APPENDIX E: MATERIAL BALANCE CALCULATIONS

Revisioning					
Rev.	**Date**	**Description**	**By**	**Checked**	**Date**
0	*07/28/2020*	*Draft for Internal Review*	*C. Fritz*	*S. Downey*	
1	*08/19/2020*	*Final*	*C. Fritz*	*J. Cumbers*	

Location and Format

Electronic copies of these calculations are located on the Stantec internal project teamsite.

The following calculations were generated using the following software:

- AutoCAD Civil 3D 2017
- Microsoft Office 365: Excel

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Objective

This appendix presents the methods and calculations performed for the St. Anthony Mine site (Site) material balance analysis. The objective was to evaluate the source of materials for the pit backfills, as well as the excavation and placement volumes required to achieve the pit reclamation and Site cleanup objectives. As described in the Closure/Closeout Plan (CCOP) main text, Pit 1 will be partially backfilled with waste material currently located inside the pit and with material excavated from the pit highwall. Pit 2 will be backfilled with waste material from storage piles and other locations throughout the Site to achieve surface drainage out of the pit. Additional waste not included in the pit backfill volumes will be stabilized in place and covered with non-impacted borrow soil during reclamation.

Background

At the conclusion of mining activities, stockpiles of overburden material excavated from the two open pits were left undisturbed at several locations within the mine permit boundary. As part of Site reclamation objectives, the following facilities (shown on Sheet 3 of the CCOP design drawings) were identified as areas containing waste material to either be excavated and placed within the pits or stabilized in-place:

- Shale Piles 1 and 2
- Pile 3
- Pile 4
- Pile 5
- Pile 6
- Pile 7
- Crusher/Stockpile Area (CS)
- West Disturbance Area (WDA)
- Ore Storage 1 and 2
- Mine Dump
- Shaft Pad
- Shaft Access Road
- South Topsoil pile (TS)
- Topsoil/Overburden pile (T/O)
- Other mine-impacted ground ("Surface Excavation") located in intermediate areas between the facilities listed above and along the Site access road

The following areas are considered sources of clean, non-impacted material suitable for use as revegetated soil covers that will be placed over waste materials either consolidated into the pits or stabilized in-place:

- West Borrow area
- Lobo Tract borrow area
- North Topsoil pile (TN)

Piles 1 through 4 contain slightly elevated Radon activity levels (see Appendix H of the CCOP) and will be regraded in-place and covered with clean borrow materials. Pile 5 and the T/O pile will be incorporated into the final Pile 4 grading and will thus be buried beneath the regraded (and covered) Pile 4 material to mitigate Radon emanation. The remaining impacted facilities listed above will be fully excavated and placed as backfill in Pit 2. The TS pile will also be fully excavated and placed as a cover layer over the impacted materials in Pit 2, followed by a layer of cover material from the West Borrow area for revegetation. Additional impacted material (Pit 1 Infill), currently located inside Pit 1 and above the top elevation of the proposed cover surface, will be excavated, placed as backfill at the base of the pit, and covered by the material excavated from the Pit 1 highwall. Appendix D of the CCOP describes the classifications and geotechnical properties of the materials discussed herein.

Existing volumes of the Site facilities were estimated by comparing the existing ground and pile surfaces with the pre-mining ground surface on which the piles were placed. The volume of material excavated from the intermediate areas was estimated using the methods described in Section 4 of the CCOP main text. Stantec calculated approximate placement (compacted) volumes of excavated materials, including impounded waste and cover soils, to determine the elevation of the Pit 1 cover surface based on the total volume of material placed in the pit. Calculated placement volumes of materials transported to and compacted in Pit 2 were compared to the total backfill volume required to achieve positive surface drainage away from the pit, to ensure that the sum volume of the selected backfill materials did not exceed the backfill capacity of the pit. Existing volumes of Piles 1 through 4, as well as Pile 5 and the T/O pile, were used to develop the grading plan for the regraded piles assuming the full volume would be reshaped into the final design.

Tables E-1 and E-2 summarize the estimated backfill and available excavation volumes, respectively. Table E-3 summarizes the volumes of the piles to be regraded in place.

Table E-1. Estimated Pit Backfill and Cover Volumes

Placement Location	Estimated Placement Volume (cy)
Pit 1 (Waste)	649,478
Pit 2 (Waste)	1,980,754
Waste Subtotal	**2,630,232**
Pit 1 (Cover)	108,000
Pit 2 (Cover)	81,403
Piles 1, 2, 3 (Cover)	98,159
Pile 4 (Cover)	637,000
Cover Subtotal	**924,562**
TOTAL	**3,554,794**

Table E-2. Available Removal Excavation Volumes

Facility	Estimated Available Volume (cy)
CS	573,847
Mine Dump	37,658
Ore Storage 1 & 2	29,030
Pile 6	254,375
Pile 7	87,086
Pit 1 Infill	527,680
Pit 1 Highwall Excavation	195,700
Shaft Area Access Road	26,401
Surface Excavation	645,000
TS	368,502
WDA	83,575
Lobo Tract Borrow*	1,065,000
TN	43,538
West Borrow	752,000
TOTAL	**4,689,392**

*Only a portion of the full available Lobo Tract volume is expected to be excavated

Table E-3. Estimated Pile Regrade Volumes

Facility	Estimated Volume (cy)
Pile 1	925,912
Pile 2	761,907
Pile 3	2,080,033
Pile 4	16,559,844
Pile 5	633,214
T/O	661,286
TOTAL	**21,622,195**

Applicable Codes and Standards

Stantec used the material balance analysis to achieve Site reclamation goals, including mine waste cleanup and reducing radon emanation, in accordance with 10 CFR Part 40 Appendix A, Criterion 6 (NRC, 2017).

Material Properties

Stantec conducted a geotechnical investigation during 2018 to supplement the 2007 materials characterization (MWH, 2007). During the 2018 investigation, field staff collected samples from Piles 1 through 4, the three topsoil piles (T/O, TS, TN), and potential borrow areas. The samples were subjected to laboratory testing for geotechnical properties (see Appendix D of the CCOP for additional details). Because testing data was not available for the other facilities listed in Table E-2, Stantec assigned measured soil properties for Pile 3 to these materials. Based on visual observations of these facilities and Pile 3, Stantec assumed the materials were excavated from the same source zone during mining activities, and therefore have similar material composition and geotechnical properties.

Laboratory testing results and visual classification of materials indicated that the TN pile may contain soil excavated from the same alluvial deposit that comprises the nearby West Borrow area. Therefore, estimation of in-situ soil properties was based on combined test results for the two facilities and the same properties were assigned to each material.

Data used in the analysis included results of index testing (e.g., in-situ dry densities) and Standard Proctor compaction testing (e.g., maximum dry densities). In-situ dry densities were estimated using the 30^{th} percentile of sample results for each facility. Compacted dry densities were calculated as 90 percent of the maximum dry density evaluated for each material type during Standard Proctor (SP) compaction testing. Table E-3 summarizes the geotechnical properties of materials for which laboratory data was available and which were used in the compaction calculations.

Table E-3. Representative Geotechnical Properties by Area

Facility	In-Situ Dry Density (pcf)	Max (SP) Dry Density (pcf)	Compacted Dry Density (90% SP) (pcf)
Piles 1 & 2	87.2	113.8	102.4
Pile 3	103.1	124.6	112.1
TS	100.3	120.0	108.0
TN/West Borrow	86.6	117.4	105.7
Lobo Tract Borrow	95.1	112.9	101.6

pcf = pounds per cubic foot, SP = Standard Proctor

Methods

Stantec performed volume reduction calculations to convert available excavation volumes to placement volumes, thus accounting for material compaction in the final pit backfill and cover configurations. These calculations were based on the geotechnical properties of the materials and performed using basic weight-volume relationships for soils.

First, Stantec calculated the dry soil weight for a given excavation volume using the following relationship:

$$W_s = V_e * \rho_{de}$$

where W_s = weight of dry soil (lb)
V_e = volume of excavated soil (ft^3)
ρ_{de} = dry density of excavated soil (lb/ft^3)

Because the dry weight of excavated material remains unchanged following transport and compaction, the compacted volume of material placed in the pits and covers can be calculated using the re-compacted dry density as follows:

$$V_c = W_s/\rho_{dc}$$

where V_c = volume of re-compacted soil (ft^3)
W_s = weight of dry soil (lb)
ρ_{dc} = dry density of re-compacted soil (lb/ft^3)

Most Site facilities contain a known volume of material available for excavation, which was then converted to a re-compacted volume using the equations above. This method was applicable to cases where the full excavation volume is expected to be transported to a single location for compaction. However, for cases where the re-compacted volume was the known variable, the calculations were performed in reverse to estimate the required excavation volume. The latter method was applicable to the soil covers for Piles 1-4 and Pits 1 and 2.

Stantec estimated the required cover volumes for each covered facility using AutoCAD, based on 2-foot cover thicknesses at each facility. In the case of Pit 2 and Piles 1-3, the full cover volume was sourced from the same borrow area (West Borrow) and the required borrow excavation volume was calculated based on the known cover volume. The Pit 1 cover comprised a known volume of material from the TN pile, with the remainder of the required cover volume sourced from the West Borrow area. Accordingly, the compacted volume of TN material was calculated based on the available volume from the pile and was subtracted from the total required Pit 1 cover volume to determine the compacted volume of West Borrow material in the cover, which was then converted to a required borrow excavation volume. The remainder of the

volume of material available for excavation in the West Borrow area was used for the Pile 4 cover, with additional material excavated from the Lobo Tract borrow area to obtain the total required cover volume at Pile 4. Hence, the compacted volume of West Borrow material in the cover was calculated based on the remaining borrow volume available for excavation and then subtracted from the total Pile 4 cover volume to obtain the compacted volume of Lobo Tract material. This compacted volume was then converted to a required excavation volume based on Lobo Tract material properties.

The volume reduction percentage calculated for Pile 3 was applied to materials excavated from impacted facilities other than Piles 1-4 to estimate the re-compacted volumes of these materials. The compacted volume of the Pit 1 Highwall Excavation was calculated using properties for Piles 1 and 2, the TN pile, and the West Borrow area. Based on a visual assessment of the highwall excavation, the material was assumed to consist of 60% shale and 40% topsoil/alluvium. Therefore, highwall excavation properties were calculated using a weighted average of Piles 1 and 2 properties (0.6 weight) and TN/West Borrow properties (0.4 weight). Attachment E.1 contains a summary table of the volume reduction calculations completed in Excel, and the resulting volume reduction percentages for each material source.

Results

Calculations were performed to estimate the required excavation and placement volumes for materials transported from Site facilities and borrow areas. Table E-4 lists the resulting excavation volumes by source, as well as the volume and location of re-compacted materials.

Table E-4. Excavation and Placement Volumes

Source	Excavation Volume (cy)	Destination	Placement Volume (cy)	Volume Reduction
Pit 1 Infill	527,680	Pit 1	485,376	8.0%
Pit 1 Highwall Excavation	195,700	Pit 1	164,102	16.1%
CS	573,847	Pit 2	527,842	8.0%
Mine Dump	37,658	Pit 2	34,639	8.0%
Ore Storage 1 & 2	29,030	Pit 2	26,703	8.0%
Pile 6	254,375	Pit 2	233,982	8.0%
Pile 7	87,086	Pit 2	80,104	8.0%
Shaft Area Access Road	26,401	Pit 2	24,284	8.0%
Surface Excavation	645,000	Pit 2	593,290	8.0%
WDA	83,575	Pit 2	76,874	8.0%
TS	368,502	Pit 2	342,213	7.1%
Waste Subtotal	**2,828,854**	**-**	**2,589,409**	
TN	43,538	Pit 1 Cover	35,674	18.1%
West Borrow	88,271*	Pit 1 Cover	72,326	18.1%
West Borrow	99,348*	Pit 2 Cover	81,403	18.1%
West Borrow	119,798*	Piles 1-3 Covers	98,159	18.1%
West Borrow	444,583	Pile 4 Cover	364,277	18.1%
Lobo Tract Borrow	291,421*	Pile 4 Cover	272,723	6.4%
Cover Subtotal	**1,086,959**	**-**	**924,562**	
TOTAL	**3,915,813**	**-**	**3,513,971**	**-**

*Indicates excavation volume was calculated based on a specified placement volume

The sum of the placement volumes for materials excavated and hauled to Pit 2 was less than the total pit backfill volume required to achieve surface drainage from the pit (1,939,931 cy vs. 1,980,754 cy). The resulting contingency volume of 40,823 cy may either be used for additional backfill materials excavated elsewhere at the Site or left as is to account for any potential error in the compaction volumes and calculations.

Attachments

Attachment E.1 – Volume Reduction Calculations

References

MWH, 2007. St. Anthony Mine Materials Characterization Report, October.

U.S. Nuclear Regulatory Commission (NRC), 2017. Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content, 10 CFR Part 40 Appendix A. August 29.

Client: *UNC - General Electric*
Project: *St. Anthony Mine*
Description: *Conceptual (30%) Closure/Closeout Plan*

Attachment E.1
Date: *July 30, 2020*
Job No: *233001363*

Attachment E.1 – Volume Reduction Calculations

Source	In-Situ				Placed/Compacted				Volume Reduction
	Excavated Vol. (cy)	Excavated Vol (ft^3)	Dry Density (pcf)	Dry Soil Weight (lb)	Max (Proctor) Dry Density (pcf)	Compacted Dry Density (pcf)	Dry Soil Weight (lb)	Compacted Vol. (cy)	
Pit 1 Highwall Excavation (60% Piles 1 & 2 Properties, 40% North Topsoil/West Borrow Properties)	195,700	5.28E+06	87.0	4.60E+08	115.3	103.7	4.60E+08	164,102	16.1%
Pit 1 Infill & Pit 2 Backfill Materials (Pile 3 Properties)	2,264,652	6.11E+07	103.1	6.31E+09	124.6	112.1	6.31E+09	2,083,094	8.0%
South Topsoil	368,502	9.95E+06	100.3	9.98E+08	120.0	108.0	9.98E+08	342,213	7.1%
North Topsoil/West Borrow	795,538	2.15E+07	86.6	1.86E+09	117.4	105.7	1.86E+09	651,839	18.1%
Lobo Tract Borrow	291,421	7.87E+06	95.1	7.48E+08	112.9	101.6	7.48E+08	272,723	6.4%
TOTAL	**3,915,813**	-	-	-	-	-	-	**3,513,971**	