4.0 AS-BUILT CONSTRUCTION DETAILS

4.1 No. 1 Shaft

A cast-in-place concrete cap was used as the closure method for No. 1 Shaft as per the original design provided in Section 2.1.

4.1.1 Modifications to Original Design

There was no requirement to modify the overall closure method because of unexpected conditions encountered in the field during construction. The only construction modification to the original design was an increase in the thickness of the concrete cap from 250 mm to 300 mm.

4.1.2 As-Built Construction Details

As-built drawings for Shaft No. 1, are provided in Appendix C, Drawing No. 10903-1C.

Actual material specifications and quantities used for the construction of the No. 1 Shaft cast-in-place concrete cap, compared to design specifications and quantities, are provided in Table 4.1.

TABLE 4.1 NO. 1 SHAFT AS-BUILT VERSES DESIGN MATERIAL SPECIFICATIONS AND QUANTITIES

Material	Design		As-Built	
	Specification	Quantity	Actual	Quantity
Concrete	Strength (28 day): 35 MPa Air Entrainment: 6 to 8 % Slump: 55 to 95 mm	2.73 m^3	Strength (28 day): 33.4 MPa Air Entrainment: 6.4% Slump: 112 mm	3.0 m^3
Rebar Reinforcement	25 M (#8) 36 @ 2.45 m 15 M (#4) 8 @ 3.56 m	88.2 m 28.5 m	25 M (#8) 36 @ 2.45 m 15 M (#4) 8 @ 3.56 m	88.2 m 28.5 m
Dowling	20 M (#6) 10 @ 0.30 m	2.7 m	20 M (#6) 10 @ 0.30 m	2.7 m

As indicated in Table 4.1, the actual 28-day concrete compressive strength was tested at 33.4 MPa verses the design strength of 35 MPa. The slump of the delivered concrete also exceeded design specifications.

Although the concrete strength is 1.6 MPa below design, because of the increased cap thickness (290 mm actual verses 250 mm design), the shaft cap still has sufficient strength to support the design axle loading of 8,650 kg plus the dead weight of the concrete slab. The 33.4 MPa strength also exceeds the Ontario

Ministry on Northern Development and Mines specification of 30 MPa concrete for shaft capping design (Rehabilitation of Mines - Guidelines for Proponents, March 1995, Drawing No. 94103-M1).

4.2 No. 2 Shaft

A steel grate closure method was used for No. 2 Shaft, as detailed in the original design provided in Section 2.2.

4.2.1 Modifications to Original Design

There was no requirement to modify the overall closure method because of unexpected conditions encountered in the field during construction. The only construction modification to the original design was a slight decrease in the width of the concrete ring used to anchor the steel grating. The width was reduced to 410 mm from 457 mm to permit placement of the steel grates which were fabricated slightly wider than design.

During construction of the steel grate, the steel bars were positioned 150 mm apart inside dimension, rather than the 150 mm spacing, measured from centre-to-centre of the steel stock as designed. This slightly increased the width and length of the steel grates.

4.2.2 As-Built Construction Details

As-built drawings for Shaft No. 2 are provided in Appendix C, Drawing No. 10903-2C. Actual material specifications and quantities used for the construction of the No. 2 Shaft steel grate closure method, compared to design specifications and quantities are provided in Table 4.2.

TABLE 4.2 NO. 2 SHAFT AS-BUILT VERSES DESIGN MATERIAL SPECIFICATIONS AND QUANTITIES

Material	Design		As-Built	
	Specification	Quantity	Actual	Quantity
Steel Grate	Steel Stock: 25 by 25 mm Grid Size: 150 mm C-to-C Welding: at each crossing Coating: rust proof coating	N/A	Steel Stock: 25 by 25 mm Grid Size: 150 mm ID Welding: at each crossing Coating: rust proof coating	N/A
Concrete	Strength (28 day): 35 MPa Air Entrainment: 6 to 8 % Slump: 55 to 95 mm	0.9 m^3	Strength (28 day): 33.4 MPa Air Entrainment: 6.4% Slump: 112 mm	0.81 m^3
Rebar Reinforcement	15 M (#5) 4 @ 7.22 m 15 M (#5) 2 @ 2.41 m	28.9 m 4.8 m	15 M (#5) 4 @ 7.22 m 15 M (#5) 2 @ 2.41 m	28.9 m 4.8 m
Dowling	15 M (#4) 16 @ 0.25 m	4.0 m	15 M (#4) 16 @ 0.25 m	4.0 m

The slight increase in the size of the grid openings (25 mm), has no significant effect on the strength of the steel grate. The slightly larger grid openings will also not affect the ability of the grate to provide a safe cover over the mine opening.

The 410 mm actual verses 457 mm design width of the concrete anchor ring resulted in the requirement for less concrete. The slightly decreased width of the anchor ring and lower 28-day concrete strength will also have no impact on the ability of the concrete ring to anchor the steel grating, since the concrete anchor ring is not under load.

4.3 No. 1 Raise

A monolithic concrete slab was used as the closure method for No. 1 Raise as per the original design provided in Section 2.3.

4.3.1 Modifications to Original Design

There was no requirement to modify the overall closure method because of unexpected conditions encountered in the field during construction. The base of the subsidence cone over the raise proved to be sufficiently stable to support the weight of the concrete. The only construction modification to the original design was an increase in the thickness of the concrete slab from 350 mm to 400 mm. This change was made to ensure a minimum design cap thickness of 350 mm was achieved over uneven areas of the base of the subsidence feature.

4.3.2 As-Built Construction Details

As-built drawings for Raise No. 1 are provided in Appendix C, Drawing No. 10903-C. Actual material specifications and quantities used for the construction of the No. 1 Raise monolithic concrete slab, compared to design specifications and quantities are provided in Table 4.3.

TABLE 4.3 NO. 1 RAISE AS-BUILT VERSES DESIGN MATERIAL SPECIFICATIONS AND QUANTITIES

Material	Design		As-Built	
	Specification	Quantity	Actual	Quantity
Concrete	Strength (28 day): 35 MPa Air Entrainment: 6 to 8 % Slump: 55 to 95 mm Ave. Thickness: 350 mm	3.0 m^3	Strength (28 day): 37.8 MPa Air Entrainment: 6.0 % Slump: 95 mm Ave. Thickness: 406 mm	4.9 m^3
Rebar Reinforcement	20 M (#7) 88 @ 3.04 m 15 M (#4) 9 @ 4.57 m	267.5 m 41.1 m	25 M (#7) 36 @ 2.45 m 15 M (#4) 8 @ 3.56 m	267.5 m 41.1 m

As shown on Table 4.3, the actual 28-day strength of the concrete was 37.8 MPa, which exceeded the design strength of 35 MPa. The average thickness of the concrete slab (406 mm), as measured at six locations within the area of the slab also exceeded the design thickness. Actual rebar usage was identical to the design size and quantities.

4.4 No. 2 Raise

Pre-cast concrete panels and a cast-in-place concrete cap were used as the closure method for No. 2 Raise. The use of the cast-in-place concrete cap was a modification to the original pre-cast concrete panel closure design outlined in Section 2.4.

4.4.1 Modifications to Original Design

A combination of material problems associated with the pre-cast panels and uneven bedrock conditions encountered along the south side of the raise opening, resulted in the required to modify the closure method for No. 2 Raise. During shipment of the pre-cast panels to the mine site, two of the panels cracked and subsequently could not be used. Uneven bedrock conditions along the southwest half of the south side of the raise opening also required the use of 100 mm to 200 mm of fill or concrete as a levelling course on which to position the pre-cast panels, or the use of an alternative closure method over the west half of the raise opening.

Following discussions with Mr. Daniel Khan, P.Eng., Mining Engineer with NSDNR, it was mutually decided to use a cast-in-place concrete cap over the west half of the raise opening. The use of a cast-in-place concrete cap would eliminate the requirement to use fill or concrete for a levelling course; permit use of the three undamaged pre-cast concrete panels; eliminate delays in casting two additional pre-cast panels; and provide the added advantage of a fifth type of closure method. A 250 mm (minimum thickness), rebar reinforced concrete cap was subsequently designed and cast over the west half of the raise opening.

4.4.2 As-Built Construction Details

As-built drawings for the No. 2 Raise concrete closure cap are provided in Appendix C, Drawing No. 10903-4C. Actual material specifications and quantities used for the construction of the No. 2 Raise pre-cast concrete panels and cast-in-place concrete cap, compared to design specifications and quantities, are provided in Table 4.4.

TABLE 4.4 NO. 2 RAISE AS-BUILT VERSES DESIGN MATERIAL SPECIFICATIONS AND QUANTITIES

Material	Design		As-Built	
	Specification	Quantity	Actual	Quantity
Pre-Cast Panels	Size: 3.04 m x 610 mm x 254 mm (each)	5 (total)	Size: 3.04 m x 610 mm x 200 mm (each)	3 (total)
Concrete	Strength (28 day): 35 MPa Air Entrainment: 6 to 8 % Slump: Not Specified	0.47 m^3 each 2.35 m^3 total	Test cylinders not obtained. Standard 35 MPa, 6% entrained air mix used	0.37 m^3 each 1.11 m^3 total
Rebar Reinforcement	25 M (#8) 6 @ 3.0 m	18 m each 90 m total	20 M (#6) 6 @ 3.0 m	18 m each 54 m total
Cast-In-Place Cap	N/A	N/A	Size: 3.04 m x 2.12 m x 254 mm	1
Concrete	Strength (28 day): 35 MPa Air Entrainment: 6 to 8 % Slump: 55 to 95 mm	N/A	Strength (28 day): 37.8 MPa Air Entrainment: 6.0 % Slump: 95 mm	1.7 m^3
Rebar Reinforcement	N/A	N/A	30 M (#10) 5 @ 1.9 m 20 M (#6) 10 @ 1.0 m 20 M (#7) 5 @ 3.0 m 20 M (#6) 7 @ 3.0 m 20 M (#6) 5 @ 2.05 m 10 M (#3) 11 @ 3.0 m	9.5 m 10 m 15 m 21 m 10.25 m 33 m

As shown in Table 4.4, the pre-cast panels fabricated off-site did not meet design specifications for thickness and rebar reinforcement. The original specifications (250 mm thick panels with 25 M (#8) rebar), were designed to provide support over the 1.4 m wide raise opening for an overburden thickness of 2.0 m, the dead weight of the concrete panels and an axle loading of 8,160 kgs. The cast-in-place cap was designed to meet the original strength specifications of the pre-cast panels.

To meet design specifications, the pre-cast panels will be replaced in the spring of 1996 with new pre-cast concrete panels which meet the original design specifications. The two existing panels located over the raise opening will be removed and new panels positioned in their place. Because the first pre-cast panel (eastern panel) is essentially positioned over bedrock, it may only be necessary to replace the two pre-cast panels spanning the raise opening. As security, one of the two panels removed from over the raise would then be positioned over the eastern pre-cast panel to provide additional strength prior to backfilling.

4.5 Operational and Construction Problems

A summary of the problems encountered during the construction activities is provided below.

4.5.1 Transport of Pre-Cast Concrete Panels

The pre-cast concrete panels were formed and cast off-site under subcontract with L.E. Shaw at their facility in Lanz, Nova Scotia. During transport to the site, two of the five pre-cast panels cracked in half across the narrow (610 mm) width and could not be used. Two reasons were attributed to the breakage of the pre-cast panels:

- Because of the relatively short time period between awarding of the contract, finalizing design criteria, ordering the pre-cast panels and the site construction activities, the pre-cast panels did not have sufficient curing time to obtain maximum strength.

- When the pre-cast panels were loaded for delivery, the method used to stack and secure the panels onto the flat bed transport trailer resulted in point loading along the centre portion of two of the panels. The point loading resulted from a centre support timber which was thicker that two outside supports. When the panels were strapped down, the bottom two panels were subjected to point loading in the centre and subsequently cracked.

This problem could be avoided by ensuring pre-cast panels have adequate 28 day curing time to reach maximum strength and are carefully loaded for transport to the construction site.

4.5.2 Availability of Construction Materials and Supplies

With the exception of obtaining additional rebar for the cast-in-place concrete cap over No. 2 Raise, there were no material supply problems encountered. Because of the relative remoteness of the site, all construction supplies and materials were transported to the site from Halifax/Dartmouth, Port Hawkesbury, Mulgrave and/or Sydney.

The availability of rebar, forming timber, concrete, etc., should be identified and confirmed prior to construction in a remote area. If a local supplier is not available, extra material should be brought on site in the event additional materials are required during field construction.

Access for concrete delivery trucks must also be identified prior to ordering concrete. Concrete mix specifications must also be provided to the concrete supplier to ensure concrete delivered to site meets design specifications.

4.5.3 Preparation of Bedrock Surface

Uneven bedrock surfaces adjacent to No. 2 Raise, which could not be levelled using the excavator, required the use of a concrete levelling course around a portion of the raise perimeter for proper placement of the pre-cast concrete panels. Additional support fill or concrete would have been required if pre-cast concrete panels had been used over the entire opening as originally planned.

In areas of hard, durable rock, where uneven bedrock conditions can be expected, a breaker attachment for an excavator, or a chipper/jack hammer should be available on site to level uneven bedrock as required for the selected closure method.

4.6 Surveying

The elevations of the concrete closure caps on No. 1 and No. 2 Raises and No. 1 Shaft, were determined following completion of construction. Future elevations can be compared to the initial values to determine if the concrete caps are subsiding or shifting over time.

4.6.1 Reference Elevation

A reference elevation of 1,000.000 m was established on a stainless steel bolt head (Benchmark No. 1), grouted into a concrete foundation within the former No. 2 Hoist Room building. Four additional reference elevations were also established on-site in the event that the benchmark is damaged or destroyed.

References No. 1 and No. 2 are located in the northern area of the mine site, 15.2 m west and 45.7 m east of Benchmark No. 1 respectively. Reference No. 1 is the top surface of the former No. 2 Shaft Headframe support beam foundation, while Reference No. 2 is the top of a bolt extending from the former Office building foundation. The location and relative elevations of Benchmark No. 1 and Reference No. 1 and No. 2 are shown on Drawing No. 10903-1A, Appendix A. Photographs No. H-3 and H-4, Appendix H, show the former No. 2 Shaft Hoist Room foundations and the hoist foundation on which Benchmark No. 1 has been established.

Two additional reference elevations (Reference No. 3 and Reference No. 4), were established on the west side of the mine site, near No. 1 Shaft. Both reference elevations were established on bolts extending from the foundations of the former No. 1 Shaft Hoist Room. The general locations and relative elevations of these two reference points are also provided on Drawing No. 10903-1A.

4.6.2 Survey Results

The relative elevations of the Benchmark, reference stations and concrete closure caps for No. 1 Shaft, No. 1 Raise and No. 2 Raise are provided in Table J-1, Appendix J. The locations where survey elevations were obtained on the concrete caps over No. 1 Shaft, No. 1 Raise and No. 2 Raise are provided on Figures J-1, J-2, and J-3, in Appendix J.

4.7 Monuments

Because the concrete caps over No. 1 Shaft and both No. 1 and No. 2 Raises were not backfilled and covered, monuments were not established over these caps which would show the location of the concrete caps with reference to surface grade. Stainless steel anchors fitted with a stainless steel bolt, were however, grouted into the monolithic concrete slab over No. 1 Raise (Survey elevation stations 1 and 2) and at three locations in the closure cap over No. 2 Raise (two of the three pre-cast concrete panels and the centre of the cast-in-place cap).

Prior to backfilling over these concrete closure caps, a concrete filled rebar reinforced PVC pipe, sized in length to extend vertically to the surface elevation, should be attached to each anchor. Once backfill is placed over the concrete cap, the top of the monument will permit new elevations to be determined and also serve to identify the location of the concrete cap.

4.8 Site Security

To warn anyone travelling on-site during the evening and overnight when construction personnel were not working, yellow security "CAUTION" ribbon was strung around both No. 1 Raise and No. 2 Raise openings. Two strands of the "CAUTION" ribbon were attached to rebar or wooden supports pushed into the ground around the perimeter of the two openings. A plywood cover was also placed over the No. 2 Raise opening. Photograph No. H-1 in Appendix H, shows the security ribbon around No. 2 Raise.

Security was not required around No. 1 or No. 2 Shafts because by the end of the first day on site, (October 23, 1995), the plywood base for the cast-in-place cap had been positioned over the shaft opening at No. 1 Shaft and the steel grating had been positioned over No. 2 Shaft opening.

Following completion of construction activities, neither No. 1 Raise or No. 2 Raise closure caps were backfilled as per instructions from NSDNR. To prevent vehicles from inadvertently driving into the excavations around the two closure caps, rock and earth safety berms approximately 1 m in height, where constructed around the perimeter of the two excavations. A view of the safety berms around No. 1 and

No. 2 raises are shown on Photograph No. H-2, Appendix H.

4.9 Occupational Health and Safety

Appropriate health and safety measures were taken during the course of the construction activities to ensure the safety of workers and minimize the potential for injuries and accidents. The use of safety lines was particularly important when work was conducted around open holes, such as at No. 2 Raise.

The following health and safety measures as required by Nova Scotia Occupational Health and Safety Regulations, were followed during the construction activity.

- Use of hard hats whenever there was potential for falling or impact with overhead objects. Typically, hard hats were worn by the entire crew at all times.

- Wearing of safety boots with steel toes.

- Use of a safety harness and safety lines when working around open holes, primarily No. 2 Raise.

- Side slopes of excavations were graded to a minimum 1:1 H:V slope angle prior to entry into the excavation.

- A first aid kit was available on site and the supervising engineer had appropriate First Aid training.

Prior to any construction activities associated with closure or capping of abandoned mine openings, which involves heavy equipment and/or work around open holes, excavations or trenches, due consideration must be given to the appropriate Nova Scotia Occupational Health and Safety Regulations. Appropriate personal protective equipment and adequate training and/or supervision must be available.

4.10 Stream Crossings

To permit access to No. 1 Shaft for construction of the cast-in-place concrete cap, it was necessary to cross over Stachans Brook which flows across the mine site. A Stream Crossing Permit from Nova Scotia Department of the Environment (NSDOE) was obtained in compliance with NSDOE regulations, pertaining to stream crossings with vehicles and construction equipment.

Application was made to the NSDOE in Halifax, with the permit issued from the Port Hawkesbury, Nova Scotia, Regional Office. A copy of the permit is included in Appendix K.

Prior to construction activity which requires that vehicles or equipment cross over streams, application must be made to the NSDOE for a Stream Crossing Permit. The permit will outline the necessary measures which are required before vehicles or construction equipment can cross over a stream. These measures may include the installation of a bridge or culvert and/or the requirement for sedimentation and erosion controls.

The application should be made 4 to 6 weeks in advance of field work to remit adequate time for NSDOE review and the design/construction of any required crossing measures.

4.11 Concrete Testing

Concrete testing services during the construction activities were provided by JWA in Port Hawkesbury, Nova Scotia. A technician was on site both times concrete was delivered, to obtain cylinders for compressive strength testing and determine the slump and percent entrained air of the concrete. Results of the concrete testing have been reported elsewhere in the report and are summarized in Table 4.5. Photograph No. H-8, Appendix H, shows concrete cylinders obtained during a concrete pour. Copies of the concrete test reports are provided in Appendix I.

TABLE 4.5 CONCRETE TEST RESULTS

Design Specifications		Actual			
		No. 1 Shaft	No. 2 Shaft	No. 1 Raise	No. 2 Raise
Compressive Strength (28 day)	35 MPa	33.4 MPa	33.4 MPa	37.8 MPa	37.8 MPa
Entrained Air	5 to 8 %	6 %	6 %	6 %	6 %
Slump	55 to 95 mm	112 mm	112 mm	95 mm	95 mm

Field collection of the test cylinders and determination of the slump and percent air entrainment are required to ensure the concrete delivered to the field meets design specifications and will set to the design strength specifications. The correct strength characteristics are required for any concrete cap which will be backfilled to ensure support of overburden loading.

A certified concrete testing firm should be contacted to obtain the test cylinders and conduct the slump and percent air tests.