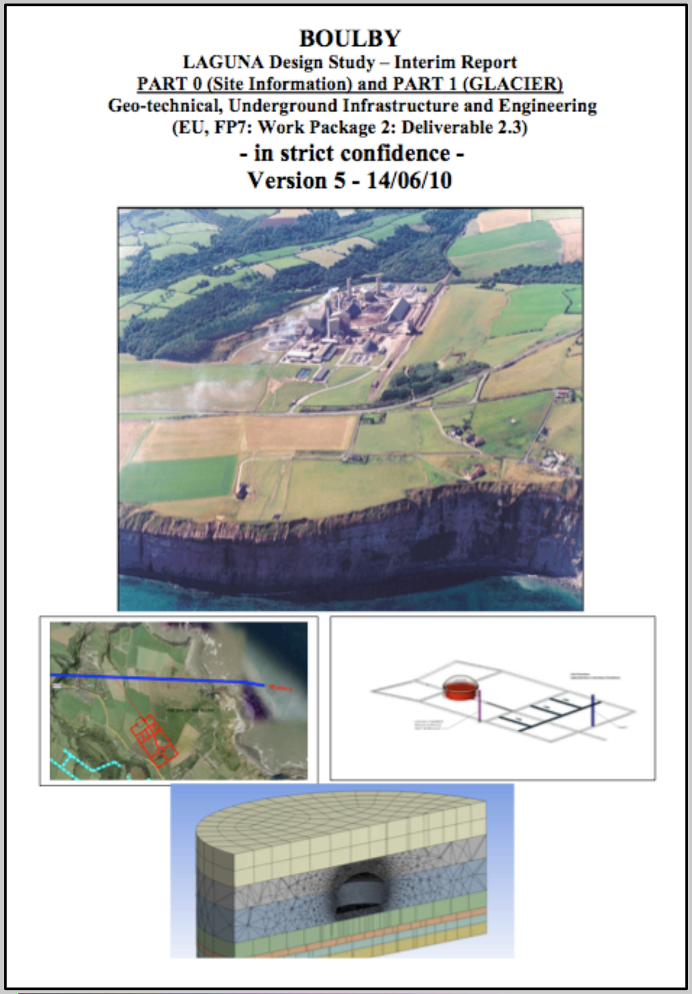
Boulby WP2.8 and Update

Interim Report (440 pages)
- includes LENA, MEMPHYS and GLACIER



NEW included in report:

Geophysics Update from Alan Auld Ltd.:
LENA Design/Simulations
MEMPHYS Designs/Simulations
GLACIER Update

Improved Cavern Designs

Liquid Procurement Assessment

New political support

Updates, transport, services and costs

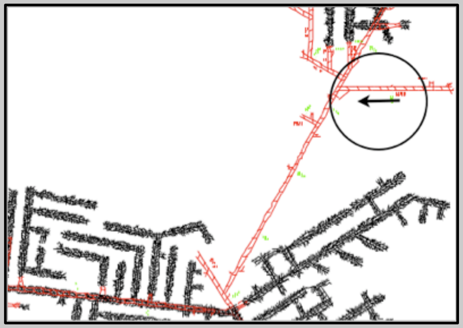
Correction of errors

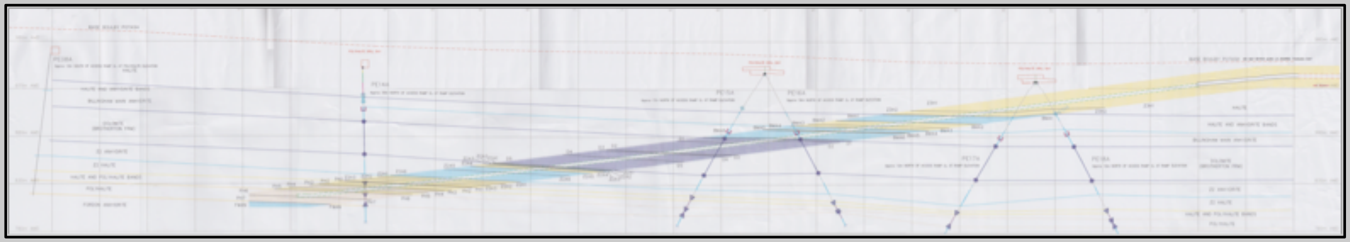
Alan Auld Ltd.: **Two-layer structure in upper region not regarded as an issue**

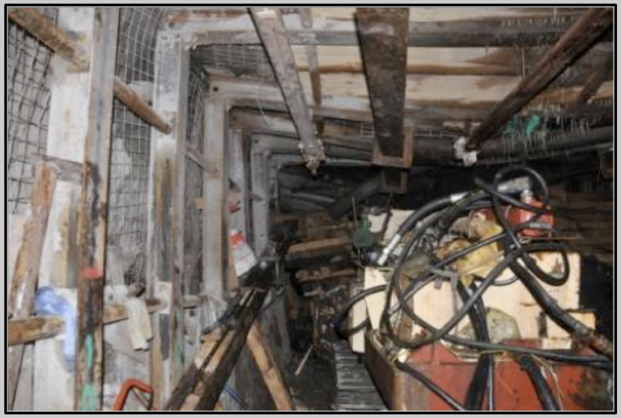
In-situ Rock Studies from Ramp

- Extensive surveys across the site: bore-holes but also IN-SITU studies

<u>**New ramp to 1300m now complete through dolomite**</u>







- New excavation to start in East region to 1500m
- New studies of dolomite below shafts

General

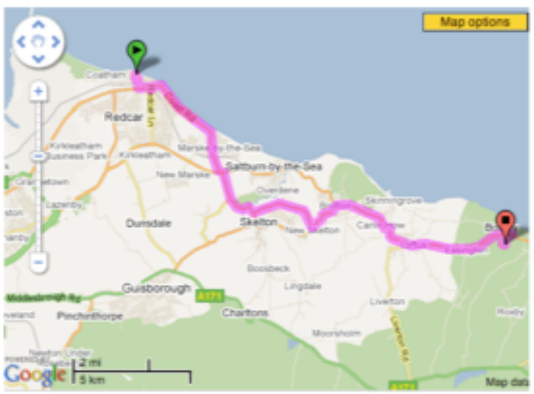
Transport	Facilities available; travel times and options
Road	A19, A1(M) main N-S motorways, 30 mins away (access for 44T lorries)
Rail	Nearest station Saltburn, 10 mins away, hourly service, 4 hrs to London
Air	Tees airport 40 mins, international connections; Manchester 2-3 hrs away
Ship	Passenger ports at Hull (1 hr away); CPL cargo port 10 miles away
Bus	Regular local bus services to the mine connecting with local towns/cities

Fig 0.2. Position of the two main shafts at Boul... rail ... for ... of ... indu... other ... indu...

Boulby mine is connected directly by rail to nearby Tees Port where the mine company CPL have a private dock (Tees Dock). This allows direct access for both inward materials to the mine and outward for export of the minerals. This dock, situated strategically on the North Sea allows straightforward links to all major European ports and beyond.

Boulby mine is 30-40 mins drive from Durham Tees Airport a local international airport with good service to Amsterdam that allows relatively fast connections world-wide. Several other airports are close by including Newcastle (~ 1hr by train to Darlington rail station) and Manchester Airport (~3 hrs by train). This is the largest in the region with direct flights world-wide including the US and far east.

Local Industry (liquids)



Liquids: There is particularly good access at Boulby to both liquid gas (including argon) and petroleum based liquids (such as mineral oil for scintillator) thanks to the proximity of the industrial base at Tees, for instance the BOC plants (see Fig. 3). There are good road links to the plants and also the direct rail link. The proximity would allow staging of liquid delivery without the need for on-site storage at the surface at Boulby itself.

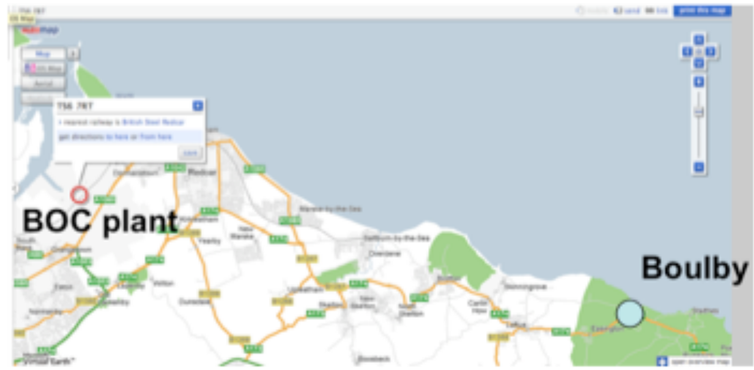


Fig. 0.4. Proximity of liquid production plants to Boulby.

Steel and materials: the mine is a regular consumer of large quantities of steel, concrete, and other building materials and has an established network of local and regional suppliers well matched to many of the requirements for LAGUNA. Bulk purchases can ensure best costs.

Skills and manpower: the strong industrial base of the region, including the petro-chemical and manufacturing industries in the Tees Valley, means there is access to a huge range of engineering, technical and scientific skills.

Rock Work Update

Table 0.3.9.1 Average Geomechanical Properties

Strength: Uniaxial compressive strength

Intact

Anhydrite	90MPa
Dolomite	200MPa

Rock mass

Anhydrite	7.3MPa
Dolomite	17MPa

Deformability: Youngs modulus

Intact

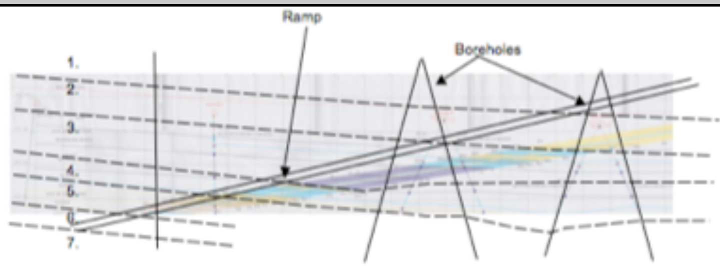
Anhydrite	46GPa
Dolomite	41GPa

Rock mass

Anhydrite	24GPa
Dolomite	21GPa

Poisson Ratio

Anhydrite	0.39
Dolomite	0.36



1. Halite
2. Halite and anhydrite
   Billingham Main Anhydrite
3. Dolomite
4. Anhydrite
5. A Halite
6. B Polyhalite
7. C Anhydrite

Some errors corrected, updates from CPL and AAE

Table 0.3.1 Strata present at Boulby

Geological Period	Approx depth (base) below ground level (m)	Approximate thickness (m)	Formation
Devensian	20	20	Boulder Clay
Jurassic	380	360	Lias Mudstones
Triassic	400	20	Rhaetic Mudstone
	600	200	Mercia Mudstone
	900	300	Sherwood Sandstone
Permian	1020	120	Saliferous Marl, Top Anhydrite and Sleights Siltstone
	1075	55	Up halite
	1082	7	Up Anhydrite
	1105	23	Carnallitic Marl and Upgang Formation
	1145	40	Boulby Halite [Middle Halite]
	1173	28	Billingham Main Anhydrite [Middle Anhydrite]
	1212	39	Upper Magnesian Limestone [Dolomite]
			Fordon Evaporites
	1240	28	Anhydrite [Lower Anhydrite]
	1264	24	Halite and Polyhalite [Lower Halite]
	1319	55	Anhydrite
	1369	50	Kirkham Abbey Formation and Lower Magnesian Marl
	1569	200	Hayton Anhydrite and Lower Magnesian Limestone
	1574	5	Marl Slate
	1583	9	Basal Sands
Carboniferous		>3000	Coal Measures (Mudstones, sandstones and coal seams) Millstone Grit (Sandstones and mudstones) Limestone Series (Limestones and mudstones)

Glacier Section

Part 1 GLACIER

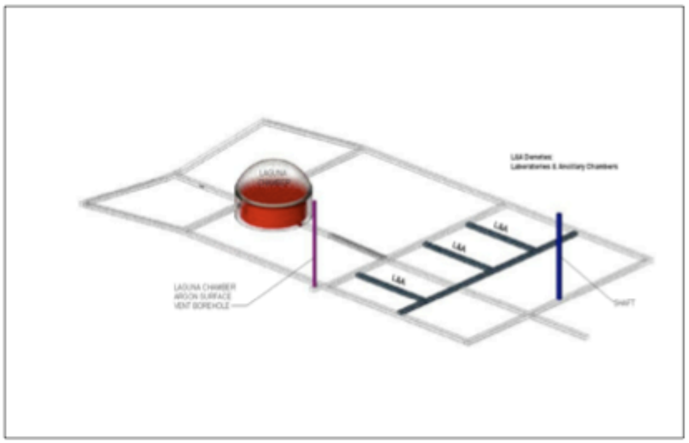
Glacier Cavern Design

Alan Auld Ltd. Design

AMCO Ltd. Construction and Cost

Part 1 GLACIER

This section details the feasibility study for constructing the massive GLACIER detector at Boulby comprising up to 100 ktons of liquid argon. As outlined in the introduction the approach has been to employ two independent companies, SES Ltd. and AMCO/AAE Ltd. experienced at working at Boulby to assess feasibility, design and cost the facility.



Figures G4.3.1 and G4.3.2 show schematics of the completed chamber design with tank installed.

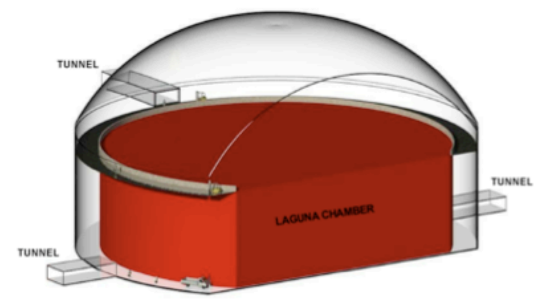


Fig. G4.3.1 Schematic of the main cavern showing access roadways and space around the tank volume

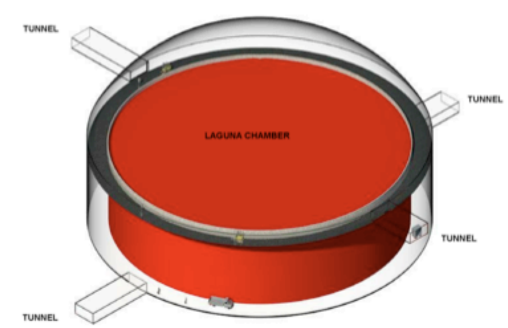


Fig. G4.3.2 Schematic downwards view of the main cavern showing access roadways and space around the tank volume

G4.3.2 Construction Sequence Outline

The construction for the main cavern is foreseen in four phases in line with the plans below. The envisaged timeline for these phases is given in Sec. 4.8. This is a conservative timeline that does not allow for the possibility of more parallel working. The phases are:

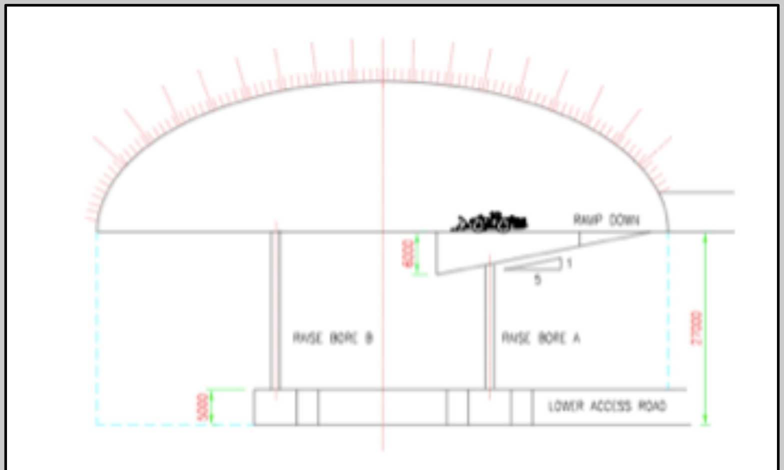
Phase 0: Preparation and Procurement
Phase I: Dome Excavation and Bolting
Phase II: Main Volume Excavation and Bolting
Phase III: Shotcrete and Finish

GLACIER Engineering (AAE)

AMCO Ltd. Construction and Cost

Fig. G4.3.3 shows the first critical stage of the dome construction. This involves drill and blast technology to build a 1 in 4 ramp towards the cavern roof, then a turn and drive of the the ramp to the centre of the roof.

Fig. G4.3.3 First stage construction methodology for formation of the dome roof.



At this stage most of the main ... blocking excavation at stage 15 ...

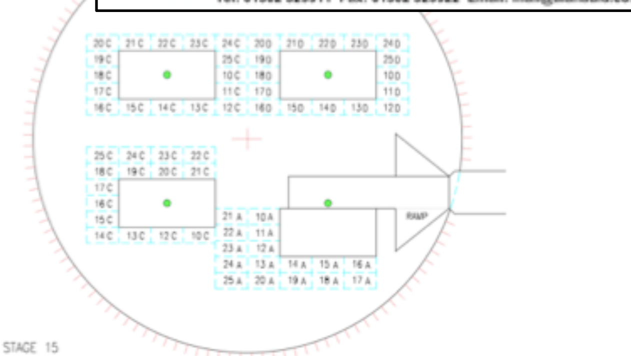


Fig. G4.3.7 Details of the blocking excavation at stage 15

Alan Auld ENGINEERING

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New Rock Analysis (AAE)

Alan Auld
ENGINEERING
1 South Parade, Doncaster, South Yorkshire, DN1 2DY, England
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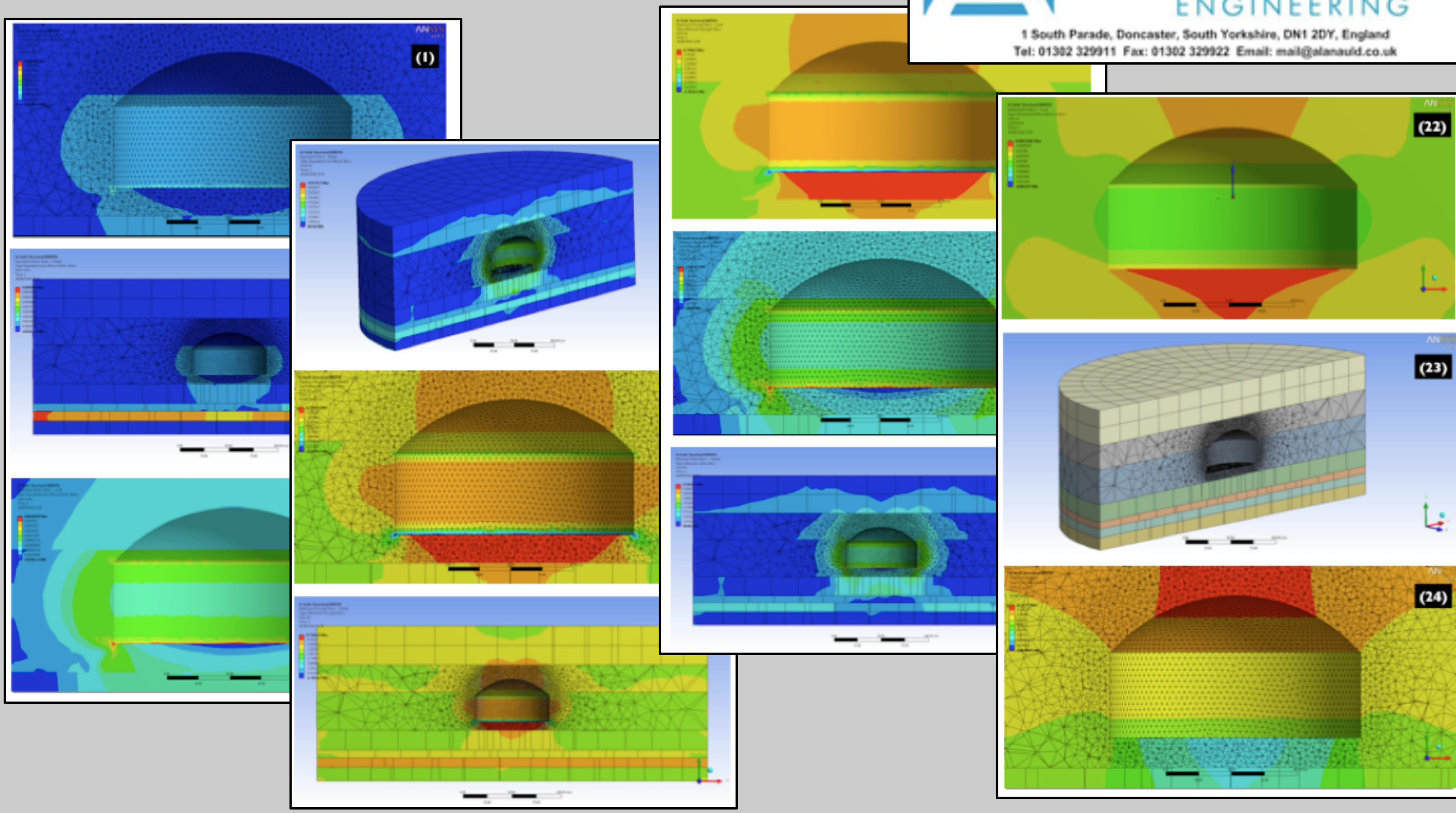
Ansys simulations



AAE conclusions agree with others

Glacier Ancillary Options

Ancillary Rooms

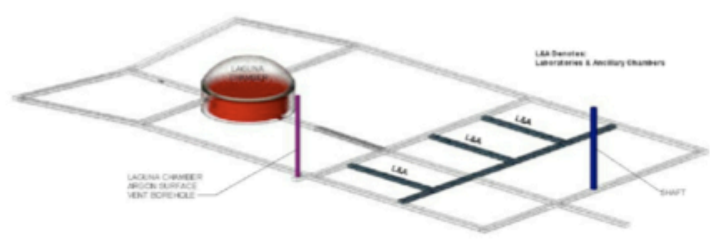


Fig. 4.4.2a Layout of ancilary ladder labs and safe haven rooms

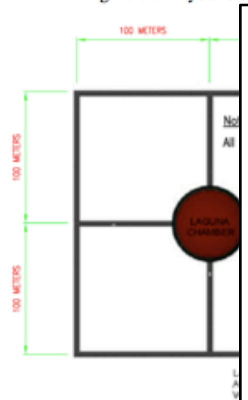


Fig. 4.4.2b Plan view

Liquid storage

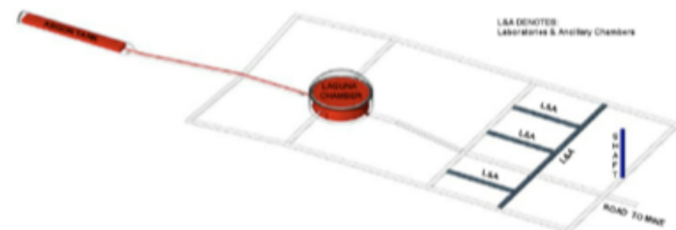
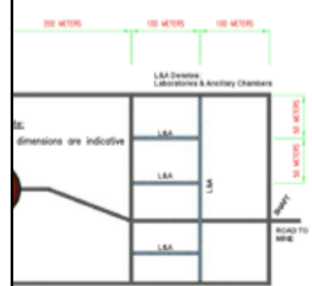


Fig. G4.4.4a Layout of ancilary labs including liquid dump area



including liquid dump area

G4.6.2 Vent Bore-hole Option Design

Design of the optional vent bore-hole has been discussed with Brittish Drilling and Freezing, Ltd. who we do a lot of work with AAE Ltd. This company is expert in large deep boreholes for the gas and oil industry. The suggested position of the hole is show in Fig. G4.6.1.

Vent-bore

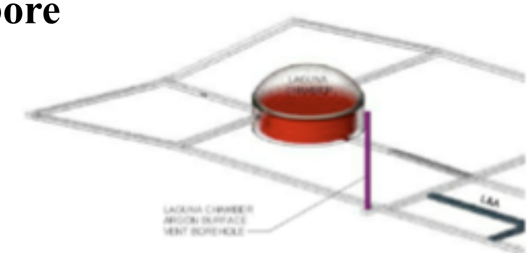


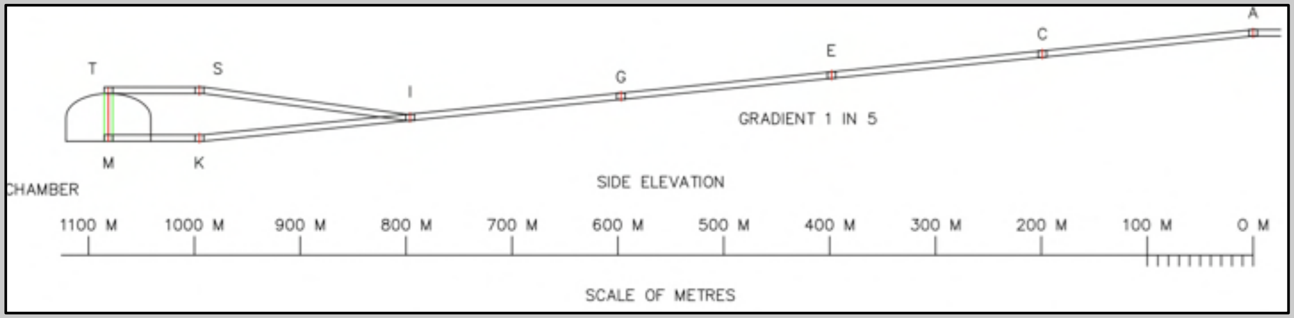
Fig. G4.6.1 Suggested position of vent bore hole

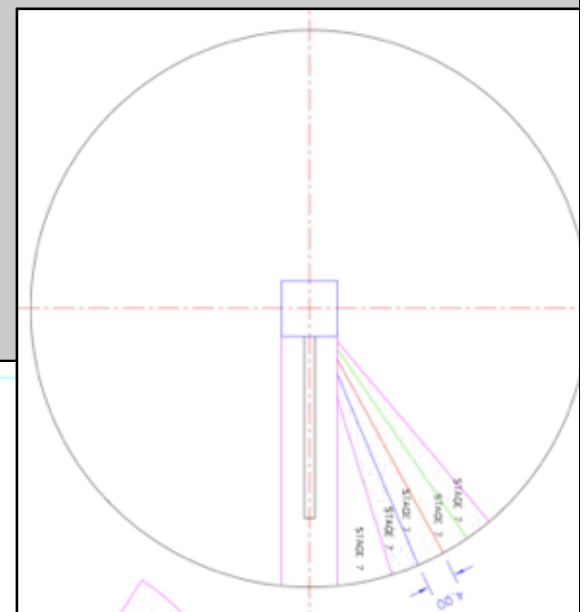
A 1500m deep hole on land would cost ~£2M for a 12" finished hole size. Such holes have been drilled in the area before. A size up to about 1.5m excavated hole size with heavy casings can also be achieved with special machinery the cost nearer £5M.

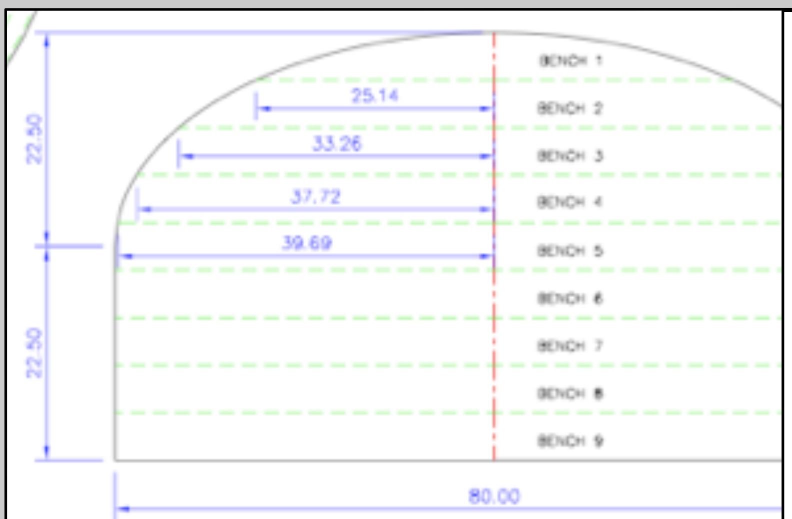
GLACIER Alternative (SES)

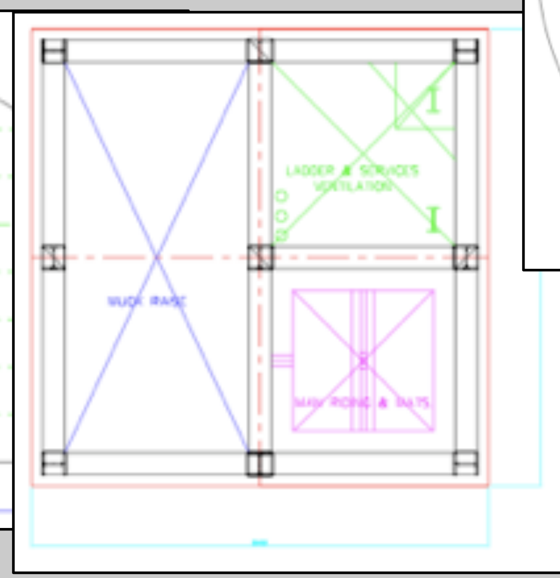
- **Single large raise-bore; internal staged spiral blasting**
- **Internal 15m cable bolting**
- **3 Phases: Roads, Dome, Main**
- **Timeline (4+ years); Cost €48.5M**

DRAWING STATUS 1. FOR INFORMATION 2. FOR TENDER
SES
SPECIALIST ENGINEERING SERVICES LTD
WRIGHT BUSINESS PARK CARR HILL
DONCASTER DN4 8DE
TEL 01302 735681 FAX 01302 733693
web site-www.ses-holdings.com
e mail-info@ses-holdings.com



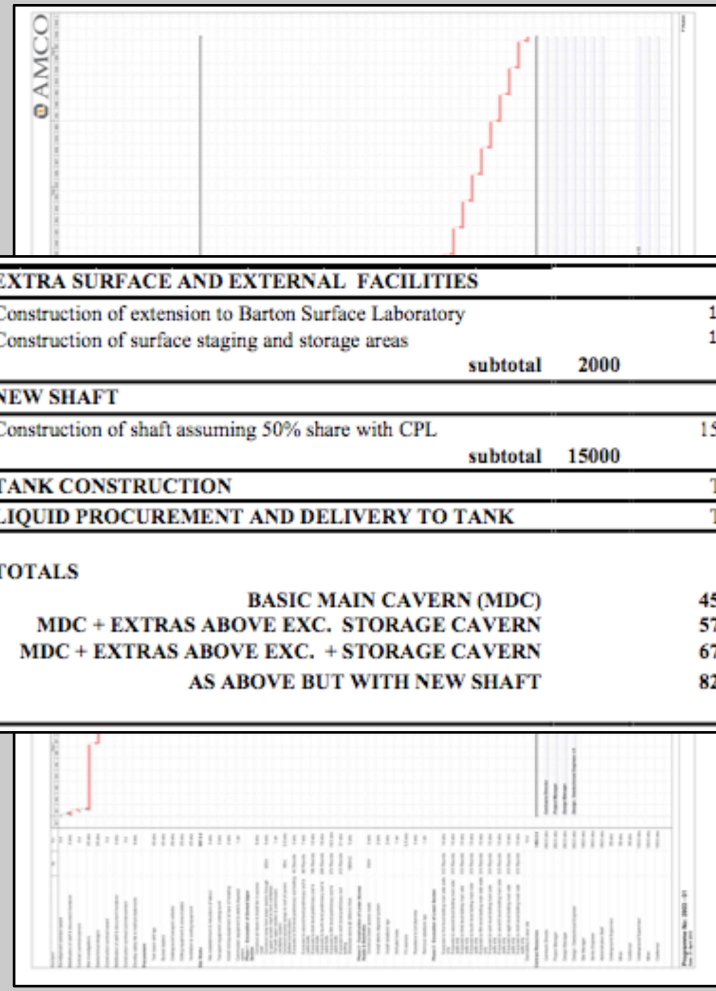






Costs and Times

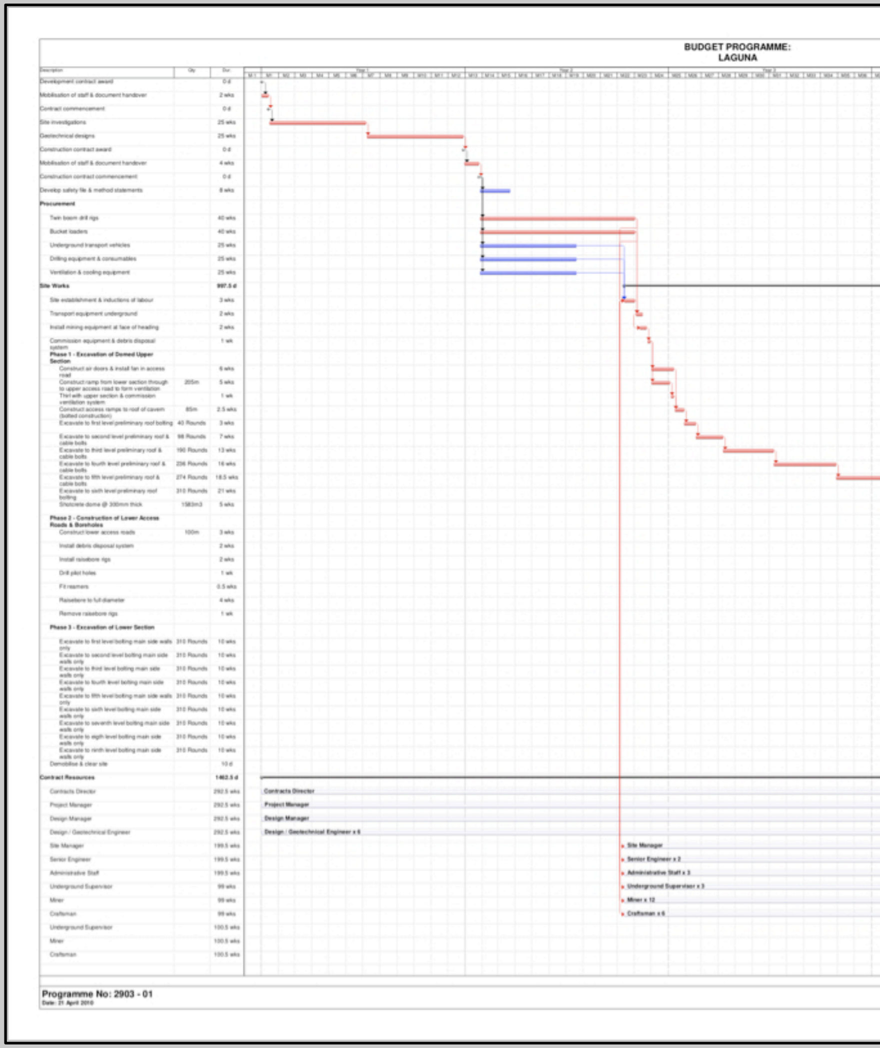
ITEM		COST (K£)
MAIN DETECTOR CAVERN (see AMCO/AAE table)		
Phase 0 – Design and Procurement		
Procurement and mobilisation of equipment		7000
Management, design, technical and engineering personnel		8000
Surface accommodation installation of plant		500
Phase I – Dome Section		8000
Phase II – Lower Section, Roads and Boreholes		4000
Phase III – Lower Section Construction		18000
subtotal	**45500**	
ADDIITONAL and OPTIONAL ITEMS		
Certification		
Inspections		20
HMI certification		10
Planning process		5
Environmental impact study		50
subtotal	**85**	
Tendering Process		
Consultation services		100
Legal and contract		20
subtotal	**120**	
Auxiliary Cavern for Liquid Storage Underground		
Excavation of liquid storage caverns		10000
subtotal	**10000**	
Additional Ancillary Laboratories		2000
subtotal	**2000**	
Additional Underground Road Access		2000
subtotal	**2000**	
Additional Ventilation Bore hole and Infrastructure		2000
subtotal	**2500**	
Contingency for Rock Removal		3000
subtotal	**3000**	
SPECIFIC CAVERN OUTFITTING		
Installation of access platforms, walkways and tank supports		500
Outfitting of control labs and storage facility (inc. cranes)		600
Outfitting of clean room facility (inc. cranes)		200
Installation of services (inc. power cables, ventilation)		500
Inspections and other costs		500
subtotal	**2300**	

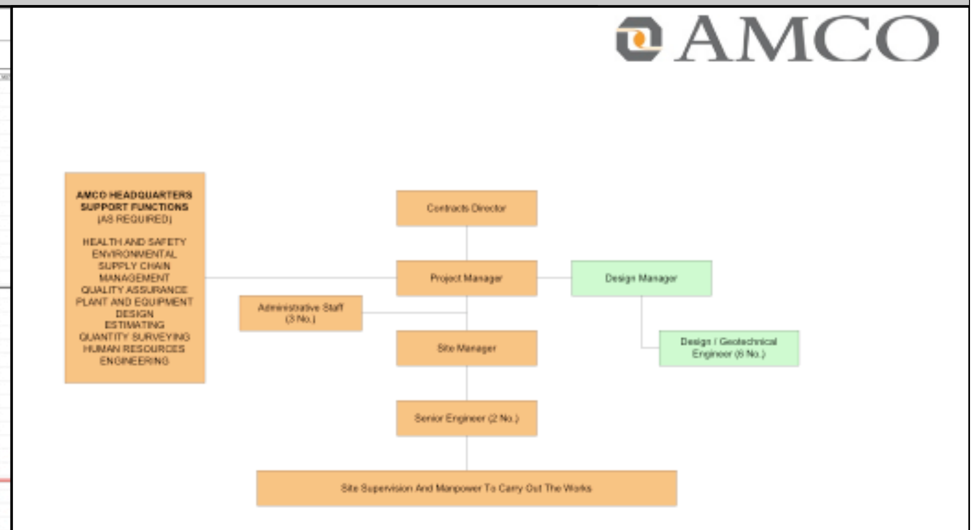


EXTRA SURFACE AND EXTERNAL FACILITIES		
Construction of extension to Barton Surface Laboratory		1000
Construction of surface staging and storage areas		1000
subtotal	**2000**	
NEW SHAFT		
Construction of shaft assuming 50% share with CPL		15000
subtotal	**15000**	
TANK CONSTRUCTION		TBD
LIQUID PROCUREMENT AND DELIVERY TO TANK		TBD
TOTALS		
BASIC MAIN CAVERN (MDC)		**45500**
MDC + EXTRAS ABOVE EXC. STORAGE CAVERN		**57205**
MDC + EXTRAS ABOVE EXC. + STORAGE CAVERN		**67205**
AS ABOVE BUT WITH NEW SHAFT		**82205**

GLACIER Management (AAE)

- Timeline (3 years); Cost €45M; management structure



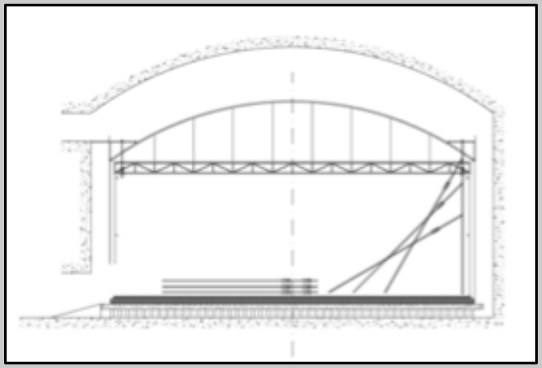


Tank Logistics

G6.2 Industrial Partnership for Tank Construction at Boulby

To achieve the proposed Boulby specific assessment a partnership has been formed between the following companies:

(1) Rhyal Engineering Ltd. – UK company expert in building large liquid petroleum gas tanks
(2) AMCO Ltd. – Mining and civil engineering company expert in building steel structures underground at Boulby
(3) AAE Ltd. – Consultant Mining and Civil Engineering company responsible for designs of the caverns envisaged at Boulby
(4) Technodyne Ltd. – Design engineers expert in large LPG tank design
(5) CPL – the mine company at Boulby, expert in the logistics of transportation of equipment underground..



Discussions with Technodyne/CPL

Meeting with Rhyal Engineering planned but not happened yet

Component LOW SEISMIC	Typical Component Size	Material	Quantity	Mass/Unit (tonne)	Total Mass (tonne)
Inner tank shell plates	Plates 76mm to 10mm thick, 2925mm x 10680mm, r = 34m	A240 type 316	160	18.2 to 2.4	1675
Inner tank annular plates	Plates 29mm thick, 980mm x 10993mm	A240 type 316	20	3.8	76
Inner tank bottom plates	Plate 5mm thick, 2270mm x 9970mm at r = 32.628m	A240 type 316	152	0.9	136
Inner tank top plates	Plate 5mm thick, 2270mm x 9970mm to r = 34m	A240 type 316	154	0.9	138
Inner tank compression ring/knuckle/top stiffener	Plates 1300 x 18 web, 400 X 20 flange x 10680mm	A240 type 316	20	2.6	53
Inner tank top support structure	Angle 250 x 250 x 20 at 3.5m spacing modules	A240 type 316	24	15.6	375
Inner tank top support structure	Plate 6mm thick, 2270mm x 9970mm at r = 35m	S275J2	135	1.1	148
Inner tank Intermediate stiffeners	4 stiffener rings 200 x12 to 350 x 20 x 10680mm	A240 type 316	80	0.2 to 0.6	46
Inner tank anchors	Reserved if needed	A240 type 316	60	0.25	15
Outer tank annular plates	Plates 9mm thick, 980mm x 10993mm	A553 type 1	20	0.75	15
Outer tank bottom plates	Plates 6mm thick 2270mm x 9970mm at r = 34.448m	A553 type 1	160	1.1	180
Outer tank sides including compression ring	Plate 13 mm to 16mm thick, 2930mm x 10995mm, r = 35m	A553 type 1	180	3.2 to 4.0	705
Outer tank compression bar	Plate 36mm thick, 850mm x 4580mm at r = 35m	S275J2	48	1.1	53
Outer tank top plate	Plate 5mm thick, 2270mm x 9970mm	S275J2	235	0.9	210
Outer tank top support structure	I Beam 300 x 150 x 10000mm IPE300	IPE300	288	0.5	155
Outer tank stiffeners	Plate 10mm thick, 2 off 450mm & 400mm x 10680mm	A553 type 1	40	1	40
Outer tank anchors	Flat bar 140mm x 10mm x 3500mm	A553 type 1	60	0.04	2.6
Access ladders and platforms external	External acess to deck area modules	S275J2	6	0.4	2.4
Access ladders and platforms internal	Inner tank only, no deck platform modules	A240 type 316	6	0.4	2.4
Nozzles	Based upon similar tanks	A240 type 316	40	0.2 to 5.0	33
Inner tank ring beam	Perlite concrete	Perlite concrete	50	2	100
Inner tank concrete levelling layers	2 off 75mm thick r = 35.1m, 1450m³ at 2500 kg/m³	Concrete	1450	2.5	3625
Inner tank bottom load bearing insulation	6 layers Expanded glass blocks	Foamglas	148000	0.005	718
Inner tank bottom DPC	Bituminious felt DPC 7 layers 950mm x 8000mm rolls	DPC	3700	0.2	813
Annular insulation system	Perlite ore and expansion fuel (cubic metres)	Perlite	6298	0.073	460
Annular insulation system	Resilient blanket and glass cloth	Blanket	685	0.035	24
Inner tank top insulation system	Fibreglass (cubic metres)	Fibreglass	4400	0.018	79
Inner tank top insulation system	Expanded glass blocks	Foamglas	56600	0.005	283
Cavern foundation / leveling layer	1.5m average thickness at r = 35.6m (cubic metres)	Concrete	6000	2.5	15000
Elevated piles	1m diameter at 3m spacing, 2m high (cubic metres)	Concrete	700	2.5	1750
Pile cap	1m thick at r = 35.6m (cubic metres)	Concrete	4000	2.5	10000

Tank Logistics

(2) logistics for steel transportation underground look reasonable in principle: There is transportation infrastructure for steel at Boulby, on the surface via the CPL rail hub and port and by road direct to the materials shaft. Underground transfer is by truck through ~10m x 5m main roads. The mine operates 24 hrs/day, 365 days/yr with shaft transfer of materials generally at night with loads of typically 10 tons and up to 10-15m length. The mine is used to shifting several hundred tons of steel per month up to 12km underground, for use in construction and support structures. Allowing for shift operations, the maximum normal capacity for bulk materials delivery underground, such as steel plate, is ~250 tons per day. The tank requires ~4000 tons of steel so over 1 year construction, i.e. ~4% of maximum capacity and not regarded as excessive. Careful staging over a longer period could reduce it further.

(3) a significant issue is concrete production and delivery, specifically the requirement for ~30,000 tons of concrete (~30% normal transport capacity per year): However, of this 2% is steel, ~82% aggregate and water, leaving ~16% (4800 tons) cement. One option would be to use excavated dolomitic rock as aggregate and only transport cement. Better would be to pump down the proposed small-bore ventilation shaft.

(4) the need for additional manpower underground: Boulby operates 3 man shifts per day, 24 hrs/day and 365 days/yr. Transport of construction staff underground is also well within maximum capacity (~180 people/hr).

Liquid Procurement

G7.2 Industrial Partnership for Liquid Procurement at Boulby

To achieve the proposed Boulby specific liquid argon delivery assessment discussion has started between the following companies:

(1) Air Products Ltd. – UK based company expert in production and delivery of cryogenic liquids in the UK and Europe (also USA and Asia).
(2) Technodyne Ltd. – Design engineers expert in large LPG tank design
(3) CPL – the mine company at Boulby, expert in the logistics of transportation of equipment underground..

(1) potential cost savings from proximity of local supplies of liquid argon from nearby Tees industry and Air Products plants at Hull: The location of Boulby close to existing Air Products and Linde/BOC liquid argon production at Tees, Hull and Carington, plus access to a dedicated port, rail and A-class roads, provide an estimated saving of 30-50% in argon costs over other locations in Europe (AP private communication).

The vast pertro-chemical industry in nearby Tees has several companies that can produce liquid argon and scintillator materials. The mine owns a rail line in that direction. Fig. G7.3.1 shows the proximity of the BOC plant to Boulby, about 30 km.

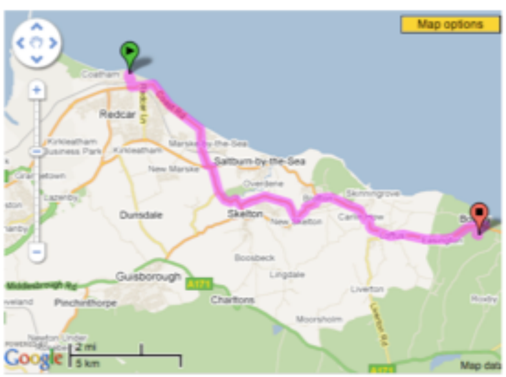
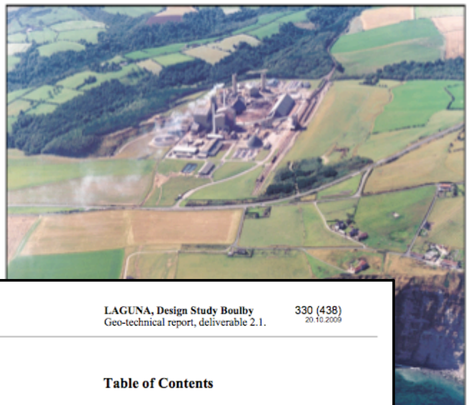


Fig. G7.3.2 Proximity of the Air Products plants to Boulby, Hull is ~150km.

LENA Section

LAGUNA, Design Study Boulby 326 (438)
Geo-technical report, deliverable 2.1. 20.10.2009

BOULBY
LAGUNA Design Study – Interim Report
PART 2 (LENA) and PART 3 (MEMPHYS)
Geo-technical, Underground Infrastructure and Engineering
(EU, FP7: Work Package 2: Deliverable 2.3)
- in strict confidence -
Version 5 - 14/05/10



LAGUNA, Design Study Boulby 330 (438)
Geo-technical report, deliverable 2.1. 20.10.2009

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LAGUNA, Design Study Boulby 331 (438)
Geo-technical report, deliverable 2.1. 20.10.2009

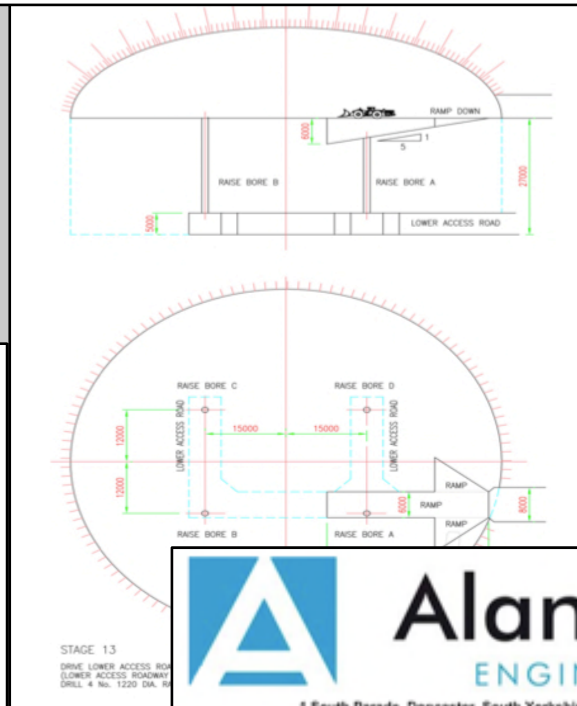
Main Focus is 1300m and below

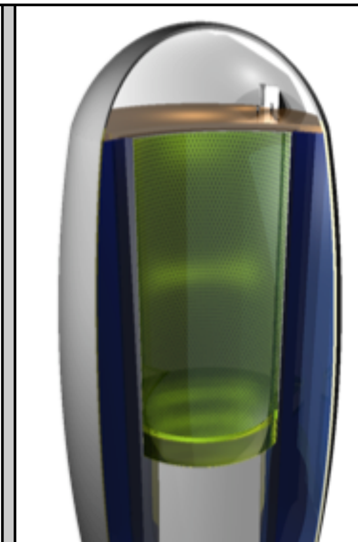
L4 LENA CAVERN SIMULATIONS – PART 2 (1300 m depth and below)

This section contains the main conclusion from preliminary simulations focused on the deeper dolomite layer. Further background information can be found in ANNEX L1.

L4.1 Introduction to Studies at 1300 m Depth

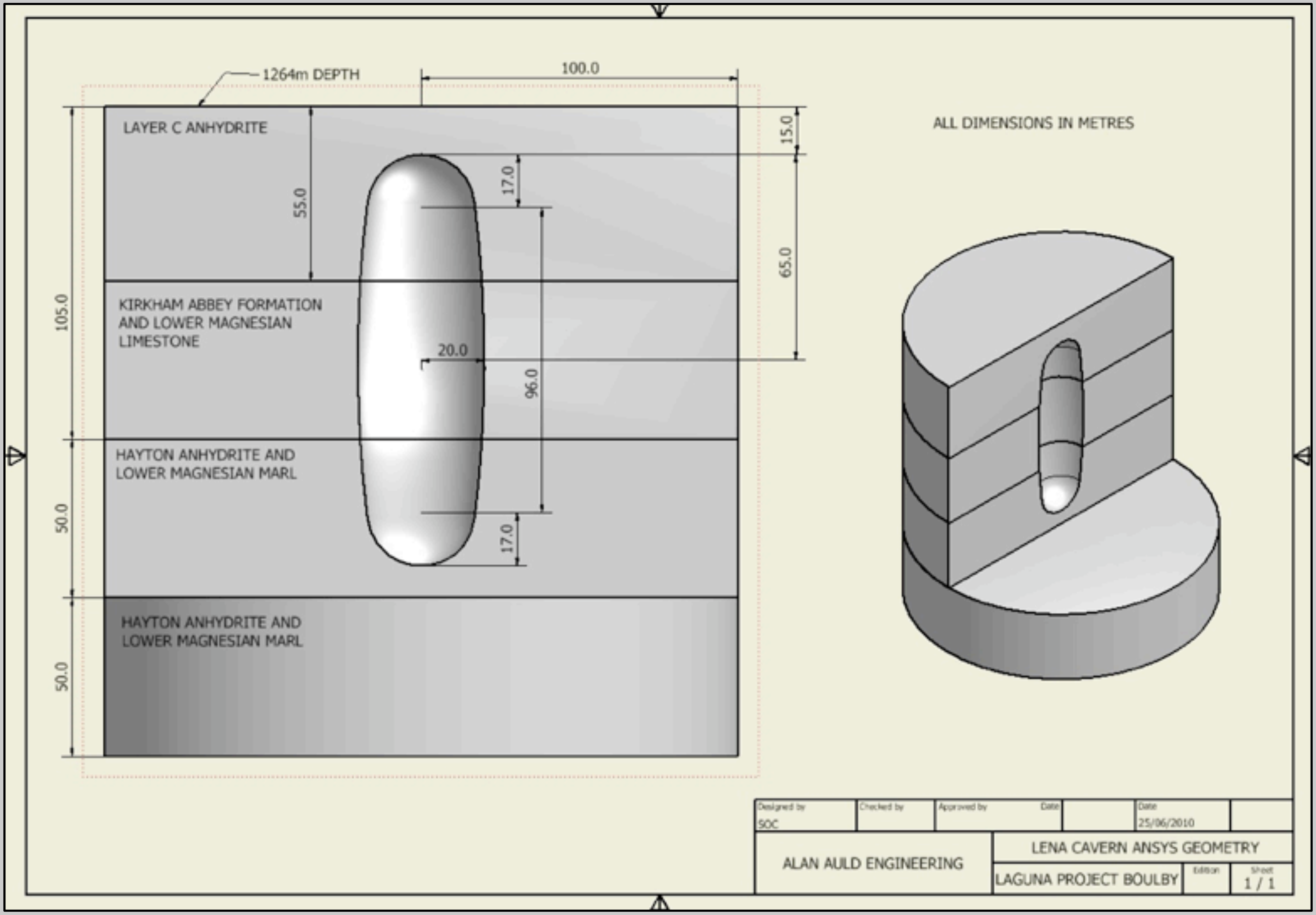
The work here focuses on the more realistic scenario of using the deeper and thicker dolomite area below 1300m and takes further account of new knowledge of the dolomite rock from in-situ studies. The simulations were undertaken with the following assumptions as in Part 1:





Alan Auld
ENGINEERING
1 South Parade, Doncaster, South Yorkshire, DN1 2DY, England
Tel: 01302 329911 Fax: 01302 329922 Email: mail@alanauld.co.uk

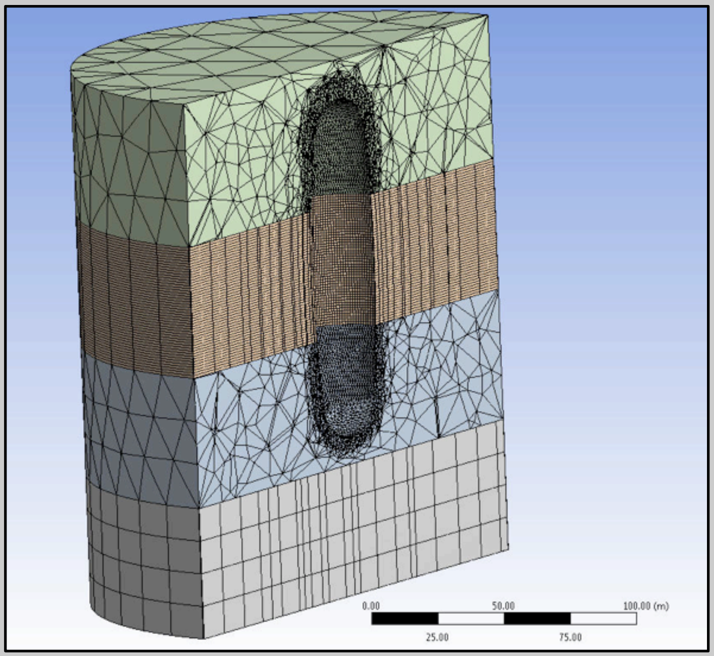
LENA - New ANSYS work (AAE)

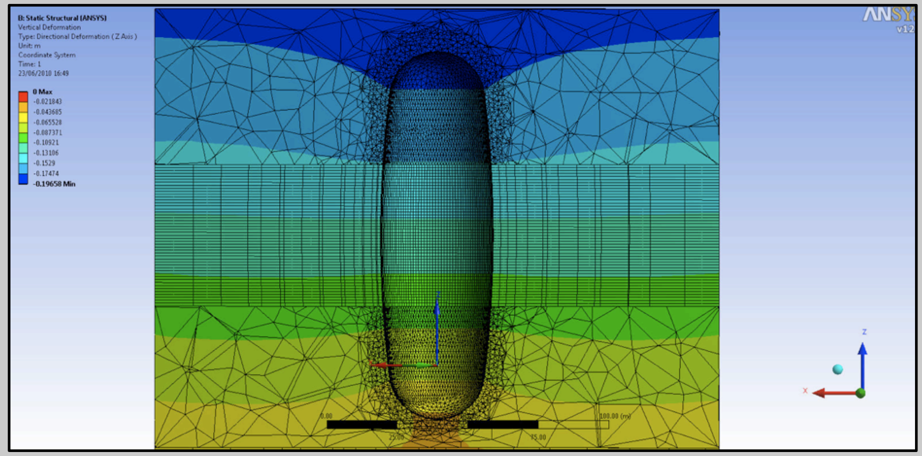


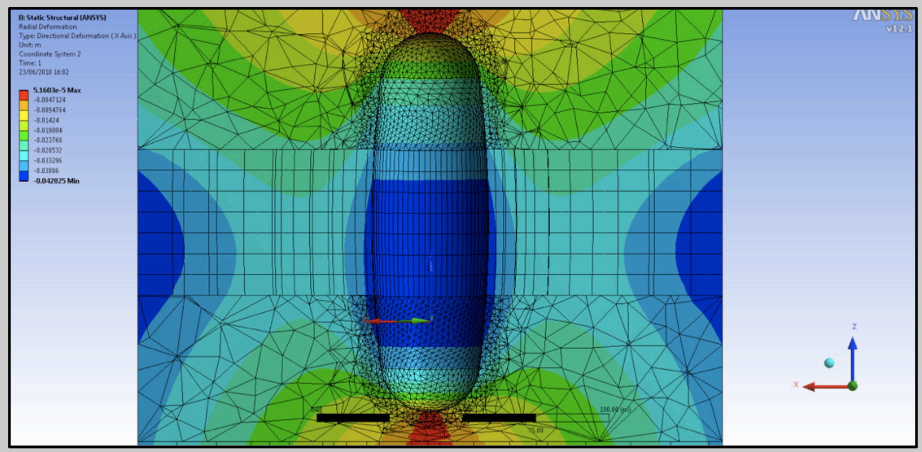
LENA - ANSYS further work

Not yet included in the report

New studies at 1400-1500m in



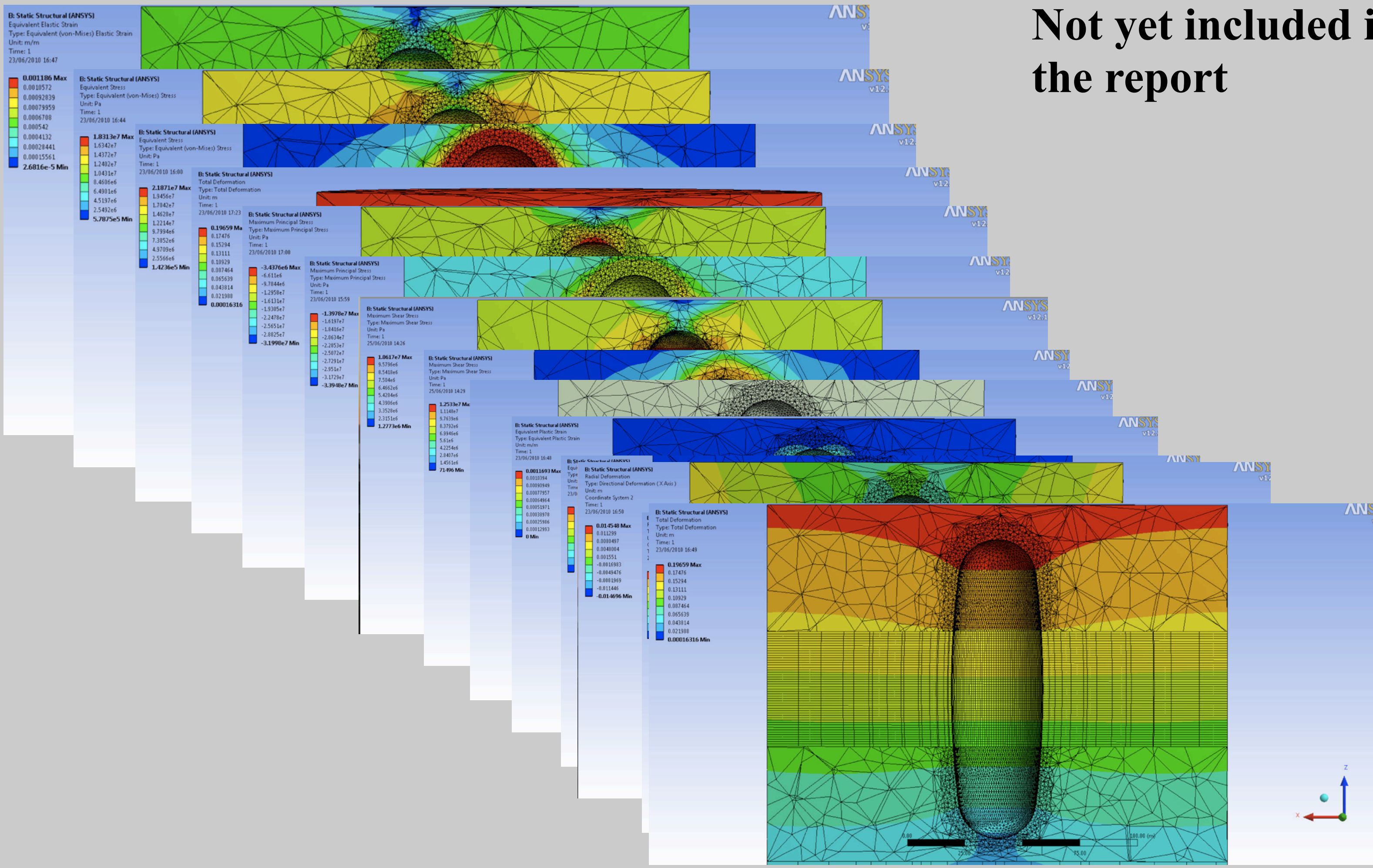




etc....

AAE conclusions agree with others

LENA - ANSYS new work

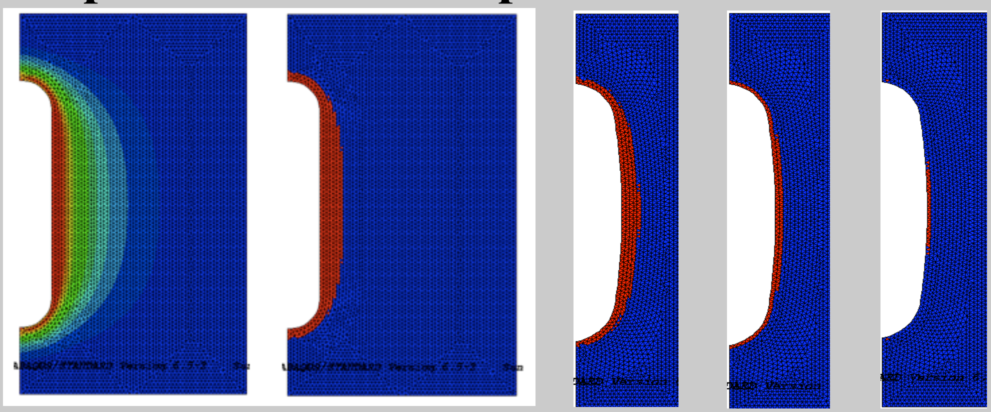


Not yet included in the report

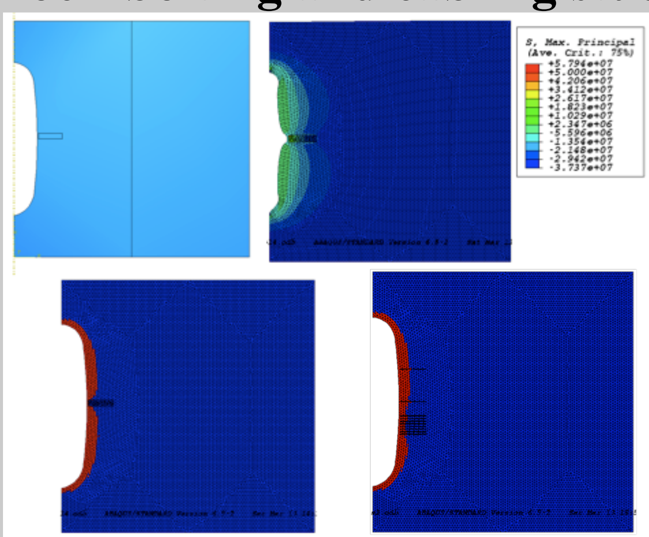
LENA Cavern previous studies

Studies at 1400-1500m in Dolomite

- **Shape selection development**



- **Rock-bolting and cabling studies**



- **Golders Ltd., AAE Ltd and our own work confirm stability is achievable**

Active yield plots showing a 10m zone of reinforcement around the cavern with strengths of 20MPa, 30MPa and 40MPa

Previous studies

LENA designs/costs

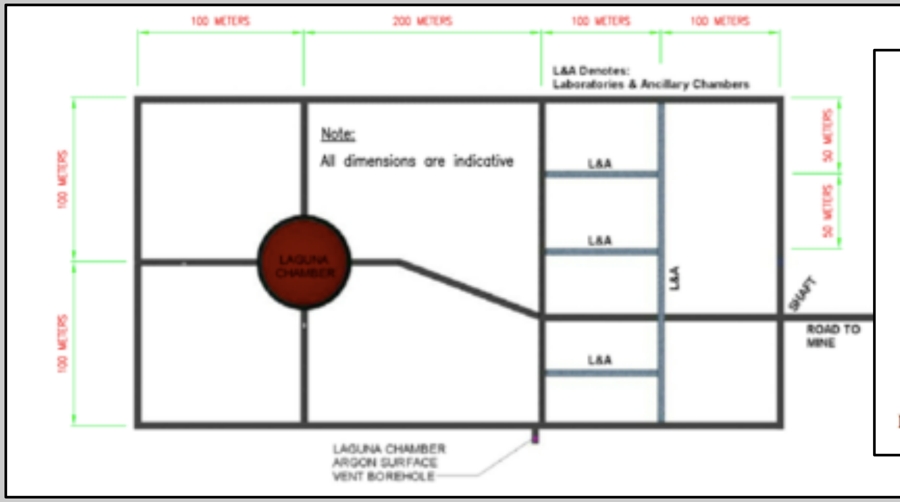


Fig. L6.4.1 shows the expected position and layout for the LENA cavern

L6.6 Ventilation Issues, Provision of Ventilation

Although not such an issue in terms of emergency as is the
reasons to include a dedicated bore-hole to the surface a
described in detail in Sec. G4.6. A 1500m deep hole on land
hole size. Such holes have been drilled in the area before. A
size with heavy casings can also be achieved with special mac

(1) Specific cost for LENA tank construction on site in the Boulby cavern
(2) Cost of liquid scintillator procurement and delivery into the tank underground at Boulby
(3) Cost of operations of LENA at Boulby over 30 years
(4) Cost of decommissioning LENA at Boulby

These issues need to resolved before the relative viability of LENA at Boulby can be assessed.

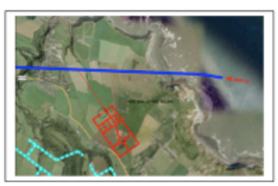
Table L6.7.1: Cost and timescale estimates for LAGUNA site infrastructure at Boulby

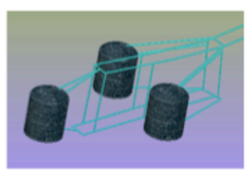
Item	LENA
Cavern (MDC)	£59.5M
Phase 1	*£8M*
Phase 2	*£5M*
Phase 3	*£29M*
Vent bore (option)	£2M
3rd Shaft (option)	£17M
Ancillary labs	£6M
Liquid store	*TBD*
Tank and Detector	*TBD*
Timescale	4.5 years

MEMPHYS section

Part 3 MEMPHYS

This section details the feasibility study for constructing the massive MEMPHYS detector at Boulby comprising up to three caverns of up to 300 ktons of water each. As outlined in the introduction the approach has been to employ two independent companies, SES Ltd. and AMCO/AAE Ltd. experienced at working at Boulby to assess feasibility, design and cost the facility.





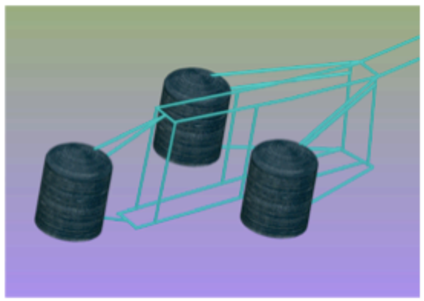
Part 3 MEMPHYS

MEMPHYS designs/costs

M3.4 Multiple MEMPHYS Caverns and Access Roadways

Following success with the single cavern simulations above some initial studies have been performed to examine the situation with multiple caverns and access roadways for the MEMPHYS detector. Fig. M3.4.1 shows a typical layout considered for the deep dolomite, including conceptual access roadways (this is indicative only).

Fig. M3.4.1 Indicative concept for multiple caverns of MEMPHYS at Boulby



To investigate the geo-mechanics with ABAQUS a multi cavern was created with 3 tanks sitting close to each other, placed 35 m apart. Preliminary results are shown in Fig. M3.4.2.

- Top load = 27MPa
- Side load = 27MPa

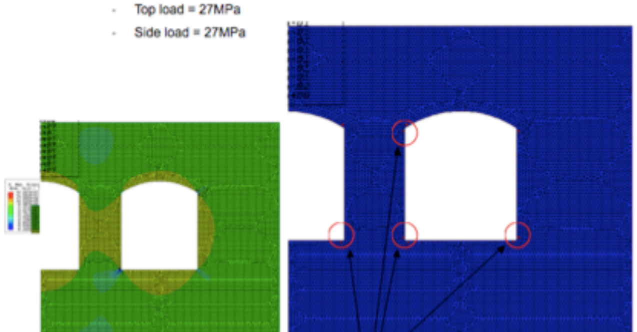
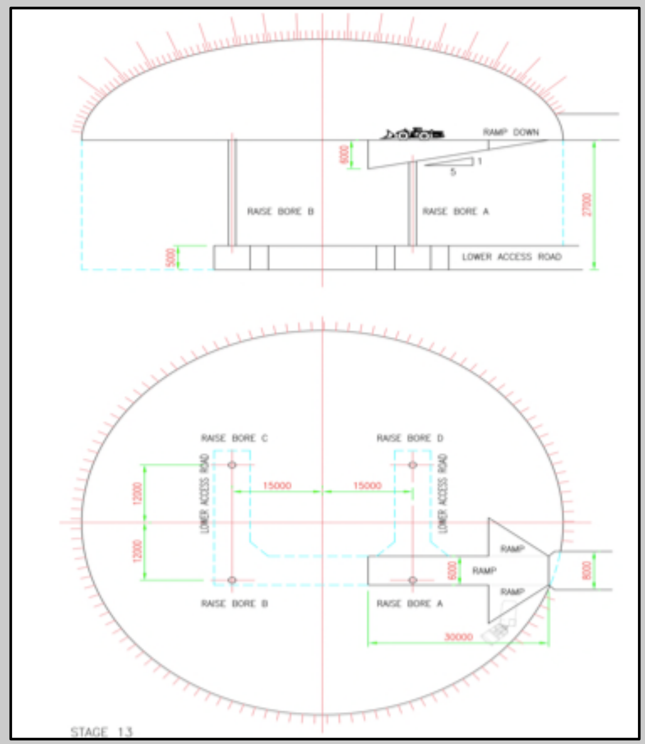
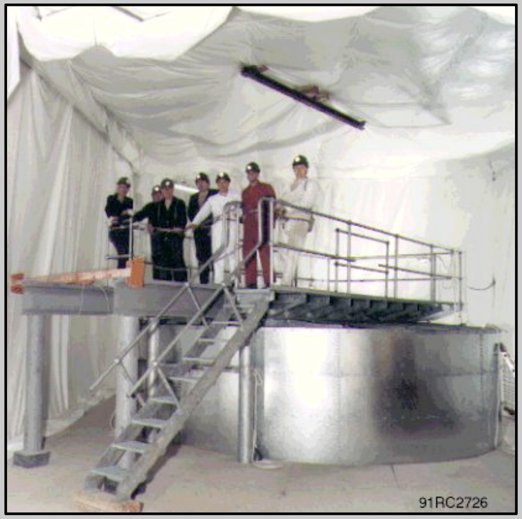
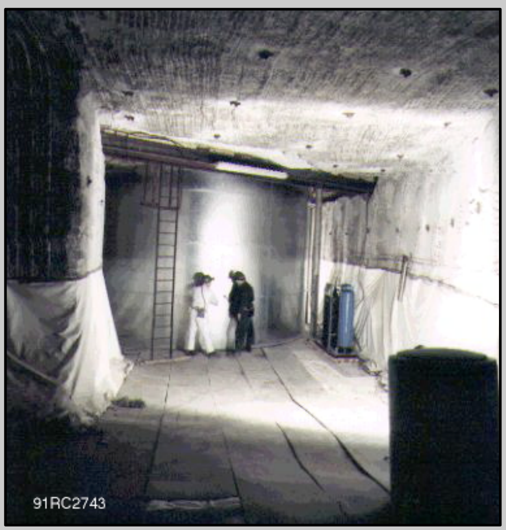


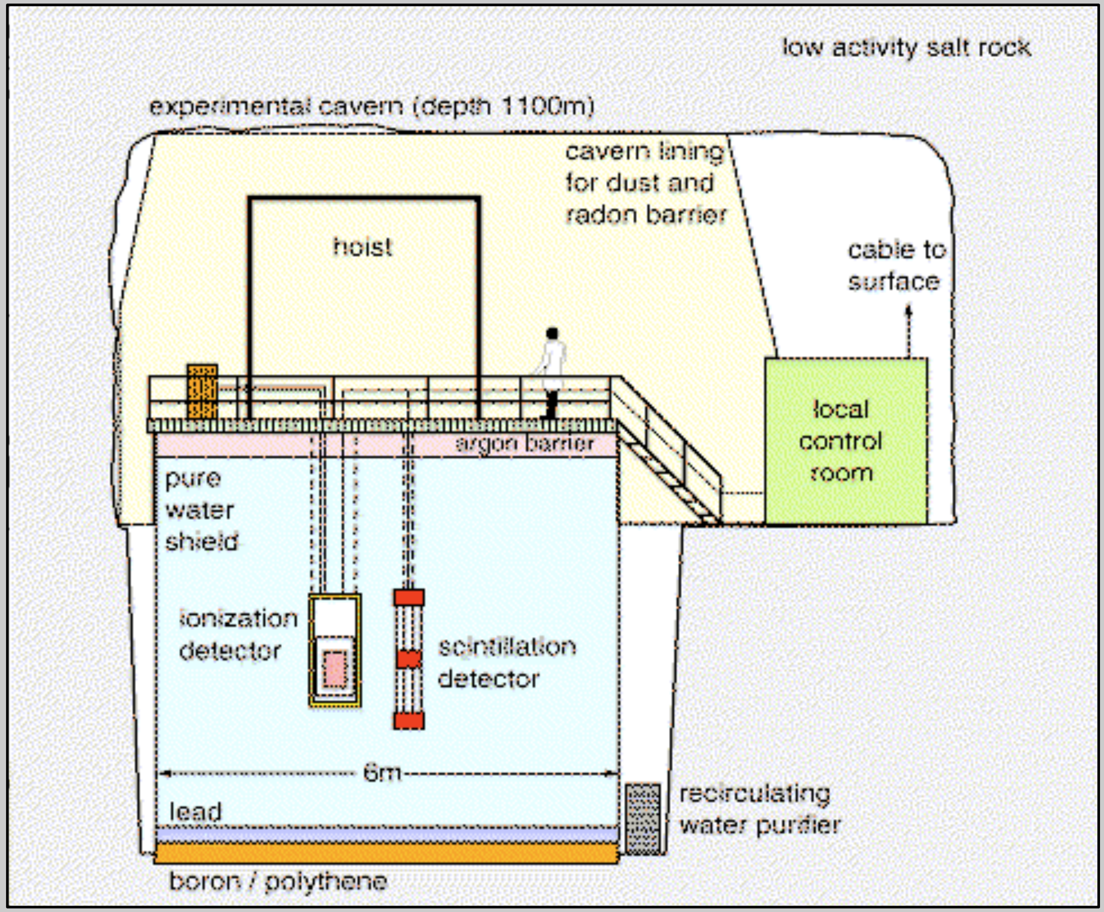
Fig. M3.4.2 Initial studies with multiple MEMPHYS caverns: (left) MPS plot for multi caverns (right) active yield plot for multi cavern MEMPHYS.



200 ton water shield at Boulby







MEMPHYS designs/costs

LAGUNA PROJECT AT BOULBY MINE — 2903

BUDGET PROPOSALS FOR CONSTRUCTION OF THE MEMPHYS CAVERN

Item	Description	Unit	Quantity	Rate	Amount £
1	Procurement and mobilisation of equipment	sum			10,000,000.00
2	Provision of management, design, technical, engineering and administrative personnel as shown on programme ref 2903-01	sum			8,000,000.00
3	Establishment of surface accommodation and installation of plant and equipment underground	sum			500,000.00
4	**Phase 1 - Construction of cavern domed section**	sum			25,000,000.00
	Unit rates upon which the above item is based -				
	a) Excavation	m3		105.00	
	b) Rockbolting	each		45.00	
	c) Cable bolting	each		180.00	
	d) Shotcrete	tonne		450.00	
	e) Ramp drivages	m		3,200.00	
5	**Phase 2 - Construction of lower connecting access roads and boreholes**	sum			10,000,000.00
	Unit rates upon which the above item is based -				
	a) Excavation	m3		105.00	
	b) Rockbolting	each		45.00	
	c) Borehole pilots	m		1,500.00	
	d) Borehole reaming	m		5,500.00	
	e) Ramp drivages	m		3,200.00	
6	**Phase 3 - Construction of lower section**	sum			55,000,000.00
	Unit rates upon which the above item is based -				
	a) Excavation	m3		105.00	
	b) Rockbolting	each		45.00	
	TOTAL BUDGET			£	**108,500,000.00**

Significant cost still to be resolved for MEMPHYS at Boulby are:

(1) Cost changes related to exact geographic separation between MEMPHYS caverns
(2) Cost tank construction on site at Boulby noting the need for detachement from the walls
(3) Underground water supply and purification plant construction costs
(4) Cost of operations of MEMPHYS at Boulby over 30 years
(5) Cost of decommissioning

These issues need to resolved before the relative viability of MEMPHYS at Boulby can be fully assessed.

Table M10.1: Cost and timescale estimates for LAGUNA site infrastructure at Boulby

Item	MEMPHYS
Cavern (MDC)	**£108.5M**
Phase 1	*£25M*
Phase 2	*£10M*
Phase 3	*£55M*
Vent bore (option)	**£2M**
3rd Shaft (option)	**£15M**
Ancillary labs	**£10M**
Liquid store	*TBD*
Tank and Detector	*TBD*
Timescale	*7 years*

Conclusion - Highlights

- LAGUNA is feasible at Boulby (confirmed by several means)
  - with many interesting features...
  - best construction start date ~ 2 years (to fit with CPL)
  - the two layer structure is NOT a technical problem
- We would like to continue the study (much still to do, e.g.):
  - understand engineering logistics better (tank construction)
  - understand rock removal logistics better
  - understand ancillary caverns and decommissioning better
  - develop liquid procurement logistics (inc. pipeline)
  - design the vent-bore concept
  - firm up TOTAL costs and timelines
  - confirm HM Inspector approval in principle

LAGUNA - WP3 [09/10-Frejus]

WP3 - deliverables (Mar 2010)

3.1	Site specific safety overview report	3	USFD	20	Report	CO	1/7/09	confidential, but EC can see it	template
3.2	Final report on safety	3	USFD	20	Report	CO	1/7/10	confidential	
3.3	Report on liquid procurement	3	USFD	10	Report	RE	1/3/10	liquids	
3.4	Report on socio-economic impact	3	USFD	10	Report	RE	1/3/10	socio-impact also restricted	

WP3.3 A restricted report on the liquid procurement

WP3.4 A restricted report on the socioeconomic impact of the research infrastructure at each site

WP3.2 Confidential final report on safety

TIMETABLE for deliverable.....

Tasks and responsibilities as specified

Task 9 Assessment of hazards events and risk analysis (USFD coordinator)

Task 10 Safety & monitoring of large underground tanks (ETHZ, Technodyne)

WP3.3

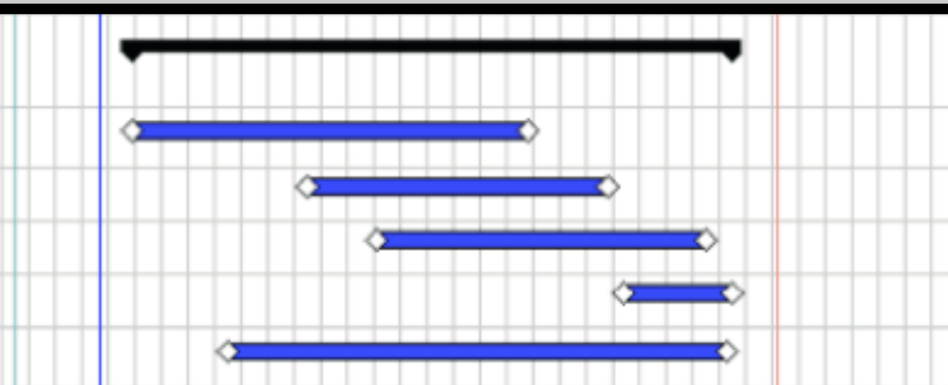
Task 11 Site specific impact of liquid procurement and tank filling (ETHZ, Technodyne, USFD)

Task 12 Final report on safety and environmental issues (USFD coordinator)

Task 13 Socio-economic impact of the research infrastructure on the sites (USFD coordinator)

WP3.4

WP3 – Safety, environmental and socio-economic issues	5/28/08	4/14/10	491.00
Assessment of hazards events and risk analysis	5/28/08	8/26/09	326.00
Safety and monitoring of large-scale tanks	12/15/08	11/24/09	247.00
Site impact of liquid procurement and tank filling	3/5/09	3/17/10	270.00
Final study on safety and environmental issues	12/14/09	4/14/10	88.00
Socio-economic impact of the research infrastructure on the sites	9/15/08	4/9/10	410.00



Deliverable
WP 3.3

WP3.3 Report Contents

Objectives as in annex 1:

- Identify potential safety and environmental risks for each target liquid
- Assess legal authorization requirements for each target liquid
- Define interface and the sharing of responsibilities in terms of safety between the research infrastructure and the host (road tunnel or mine)
- Evaluate the methods of the procurement of large quantities of each target liquid and the local safety impact and cost associated to the in-situ procurement of a given quantity of each target liquid
- Define tank filling techniques maintaining the specifications during the process and their impact on the site

Description of work as in annex 1:

Assess the procurement of the cryogenic liquids via contacts with leading European companies in the market. The study will involve estimation of costs and transport methods.

- **Each lab. provide draft report by <u>14th Jan</u>** **<u>28th Jan</u>**

Task 10 - Liquids (ETHZ, Technodyne)

Task 10 Safety and monitoring of large underground tanks

- Tank/delivery instrumentation, gauges, leak detection
- Delivery-tank interconnections, communications
- Impact on cavern construction....

Some overlap between general safety/environment deliverable and liquid procurement deliverable...

Task 11 - Liquids (ETHZ, Technodyne, USFD)

Task 11 Site specific impact of liquid procurement and tank filling

This task will evaluate the *methods of procurement* in large quantities of each target liquid and the consequence for each specific site.

- Identify potential safety and environmental risks for each target liquid
- Assess legal authorization requirements for each target liquid
- Strategies to bring very large quantities of liquids into the underground tanks
- Availability nearby the sites will be investigated and costs for transport will be estimated taking into account purity at delivery
- Methods of local production and their impact on the site will be assessed.
- The filling techniques of deep underground tanks avoiding recontamination will be defined.
- methods to further purify and maintain high purity levels
- emptying of the tanks will be addressed.

WP3.3 Template per site

(1) Identify methods of procurement of large quantities (per site, per liquid)

Liquid Argon: Andre,
Scintillator: Franz, Michael
Water: site specific...Memphys

- what (local) suppliers?, time scale for production, costs
- what transport to site (rail, road...)

(2) Environmental impact, safety, logistical, issues of transport to site

(3) On site storage and/or transfer underground

- construction of underground pipeline, intermediate storage, safety
- transfer by containers through shaft/tunnel

(4) Possibility of production on site and/or underground

- e.g. water purification, liquid argon production
- power consumption, ventilation, safety and disruption to tunnel/mining

(5) Maintenance of liquid purity during and after fill

- LAr boil-off sell it, disposal...agreements with company

WP3.3 Draft

LAGUNA, Design Study	1 (60)
Liquid Procurement, deliverable 3.3.	01.03.2010

LAGUNA Design Study
Liquid Procurement for LAGUNA
(Deliverable 3.3)

(1) Identify methods of procurement of large quantities (per site, per liquid)

	Water (1 Mtonne)	Scintillator (50 ktonnes)	Liquid Argon (100 ktonnes)
Source of liquid, company and status of contacts	**Above Ground**: Yorkshire Water, Environment Agency, North Yorkshire Moors National Park Authority. **Below Ground:** CPL Contacts and discussions with CPL ongoing	Saint Gobain, Zinsser Analytic, Perkin Elmer. Potential Teeside suppliers are: SABIC (was Huntsman) produces cyclohexane and aromatic plastics precursors; Dow Chemical (Rohm & Haas) produces acrylics; Croda Uniquema produces speciality oleochemicals. PXE (phenylxylylethane) based scintillator probably currently best option. Initial contacts and negotiations started with several companies, e.g. BOC	Contacts established in BOC Gases / Cryoservice Other possible suppliers are: Air Products, Air Liquide UK, Intergas.
Location of supplier, distance to site	Existing on site at Boulby	Potential Teeside suppliers 30 km away or if necessary the Petresa Petrochemicals company in San Roque, Spain	Suppliers based nationwide but also in Tees Valley around 30 km away
Transportation options and procedures	Pipeline underground is preferred option	Preferred option is by train from local suppliers 30 km away direct to site.	As for liquid argon. Train from local supplier in Tees Valley is preferred. Pipeline

LAGUNA, Design Study Boulby	4 (60)
Liquid Procurement, deliverable 3.3.	01.03.2010

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ANNEX 1: Identified Critical Factors

ANNEX 2: Draft Liquid Procurement Tables

(1) Identify methods of procurement of large quantities (per liquid)

(2) Transport to the site - environmental impact, safety, logistical issues

(3) On site storage and/or transfer underground

(4) Possibility of production on site and/or underground

(5) Tank filling and maintenance of liquid purity during and after fill

WP3.3 Draft Status

Canfranc: missing all information but I know it's on the way
Frejus: missing introductory section; tables not complete
Phyasalmi: missing introductory section; tables not complete
Slanic: missing some information
Sunlab: missing some information
Umbria: please can we have a word version (not pdf), also missing introductory section

Deliverable
WP 3.4

WP3.4 Report Contents

(1) Stakeholder support, risks, benefits and impact

- Social, economic and political organisations and people relevant to the infrastructure - levels of support, risks and impact
- Table 3.5 collates information on organisations that will be influential in determining whether the infrastructure can or should proceed or not at the site.

Site owners, Environment Agencies, Emergency Services, Planning Agencies, Local Council, Authority. Local Public Transport, Local Mayor, Local MPs, Local MEP, Regional Development Agency, Support from National Scientific Community, Support from Local University Scientific Community, National Science Funding Agencies, Local, Regional, National University political support, Local Schools and Educational Authorities, Local Industry, Philanthropic Support, Other

(2) Socio-economic impact assessment

- An assessment of the socio-economic impact that the new infrastructure itself will have
- Table 3.6 collates information on:

job creation, skills and knowledge exchange, economy, environment, local services, local transport, local political profile and status, impact on science for the region and nation, impact on society, schools and education, other impacts

Task 13 - Socio-economic

(USFD coordinator)

From each site, coordinated together:

Report on the potential socio-economic impact of the construction and operation of the research infrastructure

- local communities will generally directly or indirectly benefit from the presence of a lab yet could also be affected by the construction and operation

-task will attempt to quantify the impact and propose solutions to mitigate any possible negative aspects.

contact with the local governments needed

WP3.4 (1) Template per site

(1) See template used for WP3.1 (e.g. for Boulby)

Socio-economic Impact of the Research Infrastructure on the Sites

(1) Social, Economic and Political Organisations and People Relevant to the Infrastructure - levels of support, risks and impact

Type of Social, Economic and Political Organisation or Person Involved	Contact Details	Role and importance	Risk, benefit or impact to project	Status of engagement
Site owners	Cleveland Potash Ltd., Boulby Mine, Loftus Saltburn-by-the Sea, Cleveland, TS13 4UZ UK Contact: D. Pybus Tel: +44 (0) 1287 640140 E-mail: enquiries@clevelandpotash.co.uk	Owners of mine. Responsible for current operations and safety. Support is essential.	**(are all relevant ownership issues clear in law?)** Boulby mine is owned by CPL which is part of ICL. The benefit is strong experience and support for underground construction including access to mining engineers, equipment as well as experience in safety, political and planning issues. Risk: finite lifetime of mine and any conflicts of priorities. These can be mitigated against by sufficient financial backing and partnership. Impact: very high - strong experience and support for underground construction.	Good relations with scientists over 20 years. CPL management closely engaged in development of science and strongly supports LAGUNA and other science. There is a joint executive board involving members from the science community, universities and CPL, with also the Crown Estates (see below).
Environment Agencies	British Standards Institution Contact: David.Robinson Tel: +44 (0) 181 996 9000 E-mail: David.Robinson@bsi-global.com	Boulby conforms to a strict ISO14001:2004 Environmental Management System (see CPL web site) that satisfys all agency requirements (local authority, national park etc.)	**(are these agencies aware of the environmental impact - during and after construction?)** Risk: there is minimal risks - all agencies are aware of the mining operations and expansion plans. Construction of LAGUNA (for instance rock removal) is not out of line with normal workings at Boulby.	CPL are highly engaged with environment agencies and observe the strictest protocols, e.g. CPL Boulby Site is certified to the EMAS Regulations (Council Regulation 761/01) registration number UK000115). Direct discussion of LAGUNA is pending. However, significant issues are not expected as the expected environmental impact is not significantly different from normal operations

	Safety Executive HM Inspectorate of Mines, Edgar Allen House, 241 Glossop Road Sheffield S10 2GW Tel: 0114 291 2390		well in hand and understood, e.g. rock disposal is routine at Boulby.	
Emergency Services	Nearest A&E, Marton Road, Middlesbrough, Cleveland, TS4 3BW Tel: 01642 850850 Nearest Fire station: Coronation Rd, Loftus, Saltburn-By-The-Sea, Cleveland TS13 4SW Tel: 01287 640362	In addition CPL provide on site medical and fire services both above and below ground. There is the Cleveland Emergency Planning Unit. CPL hold all the details. There is over 30 years experience in all emergency procdures required for underrgound work	**(are these agencies aware of the impact on emergency services?)** Specific discussion on LAGUNA is pending However, in terms of mining activity LAGUNA is not exceptional. The special hazards of liquids needs to be discussed. Risk: low as CPL is well integrated already into emergency services. Impact: the impact of this integration is consequently high.	CPL is well integrated already into emergency services. Other interested parties, STFC, Mine Inspectorate (above), University of Sheffield etc are well integrated.
Planning Agencies	Local council: Redcar and Cleveland. www.redcar-cleveland.gov.uk North York Moors National Park Authority; The Old Vicarage, Bondgate, Helmsley, York YO62 5BP UK Crown Estates: 16 New Burlington Place, London W1S 2HX, UK Tel: +44 (0) 20 7851 5000	For workings under the land planning issues lie with the local authority and local land owner permissions. For workings under the sea the Crown Estates is required.	**(how will planning permission be obtained and what is the risk that it will not?)** Preference is for under-sea sites where the Crown Estates are the prime authority. The Crown Estates is already involved in discussions of LAGUNA and is supportive. Risk: under-land permissions are more complex due to local land ownerships. Impact: CPL are well used to tricky applications; LAGUNA not very abnormal; Crown Estates supportive of LAGUNA	All agencies are well in contact with CPL. Crown Estates is aware of LAGUNA and supportive. CR is a member of the Boulby Science Executive.
Local Council Authority	Local council: Redcar and Cleveland. www.redcar-cleveland.gov.uk North York Moors	As above	**(ditto - any other obstacles, or positive support)** As above	As above

WP3.4 (2) Template per site

(2) See template used for WP3.1 (e.g. for Boulby)

(2) Socio-Economic Impact Assessment Summary

This table outlines an assessment of the socio-economic impact that the new infrastructure itself will have.

Impact Item	Impact
Job creation	(how will the infrastructure effect local and national employment during and after construction?)
Skills and knowledge Exchange	(how will the infrastructure, during and after construction, impact on the skills base?)
Economy	(how will the infrastructure benefit the local and national economy in general?)
Environment	(what will be the short and long term environmental impact?)
Local services	(what will be the short and long term impact on emergency services?)
Local transport	(what will be the short and long term impact on roads and local transport services?)
Local political profile and status	(what benefits will there be to the profile of the region and what impact will this have?)
Impact on science for the region and nation	(what benefits will there be to the science profile of the region and nation and what impact will this have?)
Impact on society, schools and education	(what benefits will there be to society, schools and education, e.g. through outreach programmes etc, and what impact will this have?)
Other impacts	

WP3.4 Draft Status

LAGUNA, Design Study | 1 (115)
Socio-Economic, deliverable 3.4. | 01.03.2010

LAGUNA Design Study
Socio-Economic Overview Report
for LAGUNA
(Deliverable 3.4)

LAGUNA, Design Study Boulby | 14 (115)
Socio-Economic, deliverable 3.4. | 01.03.2010

ANNEX 1: Socio-economic Impact of LAGUNA at Boulby, Tables 1 and 2

(1) Social, Economic and Political Organisations and People Relevant to the Infrastructure - levels of support, risks and impact

This table collates information on organisations that will be influential in determining whether the infrastructure can or should proceed or not at the site. Priority areas are in yellow.

Type of Social, Economic and Political Organisation or Person Involved	Contact Details	Role and importance	Risk, benefit or impact to project	Status of engagement
Site owners	Cleveland Potash Ltd., Boulby Mine, Loftus Saltburn-by-the Sea, Cleveland, TS13 4UZ UK Contact: D. Pybus Tel: +44 (0) 1287 640140 E-mail: enquiries@clevelandpotash.co.uk	Owners of mine. Responsible for current operations and safety. Support is essential.	**(are all relevant ownership issues clear in law?)** Boulby mine is owned by CPL which is part of ICL. The benefit is strong experience and support for underground construction including access to mining engineers, equipment as well as experience in safety, political and planning issues. Risk: finite lifetime of mine and any conflicts of priorities. These can be mitigated against by sufficient financial backing and partnership. Impact: very high - strong experience and support for underground construction.	Good relations with scientists over 20 years. CPL management closely engaged in development of science and strongly supports LAGUNA and other science. There is a joint executive board involving members from the science community, universities and CPL, with also the Crown Estates (see below).

LAGUNA, Design Study Boulby | 4 (115)
Socio-Economic, deliverable 3.4. | 01.03.2010

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WP3.4 Draft Status

Boulby: needs editing and updating
Canfranc: missing all information but I know it's on the way
Frejus: expand intro section; tables not quite complete
Phyasalmi: missing introductory section; tables not complete
Slanic: missing introductory section
Sunlab: missing some information
Umbria: please can we have a word version (not pdf), also missi
introductory section

Environmental Impact Study

CONTENTS

This is missing from LAGUNA remit but perhaps could be included (one reason for project extension?)

e.g. see outline for Boulby in WP3.1

Annex 6: Draft Socio-economic Impact Analysis

Actions and deadlines now

Action is needed now on <u>liquids</u> (procurement) and <u>Socio-Economic</u> - these are potential critical paths

deadline: end Oct

Deliverable
WP 3.2

Deliverable 3.2 - month 24

3.2	Final report on safety	3	USFD	20	Report	CO	24

A final confidential report defining all safety and environmental issues of the sites

(i) additional infrastructure required for safe operation, in conjunction with the overall safety strategy of the host (road tunnel or mine)
(ii) include possible failure modes of each experiment
(iii) methods by which this risk can be mitigated
(iv) a risk analysis for each site

Task 12 - Final report

subject to commercial confidentiality where appropriate

assessment of:

site specific power requirements, installation of additional transformers for AC, ventilation, atmospheric purification, pumping and chiller systems, underground workshops, surface buildings, experimental areas, cranes and associated heavy duty equipment required during construction.

identify alternative ventilation and cooling schemes for tailored cooling of sensitive components such as the heat exchange on compressors.

identify safety considerations:

- **emergency response equipment**
- **air monitoring**
- **egress procedures**
- **hazardous material handling**
- **dedicated ventilation piping for the removal of boil off noble gas, cryogenic coolants, and toxic scintillator vapour**
- **containment systems for scintillator and liquid noble gas spillages.**

Task 12 - Final report

- emergency management plan
- fire containment procedures and evacuation route
- training required for the underground rescue and emergency response teams relevant to the specific experimental target material
- required steps to contain and dispose of hazardous laboratory materials
- decontamination in accordance with local law

failure modes for each experiment, making an assessment of the severity of each, the potential costs involved, and ways in which each can be mitigated.

Boulby WP3 progress [09/10]

Working on:
Liquids at Boulby
Logistics, tank construction
Safety, vent-bore concept

Liquid Procurement

G7.2 Industrial Partnership for Liquid Procurement at Boulby

To achieve the proposed Boulby specific liquid argon delivery assessment discussion has started between the following companies:

(1) Air Products Ltd. – UK based company expert in production and delivery of cryogenic liquids in the UK and Europe (also USA and Asia).
(2) Technodyne Ltd. – Design engineers expert in large LPG tank design
(3) CPL – the mine company at Boulby, expert in the logistics of transportation of equipment underground..

(1) potential cost savings from proximity of local supplies of liquid argon from nearby Tees industry and Air Products plants at Hull: The location of Boulby close to existing Air Products and Linde/BOC liquid argon production at Tees, Hull and Carington, plus access to a dedicated port, rail and A-class roads, provide an estimated saving of 30-50% in argon costs over other locations in Europe (AP private communication).

The vast pertro-chemical industry in nearby Tees has several companies that can produce liquid argon and scintillator materials. The mine owns a rail line in that direction. Fig. G7.3.1 shows the proximity of the BOC plant to Boulby, about 30 km.

Several conversations with Air Products and BOC

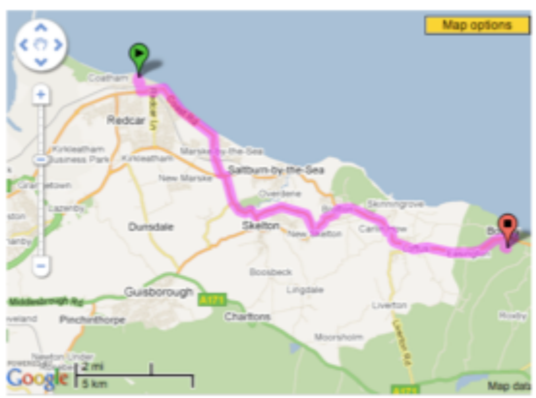


Fig. G7.3.2 Proximity of the Air Products plants to Boulby, Hull is ~150km.

Safety vent concepts

AAE designing narrow shaft for supply and for ventilation direct to the LAGUNA site

G4.6.2 Vent Bore-hole Option Design

Design of the optional vent bore-hole has been discussed with Brittish Drilling and Freezing, Ltd. who we do a lot of work with AAE Ltd. This company is expert in large deep boreholes for the gas and oil industry. The suggested position of the hole is show in Fig. G4.6.1.

Vent-bore option

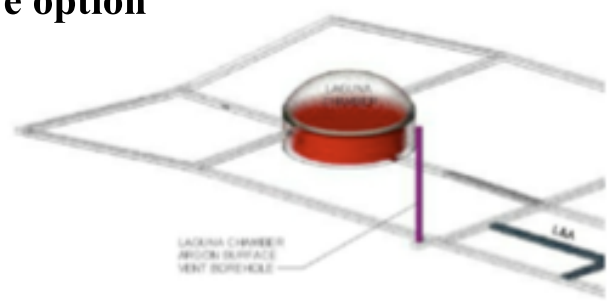


Fig. G4.6.1 Suggested position of vent bore hole

A 1500m deep hole on land would cost ~£2M for a 12" finished hole size. Such holes have been drilled in the area before. A size up to about 1.5m excavated hole size with heavy casings can also be achieved with special machinery the cost nearer £5M.

Liquid Transport

- Boulby is used to pumping liquids down from surface, e.g. 300 tons/hr pipeline exists for slurry

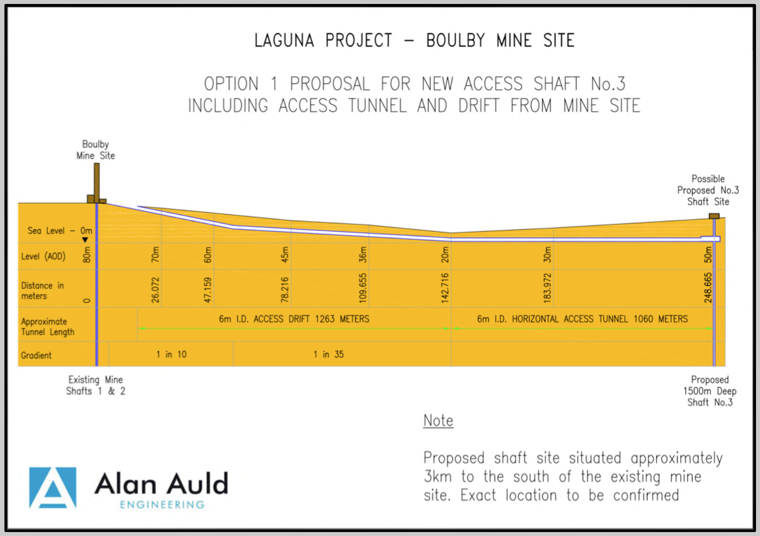
- Liquid Argon or scintillator delivery to Boulby looks feasible: CPL have dedicated rail link to nearby port and to Tees including ICI major chemical works, 20 miles away. ICI likely can produces LAr and Scintillator components? (needs confirmation)

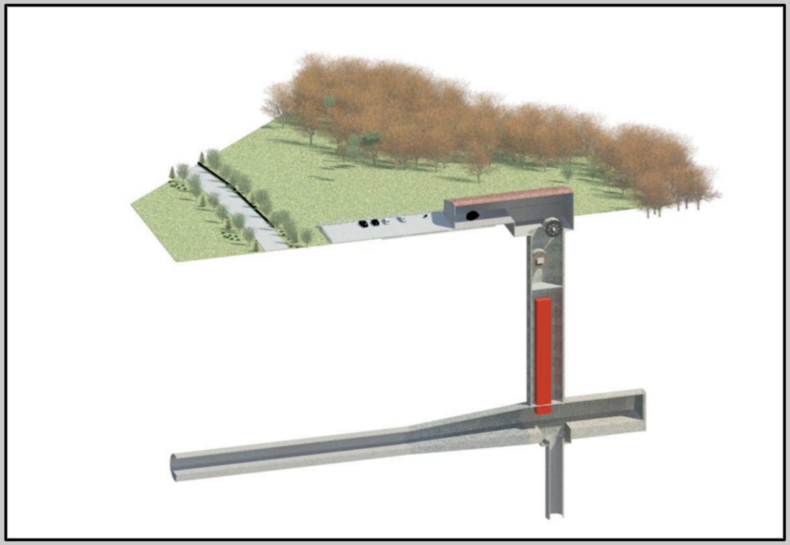
- Water supply and purification also possible underground - strong capability to pump and deal with water (megatons)

- Underground (and above ground) workshop experience for tanks is good

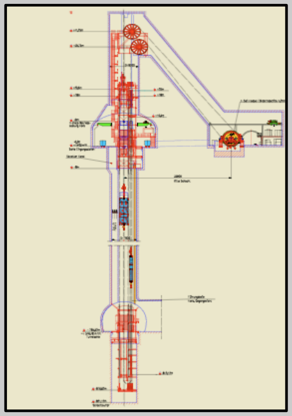
New Shaft Proposal Option

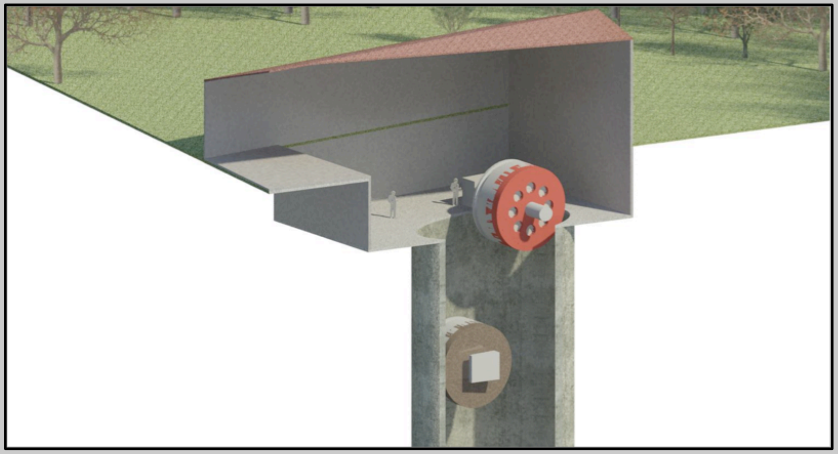
- **Additional option designed by AAE - special design to pass planning**
- **Timeline (2+ years); Cost share (TBD): €15M (CPL), €15M (LAGUNA)**





- **Based on Goddard base tunnel**





WP3 - Boulby Next Steps

(1) More work on local/regional political support:

-New Government is re-shaping Regional Development Agencies

(2) Costing of liquid procurement (work with BOC/AP)

(3) safety issues: vent-bore costs