Royal Oak Mines Inc.

Giant Mine

Arsenic Trioxide Management

Appendices

March 1998

Appendices

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Appendix I

Storage Chamber Drawings

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Appendix II

Summary of Rock Temperature Data

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Table 1
Arsenic Thermistor Temperature Readings for Hole 1

Hole 1		Thermistor Temperature Reading (°C)						
	Depth (ft)	*20*	*75*	*130*	*185*	*240*	*295*	*350*
1994	Jun-94	0.0	0.5	0.5	0.5	0.6	0.7	0.8
	Jul-94	0.0	0.4	0.4	0.5	0.6	0.7	0.9
	Aug-94	0.0	0.4	0.4	0.5	0.6	0.7	0.9
	Sep-94	-0.1	0.3	0.4	0.5	0.6	0.7	0.8
	Oct-94	0.1	0.3	0.4	0.5	0.6	0.7	0.8
	Nov-94	0.6	0.3	0.4	0.5	0.6	0.7	0.8
	Dec-94	0.5	0.3	0.4	0.5	0.6	0.7	0.8
	Avg.	*0.2*	*0.4*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*
	Avg.	*0.2*			*0.6*			
1995	Jan-95	0.3	0.3	0.4	0.5	0.6	0.7	0.8
	Feb-95	0.2	0.3	0.4	0.5	0.6	0.7	0.8
	Mar-95	nm						
	Apr-95							
	May-95	0.0	0.3	0.4	0.5	0.6	0.7	0.8
	Jun-95	nm						
	Jul-95	0.0	0.3	0.4	0.5	0.6	0.7	0.8
	Aug-95	0.4	0.3	0.4	0.4	0.6	0.7	0.8
	Sep-95	1.3	0.3	0.4	0.5	0.6	0.7	0.8
	Oct-95	nm						
	Nov-95	1.3	0.3	0.4	0.4	0.6	0.7	0.8
	Dec-95	nm						
	Avg.	*0.5*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*
	Avg.	*0.5*			*0.5*			
1996	Jan-96	nm						
	Feb-96	0.1	0.3	0.4	0.5	0.6	0.7	0.8
	Mar-96	0.0	0.4	0.4	0.5	0.6	0.7	0.8
	Apr-96	0.0	0.4	0.4	0.5	0.6	0.7	0.8
	May-96	-0.1	0.4	0.4	0.5	0.6	0.7	0.8
	Jun-96	-0.1	0.4	nm	0.4	nm	0.7	0.8
	Jul-96	-0.1	0.4	0.4	0.5	0.6	0.7	0.8
	Aug-96	0.0	0.4	0.4	0.5	0.6	0.7	0.8
	Sep-96	0.1	0.3	0.4	0.5	0.6	0.7	0.8
	Oct-96	1.5	0.3	0.4	0.5	0.6	0.7	0.8
	Nov-96	1.7	0.3	0.4	0.5	0.6	0.7	0.8
	Dec-96	1.1	0.3	0.4	0.4	0.6	0.7	0.8
	Avg.	*0.4*	*0.4*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*
	Avg.	*0.4*			*0.6*			
1997	Jan-97	0.6	0.3	0.4	0.5	0.6	0.7	0.8
	Feb-97	0.2	0.3	0.4	0.5	0.6	0.7	0.8
	Mar-97	0.0	0.3	0.4	0.5	0.6	0.7	0.8
	Apr-97	0.0	0.4	0.5	0.5	0.6	0.7	0.8
	May-97	-0.1	0.4	0.4	0.5	0.6	0.7	0.8
	Jun-97	-0.1	0.4	0.4	0.5	0.6	0.7	0.8
	Jul-97	0.0	0.4	0.4	0.5	0.6	0.7	0.8
	Aug-97	0.0	0.4	0.4	0.5	0.6	0.7	0.8
	Sep-97	0.0	0.3	0.4	0.5	0.6	0.7	0.8
	Oct-97	1.2	0.3	0.4	0.5	0.6	0.7	0.8
	Nov-97	1.1	0.3	0.5	0.5	0.6	0.7	0.8
	Dec-97	0.7	0.3	0.5	0.5	0.6	0.7	0.8
	Avg.	*0.3*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*
	Avg.	*0.3*			*0.6*			
1998	Jan-98	0.4	0.3	0.5	nm	nm	0.7	0.8
	Feb-98	0.1	0.3	0.5	0.5	0.6	0.7	0.8
	Avg.	*0.3*	*0.3*	*0.5*	*0.5*	*0.6*	*0.7*	*0.8*
	Avg.	*0.3*			*0.6*			

nm - not measured

Table 2
Arsenic Thermistor Temperature Readings for Hole 2

Hole 2		Thermistor Temperature Reading (°C)						
	Depth (ft)	*20*	*75*	*130*	*185*	*240*	*295*	*350*
1994	Jun-94	0.1	2.0	1.4	1.1	0.9	0.9	0.9
	Jul-94	1.4	1.9	1.4	1.1	0.9	0.9	0.9
	Aug-94	3.4	1.9	1.4	1.1	0.9	0.9	0.9
	Sep-94	5.1	1.8	1.4	1.1	0.9	0.8	0.8
	Oct-94	5.5	nm	1.4	1.1	0.9	0.9	0.8
	Nov-94	4.9	1.7	1.3	1.1	0.9	0.8	0.8
	Dec-94	4.0	1.7	1.3	1.1	0.9	0.8	0.8
	Avg.	*3.5*	*1.8*	*1.4*	*1.1*	*0.9*	*0.9*	*0.8*
	Avg.	*3.5*	*1.2*					
1995	Jan-95	3.0	1.7	1.3	1.1	0.9	0.8	0.8
	Feb-95	2.1	1.7	1.3	1.1	0.9	0.8	0.8
	Mar-95	nm						
	Apr-95							
	May-95	0.6	1.7	1.3	1.1	0.9	0.8	0.8
	Jun-95	2.5	1.7	1.3	1.0	0.9	0.8	0.8
	Jul-95	2.5	1.7	1.3	1.0	0.9	0.8	0.8
	Aug-95	3.9	1.8	1.3	1.0	0.9	0.8	0.8
	Sep-95	4.8	1.8	1.3	1.0	0.9	0.8	0.8
	Oct-95	nm						
	Nov-95							
	Dec-95							
	Avg.	*2.7*	*1.7*	*1.3*	*1.0*	*0.9*	*0.8*	*0.8*
	Avg.	*2.7*	*1.1*					
1996	Jan-96	nm						
	Feb-96	1.1	2.0	1.3	1.0	0.9	0.9	0.8
	Mar-96	0.5	2.0	1.3	1.0	0.9	0.9	0.8
	Apr-96	0.1	2.0	1.3	1.0	0.9	0.9	0.8
	May-96	-0.1	2.0	1.3	1.0	0.9	0.9	0.8
	Jun-96	nm						
	Jul-96							
	Aug-96							
	Sep-96							
	Oct-96							
	Nov-96							
	Dec-96							
	Avg.	*0.4*	*2.0*	*1.3*	*1.0*	*0.9*	*0.9*	*0.8*
	Avg.	*0.4*	*1.2*					
1997	Jan-97	nm						
	Feb-97							
	Mar-97							
	Apr-97							
	May-97							
	Jun-97							
	Jul-97							
	Aug-97							
	Sep-97							
	Oct-97							
	Nov-97							
	Dec-97							
	Avg.	-	-	-	-	-	-	-
	Avg.	-	-					
1998	Jan-98	nm						
	Feb-98							
	Avg.	-	-	-	-	-	-	-
	Avg.	-	-					

nm - not measured

Table 3
Arsenic Thermistor Temperature Readings for Hole 3

Hole 3		Thermistor Temperature Reading (°C)						
Depth (ft)		*20*	*75*	*130*	*185*	*240*	*295*	*350*
1994	Jun-94	0.4	1.3	1.0	0.9	0.8	0.9	1.0
	Jul-94	1.5	1.2	1.0	0.9	0.8	0.9	1.0
	Aug-94	2.9	nm	nm	1.1	0.9	0.9	0.9
	Sep-94	4.1	1.2	1.0	0.9	0.8	0.9	1.0
	Oct-94	4.1	1.2	1.0	0.9	0.8	0.9	1.0
	Nov-94	3.6	1.2	1.0	0.8	0.8	0.8	1.0
	Dec-94	2.8	1.2	1.0	0.8	0.8	0.8	1.0
	Avg.	*2.8*	*1.2*	*1.0*	*0.9*	*0.8*	*0.9*	*1.0*
	Avg.	*2.8*	*1.0*					
1995	Jan-95	1.6	1.2	1.0	0.6	0.8	0.8	1.0
	Feb-95	nm						
	Mar-95							
	Apr-95							
	May-95	0.5	1.2	1.0	0.9	0.8	0.9	1.0
	Jun-95	nm						
	Jul-95	2.2	1.2	1.0	0.9	0.8	0.8	1.0
	Aug-95	3.2	1.1	1.0	0.8	0.8	0.8	1.0
	Sep-95	3.9	1.1	1.0	0.8	0.8	0.8	1.0
	Oct-95	nm						
	Nov-95		1.1	1.0	0.8	0.8	0.8	1.0
	Dec-95	nm						
	Avg.	*2.5*	*1.1*	*1.0*	*0.8*	*0.8*	*0.8*	*1.0*
	Avg.	*2.5*	*0.9*					
1996	Jan-96	nm						
	Feb-96							
	Mar-96							
	Apr-96	-0.5	1.2	1.0	0.9	0.8	0.9	1.1
	May-96	nm	1.2	1.0	0.9	0.8	0.9	1.0
	Jun-96	nm	1.2	1.0	0.9	0.8	0.9	1.0
	Jul-96	nm	1.2	1.0	0.9	0.8	0.9	1.0
	Aug-96	nm	1.2	1.0	0.9	0.8	0.9	1.0
	Sep-96	nm	1.2	1.0	0.9	0.8	0.9	1.0
	Oct-96	nm	1.2	1.1	0.9	0.8	0.9	1.0
	Nov-96	nm	1.2	1.1	0.9	0.8	0.9	1.0
	Dec-96	nm	1.2	1.1	0.9	0.8	0.9	1.0
	Avg.	*-0.5*	*1.2*	*1.0*	*0.9*	*0.8*	*0.9*	*1.0*
	Avg.	*-0.5*	*1.0*					
1997	Jan-97	nm	1.2	1.1	0.9	0.8	0.9	1.0
	Feb-97	nm	1.1	1.1	0.9	0.8	0.9	1.0
	Mar-97	nm	1.2	1.1	0.9	0.8	0.9	1.0
	Apr-97	nm	1.2	1.1	0.9	0.8	0.9	1.0
	May-97	nm	1.2	1.1	0.9	0.8	0.9	1.0
	Jun-97	nm	1.2	1.1	0.9	0.8	0.9	1.0
	Jul-97	nm	1.2	1.1	0.9	0.8	0.9	1.0
	Aug-97	nm	1.1	1.1	0.9	0.8	0.9	1.0
	Sep-97	nm	1.1	1.1	0.9	0.8	0.9	1.0
	Oct-97	nm	1.1	1.1	0.9	0.9	0.9	1.0
	Nov-97	nm	1.1	1.1	0.9	0.8	0.9	1.0
	Dec-97	nm	1.1	1.1	0.9	0.8	0.9	1.1
	Avg.	-	*1.2*	*1.1*	*0.9*	*0.8*	*0.9*	*1.0*
	Avg.	-	*1.0*					
1998	Jan-98	nm	1.1	1.1	0.9	0.9	0.9	1.1
	Feb-98	nm	1.1	1.1	0.9	0.8	0.9	1.0
	Avg.	-	*1.1*	*1.1*	*0.9*	*0.9*	*0.9*	*1.1*
	Avg.	-	*1.0*					

nm - not measured

Table 4
Arsenic Thermistor Temperature Readings for Hole 4

Hole 4		Thermistor Temperature Reading (°C)			
	Depth (ft)	*15*	*90*	*165*	*240*
1994	Jun-94	1.8	2.1	2.7	3.8
	Jul-94	4.5	1.9	2.7	3.8
	Aug-94	7.2	1.8	2.8	3.8
	Sep-94	7.6	1.7	2.8	3.9
	Oct-94	6.1	1.7	2.8	3.9
	Nov-94	3.9	1.6	2.8	3.9
	Dec-94	2.6	1.6	2.8	3.9
	Avg.	*4.8*	*1.8*	*2.8*	*3.9*
	Avg.	*4.8*	*2.8*		
1995	Jan-95	0.6	1.6	2.8	3.9
	Feb-95	-0.7	1.6	2.8	3.9
	Mar-95	nm			
	Apr-95	nm			
	May-95	-1.3	1.8	2.8	3.8
	Jun-95	5.6	1.7	2.6	3.7
	Jul-95	nm			
	Aug-95	6.8	1.7	2.7	3.7
	Sep-95	6.7	1.7	2.7	3.7
	Oct-95	nm			
	Nov-95	2.5	1.7	2.7	3.7
	Dec-95	nm			
	Avg.	*2.9*	*1.7*	*2.7*	*3.8*
	Avg.	*2.9*	*2.7*		
1996	Jan-96	nm			
	Feb-96	-2.9	1.8	2.7	3.7
	Mar-96	-4.0	1.8	2.8	3.7
	Apr-96	-4.3	1.8	2.7	3.7
	May-96	-2.4	1.8	2.8	3.7
	Jun-96	1.1	1.8	2.8	nm
	Jul-96	4.4	1.8	2.8	3.7
	Aug-96	7.2	1.8	2.8	3.7
	Sep-96	7.1	1.8	2.8	3.7
	Oct-96	6.1	1.7	2.8	3.7
	Nov-96	3.7	1.7	2.8	3.7
	Dec-96	2.1	1.7	2.8	3.6
	Avg.	*1.6*	*1.8*	*2.8*	*3.7*
	Avg.	*1.6*	*2.7*		
1997	Jan-97	0.1	1.7	2.8	3.6
	Feb-97	-2.3	1.7	2.8	3.6
	Mar-97	-3.7	1.7	2.8	3.6
	Apr-97	-4.3	1.8	2.8	3.6
	May-97	-2.1	1.8	2.8	3.5
	Jun-97	1.4	1.8	2.8	3.5
	Jul-97	4.4	1.8	2.8	3.5
	Aug-97	7.4	1.8	2.8	3.4
	Sep-97	7.5	1.7	2.5	3.4
	Oct-97	4.8	1.7	2.8	3.4
	Nov-97	2.8	1.7	2.8	3.3
	Dec-97	1.6	1.7	2.8	3.3
	Avg.	*1.5*	*1.7*	*2.8*	*3.5*
	Avg.	*1.5*	*2.7*		
1998	Jan-98	-0.4	1.7	2.8	3.3
	Feb-98	-1.6	1.7	2.8	3.2
	Avg.	*-1.0*	*1.7*	*2.8*	*3.3*
	Avg.	*-1.0*	*2.6*		

nm - not measured

Table 5
Arsenic Thermistor Temperature Readings for Hole 5

Hole 5		Thermistor Temperature Reading (°C)						
Depth (ft)		*20*	*75*	*130*	*185*	*240*	*295*	*350*
1994	Jun-94	nm						
	Jul-94							
	Aug-94	3.5	0.4	0.4	0.6	0.8	1.1	1.4
	Sep-94	4.2	0.3	0.4	0.5	0.8	1.1	1.4
	Oct-94	4.0	0.3	0.4	0.5	0.8	1.1	1.4
	Nov-94	3.5	0.3	0.3	0.5	0.8	1.1	1.4
	Dec-94	nm						
	Avg.	*3.8*	*0.3*	*0.4*	*0.5*	*0.8*	*1.1*	*1.4*
	Avg.	*3.8*	*0.8*					
1995	Jan-95	0.9	0.3	0.3	0.4	0.8	1.1	1.4
	Feb-95	0.1	0.3	0.3	0.5	0.8	1.1	1.4
	Mar-95	nm						
	Apr-95							
	May-95	-1.2	0.3	0.3	0.5	0.8	1.1	1.4
	Jun-95	nm						
	Jul-95	1.8	0.3	0.3	0.5	0.8	1.1	1.4
	Aug-95	2.9	0.3	0.3	0.5	0.8	1.1	1.4
	Sep-95	3.7	0.3	0.3	0.5	0.8	1.1	1.4
	Oct-95	nm						
	Nov-95	2.6	0.3	0.3	0.4	0.8	1.1	1.4
	Dec-95	nm						
	Avg.	*1.7*	*0.3*	*0.3*	*0.5*	*0.8*	*1.1*	*1.4*
	Avg.	*1.7*	*0.7*					
1996	Jan-96	nm						
	Feb-96	-1.2	0.4	0.3	0.5	0.8	1.1	1.4
	Mar-96	-2.4	0.4	0.3	0.5	0.8	1.1	1.4
	Apr-96	-2.6	0.4	0.4	0.5	0.9	1.2	1.4
	May-96	-2.3	0.4	0.3	0.5	0.8	1.1	1.4
	Jun-96	-1.2	0.4	0.3	0.5	0.8	1.1	1.4
	Jul-96	1.3	0.4	0.3	0.5	0.8	1.1	1.4
	Aug-96	2.7	0.4	0.3	0.5	0.8	1.1	1.4
	Sep-96	3.5	0.3	0.3	0.5	0.8	1.1	1.4
	Oct-96	3.9	0.3	0.3	0.5	0.9	1.1	1.4
	Nov-96	3.0	0.3	0.3	0.5	0.9	1.1	1.4
	Dec-96	2.0	0.3	0.4	0.5	0.9	1.1	1.5
	Avg.	*0.6*	*0.4*	*0.3*	*0.5*	*0.8*	*1.1*	*1.4*
	Avg.	*0.6*	*0.8*					
1997	Jan-97	0.7	0.3	0.3	0.5	0.9	1.1	1.4
	Feb-97	-0.8	0.3	0.3	0.5	0.9	1.1	1.5
	Mar-97	-1.9	0.3	0.3	0.5	0.9	1.1	1.5
	Apr-97	-2.6	0.3	0.3	0.5	0.9	1.1	1.5
	May-97	-2.5	nm					1.4
	Jun-97	-0.9	0.3	0.3	0.4	0.9	1.1	1.5
	Jul-97	1.2	0.3	0.4	0.5	0.9	1.1	1.5
	Aug-97	2.9	0.3	0.3	0.5	0.9	1.1	1.5
	Sep-97	3.5	0.3	0.4	0.5	0.9	1.1	1.5
	Oct-97	3.4	0.2	0.4	0.5	0.9	1.2	1.5
	Nov-97	2.4	0.2	0.4	0.5	0.9	1.2	1.5
	Dec-97	1.4	0.2	0.3	0.5	0.9	1.2	1.5
	Avg.	*0.6*	*0.3*	*0.3*	*0.5*	*0.9*	*1.1*	*1.5*
	Avg.	*0.6*	*0.8*					
1998	Jan-98	0.3	0.2	0.3	0.5	0.9	1.2	1.5
	Feb-98	-0.7	0.3	0.3	0.5	0.9	1.2	1.5
	Avg.	*-0.2*	*0.3*	*0.3*	*0.5*	*0.9*	*1.2*	*1.5*
	Avg.	*-0.2*	*0.8*					

nm - not measured

Table 6
Arsenic Thermistor Temperature Readings for Hole 6

Hole 6		Thermistor Temperature Reading (°C)							
	Depth (ft)	*15*	*70*	*125*	*180*	*235*	*290*	*345*	*400*
1994	Jun-94	0.9	1.5	1.2	1.0	1.0	1.1	1.2	1.3
	Jul-94	2.4	1.5	1.2	1.0	1.0	1.1	1.1	1.1
	Aug-94	4.5	1.4	1.2	1.0	1.0	1.1	1.2	1.3
	Sep-94	5.8	1.4	1.2	0.9	0.9	1.1	1.1	1.3
	Oct-94	5.3	1.3	1.2	0.9	0.9	1.1	1.1	1.3
	Nov-94	4.1	1.3	1.2	0.9	0.9	1.0	1.1	1.3
	Dec-94	3.1	1.3	1.2	0.9	0.9	1.0	1.1	1.3
	Avg.	*3.7*	*1.4*	*1.2*	*0.9*	*0.9*	*1.1*	*1.1*	*1.3*
	Avg.	*3.7*				*1.1*			
1995	Jan-95	1.7	1.3	1.2	0.9	0.9	1.0	1.1	1.3
	Feb-95	0.3	1.3	1.1	0.9	0.9	1.1	1.1	1.3
	Mar-95	nm							
	Apr-95								
	May-95	-0.2	1.4	1.1	0.9	1.0	1.1	1.1	1.3
	Jun-95	3.0	1.4	1.1	0.9	0.9	1.0	1.1	1.3
	Jul-95	nm							
	Aug-95	4.7	1.4	1.1	0.9	0.9	1.0	1.1	1.3
	Sep-95	5.2	1.3	1.1	0.9	1.0	1.0	1.1	1.3
	Oct-95	nm							
	Nov-95	3.3	1.3	1.1	0.9	0.9	1.0	1.1	1.3
	Dec-95	nm							
	Avg.	*2.6*	*1.3*	*1.1*	*0.9*	*0.9*	*1.0*	*1.1*	*1.3*
	Avg.	*2.6*				*1.1*			
1996	Jan-96	nm							
	Feb-96								
	Mar-96								
	Apr-96								
	May-96	-1.3	1.4	1.1	0.9	1.0	1.1	1.1	1.3
	Jun-96	0.1	1.4	1.1	0.9	1.0	1.1	1.2	1.4
	Jul-96	2.0	1.4	1.1	0.9	1.0	1.1	1.1	1.3
	Aug-96	4.3	1.4	1.1	0.9	1.0	1.1	1.1	1.3
	Sep-96	5.1	1.3	1.1	0.9	1.0	1.1	1.1	1.3
	Oct-96	5.5	1.3	1.1	0.9	1.0	1.1	1.2	1.3
	Nov-96	3.9	1.3	1.1	0.9	1.0	1.1	1.2	1.3
	Dec-96	2.6	1.3	1.1	0.9	1.0	1.1	1.2	1.4
	Avg.	*2.8*	*1.4*	*1.1*	*0.9*	*1.0*	*1.1*	*1.2*	*1.3*
	Avg.	*2.8*				*1.1*			
1997	Jan-97	1.1	1.3	1.1	0.9	1.0	1.1	1.1	1.3
	Feb-97	0.0	1.3	1.1	0.9	1.0	1.1	1.2	1.4
	Mar-97	-1.3	1.4	1.1	0.9	1.0	1.1	1.2	1.3
	Apr-97	-1.9	1.4	1.1	0.9	1.0	1.1	1.1	1.3
	May-97	-1.1	1.4	1.1	0.9	1.0	1.1	1.1	1.3
	Jun-97	nm							
	Jul-97	2.9	1.3	nm	0.9	1.0	1.1	1.1	1.3
	Aug-97	4.5	1.3	nm	0.9	1.0	1.1	1.1	1.3
	Sep-97	5.1	1.2	nm	0.9	1.0	1.1	1.1	1.3
	Oct-97	4.3	1.2	nm	0.9	1.0	1.1	1.2	1.3
	Nov-97	2.9	1.2	nm	0.9	1.0	1.1	1.2	1.3
	Dec-97	1.3	1.2	nm	nm	nm	0.9	1.2	1.3
	Avg.	*1.6*	*1.3*	*1.1*	*0.9*	*1.0*	*1.1*	*1.1*	*1.3*
	Avg.	*1.6*				*1.1*			
1998	Jan-98	0.5	1.2	nm	0.9	1.0	1.1	1.2	1.4
	Feb-98	-0.3	1.2	nm	0.9	1.0	1.1	1.2	1.4
	Avg.	*0.1*	*1.2*	*-*	*0.9*	*1.0*	*1.1*	*1.2*	*1.4*
	Avg.	*0.1*				*1.1*			

nm - not measured

Table 7
Arsenic Thermistor Average Yearly Temperature Readings

Hole 1	Average Thermistor Temperature Reading (°C)					Summary Average	
Depth (ft)	1994	1995	1996	1997	1998		
20	0.2	0.5	0.4	0.3	0.3	0.3	0.3
75	0.4	0.3	0.4	0.3	0.3	0.3	0.6
130	0.4	0.4	0.4	0.4	0.5	0.4	
185	0.5	0.5	0.5	0.5	0.5	0.5	
240	0.6	0.6	0.6	0.6	0.6	0.6	
295	0.7	0.7	0.7	0.7	0.7	0.7	
350	0.8	0.8	0.8	0.8	0.8	0.8	
Hole 2	Average Thermistor Temperature Reading (°C)					Summary Average	
Depth (ft)	1994	1995	1996	1997	1998		
20	3.5	2.8	0.4	na		2.2	2.2
75	1.8	1.7	2.0			1.9	1.1
130	1.4	1.3	1.3			1.3	
185	1.1	1.0	1.0			1.0	
240	0.9	0.9	0.9			0.9	
295	0.9	0.8	0.9			0.9	
350	0.8	0.8	0.8			0.8	
Hole 3	Average Thermistor Temperature Reading (°C)					Summary Average	
Depth (ft)	1994	1995	1996	1997	1998		
20	2.8	2.3	-0.5	na	na	1.5	1.5
75	1.2	1.2	1.2	1.2	1.1	1.2	1.0
130	1.0	1.0	1.0	1.1	1.1	1.0	
185	0.9	0.8	0.9	0.9	0.9	0.9	
240	0.8	0.8	0.8	0.8	0.9	0.8	
295	0.9	0.8	0.9	0.9	0.9	0.9	
350	1.0	1.0	1.0	1.0	1.1	1.0	
Hole 4	Average Thermistor Temperature Reading (°C)					Summary Average	
Depth (ft)	1994	1995	1996	1997	1998		
15	4.8	2.9	1.6	1.5	-1.0	2.0	2.0
90	1.8	1.7	1.8	1.7	1.7	1.7	2.7
165	2.8	2.7	2.8	2.8	2.8	2.8	
240	3.9	3.8	3.7	3.5	3.3	3.6	
Hole 5	Average Thermistor Temperature Reading (°C)					Summary Average	
Depth (ft)	1994	1995	1996	1997	1998		
20	3.8	1.5	0.6	0.6	-0.2	1.3	1.3
75	0.3	0.3	0.4	0.3	0.3	0.3	0.8
130	0.4	0.3	0.3	0.3	0.3	0.3	
185	0.5	0.5	0.5	0.5	0.5	0.5	
240	0.8	0.8	0.8	0.9	0.9	0.8	
295	1.1	1.1	1.1	1.1	1.2	1.1	
350	1.4	1.4	1.4	1.5	1.5	1.4	
Hole 6	Average Thermistor Temperature Reading (°C)					Summary Average	
Depth (ft)	1994	1995	1996	1997	1998		
15	3.7	2.6	2.8	1.6	0.1	2.2	2.2
70	1.4	1.3	1.4	1.3	1.2	1.3	1.1
125	1.2	1.1	1.1	1.1	na	1.1	
180	0.9	0.9	0.9	0.9	0.9	0.9	
235	0.9	0.9	1.0	1.0	1.0	1.0	
290	1.1	1.0	1.1	1.1	1.1	1.1	
345	1.1	1.1	1.2	1.1	1.2	1.1	
400	1.3	1.3	1.3	1.3	1.4	1.3	

na - not available

Table 8
Arsenic Thermistor Data - Overall Average Temperatures

Hole 1		Hole 2		Hole 3	
Depth (ft)	Temp (°C)	Depth (ft)	Temp (°C)	Depth (ft)	Temp (°C)
20.00	0.33	20.00	2.52	20.00	2.33
75.00	0.34	75.00	1.83	75.00	1.17
130.00	0.42	130.00	1.33	130.00	1.05
185.00	0.49	185.00	1.06	185.00	0.88
240.00	0.60	240.00	0.90	240.00	0.81
295.00	0.70	295.00	0.84	295.00	0.88
350.00	0.81	350.00	0.82	350.00	1.01
Hole 4		**Hole 5**		**Hole 6**	
Depth (ft)	Temp (°C)	Depth (ft)	Temp (°C)	Depth (ft)	Temp (°C)
15.00	2.25	20.00	1.09	15.00	2.41
90.00	1.74	75.00	0.31	70.00	1.33
165.00	2.77	130.00	0.33	125.00	1.13
240.00	3.64	185.00	0.49	180.00	0.91
		240.00	0.85	235.00	0.97
		295.00	1.12	290.00	1.07
		350.00	1.44	345.00	1.14
				400.00	1.31

1st Level		2nd Level	
Hole	Temp. (°C)	Hole	Temp. (°C)
1	0.38	1	0.70
2	1.33	2	0.84
3	1.05	3	0.88
4	2.77	4	-
5	0.32	5	0.99
6	1.02	6	1.11

Table 9

Arsenic Thermistor Average Temperature Readings for Each Depth Range

All Holes		Thermistor Temperature Reading (°C)						
Depth (ft)		*15-20*	*70-90*	*125-130*	*165-185*	*235-240*	*290-295*	*345-400*
1994	Jun-94	0.5	1.2	0.8	1.0	1.2	0.7	0.9
	Jul-94	1.6	1.2	0.8	1.0	1.2	0.7	0.8
	Aug-94	3.6	1.0	0.7	1.2	1.3	0.9	1.1
	Sep-94	4.5	1.1	0.9	1.1	1.3	0.9	1.1
	Oct-94	4.2	0.8	0.9	1.1	1.3	0.9	1.1
	Nov-94	3.4	1.1	0.8	1.1	1.3	0.9	1.1
	Dec-94	2.2	1.0	0.8	1.0	1.2	0.7	0.8
1995	Jan-95	1.4	1.1	0.8	1.1	1.3	0.9	1.1
	Feb-95	0.3	0.9	0.6	1.0	1.2	0.7	0.9
	Mar-95	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Apr-95	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	May-95	-0.3	1.1	0.8	1.1	1.3	0.9	1.1
	Jun-95	1.9	0.8	0.5	0.8	0.9	0.4	0.5
	Jul-95	1.1	0.6	0.6	0.5	0.5	0.7	0.7
	Aug-95	3.7	1.1	0.8	1.1	1.3	0.9	1.1
	Sep-95	4.3	1.1	0.8	1.1	1.3	0.9	1.1
	Oct-95	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nov-95	1.6	0.8	0.6	0.9	1.1	0.7	0.9
	Dec-95	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	Jan-96	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Feb-96	-0.5	0.8	0.4	0.8	1.0	0.5	0.5
	Mar-96	-1.0	0.8	0.4	0.8	1.0	0.5	0.5
	Apr-96	-1.2	1.0	0.6	0.9	1.2	0.7	0.7
	May-96	-1.0	1.2	0.8	1.1	1.3	0.9	1.1
	Jun-96	0.0	0.9	0.5	0.9	0.4	0.8	1.0
	Jul-96	1.3	0.9	0.6	0.9	1.2	0.8	0.9
	Aug-96	2.4	0.9	0.6	0.9	1.2	0.8	0.9
	Sep-96	2.6	0.8	0.6	0.9	1.2	0.8	0.9
	Oct-96	2.8	0.8	0.6	0.9	1.2	0.8	1.0
	Nov-96	2.1	0.8	0.6	0.9	1.2	0.8	1.0
	Dec-96	1.3	0.8	0.6	0.9	1.2	0.8	1.0
1997	Jan-97	0.4	0.8	0.6	0.9	1.2	0.8	0.9
	Feb-97	-0.5	0.8	0.6	0.9	1.2	0.8	1.0
	Mar-97	-1.2	0.8	0.6	0.9	1.2	0.8	1.0
	Apr-97	-1.5	0.9	0.6	0.9	1.2	0.8	1.0
	May-97	-1.0	0.8	0.5	0.9	1.0	0.5	0.9
	Jun-97	0.1	0.6	0.4	0.8	1.0	0.5	0.6
	Jul-97	1.4	0.8	0.4	0.9	1.1	0.8	1.0
	Aug-97	2.5	0.8	0.4	0.9	1.1	0.8	1.0
	Sep-97	2.7	0.8	0.4	0.9	1.1	0.8	1.0
	Oct-97	2.3	0.8	0.4	0.9	1.1	0.8	1.0
	Nov-97	1.5	0.8	0.4	0.9	1.1	0.8	1.0
	Dec-97	0.8	0.8	0.4	0.8	0.9	0.7	1.0
98	Jan-98	0.1	0.8	0.4	0.9	1.0	0.8	1.0
9	Feb-98	-0.4	0.8	0.4	0.9	1.1	0.8	1.0

Table 10

Arsenic Thermistor Average Temperature Readings by Month for Each Hole Sorted by Depth

Hole 1		Hole 1		Hole 1		Hole 1	
20ft	Avg.	*75ft*		*130ft*	Avg.	*185ft*	Avg.
Jan	0.4	Jan	0.3	Jan	0.4	Jan	0.5
Feb	0.2	Feb	0.3	Feb	0.4	Feb	0.5
Mar	0.0	Mar	0.4	Mar	0.4	Mar	0.5
Apr	0.0	Apr	0.4	Apr	0.5	Apr	0.5
May	-0.1	May	0.4	May	0.4	May	0.5
Jun	-0.1	Jun	0.4	Jun	0.5	Jun	0.5
Jul	0.0	Jul	0.4	Jul	0.4	Jul	0.5
Aug	0.1	Aug	0.4	Aug	0.4	Aug	0.5
Sep	0.3	Sep	0.3	Sep	0.4	Sep	0.5
Oct	0.9	Oct	0.3	Oct	0.4	Oct	0.5
Nov	1.2	Nov	0.3	Nov	0.4	Nov	0.5
Dec	0.8	Dec	0.3	Dec	0.4	Dec	0.5

Hole 1		Hole 1		Hole 1	
240ft	Avg.	*295ft*	Avg.	*350ft*	Avg.
Jan	0.6	Jan	0.7	Jan	0.8
Feb	0.6	Feb	0.7	Feb	0.8
Mar	0.6	Mar	0.7	Mar	0.8
Apr	0.6	Apr	0.7	Apr	0.8
May	0.6	May	0.7	May	0.8
Jun	0.6	Jun	0.7	Jun	0.8
Jul	0.6	Jul	0.7	Jul	0.8
Aug	0.6	Aug	0.7	Aug	0.8
Sep	0.6	Sep	0.7	Sep	0.8
Oct	0.6	Oct	0.7	Oct	0.8
Nov	0.6	Nov	0.7	Nov	0.8
Dec	0.6	Dec	0.7	Dec	0.8

Table 11

Arsenic Thermistor Average Temperature Readings by Month for Each Hole Sorted by Depth

Hole 2		Hole 2		Hole 2		Hole 2	
20ft	Avg.	*75ft*	Avg.	*130ft*	Avg.	*185ft*	Avg.
Jan	3.0	Jan	1.7	Jan	1.3	Jan	1.1
Feb	1.6	Feb	1.9	Feb	1.3	Feb	1.1
Mar	0.5	Mar	2.0	Mar	1.3	Mar	1.0
Apr	0.1	Apr	2.0	Apr	1.3	Apr	1.0
May	0.3	May	1.9	May	1.3	May	1.1
Jun	1.3	Jun	1.9	Jun	1.4	Jun	1.1
Jul	2.0	Jul	1.8	Jul	1.4	Jul	1.1
Aug	3.7	Aug	1.9	Aug	1.4	Aug	1.1
Sep	5.0	Sep	1.8	Sep	1.4	Sep	1.1
Oct	5.5	Oct	0.0	Oct	1.4	Oct	1.1
Nov	4.9	Nov	1.7	Nov	1.3	Nov	1.1
Dec	4.0	Dec	1.7	Dec	1.3	Dec	1.1

Hole 2		Hole 2		Hole 2	
240ft	Avg.	*295ft*	Avg.	*350ft*	Avg.
Jan	0.9	Jan	0.8	Jan	0.8
Feb	0.9	Feb	0.9	Feb	0.8
Mar	0.9	Mar	0.9	Mar	0.8
Apr	0.9	Apr	0.9	Apr	0.8
May	0.9	May	0.9	May	0.8
Jun	0.9	Jun	0.9	Jun	0.9
Jul	0.9	Jul	0.9	Jul	0.9
Aug	0.9	Aug	0.9	Aug	0.9
Sep	0.9	Sep	0.8	Sep	0.8
Oct	0.9	Oct	0.9	Oct	0.8
Nov	0.9	Nov	0.8	Nov	0.8
Dec	0.9	Dec	0.8	Dec	0.8

Table 12
Arsenic Thermistor Average Temperature Readings by Month for Each Hole Sorted by Depth

Hole 3		Hole 3		Hole 3		Hole 3	
20ft	Avg.	*75ft*	Avg.	*130ft*	Avg.	*185ft*	Avg.
Jan	1.6	Jan	1.2	Jan	1.1	Jan	0.8
Feb	0.0	Feb	1.1	Feb	1.1	Feb	0.9
Mar	0.0	Mar	1.2	Mar	1.1	Mar	0.9
Apr	-0.5	Apr	1.2	Apr	1.1	Apr	0.9
May	0.5	May	1.2	May	1.0	May	0.9
Jun	0.4	Jun	1.2	Jun	1.0	Jun	0.9
Jul	1.9	Jul	1.2	Jul	1.0	Jul	0.9
Aug	3.1	Aug	1.1	Aug	1.0	Aug	0.9
Sep	4.0	Sep	1.2	Sep	1.0	Sep	0.9
Oct	4.1	Oct	1.2	Oct	1.1	Oct	0.9
Nov	3.6	Nov	1.2	Nov	1.1	Nov	0.9
Dec	2.8	Dec	1.2	Dec	1.1	Dec	0.9

Hole 3		Hole 3		Hole 3	
240ft	Avg.	*295ft*	Avg.	*350ft*	Avg.
Jan	0.8	Jan	0.9	Jan	1.0
Feb	0.8	Feb	0.9	Feb	1.0
Mar	0.8	Mar	0.9	Mar	1.0
Apr	0.8	Apr	0.9	Apr	1.1
May	0.8	May	0.9	May	1.0
Jun	0.8	Jun	0.9	Jun	1.0
Jul	0.8	Jul	0.9	Jul	1.0
Aug	0.8	Aug	0.9	Aug	1.0
Sep	0.8	Sep	0.9	Sep	1.0
Oct	0.8	Oct	0.9	Oct	1.0
Nov	0.8	Nov	0.9	Nov	1.0
Dec	0.8	Dec	0.9	Dec	1.0

Hole 4		Hole 4		Hole 4		Hole 4	
15ft	Avg.	*90ft*	Avg.	*165ft*	Avg.	*240ft*	Avg.
Jan	0.1	Jan	1.7	Jan	2.8	Jan	3.6
Feb	-1.9	Feb	1.7	Feb	2.8	Feb	3.6
Mar	-3.9	Mar	1.8	Mar	2.8	Mar	3.7
Apr	-4.3	Apr	1.8	Apr	2.8	Apr	3.7
May	-1.9	May	1.8	May	2.8	May	3.7
Jun	2.5	Jun	1.9	Jun	2.7	Jun	3.7
Jul	4.4	Jul	1.8	Jul	2.8	Jul	3.7
Aug	7.2	Aug	1.8	Aug	2.8	Aug	3.7
Sep	7.2	Sep	1.7	Sep	2.7	Sep	3.7
Oct	5.7	Oct	1.7	Oct	2.8	Oct	3.7
Nov	3.2	Nov	1.7	Nov	2.8	Nov	3.7
Dec	2.1	Dec	1.7	Dec	2.8	Dec	3.6

Table 13
Arsenic Thermistor Average Temperature Readings by Month for Each Hole Sorted by Depth

Hole 5		Hole 5		Hole 5		Hole 5	
20ft	Avg.	*75ft*	Avg.	*130ft*	Avg.	*185ft*	Avg.
Jan	0.6	Jan	0.3	Jan	0.3	Jan	0.5
Feb	-0.7	Feb	0.3	Feb	0.3	Feb	0.5
Mar	-2.2	Mar	0.4	Mar	0.3	Mar	0.5
Apr	-2.6	Apr	0.4	Apr	0.4	Apr	0.5
May	-2.0	May	0.4	May	0.3	May	0.5
Jun	-1.1	Jun	0.4	Jun	0.3	Jun	0.5
Jul	1.4	Jul	0.3	Jul	0.3	Jul	0.5
Aug	3.0	Aug	0.4	Aug	0.3	Aug	0.5
Sep	3.7	Sep	0.3	Sep	0.4	Sep	0.5
Oct	3.8	Oct	0.3	Oct	0.4	Oct	0.5
Nov	2.9	Nov	0.3	Nov	0.3	Nov	0.5
Dec	1.7	Dec	0.3	Dec	0.4	Dec	0.5

Hole 5		Hole 5		Hole 5	
240ft	Avg.	*295ft*	Avg.	*350ft*	Avg.
Jan	0.9	Jan	1.1	Jan	1.4
Feb	0.9	Feb	1.1	Feb	1.5
Mar	0.9	Mar	1.1	Mar	1.5
Apr	0.9	Apr	1.2	Apr	1.5
May	0.8	May	1.1	May	1.4
Jun	0.9	Jun	1.1	Jun	1.5
Jul	0.8	Jul	1.1	Jul	1.4
Aug	0.8	Aug	1.1	Aug	1.4
Sep	0.8	Sep	1.1	Sep	1.4
Oct	0.9	Oct	1.1	Oct	1.4
Nov	0.9	Nov	1.1	Nov	1.4
Dec	0.9	Dec	1.2	Dec	1.5

Table 14

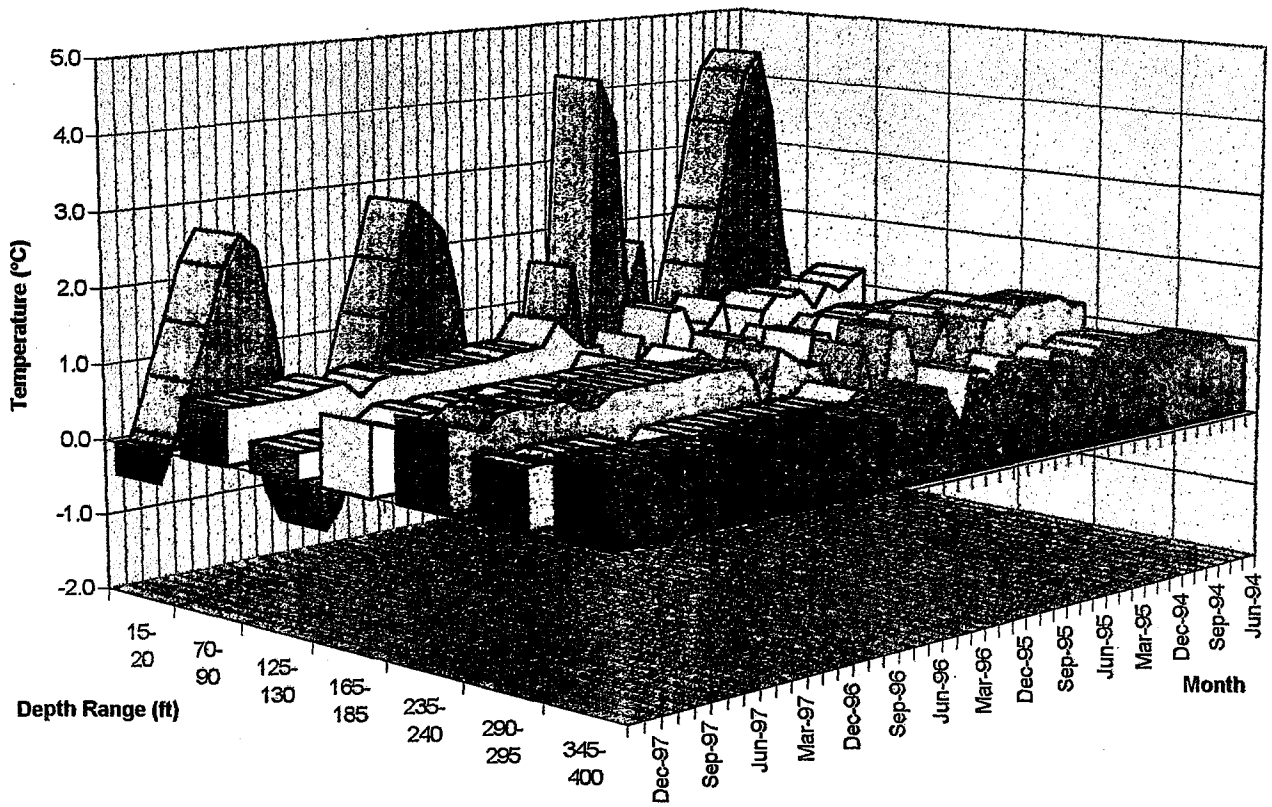
Arsenic Thermistor Average Temperature Readings by Month for Each Hole Sorted by Depth

Hole 6		Hole 6		Hole 6		Hole 6	
15ft	Avg.	*70ft*	Avg.	*125ft*	Avg.	*180ft*	Avg.
Jan	-1.1	Jan	1.3	Jan	1.2	Jan	0.9
Feb	0.0	Feb	1.3	Feb	1.1	Feb	0.9
Mar	-1.3	Mar	1.4	Mar	1.1	Mar	0.9
Apr	-1.9	Apr	1.4	Apr	1.1	Apr	0.9
May	-0.9	May	1.4	May	1.1	May	0.9
Jun	1.3	Jun	1.4	Jun	1.1	Jun	0.9
Jul	2.4	Jul	1.4	Jul	1.2	Jul	0.9
Aug	4.5	Aug	1.4	Aug	1.1	Aug	0.9
Sep	5.3	Sep	1.3	Sep	1.1	Sep	0.9
Oct	5.0	Oct	1.3	Oct	1.2	Oct	0.9
Nov	3.6	Nov	1.3	Nov	1.1	Nov	0.9
Dec	2.3	Dec	1.3	Dec	1.2	Dec	0.9

Hole 6		Hole 6		Hole 6		Hole 6	
235ft	Avg.	*290ft*	Avg.	*345ft*	Avg.	*400ft*	Avg.
Jan	1.0	Jan	1.1	Jan	1.1	Jan	1.3
Feb	1.0	Feb	1.1	Feb	1.2	Feb	1.4
Mar	1.0	Mar	1.1	Mar	1.2	Mar	1.3
Apr	1.0	Apr	1.1	Apr	1.1	Apr	1.3
May	1.0	May	1.1	May	1.1	May	1.3
Jun	1.0	Jun	1.1	Jun	1.2	Jun	1.3
Jul	1.0	Jul	1.1	Jul	1.1	Jul	1.2
Aug	1.0	Aug	1.1	Aug	1.1	Aug	1.3
Sep	1.0	Sep	1.1	Sep	1.1	Sep	1.3
Oct	1.0	Oct	1.1	Oct	1.2	Oct	1.3
Nov	1.0	Nov	1.1	Nov	1.2	Nov	1.3
Dec	1.0	Dec	1.0	Dec	1.2	Dec	1.3

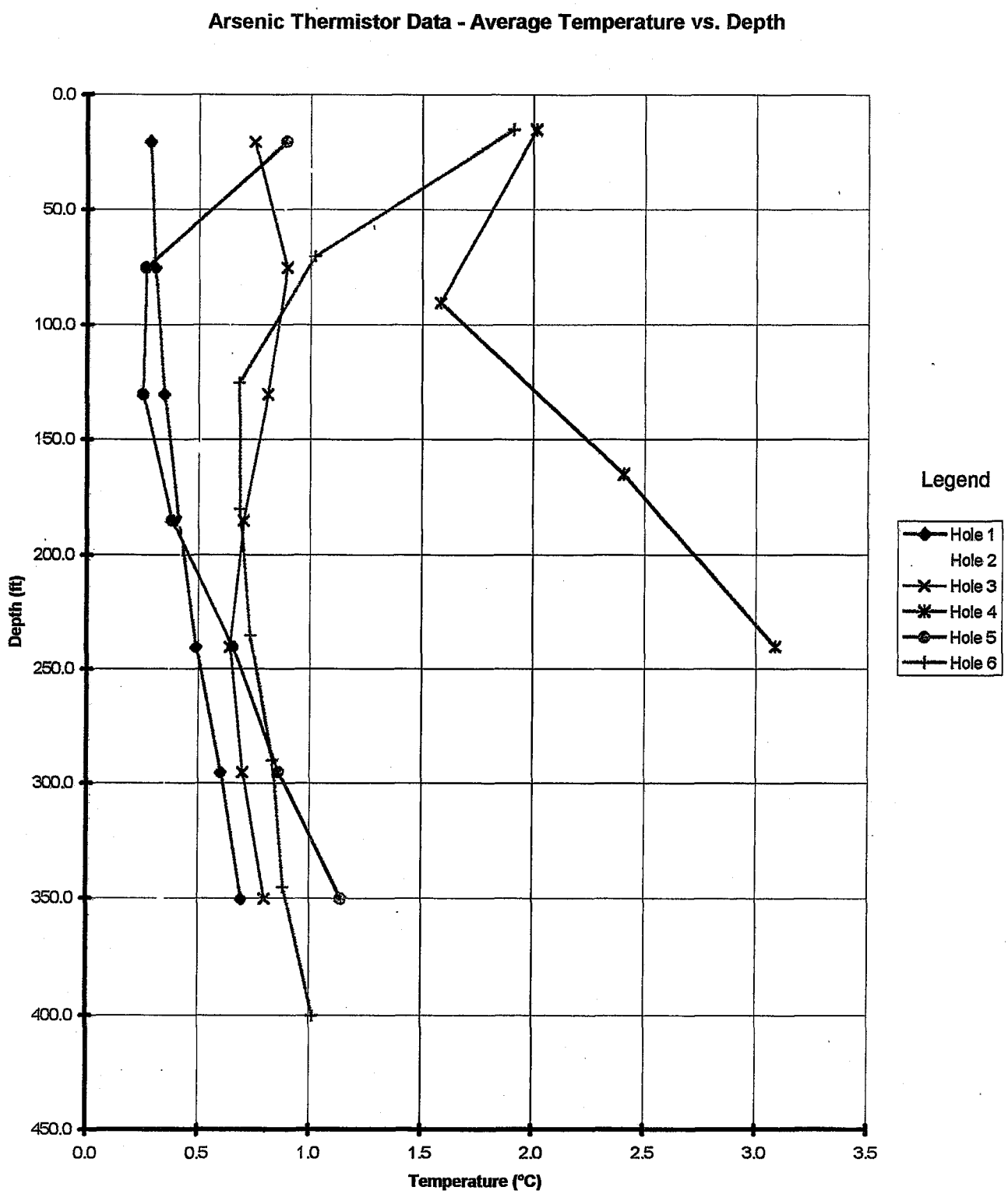
Figure 1

Arsenic Thermistor Data - Average Temperature Variation by Depth Range



Note: Gaps or breaks that appear in this chart represent missing data points.

Figure 2


Arsenic Thermistor Data - Average Temperature vs. Depth
Depth (ft)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Temperature (°C)
Legend
Hole 1
Hole 2
Hole 3
Hole 4
Hole 5
Hole 6

Appendix III

Mine Level Plans

Giant Mine

Mine Levels: 100 level
250 level
425 level
575 level

Royal Oak Mines Inc.

Appendix IV

Typical Mine Geology Sections

Giant Mine

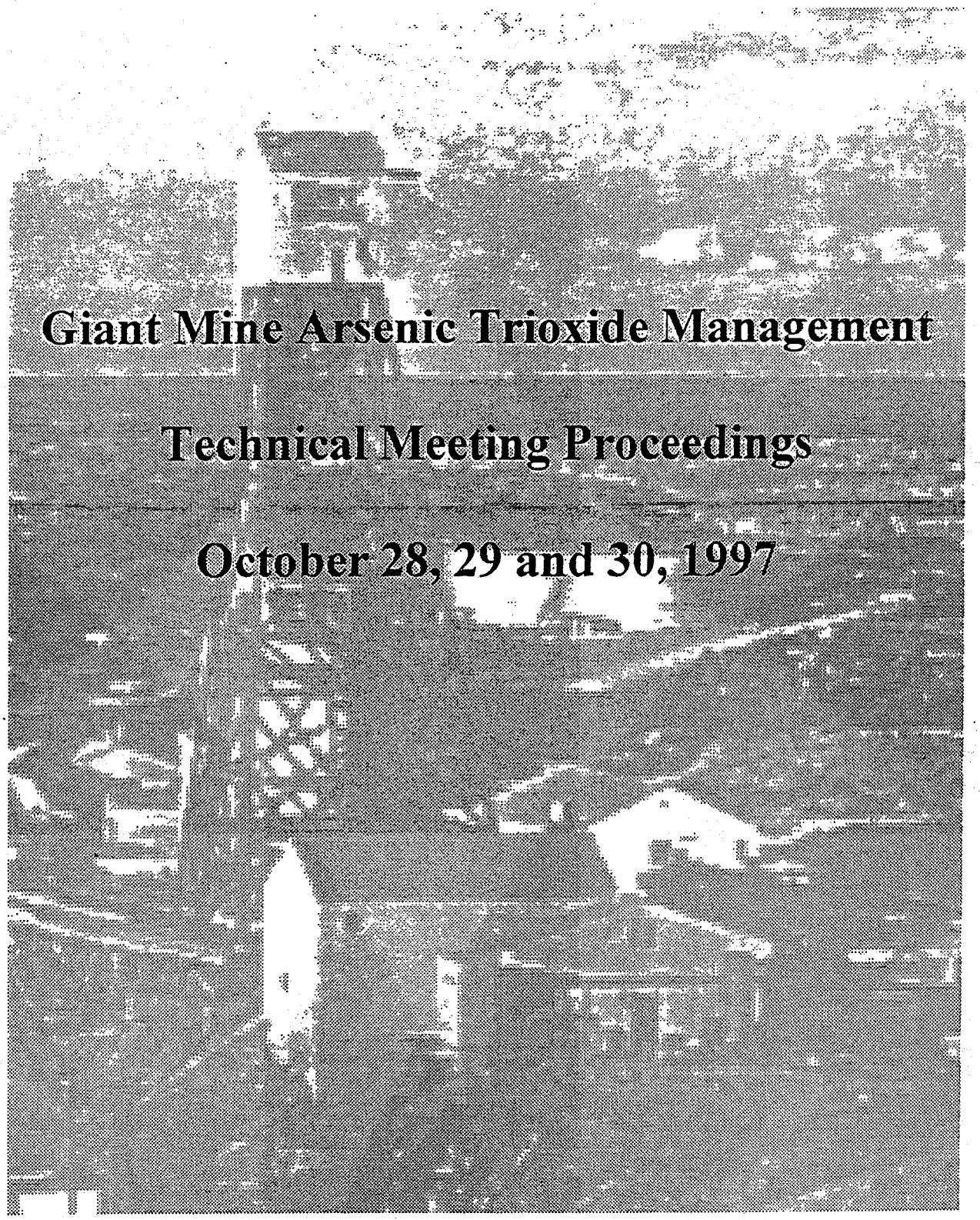
Royal Oak Mines Inc.

Appendix V

Giant Mine - Arsenic Trioxide Management
October 28, 29 and 30th, 1997

Technical Meeting Proceedings

Royal Oak
Mines Inc.



Giant Mine Arsenic Trioxide Management

Technical Meeting Proceedings

October 28, 29 and 30, 1997

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Appendix I Technical Meeting Presentations - Day 1
Appendix II Technical Meeting Presentations - Day 2

1.0 INTRODUCTION

Royal Oak's Giant Mine in Yellowknife, NT processes refractory ores using roaster technology to facilitate gold removal. After 50 years of mine operation, approximately 260,000 tons of dust has accumulated as a by-product of the roasting process. On average, approximately 78% by mass (200,000 tons) of this material is arsenic trioxide (As_2O_3). In addition, approximately 137,000 ounces of gold are contained in the dust by-product.

Arsenic trioxide is a slightly soluble compound that has known toxic and carcinogenic properties and must be carefully managed. There is a general public perception that the continued storage (either short or long term) of arsenic trioxide underground is not an acceptable practice. This is due, in part, to growing environmental and public health awareness and to a series of unknowns that result from insufficient knowledge of technical factors such as the hydrology if the mine is flooded, vault seepage (currently and if the mine is flooded), permafrost conditions and the long term stability of the underground storage vaults.

Giant Mine's current water license expires on April 30, 1998 and a component of this licence requirement involves the management of and ultimate disposal strategies for the arsenic trioxide dust stored underground. Royal Oak Mines has recently submitted their application for renewal of the license under the Northwest Territory Waters Act (NWTWA). The Department of Indian Affairs and Northern Development (DIAND), as the regulator authority (RA), is currently assessing the application. Other regulatory agencies will be involved in the review process.

To assist in the review of the licence application, a background report on current management options was developed. The Water Resources Division of DIAND retained Dillon Consulting Limited to produce this report entitled "*Arsenic Trioxide Management Feasibility Study*", October 1997.

As a further step in the licencing process DIAND in conjunction with other federal government agencies, the territorial government, the City of Yellowknife and Royal Oak Mines held a Technical Meeting to review and discuss the technical aspects of potential management options for the arsenic trioxide stored underground. Technical experts, selected in part from information provided in the Dillon report, were identified and invited to provide a strong knowledge and experience base for discussing the feasibility of arsenic trioxide management options (See **Table 1**: List of Attendees). Technical presentations were given by Royal Oak staff, environmental consultants, academics, health and safety experts, government regulators and personnel from the mining industry who have previously implemented arsenic trioxide management strategies. Presentation and discussion topics related to arsenic trioxide included the history, production and storage at Giant Mine, the high purity arsenic trioxide market, the environmental and health risks, methods for moving and handling the dust, methods of purifying the dust, methods of stabilizing the dust to reduce the environmental impact, processing the gold in the dust and case studies outlining the experience of other groups in managing the material.

TABLE 1
Attendance List

Royal Oak Mines Inc.	
NWT Division	John Stard, Mine Manager Stephen Schultz, Environmental Manager Kent Morton, Mill Superintendent
Corporate Office	Rick Allan, Manager - Mining Projects
Technical Experts	Sue Lendrum, Senior Project Geologist Serena Domville, Manager - Environmental Services, Beacon Hill Consultants (1988) Ltd. David Donison, Projects Manager - Graham Mining Ltd. Holger Krutzelmann, Senior Metallurgist - Autoclave Technology, Non-Ferrous, Hatch Associates Ltd. Terry Pepper, Vice President - Technical Development, Highwood Resources Ltd. Tony Willacy, Manager, Westmar Consulting
Environment Canada	
Yellowknife	Ed Collins, Chief - Environmental Engineering Steve Harbicht, Chief - Assessment/Monitoring
National Hydrology Research Institute	Dr. John Gibson, NSERC Visiting Scientist
Government of the Northwest Territories	
Renewable, Wildlife and Economic Development	Lisa Dyer, Environmental Impact Analyst, Environmental Protection Service
Municipal and Community Affairs	Terry Brooks, Director Community Operations
Health and Social Services	Frank Hamilton, Environmental Health Consultant Dr. Sylvain Chouinard, Specialist Internal Medicine
Workers Compensation Board - Mines	Sylvester Wong, Chief Inspector of Mines Peter Bengts, Inspector Mines and Mining Engineering
Yellowknife Health and Social Services	Brad Colpitts, Senior Environmental Health Officer
City of Yellowknife	Adrian Bader, Manager Public Works

Department of Indian and Northern Development	
Water Resources Division	David Livingston, Director Renewable Resources and Environment David Milburn, Manager - Water Resources Division, Renewable Resources and Environment Jim McCaul, Head - Regulatory Approvals Neill Thompson, Pollution Control Specialist Shannon Pagotto, Regional Coordinator - Water Resources Division, Renewable Resources and Environment
Minerals	Dave Nutter, Director - Mineral Resources, NWT Division
Environment and Conservation	Rob Walker, Environmental Scientist
Department of .. Fisheries and Oceans	Maria Healy, Habitat Biologist
University of British Columbia	Dr. Bill Cullen, Professor of Chemistry
University of Alabama	Dr. Martin Bakker, Associate Professor of Chemistry
Weber State University	Dr. Jack Adams, Director - Center for Bioremediation
EMR Microwave Technology Corporation	Dr. J.M. Tranquilla, President, CEO, Director
Ministry of Environment and Energy	John Barr, Supervisor/Coordinator - District Projects, Kenora Office, Northern Region
Atomic Energy Canada Ltd.	Dr. Gary Thorne, Section Head - Hydrology, Applied Geoscience
Miramar Con Mine	Cary Johnson, Mill Shift Supervisor Mike Borden, Senior Engineer
Barrick Gold Ltd, El Indio Mine, Chile	Luis Wilson, Plant Manager

1.1 Objective

The meeting was organized in a spirit of cooperation between Royal Oak Mines and DIAND to address an issue of common importance. It provided a venue for government agencies to develop a sound technical understanding, through presentations on technical management alternatives and related discussion, of viable options for the ultimate management of arsenic trioxide byproduct at Royal Oak's Giant mine site in Yellowknife. Further it provided an opportunity for Royal Oak Mines to develop an understanding of the concerns and issues related to the management options.

1.2 Scope

The meeting was carried out over a period of three consecutive days. Day 1 and Day 2 provided historical background and technical information to be used as a basis for assessing the various management strategies. Day 3 provided the opportunity for the issues to be discussed within smaller, more focused, technical groups. The meeting agenda for the three days is provided below:

TECHNICAL MEETING AGENDA

Day 1, October 28, 1997:

08:20	**Introduction** Craig Thomas, Dillon Consulting Limited Neill Thompson, WRD-DIAND
08:45	**Giant Mine History and Current Practices** Rick Allan (Project Manager), John Stard (Mine Manager), Kent Morton (Mine Operations) Royal Oak Mines
09:30	**What is Arsenic Trioxide and What are its Effects?** Serena Domvile, forms and chemistry of arsenic, environment and health; Dr. Bill Cullen, arsenic and the environment Dr. Sylvain Chouinard, health effects of arsenic
11:00	**Mine Facility Brief and Tours** Rick Allan, Royal Oak Mines; 3 tour groups to be formed of 8-10 people. 1. Surface tour - general plant and mine facilities. 2. Mill tour - process tour from crushing to roaster to baghouse. 3. Underground tour - storage facilities.
15:30	**Meeting Venue Shift to Royal Oak Guest Lodge** Light snacks and refreshments provided
16:30	**The Economics of Arsenic Trioxide.** Sue Lendrum, Royal Oak Mines
17:45	**Day 1 Summary and Closure** Craig Thomas, Dillon Consulting Limited

Day 2, October 29, 1997:

08:15	**Opening Comments, Day 2 Agenda and Introductions** Dave Clark, Dillon Consulting Limited
08:30	**Regulatory Overview** Dave Clark, Dillon Consulting Limited; Water Licence Laurie Bruce, Dillon Consulting Limited; CEAA
09:15	**Underground Storage of Arsenic Trioxide** Rick Allan, Royal Oak; Overview, history and storage rationale.
10:00	**Transport and Handling of Arsenic Trioxide.** Dave Donison, Royal Oak; Underground removal methods. Tony Willacy, Westmar Consulting; Surface handling.
11:00	**Material Processing/Upgrading as an Economic Commodity** Terry Pepper, Highwood Resources Kent Morton, Royal Oak
12:45	**Material Processing/Stabilization/Neutralization as an Uneconomic Waste** Dr. J.M. Tranquilla - EMR Microwave Technology Dr. Martin G. Bakker, University of Alabama, Zeolite-Hydraulic Cement Dr. Jack Adams, Centre for Bioremediation, Weber State University
15:30	**Case Studies** John Barr, MOEE regulatory experience Holger Krutzelmann, Hatch Consulting Luis Wilson, El Indio Cary Johnson, Miramar Con Mine Dr. Gary Thorne, AECL
17:30	**Day 2 Summary** Dave Clark, Dillon Consulting Limited
18:30	**Informal Discussion and Social** Explorer Hotel Hospitality Suite

Day 3, October 30, 1997:

08:30	**Opening Comments and Day 2 Review** Dave Clark, Dillon Consulting Limited
08:45	**Working Group Sessions** Group facilitators from Dillon Consulting 3 working group discussions to identify the issues and concerns i.e., underground storage, environmental impact, process, economics and viable management options.
10:30	**Meeting Group Session** Facilitators reports and total meeting group discussions to determine main management options and issues.
13:00	**Working Group Sessions** Group facilitators from Dillon Consulting 3 working group discussions based on task assigned issues from morning sessions and development of recommendations based on assigned management options or issues.
14:45	**Meeting Group Session** Facilitators reports and total meeting group discussions to determine main management options and issues.
15:30	**Technical Meeting Conclusions/Recommendations** Dave Clark, Dillon Consulting Limited; Open Session Discussions
16:45	**Closing Comments** David Livingstone, DIAND

General Meeting Proceedings

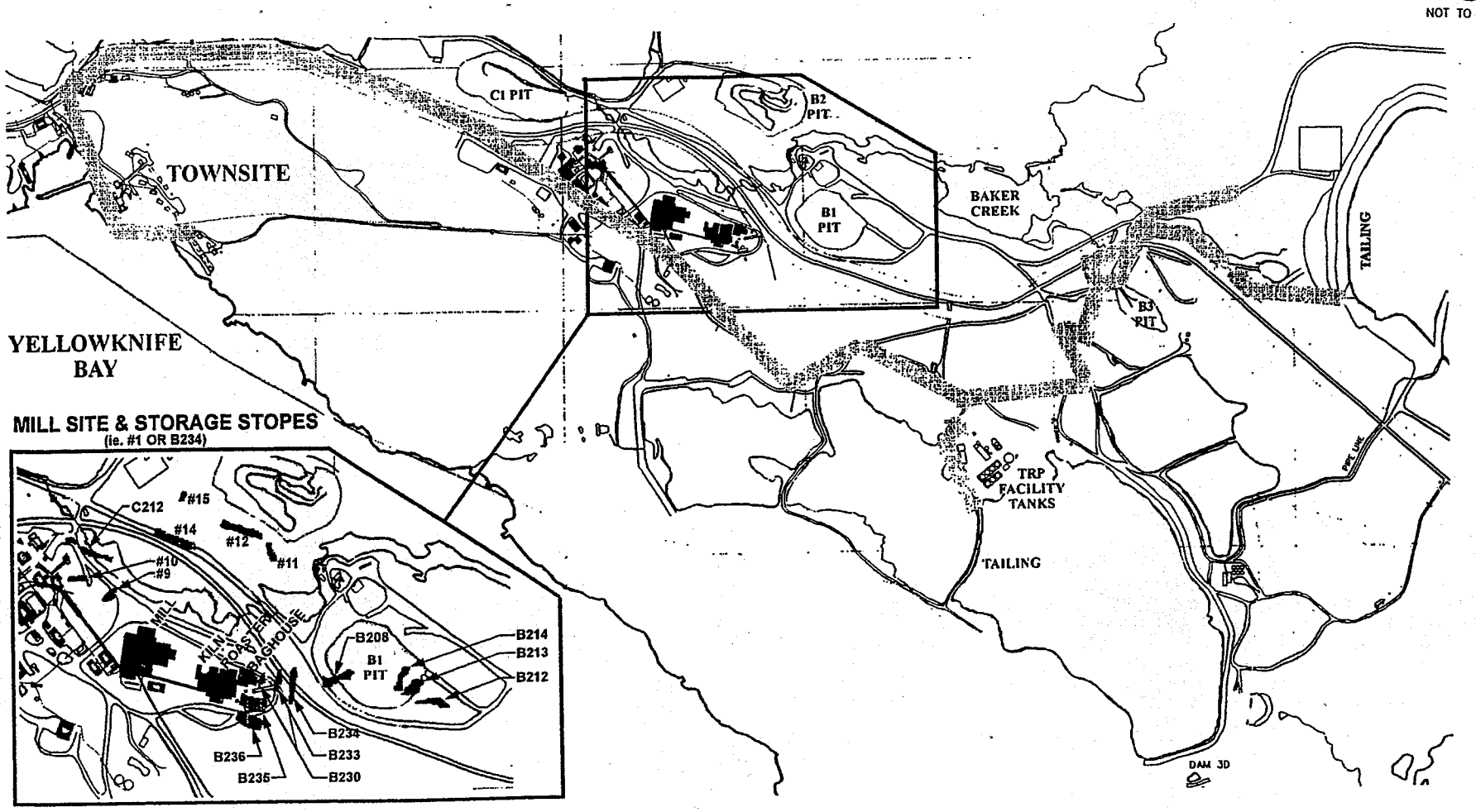
Day 1 provided a history of the Giant Mine and information on the current mine operations through tours of the surface facilities (Figure 1), the mill workings and the underground arsenic trioxide storage vaults (Figure 1). Presentations were given on the environmental and health effects of arsenic trioxide and on the current market conditions for arsenic trioxide.

Day 2 was used to provide the attendees with specific technical information on the underground storage of arsenic trioxide, the transport and handling of arsenic trioxide from underground to the surface and on the surface, methods for upgrading the baghouse dust to a salable purity level, options for converting the arsenic trioxide into a more stable disposable form and five case studies detailing the experience of others in handling arsenic trioxide waste material.

On the morning of Day 3 the attendees were divided into three groups to discuss the arsenic trioxide situation at the mine in a general manner. The results of each subgroup's discussions were presented to the group as a whole and were used to help form a basis for the afternoon's discussions. In the afternoon a group was formed to discuss each of three individual issues: the continued storage of

arsenic trioxide underground at Giant, removing the arsenic trioxide dust to surface for treatment and possible options for treating the dust for sale or disposal. The results of these discussions were presented to the group as a whole.

During the last session, an attempt was made to generally assess the feasibility of management options using both a common criteria that formed the framework of discussion and other criteria identified within each group through discussion. A ranking of options (i.e. high, medium or low) was given by participants based on technical discussions and input from the meeting sessions technical experts.



DILLON CONSULTING	GIANT MINE ARSENIC TRIOXIDE MANAGEMENT	97-4724
		NOV 97
	SITE LOCATION PLAN	FIG 1

2.0 TECHNICAL MEETING

2.1 Day 1 Proceedings

2.1.2 Giant Mine History and Current Practices

Giant Mine currently produces 10-13 tons per day of arsenic trioxide containing dust from it's gold roasting process. The dust is pneumatically conveyed to an underground vault, at a depth of 75 to 250 feet, for storage. Including the vault currently being filled (B14), there are 15 stopes containing arsenic trioxide dust. Five of the containment locations are former production stopes and are irregular in shape. The remainder were constructed for the purpose of storing the trioxide and have a more regular rectangular shape. The dust contains an average of 78% arsenic trioxide by mass and an average of 0.5 ounces of gold per ton.

Giant has approximately 6 months of storage remaining in vault B14. Construction of vault B15 has been put on hold pending implementation of a new management strategy for the arsenic trioxide by product.

Giant Mine History and Current Practices
Presenter- Rick Allan, Manager - Mining Projects

Personal Information

Richard Allan graduated with a B.Sc. Mining Engineering from Queen's University, in 1978. He joined Royal Oak in 1991 as Chief Engineer at Giant and progressed to Technical Services Manager for the NWT, then transferred to Corporate Office in 1995 to head a team responsible for development of new mining projects. His background includes mine operations experience at Eldorado Nuclear, Canada Tungsten, and Barrick Gold (Holt-McDermott Mine).

Presentation Abstract

A review of the history of Giant Mine and underground storage of arsenic trioxide was presented, including the rationale behind the decision to place the material underground. The individual storage chambers were identified, along with the inventory of stored material and its composition.

An overview of conditions in the area of the chambers was given to establish some of the extraction parameters.

Royal Oak's short and long term strategy for storage and final disposition of the material were described.

See **Appendix I** for presentation notes.

Giant Mine History and Current Practices
Presenter- Kent Morton, Mill Superintendent

Personal Information

Kent Morton has been involved in mill operations in base metals, potash and gold for nearly thirty years. He has been at the Giant mine for a little over a year as mill superintendent. Previous to this posting he was site manager at Golden Bear mine, a gold roasting and heap leach operation in Northern B.C.

He has worked at Giant on two previous occasions, seven years as mill superintendent and five years working as project superintendent and sat on the Technical Advisory committee to the NWT Water Board during these periods. He has been involved with various arsenic studies over the years and was instrumental in developing the WAROX purification process in the late 1980's.

Presentation Abstract

The current milling practices at Royal Oak's Giant Mine were explained and flow diagrams were provided.

See **Appendix I** for presentation notes.

2.1.2 Arsenic Trioxide Environmental and Health Effects

Arsenic is a naturally occurring element, commonly found in gold and base metal ores. In it's naturally occurring state, arsenic is relatively insoluble and does not generally pose a large health risk. Endogenous arsenic compounds tend to have a higher solubility and pose a correspondingly greater risk to human and environmental health. The arsenic trioxide produced at Giant Mine is highly soluble. In humans arsenic shows skin toxicity (dermatosis, keratoses), neurological toxicity (peripheral neuropathy), liver toxicity (enzyme inhibition), cardiovascular toxicity (peripheral vascular disease), hematopoietic toxicity (disturbed erythropoiesis), respiratory toxicity (perforation of the nasal septum) and carcinogenesis (skin, liver, lung and lymphoid cancers). Arsenic is considered a carcinogen at levels in excess of 500 ppb in water.

Environmentally arsenic has been shown to produce changes in phytoplankton communities, histopathological changes in fish populations and produces teratogenic, carcinogenic, mutagenic, cellular and enzymatic effects in terrestrial animals.

Forms and Chemistry of Arsenic and it's Effects on the Environment and Human Health
Presenter- Serena Domville, Manager Environmental Services, Domvile and Associates

Personal Information

Serena Domvile is a consulting scientist (SJ Domvile & Associates) specializing in the monitoring, minimization and management of arsenical waste streams produced at mining operations through hydrometallurgical and pyrometallurgical processes. In support of programs for monitoring worker

and environmental risks, she has installed systems to speciate arsenic present in biological, process and environmental media at mine sites in Canada, USA and South America. She holds numerous patents in the reprocessing and treatment of arsenical mine wastes.

Presentation Abstract

An overview was given of the human and environmental risks associated with arsenic and the status of technology to address them. The typical sources and routes of arsenic exposure to worker and affected community populations and the role of engineering controls and hygiene practices in minimizing the potential for exposure were described. The behavior and toxicological effects of different arsenical species were compared and methods for monitoring these species outlined. The behavior of arsenic in disposal and receiving environments and the options for minimizing its mobility and/or bioavailabiltiy to receptors was discussed.

See **Appendix I** for presentation notes.

Health Effects of Arsenic
Presenter- Dr. Sylvain Chouinard, M.D. Internal Medicine Specialist

Personal Information

Dr. Chouinard is a specialist in internal medicine with over 10 years experience working in the Yellowknife region. He has had toxicological training in environmental contaminants and has had a great interest in environmental factors and their health effects for the last 30 years. He is the Chairman of the Environmental Committee of the NWT Medical Association.

Presentation Abstract

The acute and chronic health effects of arsenic exposure were discussed.

See **Appendix I** for presentation notes.

Arsenic and the Environment
Presenter- Dr. W.R. Cullen, Department of Chemistry, University of British Columbia

Personal Information

Dr. Bill Cullen was born in Dunedin, New Zealand. He attended Otago Boys' High School and the University of Otago (B.Sc., M.Sc. with Dr. G.A. Bottomley) before moving to Cambridge University (Ph.D. with Professor H.J. Emèleus). He was appointed to the faculty of the Chemistry Department at the University of British Columbia, Vancouver, in 1958, where he has remained, apart from time spent visiting universities in Europe and Australia. He is a member of the American Chemical Society, a Fellow of the Chemical Institute of Canada and a Fellow of the Royal Society of Canada. His current research interests involve many aspects of the biogeochemistry of arsenic and antimony, the microbial degradation of PAH's and other organic contaminants, and the development of analytical methodology for the identification of metabolites. He is chair of the Environmental Chemistry Group at UBC and associate editor of *Applied Organometallic Chemistry.*

Presentation Abstract

The environmental chemistry of arsenic was presented with consideration given to: the abundance and occurrence of arsenic, the affinity of arsenic for sulfur, the biological methylation of arsenic, the toxicological properties of arsenic, arsenic species in the terrestrial environment, arsenic in the marine environment and the biological demethylation of arsenic.

See **Appendix I** for presentation notes.

2.1.3 Economic Factors

Arsenic trioxide accounts for 97% of world arsenic production. It is primarily produced as a byproduct of refractory ore treatment processes. In 1996, 18 countries produced a total of 46,305 tons of arsenic trioxide. The U.S. accounts for approximately 2/3 of world arsenic demand. 90% of the arsenic trioxide imported into the U.S. is used by the wood preservatives industry, which is comprised of three main companies: Hickson Corp., Conley, GA; CSI, Harrisburg, NC and Osmose Corp., Memphis, TN. The price for arsenic varies with purity, and in 1996 was listed as 0.33 U.S.$/pound for Mexican product. The current stockpile at Giant could supply world demand for 4-5 years, making marketing a sensitive undertaking.

The Economics of Arsenic Trioxide
Presenter- Sue Lendrum, Senior Project Geologist, Royal Oak Mine

Personal Information

Sue Lendrum graduated from Queen's University in 1983 (Applied B.Sc. in Geological Engineering) and from McGill University in 1993 (Applied M.Sc. in Mineral Exploration). since 1989 she has worked with royal Oak Mines Inc. in both production and exploration.

Presentation Abstract

A review of historic, current and projected market conditions (supply, demand, sources, uses, prices) for arsenic trioxide and the wood preservatives, and their implications with respect to the possible extraction and upgrading of the Giant Mine's baghouse dusts was provided.

See **Appendix I** for presentation notes.

2.1.4 Mine Site Tours

The tour consisted of three separate segments: surface, mill and underground storage vaults. The surface tours were led by John Stard and Stephen Schultz, the mill tours were led by Kent Morton and Brian Cross and the underground tours were led by Rick Allan and Denis Gratton all of Royal Oak Mines.

The surface tour provided an overview of the mine processing facilities and infrastructure. The tour

included a visit to the town site, the abandoned Tailings Retreatment Plant (TRP) which is a possible location for arsenic trioxide surface storage and a view of the water treatment facilities and tailings ponds. The entrance points and sealed piping inlets to a number of the arsenic storage vaults were also indicated.

The tour of the mill followed the path of the ore through it's various processing steps, starting with the grinding mills and ending at the baghouse where the arsenic trioxide dust is collected and fed to the pneumatic conveyance system.

The final leg of the tour went underground to observe three of the arsenic storage vaults. Vaults B208, 14 and partially completed vault 15 were visited. Vault 14 is currently in use and has about 6 months of capacity remaining based on a production rate of 10 - 13 tons/day. Vault B208 is older, and was filled in the 1950's and 60's. It appeared to be frozen, with ice visible on the walls of the access tunnel. Vault 15 is partially completed. Development of this vault has been put on hold pending the decision on which management option Royal Oak will use.

2.2 Day 2 Proceedings

2.2.1 Regulatory Considerations

Management options involving construction of new process plants requires environmental revue under the Canadian Environmental Assessment Act (CEAA). This may be a screening completed by the RA, or a comprehensive study. If the project is deemed to have an effect on the environment including effect of change on: health and socio-economic conditions physical and cultural heritage; current us of lands and resources for traditional purposes by aboriginal persons; structures or sites of significance; the land, water and air; organic and inorganic matter and living organisms and interacting natural systems a comprehensive study may be required.

Giant Mine Water Licence
Presenter- Dave Clark, Managing Partner Dillon Consulting Limited, Vancouver

Personal Information

Dave Clark is a Partner of Dillon and is manager of our Vancouver regional office. He holds a Master's degree in Environmental engineering and has over 20 years of experience in the assessment of environmental impacts and environmental audits. Dave has been Project Manager on a number of large, multi-disciplined environmental assessment projects that have required approval under federal and provincial environmental guidelines and legislation. He has a sound working knowledge of federal, provincial, territorial and municipal environmental legislation in the Northwest Territories, Western Canada and Ontario.

Presentation Abstract

The regulatory issues pertaining to the water licence renewal at Royal Oak's Giant Mine were discussed.

Canadian Environmental Assessment Act
Presenter- Laurie Bruce, Senior Environmental Planning, Dillon Consulting Limited

Personal information

Laurie Bruce has worked in the environmental field for over fourteen years. Her experience as an environmental planner includes the project management and co-ordination of numerous multi-disciplinary environmental assessments under the Environmental assessment and Review Process (E.A.R.P.), the Canadian Environmental assessment Act (CEAA) and the Ontario Environmental Assessment Act (OEAA). These environmental assessments have been for waste management projects, harbor remediation programs, bridges, municipal infrastructure, Defense Canada initiatives, dredging activities, water control structures and marina developments.

Presentation Abstract

An outline of the Canadian Environmental Assessment Act was provided, specifically: the purpose of the act, the applicability of the act, types of studies, requirements of studies, process and implications for the management of Giant Mine's arsenic trioxide.

See **Appendix II** for presentation notes.

2.2.2 Underground Storage

The arsenic trioxide dust is currently stored in 15 underground storage chambers. The sixteenth of these chambers is currently under construction. Five of the chambers are former production stopes and the remainder were developed for the purpose of storing the arsenic trioxide waste. The design of the chambers considers the following criteria: the chambers are developed in permafrost, the openings are bulkheaded in accordance with the mine safety act, the storage areas are excavated in competent rock and the area is dry before arsenic trioxide storage proceeds.

Currently, the material in the vaults has a density ranging from 41.6 to 91.1 lb/cu. ft (666 to 1460 kg/m^3) and a moisture content of <1 to 6.4%. The material tends to be more moist on the bottom (with the exception of vault B2-34). The area around vaults B208, B233 and B234 has been sealed off with concrete plugs and conditions around B212, B213 and B214 may make access to these vaults difficult.

Thermistors have been installed at five locations on the mine site at depths of 23 to 107 meters. The temperatures at these locations and depths ranged between +0.3 to +3.7°C (May 1996 data), indicating the absence of permafrost in the area. It has been speculated that mining activity may have disturbed the permafrost, but temperatures from a control point 610m south of the mine also indicate temperatures above 0°C to a depth of 122m.

Giant Mine History and Current Practices
Presenter- Rick Allan, Manager Mining Projects, Royal Oak Mines

Personal Information

Richard Allan graduated with a B.Sc. Mining Engineering from Queen's University, in 1978. He joined Royal Oak in 1991 as Chief Engineer at Giant and progressed to Technical Services Manager for the NWT, then transferred to Corporate Office in 1995 to head a team responsible for development of new mining projects. His background includes mine operations experience at Eldorado Nuclear, Canada Tungsten, and Barrick Gold (Holt-McDermott Mine).

Presentation Abstract

A review of the current state of the underground storage chambers was presented, including a brief assessment of the accessibility of the various locations.

See **Appendix I** for presentation notes. (Giant Mine History and Current Practices)

2.2.3 Transport and Handling of Arsenic Trioxide

The physical characteristics of the dust stored in the stopes varies from dry and dusty (like processed flour) to damp and compacted depending on the length of time it has been stored and the stope environment. From a handling perspective there are several factors complicating dust removal. The dust is toxic/carcinogenic, prone to become airborne and not soluble enough in water to make dissolution a viable removal option. The challenges to be overcome in removing the dust to the surface include confining the dust (i.e. preventing air, water or soil contamination during movement), minimizing worker exposure (i.e. use of personal protective equipment, remote control operations, etc.), using proven technology, applying removal methods to variable stope geometries and material characteristics and cleaning/securing the storage chambers for abandonment. It is probable that a combination of methods will be required to remove the material to the surface. Technologies under consideration which could meet the desired 75 tonne/day removal rate currently include: vacuuming, slurry pumping, remote "clam" mining and drawpoint mucking.

If a decision is made to treat arsenic trioxide for purification or stabilization purposes, there will be a need for surface transportation and storage facilities. Surface transportation could be via truck or using an upgraded (more powerful) pneumatic system similar to what is currently being used. Surface storage could be carried out in number of ways. The material could be stored in drums or bags, in existing decommissioned TRP storage tanks (80% usable capacity) or in a facility constructed specifically for the purpose. Storage in bags or drums is potentially cheaper in the short term, but may result in a hazardous material disposal problem once they are emptied. Construction of a new facility is potentially expensive, therefore modifying the existing TRP tanks (adding sealed roof, developing add-on materials access technology) may be the most economically attractive option. The tanks were not designed to be under stress during cold temperatures, and steel testing is underway to determine their mechanical and chemical (corrosion tests) suitability for arsenic trioxide storage.

Transferring the arsenic trioxide into the storage tanks was not anticipated to be technically difficult. Any process to remove the material from the tanks would encounter difficulties similar to those encountered during removal of the material to surface and is considered more technically challenging. Several options are being explored, including rotating screw conveyors, articulated vacuum arms and

telescoping vacuum arms. As with the removal to surface, a combination of technologies will probably be required to transport and store the material safely on the surface.

Underground Removal Methods
Presenter- Dave Donison, Projects Manager

Personal Information

Dave Donison is a 1985 mining engineering graduate from Laurentian University in Sudbury, Ontario. He has had a range of production and engineering assignments both in Canada and abroad working for various mining companies and mining contractors/consulting engineers. Until recently, he was employed with Royal Oak Mines Ltd. in various capacities including General Manager at the Hope Brook Mine in Newfoundland and as Senior Engineer with the Projects Development Group. He is presently employed as Projects Manager overseeing various mine development projects in Eastern Canada with the mine contracting, project management and engineering firm, Graham Mining Ltd.

Presentation Abstract

Arsenic trioxide dust is a byproduct of milling activities at the Giant Mine in Yellowknife. It has been stored underground at Giant since the mid-1950's in specially excavated chambers or in completed/abandoned stops.

The dust ranges in characteristics from dry, dusty material (similar to processed flour) to damp, slightly compacted material, depending on the length of time it has been in storage as well as the local environment.

Presently, consideration is being given to removing or "mining " the dust from the underground storage chambers to surface for reprocessing. A summary of the various methods being examined for the removal of this dust was presented including a brief description of the evaluations required to advance these methods from the conceptual to operating stage.

See **Appendix II** for presentation notes.

Surface Handling of Arsenic Trioxide
Presenter- Tony Willacy, Manager, Westmar Consulting Inc.

Personal Information

Mr. Willacy has over 30 years extensive and diverse experience in project management, engineering and plant management in the consulting engineering, oil sand, primary aluminum and steel industries. In March 1996 he joined Westmar Consultants Inc., a firm specializing in the planning and design of bulk materials handling systems and civil and structural design engineering. He has worked on projects involving the handling of materials such as alumina oxide, oil sands, limestone, ores, sand and clay overburden, lead and zinc concentrates and coal.

Presentation Abstract

The materials handling characteristics of the material were described. Concepts for handling the material on surface in specific relation to the Giant property were presented. Optional storage techniques were outlined, along with progress to date in developing these options as viable alternatives.

See **Appendix II** for presentation notes.

2.2.4 Material Processing/Upgrading for an Economic End Use

Before the arsenic trioxide can be successfully sold on the open market, it must be processed to 99+% purity with contaminant concentrations in the range of 0.05-0.30% Sb, 0.025-0.3% Fe and 0.001-0.1% Cu. There are several methods available to achieve these levels.

The arsenic trioxide can be evaporated at a temperature of around 193°C while the impurities remain as solids until temperatures in excess of 1000°C. The purified arsenic can then be condensed out in brick cooling chambers, air-cooled condensers or using a cold air quench.

In the late 1980's, work on a variation of the evaporation method was begun at Giant Mine (WAROX filter). A sintered metal filter was used to remove impurities from the arsenic trioxide vapor exiting the baghouse. Difficulties were encountered meeting antimony and iron specifications, and the process was never fully developed.

An alternative to high temperature processing is dissolve the arsenic trioxide using a solvent which solubilizes the arsenic at a higher level than the impurities. The arsenic trioxide is then crystallized out in a purified form. Hot water, ammonia and methanol have all shown promise for use as solvents in this process. The wet processes allow greater flexibility in the methods used to remove the arsenic trioxide from the storage chambers.

All of these processes leave behind a residue which will probably contain some arsenic as well as the other contaminants, and consideration must be made for disposal of this material. There will also be a fairly high concentration of gold left in this residue. Recovery of the gold would contribute to the economic viability of marketing arsenic trioxide.

Processes for Treating Arsenic Trioxide Containing Baghouse Dust
Presenter- Terry Pepper, Vice President Technical Development, Highwood Resources

Personal Information

Mr. Pepper is a metallurgist with almost 30 years experience in research, development, production, technical support and remediation. He has a Professional Degree from the Colorado School of Mines and a Master's Degree from the University of Utah. He has worked fro Kennecott Copper Corporation, the Colorado School of Mines Research Institute, Texasgulf Inc., Unocal/Molycorp and is currently Vice-President of Technical Development for Highwood Resources Ltd. He has developed patented precesses for the recovery of copper, lead, zinc and silver from pyrite concentrates.

Presentation Abstract

Once the arsenic concentrate is recovered from the underground storage, the material may be treated to stabilize the arsenic for disposal or purified to allow sale to customers in the US. Three stabilization options are generally considered: limiting water penetration (cements polymers), limiting arsenic solubility (precipitation with iron in autoclave) and adsorption of dissolved arsenic (zeolite and flyash). Purification is carried out using the differential chemical, thermal and physical properties of arsenic and it's contaminants to achieve a separation of the materials. Current Royal Oak test work focusing on hydrometallurgical purification of the arsenic through either hot water or ammonium hydroxide leaching of the arsenic concentrate was discussed.

See Appendix II for presentation notes.

The Giant WAROX Process
Presenter- Kent Morton, Mill Supervisor Giant Mine

Personal Information

Kent Morton has been involved in mill operations in base metals, potash and gold for nearly thirty years. He has been at the Giant mine for a little over a year as mill superintendent. Previous to this posting he was site manager at Golden Bear mine, a gold roasting and heap leach operation in Northern B.C.

He has worked at Giant on two previous occasions, seven years as mill superintendent and five years working as project superintendent and sat on the Technical Advisory committee to the NWT Water Board during these periods. He has been involved with various arsenic studies over the years and was instrumental in developing the WAROX purification process in the late 1980's.

Presentation Abstract

The history of Giant's WAROX project was presented and the current developmental state of this process was discussed.

2.2.5 Arsenic Trioxide Stabilization

The relative uncertainty of the world arsenic trioxide market and the presence of arsenic in waste streams from any purification process may require development of a process to stabilize arsenic trioxide for long term storage. Arsenic trioxide can be converted to less soluble arsenic compounds such as ferric arsenate or arsenic sulfide using an autoclave, a microwave reactor or if the volumes were small enough using biological processes. The arsenic sulfide is considered stable on an indefinite basis if it can be kept under anaerobic conditions (i.e. covered in sufficient biomass) as it oxidizes and solubilizes in the presence of oxygen whereas the ferric arsenate does not require specific storage conditions.

The arsenic trioxide can also be encapsulated in a cement medium to increase its' stability. Use of Portland cement alone does not allow a very high loading rate (1% arsenic trioxide) but use of additives such as zeolite increases the capacity considerably and may provide a viable storage alternative. The exact methodology of the encapsulation process is not entirely known. X-ray diffraction studies suggest that the zeolite structure is retained (98% probable) and the arsenic trioxide

is contained in cavities in the open crystal structure of the zeolite. The cost of obtaining suitable natural zeolites can be high, but recent advances in synthetic zeolite manufacture may reduce this factor.

Drawbacks to stabilization methods are the cost of constructing treatment plants, the cost of additives (particularly zeolites) and the increased volume of material produced. Testing is underway to determine where gold recovery fits in to the stabilization options.

EMR Microwave Technology
Presenter- Dr. J.M. Tranquilla, President EMR Microwave Technology Inc.

Personal Information

James Tranquilla received the B.Sc.E (1971) and M.Sc.E. (1973) degrees in electrical engineering from the University of New Brunswick and the Ph.D. degree in electrical engineering from the University of Toronto in 1979. From 1979 to 1996 he was a Professor in the Electrical Engineering Department at the University of New Brunswick and head of the Radiating Systems Research Laboratory where his research interests included electromagnetic propagation, antennas, space based navigation systems, numerical modeling and microwave power applications. In 1987, Dr. Tranquilla founded EM Technologies Inc., a private company, to develop industrial microwave applications. This company became a public company, EMR Microwave Technology Corporation in 1995, where he is President and CEO. EMR has developed several applications of its' microwave technology in the mining and petroleum industries and is presently commercializing several of its' processes in the pretreatment of precious metal bearing ores.

Presentation Abstract

Options for using microwave technology to treat arsenic containing mine waste were discussed, with primary consideration given to conversion into a lower solubility product.

See **Appendix II** for presentation notes.

Zeolite - Hydraulic Cement Containment
Presenter- Dr. Martin G. Bakker, Associate Professor of Chemistry, University of Alabama

Personal Information

Dr. Bakker graduated with a B.Sc. in Chemistry (1st Class honors) in 1980 and a Ph.D. in Physical Chemistry in 1985 from Canterbury University, New Zealand. From 1986 to 1988 he was a Postdoctoral Fellow at the Australian Institute of Nuclear Science and Engineering, Sydney, Australia and The University of Western Australia, Perth, Australia (1986-1988), and as a member of the Radiation and Photochemistry Group, Chemistry Division, Argonne National Laboratory (1988-1990). He is currently an Associate and Assistant Professor in the Department of Chemistry at the University of Alabama.

Dr. Bakker's research experience has centered on the use of Spectroscopic Techniques, particularly Electron Paramagnetic Resonance (EPR), to study molecular structure and motion. EPR, NMR and other techniques have been applied to study:

1. The interaction of surfactants on particle surfaces,
2. Formation of radical cations in zeolite matrices,
3. Mechanism of action of a zeolite/cement medium for the stabilization of wastes containing arsenic and other inorganic pollutants,
4. Sheer flocculation of fine particles in the mining industry,
5. Charge transfer in conducting polymers,
6. Formation and reactions of sugar radicals.

Presentation Abstract

Between 1993 and 1995 the U.S. Bureau of Mines carried out a study of various methods for stabilizing arsenic containing mine waste. This work led to the development of a cement/zeolite containment media capable of stabilizing arsenic at levels well above that obtainable with cement only. Samples of arsenic containing waste from a copper smelter and from arsenic acid production were stabilized using the medium and successfully passed the TCLP leaching tests.

In the containment media the arsenic was believed to be present predominantly as arsenate ions. Work carried out at the University of Alabama focused on understanding why the zeolites, which contain sites where cations are bound to the zeolite, should act to contain the negative arsenate anions. Investigations have confirmed that the zeolite is neither decomposed, nor sealed in the basic cement medium, so that migration between the zeolite and the cement portions of the matrix appears possible.

Prior to the closure of the Bureau of Mines the U.S. patent had been applied for. This patent has been allowed, and the rights are held by the inventors of the process, as the U.S. government has no interest in developing the process further.

See **Appendix II** for presentation notes.

Bioremediation of Arsenic Containing Wastes
Presenter- Dr. Jack Adams, Director - Center for Bioremediation

Personal Information

Dr. Adams is currently the Director of the Center for Bioremediation at Weber State University, Ogden, UT. The Center was established to facilitate development, enhancement, and marketing of bioremediation and environmental restoration technologies based on microorganisms, biological materials, and enzyme components. The Center's focus is on metals, other inorganics, and metal-organic mixed contaminants. His education and research background is in molecular and applied environmental microbiology. He received my Ph.D. from Utah State University, Logan, UT in molecular environmental microbiology. Before his current position, he worked for the federal government in environmental biotechnology for 18+ years as an employee and consultant. Research and projects centered on factors affecting microbial environmental stability, modification of microbial attributes, and microbial function in the environment. In his two most recent positions prior to the Center for Bioremediation, the U.S. Bureau of Mines and U.S. Army, he was responsible for developing and evaluating technologies at bench-, pilot-, and field-scale. At the Bureau he headed the Biotechnology Program which developed and implemented technologies for metal and other inorganic remediation.

Presentation Abstract

The use of bioremediation technology to treat arsenic containing waste was discussed, with consideration given to converting the arsenic trioxide into a more stable sulfide product..

See **Appendix II** for arsenic treatment information.

2.2.6 Case Studies

A number of case studies were presented to provide information on past and present attempts at managing arsenic trioxide. Speakers talked about current regulatory practices, alternative pretreatment processes, current arsenic trioxide management at a Chilean gold mine, the results of the Con Mine's arsenic treatment plant and groundwater monitoring programs.

The Ministry of Environment and Energy is dealing with similar issues to those faced by regulators in the NWT with respect to arsenic trioxide produced by gold roasting operations. A number of regulations have been implemented to minimize the environmental impact associated with arsenic trioxide production and storage.

There are three refractory ore pretreatment methods in general usage: pressure oxidation, bio-oxidation and roasting. Pressure oxidation (autoclaving) and bio-oxidation produce relatively stable arsenic by products, ferric arsenate and arsenic sulfide respectively, that can be disposed of without further treatment. The cost of replacing the roasters at Giant with a pressure oxidation of bio-oxidation circuit would be very high.

Barrick's El Indio mine in Chile faces a similar arsenic trioxide problem to Royal Oak. Arsenic trioxide produced at the mine has been sold to Hickson, CSI and Codelco. Currently a quantity of lower grade arsenic trioxide is being kept in drums and large bags at a surface storage facility until a disposal method can be developed.

The Con Mine's experience began in the early 1980's after unsuccessful attempts at cement encapsulation that led the mine to develop a purification process. In 1983 a hot water leach process was developed to produce a 99+% arsenic trioxide crystal product. Worker safety was a major concern during operation of the treatment plant. Hygiene measures were taken every hour (e.g. showering and applying barrier creams), urine samples were taken daily and every action taken on the floor of the plant had to be pre-planned. Highly educated people were not required to operate the plant. Individuals who could "make a job their own" were found to be most successful and top operator wages were paid to each plant worker. "Incidental" contact due to non-conscious behavior (e.g. rubbing chin while thinking) was found to be the primary method of employee contamination.

Ultimately, the economics of the hot water leach process did not work out and an autoclave capable of processing 2 to 4 tons of feed per hour was installed to handle Con's refractory ore. The opinion was expressed that a hot water leach plant would be feasible if worker controls were implemented from the very beginning.

Any management option chosen for the Giant Mine scenario will require a comprehensive hydrogeological study to determine potential impacts on the environment due to arsenic trioxide entering the groundwater. AECL has done considerable research on groundwater monitoring at the Whiteshell Laboratories in Pinawa Manitoba.

MOEE Regulatory Experience
Presenter- John Barr, Supervisor/Coordinator District Projects, Northern Region

Presentation Abstract

The regulatory experience of the Ministry of Energy and the Environment (MOEE) in Ontario was presented. Reference was provided to gold mines operating in the Red Lake district of Ontario.

See **Appendix II** for presentation notes.

Gold Ore Processing Options
Presenter- Holger Krutzelmann, Senior Metallurgist, Hatch Associates

Personal Information

Mr. Krutzelmann has a B.Sc. Mining Engineering (Mineral Processing) from Queen's University, 1978. He has 22 years of operating and metallurgical experience in the mining industry in base metal, potash and gold operations in Canada, Greece, Indonesia and the USA. His positions have ranged from operator to superintendent and he was Chief Metallurgist in two plants utilizing pressure oxidation.

Presentation Abstract

A review of operating gold plants that process arsenopyrite for gold recovery was presented. A listing of these plants and relative operating and capital costs was provided along with a description of the arsenic residue management involved.

Various processing options were presented including roasting, pressure oxidation and others. Operating problems regarding arsenic residue were also discussed.

See **Appendix II** for presentation notes.

Barrick Gold's El Indio Mine
Presenter- Luis Wilson, Plant Manager

Personal Information

Mr. Luis J. Wilson was born in Chile where he obtained the Civil Metallurgist Engineer Degree (1969) at the University of Santiago, Chile. He worked in Chile in the mineral processing at Chuquicamata copper mine and as a metallurgical consultant for small mines process improvement. In Canada, Luis worked at Dow Chemical, Sarnia, Ontario and at Rabbit Lake Operations, Camenco Corporation. Presently, he is working as Plant Manager at El Indio Plant, Chile (Barrick Gold Corporation).

Presentation Abstract

The current operation conditions of the El Indio mine were presented, including the mine's strategy for handling arsenic trioxide containing dust.

Miramar Con Mine - Autoclave Operation
Presenter- Cary Johnson, Mill Shift Supervisor, Miramar Con Mine

Presentation Abstract

The current use of the autoclave at the Con mine was explained, and a history of Con's arsenic trioxide treatment program was given.

See **Appendix II** for presentation notes.

Groundwater Monitoring
Presenter- Dr. Gary Thorne, Section Head - Hydrology, Applied Geoscience, AECL.

Presentation Abstract

Current AECL practices and research regarding monitoring groundwater for contaminants were presented.

See **Appendix II** for presentation notes.

2.3 Day 3 Proceedings

2.3.1 Morning Session

The morning session provided the technical meeting group the opportunity to discuss the broad issues related to arsenic management. A framework of management options and questions was provided to assist in the initiation of further discussion. These are provided as follows:

Management Alternatives

1. Underground storage and maintenance of arsenic trioxide.
   (leave and dispose in place)

2. Transport and handling of arsenic trioxide to surface.
   (surface disposal)

3. Material processing/upgrading as an economic commodity.
   (disposal in part as a salable product)

4. Material processing/stabilization/neutralization as an uneconomic waste.
   (disposal as stabilized arsenic)

5. Any other alternatives.

Discussion Questions/Assessment Criteria

1. What are the technical difficulties to overcome? What are the potential solutions?

2. What further studies are needed to fully understand the technological feasibility of the management alternatives?

3. What are the potential environmental effects/benefits?
   (Environment is defined as more than the physical environment, i.e. socio-economic

4. What are the potential effects to Occupational Health & Safety (OH & S)?

5. What are potential ways to mitigate effects?

6. What are the risks and uncertainties?

7. Are the alternatives economically feasible?

The discussion break-up groups and results of their discussions were as follows:

Group 1:

Members:	Stephen Schultz	-	Royal Oak Mines Inc.
	Rick Allan	-	Royal Oak Mines Inc.
	Ed Collins	-	Environment Canada
	Denis Adams	-	GNWT, MACA
	Sylvester Wong	-	GNWT, WCB
	Adrian Bader	-	City of Yellowknife
	Jim McCaul	-	DIAND, WRD
	Dave Nutter	-	DIAND, Minerals
	Terry Pepper	-	Highwood Resources
	Dr. Jack Adams	-	Weber State University
	John Barr	-	MOEE, Ontario
	Cary Johnson	-	Miramar Con Mine
Facilitator:	Craig Thomas	-	Dillon Consulting Limited

Management Alternative

Underground
- leave & monitor storage (pumped out or flooded)
- move to deeper storage
- treat-in situ (stabilize?)
- provide large new underground area for disposal/storage
- add stabilizer either lime or ferric sulphate?
- regardless there will always be a requirement to manage the underground storage/disposal of remnant material not removed from other removal options
- consider developing preferential pathways for groundwater and relocate Baker Creek. (surface water interception) (maintaining drier state). This will require geotechnical, hydrologic, and hydrogeologic studies.

- insulate storage areas and freeze or create ice cap (frozen tailing) over storage areas to entrance and establish, re-establish? perma-frost.

Transport & Handling to surface

- any option must 1st consider worker safety
- how and where is the material to be moved ?
- Spill contingency planning is a key issue as well as material handling facilities.

How

- should make sure it is the shortest time/distance to end use (either processing for disposal or sale)
- no one technology will cover all material and various storage areas may require various technologies
- decision to process may trigger surface storage of all new production of arsenic concentrate.
- plant size will determine storage size (80 tons/day)
- will not be able to remove all dust material from underground storage.
- some level of decontamination will be required for the storage vaults?
- where does end residue go and how can we treat this in either the existing plant process or other new processes

Material Processing/Upgrading to Economic Use

Most likely options

- WAROX Process Options - must be tested further and proven beyond the pilot plant work.
- hot water process - baseline and test work has been done but to go further the process must be improved from historic and pilot work. Both Miramar Con and Giant have experience.
- ammonia process is feasible with much more test work required to include identification of process to deal with waste ammonia by-product. These processes exist but must be identified.

Material Processing to an Uneconomic Use/Waste

Stabilization

- all result in low arsenic residue which will result in other management requirements for disposal.
- reduced volume of material
- arsenic removal processing may influence gold recovery technique
- market instability will likely influence processing/stabilization decision
- where and how do you dispose of end product?

Bulk Material (260,000 tons)

- Autoclave 1.1:1 - requirements iron, sulphur, lime, and oxygen
  - bench scale and pilot projects exist from Con's experience but not at Giant
  - proven technically, economics for Giant a big question??

- what possibilities are there for joint venture with Miramar Con - this should be considered
- calcium arsenate - produce and isolate from atmospheric CO_2
- production of ferric arsenate through non-autoclave technology
- Microwave technology

Other Alternatives

- pay to have material (as is) taken away by a processor - potential liability problems with end waste and transportation/handling.
- pay to have material disposed of (product and residue)
- 100% surface storage/maintenance (monitoring) - increases the ability to properly monitor and provide feasible contingency and spill response plans.
- look for mine with perma frost for disposal/storage however liability would be great and it is just a transfer of the problem to another location

Two Issues to be resolved
- product underground
- product produced daily

To deal with the two issues must determine how do you manage risks of each issue. (looking at all questions?) Risk assessments must be completed to move forward.

Group 2:

Members:	John Stard	-	Royal Oak Mines Inc.
	David Donison	-	Graham Mining Ltd.
	Serena Domville	-	Beacon Hill Consultants Ltd.
	Lisa Dyer	-	GNWT, EPS
	Dr. Sylvain Chouinard	-	Stanton Medical Clinic
	Brad Colpitts	-	YK Health & Social Services
	Neill Thomson	-	DIAND, WRD
	Shannon Pagotto	-	DIAND, WRD
	Maria Healy	-	DFO
	Dr. Bill Cullen	-	University of B.C.
	Holger Krutzelmann	-	Hatch Consulting
	Dr. John Gibson	-	NHRI
	Luis Wilson	-	El Indio Mine
Facilitator:	Dave Clark	-	Dillon Consulting Ltd (Van)

Discussion

- Removal from U/G
- Hydrology - uncertain
- Safety is primary issue
- Money is secondary (recovery)
- Manage the residue
- All options must have a contingency

Action/Issues

- Markets (stability)
- Plants needed (2 years + 3)
- Recovery of Gold - viable (in part)

Issues/Criteria

1. Human Health Risk (strive towards 0 exposure)
   - Worker
   - Population @ large
2. Ecological Risk
3. Public Perception
   - Relations/Management/Education
4. Time Scale & Change
   - To Implement
   - global warming
   - durability
5. Approvability with existing/anticipated regulations (National/International)
6. Availability
7. Technical Feasibility
8. Economic
9. Liability - Residual
   - Future Liability/Responsibility
10. Inherent Risk
11. Existing Expertise
12. Status of Confidence in Technology/Science/Market
    - Proven?
    - Stable?
13. Monitor - ability
    - Contingency/ability to respond
14. Flexibility for future modification/expansion
15. Ability to initiate contingency
16. Exporting our problems?
17. Ease of implementation
18. Ability to integrate with other MGT. options
19. Changing attitudes within other jurisdictions
20. Simplicity

Options

1. Leave U/G with risk Mgt./ Assessments & maintenance (Medium <20 years/ Long +20 years)
   a) With:
      - (refreeze)
      - (Hydrogeo)
      - (in situ treatment)
2. No more dust to go U/G → 0 production - EMR
   - Bio Ox
   - Autoclave

(or)

Ongoing generation → Treatment - Upgrade
- Improved production process
- Ferric arsenate

→ Market
→ Disposal (all) or (residual)

3. Remove to surface with risk assessment/risk management (RA/RM)
Middle Man??

Commodity value → Market (as is)
Gold
→ Market (after upgrade)
→ Disposal - with treatment
- with out treatment
→ Process Gold - Replace U/G
- treat residual & dispose U/G ?

No market value

4. Remove to surface (with RA/RM)
- stabilization/encapsulation
  - biomass/pond
- Dispose
  - @ surface
  - U/G

Group 3:

Members:	Kent Morton	-	Royal Oak Mines Inc.
	Sue Lendrum	-	Royal Oak Mines Inc.
	Steve Harbicht	-	Environment Canada
	Frank Hamilton	-	GNWT, H&SS
	Peter Bengts	-	GNWT, WCB
	David Livingston	-	DIAND, WRD
	Neill Thompson	-	DIAND, WRD
	Rob Walker	-	DIAND, E&C
	Tony Willacy	-	Westmar Resources
	Dr. J.M. Tranquilla	-	EMR Microwave Technology Corp.
	Dr. Gary Thorne	-	Atomic Energy Canada Limited
	Mike Borden	-	Miramar Con Mine
Facilitator:	Gary Strong	-	Dillon Consulting Limited

1. Underground Storage and Maintenance of Arsenic Trioxide (leave and dispose in-place)

- Temporary in beginning
- Integrity of Rock & Bulkheads - leave as is
- Public Perception - take it out
  a) Leave and Pump forever, treat seepage.
  b) (Re)establish Permafrost.

c) Barrier - grout curtain, etc.
d) relocate to an Engineered U/G Facility.

2. Transport and Handling of Arsenic Trioxide to Surface (surface disposal)
   a) Tankage
   b) Concrete vault
   c) Drainage - controls
   d) Lined pond c/w biomass

3. Material Processing/Upgrading as an Economic Commodity (disposal, in part, as a saleable product)
   a) currently usable
   b) still a short term storage issue
   c) Need back up plan if no market
      - Saleable Product is Gold
      - Environmental Liability
4. Material Processing/Stabilization/Neutralization as an Uneconomic Waste (disposal as stabilized arsenic)
   a) Ferric - Autoclave - no feed
      - EMR - need raw feed
   b) Zeolite - Back fill - paste
   c) Disposal into tails
   - Can we recover Gold? YES
5. Any other Alternatives
   a) Process U/G
   b) Fuse in situ
   c) Treat in vaults, by injection? (polymers)

   Unproven Technologies
   - Handling concerns
   - Containment process

Technical Difficulties

Underground

1. Make sure it stays Dry, Forever.
   - Not Possible
2. Public Perception
   - Education
   - Fix problem
3. Monitoring System
   - Can be achieved if all As_2O_3 is in single area
4. What if As levels start to go up overtime?
5. Water migration to location where treatment difficult, what then?
6. Seismic Activity
   - potential? can studies provide any assurances?
7. Change in Mine stability after closure
   - Eng. guess
8. Legal liability after closure
   - fix problem

9. Pumping forever not an option
   → Groundwater is important

10. Residuals, must be dealt with
11. Production of by products over time

Transport

1. Handling
   - Robotics
2. Excavation
   - Top down
   - Sublimate?
3. OH&S
4. How much removal? What percentage can be achieved?
   How clean is clean?
5. What happens to stope after?
   - some will be mined (OH&S)
6. Waste barrels and bags in some of the stopes
7. Contingency plans

Upgrade to Saleable Product

1. Identify all final products
2. Storage/disposal of byproducts
3. Transport to market
4. Instability of market
5. Pretreatment
   - filtration
   - grinding, drying

Unsalable Waste

1. Technical Certainty unknown
   (Proven?)
2. Economics
3. Same transport problems as saleable
4. Public perception of Yellowknife public
   (How safe is Safe?)
5. Storage location/system
6. Feed stock
7. Use of Con's Autoclave
8. Production Rate

Future Studies

1. Handling
2. Pilot Base studies using As_2O_3 in processes
3. Will zeolite work?
   ↑ As_2O_3 in tail paste backfill
4. Water movement underground. Assume flooded conditions.
   - To ensure transport

Environment Considerations
Water Quality
Air Emissions
Dust
Fish
OH&S
- Immediate contact
- Indirect contact
- Failure modes

Other Considerations
- political
- public
- legal
- time line to completion
- other jurisdictions

Plenary:

A plenary group discussion followed the individual group workshop. At this session the results of each small group's meeting were presented for open discussion. Comments and ideas put forth in this session were used to prepare a format for the afternoon technical group meeting and the groups came to some agreement as to the main issues and management alternatives to further explore.

2.3.2 Afternoon Session

The afternoon group discussions focused on three topics decided upon in the morning plenary:
- the storage of arsenic trioxide underground
- the transport and handling of arsenic trioxide to/on the surface
- options for treating the arsenic trioxide for sale or disposal.

Each topic provided the basis of discussion for one of the three individual break-out groups. The groups were formed based on technical expertise and relevant regulatory requirements. Each group attempted to assess the various management options based on the following common criteria discussed during the morning sessions. Table 2.0, found at the end of this section provides a summary of the group assessments.

Discussion Issues and Assessment Criteria

1. Human Health:
   a. Occupational Health and Safety (OH&S)
   b. Effects on the general population
2. Environmental/Ecological Risk
   - The effect on the larger environment was to be considered (i.e. socio-economic)
3. Public Perception/Education Requirements
4. Regulatory Concerns:
   a. Approvability/Acceptance of the option
   b. National/International regulations

c. Current/Future regulatory trends
d. Requirements

5. Technical Feasibility
   a. Simplicity of the option
   b. The ability to install the technology
   c. The possibility of short term implementation
   d. The current state of development of the technology
   e. Available contingency plans for option failure
   f. Research and development requirements to bring the technology on-line
   g. Unknowns
6. Liability
   a. To the company
   b. To the Crown
   c. To 3rd parties
   d. Future/long term liabilities
7. Economics/Cost

The results of these group discussion sessions and group compositions follow. A summary of the results of each group's assessments are presented in Table 2: Feasibility of Management Options, following this Section of the report.

Group 1: Arsenic Trioxide Underground

Members:	Rick Allan	-	Royal Oak Mines Inc.
	Sue Lendrum	-	Royal Oak Mines Inc.
	Steve Harbicht	-	Environment Canada
	Frank Hamilton	-	GNWT, H&SS
	Dr. Sylvain Chouinard	-	Stanton Medical Clinic
	Sylvester Wong	-	GNWT, WCB
	David Livingston	-	DIAND, WRD
	Jim McCaul	-	DIAND, WRD
	John Barr	-	MOEE, Ontario
	Dr. Gary Thorne	-	Atomic Energy Canada Limited
	John Gibson	-	NHRI
Facilitator:	Gary Strong	-	Dillon Consulting Limited

Discussions based on Economics

3) As Is - Pumping

- $40/ton vault development for next ton of dust
- +15% operations and maintenance (O&M)

  Pumping - can/was calculated ± $250,000 / year
  - water quality unknown possible treatment ?? $

- studies - Hydro Geo Study

- monitoring wells development based on $150,000
- interp of G/W movement annual $35,000
- Recharge/infiltration
- water chemistry
- isotope
- 3.D mapping - $0
- water balance - $200,000
  - Required even if As_2O_3 removed
- MET - 1 time
- Consultant - annual $50,000
- effects of shafts, drifts, etc
- risk assessment
- failure assessment

Public Education

- front end - $10,000 + cost of each presentation or open house
- form public advisory committees

Legal Implications / Challenges

- dollar ($) value unknown and could be very high

4) As Is - No Pumping

- larger study - ecological risk assessment
- legal problems

In Situ Treatment

- Unknown

New Location

- cost of development & all other sites

(Re)freeze / Barrier (Grouting)

- No technology for long term
- 100% Containment not possible

Relocation to Permafrost Zone

- Same costs and transport
  (x2) x extraction

Risk Assessment

	Risk	Impact	Assessment
G/W	high	known	unknown
S/W	high	known	unknown
workers	low-high	known	low
Public contact	unknown	high	unknown
Air	low	unknown	unknown

Regulatory Approvability

- marginal
- several agencies
  Land Issues
  - City of Yellowknife
  - GNWT
  - Land Claims Groups
    - land use plan
- lack of certainty
- water - DFO
  - DIAND/WB
  - EC
  - HSS - Hamilton
- Air - GNWT/EC
- WBC/Mine Safety
- Mackenzie Valley Resource Management Act
  - WB
  - LB
  - RB
- Sustainable Develop Objectives

Technical Feasibility

- simplicity - yes
- ability to do now - yes
- state of development - yes
- research requires - many studies re G/W & S/W
- contingency - other options if pumped
  weak - if flooded - pump out & treat

Liability - Future / Present / who

NOW - Previous Owners ???
- Current Owner

FUTURE - crown may never release mine from responsibility and liability

Underground Storage

a) As Is - let flood
   - pump
b) Refreeze/Barrier
c) In Situ Treatment
d) New Location
e) Risk Management & Maintenance

Criteria/Issues

1. Economics - low capital cost
   - an unknown cost associated with all aspects of option
2. Risk - unknown Medium to High
3. OH&S - potentially low
4. Environmental/Ecological Risk - Medium to High
5. Public Perception - poor (High)
   - relation, education
6. Regulatory - approvability - low probability
   - national - low probability.
   - international - low probability.
   - current/future - low probability.
   - requirements - low risk
7. Technical Feasibility - flexible - low risk
   - simplicity
   - ability to install in short-term
   - state of development
   - research requirements
   - contingency
8. Liability - future / present - high
   - company
   - crown
   - 3rd parties

Group 2: Transport of Arsenic Trioxide to Surface

Members:	Stephen Schultz	-	Royal Oak
	David Donison	-	Graham Mining
	Terry Brooks	-	MACA
	Peter Bengts	-	WCB
	Shannon Pagotto	-	DIAND, WRD
	Dave Nutter	-	DIAND, Minerals
	Rob Walker	-	DIAND, E & C
	Maria Healy	-	DFO
	Tony Willacy	-	Westmar Consulting
	Mike Borden	-	Miramar Con Mine
Facilitator:	Dave Clark	-	Dillon Consulting Ltd (Van)

Discussion of Criteria/Issues by Group:

#2. In principle - minimize quantity stored at surface.

#4. General Points: OH & S
Workers Comp.
Component of licence/CEAA
Fisheries Act (where drilling or discharge)
Microwave Energy

- International less important
- In future:- Mackenzie Valley Resource Management Act?
  - CEPA - Arsenic?
  - Dogrib Land Claim Settlement?

#5. Add effectiveness to criteria list

#6. Long term reduction potential to Crown and company, but labor relations an issue in short term.

Alternatives for Removal to Surface:

Removal and Lift to surface undertaken to minimize amount to be stored at surface - demand management.

Alternatives with High Technical Confidence

- Vacuum
- Pumping (water/dust)
- Digging (clam/base removal)

Evolving applications of technologies for this activity - R&D required:

- Sublimation:- Microwave heat to form gas for removal
- Electrostatic removal
- Solidification/followed by removal
- Vaporization (nuclear)

Surface Movement and Storage:

- Pneumatic:- pressure or vacuum
  - low installation/maintenance
- Truck: (relative to vacuum)
  - new introduced handling & transfer
  - higher public concern and worker concern
  - higher risk to population at large and eco/env
  - liability increased with increased handling
- Slurry:- perception of public may be lower risk
- Economic/cost of above are uncertain - f(time)

- TRP Tanks:- short term storage
  - greater perception concern
  - good setting
  - lower cost and assured quantity stored

New Storage:- greater life expectancy- need to identify with/without treatment
- higher efficiency
- amount of storage (disposition alternatives)

Conveyors:- questionable costs (high) at this anticipated scale

Assessment of Options:

Vacuum:

1a. OH&S
-installation/maintenance HIGH- but mitigatable with
- hygiene
- personal protection equipment
- selected engineering technique

b. Pop. at Large LOW (normal operations)
HIGH - mitigatable with:
-proper design and monitoring
-ventilation isolation

2. Ecological/Environmental - LOW
- HIGH (under upset) - mitigate as above

3. Public Perception - MODERATE - mitigated by education
-workers - HIGH - mitigate by education/training (ongoing)

4. Regulatory - MODERATE

5. Technical - LOW
-Challenging but low risk
-Further development required

6. Liability - MODERATE

7. Economic/Cost - MODERATE

Pumping/Slurry:

1a. See vacuum

b. See vacuum

2. See vacuum

3. See vacuum

4. Regulatory - MODERATE
-additional water discharge quality challenges

5. Technical - MODERATE
-water balance - further examination of issues related to storing wet dust

6. Same as vacuum

7. Same as vacuum

Digging:

1a. Clam: LOW
Draw Point: MODERATE
-installation/maintenance/operation - HIGH but mitigatable: see vacuum
-more ????ing than vacuum

b. Same as vacuum

2. Same as vacuum
   -MODERATE under upset
   *Control fugitive dust during loading
3. No difference
4. MODERATE
5. LOW- challenge/available components/less simple/less effective
6. Same as vacuum
   -but new contaminated area - tunnel
7. Same as vacuum - slightly higher operating cost.

Group 3: Arsenic Trioxide Treatment Options

Members:	John Stard,	-	Royal Oak Mines Inc.
	Kent Morton	-	Royal Oak Mines Inc.
	Serena Domvile	-	Beacon Hill Consultants Ltd.
	Ed Collins	-	Environment Canada
	Brad Colpitts	-	YK Health & Social Services
	Neill Thompson	-	DIAND, WRD
	Terry Pepper	-	Highwood Resources
	Dr. Bill Cullen	-	University of B.C.
	Dr. Jack Adams	-	Weber State University
	Dr. J.M. Tranquilla	-	EMR Microwave Technology
	Holger Krutzelmann	-	Hatch Associates, Ltd.
	Cary Johnson	-	Miramar Con Mine
	Luis Wilson	-	Barrick El Indio Mine
Facilitator:	Craig Thomas	-	Dillon Consulting Limited

Discussion - Processing to an Economic or Uneconomic end product

<u>Economic Use</u> - WAROX treatment or hot water leach process

1. Additional Handling - New Process
   OH&S - with new process additional risks are probable
   - General Public - transport to markets increase risk to general public but reduces long-term risk in exchange for acute short-term risk
   - emergency spill response plan and team will be required

2. Enviro./Ecolog. risk
   - Additional handling, transport and maintenance production of pure arsenic increases risk, but over long term reduces risk at site with storage of large amounts of arsenic dust material.
3. Public Perception/Education
   - If it is done openly, the public will come on-side.
   - Less Public Relations will be required than if the material is left underground.
   - Public education and full participation would be required to provide comfort level for acceptance of processing handling and transportation.

4. Regulatory
   - approv./accept
   - nat./internat
   - current/future
   - requirement

Regulatory - approvals?

- process modification will require various levels of approvals but will not likely require major changes in mine operations.
- timing & requirements may extend period for implementation therefore storage and contingency plans are important.
- water licence/CEAA?
- what land requirements

5. Technical Feasibility
   - relatively simple related to modification to existing process yet transportation handling requirements increase technological requirement.
   - ability to install
   - short term
   - state of develop.
   - available contingency
   - future R/D required
   - # unknown

- simplicity - WAROX more so than others
- installation - high technical requirements
- state of development - low - med WAROX treatment require much more research.
  - low - others (water leach) is proven technology to some degree.
- contingency - storage
- comprehensive R&D required

<u>Unknown</u>
- market and marketable is an unknown for stability and availability.
- modification or new plant
- impurities to market product may create periodic problems meeting market requirements
- process chemistry requires further study
- economics (cost)
- time line for implementation
- process demonstration - ranking study

6. Liability
   - company
   - crown
   - 3rd party
   - future/long term

- liability to shipping
- product handling & liability
- market liability to and at receiver
- higher liability to worker safety in short-term for long-term gain

7. Economic/cost

- WAROX lower than others
- wet process - mod. high

Process Considerations
Short Term Goal to Longer term.

- minor modification better gold recovery but not to a marketable arsenic product
- in 2-3 years may find a process to meet market conditions but market may not exist
- market review & process development required which will take time to fully understand
- it is very likely that ROM can't meet short-term objective to marketable product with successful market acceptance.
- underground storage capacity with process modifications to saleable market product, but surface storage will provide time line.
- need 95% at least 99% to break market
- additional storage capacity will provide contingency plan & process development time, but commitment to process needs to be confirmed in a short-term (6 - 12 months)?
- storage will be part of the process
- the durability of the storage tanks is an issue
- any short-term decision requires further option to be developed as contingency plan due to market volatility.
- regulatory requirements & timing that will allow targets to be used
- it may be faster to modify a process from a regulatory process than to build a new one

Non-marketable Product

- two products after gold recovery increase 1) low grade stored arsenic trioxide 2) high grade arsenic trioxide from daily process.
- Encapsulate in concrete back to mine storage facilities underground or on surface
- Production of ferric arsenate is complicated (the material must be solubilized and then precipitated) so encapsulation may be the preferred option.

1. - lower risk but handling associated with cement will be required.
   - low risk increase from current storage due to existing unknowns
2. - reduces risk as the process produces a more stable product
3. - questionable issues based on product being stored at site thus not necessarily dealing with the local issue.
4. - leachate quality, quantity and monitoring capabilities will be questioned by regulators long-term stability can't be quantified.
5. a) high feasibility process
   b) should be able to stabilize with current technologies
   c) available technology exists but must be defined

Unknowns include:

- leachability with concentration
- cement formulations

6. - liability will be long-term stabilization and monitoring capabilities
7. - high cost relationship with ratio of arsenic to cement a stabilizing material (zeolites)

Microwave and Autoclave Processes

	Microwave Technology	Autoclave Technology
	New Plant	New Plant or Transport/Transfer to existing Plant
1	- handling only, less risk - no transport	- exposure is low to general public and operator - generally some higher risks
2	- low risk - ferric arsenate by product	- low risk
3	- acceptable but not totally proven	- exists, acceptable
4	- different and may be longer-term due to new technology ?	- has been regulated previously in local setting
5	- 100 ton/day any feedstock - pilot studies indicator if is feasible - simple to install - established pilot plant - characterize feedstock	- highly feasible has been done - complex operation requiring further study to Giant's material and conditions - exists - state of development - established - characterize feedstock
6	- addition to process, long-term stability	- shipping if to Con - long-term stability
7	- 35% of capital cost as compared to new autoclave	HIGH - existing Con Autoclave - not as high - current owner? no control

Plenary:

A plenary session was held, and the results of each technical group were presented. At this session it was decided that there are many options that show high potential for success, but that there is still development work to be done and management planning to be completed before any one or number of options can be implemented.

Table 2: Alternatives Assessment

Assessment Criteria	Underground Storage	Transportation to Surface			Processing to Upgrade	Processing to Stabilize		
		Vacuum	Pumping/Slurry	Clam/Drawpoint Mucking	WAROX/Wet Process	Stabilization with Zeolite/Cement	Microwave New Plant	Autoclave New Plant or Transport/Transfer
Human Health: -OH & S -General Population	-LOW OH & S risks	-OH & S - installation/ maintenance is of HIGH concern but mitigatable with hygiene, personal protection equipment and selected engineering technique -General Population - LOW under normal conditions, HIGH under upset conditions, mitigatable with proper design and monitoring and ventilation isolation	-As with Vacuum	-OH & S LOW with clam, moderate with drawpoint, installation/maintenance/operation HIGH but mitigatable as with vacuum -General population is same as with vacuum	-Risk is involved since there will be additional handling	-LOWER risk but increased handling with cement -LOW risk increase from current storage -No change	-Handling only, less risk -No transport	-Exposure is LOW to operator and general public -Generally some HIGHER risks than microwave
Environmental/Ecological Risk:	-MEDIUM to HIGH	-Generally LOW but HIGH under upset, mitigate as above	-As with vacuum	-LOW but MODERATE under upset. *must control fugitive dust during loading	-There will be risk	-Reduces risk	-LOW risk -ferric arsenate by-product	-LOW risk
Public Perception/Education:	-POOR, would need education, public relations	-MODERATE, mitigated by education -HIGH to workers, mitigate with education/training (ongoing)	-As with vacuum	-No difference	-Will need to be very up-front with process	-Questionable issues	-Acceptable	-Exists, therefore acceptable
Regulatory: -Approvability/Acceptance -National/International -Current/Future Regulations -Requirements	-LOW Prob. -LOW Prob./LOW Prob. -LOW Prob. -LOW Risk	-MODERATE	-MODERATE, additional water discharge quality challenges	-MODERATE	-Regulatory requirements will vary depending on whether a new plant is constructed or if the current process is modified	-Leachate quality & monitoring - long term stability	-Different and may be long term due to new technology	-Has been regulated previously
Technical feasibility: -Simplicity -Ability to Install -Short Term -State of Development -Available Contingency -Future R & D Required -Unknowns	-flexible, LOW risk	-LOW, challenging but low risk	-MODERATE - water balance, further examination of issues related to storing wet dust	-LOW: -challenge/available components/less simple/less effective	-WAROX is more simple than others -Installation cost will be HIGH -State of development: LOW to MEDIUM with WAROX, LOW with others -Storage is contingency plan -Comprehensive R & D is required -Unknowns: market and marketability, process modification or new plant required, impurities in market product, process chemistry, economics/cost, time line for implementation, process demonstration, need ranking study	-HIGH feasibility, Available -Unknowns: Leachability with concentration, cement formulation	-100 ton/day feedstock -simple to install -establish pilot plant -characterize feedstock	-HIGH -Complex operation -Exists -State of development is established -Characterize feedstock
Liability: -To Company -To Crown -To 3rd Parties -Future/Long Term	-Future/Long term liability is potentially HIGH	-MODERATE	-MODERATE	-MODERATE, but new contaminated area (tunnel)	-Liability involved in shipping, product handling, market liability to and at receiver, higher liability to worker safety in short term for long term gain	-LOWER liability	-Addition to process -Long term stability	-Shipping, if to Con -Long term stability
Economics/Cost:	-LOW capital but an increasing unknown	-MODERATE	-MODERATE	-MODERATE, with slightly higher operating cost than vacuum	-WAROX LOWER than others -Wet process - MODERATE to HIGH	-HIGH	-35% of capital compared to new autoclave	-HIGH -Less if using existing plant -If not owner than have no control

3.0 MEETING SUMMARY

The three day technical meeting was concluded with comments from Dave Clark, Dillon Consulting Limited; Rick Allan, Royal Oak Mines; and David Livingston, WD-DIAND.

It was the general consensus of the entire group that this forum with regulatory representatives, technical experts and the proponent (Royal Oak Mine) was the first of its kind to deal with management options for the stored arsenic trioxide. Most issues were brought to the meeting table very openly, by all parties, allowing attendees to gain a fuller understand of the existing situation at the mine and gain insight into the feasibility of various management options, both proven and under development, from a technical and regulatory stand point.