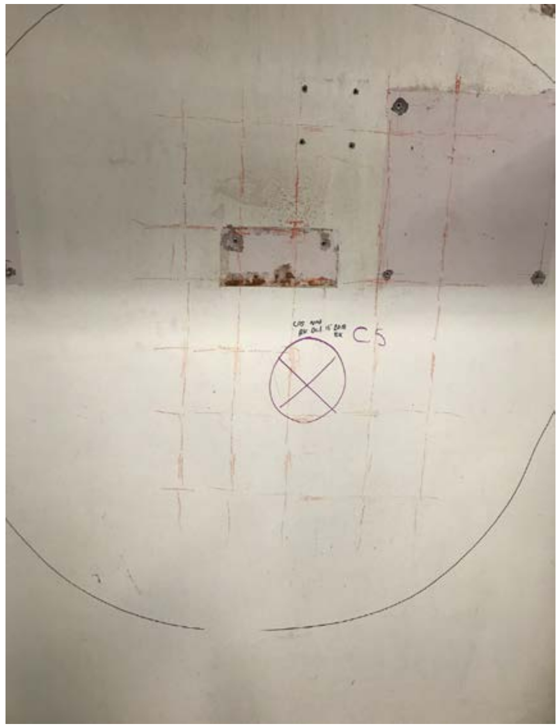
Location of Core C3 after GPR scanning



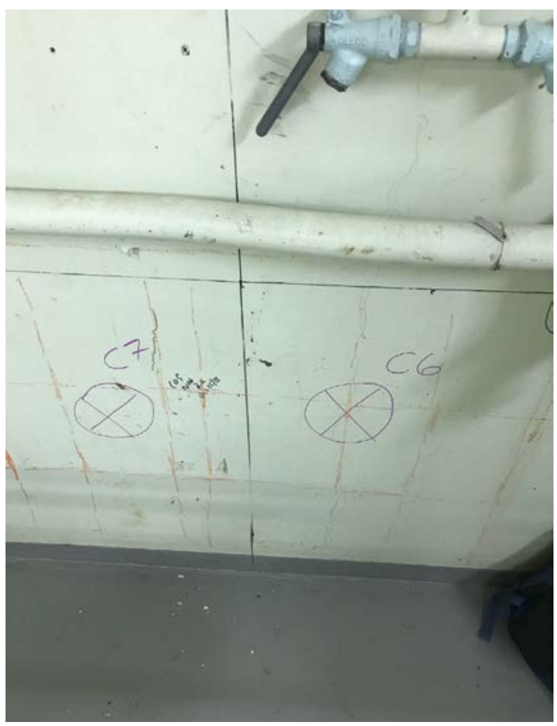
Location of Core C4 after GPR scanning

Date: March 2019	Golder Associates Ltd.	Inputted By:	MR
Project: 18101723		Checked By:	MPN

Core Location Photographs In-situ Decommissioning of Whiteshell Reactor 1 Pinawa, Manitoba	Figure A-3



Location of Core C5 after GPR scanning



Location of Cores C6 and C7 after GPR scanning

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Project:	18101723		Checked By:	MPN

Core Location Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure A-4

Location of Cores C8 and 9 after GPR scanning

Location of Core C10 before GPR scanning

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Core Location Photographs In-situ Decommissioning of Whiteshell Reactor 1 Pinawa, Manitoba	Figure A-5

Location of Core C11 before GPR scanning

Location of Core C12 after GPR scanning

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Project:	18101723		Checked By:	MPN

Core Location Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure A-6

Location of Core C13 after GPR scanning

Location of Cores C14 and 15 after GPR scanning

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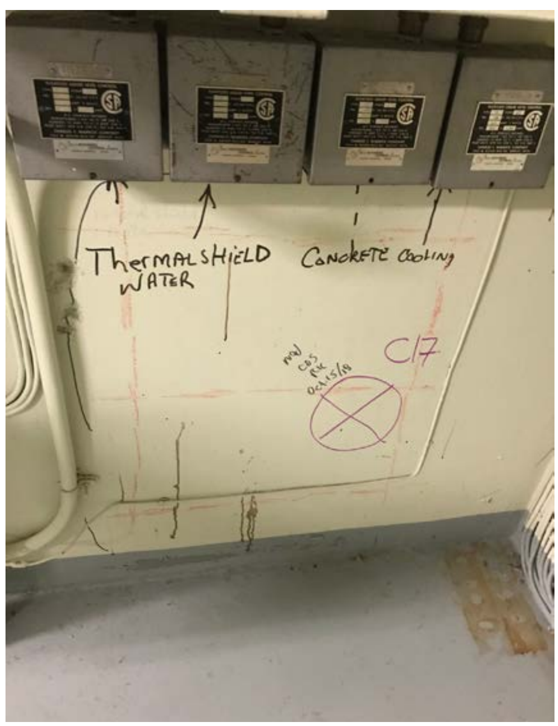
Core Location Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure A-7

Location of Core C16 after GPR scanning



Location of Core C17 after GPR scanning

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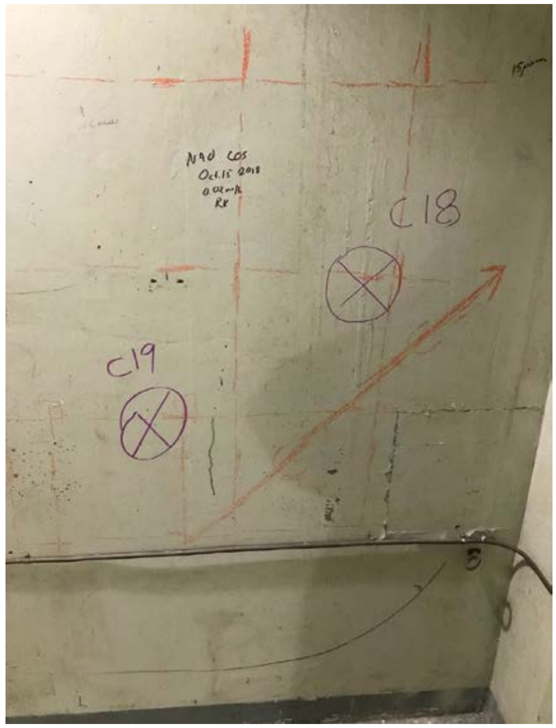
Project:	18101723		Checked By:	MPN

Core Location Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure A-8



Location of Cores C18 and 19 after GPR scanning

Location of Core C20 after GPR scanning

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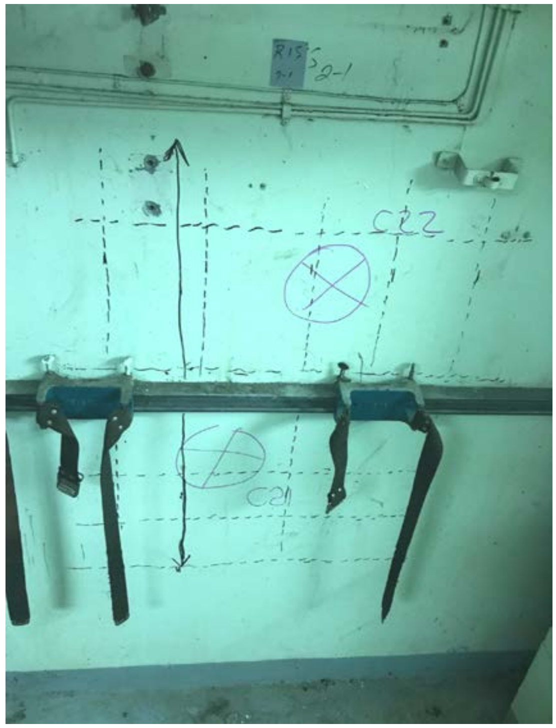
Project:	18101723		Checked By:	MPN

Core Location Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure A-9



Location of Cores C21 and C22 after GPR scanning

Location of Core C23 after GPR scanning

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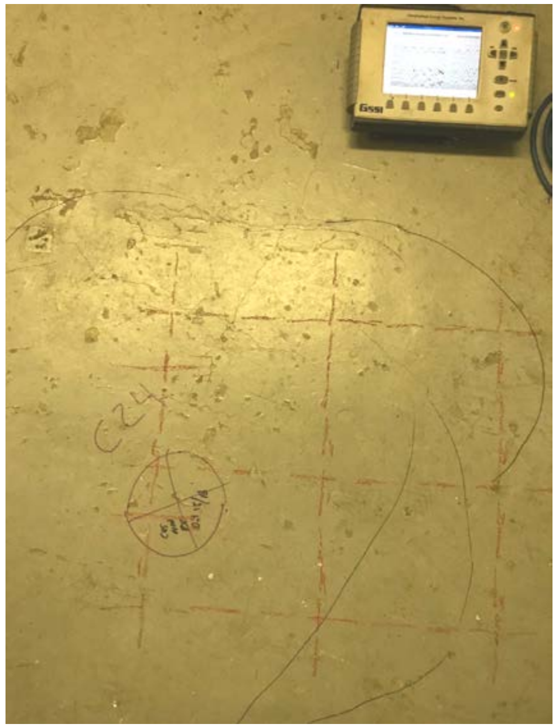
Project:	18101723		Checked By:	MPN

Core Location Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure A-10



Location of Core C24 after GPR scanning

Location of Core C25 after GPR scanning

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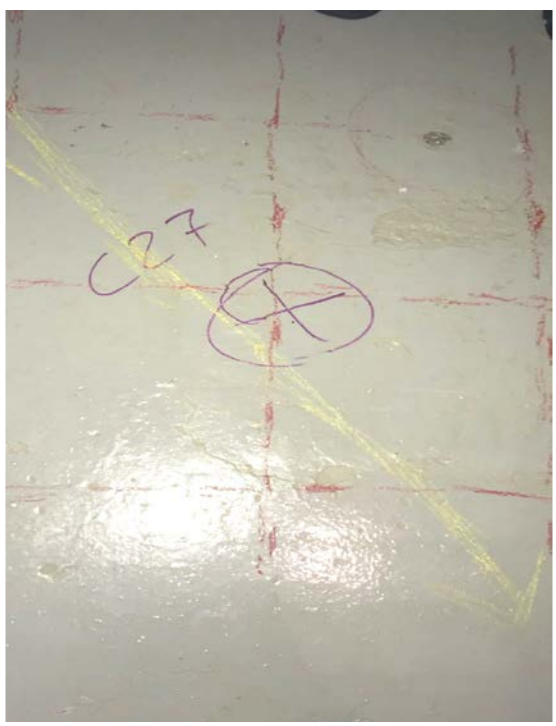
Project:	18101723		Checked By:	MPN

Core Location Photographs In-situ Decommissioning of Whiteshell Reactor 1 Pinawa, Manitoba	**Figure A-11**

Location of Core C26 after GPR scanning



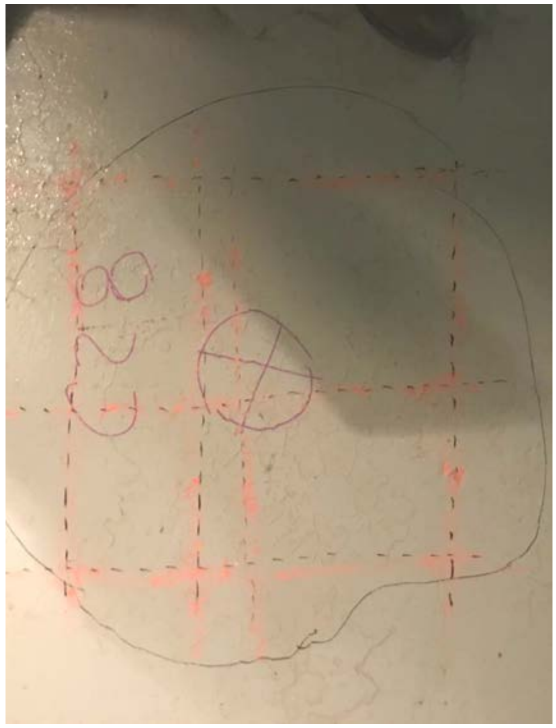
Location of Core C27 after GPR scanning

Date: March 2019	**Golder Associates Ltd.**	Inputted By: MR
Project: 18101723		Checked By: MPN

Core Location Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure A-12



Location of Core C28 after GPR scanning

Location of Cores C29 and 30 after GPR scanning

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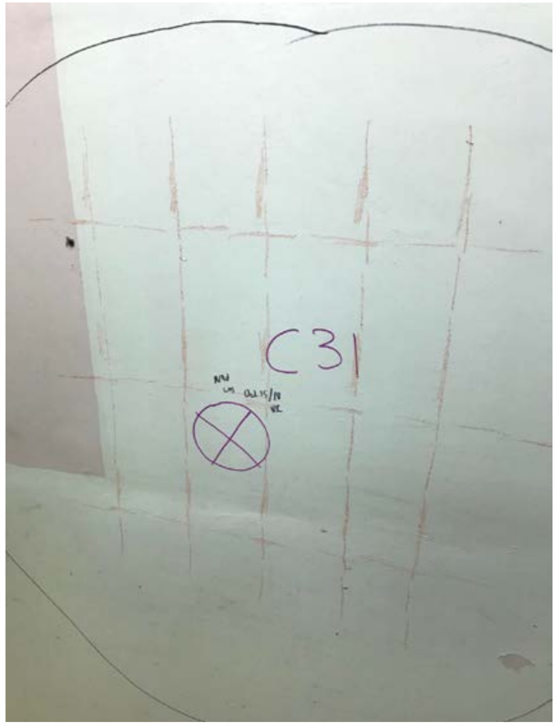
Project:	18101723		Checked By:	MPN

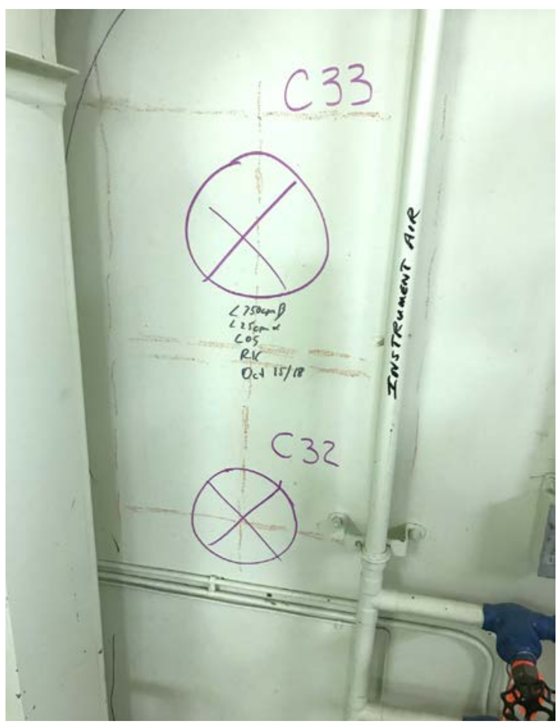
Core Location Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure A-13



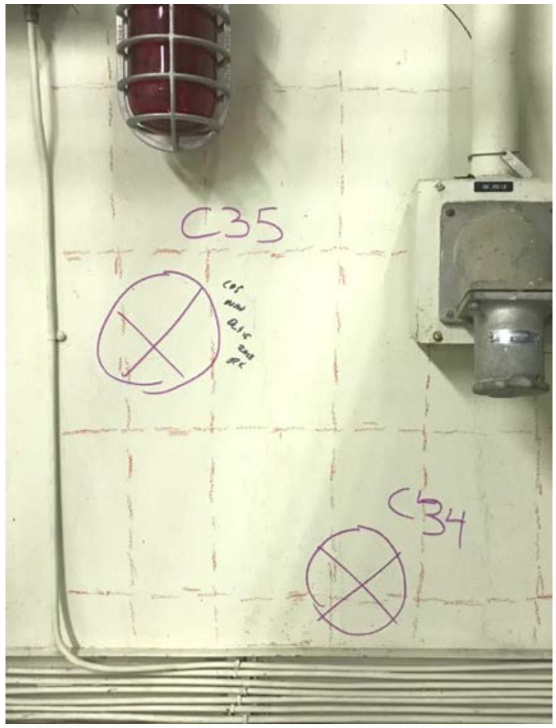
Location of Core C31 after GPR scanning



Location of Cores C32 and 33 after GPR scanning

Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Location Photographs In-situ Decommissioning of Whiteshell Reactor 1 Pinawa, Manitoba	Figure A-14



Location of Cores C34 and 35 after GPR scanning

Date:	March 2019	Golder Associates Ltd.	Inputted By:	MR
Project:	18101723		Checked By:	MPN

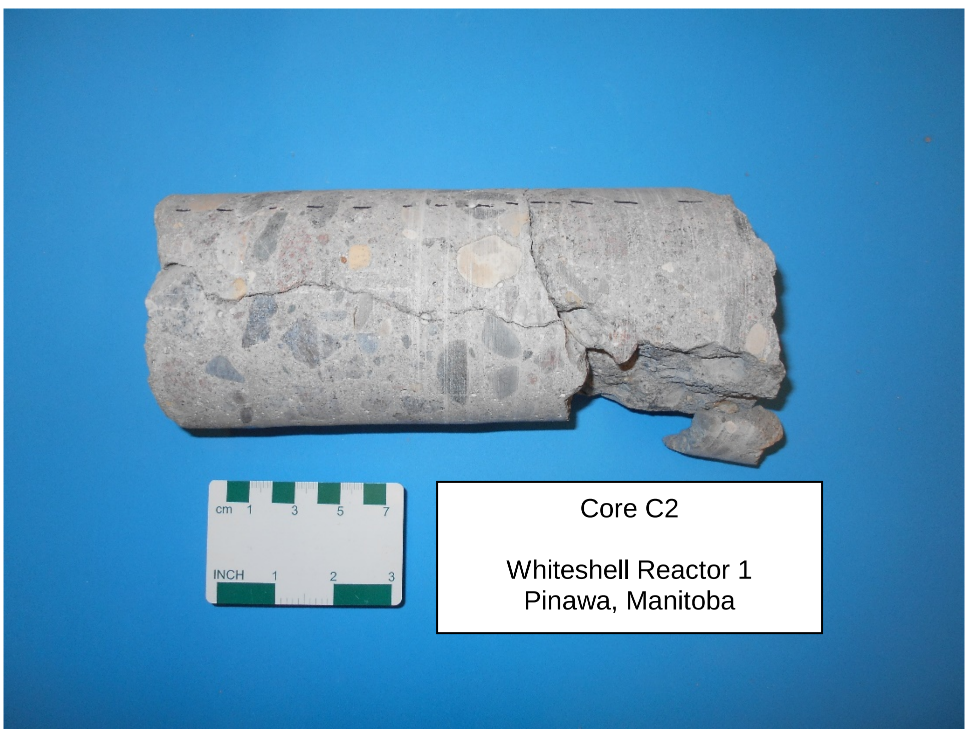
APPENDIX B

Core Photographs

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-1

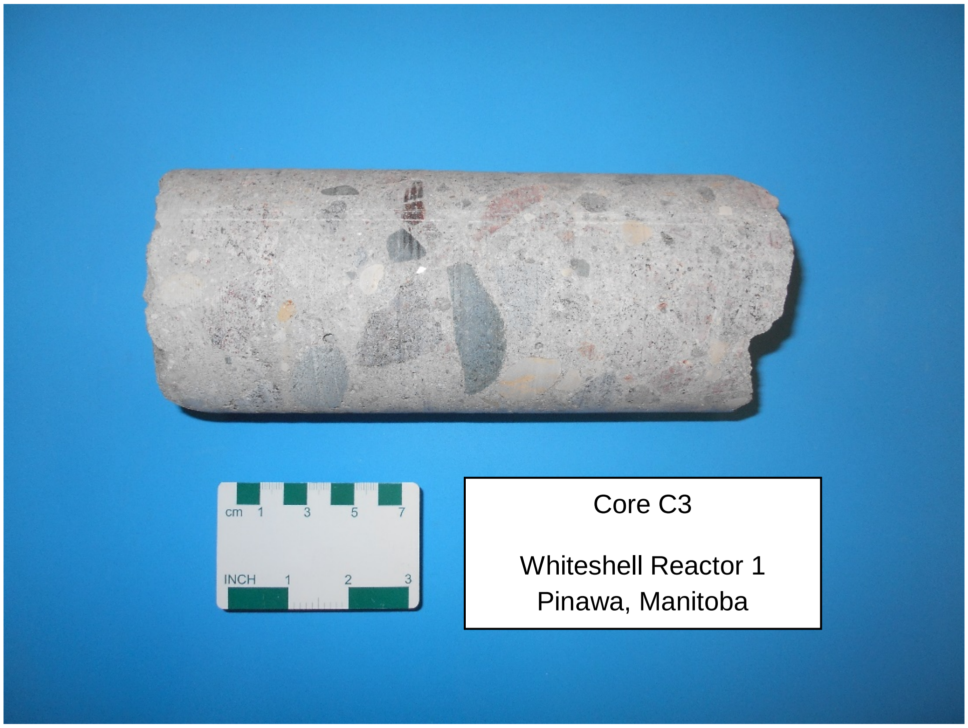


Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-2

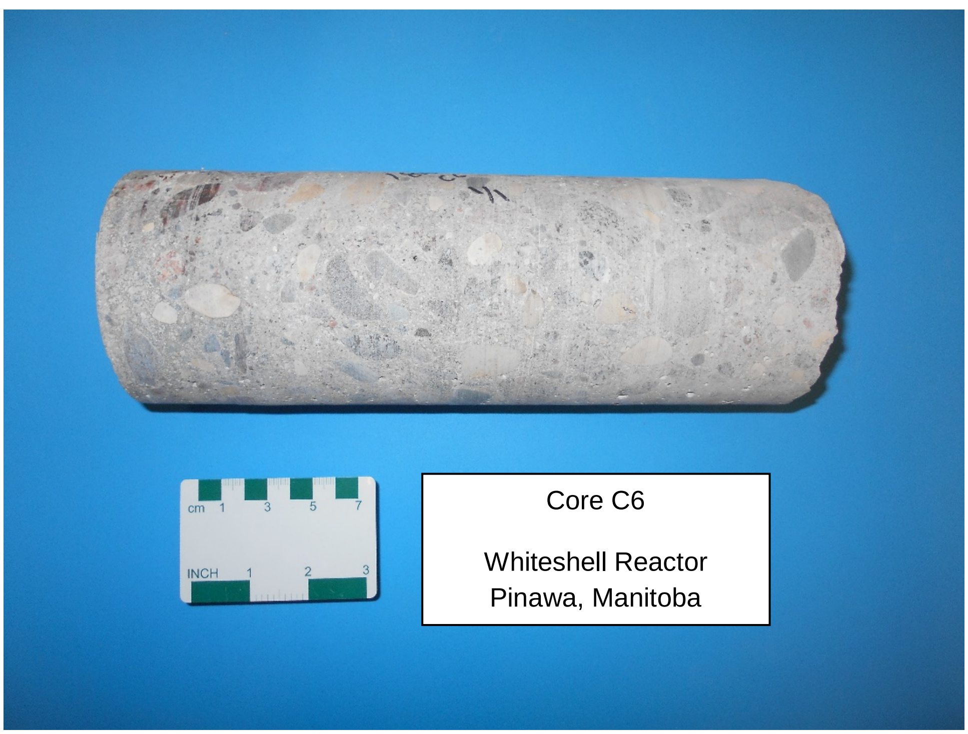


Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-3

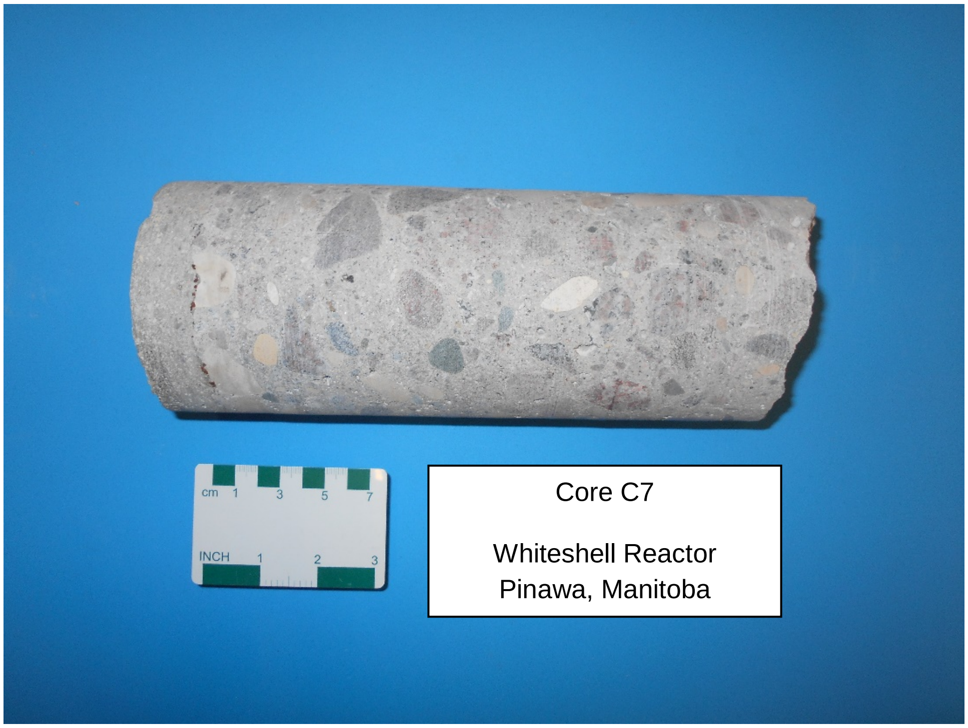


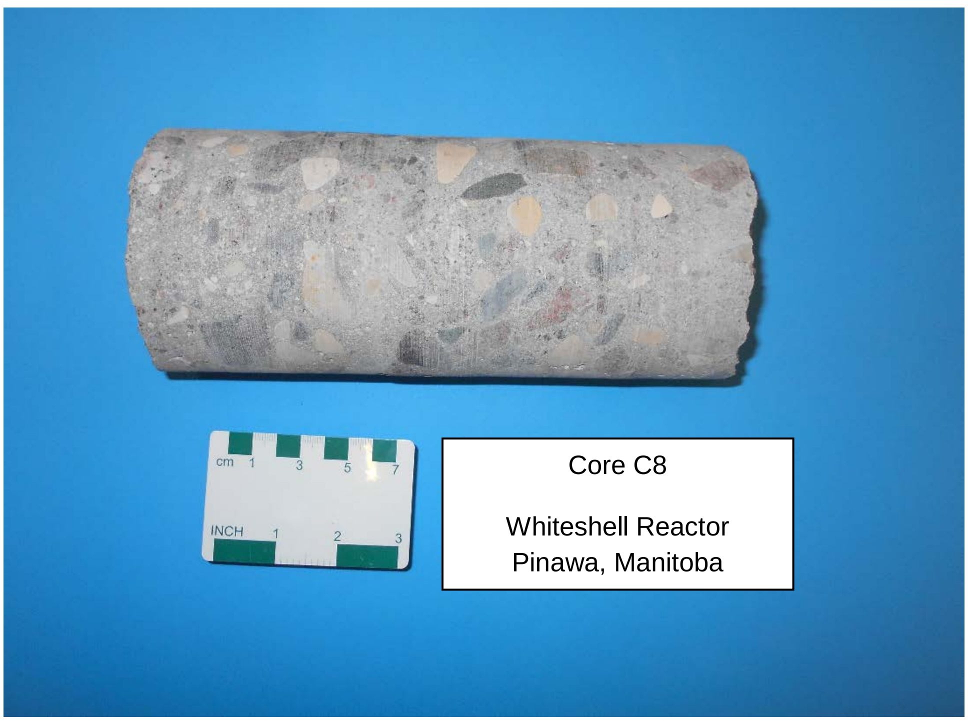
Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-4



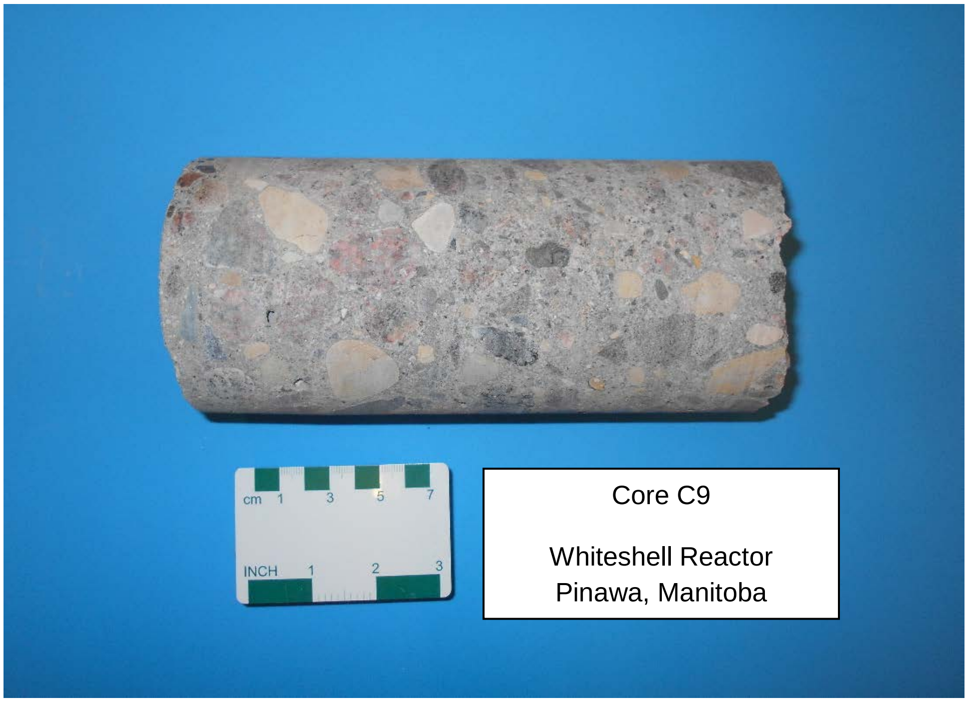


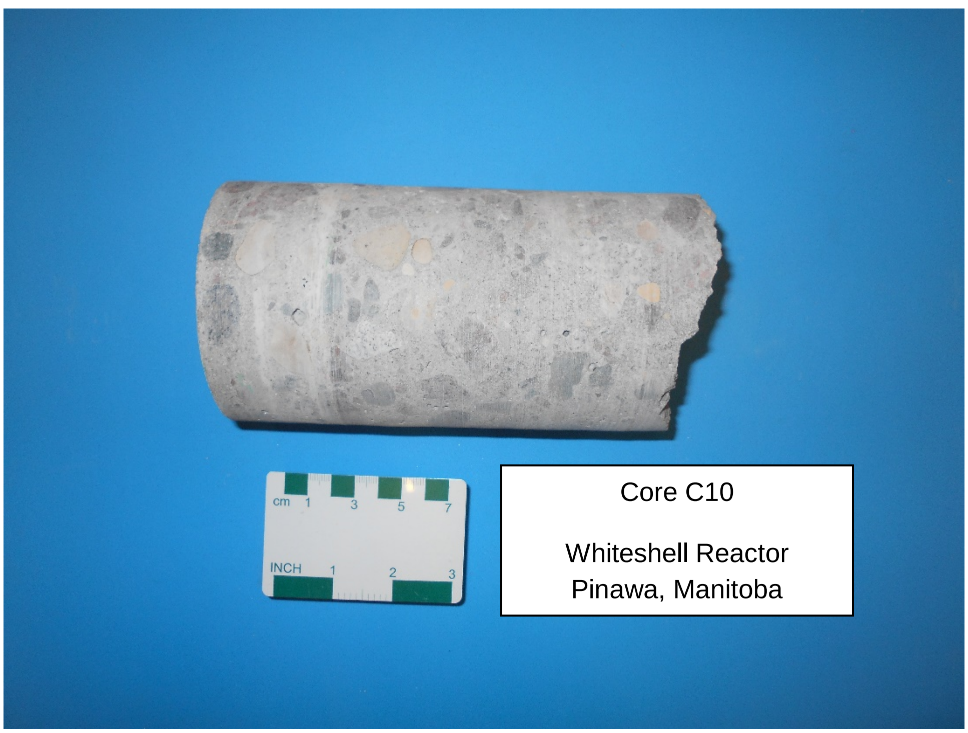
Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

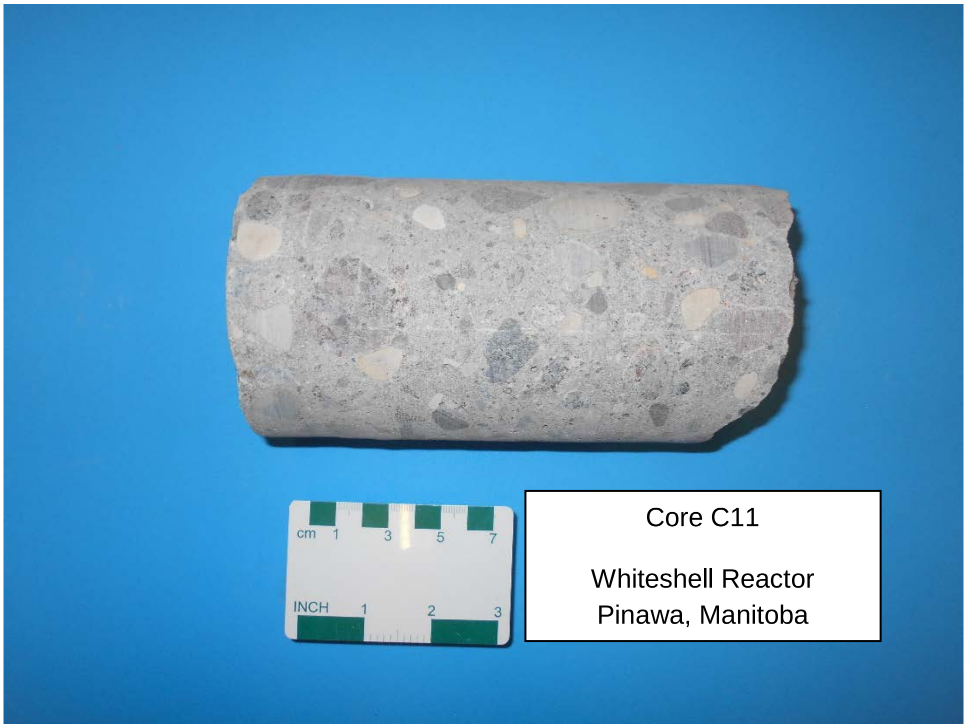
Figure B-5

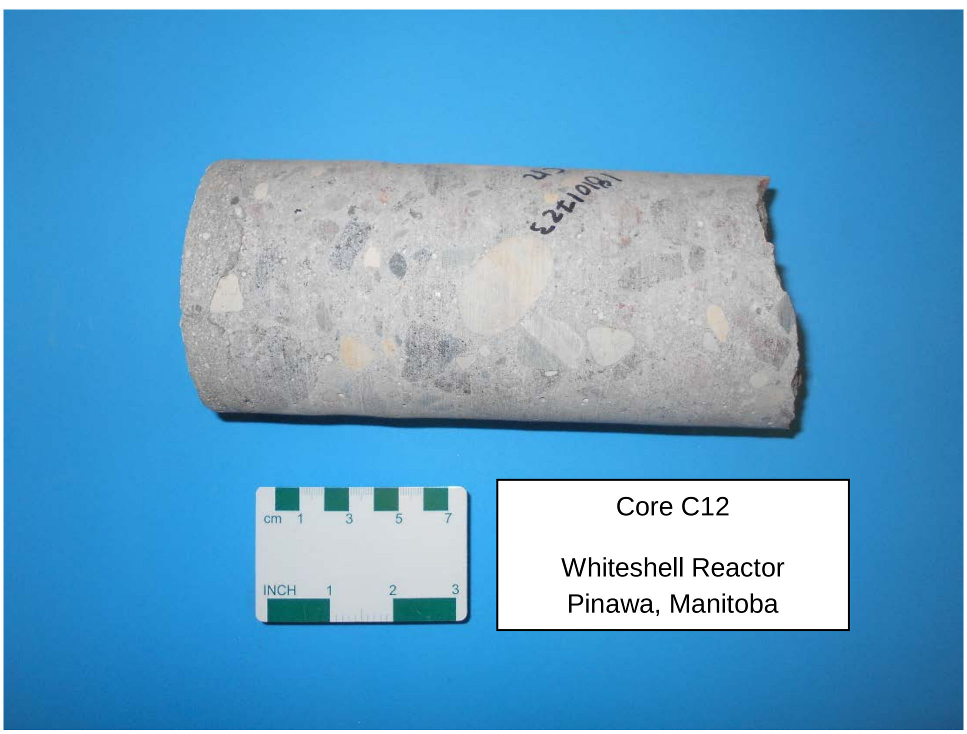




Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs In-situ Decommissioning of Whiteshell Reactor 1 Pinawa, Manitoba	**Figure B-6**



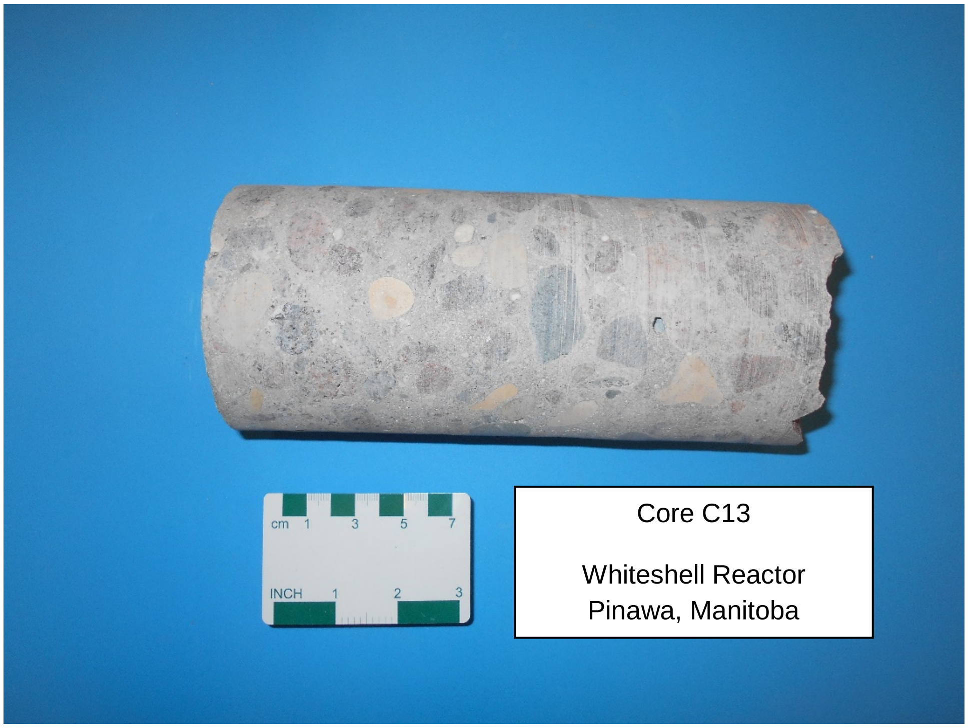


Date: March 2019	**Golder Associates Ltd.**	Inputted By: MR	
Project: 18101723		Checked By: MPN	

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-7



Core C13

Whiteshell Reactor
Pinawa, Manitoba

Core C14

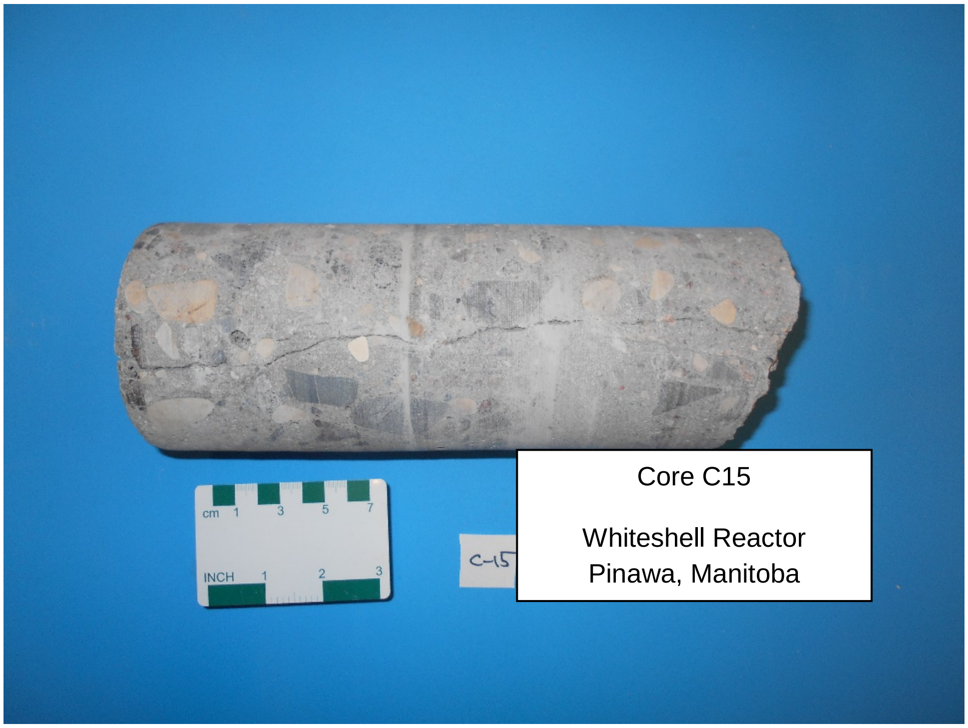
Whiteshell Reactor
Pinawa, Manitoba

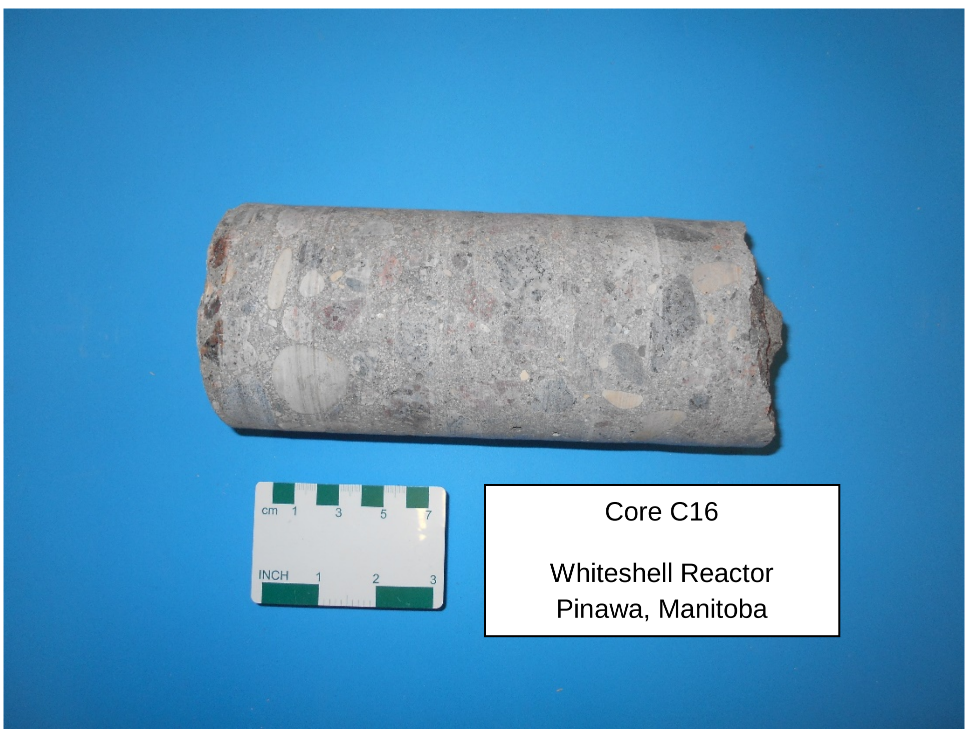
Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-8



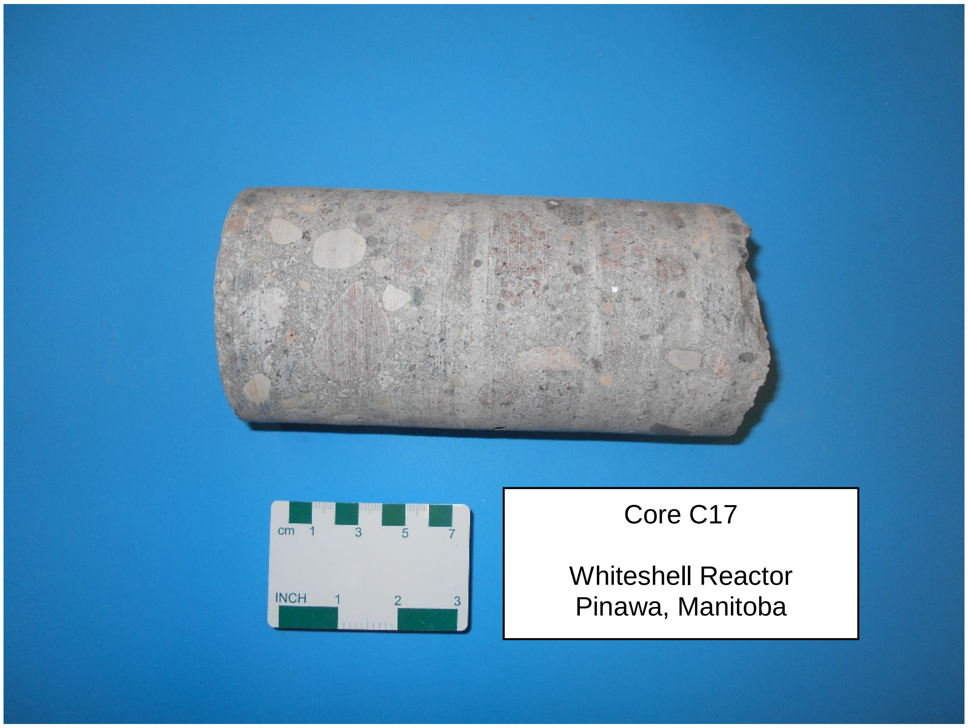


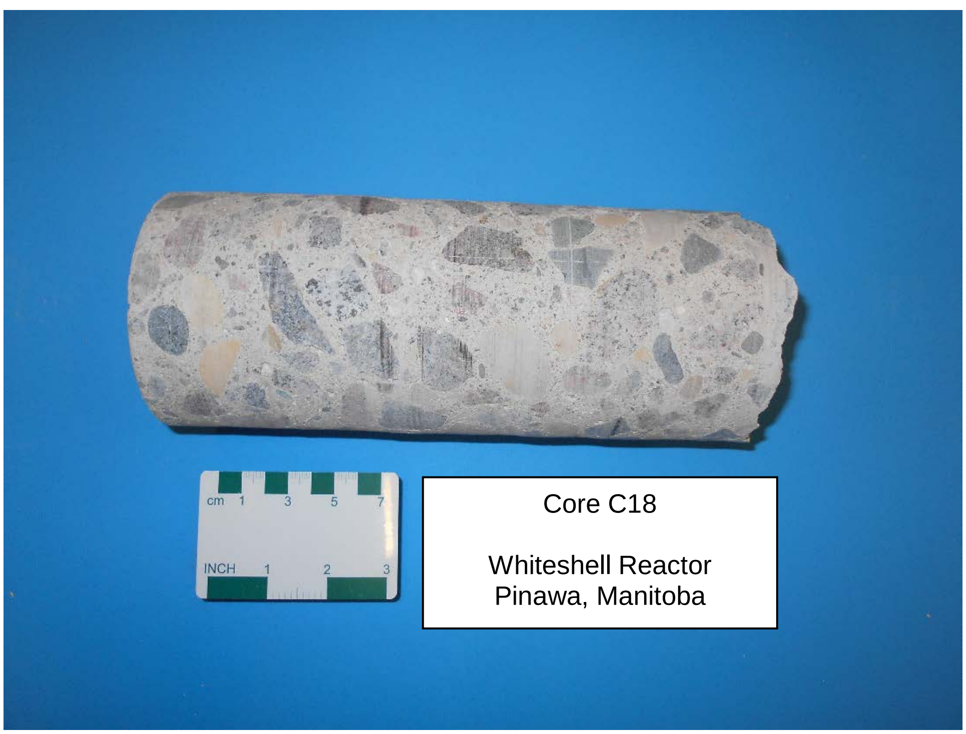
Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-9



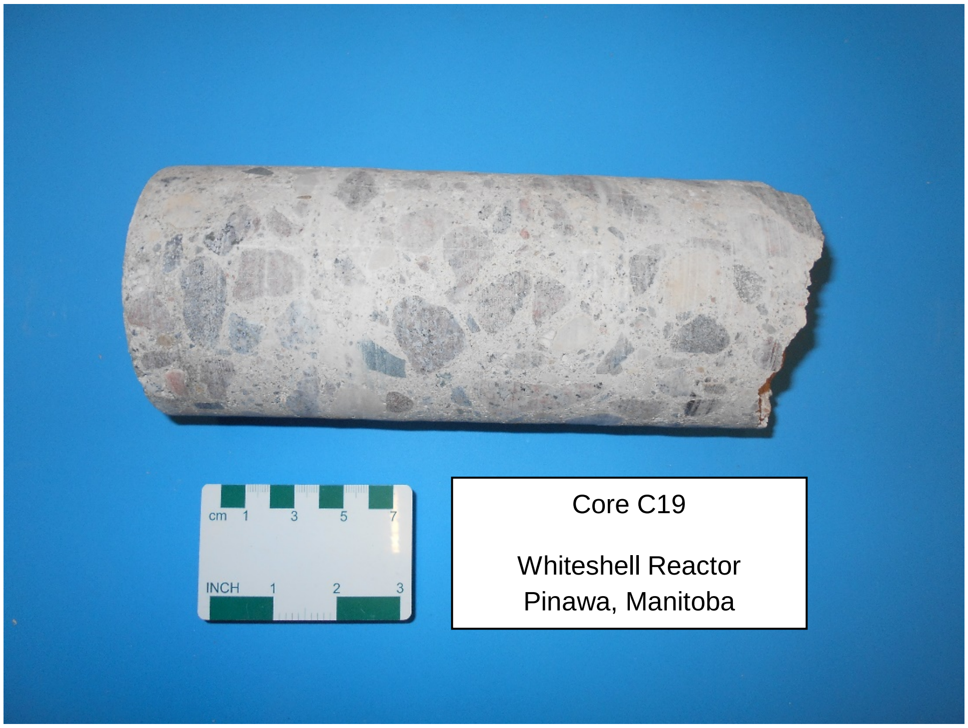


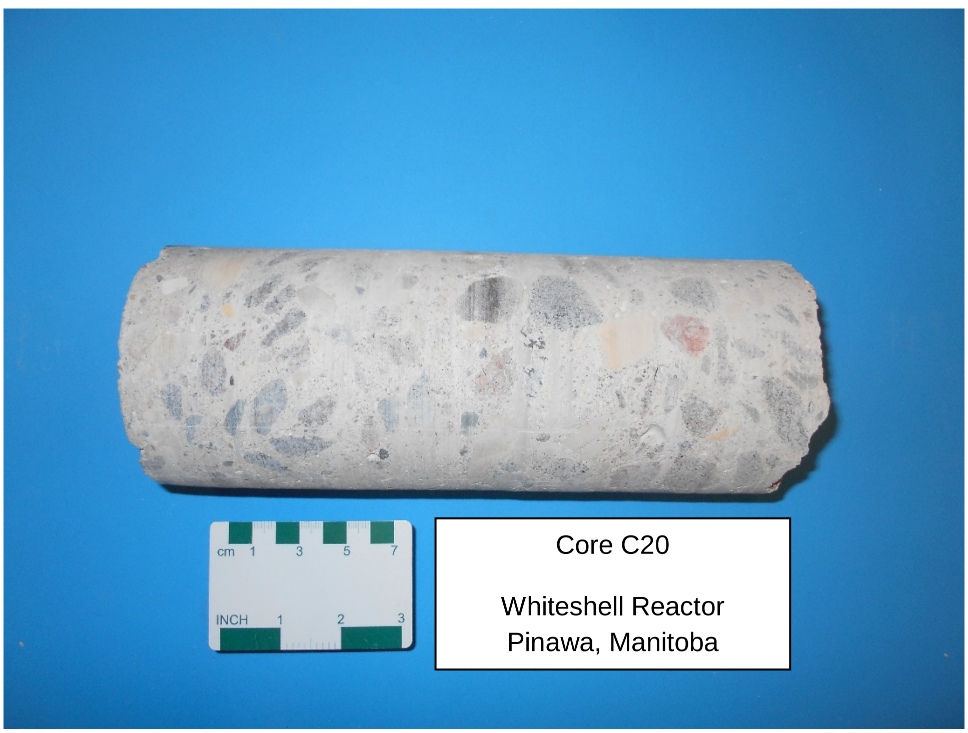
Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-10



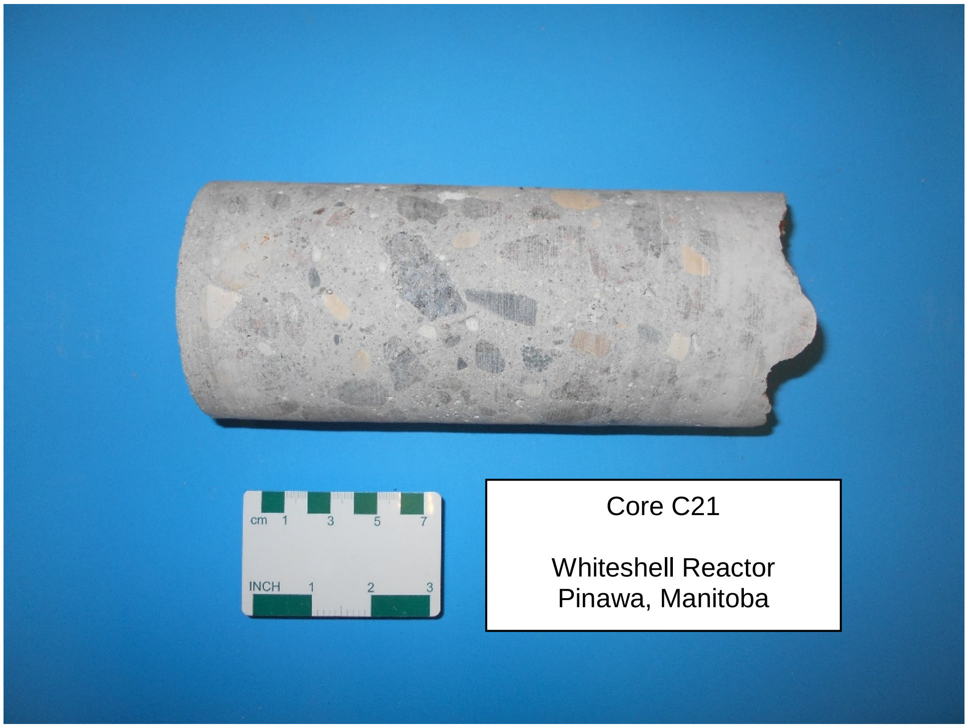


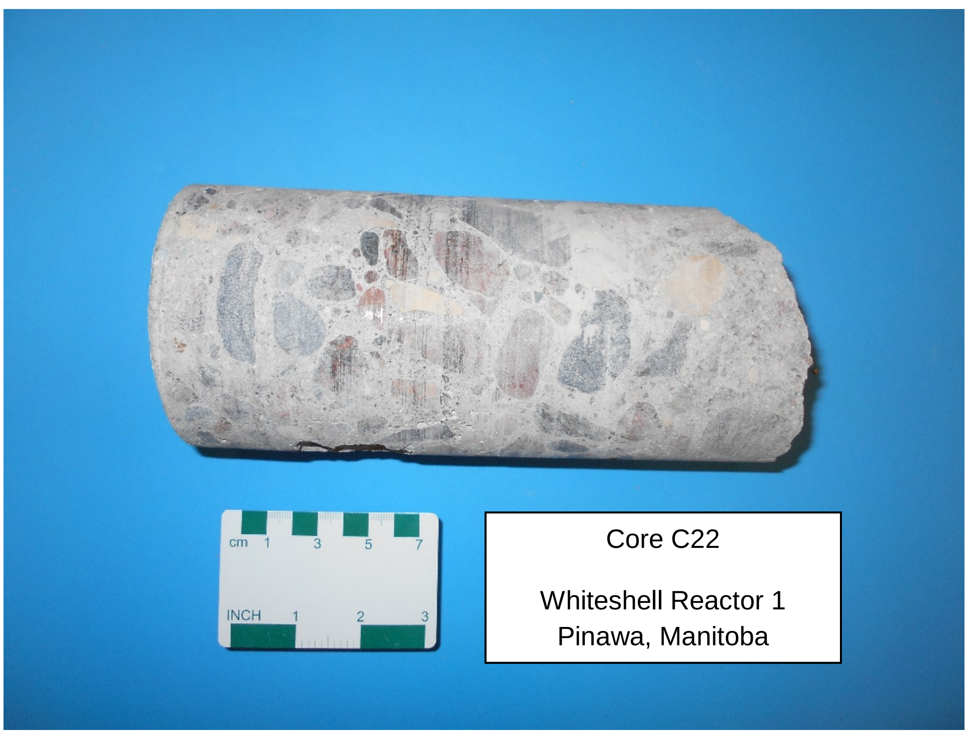
Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-11



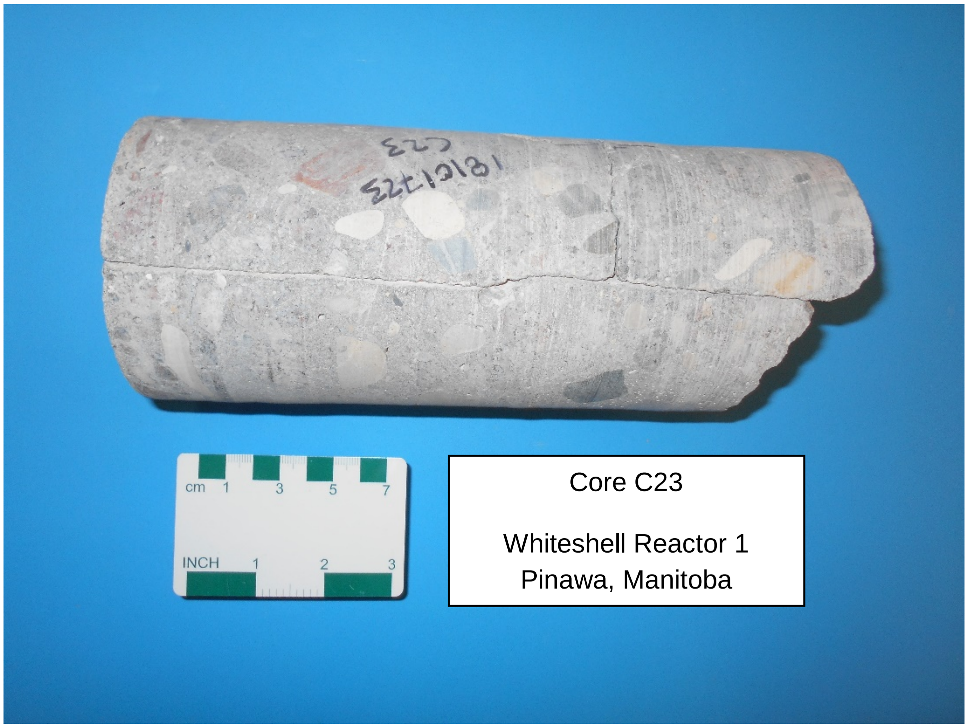


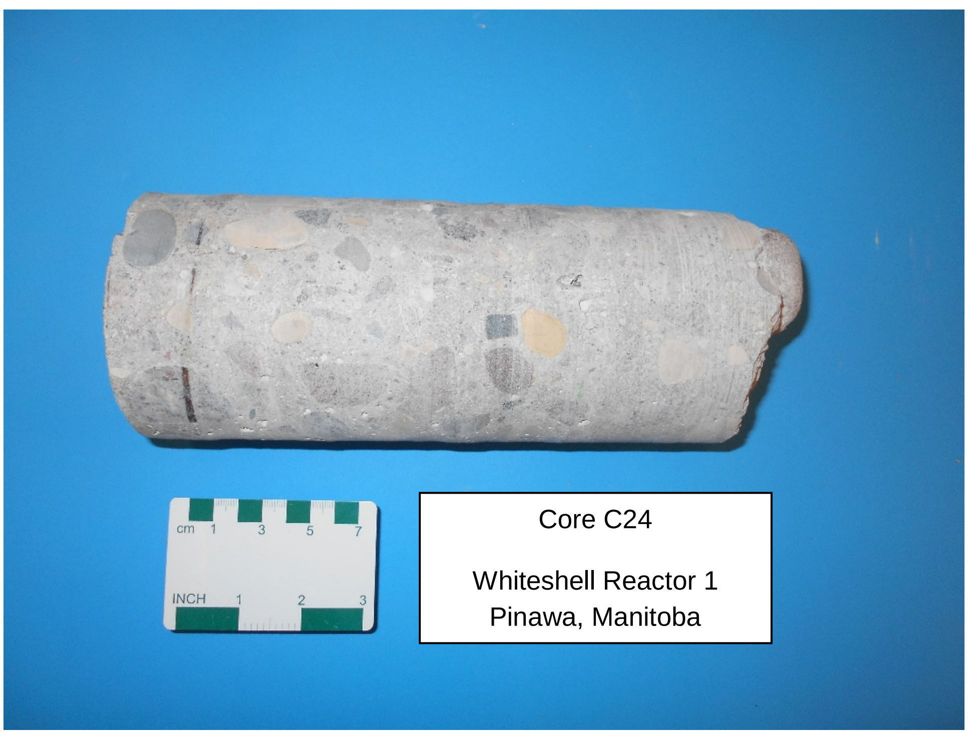
Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-12



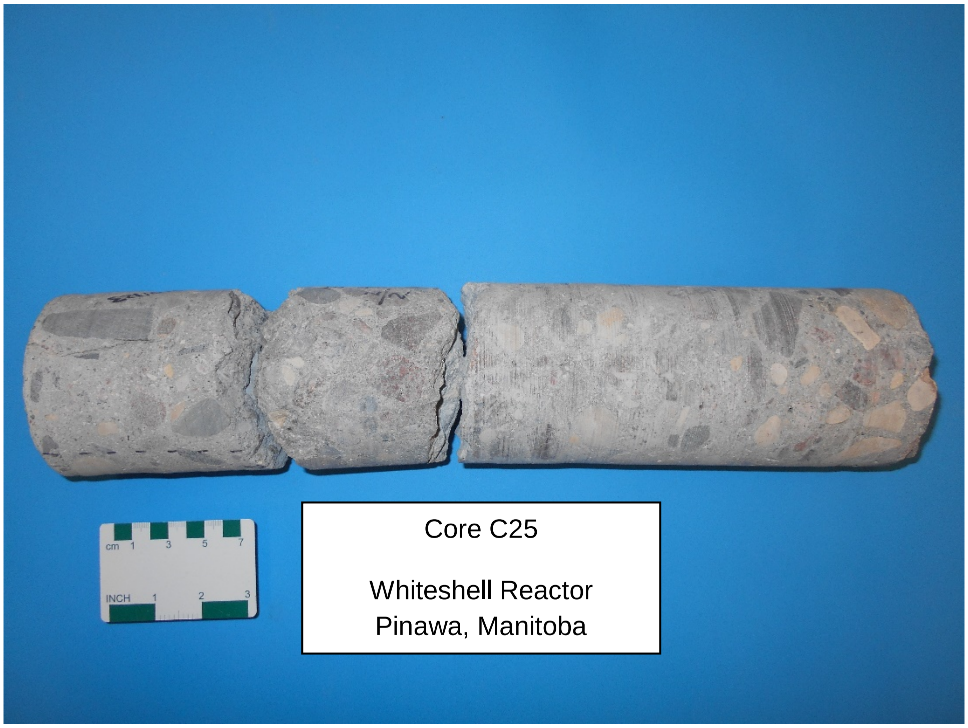


Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-13

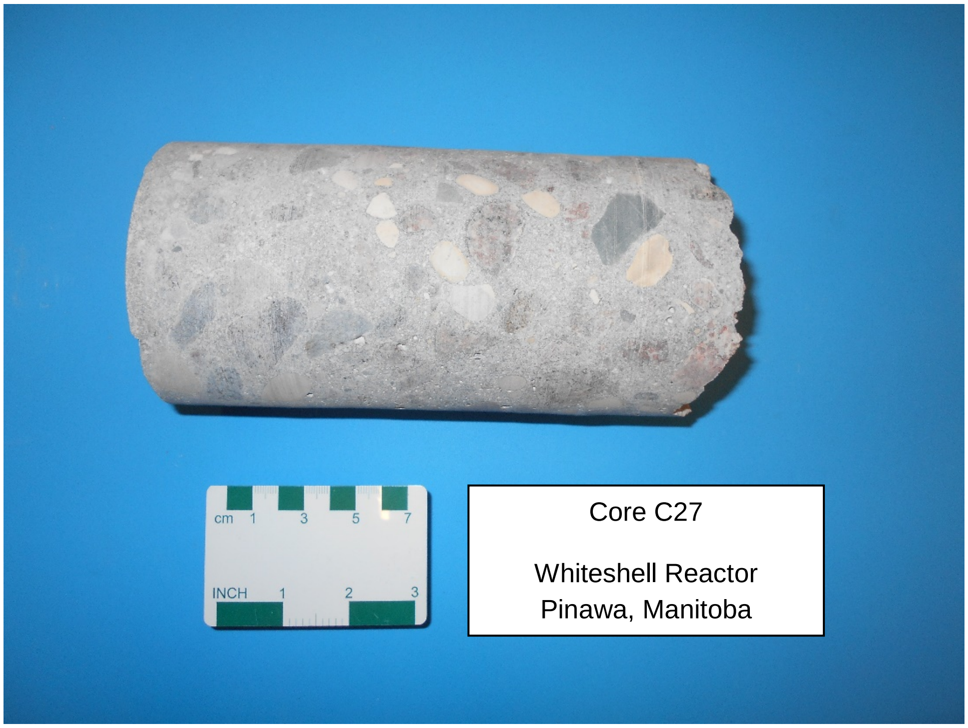


Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-14

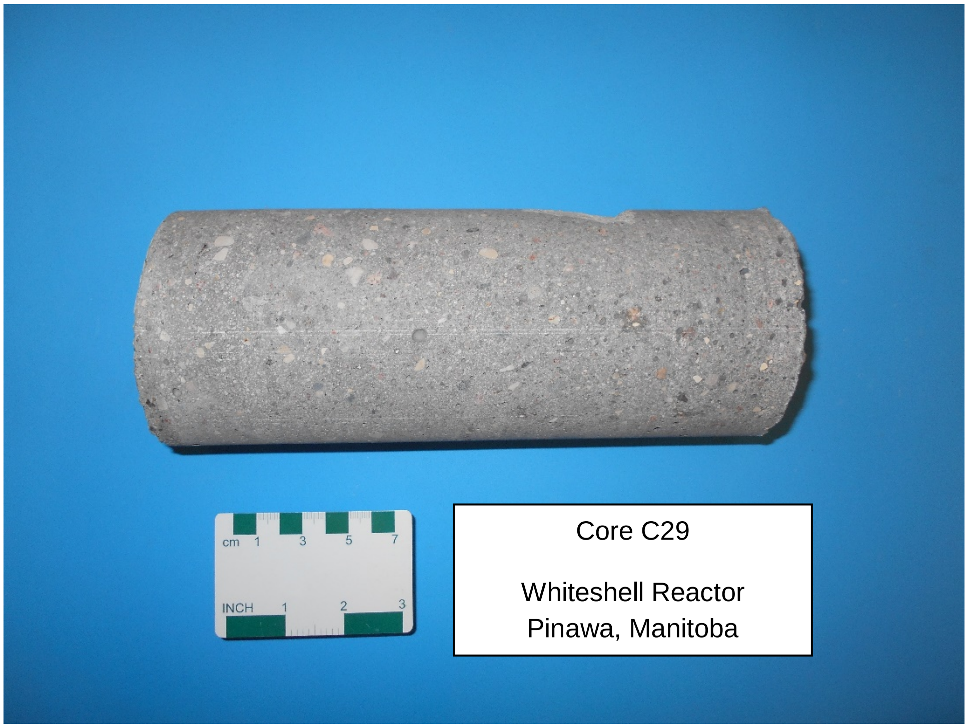


Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-15



Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-16

Core C31

Whiteshell Reactor
Pinawa, Manitoba

Core C32

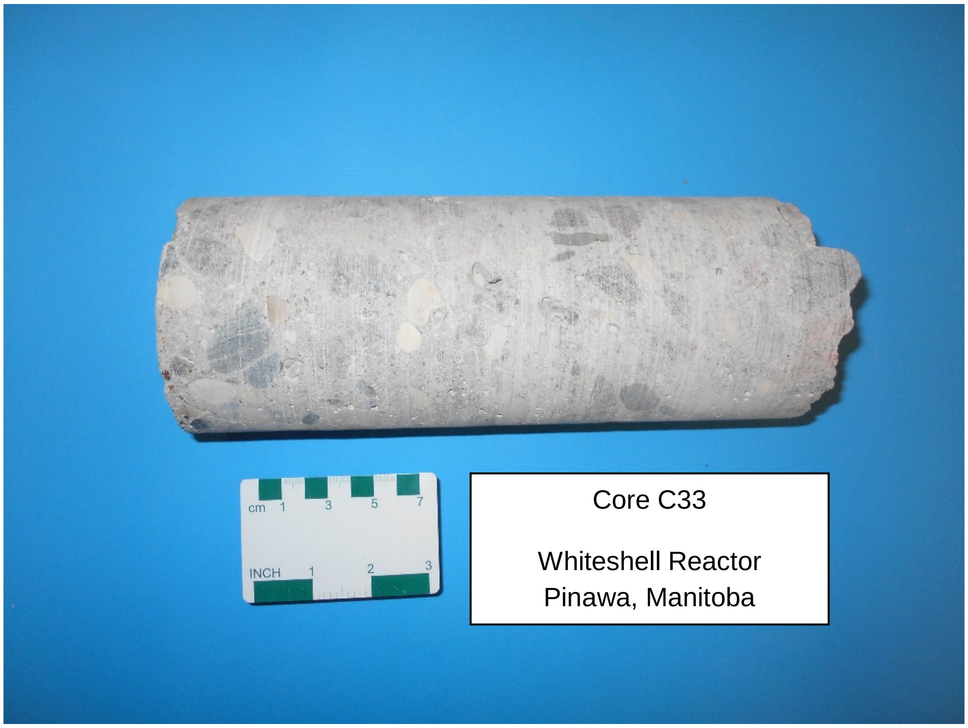
Whiteshell Reactor
Pinawa, Manitoba

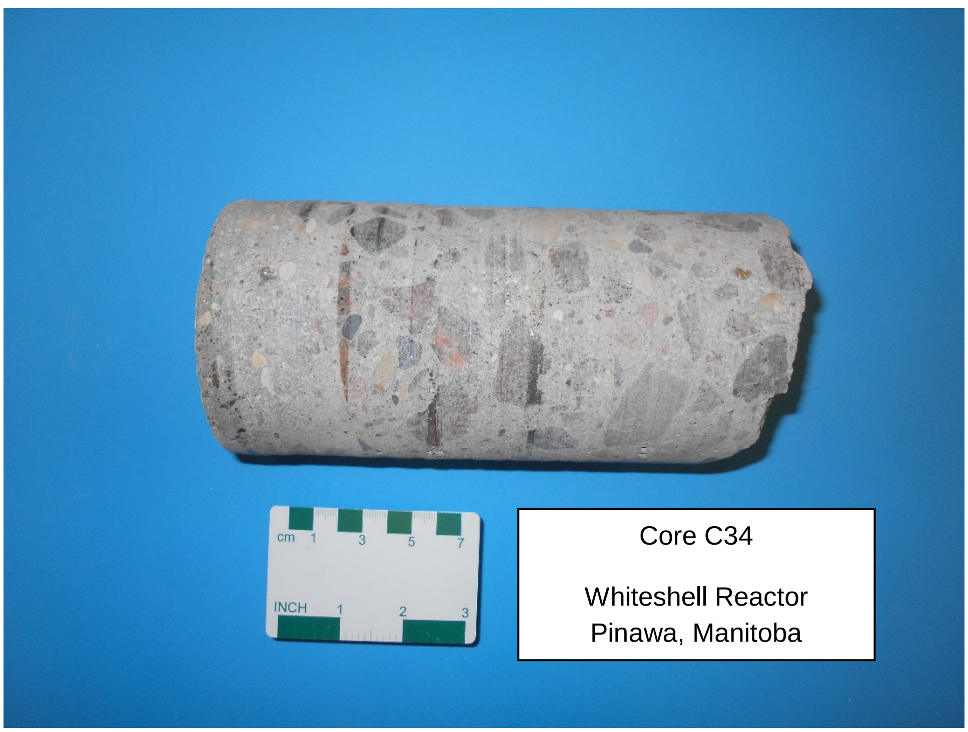
Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-17



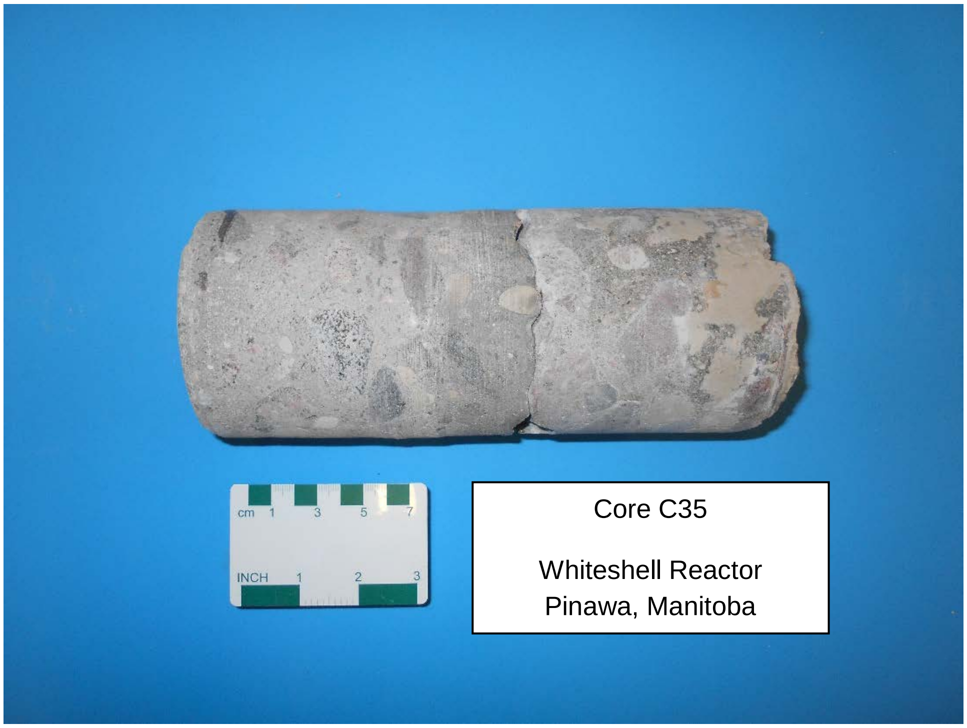


Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

Core Photographs

In-situ Decommissioning of Whiteshell Reactor 1
Pinawa, Manitoba

Figure B-18



Date:	March 2019	**Golder Associates Ltd.**	Inputted By:	MR
Project:	18101723		Checked By:	MPN

APPENDIX C

Core Logs

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		South Wall	South Wall	East Wall
Core No.		Core 1	Core 2	Core 3
Core Location		Room 107	Room 107	Room 109
Diameter, mm		95	95	95
Length, mm		220	235	210
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		F	F	G
Defects in Concrete		Y	Y	N
Condition of Rebar[2]		N/A	N/A	N/A
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa				
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm			
pH value				
Absorption After Immersion and Boiling, %		4.0		
Bulk Dry Density, kg/m^3		2,352		
Volume of Permeable Pore Space, %		9.5		
Hydraulic Conductivity, m/s				
Testing Laboratory		Golder Associates Ltd.		
Remarks		Concrete core broke during extraction at a depth of 140 mm Vertical cracking (cold joint) throughout the core Clean 20 mm diameter horizontal reinforcing steel at depths of 30 mm and 70 mm	Concrete core broke during extraction at 140 mm Vertical cracking throughout the core No other defects noted in concrete core No reinforcing steel encountered	No defects noted in concrete core No reinforcing steel encountered

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

 Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		North Wall	South Wall	East Wall
Core No.		Core 4	Core 5	Core 6
Core Location		Stairs 1	Room 538	Room 508
Diameter, mm		95	95	95
Length, mm		200	225	260
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		G	G	G
Defects in Concrete		Y	Y	Y
Condition of Rebar[2]		N/A	N/A	N/A
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa			18.0	29.0
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm			
pH value			12	
Absorption After Immersion and Boiling, %		3.9/7.3[3]		
Bulk Dry Density, kg/m^3		2,336/2,111[3]		
Volume of Permeable Pore Space, %		9.2/15.4[3]		
Hydraulic Conductivity, m/s				
Testing Laboratory		Golder Associates Ltd.	Golder Associates Ltd.	Golder Associates Ltd.
Remarks		Vertical crack (cold joint) throughout the core No other defects noted in concrete core No reinforcing steel encountered	Minor voids in concrete core No other defects noted in concrete core No reinforcing steel encountered	Minor voids in concrete core No other defects noted in concrete core No reinforcing steel encountered

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas
3 – The Core C4 was drilled through a cold joint, i.e. the joint between two different concrete pours. Each half of the core was tested separately providing testing results for two sections of the Stair 1 north wall which were concreted separately.

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

 Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		East Wall	East Wall	East Wall
Core No.		Core 7	Core 8	Core 9
Core Location		Room 508	Room 203	Room 203
Diameter, mm		95	95	95
Length, mm		240	225	200
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		F	G	G
Defects in Concrete		Y	N	Y
Condition of Rebar[2]		N/A	C	N/A
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa				31.9
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm			
pH value				
Absorption After Immersion and Boiling, %				
Bulk Dry Density, kg/m3				
Volume of Permeable Pore Space, %				
Hydraulic Conductivity, m/s			1.62×10^{-11}	
Testing Laboratory			Golder Associates Ltd.	Golder Associates Ltd.
Remarks		Minor voids in concrete core No defects noted in concrete core No reinforcing steel encountered	Clean 20 mm diameter horizontal reinforcing steel encountered No defects noted in concrete core	Minor voids in concrete core No other defects noted in concrete core No reinforcing steel encountered

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

 Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		East Wall	North Wall	West Wall
Core No.		Core 10	Core 11	Core 12
Core Location		Room 110/111	Strainer	Strainer
Diameter, mm		95	95	95
Length, mm		200	170	210
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		G	G	G
Defects in Concrete		N	N	Y
Condition of Rebar[2]		N/A	N/A	N/A
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa				41.1
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm		Measured 0.016 0.000 0.000 0.000 - -	
pH value				
Absorption After Immersion and Boiling, %				
Bulk Dry Density, kg/m3				
Volume of Permeable Pore Space, %				
Hydraulic Conductivity, m/s				
Testing Laboratory			Golder Associates Ltd.	Golder Associates Ltd.
Remarks		No defects noted in concrete core No reinforcing steel encountered	Concrete core broke during extraction at a depth of 170 mm No other defects noted in concrete core No reinforcing steel encountered	Horizontal medium crack ~20 mm in length from edge of the core through patching mortar to existing concrete No other defects noted in concrete core No reinforcing steel encountered

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		North Wall	East Wall	East Wall
Core No.		Core 13	Core 14	Core 15
Core Location		Room 103	Stairs 1	Stairs 1
Diameter, mm		95	95	95
Length, mm		215	210	225
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		G	G	G
Defects in Concrete		N	Y	Y
Condition of Rebar[2]		N/A	N/A	N/A
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa		28.6	32.4	
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm			 0.019 0.010 0.009 0.009 0.006 0.010
pH value		12	12/12	
Absorption After Immersion and Boiling, %				
Bulk Dry Density, kg/m3				
Volume of Permeable Pore Space, %				
Hydraulic Conductivity, m/s				
Testing Laboratory		Golder Associates Ltd.	Golder Associates Ltd.	Golder Associates Ltd.
Remarks		No defects noted in concrete core No reinforcing steel encountered	Minor voids in concrete core	Vertical medium crack throughout the core No other defects noted in concrete core No reinforcing steel encountered

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		West Wall	North Wall	West Wall
Core No.		Core 16	Core 17	Core 18
Core Location		Stairs 2	Room 402	Room 505
Diameter, mm		95	95	95
Length, mm		200	200	230
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		G	G	G
Defects in Concrete		Y	Y	Y
Condition of Rebar[2]		N/A	N/A	N/A
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa		39.6	41.3	
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm			
pH value				
Absorption After Immersion and Boiling, %				
Bulk Dry Density, kg/m3				
Volume of Permeable Pore Space, %				
Hydraulic Conductivity, m/s				9.75×10^{-11}
Testing Laboratory		Golder Associates Ltd.	Golder Associates Ltd.	Golder Associates Ltd.
Remarks		Minor voids in concrete core No other defects noted in concrete core No reinforcing steel encountered	Minor voids in concrete core No other defects noted in concrete core No reinforcing steel encountered	Minor voids in concrete core No other defects noted in concrete core No reinforcing steel encountered

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

 Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		West Wall	West Wall	North Wall
Core No.		Core 19	Core 20	Core 21
Core Location		Room 505	Room 536	Room 202
Diameter, mm		95	95	95
Length, mm		220	200	215
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		G	G	G
Defects in Concrete		Y	N	Y
Condition of Rebar[2]		N/A	N/A	N/A
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa		14.3		30.3
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm			
pH value		12/12		
Absorption After Immersion and Boiling, %				
Bulk Dry Density, kg/m3				
Volume of Permeable Pore Space, %				
Hydraulic Conductivity, m/s				
Testing Laboratory		Golder Associates Ltd.		Golder Associates Ltd.
Remarks		Minor voids in concrete core No other defects noted in concrete core No reinforcing steel encountered	No defects noted in concrete core No reinforcing steel encountered	Minor voids in concrete core No other defects noted in concrete core No reinforcing steel encountered

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

 Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		North Wall	Floor Slab	Floor Slab
Core No.		Core 22	Core 23	Core 24
Core Location		Room 202	Room 107	Room 107
Diameter, mm		95	95	95
Length, mm		200	230	235
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		F	F	G
Defects in Concrete		Y	Y	Y
Condition of Rebar[2]		N/A	N/A	N/A
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa				
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm			
pH value				
Absorption After Immersion and Boiling, %				
Bulk Dry Density, kg/m3				
Volume of Permeable Pore Space, %				
Hydraulic Conductivity, m/s		7.26×10^{-11}		
Testing Laboratory		Golder Associates Ltd.		
Remarks		Large void ~40 mm in length at a depth of 35 mm No other defects noted in concrete core No reinforcing steel encountered	Vertical crack (cold joint) throughout the core Concrete core broke during extraction at 150 mm 10-15 mm diameter voids in concrete core	Vertical medium crack from the top of core to a depth of 100 mm No other defects noted in concrete core No reinforcing steel encountered

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		Floor Slab	Floor Slab	Floor Slab
Core No.		Core 25	Core 26	Core 27
Core Location		Room 108	Room 109	Room 110/111
Diameter, mm		95	95	95
Length, mm		430	200	200
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		G	G	G
Defects in Concrete		Y	N	N
Condition of Rebar[2]		N/A	N/A	N/A
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa		42.5		30.1
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm			
pH value				
Absorption After Immersion and Boiling, %		5.5		
Bulk Dry Density, kg/m3		2.253		
Volume of Permeable Pore Space, %		12.4		
Hydraulic Conductivity, m/s				
Testing Laboratory		Golder Associates Ltd.		Golder Associates Ltd.
Remarks		Core was advanced in two steps: 205 mm (Oct 30, 2018) and 225 mm (Oct 31, 2018) Vertical medium crack from the top of core to a depth of 205 mm Concrete core broke during extraction at depths of 100 mm and 205 mm No reinforcing steel encountered	No defects noted in concrete core No reinforcing steel encountered	No defects noted in concrete core No reinforcing steel encountered

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		Floor Slab	South Wall	South Wall
Core No.		Core 28	Core 29	Core 30
Core Location		Room 103	Stairs 2	Stairs 2
Diameter, mm		95	95	95
Length, mm		200	240	180
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		G	G	G
Defects in Concrete		N	Y	Y
Condition of Rebar[2]		N/A	N/A	C
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa			90.2	
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm			
pH value				
Absorption After Immersion and Boiling, %				
Bulk Dry Density, kg/m3				
Volume of Permeable Pore Space, %				
Hydraulic Conductivity, m/s		1.16×10^{-11}		
Testing Laboratory		Golder Associates Ltd.	Golder Associates Ltd.	
Remarks		No defects noted in concrete core No reinforcing steel encountered	No coarse aggregate in concrete, lower density, possible repairs mix Chip at a depth of 140 mm No other defects noted in concrete core No reinforcing steel encountered	Vertical medium crack throughout the core Clean 20 mm diameter horizontal reinforcing steel at a depth of 150 mm No other defects noted in concrete core

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

 Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		South Wall	North Wall	North Wall
Core No.		Core 31	Core 32	Core 33
Core Location		Room 538	Room 508	Room 508
Diameter, mm		95	95	95
Length, mm		250	315	240
Full Depth (Yes/No)		N	N	N
Condition of Concrete[1]		G	G	G
Defects in Concrete		Y	N	Y
Condition of Rebar[2]		C	N/A	N/A
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	N/A
Compressive Strength, MPa			25.0	
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm	Measured 0.014 0.010 0.020 0.014 0.010 0.008		
pH value				
Absorption After Immersion and Boiling, %			4.1	
Bulk Dry Density, kg/m3			2.330	
Volume of Permeable Pore Space, %			9.6	
Hydraulic Conductivity, m/s				$4.84x10^{-11}$
Testing Laboratory		Golder Associates Ltd.	Golder Associates Ltd.	Golder Associates Ltd.
Remarks		Clean 20 mm diameter horizontal reinforcing steel at a depth of 40 mm Minor voids in concrete core No other defects noted in concrete core	Concrete core broke during extraction at a depth of 160 mm No other defects noted in concrete core No reinforcing steel encountered	Minor voids in concrete core No other defects noted in concrete core No reinforcing steel encountered

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

CORE LOG FOR EXPOSED CONCRETE COMPONENTS

Whiteshell Reactor 1
Golder Project Number:18101723

Component Type and Location		West Wall	West Wall	
Core No.		Core 34	Core 35	
Core Location		Room 107	Room 107	
Diameter, mm		95	95	
Length, mm		195	210	
Full Depth (Yes/No)		N	N	
Condition of Concrete[1]		G	G	
Defects in Concrete		N	N	
Condition of Rebar[2]		N/A	C	
Corrosion Potential at Nearest Grid Point, V		N/A	N/A	
Compressive Strength, MPa		40.3		
Chloride Content % Chloride by Weight of Concrete	Horizon 0–10 mm 50–60 mm 100–110 mm 150–160 mm 200–210 mm 250–260 mm			
pH value				
Absorption After Immersion and Boiling, %			5.3	
Bulk Dry Density, kg/m3			2.235	
Volume of Permeable Pore Space, %			11.8	
Hydraulic Conductivity, m/s				
Testing Laboratory		Golder Associates Ltd.	Golder Associates Ltd.	
Remarks		No defects noted in concrete core No reinforcing steel encountered	Concrete core broke during extraction at a depth of 130 mm Clean 25 mm diameter horizontal reinforcing steel at a depth of 70 mm No other defects noted in concrete core	

1 – Condition of Concrete: G = Good, F= Fair, P = Poor
2 – Condition of Rebar: C = Clean, LR = Light Rust, MR = Moderate Rust, SR = Severe Rust, N/A = No Rebar Exposed
Condition of Epoxy Coating: ECG = Good, ECF = Fair, ECP = Poor – rusted and debonded areas

APPENDIX D

Laboratory Test Results

GOLDER

OBTAINING AND TESTING DRILLED CORES FOR COMPRESSIVE STRENGTH (CSA A23.2-14C)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

December 12, 2018
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessment**

Date Sampled:	October 29, 2018 to November 5, 2018	Date Tested:	December 3, 2018
Date Received:	November 27, 2018	Tested By:	D. Kaur

Core ID	Golder Lab Number	Moisture Conditioning	Diameter (mm)	Length (mm)	Density (Mg/m^3)	Load (kN)	Corrected Compressive Strength (Mpa)
Location: Room 538, South Wall, Horizontal							
C-5	C-18-0806	Wet	95	186	2.294	128.00	**18.0**
Location: Room 508, East Wall, Horizontal							
C-6	C-18-0807	Wet	95	186	2.321	206.11	**29.0**
Location: Room 203, East Wall, Horizontal							
C-9	C-18-0808	Wet	95	184	2.377	226.95	**31.8**
Location: Strainer, West Wall, Horizontal							
C-12	C-18-0809	Wet	95	156	2.429	299.50	**41.1**
Location: Room 103, North Wall, Horizontal							
C-13	C-18-0810	Wet	95	188	2.382	201.15	**28.6**
Location: Stairs 1, East Wall, Horizontal							
C-14	C-18-0811	Wet	95	178	2.351	231.35	**32.4**

Data Input By: D. Tompkins

Reviewed by: ______________________
Jeremy Rose, Laboratory Supervisor

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La voix des laboratoires indépendants canadiens

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OBTAINING AND TESTING DRILLED CORES FOR COMPRESSIVE STRENGTH (CSA A23.2-14C)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

December 12, 2018
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessment**

Date Sampled:	October 29, 2018 to November 5, 2018	Date Tested:	December 3, 2018
Date Received:	November 27, 2018	Tested By:	D. Kaur

Core ID	Golder Lab Number	Moisture Conditioning	Diameter (mm)	Length (mm)	Density (Mg/m^3)	Load (kN)	Corrected Compressive Strength (Mpa)
Location: Stairs 2, West Wall, Horizontal							
C-16	C-18-0813	Wet	94	184	2.390	275.50	**39.6**
Location: Room 402, North Wall, Horizontal							
C-17	C-18-0814	Wet	95	170	2.377	294.10	**41.3**
Location: Room 505, West Wall, Horizontal Water Level: Below							
C-19	C-18-0815	Wet	95	175	2.268	101.90	**14.3**
Location: Room 202, North Wall, Horizontal							
C-21	C-18-0816	Wet	95	183	2.325	216.20	**30.3**
Location: Room 108, Vertical							
C-25	C-18-0817	Wet	96	165	2.375	311.60	**42.5**
Location: Room 111, Vertical							
C-27	C-18-0818	Wet	95	167	2.382	217.15	**30.1**

Data Input By: D. Tompkins

Reviewed by: ____________________
Jeremy Rose, Laboratory Supervisor

OBTAINING AND TESTING DRILLED CORES FOR COMPRESSIVE STRENGTH (CSA A23.2-14C)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

December 12, 2018
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessment**

Date Sampled:	October 29, 2018 to November 5, 2018	Date Tested:	December 3, 2018
Date Received:	November 27, 2018	Tested By:	D. Kaur

Core ID	Golder Lab Number	Moisture Conditioning	Diameter (mm)	Length (mm)	Density (Mg/m^3)	Load (kN)	Corrected Compressive Strength (Mpa)
Location: Stairs 2, South Wall, Horizontal							
C-29	C-18-0819	Wet	95	181	2.262	643.25	**90.2**
Location: Room 508, North Wall, Horizontal							
C-32	C-18-0821	Wet	95	144	2.325	184.35	**25.0**
Location: Room 107, West Wall, Horizontal							
C-34	C-18-0822	Wet	95	150	2.301	295.75	**40.3**

Data Input By: D. Tompkins

Reviewed by: ______________________
Jeremy Rose, Laboratory Supervisor

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GOLDER

DETERMINATION OF TOTAL ACID SOLUBLE CHLORIDE ION IN CONCRETE (MTO LS-417)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

January 11, 2019
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessments**

Date Sampled:	October 11, 2018	Date Tested:	January 11, 2019
Date Received:	November 27, 2018	Tested By:	J. Allen

Core ID:	C11
Location:	Strainer, North Wall, Horizontal
Golder Lab Number:	C-19-0010
Horizon Depth (mm)	% Chloride Ion by Weight of Concrete
0 - 10	0.016
50 - 60	0.000
100 - 110	0.000
150 - 160	0.000

Data Input By: D. Tompkins

Reviewed by: ______________________
Jeremy Rose, Laboratory Supervisor

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GOLDER

DETERMINATION OF TOTAL ACID SOLUBLE CHLORIDE ION IN CONCRETE (MTO LS-417)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

December 12, 2018
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessments**

Date Sampled:	October 31, 2018 to November 2, 2018	Date Tested:	December 11, 2018
Date Received:	November 27, 2018	Tested By:	J. Allen

Core ID:	C-15	C-31
Location:	Stairs 1, East Wall, Horizontal	Room 538, South Wall, Horizontal
Golder Lab Number:	C-18-0812	C-18-0820
Horizon Depth (mm)	% Chloride Ion by Weight of Concrete	
0 - 10	0.019	0.014
50 - 60	0.010	0.010
100 - 110	0.009	0.020
150 - 160	0.009	0.014
200 - 210	0.006	0.010
240 - 250	0.010	0.008

Data Input By: D. Tompkins

Reviewed by: ______________________
Jeremy Rose, Laboratory Supervisor

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PH VALUE OF CONCRETE (ASTM F170)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

December 5, 2018
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessment**

Date Sampled:	October 31, 2018 to November 5, 2018	Date Tested:	November 29, 2018
Date Received:	November 27, 2018	Tested By:	J. Allen

Core ID	Golder Laboratory Number	Location of Core	PH Value
Location: Room 538, South Wall, Horizontal			
C-5	C-18-0806	Bottom	12
Location: Room 103, North Wall, Horizontal			
C-13	C-18-0810	Bottom	12
Location: Stairs 1, East Wall, Horizontal			
C-14-2	C-18-0811	Top	12
		Bottom	12
Location: Room 505, West Wall, Horizontal			
C-19	C-18-0815	Top	12
		Bottom	12
Location: Room 111, Vertical			
C-27	C-18-0818	Top	12

Data Input By: D. Tompkins

Reviewed by:

Jeremy Rose, Laboratory Supervisor

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GOLDER

WATER CONTENT, DENSITY, ABSORPTION, AND VOIDS IN HARDENED CONCRETE, GROUT, OR MORTAR (CSA A23.2-11C)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

December 12, 2018
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessment - C-1, Room 107 South Wall, Horizontal**

Date Sampled:	October 29, 2018	Golder Lab No.:	C-18-0804
Time Sampled:	Not Available	Date Tested:	December 4, 2018
Date Received:	November 27, 2018	Tested By:	J. Allen

Sample ID:	A	B	C
Water Content (%):	1.6	1.3	1.1
Absorption After Immersion (%):	3.5	3.4	3.8
Absorption After Immersion and Boiling (%)	3.9	3.8	4.4
Dry Density (kg/m^3):	2345	2347	2364
Density After Immersion (kg/m^3):	2428	2426	2452
Density After Immersion and Boiling (kg/m^3):	2437	2438	2467
Volume of Permeable Pore Space (%):	9.2	9.0	10.3

Data Input By: D. Tompkins

Reviewed by:
Jeremy Rose, Laboratory Supervisor

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WATER CONTENT, DENSITY, ABSORPTION, AND VOIDS IN HARDENED CONCRETE, GROUT, OR MORTAR (CSA A23.2-11C)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

December 12, 2018
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessment - C-4, Stairs 1 North Wall, Horizontal**

Date Sampled:	November 2, 2018	Golder Lab No.:	C-18-0805
Time Sampled:	Not Available	Date Tested:	December 4, 2018
Date Received:	November 27, 2018	Tested By:	J. Allen

Sample ID:	A	B	C
Water Content (%):	1.6	1.4	2.0
Absorption After Immersion (%):	3.2	4.1	6.5
Absorption After Immersion and Boiling (%)	3.4	4.4	7.3
Dry Density (kg/m^3):	2372	2300	2111
Density After Immersion (kg/m^3):	2448	2394	2248
Density After Immersion and Boiling (kg/m^3):	2454	2402	2265
Volume of Permeable Pore Space (%):	8.2	10.2	15.4

Data Input By: D. Tompkins

Reviewed by: ______________________
Jeremy Rose, Laboratory Supervisor

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GOLDER

WATER CONTENT, DENSITY, ABSORPTION, AND VOIDS IN HARDENED CONCRETE, GROUT, OR MORTAR (CSA A23.2-11C)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

December 19, 2018
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessment - C-25, Room 108, Vertical**

Date Sampled:	October 31, 2018	Golder Lab No.:	C-18-0817
Time Sampled:	Not Available	Date Tested:	December 13, 2018
Date Received:	November 27, 2018	Tested By:	J. Allen

Sample ID:	A	B	C
Water Content (%):	1.9	1.8	2.5
Absorption After Immersion (%):	4.9	4.5	3.8
Absorption After Immersion and Boiling (%)	6.2	5.6	4.8
Dry Density (kg/m^3):	2218	2239	2303
Density After Immersion (kg/m^3):	2326	2340	2391
Density After Immersion and Boiling (kg/m^3):	2354	2364	2414
Volume of Permeable Pore Space (%):	13.7	12.5	11.1

Data Input By: D. Tompkins

Reviewed by:

Jeremy Rose, Laboratory Supervisor

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GOLDER

WATER CONTENT, DENSITY, ABSORPTION, AND VOIDS IN HARDENED CONCRETE, GROUT, OR MORTAR (CSA A23.2-11C)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

December 12, 2018
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessment - C-32, Room 508 North Wall, Horizontal**

Date Sampled:	November 1, 2018	Golder Lab No.:	C-18-0821
Time Sampled:	Not Available	Date Tested:	December 4, 2018
Date Received:	November 27, 2018	Tested By:	J. Allen

Sample ID:	A	B	C
Water Content (%):	1.8	2.2	2.3
Absorption After Immersion (%):	3.5	3.5	3.7
Absorption After Immersion and Boiling (%)	4.0	4.0	4.3
Dry Density (kg/m^3):	2320	2325	2346
Density After Immersion (kg/m^3):	2401	2405	2434
Density After Immersion and Boiling (kg/m^3):	2414	2418	2447
Volume of Permeable Pore Space (%):	9.4	9.3	10.0

Data Input By: D. Tompkins

Reviewed by: ______________________
Jeremy Rose, Laboratory Supervisor

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WATER CONTENT, DENSITY, ABSORPTION, AND VOIDS IN HARDENED CONCRETE, GROUT, OR MORTAR (CSA A23.2-11C)

Canadian Nuclear Laboratories Ltd.
1 Ara Mooradian Way
Pinawa, MB R0E 1L0

December 12, 2018
Golder Project Number: 18101723-6000-6300

Sample Description: **CNL - WR-1 _ Building Condition Assessment - C-35, Room 107 West Wall, Horizontal**

Date Sampled:	November 5, 2018	Golder Lab No.:	C-18-0823
Time Sampled:	Not Available	Date Tested:	December 4, 2018
Date Received:	November 27, 2018	Tested By:	J. Allen

Sample ID:	A	B	C
Water Content (%):	1.4	1.5	1.7
Absorption After Immersion (%):	5.4	4.4	4.4
Absorption After Immersion and Boiling (%)	5.8	4.8	5.2
Dry Density (kg/m^3):	2129	2299	2277
Density After Immersion (kg/m^3):	2243	2400	2377
Density After Immersion and Boiling (kg/m^3):	2253	2410	2394
Volume of Permeable Pore Space (%):	12.4	11.1	11.8

Data Input By: D. Tompkins

Reviewed by: ______________________
Jeremy Rose, Laboratory Supervisor

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GOLDER

January 23, 2019 Project No. 18101723

GEOTECHNICAL LABORATORY TESTING

Dear Sir,

This letter reports the results of laboratory testing carried out on the samples received at our lab in Mississauga. The results of the test are summarized below and in the attached figures.

Sample C-8 was tested in the Mississauga lab for hydraulic conductivity and the value of $1.62x10^{-11}$m/s was measured.

Sample C-18 was tested in the Mississauga lab for hydraulic conductivity and the value of $9.75x10^{-11}$m/s was measured.

Sample C-22 was tested in the Mississauga lab for hydraulic conductivity and the value of $7.26x10^{-11}$m/s was measured.

Sample C-28 was tested in the Mississauga lab for hydraulic conductivity and the value of $1.16x10^{-11}$m/s was measured.

Sample C-33 was tested in the Mississauga lab for hydraulic conductivity and the value of $4.84x10^{-11}$m/s was measured.

The testing services reported herein have been performed in accordance with the indicated recognized standard. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability.

We trust that the results are sufficient for your current requirements. If you have any questions, please do not hesitate to call us.

Golder Associates Ltd.

Marijana Manojlovic
Laboratory Manager

MM/lh

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HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD - Method A)

SAMPLE IDENTIFICATION

PROJECT NUMBER	18101723	SAMPLE	C-8
PROJECT TITLE	CNL_WR-1 _MN	SAMPLE DEPTH, m	-
BOREHOLE NUMBER	-	DATE	December 28, 2018

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	4.92	UNIT WEIGHT, kN/m^3	24.69
SAMPLE DIAMETER, cm	9.27	DRY UNIT WEIGHT, kN/m^3	23.17
SAMPLE AREA, cm^2	67.49	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	332.13	VOLUME OF SOLIDS, cm^3	290.62
TOTAL MASS, g	836.15	VOLUME OF VOIDS, cm^3	41.51
DRY MASS, g	784.67	VOID RATIO	0.14
WATER CONTENT, %	6.6		

SATURATION STAGE

CELL PRESSURE, kPa	140.00	EFFECTIVE CONSOLIDATION STRESS, kPa	10
HEAD PRESSURE, kPa	130.00	DURATION, min	1,221
BACK PRESSURE, kPa	130.00	B COEFFICIENT	0.96

CONSOLIDATION STAGE

CELL PRESSURE, kPa	230.00	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	130.00	DURATION, min	93
BACK PRESSURE, kPa	130.00	VOLUME CHANGE, cm^3	0.60
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	4.92	SAMPLE AREA, cm^2	67.41
SAMPLE DIAMETER, cm	9.26	SAMPLE VOLUME, cm^3	331.53

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	249	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	149	DURATION, min	9488
BACK PRESSURE, kPa	130	HYDRAULIC GRADIENT, i	39

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	4.92	UNIT WEIGHT, kN/m^3	24.00
SAMPLE DIAMETER, cm	9.26	DRY UNIT WEIGHT, kN/m^3	23.21
SAMPLE AREA, cm^2	67.41	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	331.53	VOLUME OF SOLIDS, cm^3	290.62
TOTAL MASS, g	811.35	VOLUME OF VOIDS, cm^3	40.91
DRY MASS, g	784.67	VOID RATIO	0.14
WATER CONTENT, %	3.4		

TEST RESULTS

ELAPSED TIME TO STEADY STATE FLOW (min)	0.0
DURATION OF STEADY STATE FLOW (min)	9488
INFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	2.0
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	2.9
INFLOW TO OUTFLOW RATIO	0.69
HYDRAULIC CONDUCTIVITY (INFLOW) (m/s)	1.32E-11
HYDRAULIC CONDUCTIVITY (OUTFLOW) (m/s)	1.92E-11
HYDRAULIC CONDUCTIVITY, K, m/s	1.62E-11
HYDRAULIC CONDUCTIVITY AT STANDARD TEMPERATURE, K_{20}, m/s	**1.51E-11**

NOTES:

Effective consolidation stress assigned, by client.

PERMEANT FLUID	Deaired tap water
AVERAGE TEST TEMPERATURE	23.0 °C

Checked By:MM

Prepared By: AH

Golder Associates

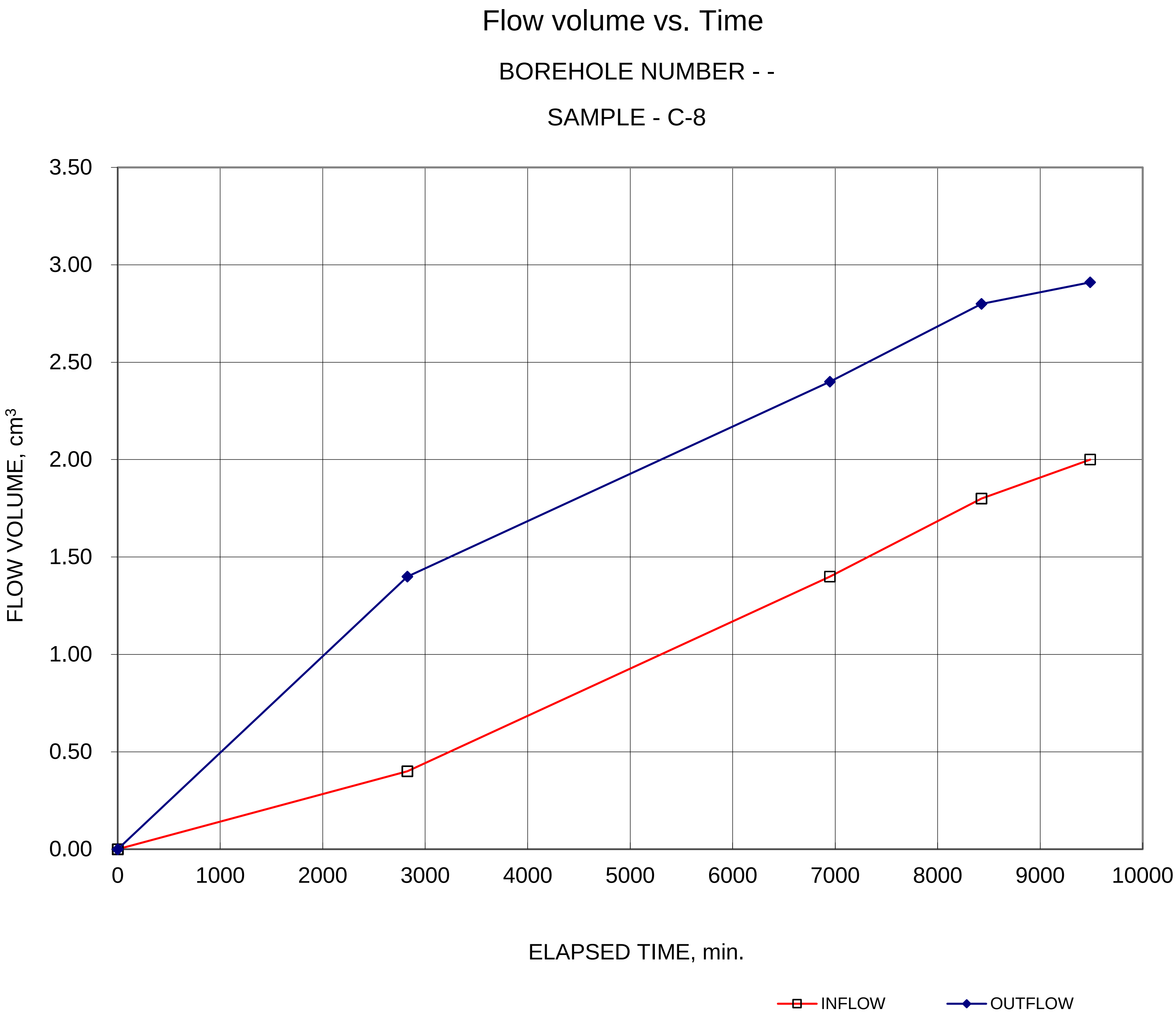
Project number : 18101723
Prepared by : AH

Golder Associates

Checked by : MM

HYDRAULIC CONDUCTIVITY TEST
ASTM D5084-METHOD A

Project title: CNL_WR-1_MN



HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD - Method A)

SAMPLE IDENTIFICATION

PROJECT NUMBER	18101723	SAMPLE	C-18
PROJECT TITLE	CNL_WR-1 _MN	SAMPLE DEPTH, m	-
BOREHOLE NUMBER	-	DATE	December 21, 2018

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	4.77	UNIT WEIGHT, kN/m^3	22.68
SAMPLE DIAMETER, cm	9.47	DRY UNIT WEIGHT, kN/m^3	21.73
SAMPLE AREA, cm^2	70.41	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	335.83	VOLUME OF SOLIDS, cm^3	275.59
TOTAL MASS, g	776.82	VOLUME OF VOIDS, cm^3	60.24
DRY MASS, g	744.10	VOID RATIO	0.22
WATER CONTENT, %	4.4		

SATURATION STAGE

CELL PRESSURE, kPa	420.00	EFFECTIVE CONSOLIDATION STRESS, kPa	10
HEAD PRESSURE, kPa	410.00	DURATION, min	3,916
BACK PRESSURE, kPa	410.00	B COEFFICIENT	0.96

CONSOLIDATION STAGE

CELL PRESSURE, kPa	510.00	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	410.00	DURATION, min	151
BACK PRESSURE, kPa	410.00	VOLUME CHANGE, cm^3	1.70
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	4.76	SAMPLE AREA, cm^2	70.17
SAMPLE DIAMETER, cm	9.45	SAMPLE VOLUME, cm^3	334.14

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	529	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	429	DURATION, min	8441
BACK PRESSURE, kPa	410	HYDRAULIC GRADIENT, **i**	41

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	4.76	UNIT WEIGHT, kN/m^3	23.24
SAMPLE DIAMETER, cm	9.45	DRY UNIT WEIGHT, kN/m^3	21.84
SAMPLE AREA, cm^2	70.17	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	334.14	VOLUME OF SOLIDS, cm^3	275.59
TOTAL MASS, g	791.72	VOLUME OF VOIDS, cm^3	58.54
DRY MASS, g	744.10	VOID RATIO	0.21
WATER CONTENT, %	6.4		

TEST RESULTS

ELAPSED TIME TO STEADY STATE FLOW (min)	0.0
DURATION OF STEADY STATE FLOW (min)	8441
INFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	12.8
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	15.4
INFLOW TO OUTFLOW RATIO	0.83
HYDRAULIC CONDUCTIVITY (INFLOW) (m/s)	8.85E-11
HYDRAULIC CONDUCTIVITY (OUTFLOW) (m/s)	1.07E-10
HYDRAULIC CONDUCTIVITY, K, m/s	9.75E-11
HYDRAULIC CONDUCTIVITY AT STANDARD TEMPERATURE, K_{20}, m/s	**9.08E-11**

NOTES:

Effective consolidation stress assigned, by client.

PERMEANT FLUID	Deaired tap water
AVERAGE TEST TEMPERATURE	23.0 °C

Project number : 18101723
Prepared by : AH

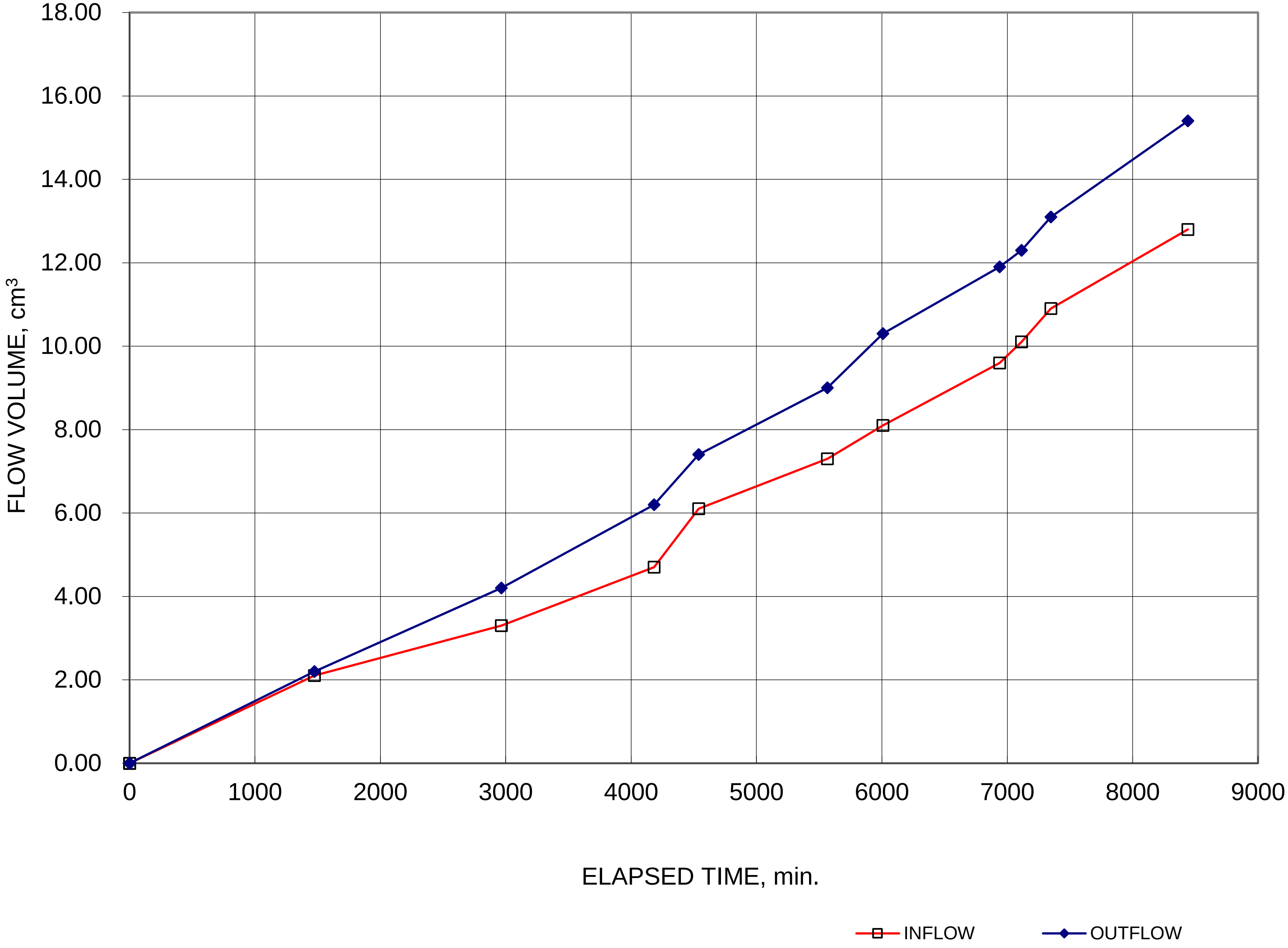
Golder Associates

Checked by : MM

Flow volume vs. Time

BOREHOLE NUMBER - -

SAMPLE - C-18



HYDRAULIC CONDUCTIVITY TEST
ASTM D5084-METHOD A

Project title: CNL_WR-1_MN

HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD - Method A)

SAMPLE IDENTIFICATION

PROJECT NUMBER	18101723	SAMPLE	C-22
PROJECT TITLE	CNL_WR-1 _MN	SAMPLE DEPTH, m	-
BOREHOLE NUMBER	-	DATE	December 11, 2018

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	4.96	UNIT WEIGHT, kN/m^3	22.93
SAMPLE DIAMETER, cm	9.52	DRY UNIT WEIGHT, kN/m^3	22.13
SAMPLE AREA, cm^2	71.18	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	353.06	VOLUME OF SOLIDS, cm^3	295.06
TOTAL MASS, g	825.45	VOLUME OF VOIDS, cm^3	58.00
DRY MASS, g	796.66	VOID RATIO	0.20
WATER CONTENT, %	3.6		

SATURATION STAGE

CELL PRESSURE, kPa	110.00	EFFECTIVE CONSOLIDATION STRESS, kPa	10
HEAD PRESSURE, kPa	100.00	DURATION, min	96
BACK PRESSURE, kPa	100.00	B COEFFICIENT	0.96

CONSOLIDATION STAGE

CELL PRESSURE, kPa	200.00	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	100.00	DURATION, min	94
BACK PRESSURE, kPa	100.00	VOLUME CHANGE, cm^3	2.50
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	4.95	SAMPLE AREA, cm^2	70.84
SAMPLE DIAMETER, cm	9.50	SAMPLE VOLUME, cm^3	350.56

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	219	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	119	DURATION, min	7196
BACK PRESSURE, kPa	100	HYDRAULIC GRADIENT, i	39

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	4.95	UNIT WEIGHT, kN/m^3	23.27
SAMPLE DIAMETER, cm	9.50	DRY UNIT WEIGHT, kN/m^3	22.29
SAMPLE AREA, cm^2	70.84	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	350.56	VOLUME OF SOLIDS, cm^3	295.06
TOTAL MASS, g	831.71	VOLUME OF VOIDS, cm^3	55.50
DRY MASS, g	796.66	VOID RATIO	0.19
WATER CONTENT, %	4.4		

TEST RESULTS

ELAPSED TIME TO STEADY STATE FLOW (min)	0.0
DURATION OF STEADY STATE FLOW (min)	7196
INFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	7.5
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	9.9
INFLOW TO OUTFLOW RATIO	0.76
HYDRAULIC CONDUCTIVITY (INFLOW) (m/s)	6.26E-11
HYDRAULIC CONDUCTIVITY (OUTFLOW) (m/s)	8.27E-11
HYDRAULIC CONDUCTIVITY, K, m/s	7.26E-11
HYDRAULIC CONDUCTIVITY AT STANDARD TEMPERATURE, K_{20}, m/s	**6.76E-11**

NOTES:

Effective consolidation stress assigned, by client.

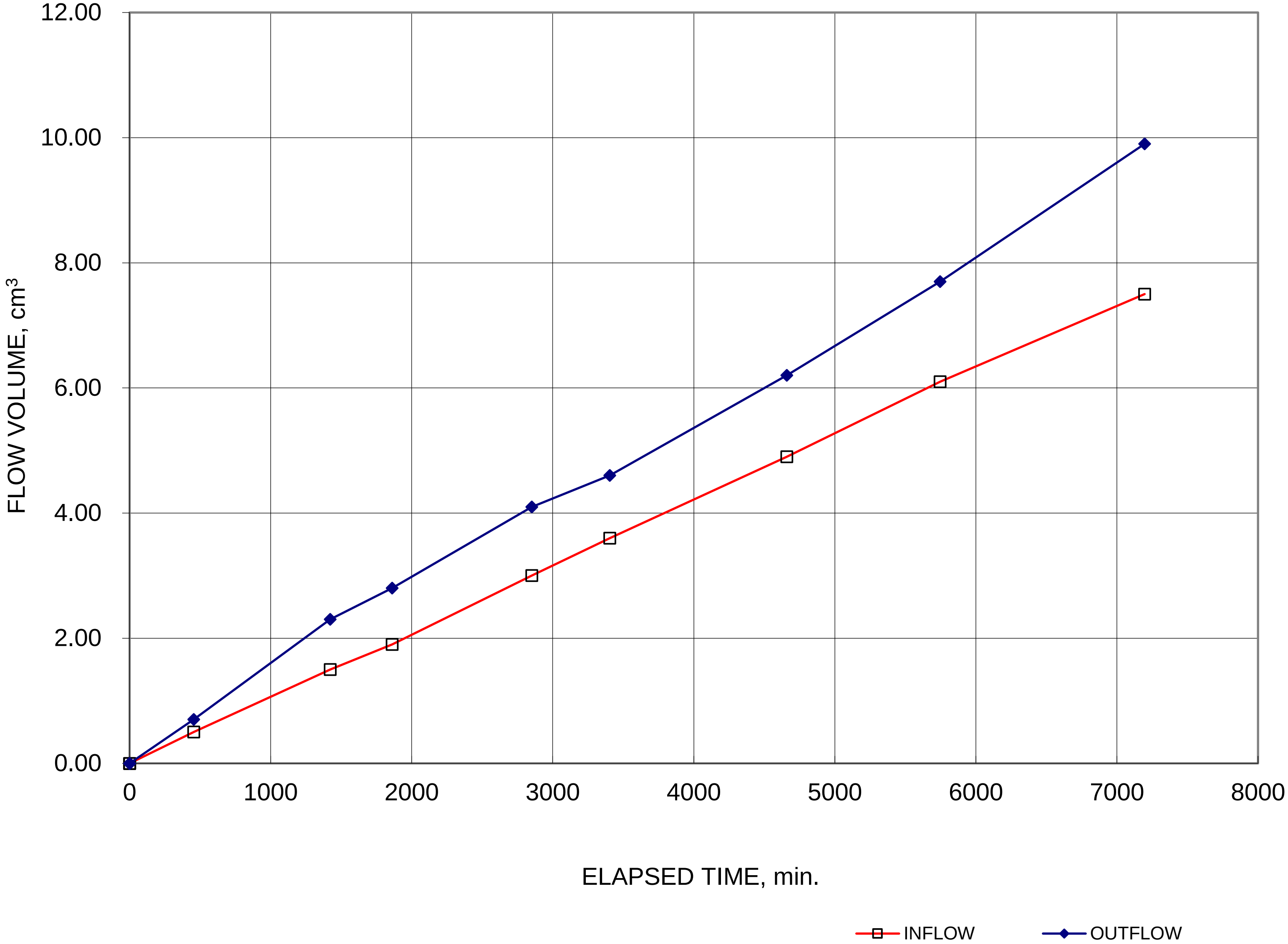
PERMEANT FLUID	Deaired tap water
AVERAGE TEST TEMPERATURE	23.0 °C

Prepared By: AH **Golder Associates** Checked By:MM

Flow volume vs. Time

BOREHOLE NUMBER - -

SAMPLE - C-22



HYDRAULIC CONDUCTIVITY TEST
ASTM D5084-METHOD A

Project title: CNL_WR-1_MN

Project number : 18101723
Prepared by : AH

Golder Associates

Checked by : MM

HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD - Method A)

SAMPLE IDENTIFICATION

PROJECT NUMBER	18101723	SAMPLE	C-28
PROJECT TITLE	CNL_WR-1 _MN	SAMPLE DEPTH, m	-
BOREHOLE NUMBER	-	DATE	December 21, 2018

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	5.30	UNIT WEIGHT, kN/m^3	22.75
SAMPLE DIAMETER, cm	9.53	DRY UNIT WEIGHT, kN/m^3	22.29
SAMPLE AREA, cm^2	71.27	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	377.52	VOLUME OF SOLIDS, cm^3	317.79
TOTAL MASS, g	875.64	VOLUME OF VOIDS, cm^3	59.73
DRY MASS, g	858.05	VOID RATIO	0.19
WATER CONTENT, %	2.1		

SATURATION STAGE

CELL PRESSURE, kPa	420.00	EFFECTIVE CONSOLIDATION STRESS, kPa	10
HEAD PRESSURE, kPa	410.00	DURATION, min	3,925
BACK PRESSURE, kPa	410.00	B COEFFICIENT	0.96

CONSOLIDATION STAGE

CELL PRESSURE, kPa	510.00	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	410.00	DURATION, min	2,993
BACK PRESSURE, kPa	410.00	VOLUME CHANGE, cm^3	0.60
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	5.29	SAMPLE AREA, cm^2	71.20
SAMPLE DIAMETER, cm	9.52	SAMPLE VOLUME, cm^3	376.92

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	531	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	431	DURATION, min	6973
BACK PRESSURE, kPa	410	HYDRAULIC GRADIENT, i	40

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	5.29	UNIT WEIGHT, kN/m^3	23.08
SAMPLE DIAMETER, cm	9.52	DRY UNIT WEIGHT, kN/m^3	22.32
SAMPLE AREA, cm^2	71.20	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	376.92	VOLUME OF SOLIDS, cm^3	317.79
TOTAL MASS, g	887.22	VOLUME OF VOIDS, cm^3	59.13
DRY MASS, g	858.05	VOID RATIO	0.19
WATER CONTENT, %	3.4		

TEST RESULTS

ELAPSED TIME TO STEADY STATE FLOW (min)	0.0
DURATION OF STEADY STATE FLOW (min)	6973
INFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	1.5
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	1.3
INFLOW TO OUTFLOW RATIO	1.15
HYDRAULIC CONDUCTIVITY (INFLOW) (m/s)	1.24E-11
HYDRAULIC CONDUCTIVITY (OUTFLOW) (m/s)	1.08E-11
HYDRAULIC CONDUCTIVITY, K, m/s	1.16E-11
HYDRAULIC CONDUCTIVITY AT STANDARD TEMPERATURE, K_{20}, m/s	**1.08E-11**

NOTES:

Effective consolidation stress assigned, by client.

PERMEANT FLUID	Deaired tap water
AVERAGE TEST TEMPERATURE	23.0 °C

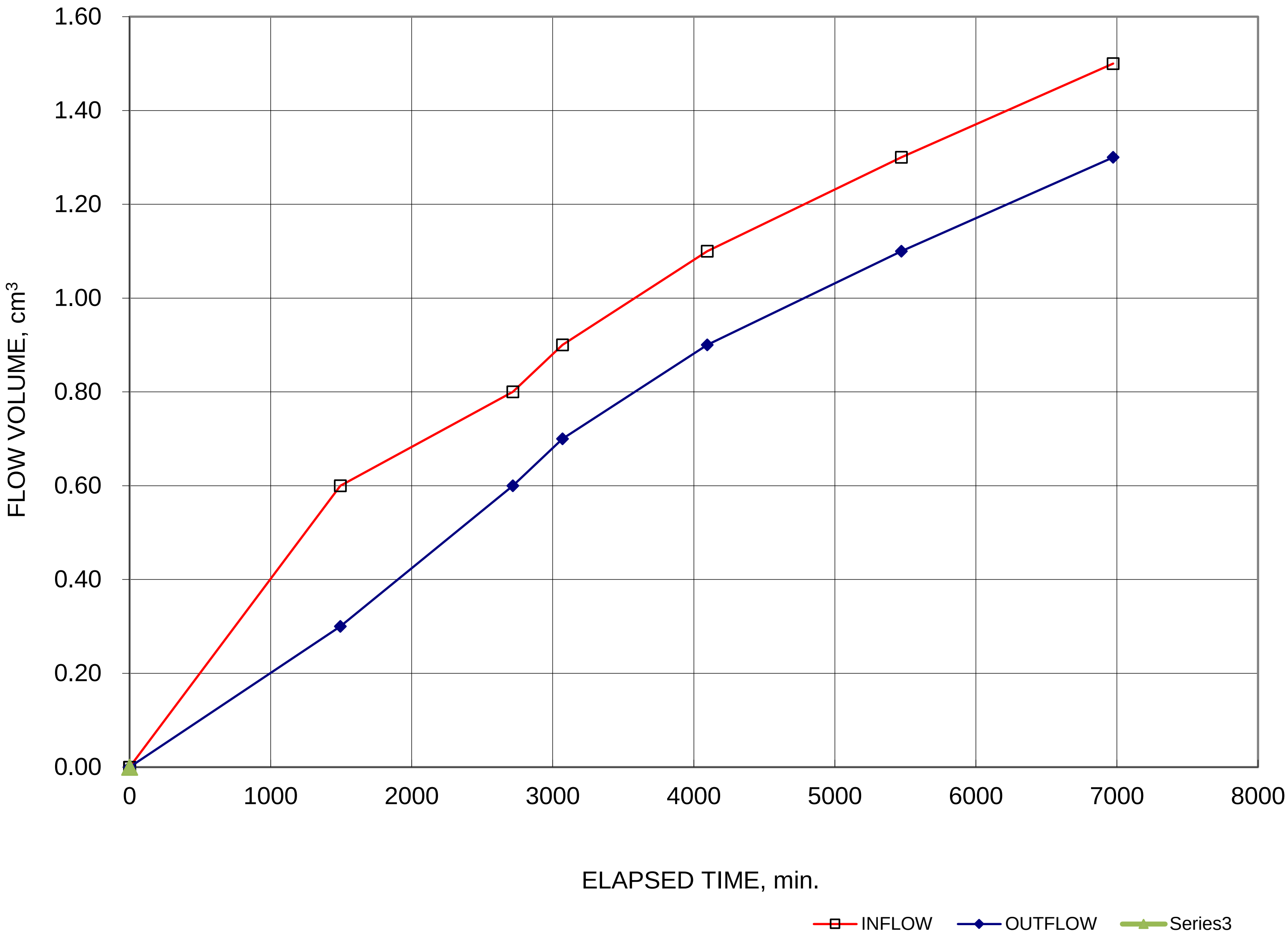
HYDRAULIC CONDUCTIVITY TEST
ASTM D5084-METHOD A

Project title: CNL_WR-1_MN

Flow volume vs. Time

BOREHOLE NUMBER - -

SAMPLE - C-28



Project number : 18101723
Prepared by : AH

Golder Associates

Checked by : MM

HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD - Method A)

SAMPLE IDENTIFICATION

PROJECT NUMBER	18101723	SAMPLE	C-33
PROJECT TITLE	CNL_WR-1 _MN	SAMPLE DEPTH, m	-
BOREHOLE NUMBER	-	DATE	December 11, 2018

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	5.01	UNIT WEIGHT, kN/m^3	22.99
SAMPLE DIAMETER, cm	9.50	DRY UNIT WEIGHT, kN/m^3	22.16
SAMPLE AREA, cm^2	70.85	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	355.04	VOLUME OF SOLIDS, cm^3	297.10
TOTAL MASS, g	832.42	VOLUME OF VOIDS, cm^3	57.94
DRY MASS, g	802.17	VOID RATIO	0.20
WATER CONTENT, %	3.8		

SATURATION STAGE

CELL PRESSURE, kPa	110.00	EFFECTIVE CONSOLIDATION STRESS, kPa	10
HEAD PRESSURE, kPa	100.00	DURATION, min	41
BACK PRESSURE, kPa	100.00	B COEFFICIENT	0.96

CONSOLIDATION STAGE

CELL PRESSURE, kPa	200.00	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	100.00	DURATION, min	993
BACK PRESSURE, kPa	100.00	VOLUME CHANGE, cm^3	0.00
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	5.01	SAMPLE AREA, cm^2	70.85
SAMPLE DIAMETER, cm	9.50	SAMPLE VOLUME, cm^3	355.04

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	220	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	120	DURATION, min	6926
BACK PRESSURE, kPa	100	HYDRAULIC GRADIENT, i	41

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	5.01	UNIT WEIGHT, kN/m^3	23.11
SAMPLE DIAMETER, cm	9.50	DRY UNIT WEIGHT, kN/m^3	22.16
SAMPLE AREA, cm^2	70.85	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	355.04	VOLUME OF SOLIDS, cm^3	297.10
TOTAL MASS, g	836.66	VOLUME OF VOIDS, cm^3	57.94
DRY MASS, g	802.17	VOID RATIO	0.20
WATER CONTENT, %	4.3		

TEST RESULTS

ELAPSED TIME TO STEADY STATE FLOW (min)	0.0
DURATION OF STEADY STATE FLOW (min)	6926
INFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	6.4
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	5.2
INFLOW TO OUTFLOW RATIO	1.2
HYDRAULIC CONDUCTIVITY (INFLOW) (m/s)	5.34E-11
HYDRAULIC CONDUCTIVITY (OUTFLOW) (m/s)	4.34E-11
HYDRAULIC CONDUCTIVITY, K, m/s	4.84E-11
HYDRAULIC CONDUCTIVITY AT STANDARD TEMPERATURE, K_{20}, m/s	**4.51E-11**

NOTES:

Effective consolidation stress assigned, by client.

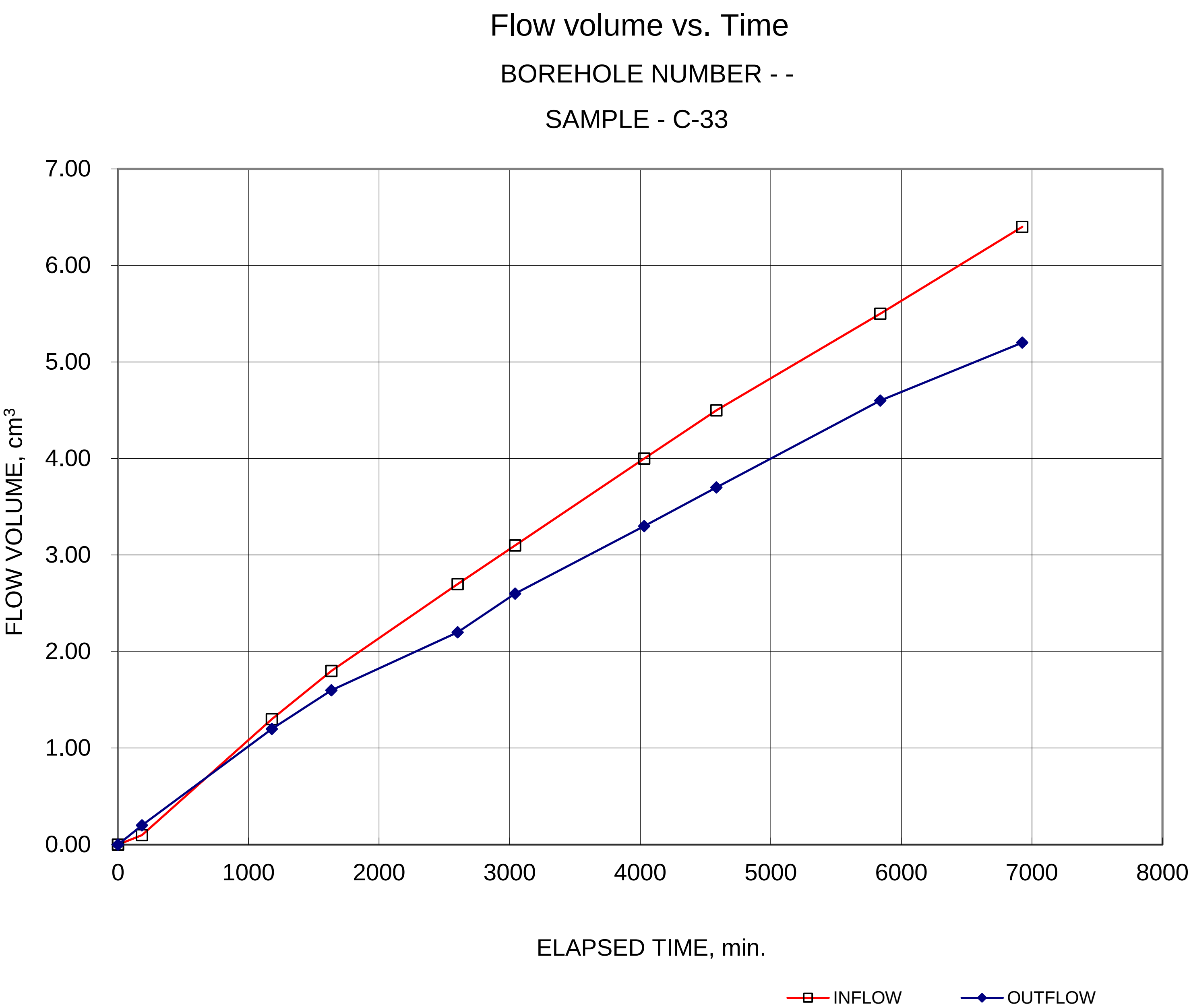
PERMEANT FLUID	Deaired tap water
AVERAGE TEST TEMPERATURE	23.0 °C

Prepared By: AH | **Golder Associates** | Checked By:MM

Project number : 18101723
Prepared by : AH

Golder Associates

Checked by : MM



HYDRAULIC CONDUCTIVITY TEST
ASTM D5084-METHOD A

Project title: CNL_WR-1_MN

GOLDER

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ASTM C856-18

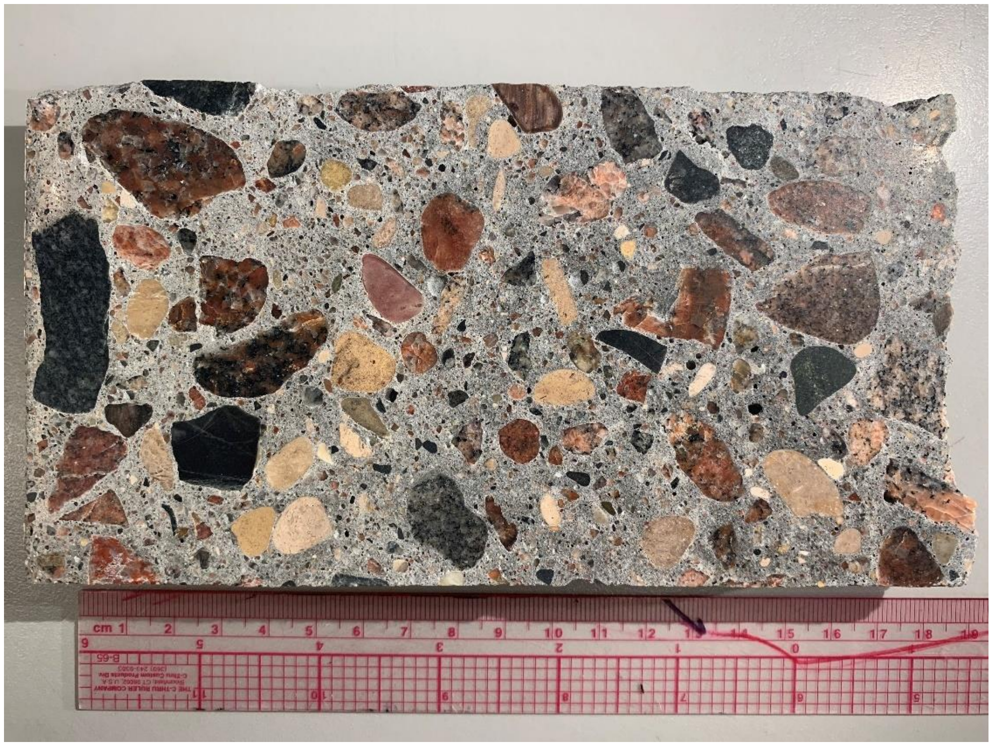
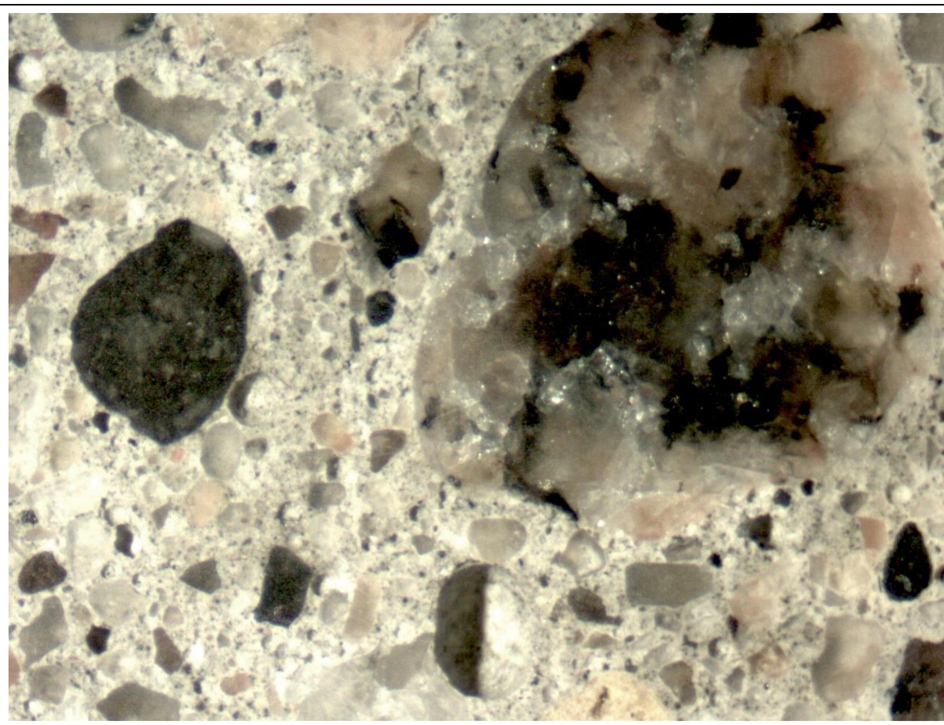
Canadian Nuclear Laboratories Ltd.
Whiteshell Reactor
1 Ara Mooradian Road
Pinawa, Manitoba
MN R0E 1L0

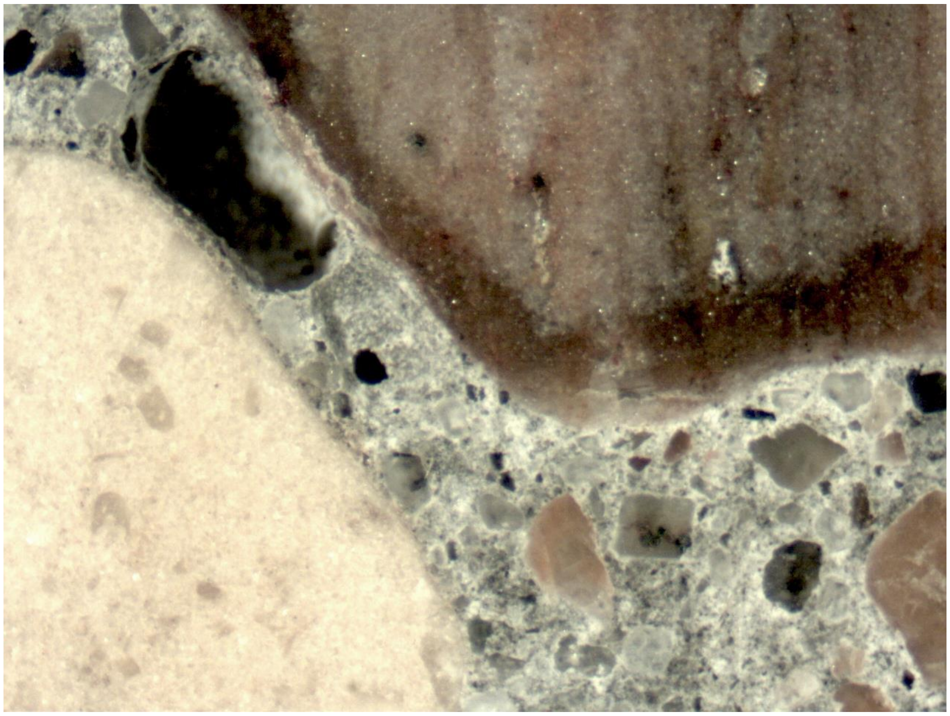
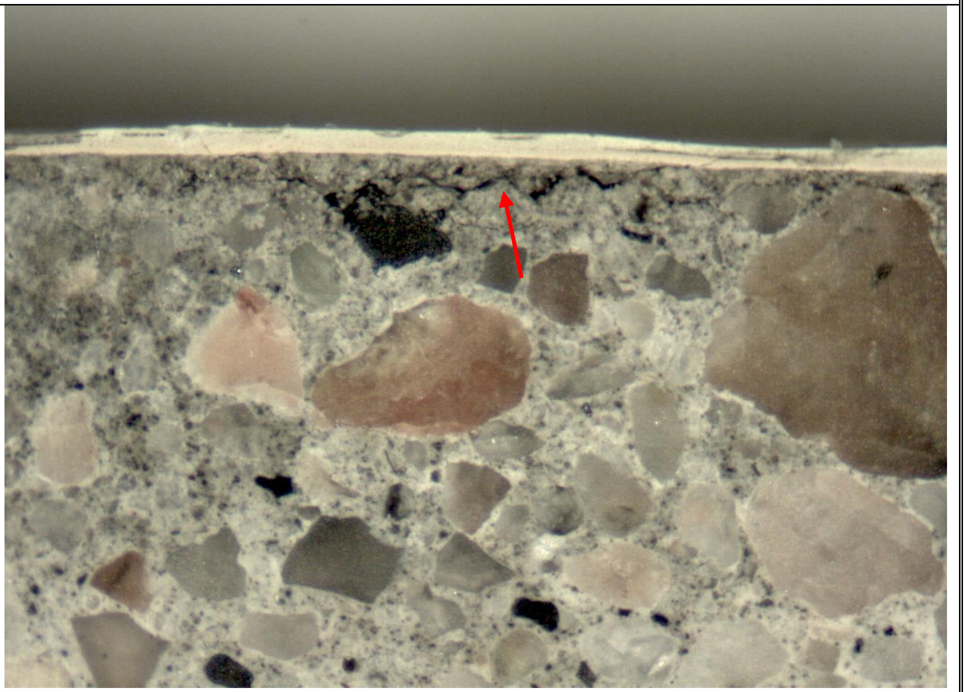
Project number: 18101723
January 16, 2019

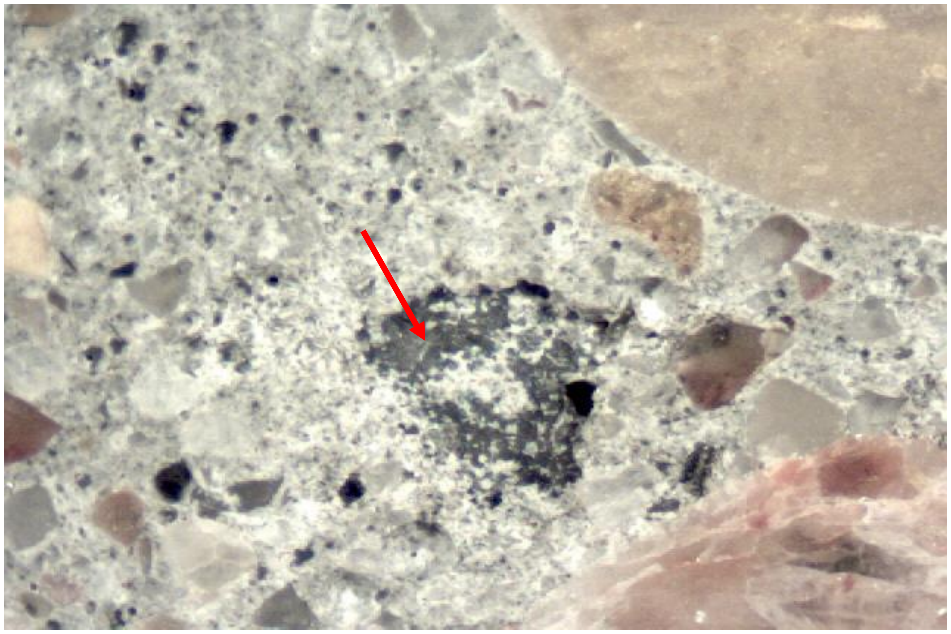
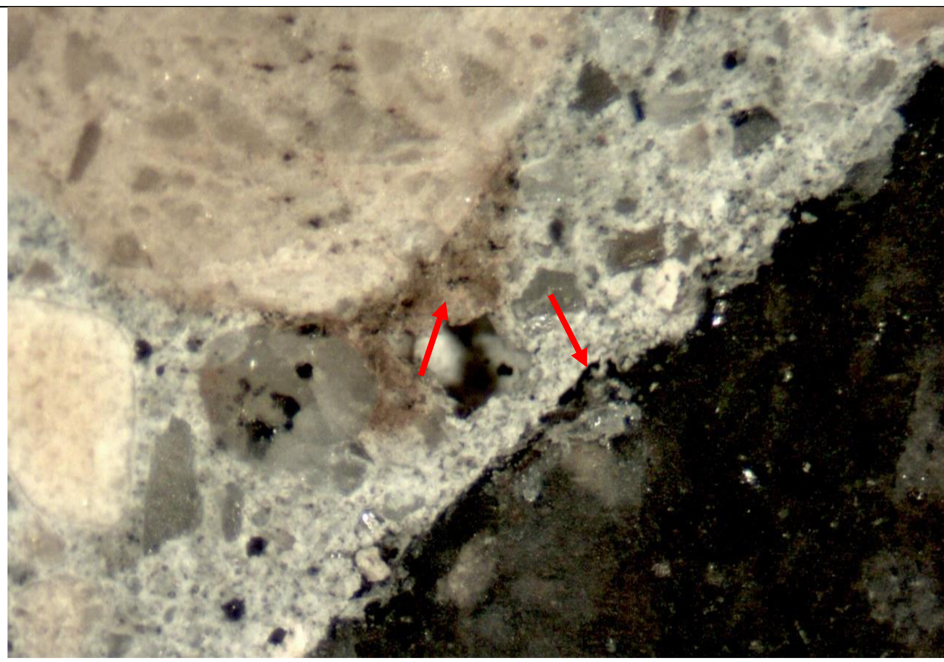
Attention: Mr. Nohman Ishfaq

PROJECT:	**Building Condition Assessment** **In-situ Decommissioning of Whiteshell Reactor 1 (WR-1)**
Sample:	**Core C10**

SAMPLE TYPE – GENERAL	94 mm diameter drilled core, length varies from 165 to 177 mm. Outer surface painted surface. No reinforcing steel or mesh observed in the core. Air entrained.
Aggregate maximum size	20 mm
Aggregate grading	Well-graded coarse and fine aggregates.
Concrete consolidation & density	Concrete is generally dense and well-consolidated; a zone about 20 mm thick at the outer edge exhibits carbonation. Air entrained.
Cement paste	Paste ranges from firm to soft, and is medium grey in colour. Cement is well-hydrated. Low response to dilute HCl. Water/cementing materials ratio estimated to be in the 0.5-0.6 range.
Coarse Aggregate	A mixture of fluvial (subrounded to rounded) and crushed rock aggregate. The crushed rock particles are generally granitic in composition while the fluvial materials include granite, sandstone, quartzite, carbonates, gneiss and metasandstone.
Fine Aggregate	Fine aggregate is a natural sand composed of limestone, granite, sandstone and quartz, feldspar, biotite.
Defects	Paste ranges in stiffness and porosity. W/CM ratio ranges up to 0.6+. After wetting, some paste becomes softer and is easily gouged/removed. Some disturbance of paste and zones of porous/low quality paste are observed. Debonded zones where paste is removed over coarse aggregates are occasionally observed.

Photos	
1. View of the core, after sawcutting and polishing. Surface is at far left.	
2. View of matrix of the concrete showing granite aggregate dominating the view. 10x magnification; field of view is 8.5 mm across.	

<table>
<tr><td>3. Detail of sample showing darkened rims on cream-coloured sandstone in lower left and metasandstone-quartzite in upper right. 10x magnification, field of view 8.5 mm.</td><td></td></tr>
<tr><td>4. View at upper edge of core showing painted surface with minor matrix disturbance (arrow) immediately below the paint coating. Magnification 15x, FOV = 6 mm.</td><td></td></tr>
</table>

5. View showing disturbed paste having debonded over coarse aggregate; magnification 15 x, field of view 6.5 mm.	
6. View of two aggregate particles with soft/porous paste. Magnification 20x, field of view 4.5 mm.	
SUMMARY	The concrete is well-consolidated with adequate proportioning and distribution of aggregates in the paste matrix. Areas of softer paste observed throughout, with evidence of low strength particularly at aggregate-paste interface zones.

Petrographer: ______________________ DATE: January 16, 2019
F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ASTM C856-18

Canadian Nuclear Laboratories Ltd.
Whitshell Reactor
1 Ara Mooradian Road
Pinawa, Manitoba
R0E 1L0

Project number: 18101723
January 21, 2019

Attention: Mr. Nohman Ishfaq

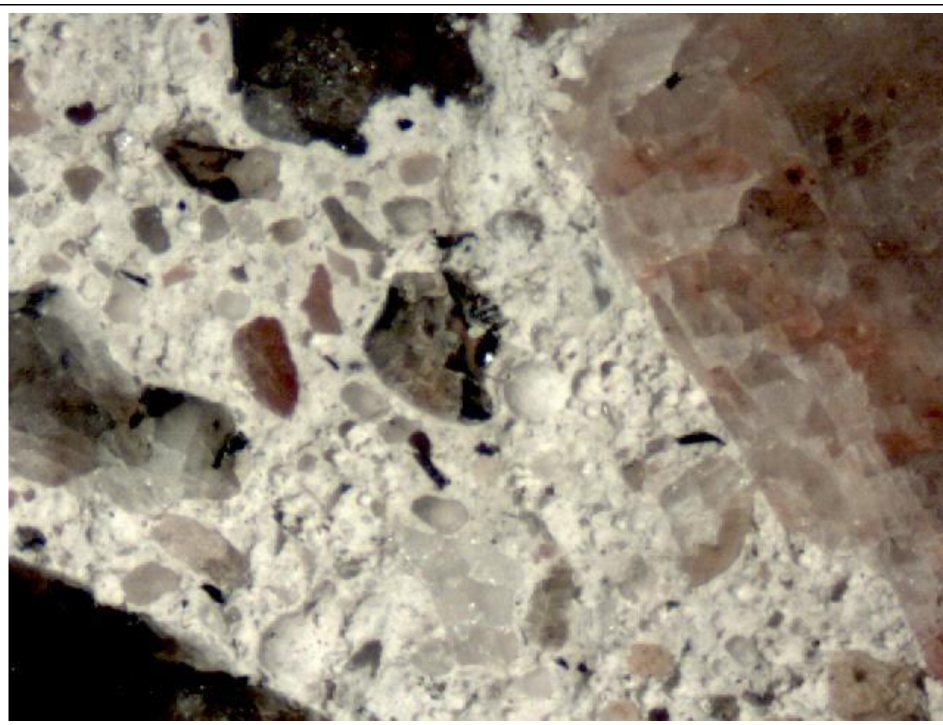
PROJECT:	Error! Unknown document property name. *Error! Unknown document property name.*
Sample:	**Core C18**

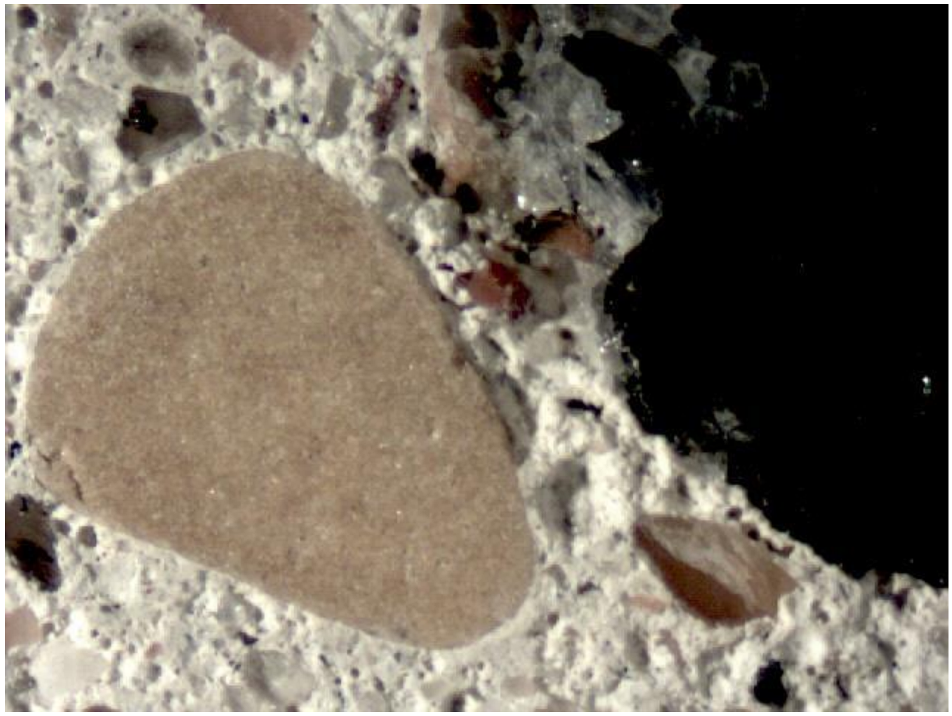
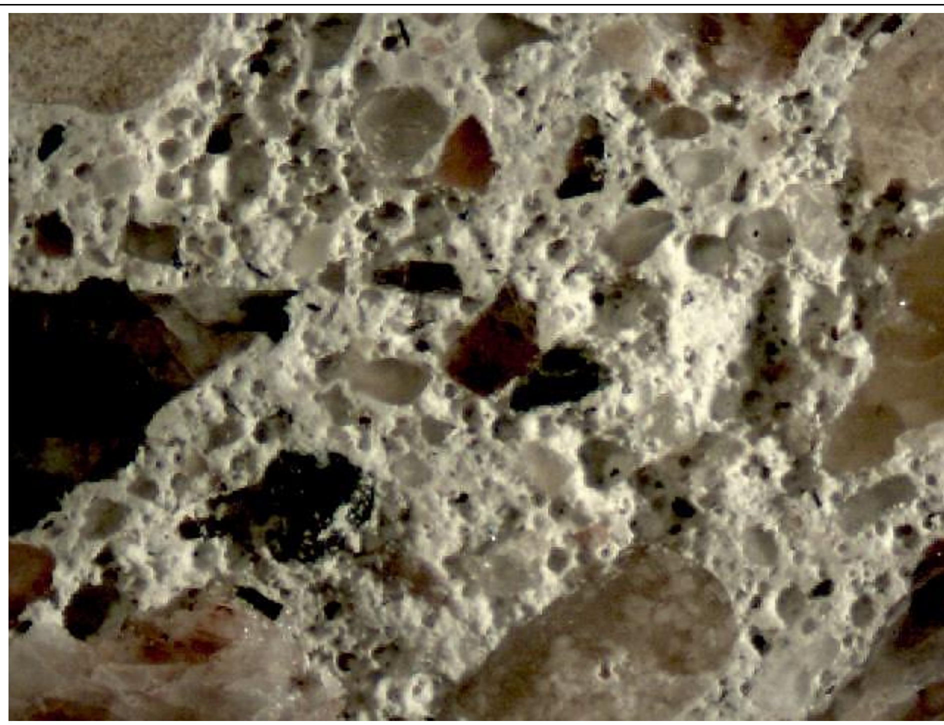
SAMPLE TYPE – GENERAL	94 mm diameter drilled core, length varies from 175 to 182 mm. Outer surface is sawcut. No reinforcing steel or mesh observed in the core. Air entrained.
Aggregate maximum size	20 mm
Aggregate grading	Well-graded coarse and fine aggregates.
Concrete consolidation & density	Concrete is generally dense and well-consolidated. Air entrained; high air content (estimated up to 10%).
Cement paste	Paste ranges from firm to soft, and is light beige in hand sample, light grey/beige in the microscope. Cement is well-hydrated. Modearte response to dilute HCl. Water/cementing materials ratio estimated to be in the >0.6 range.
Coarse Aggregate	A mixture of fluvial (subrounded to rounded) and crushed rock aggregate. The crushed rock particles are generally granitic in composition while the fluvial materials include granite, sandstone, quartzite, carbonates, gneiss and metasandstone.
Fine Aggregate	Fine aggregate is a natural sand composed of limestone, granite, sandstone and quartz, feldspar, biotite.
Defects	Air voids content is high, estimated to be on the order of 10%. Paste ranges in stiffness and porosity. W/CM ratio is estimated to range up to 0.6 or more. After wetting, some paste becomes softer and is easily gouged/removed. Some of the paste appears to be disturbed/weak, and zones of porous/low quality paste are observed. Debonded zones where paste is removed over or next to coarse aggregates are commonly observed.

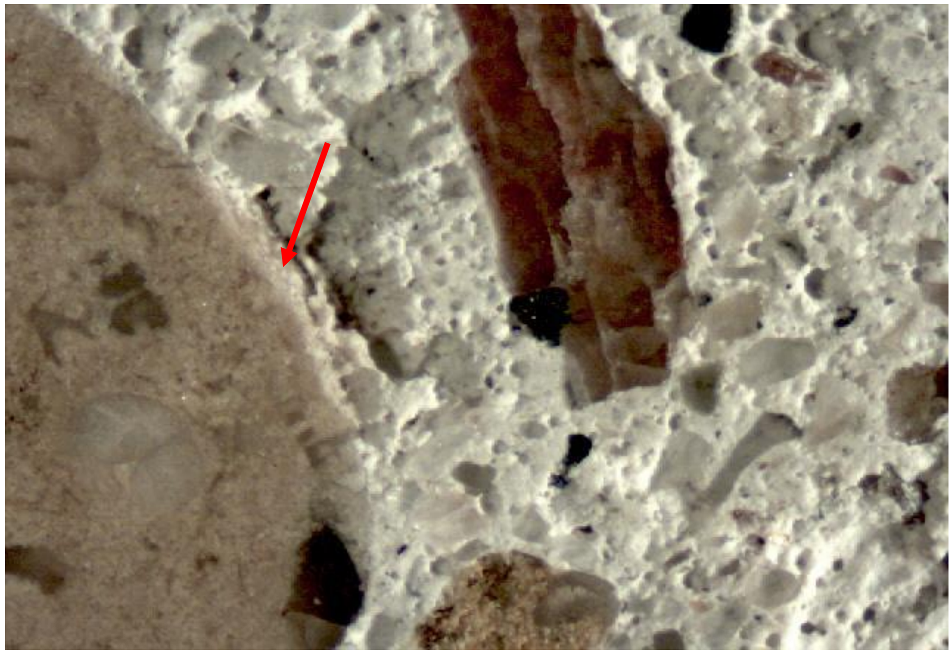
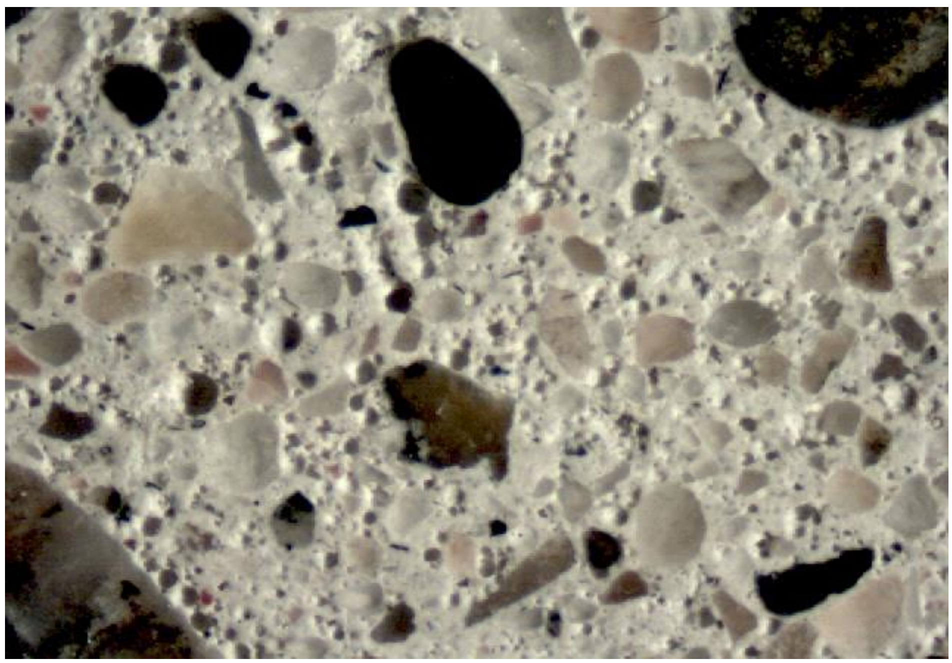
Photos

1. View of the core, after sawcutting and polishing. Surface is at far right.

2. View of matrix of the concrete showing general appearance. 10x magnification; field of view is 8.5 mm across.



<table>
<tr><td>3. Detail of sample showing weak interface zones adjacent two aggregate particles. On the left particle, debonding appears to be underway. 10x magnification, field of view 8.5 mm.</td><td></td></tr>
<tr><td>4. View of paste matrix illustrating porosity and poor quality of paste. Numerous voids characterize the paste in this view. Absorption is fast. Enclosure of fine and coarse aggregate is moderate at best. Magnification 10x, FOV = 8.5 mm.</td><td></td></tr>
</table>

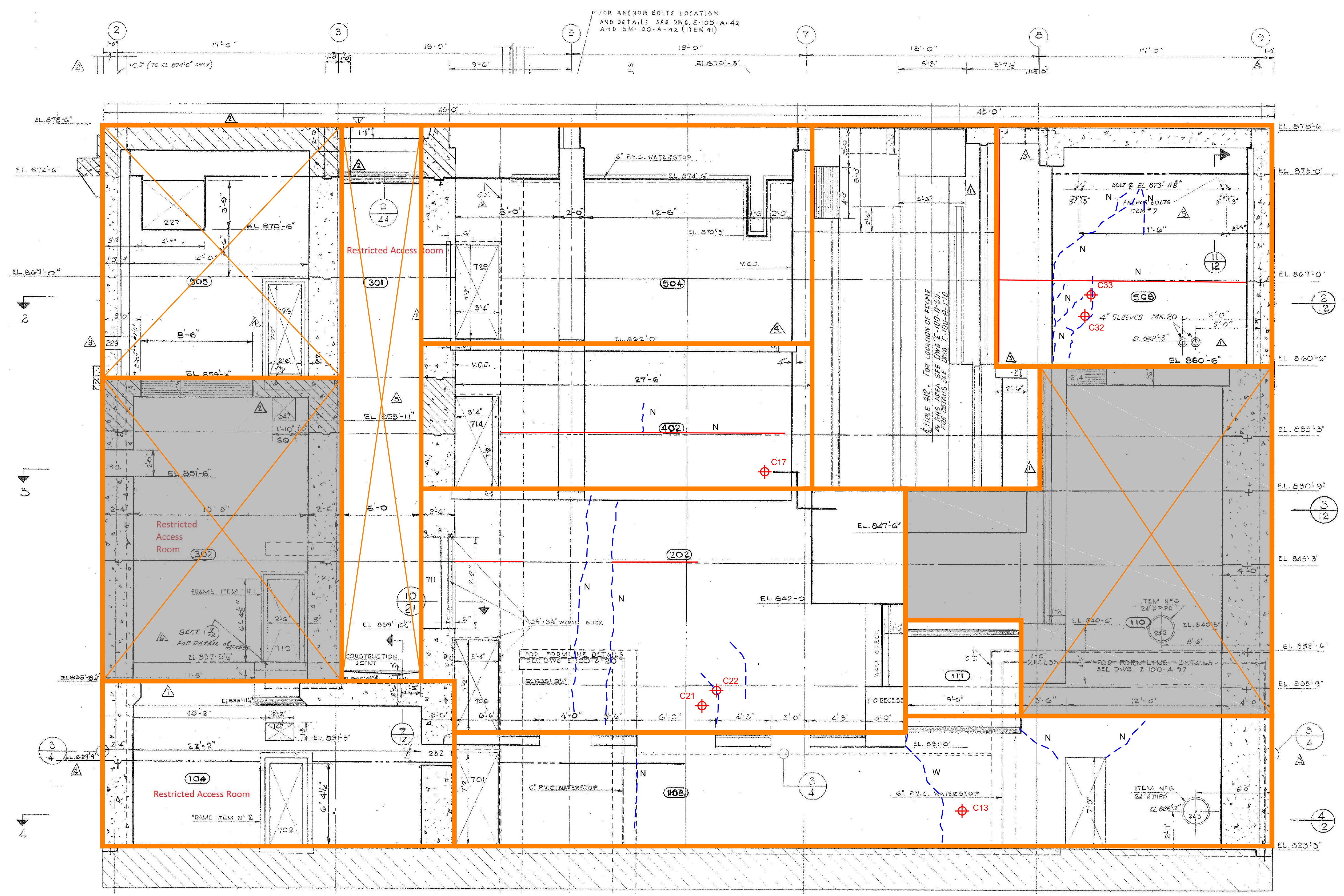
5. View showing weak paste adjacent the limestone coarse aggregate particle at left of view: a portion of the particle's surface is visible (arrow); magnification 15x, field of view 6.5 mm.	
6. View of air voids in a paste-dominated portion of the sample. Magnification 10x, field of view 8.5 mm.	
SUMMARY	The concrete is characterized by high air content, likely high water/cementing materials ratio (≥0.6), high porosity, and often low particle-paste interface strength. Several examples of debonds in progress are observed. Areas of softer paste observed throughout; these are associated with evidence of low strength particularly at aggregate-paste interface zones.

Petrographer: ____________________ DATE: January 21, 2019
F. Shrimer, P. Geo.

PROFESSIONAL GEOSCIENTIST, PROVINCE OF BRITISH COLUMBIA, F. H. SHRIMER

APPENDIX E

Drawings



NOT TO SCALE

LEGEND

- CORE LOCATION
- CONCRETE CRACKS N = NARROW, M = MEDIUM, W = WIDE
- COLD JOINTS

CLIENT
CANADIAN NUCLEAR LABORATORIES

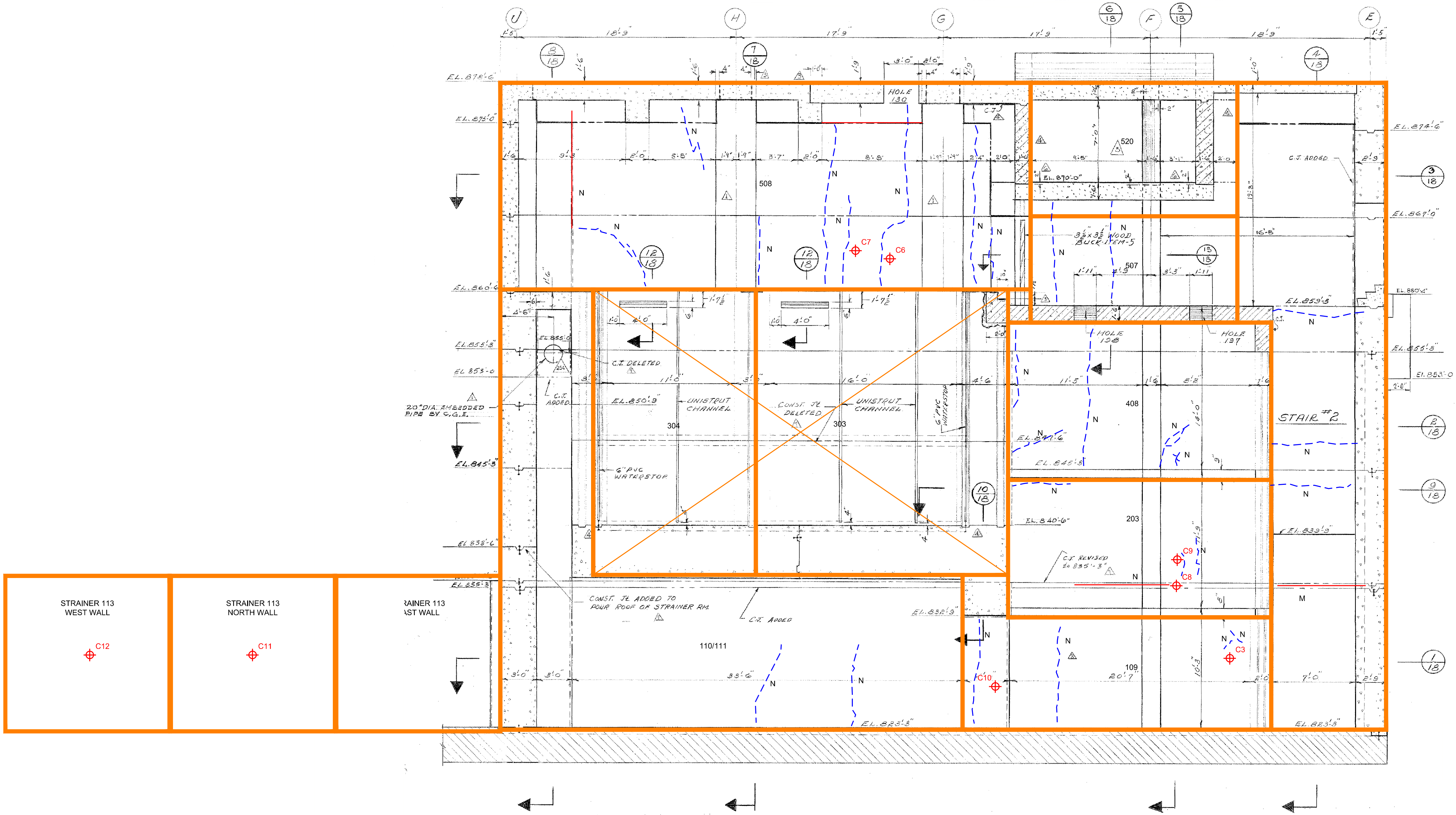
CONSULTANT
GOLDER

YYYY-MM-DD	2018-10-04
DESIGNED	
PREPARED	MK
REVIEWED	
APPROVED	

PROJECT
BUILDING CONDITION ASSESSMENT
IN-SITU DECOMMISSIONING OF WHITESHELL REACTOR 1 (WR-1)

TITLE
NORTH WALL

PROJECT NO.	CONTROL	REV.	FIGURE
18101723		----	E-1



NOT TO SCALE

LEGEND

⌖	CORE LOCATION
(blue dashed line)	CONCRETE CRACKS N = NARROW, M = MEDIUM, W = WIDE
(red line)	COLD JOINTS

CLIENT
CANADIAN NUCLEAR LABORATORIES

CONSULTANT

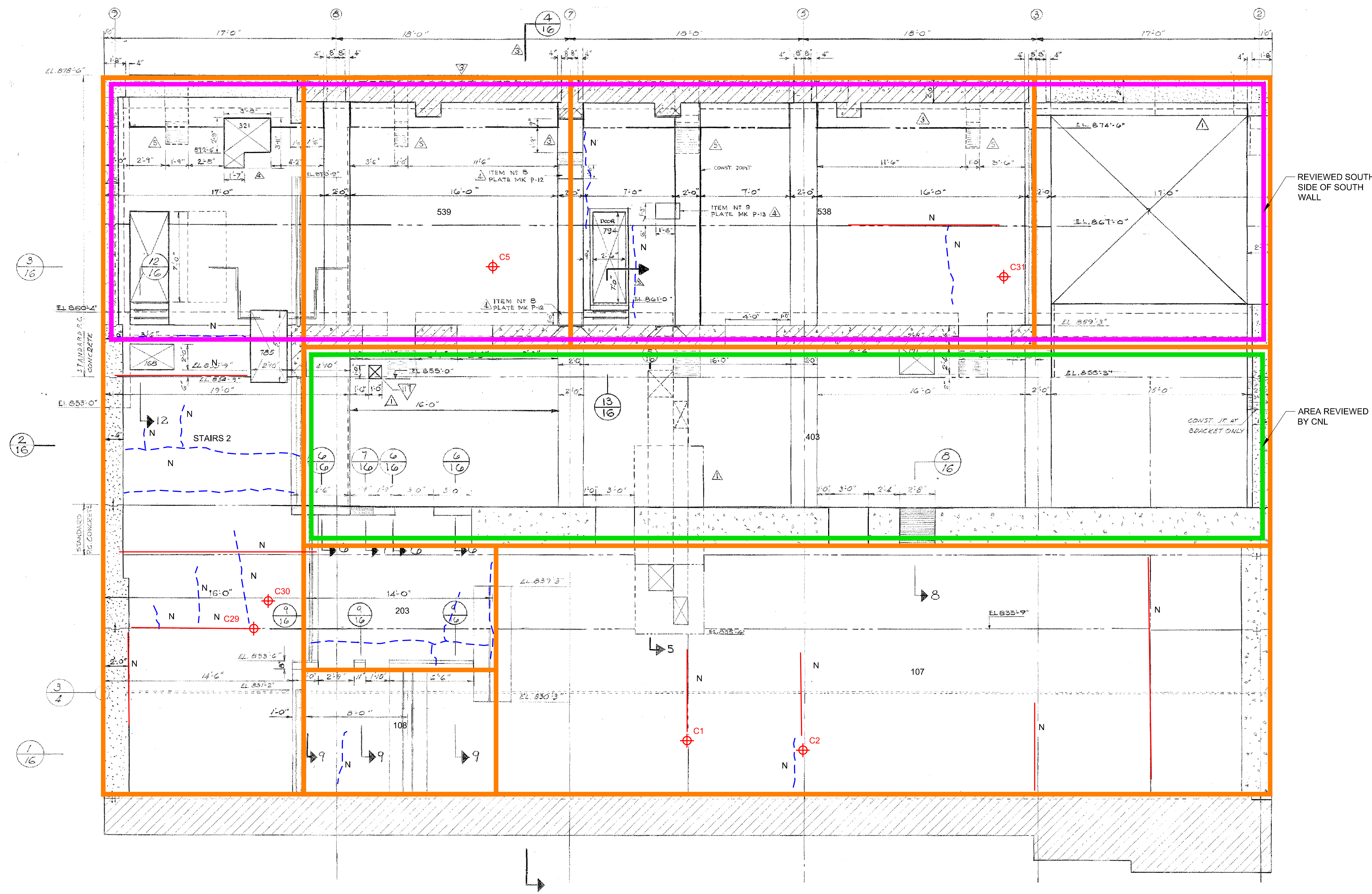
GOLDER

YYYY-MM-DD	2018-10-04
DESIGNED	
PREPARED	MK
REVIEWED	
APPROVED	

PROJECT
BUILDING CONDITION ASSESSMENT
IN-SITU DECOMMISSIONING OF WHITESHELL REACTOR 1 (WR-1)

TITLE
EAST WALL

PROJECT NO.	CONTROL	REV.	FIGURE
18101723		----	E-2



NOT TO SCALE

LEGEND

- CORE LOCATION
- CONCRETE CRACKS N = NARROW, M = MEDIUM, W = WIDE
- COLD JOINTS

CLIENT
CANADIAN NUCLEAR LABORATORIES

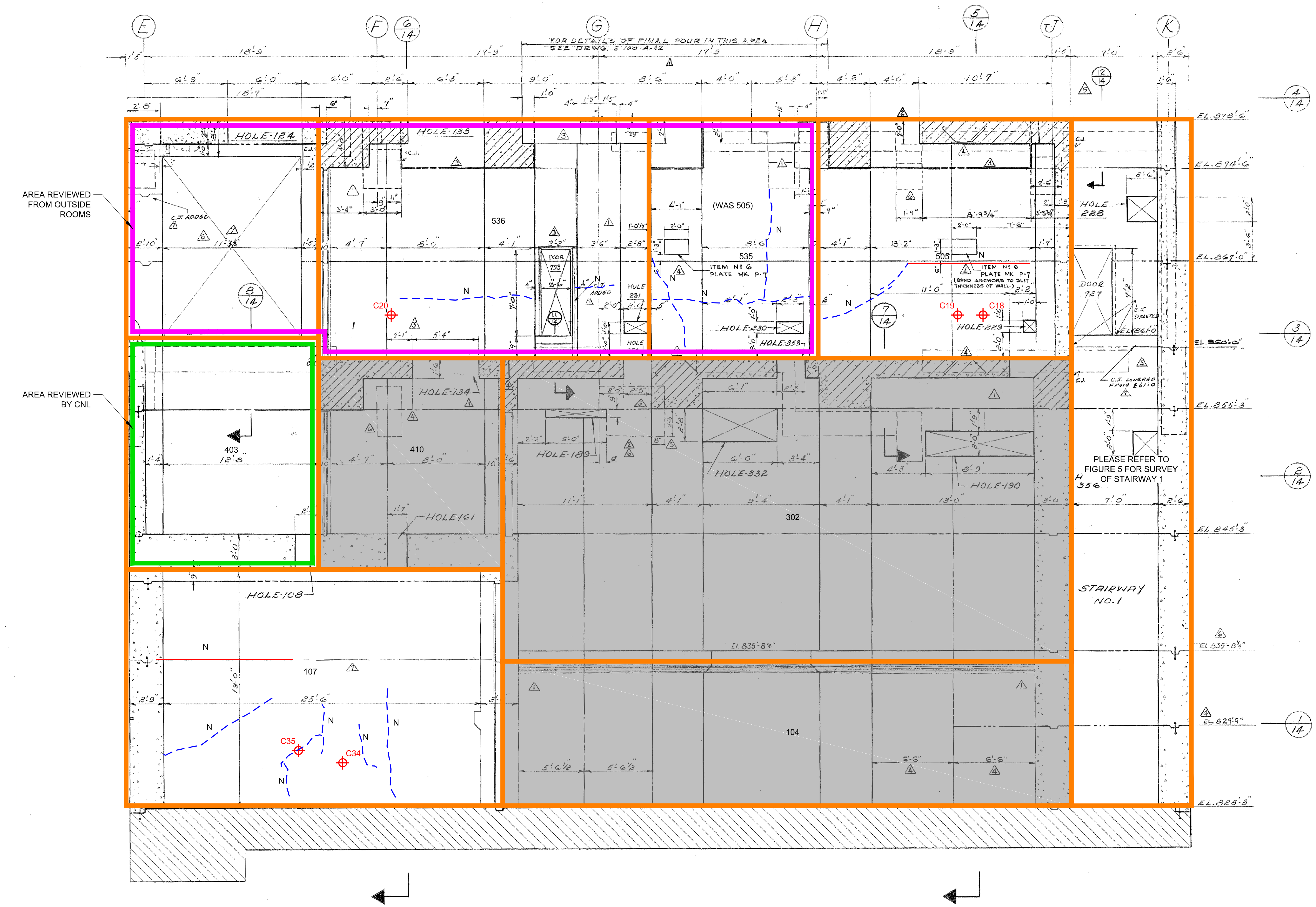
CONSULTANT
GOLDER

YYYY-MM-DD	2018-10-04
DESIGNED	
PREPARED	MK
REVIEWED	
APPROVED	

PROJECT
BUILDING CONDITION ASSESSMENT
IN-SITU DECOMMISSIONING OF WHITESHELL REACTOR 1 (WR-1)

TITLE
SOUTH WALL

PROJECT NO.	CONTROL	REV.	FIGURE
18101723		----	E-3



NOT TO SCALE

LEGEND

CORE LOCATION

CONCRETE CRACKS N = NARROW, M = MEDIUM, W = WIDE

COLD JOINTS

CLIENT
CANADIAN NUCLEAR LABORATORIES

CONSULTANT
GOLDER

YYYY-MM-DD	2018-10-04
DESIGNED	
PREPARED	MK
REVIEWED	
APPROVED	

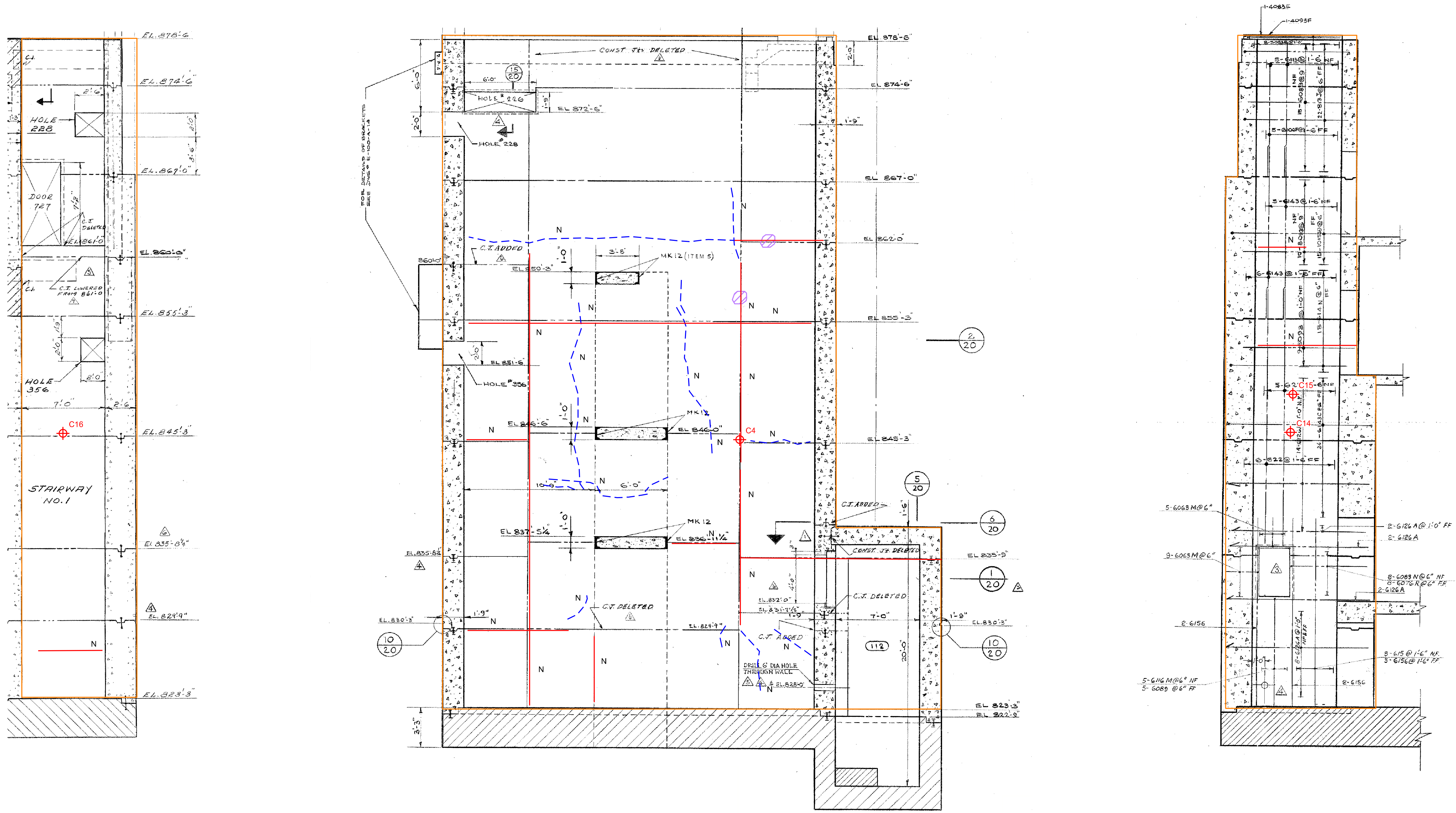
PROJECT
BUILDING CONDITION ASSESSMENT
IN-SITU DECOMMISSIONING OF WHITESHELL REACTOR 1 (WR-1)

TITLE
WEST WALL

PROJECT NO.	CONTROL	REV.	FIGURE
18101723		----	E-4

OFFICIAL USE ONLY
WLDP-26000-REPT-001 REV 1

WEST WALL   NORTH WALL   EAST WALL



NOT TO SCALE

LEGEND

- CORE LOCATION
- CONCRETE CRACKS N = NARROW, M = MEDIUM, W = WIDE
- DELAMINATION
- COLD JOINTS

CLIENT
CANADIAN NUCLEAR LABORATORIES

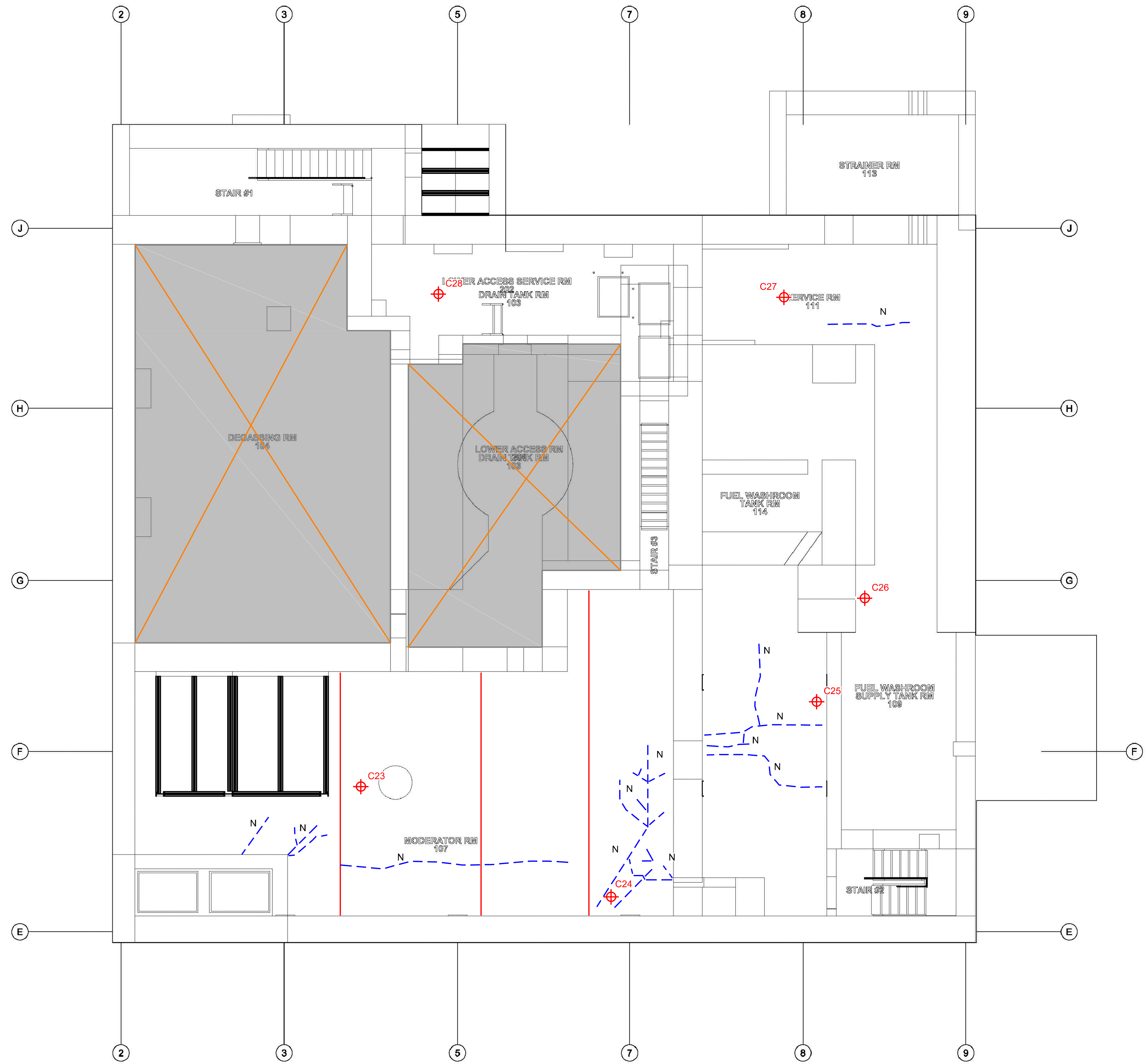
CONSULTANT
GOLDER

YYYY-MM-DD	2018-10-04
DESIGNED	
PREPARED	MK
REVIEWED	
APPROVED	

PROJECT
BUILDING CONDITION ASSESSMENT
IN-SITU DECOMMISSIONING OF WHITESHELL REACTOR 1 (WR-1)

TITLE
STAIRS 1

PROJECT NO.	CONTROL	REV.	FIGURE
18101723		----	E-5



NOT TO SCALE

LEGEND

(core symbol)	CORE LOCATION
(dashed blue line)	CONCRETE CRACKS N = NARROW, M = MEDIUM, W = WIDE
(red line)	COLD JOINTS

REFERENCE

BASE PLAN PROVIDED BY ??, ENTITLED ??, PROJECT NO., DRAWING NO. DATED.

CLIENT
CANADIAN NUCLEAR LABORATORIES

CONSULTANT
GOLDER

YYYY-MM-DD	2018-10-15
DESIGNED	
PREPARED	MK
REVIEWED	
APPROVED	

PROJECT
BUILDING CONDITION ASSESSMENT
IN-SITU DECOMMISSIONING OF WHITESHELL REACTOR 1 (WR-1)

TITLE
BASEMENT FLOOR SLAB

PROJECT NO.	CONTROL	REV.	FIGURE
18101723		----	E-6

GOLDER
MEMBER OF WSP

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