4.0 PROBABLE BREAKTHROUGH MECHANISM

To determine the probable cause of the 2000 breakthrough, OSM considered four potential failure mechanisms. These are addressed in Section 3.1 and are summarized below:

1. Failure of sealed underground mine openings

2. Breakthrough at an unsealed underground mine opening

3. Breakthrough at coal barriers

4. Breakthrough at strata overlying the coal seam

4.1 Failure of Sealed Underground Mine Openings

This failure mechanism relates to mine openings that have been sealed with rock, soil, or other material. Mine openings are entries or borings within the impoundment area that connect the underground mine with the surface. OSM's review did not find any evidence of mine openings at the 2000 breakthrough.

The impoundment is bounded by the MCCC 1-C underground mine on all sides except the valley of Big Branch south-southeast of the embankment (Figure 2 [Page 4]). Two areas of the underground mine, mined during 1981 and 1982, abut the impoundment to the north and south, and at some points extend short distances under the impoundment. As addressed in Section 3.3.2.5, OSM's review of the underground mine maps did not find any evidence that any of the underground mine entries extended to the surface at the 2000 breakthrough. Further, as addressed in Section 3.5.1.2, the Triad drilling at the breakthrough did not identify any entries that extended to the surface.

4.2 Breakthrough at an Unsealed Underground Mine Opening

This failure mechanism relates to mine openings that have not been sealed. As addressed in Section 4.1, OSM did not identify any openings at the 2000 breakthrough.

4.3 Breakthrough at Coal Barriers

This failure mechanism relates to the failure of coal barriers. The barriers may be: (1) underground mine outcrop barriers within the impoundment area, (2) coal barriers between surface mines within the impoundment area and adjacent underground mines, or (3) coal barriers between different underground mines where at least one of the mines has surface openings within the impoundment area. OSM concludes that the mechanism for the 2000 breakthrough was primarily an outcrop barrier failure.

OSM concludes that the breakthrough was caused by seepage and piping through the outcrop barrier at the southwest corner of the 50-foot long, dead-end entry. The seepage from the impoundment may have been through: (1) natural fractures that connected with the entry, (2) natural fractures exposed by a roof fall, (3) fractures created by a roof fall, and/or (4) weathered coal and overburden. The various conditions related to these conclusions are addressed below.

4.3.1 Barrier size and composition: The MCCC underground mine at the 2000 breakthrough was separated from the impoundment by an outcrop barrier. The outcrop barrier, as addressed in Section 3.5.1.3, was composed of colluvium, sandstone, shale, and coal. As addressed in Sections 2.1.3 and 2.1.5, there are no indications that the outcrop barrier was disturbed by surface mines or small underground mines at the breakthrough. OSM's review of maps and photographs found that an access road had been constructed over the outcrop barrier but was unable to determine if the road was cut into the outcrop barrier or was built on fill material. OSM has not been able to determine whether the road contributed to the breakthrough. As addressed in Section 3.3.2.5, MCCC did not conduct a geotechnical investigation to determine the nature and width of the outcrop barrier.

As addressed in Section 3.5.1.3, at the end of the mine entry where the 2000 breakthrough occurred, the overburden, based on vertical measurements from Figure 7 [Page 55], was composed of about 14 feet of sandstone and 11 feet of colluvium. (Note: MSHA has characterized this distance by a diagonal measurement of 27 feet at the end of the mine entry. MSHA's measurement was made along Triad Profile D-D [see Inset Figure 4 on Page 18] while OSM's measurement was made along Triad Profile A-A, Figure 7 [Page 55].) The upper half of the sandstone overlying the entry was weathered. At the end of the 10- to 12-foot section of "missing coal" (Figure 7 [Page 55]), the overburden is composed of only about four feet of weathered sandstone and 15 feet of colluvium. Prior to the breakthrough, the weathered sandstone may have been underlain by one to two feet of shale.

The full thickness of the Coalburg coal seam exists for only about 15 feet beyond the mine limit as mapped, and then it thins to zero feet thick at about 33 feet from the end of the mine (Figures 6 and 7 [Pages 53 and 55]). The Triad drill logs did not identify coal in the remaining portion of the 70-foot wide outcrop barrier. This coal is presumed to be in a weathered condition, and it may have been transported downslope due to hillside creep.

4.3.2 Subsidence potential: As addressed in Section 3.5.1.1, the 2000 breakthrough occurred at the southwest corner of the 50-foot long, dead-end entry at Line #1 as illustrated in Figures 2, 4, and 6 (Pages 4, 18, and 53). A cross-section of the failure area is shown on Figure 4 (Page 18). Cross-section A-A at Line #1 from the Triad report is shown on Figure 7 (Page 55). OSM's assessment of the potential that subsidence was a factor in the breakthrough is as follows.

The roof condition along the centerline of the mapped entry (Figure 7 [Page 55]) indicates that the breakthrough was not the result of a massive roof fall. The figure shows that the roof along the centerline at the end of the entry is still standing, proving that no massive roof fall occurred.

Finally, a localized roof fall could have occurred at the southwest corner of the entry as mapped. The Figure 4 (Page 18), Triad Profile D-D inset, shows that the sandstone overhangs the entry and is largely intact. Therefore, if a localized roof fall did occur, it did not extend vertically upward through the overlying sandstone. However, the roof fall could have intercepted natural fractures.

4.3.3 Seepage barrier permeability: As addressed in Sections 3.3.2.1 and 3.5.1.4, the seepage barrier was permeable and saturated near the outcrop barrier. While the colluvial portion of the outcrop barrier may not have been as permeable as the seepage barrier, the colluvium was also saturated. As addressed in Section 3.3.2.1, MCCC did not discharge slurry along the seepage barrier as required to inhibit seepage. The permeable and saturated nature of the colluvium and seepage barrier did not prevent seepage into the underground mine. Increased seepage may have started as early as April 1998. Starting in September 1999, seepage increased significantly (Section 3.5.2 and Figure 9 [Page 62]). OSM's review found that the increase was likely due to leakage from the impoundment into the underground mine and was an indicator of the impending breakthrough.

4.3.4 Seepage and piping: OSM believes that seepage into the underground mine removed fine soil material from the outcrop barrier as well as the seepage barrier. The seepage may have also caused additional weathering and erosion of the outcrop barrier. This process of internal erosion is known as "piping." OSM believes that piping caused the breakthrough.

Starting in September 1999, there was a significant increase in the rate of seepage into the underground mine (Section 3.5.2). The seepage may have exceeded 500 gallons per minute. This seepage may have occurred through the coal seam, the interface between the coal seam and the shale, the interface between the shale and sandstone, natural fractures, and roof-fall related fractures. Seepage and piping along the interfaces may have removed the support under the overlying sandstone causing it to settle and develop open fractures. This would have allowed increased seepage through the seepage barrier and colluvium with a resulting increase in piping.

The piping and erosion would have created increasingly larger voids or cavities in the outcrop barrier and seepage barrier. At the time of the failure, the cavities may have extended through, or almost through, the seepage barrier itself creating a direct connection between the underground mine and the slurry impoundment.

4.3.5 Bridging and plugging: As addressed in Section 3.3.2.1, large rocks were deposited at the base of the seepage barrier during construction due to gravity segregation. Initially, the larger rocks may have bridged over the cavities created by the piping and erosion. However, over a period of time, these rocks would not be able to permanently bridge the cavities and ultimately would collapse, allowing the slurry to rapidly discharge into the underground mine. As addressed in Section 3.5, the seepage barrier failed to plug the breakthrough, which was a stated purpose of the sealing plan.

4.3.6 Other factors: OSM reviewed several other factors to determine if they contributed to the breakthrough, including precipitation (Section 3.5.2), blasting (Section 3.5.3), seismic activity (Section 3.5.4), seepage barrier stability (Section 3.5.5), and underground mine pillar stability (Section 3.5.6). OSM concluded that the breakthrough was not related to these factors.

4.4 Breakthrough at Strata Overlying the Coal Seam

This failure mechanism relates to mine roof falls that extend to the surface or subsidence induced by pillar failure or pillar extraction. As addressed in Section 4.3.2, Subsidence Potential, OSM's review indicates that the 2000 breakthrough may, in part, be related to a roof fall. OSM's review indicates that the pillars are stable (Section 3.5.6), and that the pillars were not extracted (Section 3.5.1.2).