Water containment and PMT deployment designs for the LBNE water detector

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BNL

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Outline

- Introduction to the LBNE water Cherenkov Detector
- Development of the water containment system
- Development of the PMT deployment system

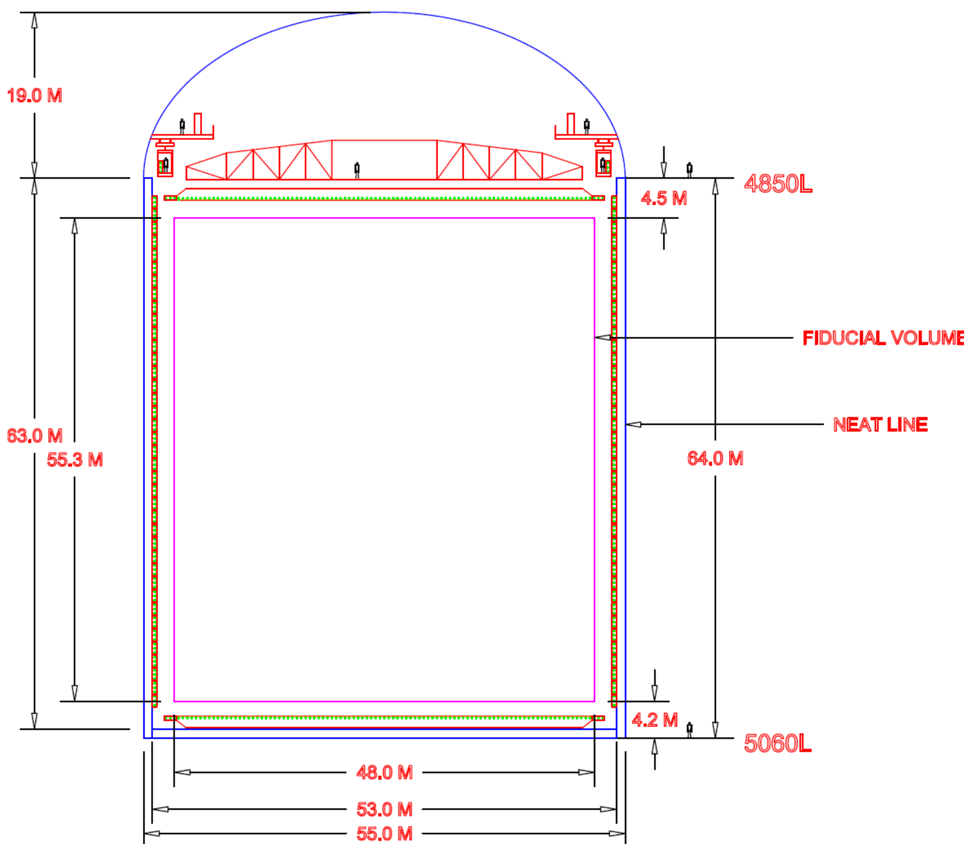
Development of the LBNE Water Cherenkov detector design

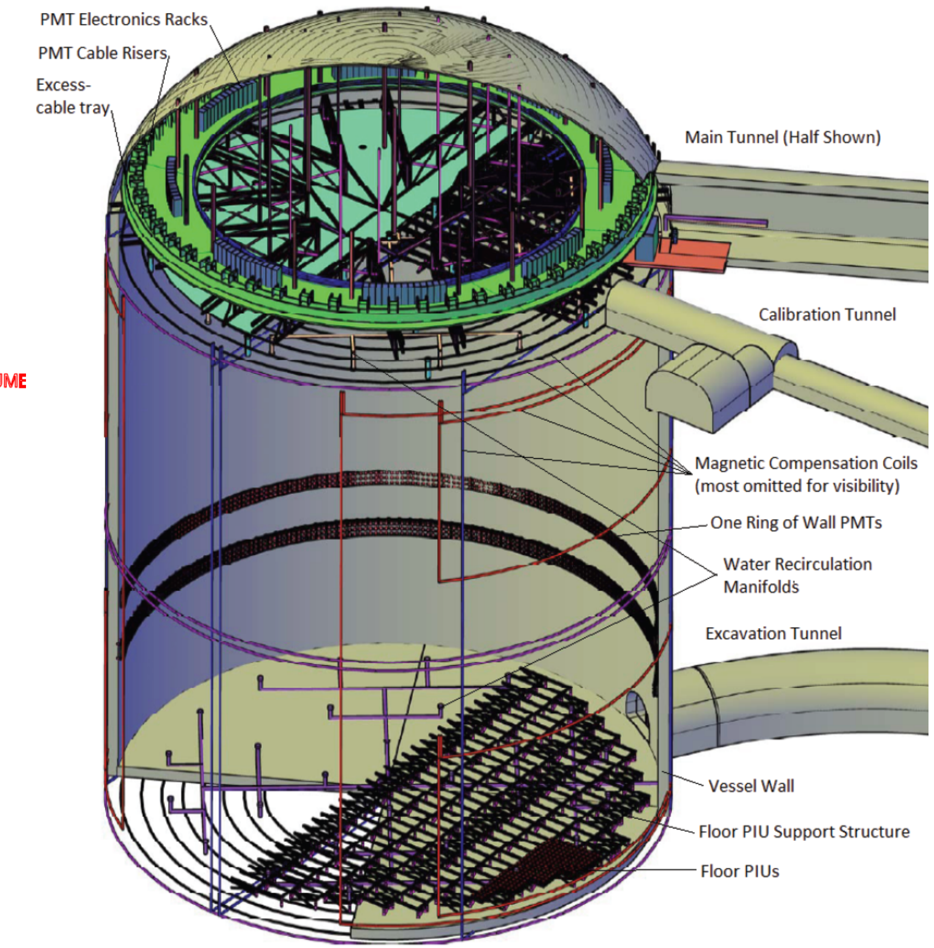
- Initial detector design was based on multiple 100 kt fiducial volume detectors.
  - Before detailed geotechnical investigations were completed the 55m span of the 100 kt excavation was taken as a reasonable limit.
  - As the technology decision in LBNE was not taken (H_2O vs LAr) the option of one H_2O and one LAr was adopted as a baseline.

- The final water Cherenkov detector design was a 200 kt design.
  - Geotechnical investigations indicated the 65m span was constructible.
  - Cost evaluations indicated a multi-technoligy design was excluded

Initial LBNE Water Cherenkov Design

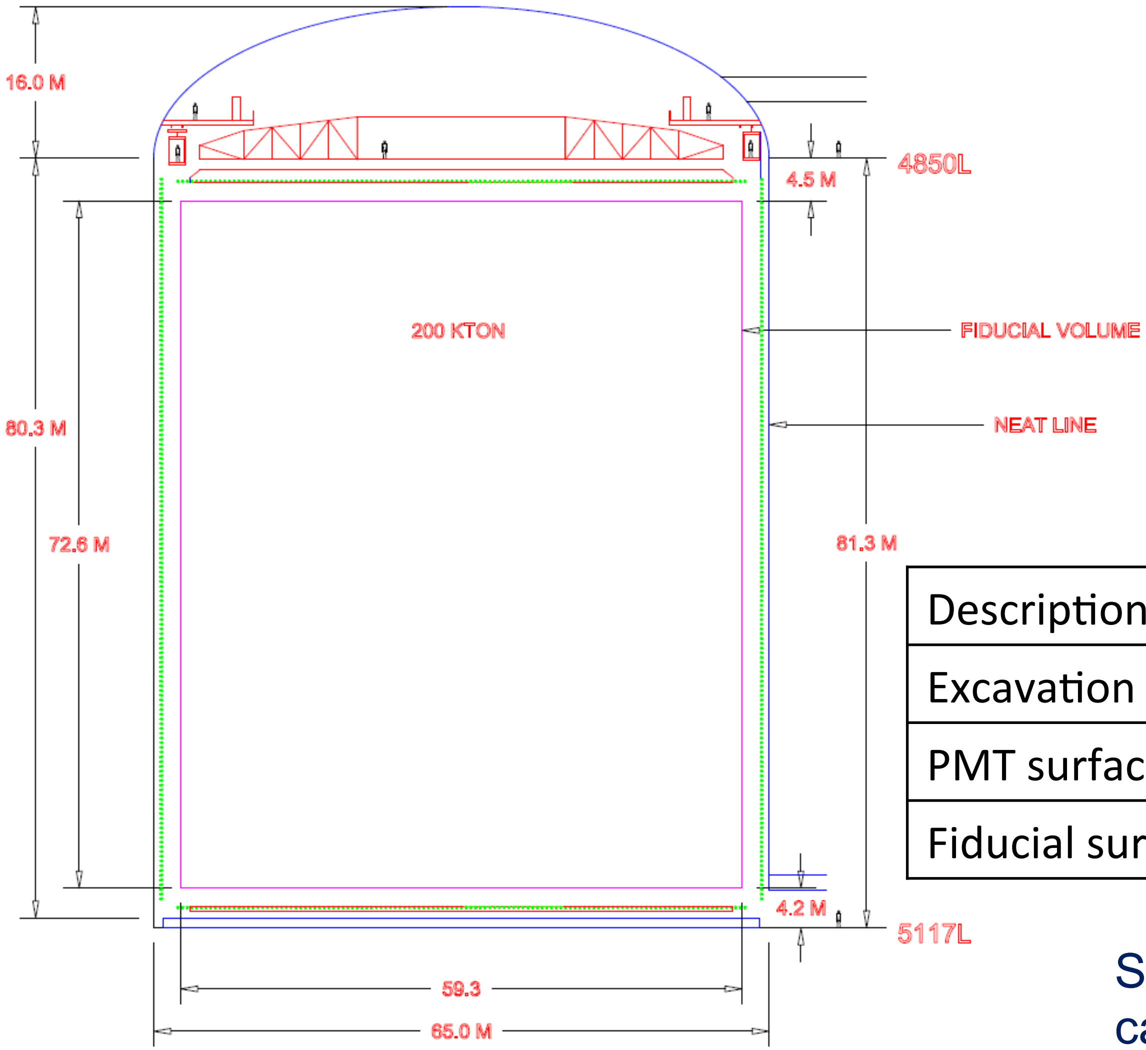
Region	Description	Diameter (m)	Height (m)	Volume (m^3)
Fiducial	Detector fiducial volume	48	55.3	100,000
PMT Apex	Volume defined by apex of all PMTs	52	59.3	126,000
Sensitive	Volume defined by equator of all PMTs	52.21	59.51	127,000
Water	Water volume	53	62.6	138,000
Vessel	Vessel volume	53	63	139,000





55m x 63m excavation

Final LBNE Water Cherenkov Detector



- Final design called for larger span and depth to make a single 200kt fiducial volume detector

Description	Diameter m	Height m
Excavation Dia.	65	80.3
PMT surface Dim.	63.3	76.6
Fiducial surface	59.3	72.6

See Golder CD1 Report for cavern design
(DocuShare Collection-15391)

Final LBNE Water Cherenkov Detector

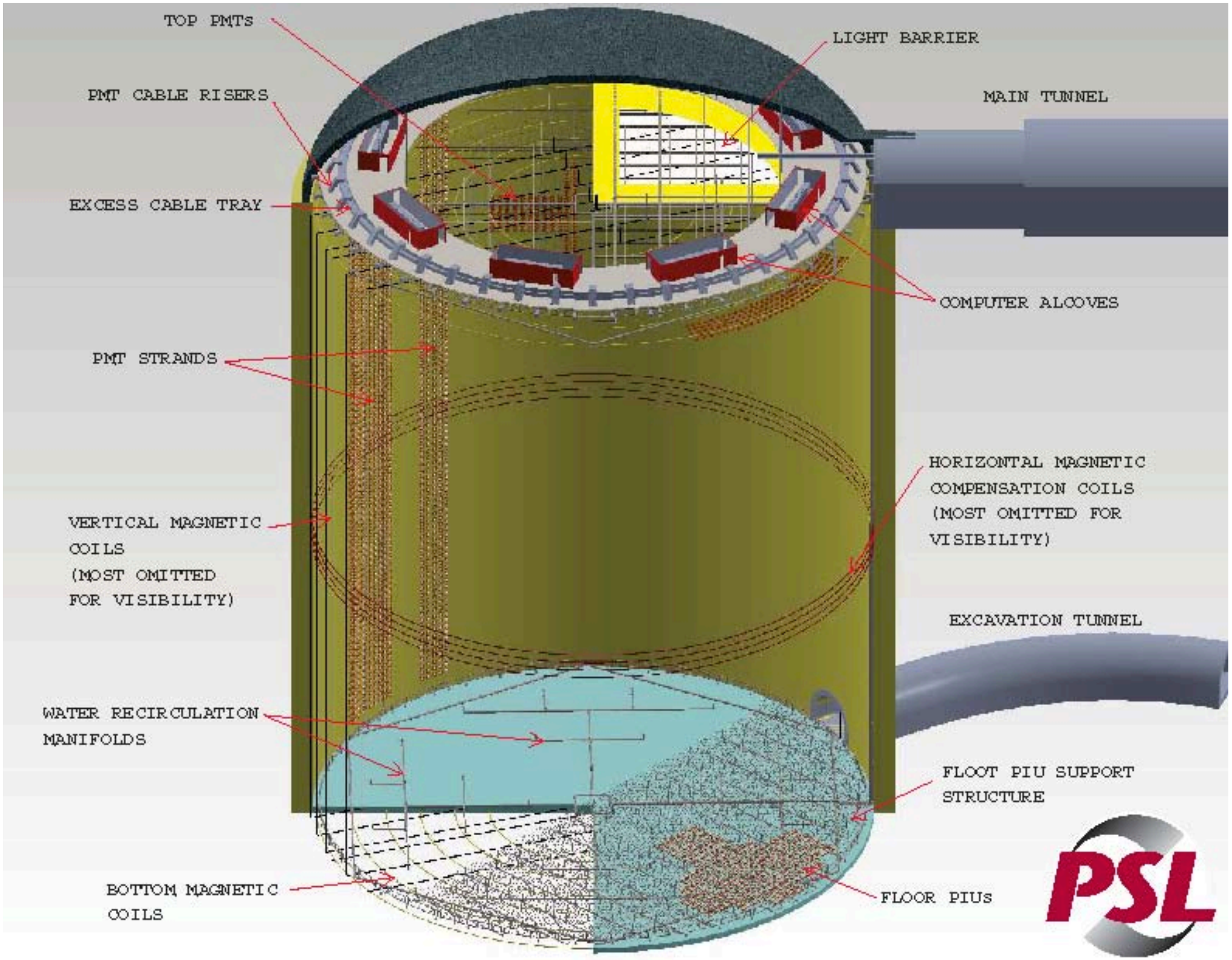


Figure 2–1: Overall 3D model of 200 kTon detector

University of Wisconsin and PSL were responsible for the water containment system design.

Contact Farshid Feyz at PSL.

Water Containment

- The water containment system was defined as the construction going from cavern excavation to the ultra-pure water surface.
  – It included the membrane in contact with the water and any concrete needed for support
- Design went through various design steps utilizing several architectural engineering companies.

Design process for the water containment system

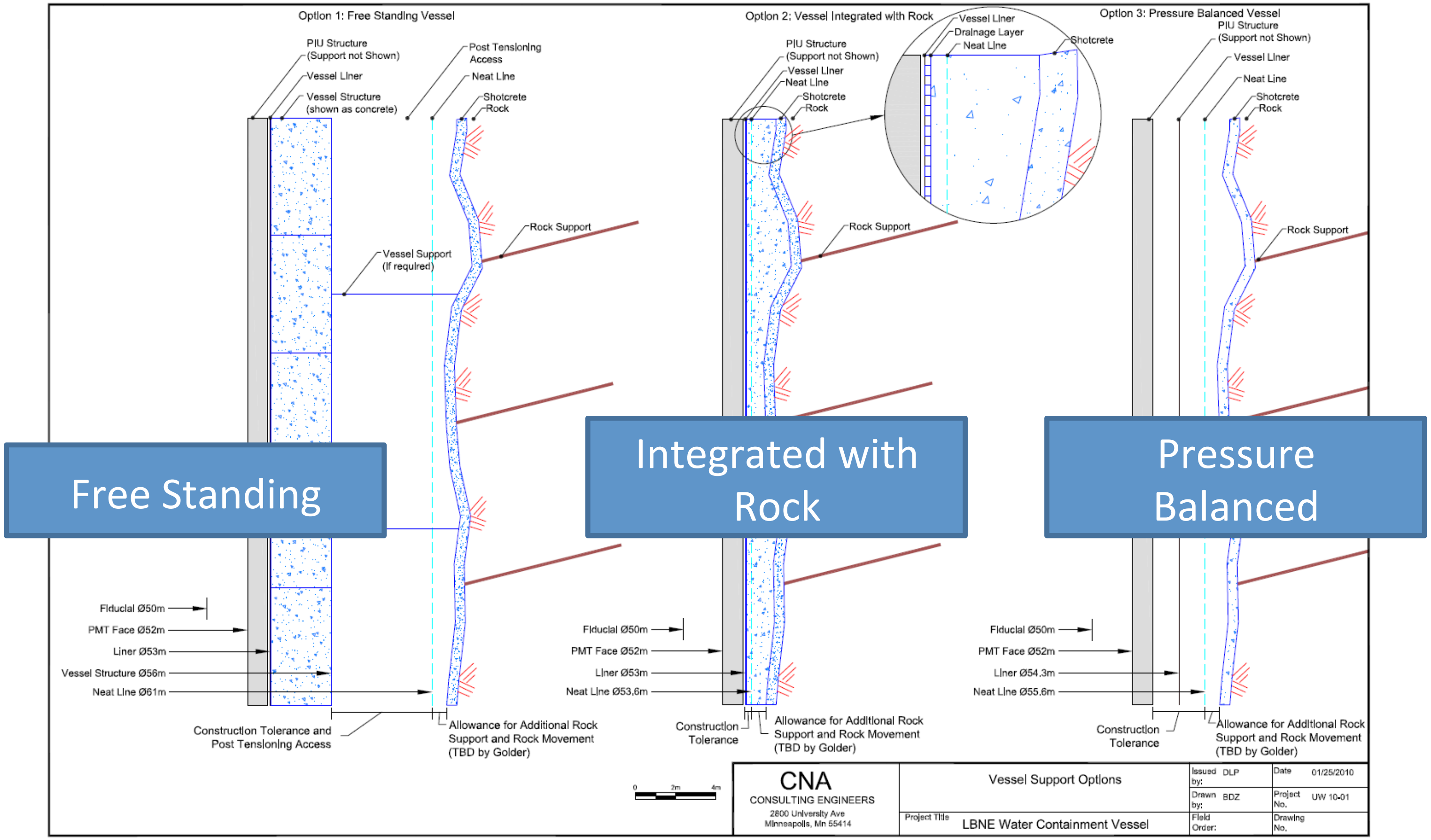
- Initial design contract issued to a team of A&E companies. Contract had 3 phases.

> - CNA Consulting Engineers—project management, technical coordination within the design team, coordination with LBNE, coordination with DUSEL cavern designers, sealing and lining of rock excavations, sealing and lining of free-standing water containment vessels, WBS development and maintenance, concept evaluation criteria, constructability review, NSF experience, DOE experience, report preparation
> - Hatch Mott MacDonald—risk assessment, construction cost, construction schedule, material handling, constructability, underground science experience
> - Simpson Gumpertz & Heger—structural analysis, seismic analysis, sloshing, sealing and lining, DOE experience

2 CNA reports
1 Golder report

- An additional company Golder was contracted to evaluate the CNA design and propose changes.

Concepts Studied initially by CNA

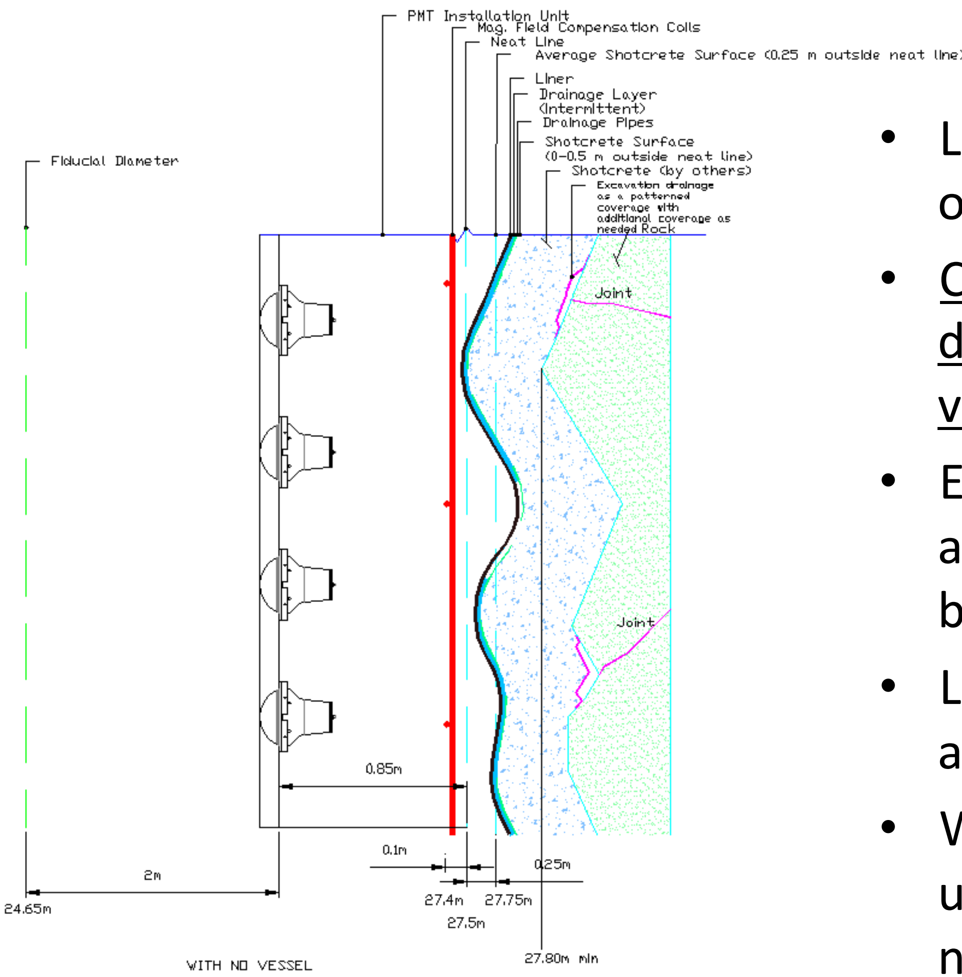


Eventually rejected as it required a much larger excavation

Evolved into two designs. Membrane on shotcrete and membrane on reinforced concrete

Development stopped when leakage estimates indicated other designs viable

Rock Integrated Option 2C

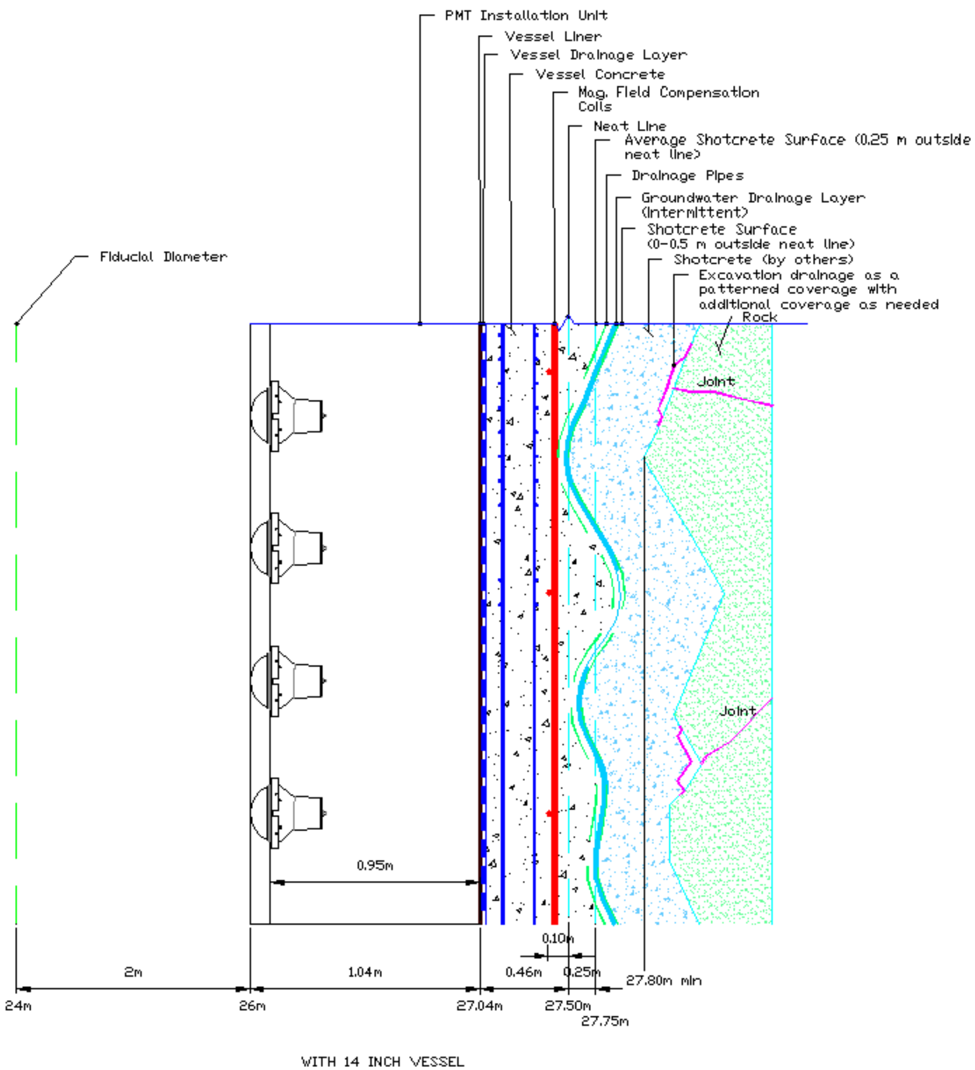


- Liner and drainage directly on shotcrete
- Cavern design team has determined rock motions are very small so this is feasible
- Estimates indicated that acceptable leak rates could be achieved.
- Lowest cost option that met all requirements.
- Wanted additional studies to understand better the necessary specification on wall flatness.

CNA Engineers

Baseline design for LBNE

Rock Integrated Option 2A



- 35 cm reinforced concrete vessel
- Alternate solution

Advantages

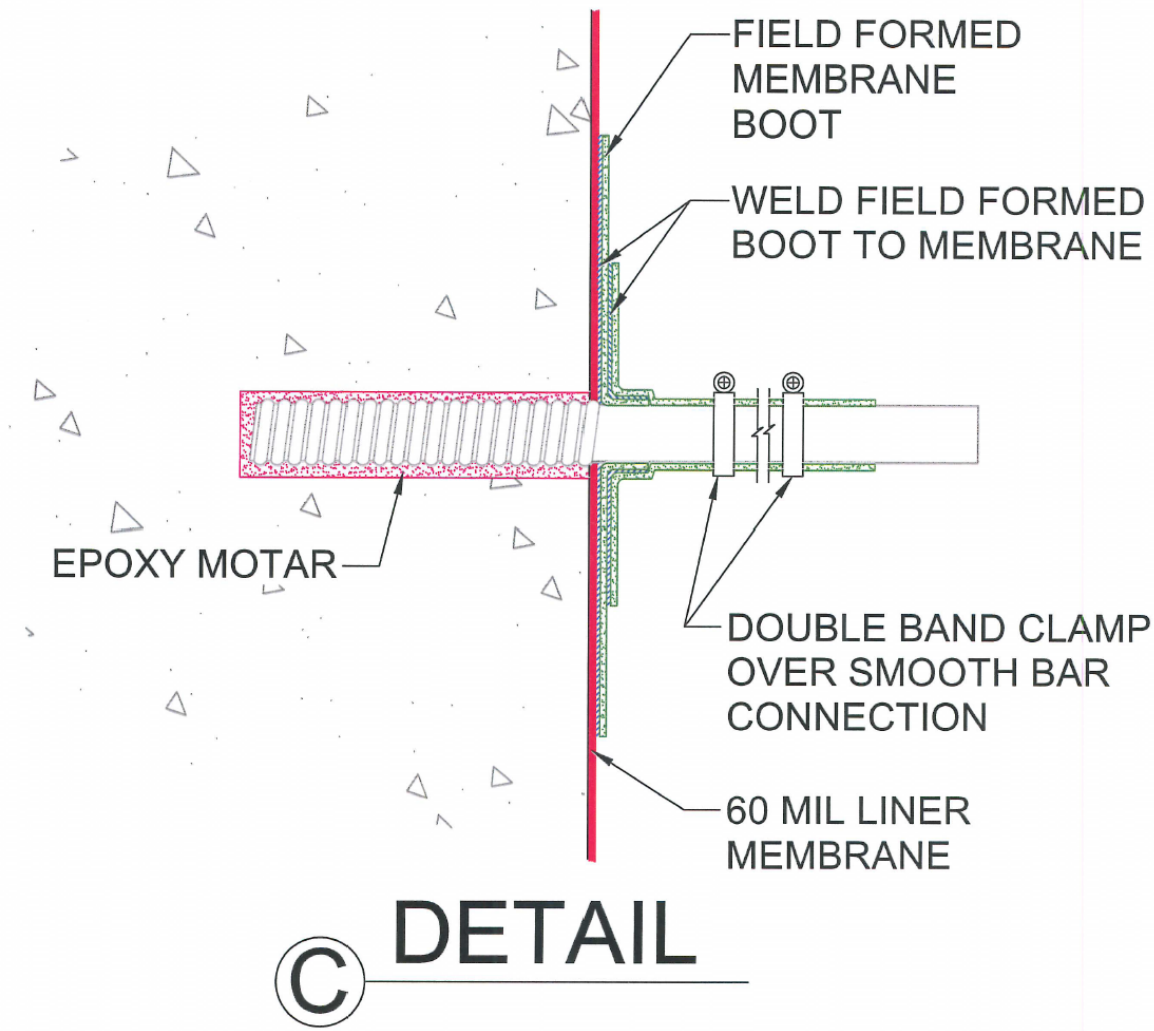
- Lower expected leak rate
  - Leak free design
- Lower risk as the concrete gave essentially a double layer water seal
- Easier liner installation
- Easier installation of magnetic coils

Disadvantage

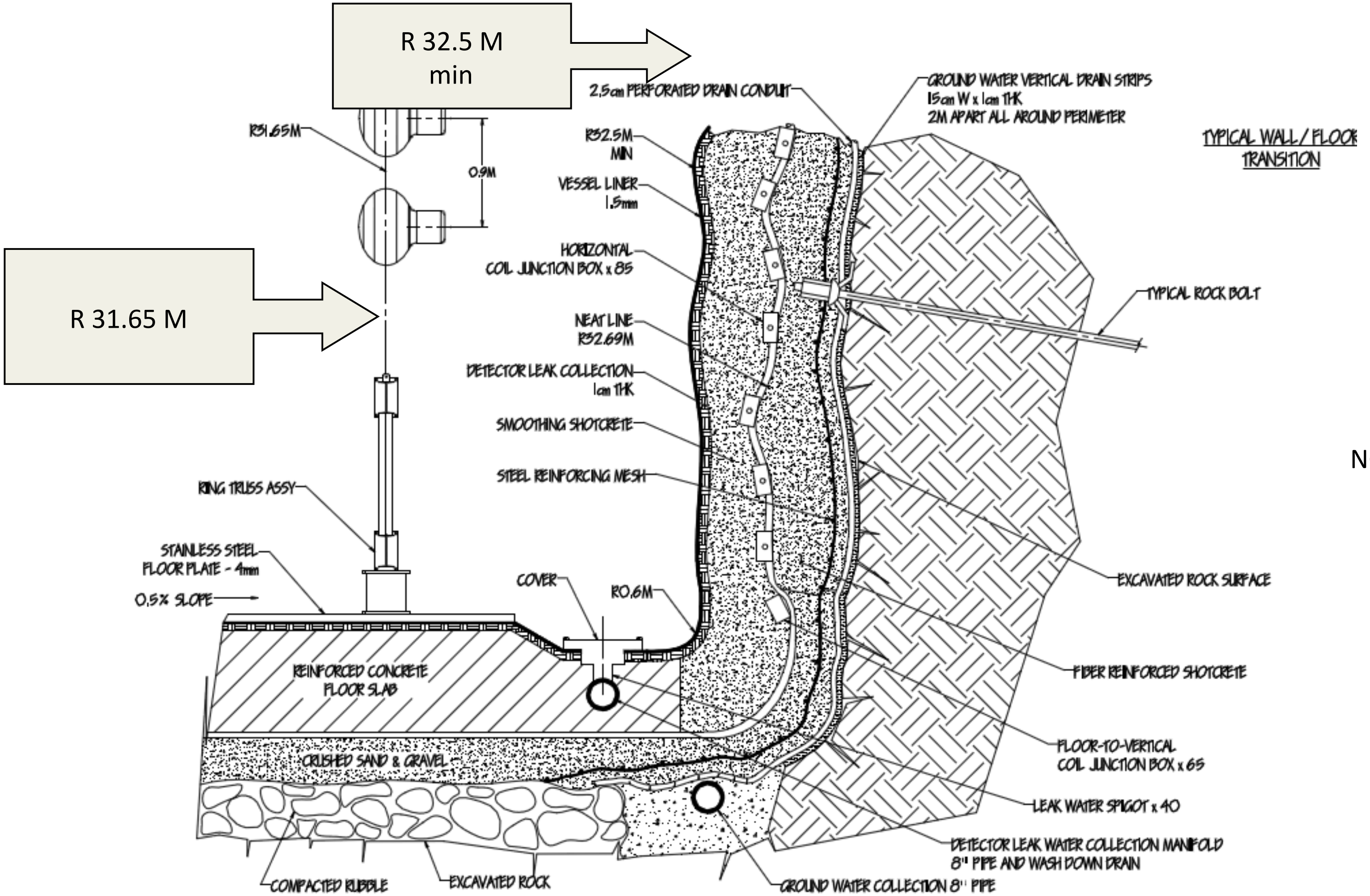
- Higher cost – 10M$

CNA Engineers

Typical Liner Penetration



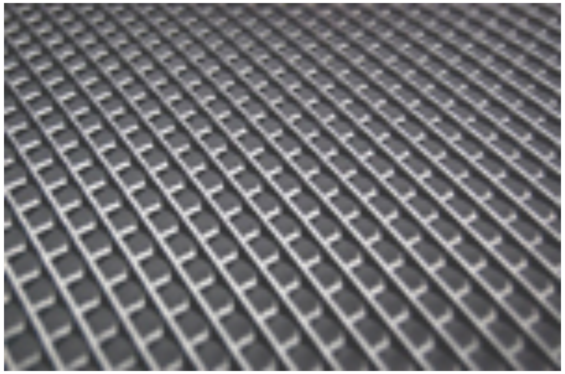
Wall-Floor Interface (one possibility)



NOT TO SCALE

Liner Material Choices

- Baseline (Leak Free Design):
  - Liner: 2.5 mm conductive LLDPE (Linear Low Density Poly Ethylene) Geomembrane
  - LLDPE is flexible and compatible with UHP water
  - Drainage layer: 8 mm Geocomposite (Geonet)



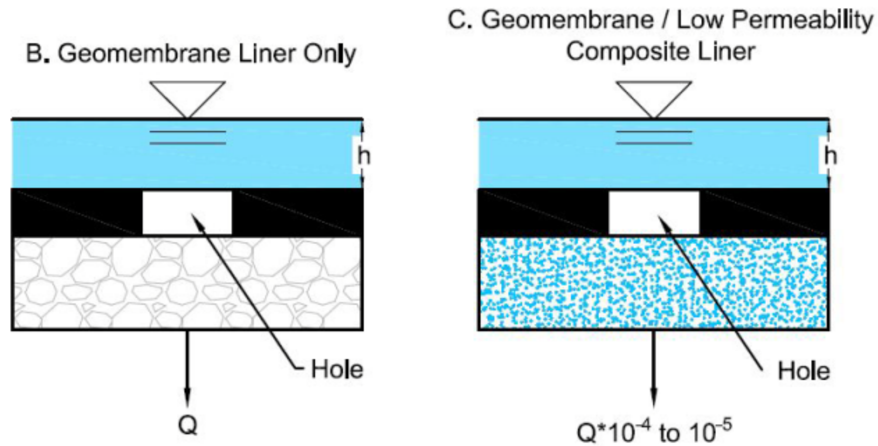
Gundle/SLT Environmental, Inc.

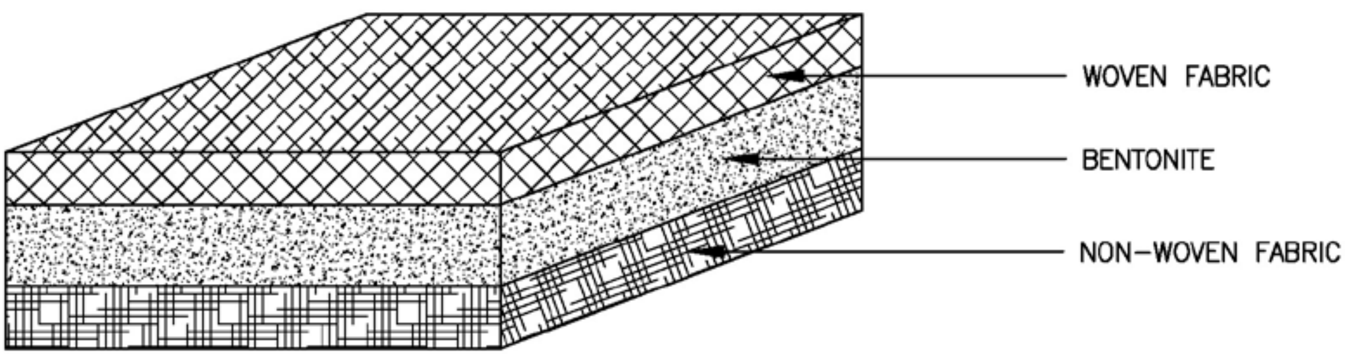
- Alternate (Zero Leak Design):
  - Liner: 1.5 mm conductive LLDPE Geomembrane
  - Secondary layer: Restricted Flow GCL or none

Geosynthetic Clay Liners (GCL's) are composites that combine geotextile outer layers with a core of low-permeability sodium bentonite clay.

No Drainage Layer Concept
"Zero Leak" Design

- Minimize effects of leaks by not allowing free flow
- Do not collect whatever does leak
- Let combine with groundwater collection



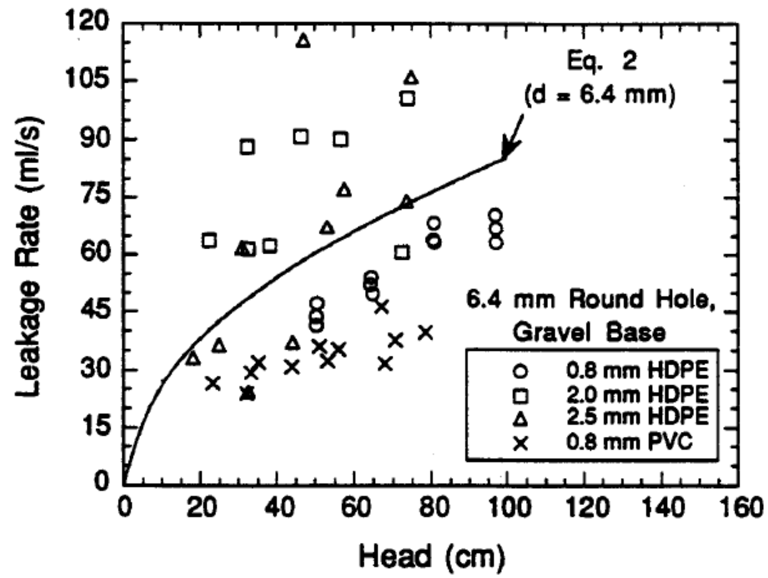


Golder Assoc.

Leakage Rates from Geomembrane Liners Containing Holes

C.H. Benson
University of Wisconsin
J.M. Tinjum
University of Wisconsin
C.J. Hussin
University of Wisconsin

Estimating Leak Rates for Liner



- Leakage is, of course, dependent on size and quantities of defects
- Maximum 5 defects per hectare is an achievable number based on advice from experts
- This gives about 12 total defects for liner
- Table below is an estimate based on Benson method

Note: Fill rate is about 1m^3 per minute

	No. of defects	Defect dia (mm)	Defect depth (m)	Leakage (m^3/day)	Level drop (m/day)	Drainage type
Median Rate	6	1	5 at 40, 1 at 80	7.4	0.002	Free flow
Median Rate	6	2	5 at 40, 1 at 80	29.8	0.009	Free flow
Maximum rate	12	1	All at bottom	19.7	0.006	Free flow
Maximum rate	12	2	All at bottom	78.7	0.024	Free flow
Best estimate	12	1	Distributed	14.1	0.004	Free flow
Best estimate	12	2	Distributed	56.3	0.017	Free flow

Liner Penetrations

Table 2: Anticipated Geomembrane Liner Penetrations, 200kT WCD

Description	Location	Quantity	Comment
Magnetic Compensation	Floor	0	Assume mag comp coils within wall. Assume 500 if in water.
Magnetic Compensation	Wall	0	Assume mag comp coils within wall. Assume 4,000 if in water.
Floor Water Manifolds	Floor	210	
Upper Outer Zone Water Manifold	Wall	110	
Pump Casing	Wall	136	
Riser to/from Floor Manifold	Wall	68	
PIU Support	Floor	500	
Ring Truss	Floor	128	
Mast Climbers	Wall	1,000	Could be up to 1,300.
Estimated Total Penetrations	**2,152**		
Total without Mast Climber	**1,152**		Assume mast climber done before liner installed.
Maximum Penetrations	**6,952**		Includes mag comp coils in water, upper estimate for mast climbers.

Number of penetrations through the liner can dominate the expected leak rate and influence the construction decisions

Golder Recommended designs

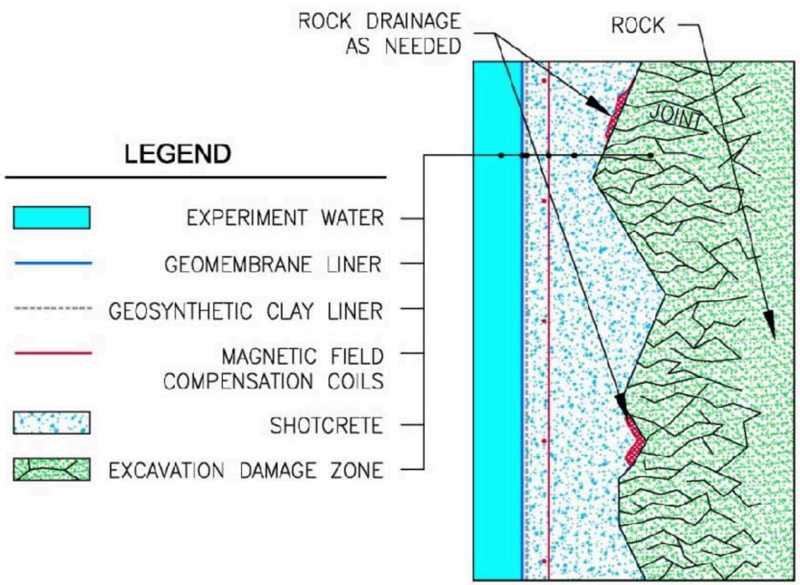


Figure 5: Typical Wall Section of Golder Concept A

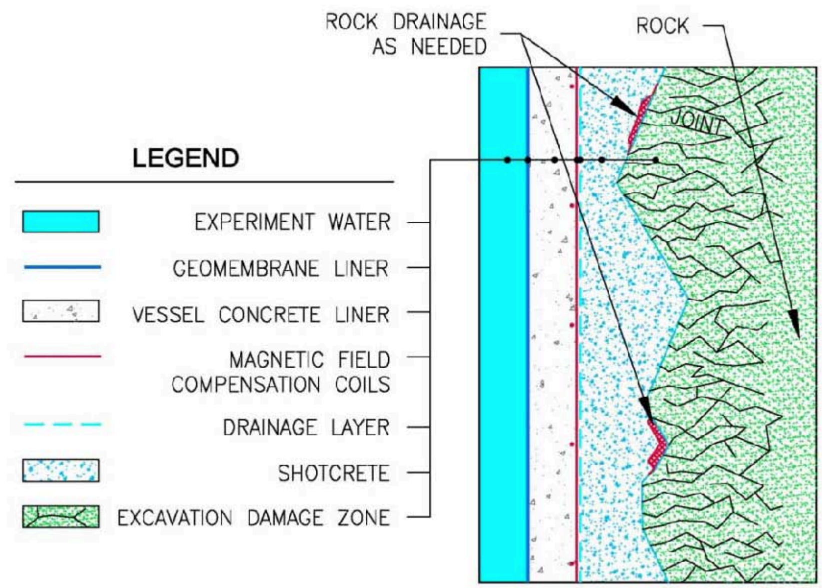


Figure 6: Typical Wall Section of Golder Concept B

- Smooth layer of Shotcrete
- No dranage layer betewwn shotcrete and membrane
- Use synthetic clay under the membrane to limit water migration
  - Clay layer reduced leakage by 10^3

- Poured reinforced concrete layer
  - Reduces leakage by factor 10^3 - 10^4
- Membrane in direct contact with concrete
- Drainage outside convrete vessel

Vessel liner open questions

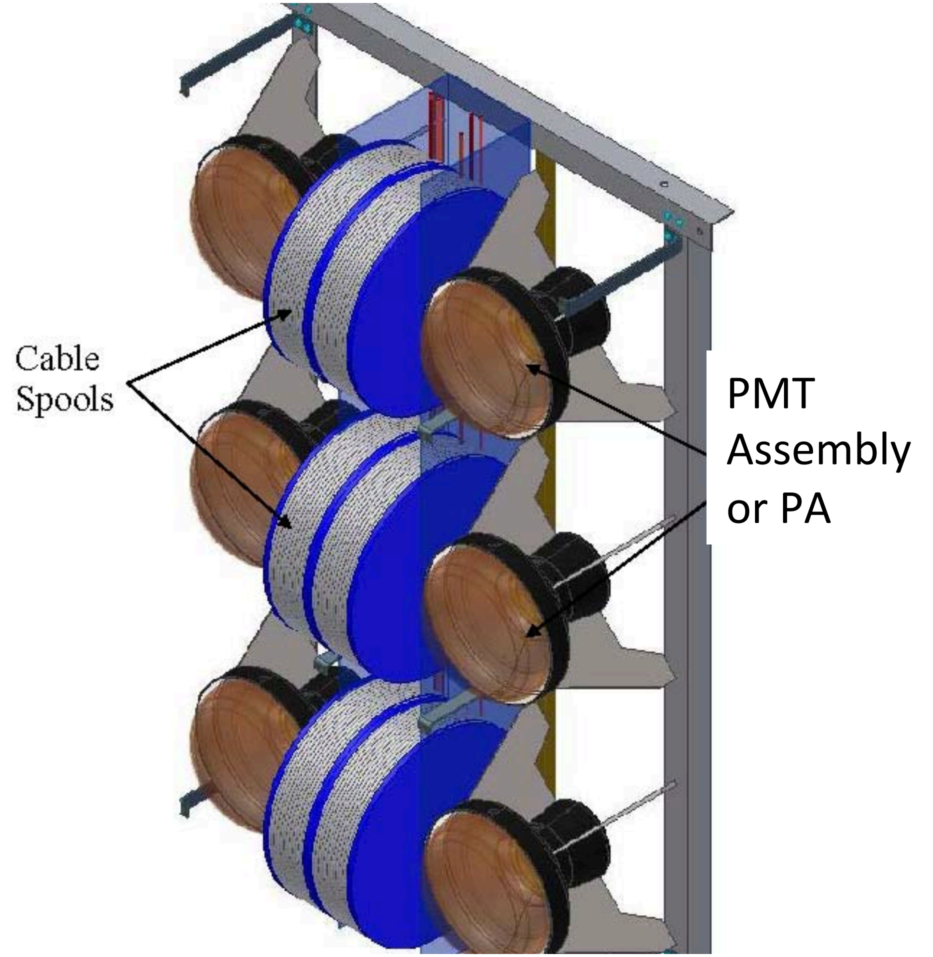
- Is synthetic clay compatable with ultra pure water?
- What is the best estimate for the leak rate?
- How many wall penetrations are needed?
- If a rough surface is tollerated how rough?

Terry Benson PSL, Farshid Feyz PSL and David Warner Colorado State are the best contacts

PMT DEPLOYMENT SCHEME

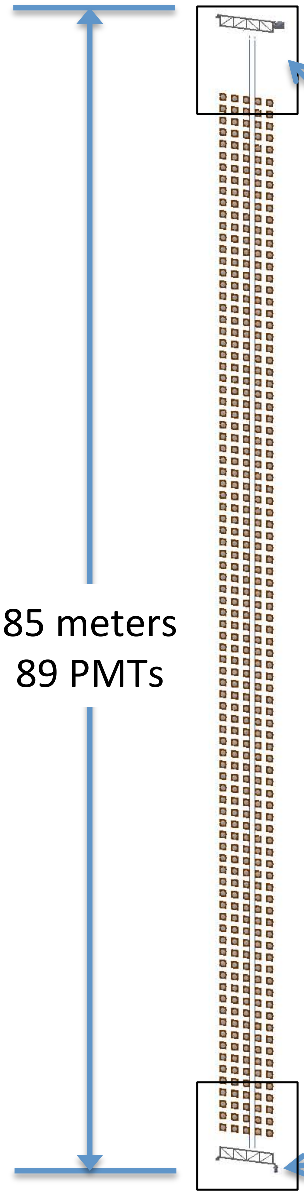
First PMT mounting concept

- Use rigid frame to hole 6 PMTs
- Mount to wall at 4 corners
- Metal straps to hold PMTs in place
- Advantages
  - Simple modular design which is easy to cost
- Disadvantages
  - Large number of wall penetrations and a fairly large amount of material

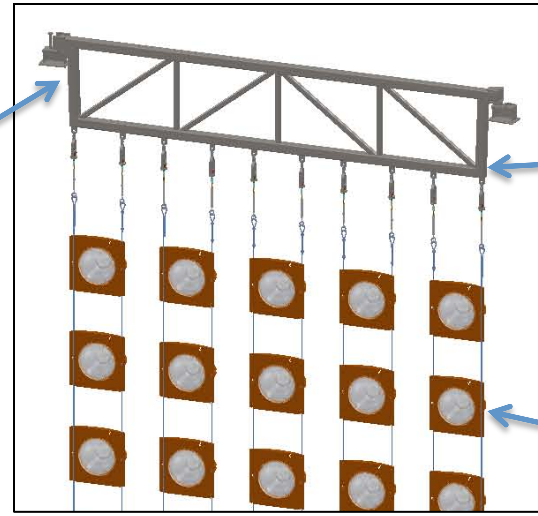


100 kt detector had 6000 penetrations just through the walls. Reviews recommended minimizing liner penetrations

Final PMT Deployment Concept



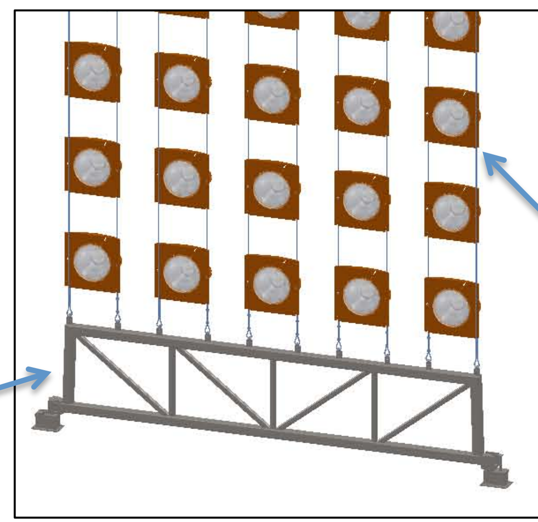
Upper Ring Truss



Top mounting includes turnbuckle and tensioning spring

PMT Assemblies

Attach PMTs to cables eliminating most wall penetrations

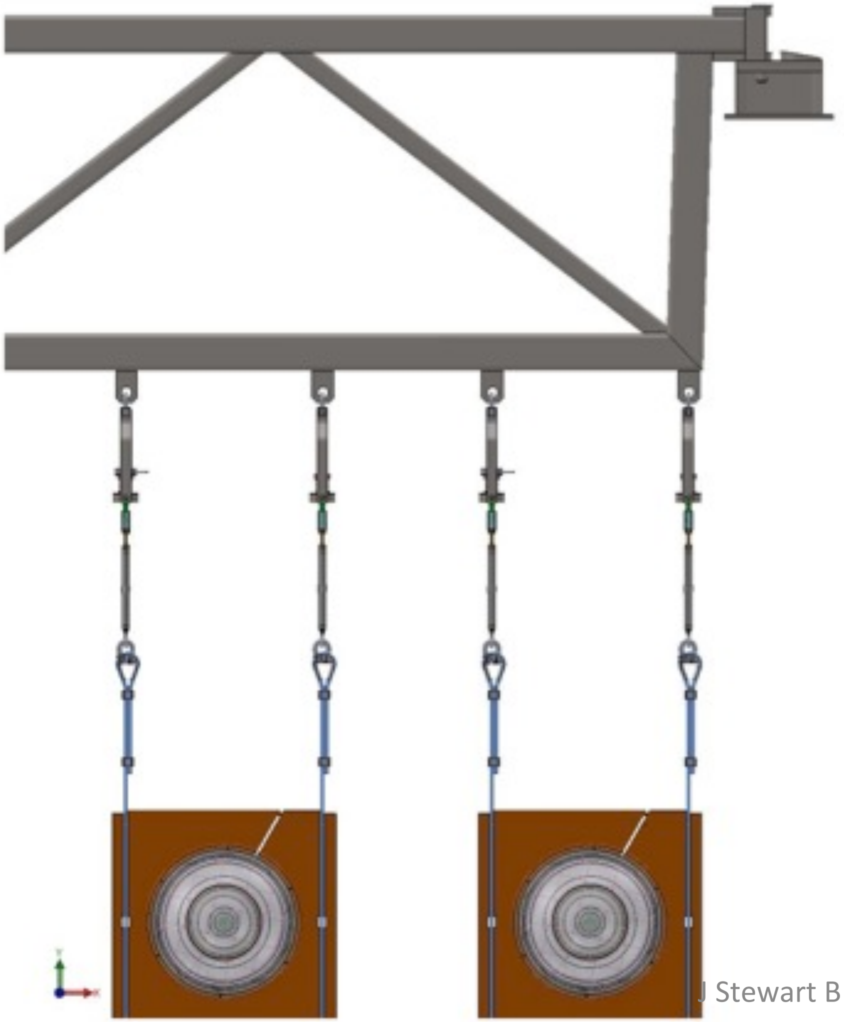


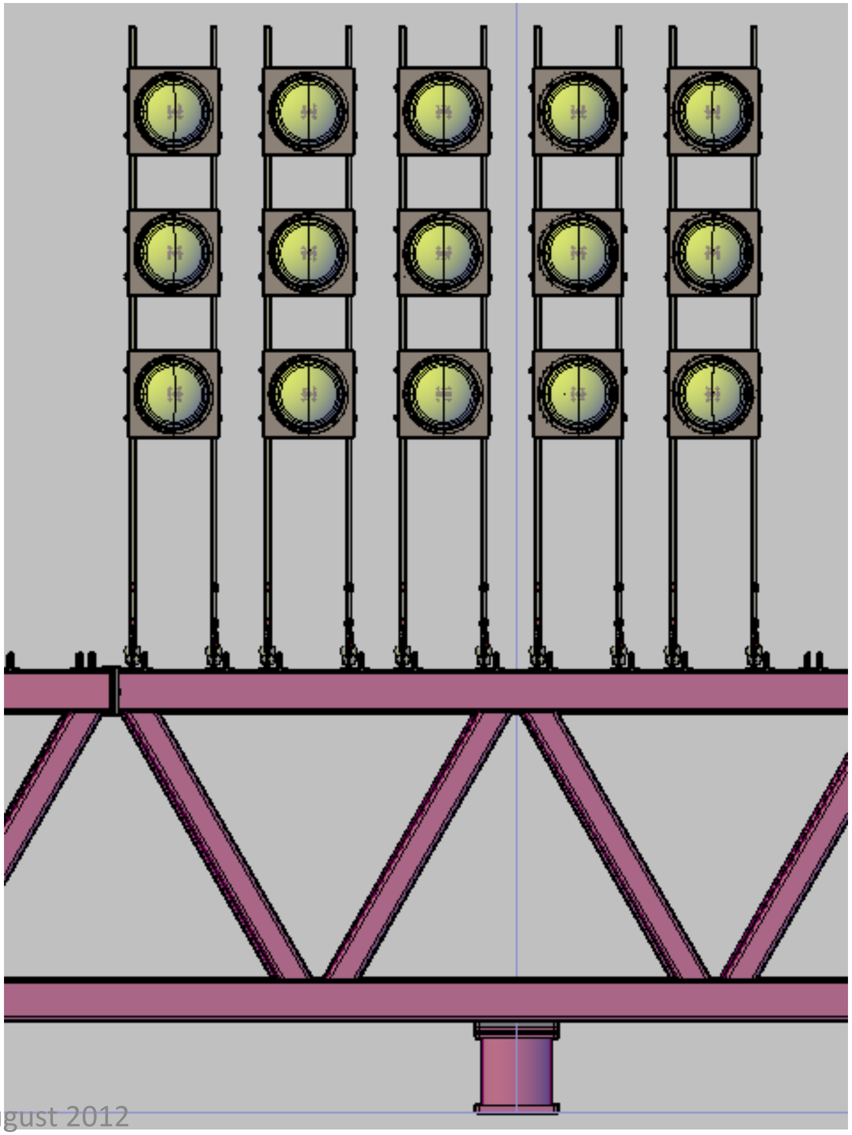
PMT assemblies attach to stainless steel cables

Lower ring truss

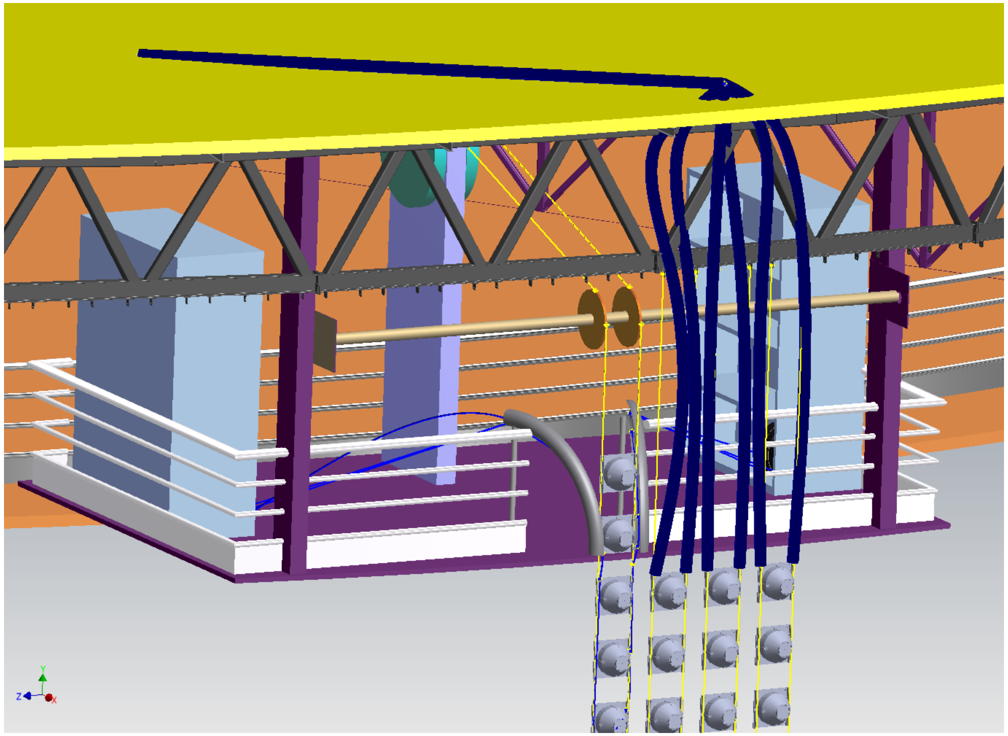
PMT Installation Unit - PIU

Top/Bottom Connection Detail

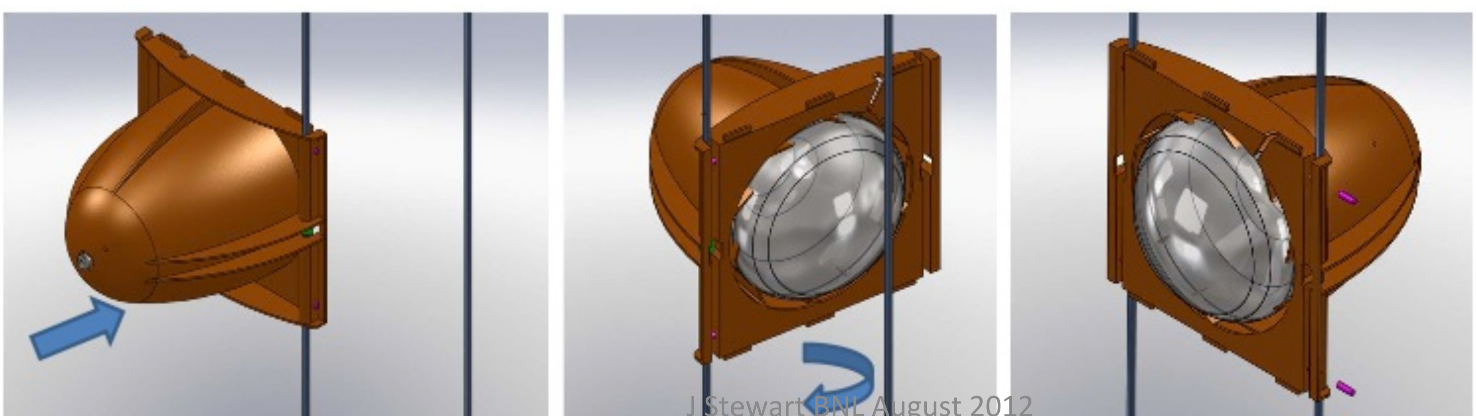




Linear PIU Installation

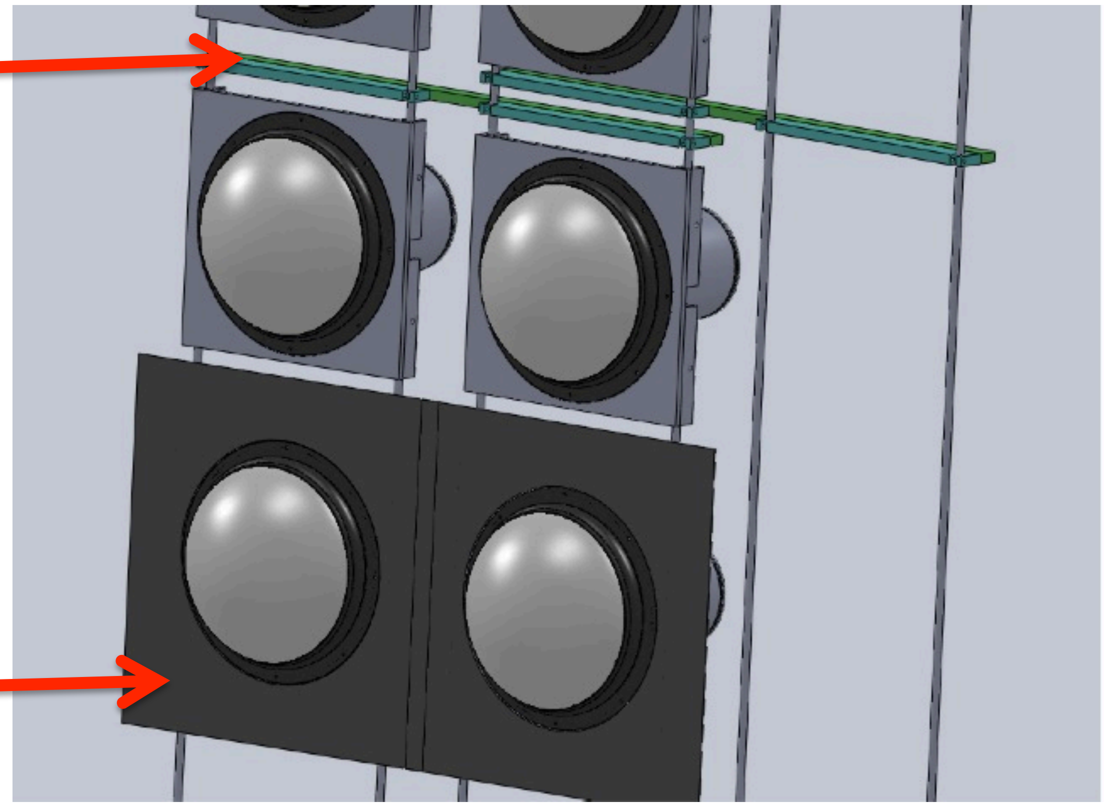


- Linear PIU installation is conducted from 3 installation platforms supported from the upper deck.
- Winches are used to deploy cable from reels
- PMT cables are stored in racks during installation. Cable pays out of the racks as the strings are deployed
- PAs are attached to the strings as they are lowered
- Weights and guide cables are used to align the PAs during installation.



Stabilization Bars and Light Barrier Sheets

- Linear PIU stabilizing bars were designed to control bowing due to buoyant forces.
- These bars join two or more neighboring PIU strings, fixing their distance and angular orientation with respect to each other.



- Plastic sheets form light barrier and are installed either from Gondolas or boats

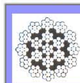
Linear PIU Support Cable Candidate

- Candidate cable was selected
- Initial material tests were unfavorable
  - Rapid contamination
- Started investigating cleaning procedures
- Work unfinished
- Alternate would have been chain

SF37597 TECHNICAL DATA SHEET

LOOS & CO

PRODUCT TECHNICAL DATA SHEET



19X7

SF37597
MILITARY WIRE ROPE FLEXIBLE
PREFORMED STAINLESS 302/304

Product Type	WIRE ROPE
Type Description	NON-ROTATING, HELICOPTER RESCUE
Commercial/Military	MILITARY
Flexibility	FLEXIBLE
Strand Construction	19X7
Core Type	
Material	STAINLESS
Material Type	302/304
Diameter Fraction Inches *	3/8
Diameter Decimal Inches *	.3750
Diameter MM *	9.525
Minimum Break Strength in Lbs.	10800
Minimum Break Strength in Kilograms	4898
Approximate Weight per 100 Feet in Lbs.	24.3
Bare/Coated	BARE
Plastic Jacket Type	
Jacket Color	
Origin	DOMESTIC
Qualifying Specification	MIL-DTL-83140, LASTEST REVISION, TYPE I, FOR AIRCRAFT RESCUE HOIST AND CARGO HANDLING

Linear PIU Support Cable Candidate

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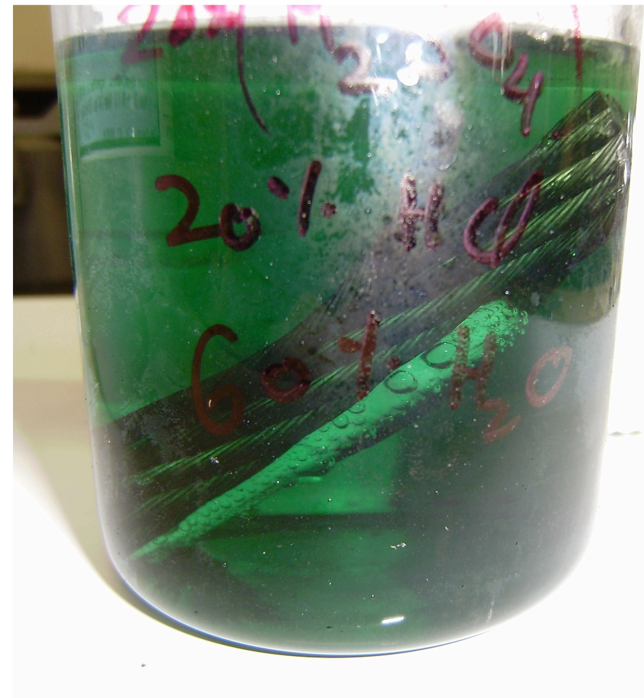
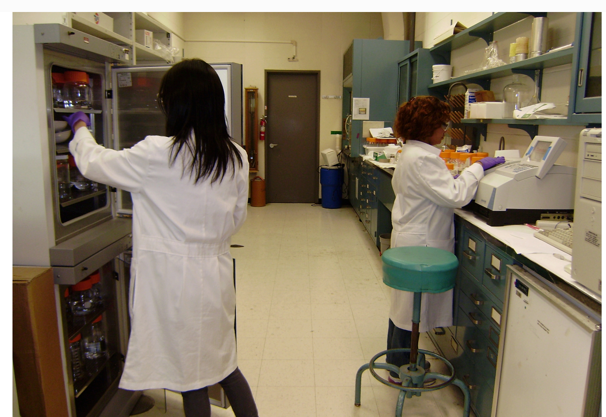
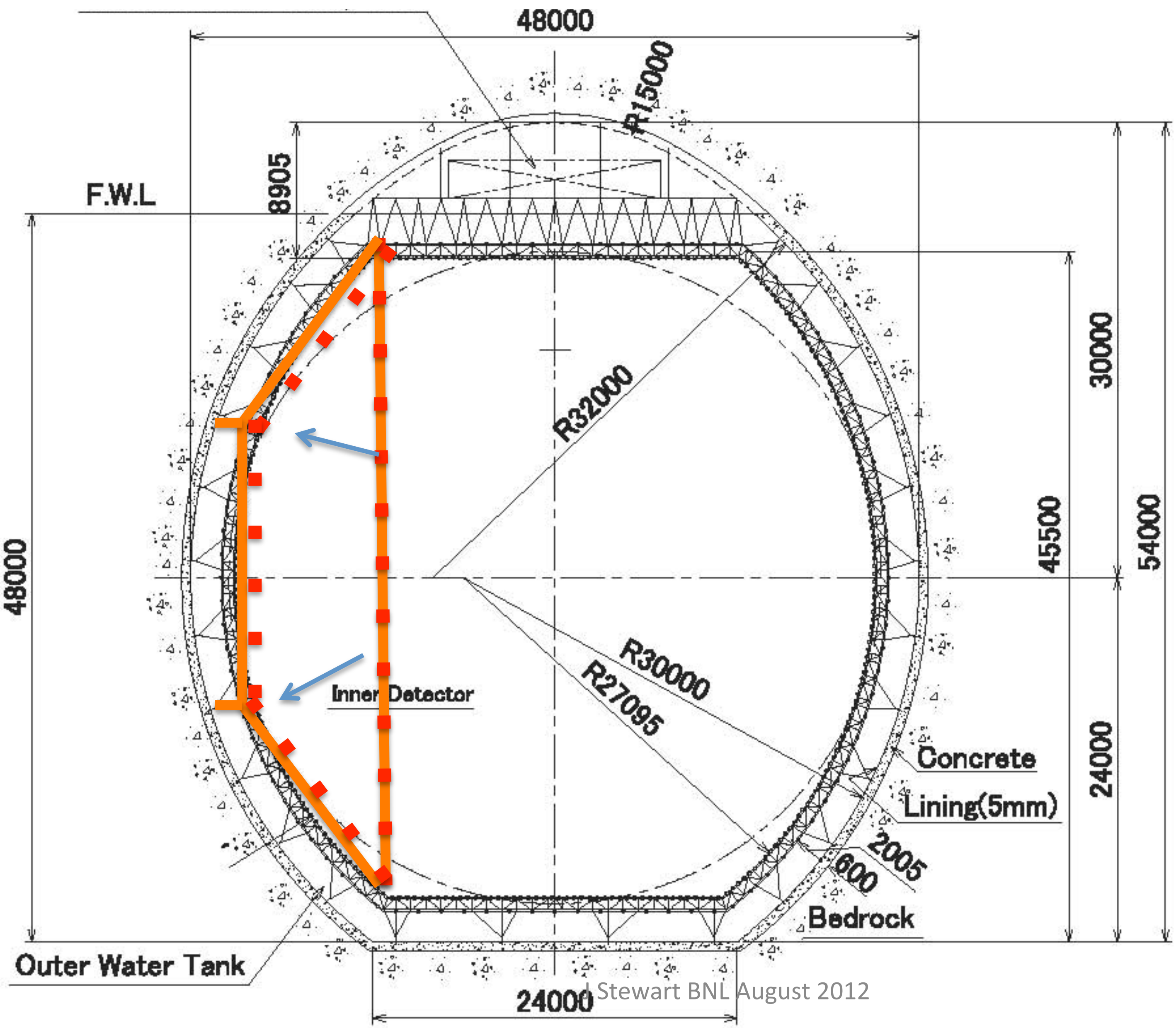




PMT deployment open quesitons

- Stability under buoyant forces needed studied
  - How often were ring braces needed?
  - How often did the cables need to be anchored to the wall?
- Material selection and cleaning procedures needed determined
  - Initial cable sample contaminated the water in test
  - Cleaning (possible acid etch) needed developed

Possible Application to Hyper-K



Conclusions

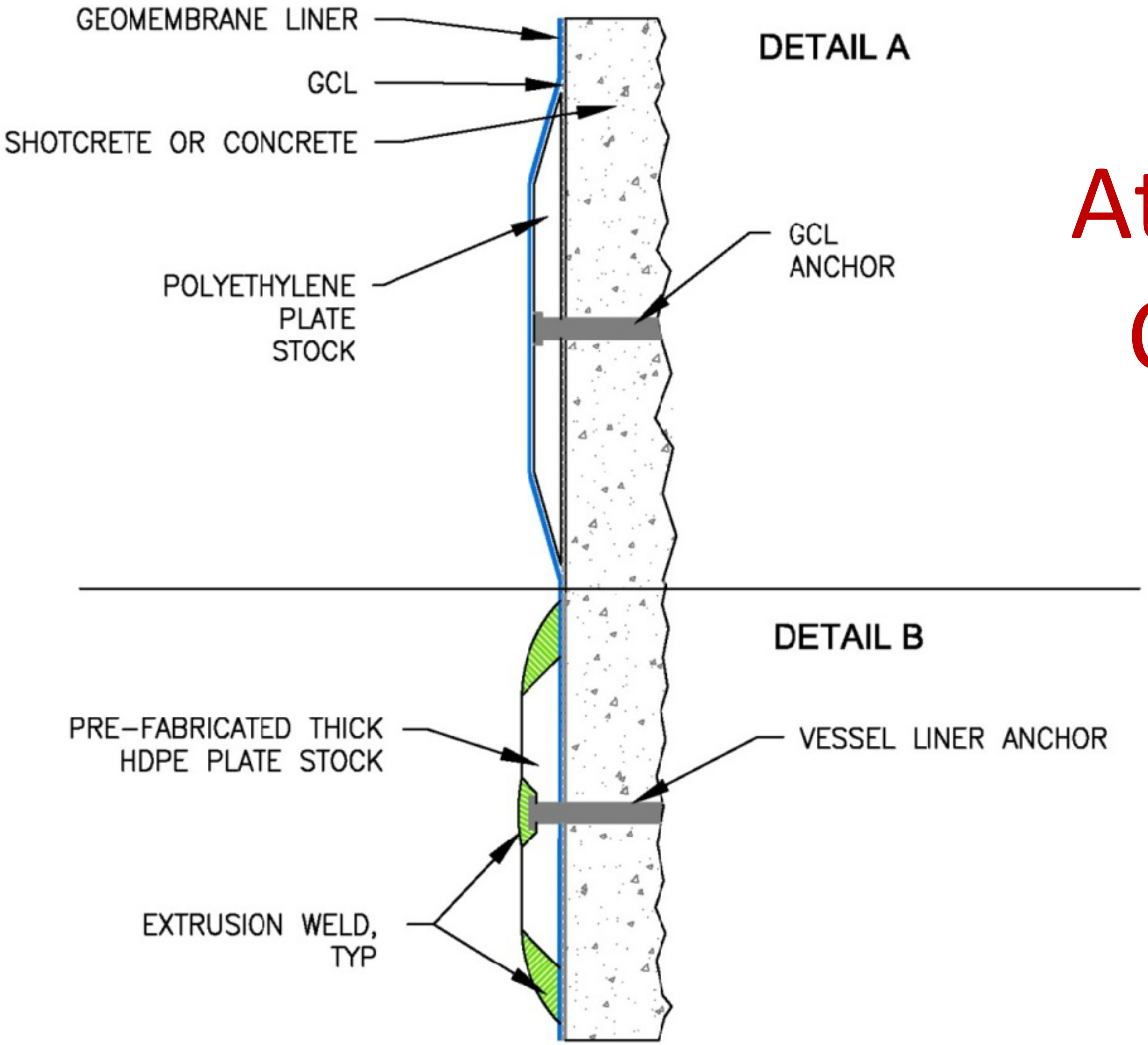
- The LBNE design was well advanced for a conceptual design.
- Several options remained but it was clear solutions would be found.
- Wall smoothness and number of penetrations were a critical design issue.
- Cable selection and cleaning were next critical steps in deployment design
- A lot of detailed studies were documented in the LBNE data base.

BACKUP

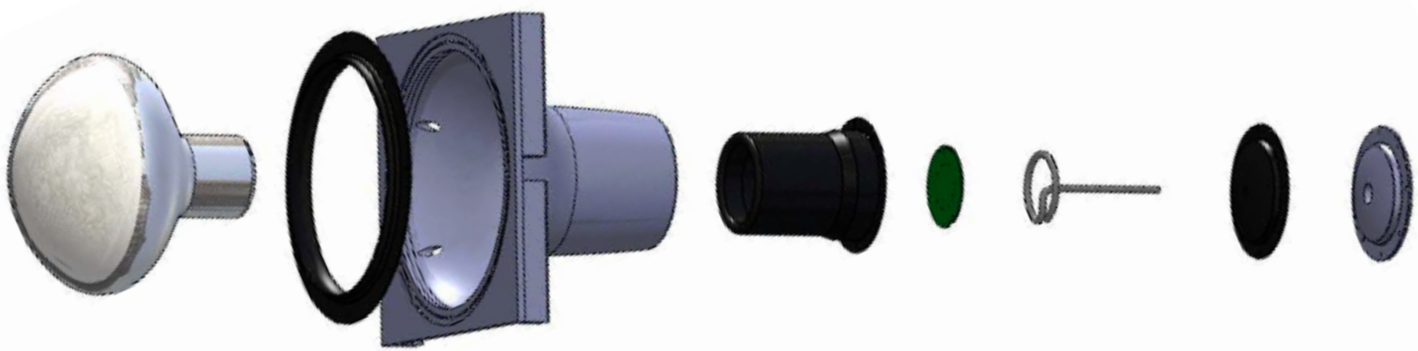
Liner Welding and Leak Check

- Liner material will come in large rolls and will be welded in place
- Fusion and extrusion weld will both be used
- Seams will have an overlap with two fusion welds, will allow for air pressure test of space between welds
- Fusion welds will mostly be used for attachment points
- Extrusion welds will be used at penetrations
- Leak checking by spark method used on liner, conductive liner will facilitate this
- Other methods may also used (vacuum box, gas, etc.)

Liner Attachment Concepts

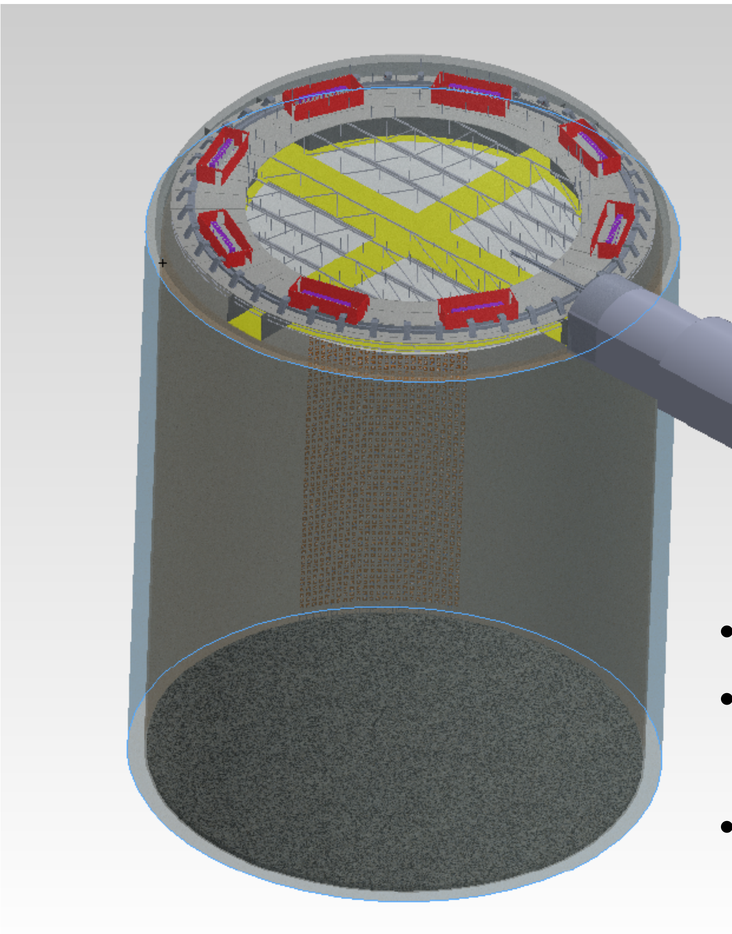


The PMT Assembly (PA)

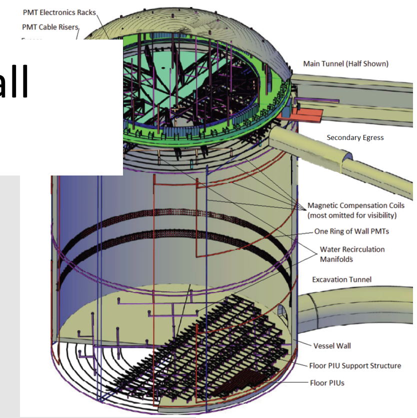


PMT housing from plastic was designed to hold the PMTs and mount easily to the cables

200 kton 3-D Models



Model with wall mounted PIUs



- Full 3-d models in preparation
- New models include linear PIU scheme- No wall penetrations
- They are consistent with cavern and CF
- Modeling as much detail as practical and needed at this stage

Wall Penetrations for Baseline Design

- Install insert at the time of vessel pour
- Cut hole and install rod after liner installation
- Install boot and weld
- Test and install collar
- About 6000 required at the cost of about $2.5M per detector