

An Update on the LBNF/DUNE Project

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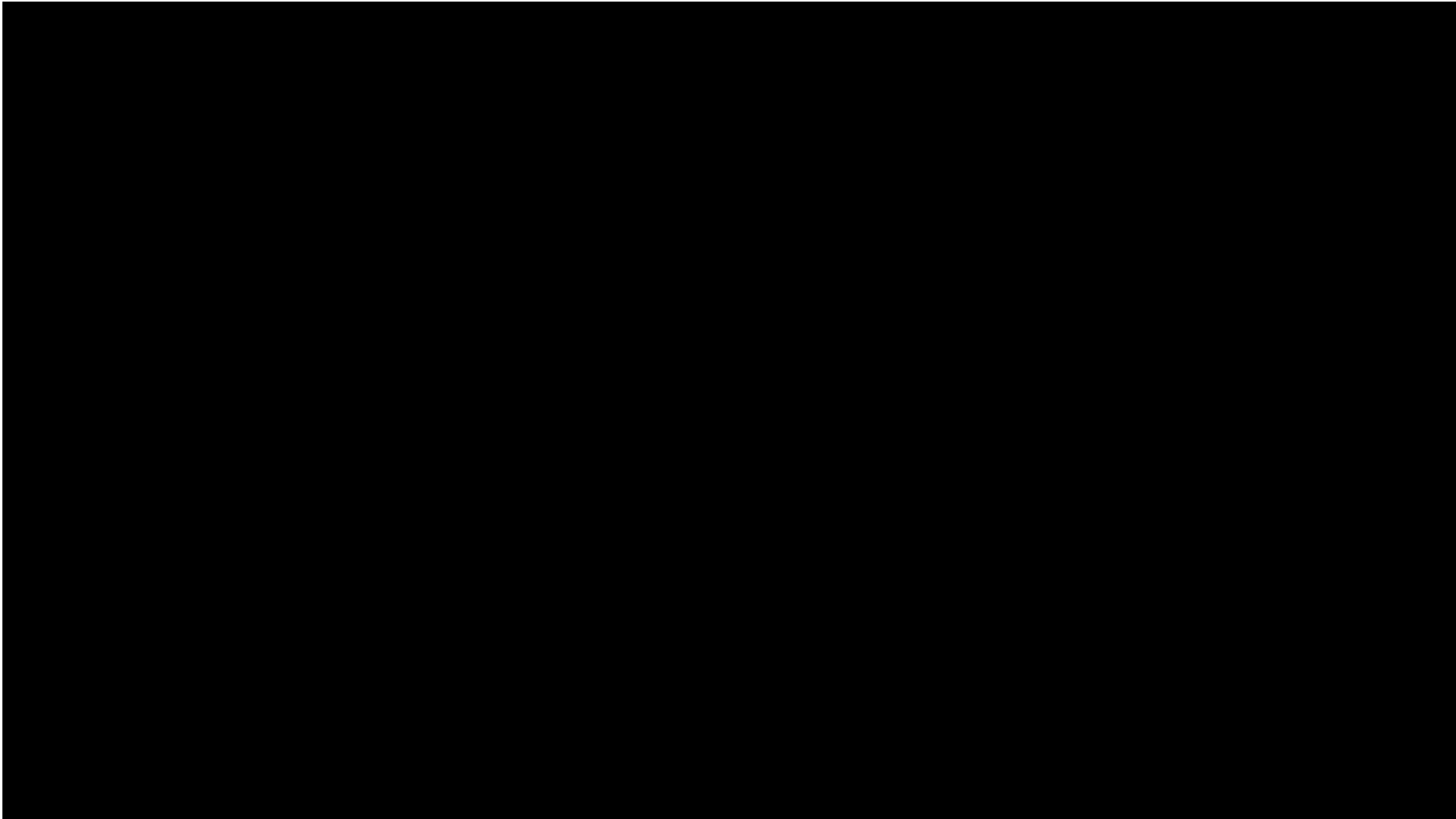
Who Am I?

- I'm responsible for construction of the “conventional facilities” for LBNF, which includes excavating the spaces underground, constructing a building on surface, providing a means to move rock, and getting utilities where needed.
 - Others are responsible for the more unique parts of the projects, such as cryogen handling and the detectors.
- I was born in Rapid City, and have spent most of my life in the area.
- For the past 7 years I have been associated with DUSEL, LBNE, and LBNF as an engineer and manager, approximately half of which was in this role.
- Prior experience includes 14 years as an engineer or manager for cement manufacturing facilities, most recently at GCC Dacotah in Rapid City for 7 years.
- Certified Project Management Professional (PMP)
- Registered Professional Engineer

Topics

- Overview of the LBNF and DUNE projects
- Key project statistics
- Update on project progress

LBNF / DUNE – The International mega-science project



Neutrinos are Exciting Science!

The Nobel Prize in Physics 2002



Raymond Davis Jr.
Prize share: 1/4



Masatoshi Koshihba
Prize share: 1/4



Riccardo Giacconi
Prize share: 1/2

The Nobel Prize in Physics 2002 was divided, one half jointly to Raymond Davis Jr. and Masatoshi Koshihba *"for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"* and the other half to Riccardo Giacconi *"for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources"*.



The Nobel Prize in Physics 2015



Photo: A. Mahmoud
Takaaki Kajita
Prize share: 1/2



Photo: A. Mahmoud
Arthur B. McDonald
Prize share: 1/2

The Nobel Prize in Physics 2015 was awarded jointly to Takaaki Kajita and Arthur B. McDonald *"for the discovery of neutrino oscillations, which shows that neutrinos have mass"*

Photos: Copyright © The Nobel Foundation



What is DUNE? What is LBNF?

- The Deep Underground Neutrino Experiment will be a game-changing experiment for **neutrino science**, potentially transforming our understanding of why the universe exists as it does.
- The Long-Baseline Neutrino Facility is the infrastructure necessary to send a powerful beam of neutrinos 800 miles through the earth, and measure them deep underground at South Dakota's Sanford Underground Research Facility.
- The DUNE/LBNF project will be the first internationally conceived, constructed, and operated mega-science project hosted by the Department of Energy in the United States.

LBNF will drive neutrino science forward the way CERN's Large Hadron Collider drove Nobel Prize-winning Higgs discovery

DUNE Collaboration Span

As of today:

960 collaborators from **163 institutions** in **31 nations**
Armenia, Brazil, Bulgaria, Canada, CERN, Chile, China, Colombia, Czech Republic, Finland, France, Greece, India, Iran, Italy, Japan, Madagascar, Mexico, Netherlands, Peru, Poland, Romania, Russia, South Korea, Spain, Sweden, Switzerland, Turkey, UK, Ukraine, USA

60 % non-US

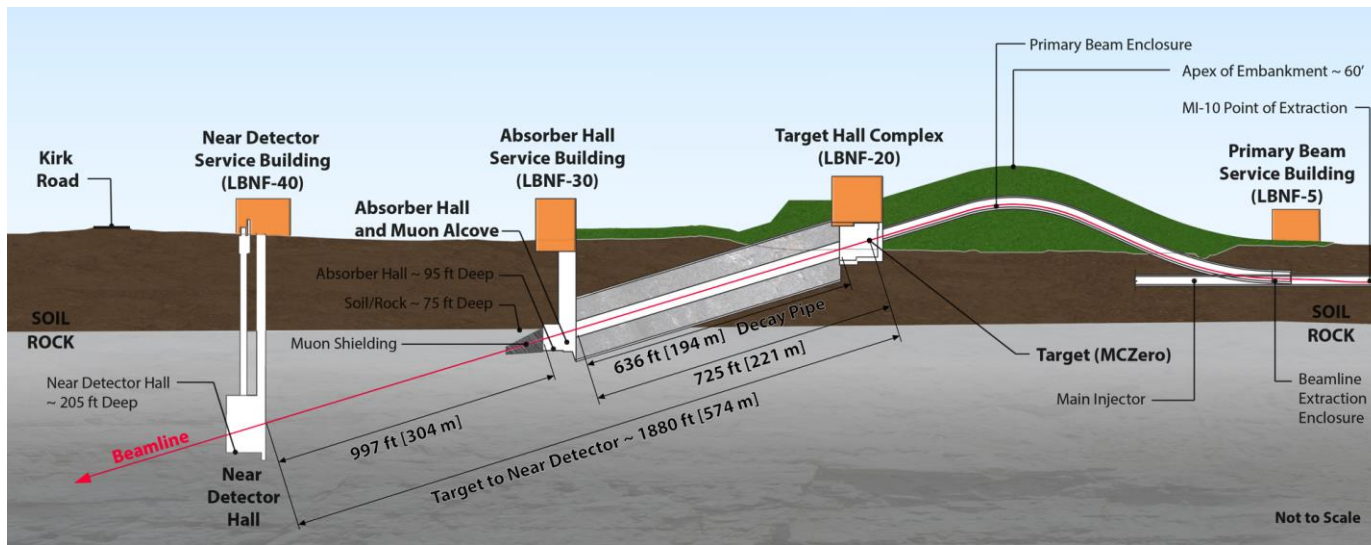


DUNE has broad international support and is growing

DUNE Collaboration



Overview - “Near Site” - LBNF/DUNE at Fermilab, Batavia, IL

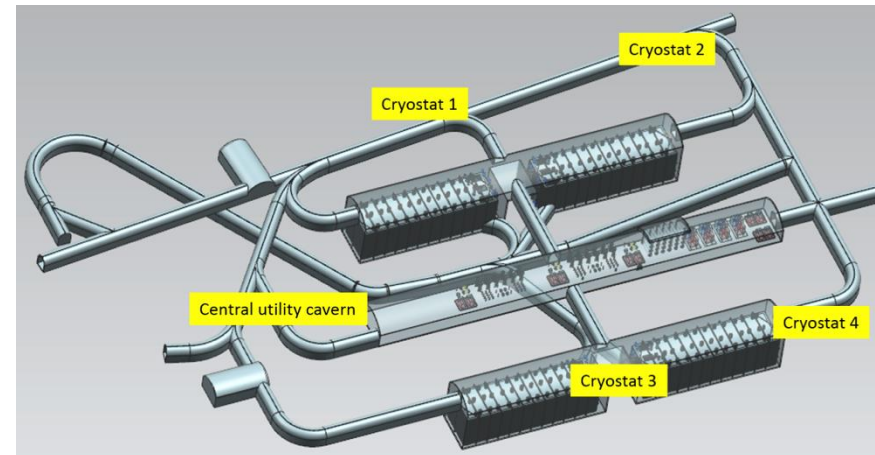


- Primary proton beam @ 60-120GeV extracted from Main Injector
- Initial 1.2 MW beam power, upgradable to 2.4 MW
- Embankment allows target complex to be at grade and neutrino beam to be aimed to Lead, SD
- Decay region followed by absorber
- Four surface support buildings
- Near Detector facility
- **DUNE Near Detectors (fine grained straw tube with gas targets)**

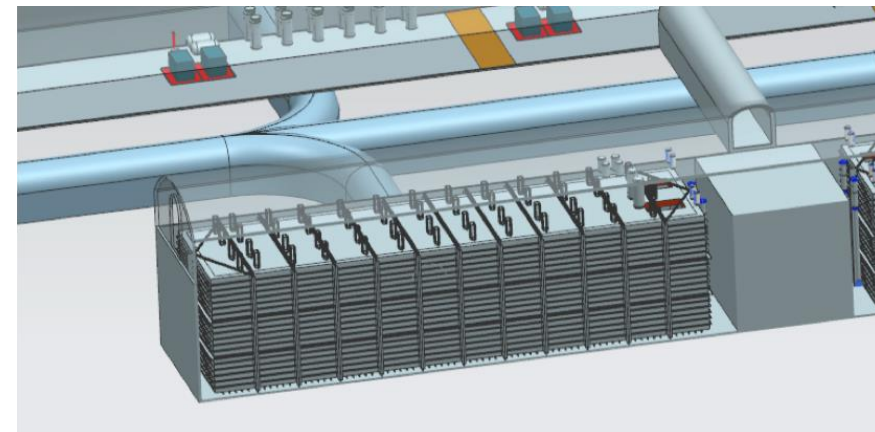
Beamline design based on Fermilab's NOvA beam, currently the most powerful neutrino beam in the world

Overview - “Far Site” - LBNF/DUNE at Sanford Lab, Lead, SD

- **Conventional Facilities:**
 - Surface and shaft Infrastructure including utilities
 - Drifts and two caverns for detectors
 - Central utility cavern for conventional and cryogenic equipment
- **Cryostats:**
 - Four membrane cryostats supported by external steel frames
- **Cryogenic Systems:**
 - LN2 refrigeration system for cooling and re-condensing gaseous Argon
 - Systems for purification and recirculation of LAr
- **Argon: 70kt LAr (~40kt “fiducial” mass)**
- **DUNE LAr-TPC Detectors**



4850L cavern and drift layout



Single cryostat

Far Site Scope – Timeline

1. Sanford Lab Reliability Projects

FY16 – 18

- Ross shaft rehab
- Hoist motor rebuilds, more...

2. Pre-Excavation

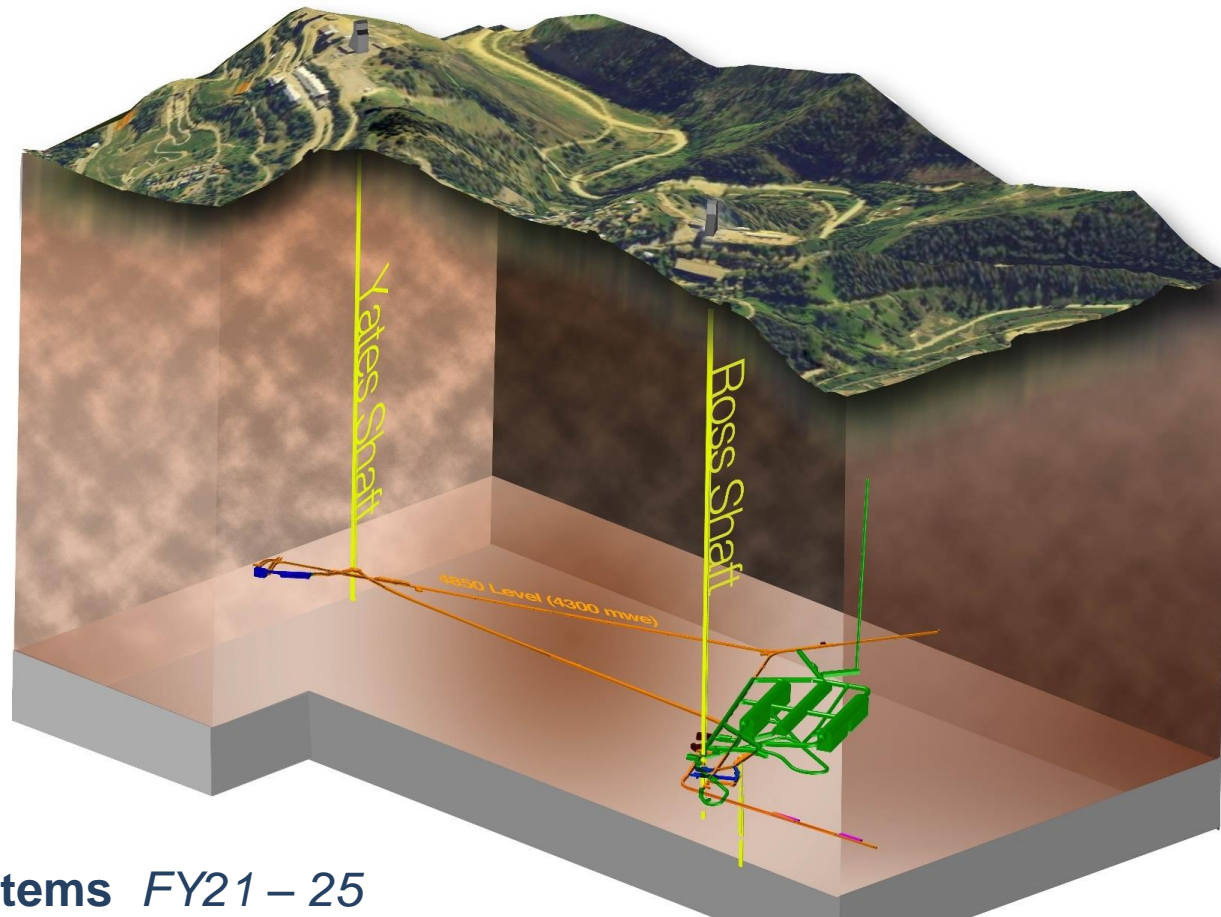
FY17 - 20

- Rock disposal systems
- Headframe Reinforcement
- Conveyor System

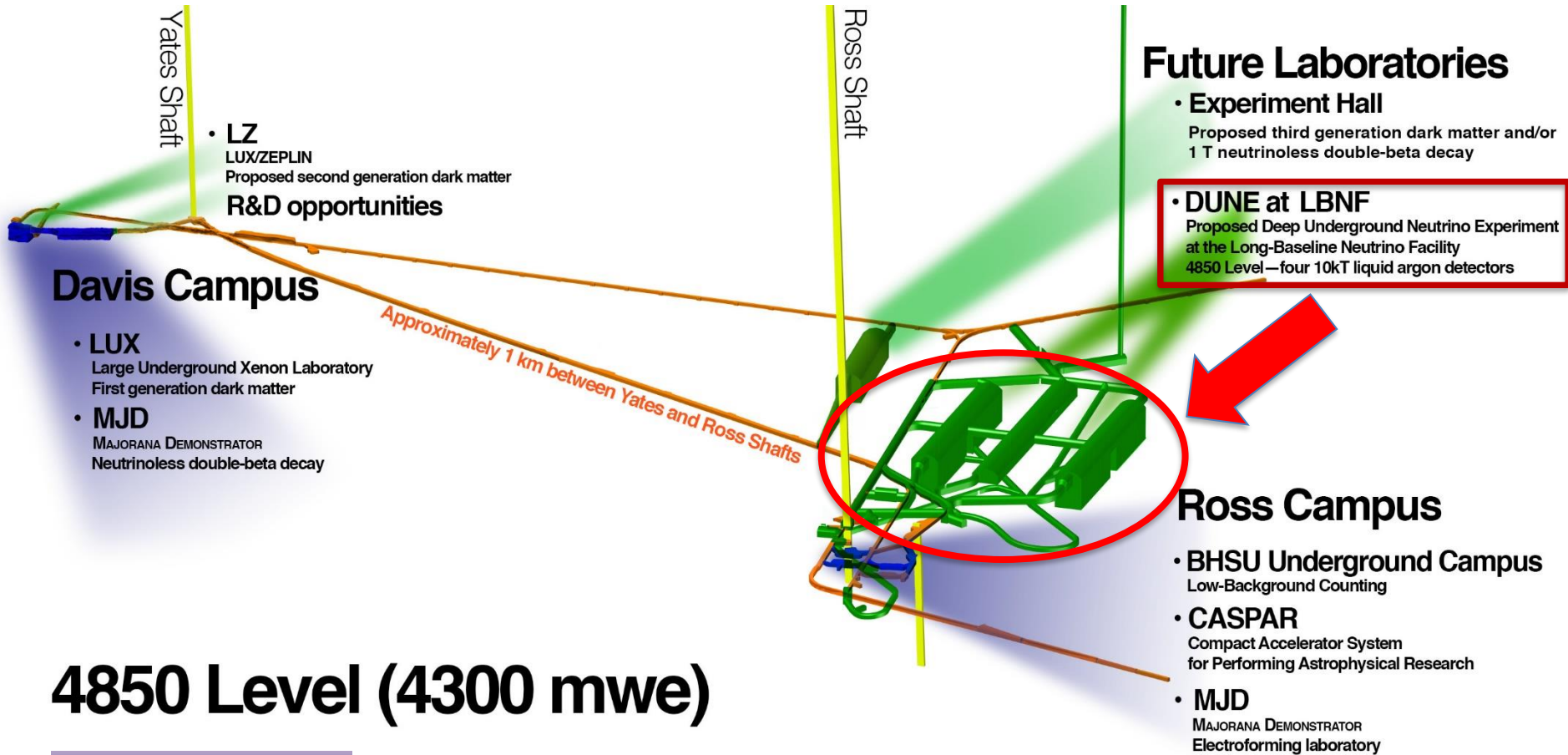
3. Excavation/Construction

FY19 – 22

4. Cryostats/Cryogenic Systems *FY21 – 25*



Underground Context

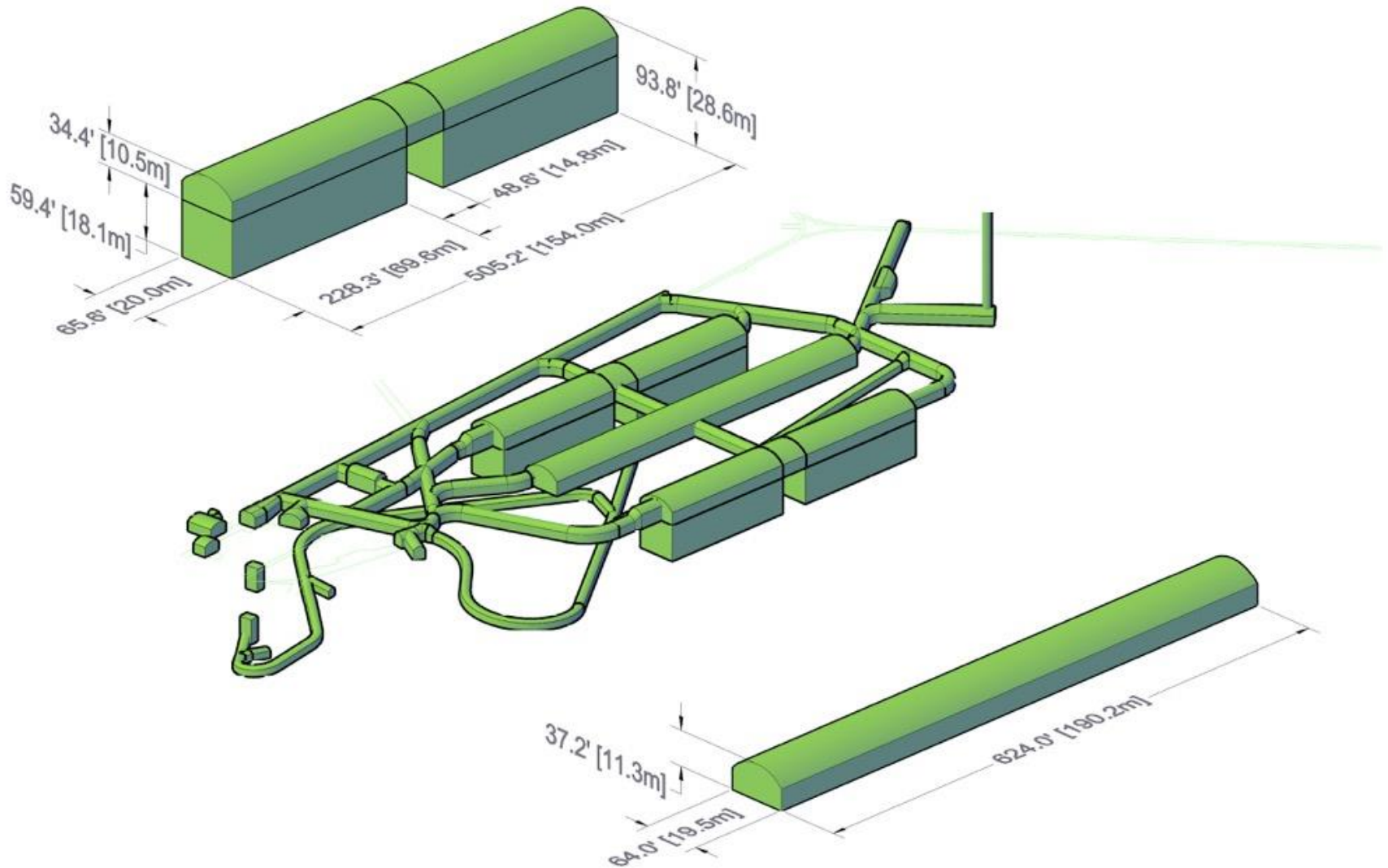


4850 Level (4300 mwe)

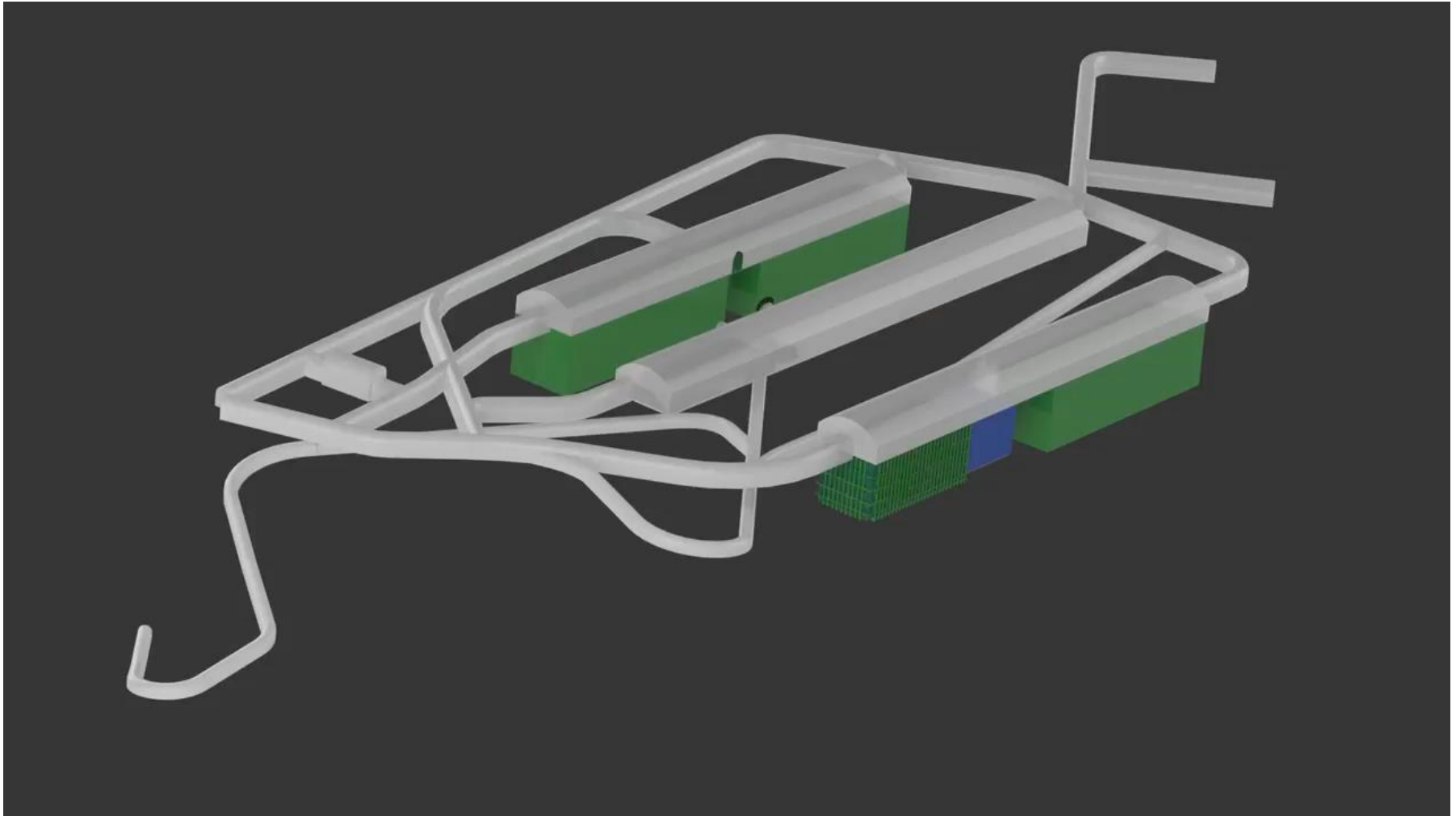
Existing facilities

Proposed facilities

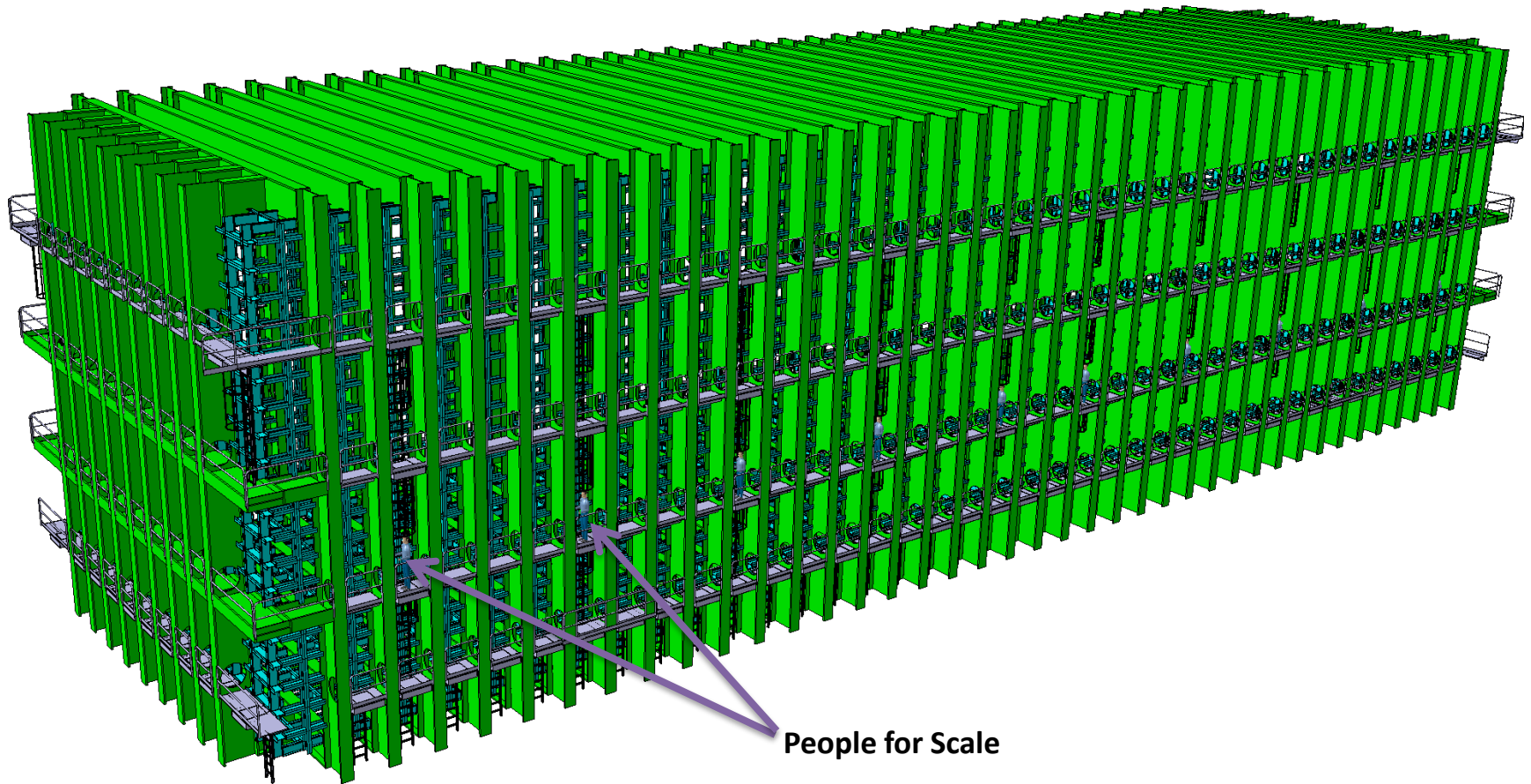
Size of Excavations



LBNF / DUNE Far Site



Steel Cryostat Design



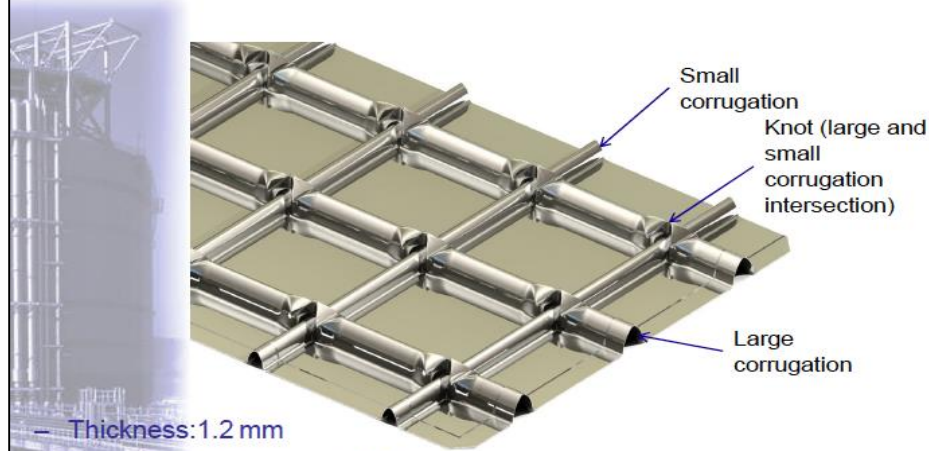
External (Internal) Dimensions

19.1m (15.1m) W x 18.0m (14.0m) H x 66.0m (62.0m) L

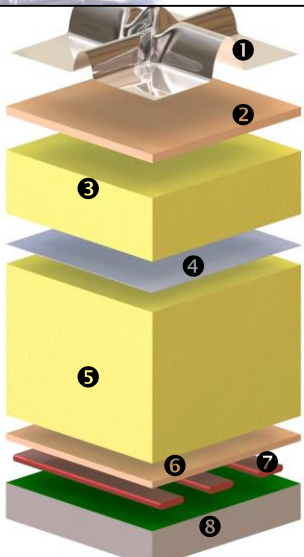
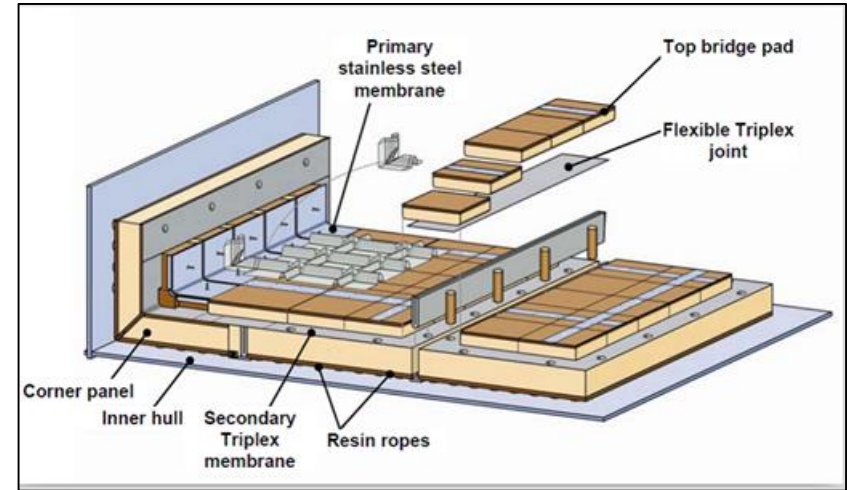
62.7' (49.5') W x 59' (45.9') H x 216.5' (203.4') L

Membrane Cryostat Design

The corrugated stainless steel primary barrier:



- Thickness: 1.2 mm
- Material: Stainless steel 304L

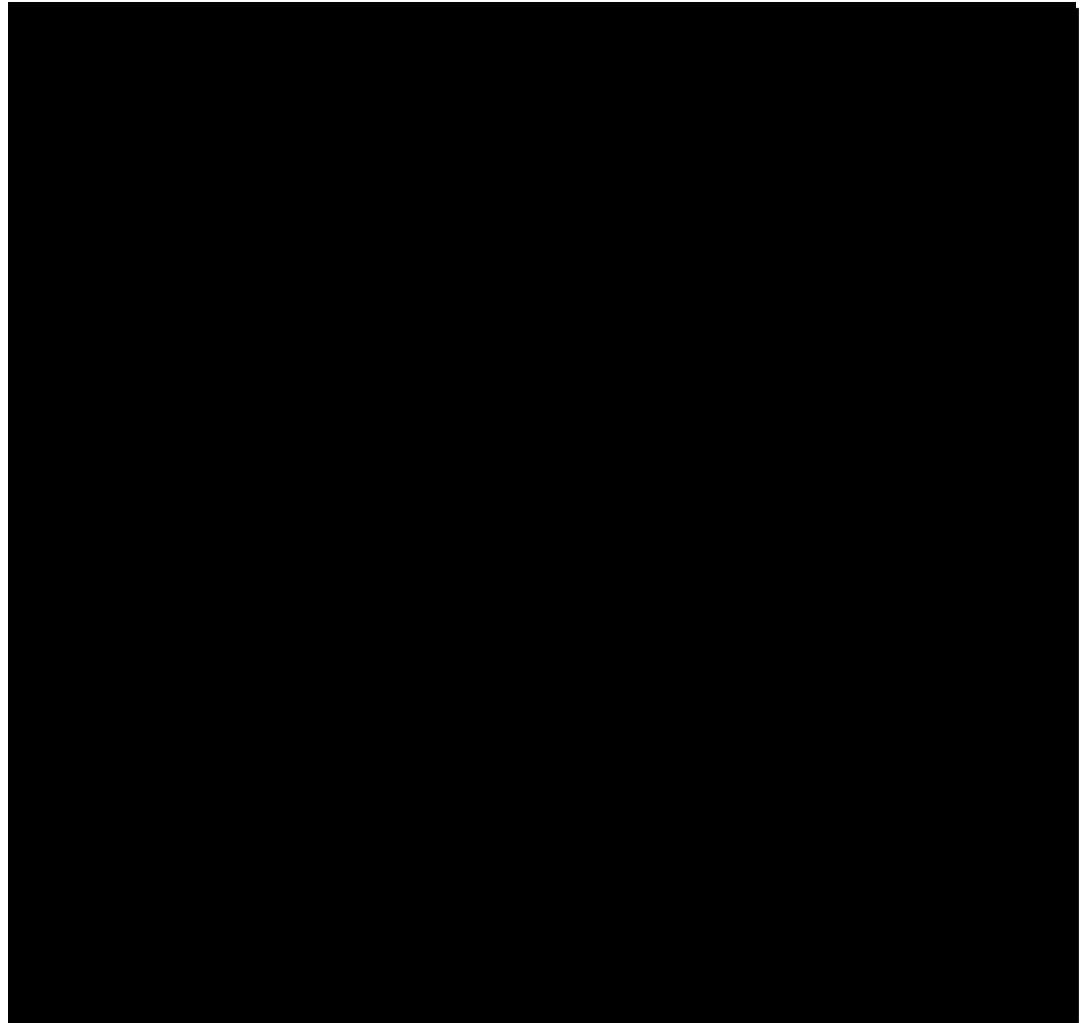


- 1 Stainless steel primary membrane
- 2 Plywood board
- 3 Reinforced polyurethane foam
- 4 Secondary barrier
- 5 Reinforced polyurethane foam
- 6 Plywood board
- 7 Bearing mastic
- 8 Steel structure with moisture barrier

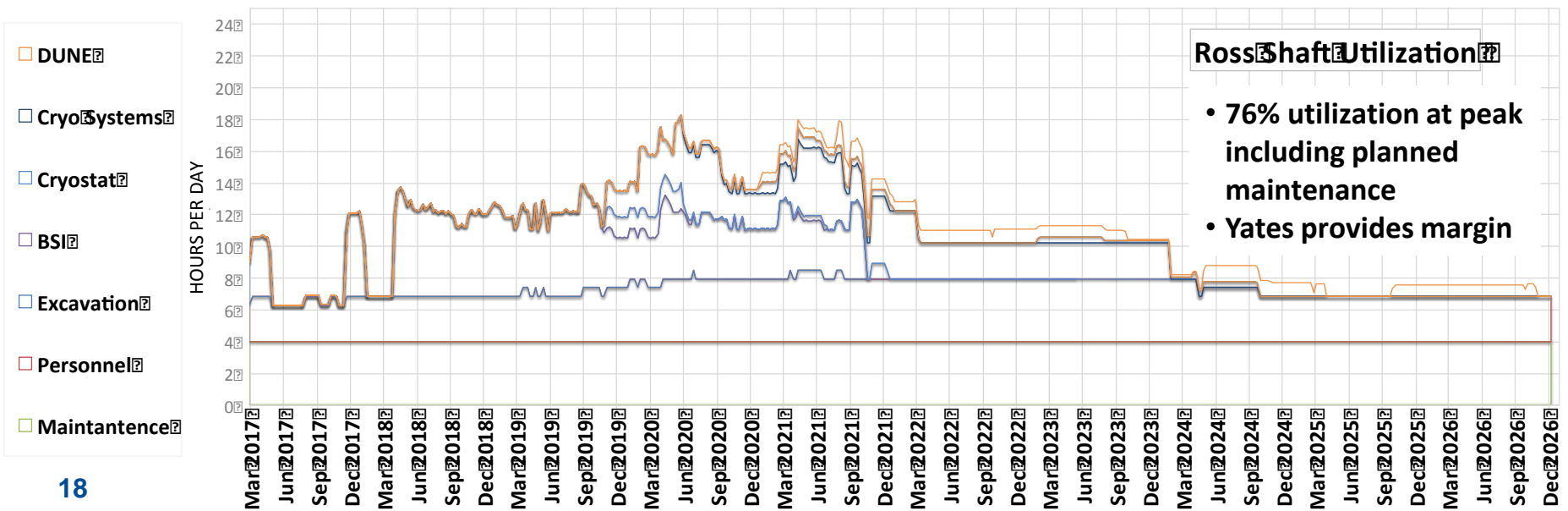
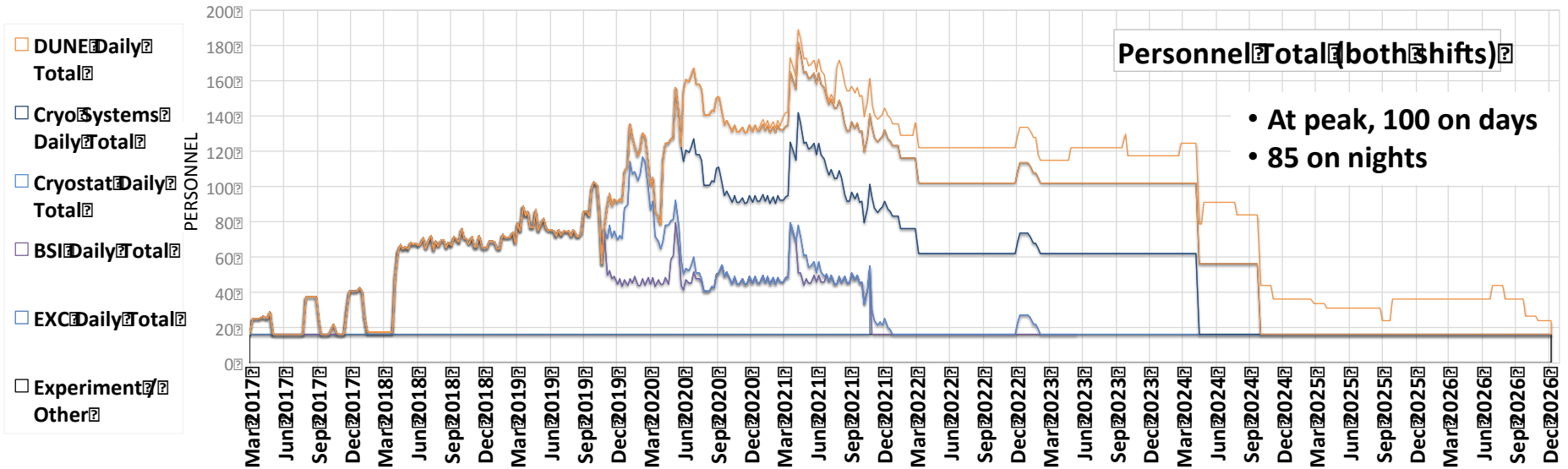


Single Phase Detectors inside the Cryostats

- Detectors consist of:
 - Anode Plane Arrays
 - Cathode Plane Arrays
 - Field Cage
 - Photon detectors
 - Readout electronics and DAQ
- How they work:
 - Neutrinos (occasionally) collide with Argon atom.
 - Resulting particles cause electrons to be knocked loose from liquid argon atoms, which “drift” to the APAs



Personnel Underground & Ross Shaft Utilization



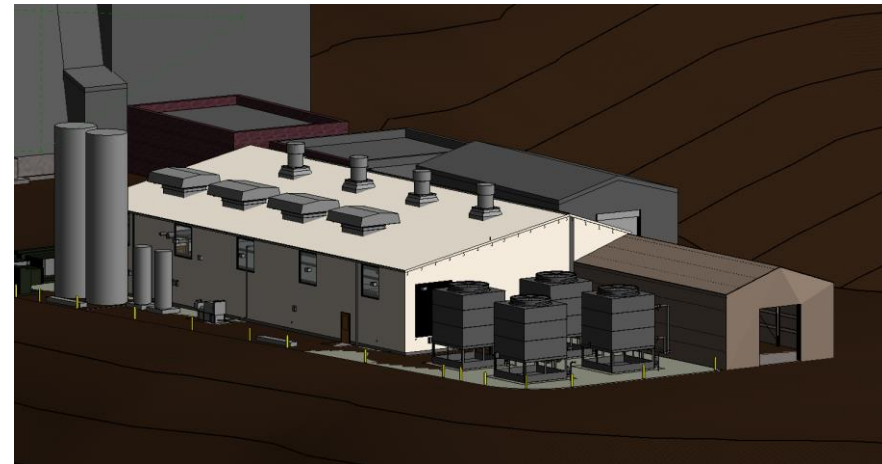
Interesting (to me!) data

- Excavating approximately 875,000 tons of rock
- Placing over 54,000 cubic yards of concrete and shotcrete underground
- Delivering over 14,000 tons of steel underground, and that's just for the cryostats
- Installing what may be the world's largest refrigeration system in terms of distance between the cooling and the heat removal
 - I made this up, but it's probably true!
- Already performed the worlds deepest plumb bob survey, which will allow us to measure the distance and orientation from Fermilab to the detectors within inches.

Construction around the Ross Headframe

The Ross Shaft will be the hub of LBNF construction, including a few construction items on surface:

- The headframe requires some structural reinforcement (all interior)
- The crushing system will be restored (for the most part) to crush LBNF rock
- A new building will be built next to the existing warehouse
- The electrical substation will be upgraded, and a new trench to replace the overhead lines



What will you see and hear at the Ross?

- More traffic – all workers will start here daily, and all deliveries will come here.
- Some temporary offices and laydown areas to support construction
- The crushing system will be operating throughout excavation (~2019-2021). Our studies suggest this will add a little noise (~5 dBA) above existing (from 45 to 50)
- When the detectors start filling (~2022), the nitrogen compressors will start running.

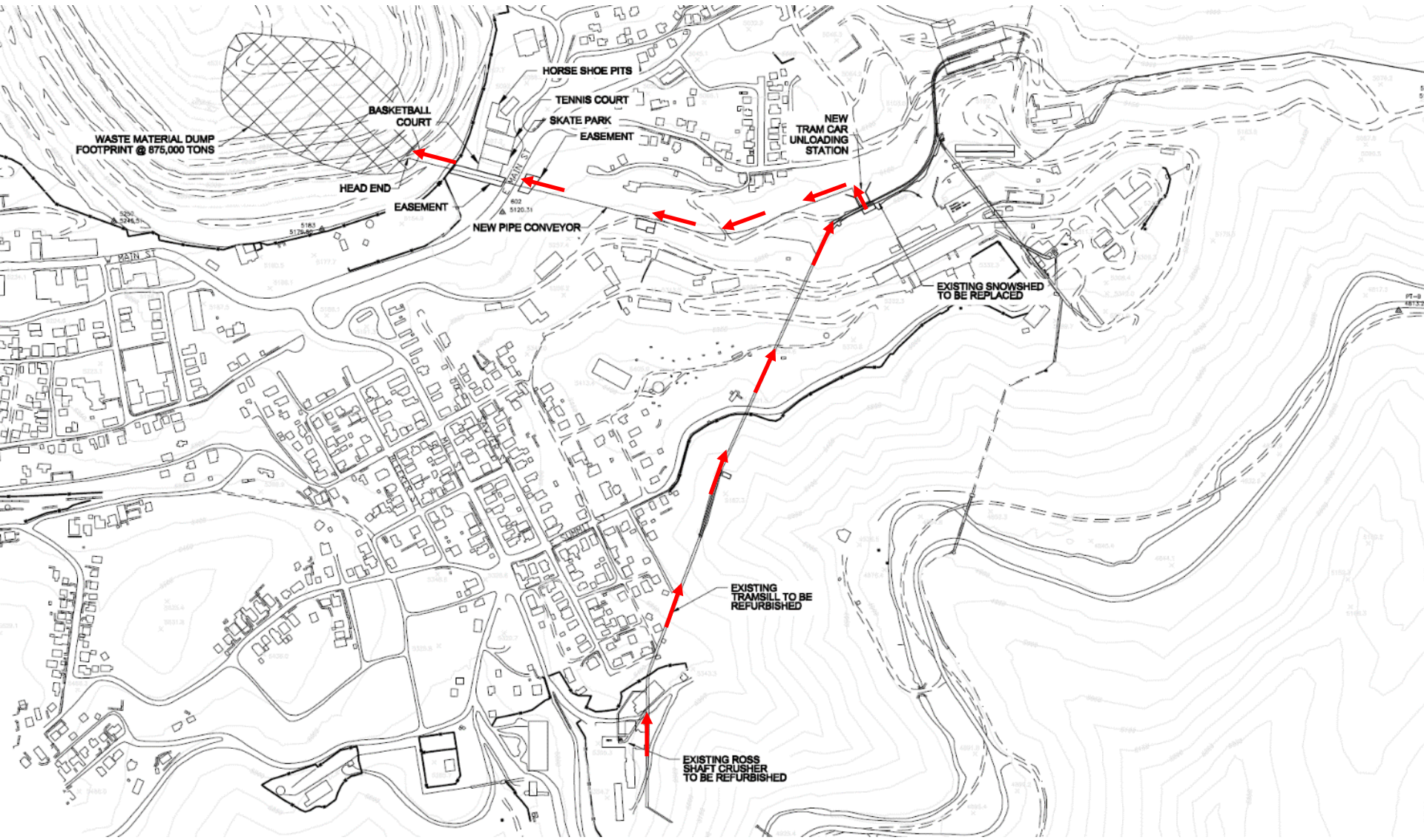
We've built noise and dust controls into the design to minimize community effects.

Rock Handling

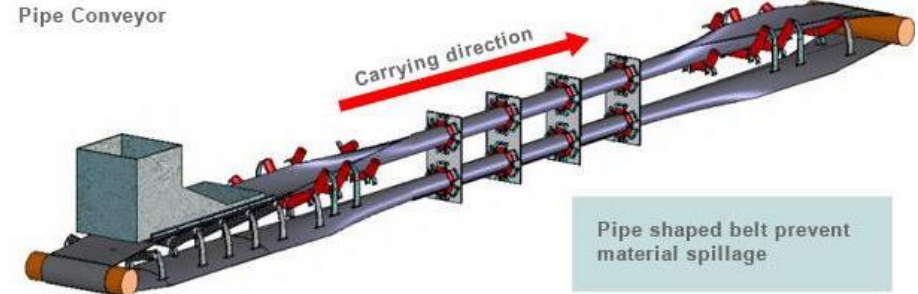
We've met with the city a few times to discuss the rock handling system, and have established an easement to cross the park near the Rod and Gun Club.

We've continued to develop the design with a focus on limiting effects to the community.

Plan Presented Previously in City Commission Meetings



What's a pipe conveyor?

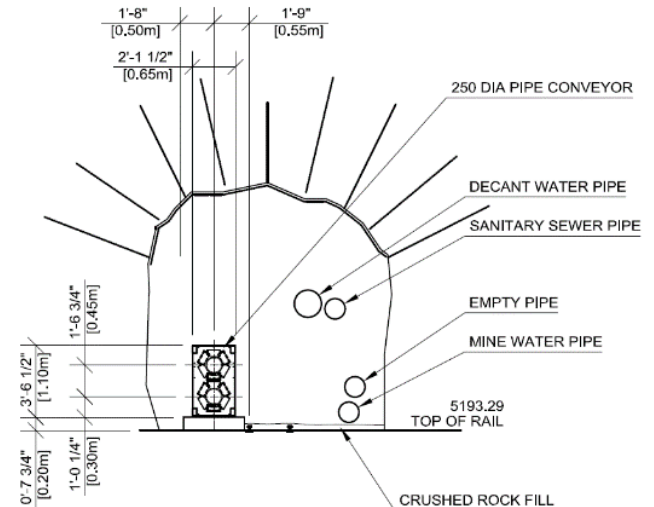


A pipe conveyor is a form of belt conveyor that folds over itself to create a “pipe” shape. This allows the conveyor to turn tighter corners than traditional belt conveyors, and also keeps the material completely enclosed for most of the conveyor length.



The pipe closes both ways, so even material that doesn't fall off at the discharge is enclosed for the return trip.

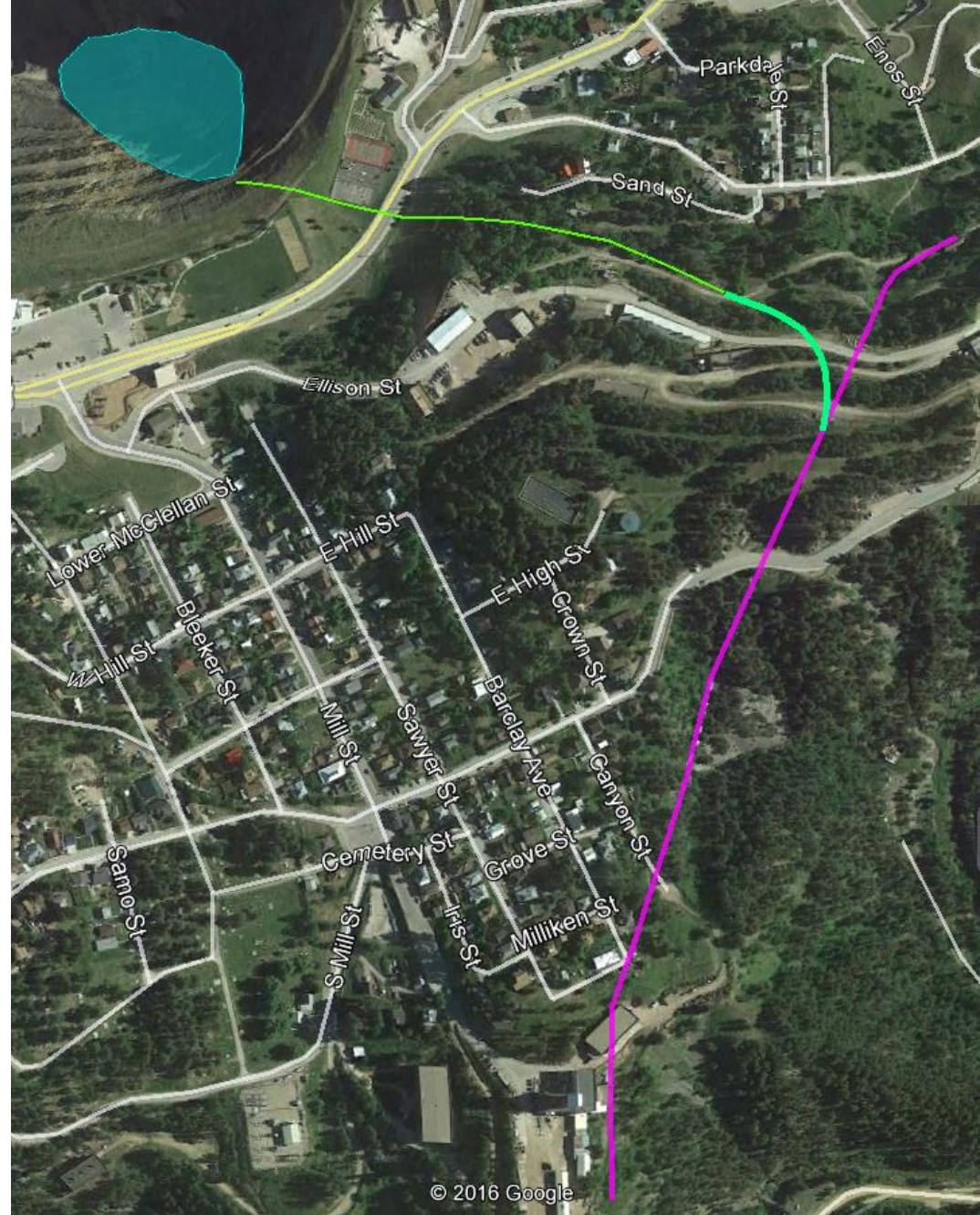
Homestake had what was then the world's longest pipe conveyor in the same area.



Revised plan – the good

By eliminating rail transport and a transfer station we've:

- Avoided having to control noise and dust at the transfer point
- Reduced overall energy consumption
- Eliminated one of the more visible parts of the system, which would have been directly above Gold Run Park.
- Minimized people working in the tramway tunnel, thereby reducing potential for safety incidents.



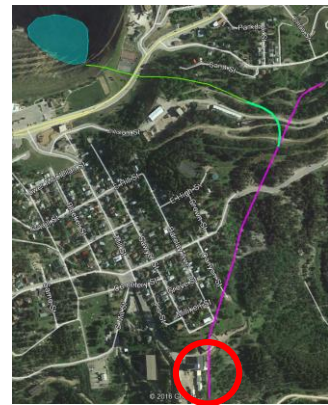
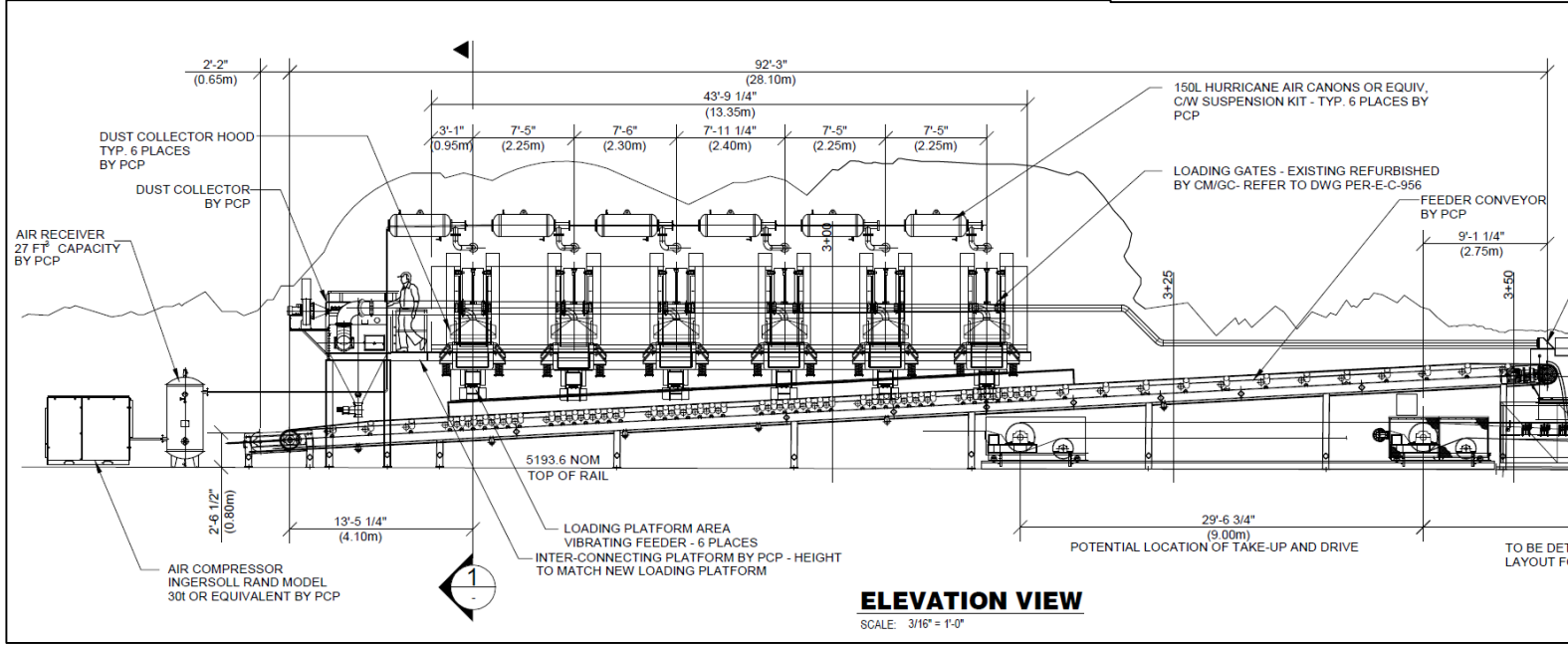
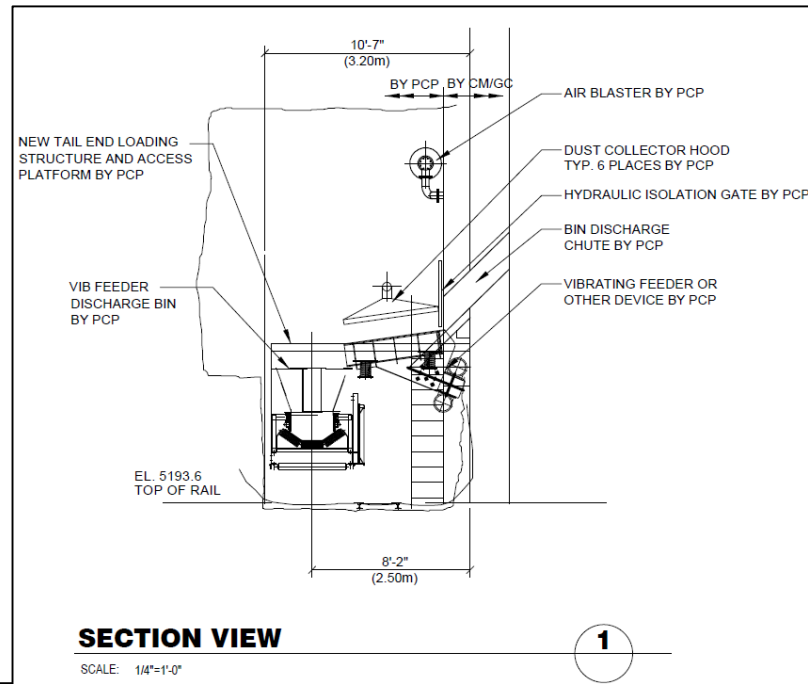
Revised plan – the challenge

While the advantages of this approach are significant, it's not all simple. This revised approach requires a modest amount of drill and blast excavation initially (a 3-6 month process)

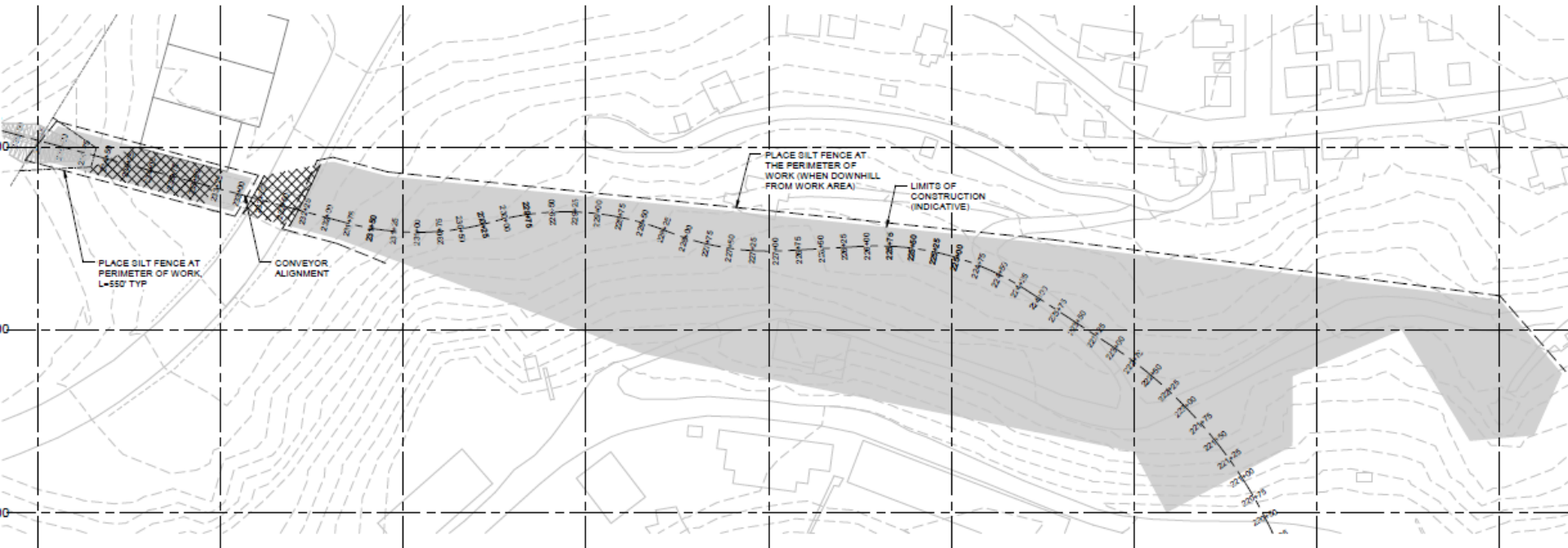
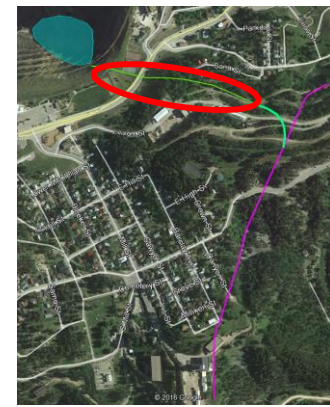
To limit community effects, the following measures will be taken:

- Excavation will only occur during the “day” – 7 AM to 5 PM
- Blasting will be performed on a set schedule
- Vibrations will be monitored and controlled
- We'll be asking to document existing conditions of nearby residences. If we do have any impact, those residences will have indisputable evidence of the condition before construction.

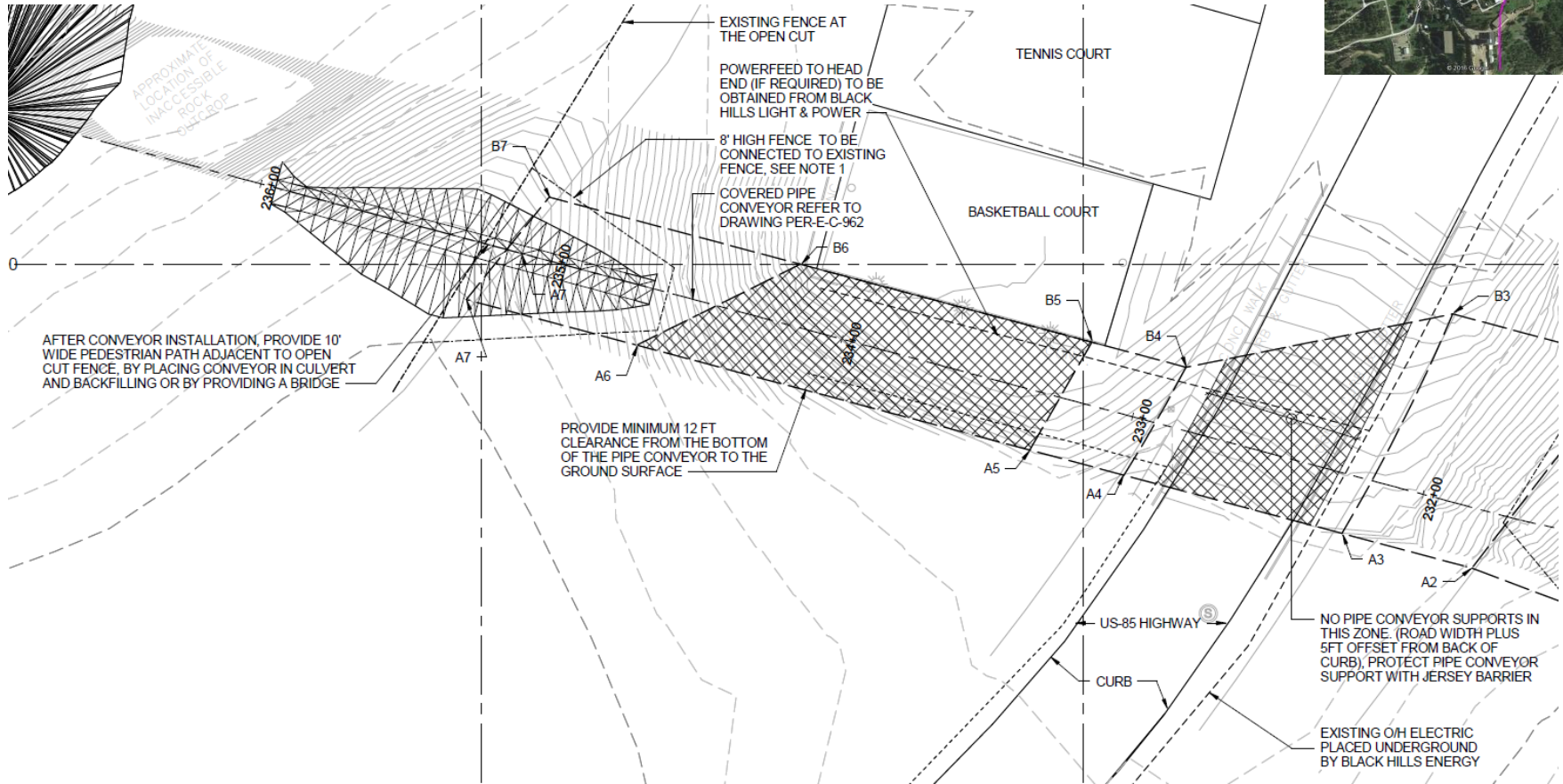
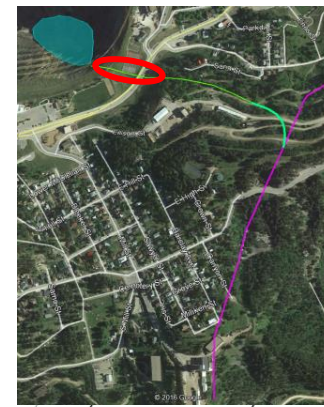
Conveying underground



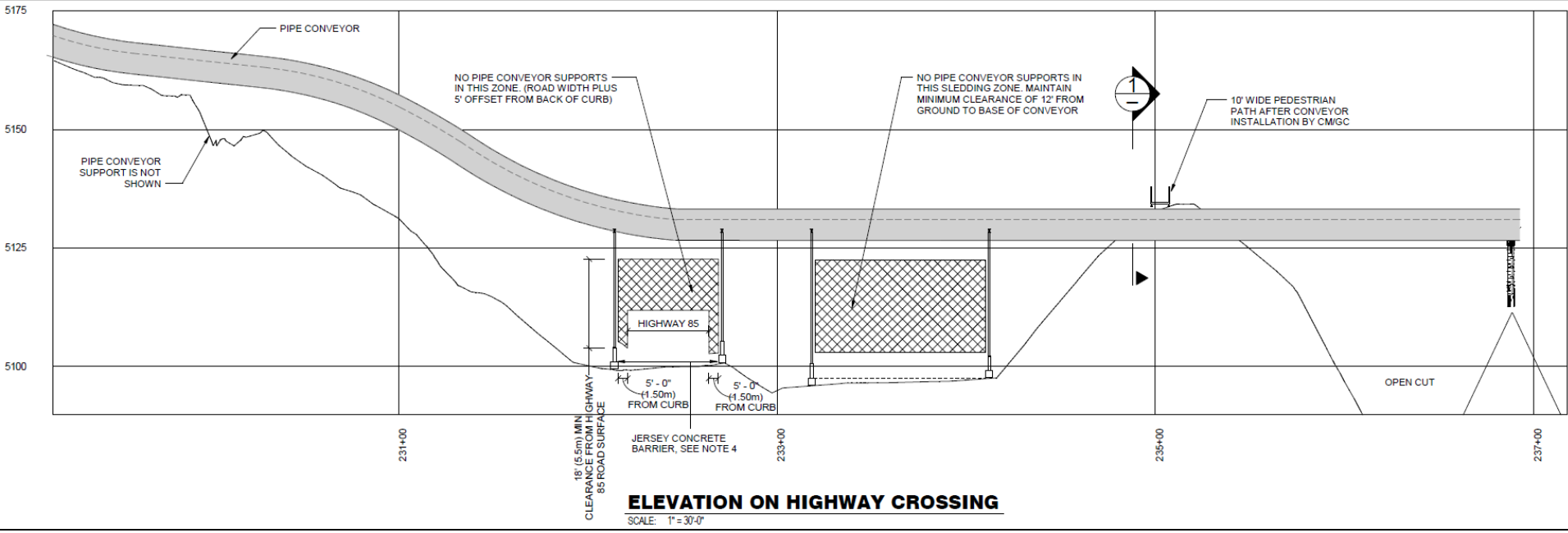
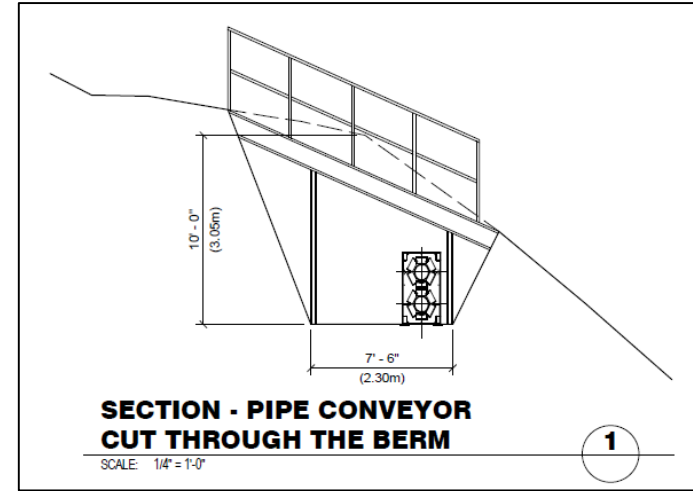
Conveying outside tramway



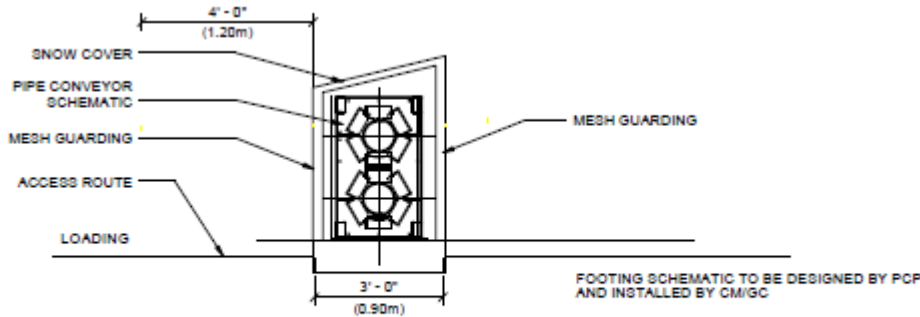
Conveyor Road and Park Crossing (Plan)



Conveyor Road and Park Crossing (Elevations)



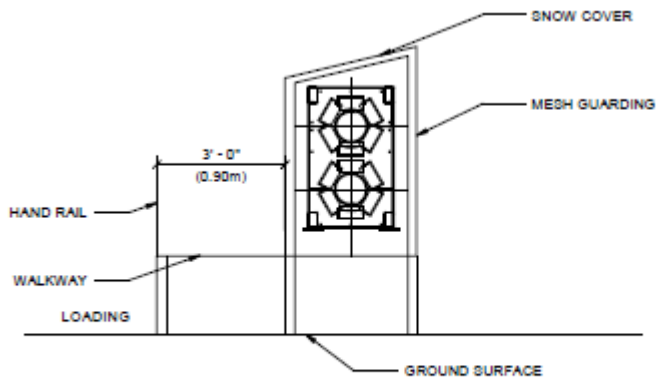
Conveyor Enclosures



SECTION ON CONVEYOR-GROUND MODULE

SCALE: 1/2" = 1'-0"

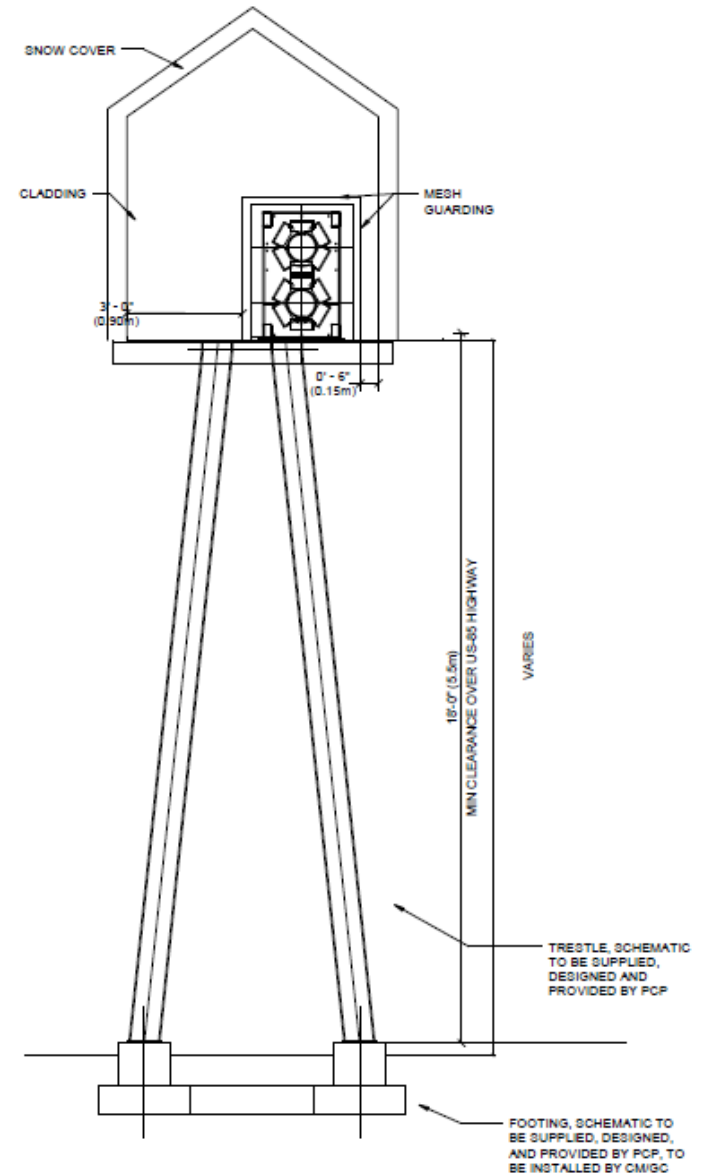
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CONVEYOR-ELEVATED MODULE

SCALE: 1/2" = 1'-0"

2



TRESTLE SUPPORT ELEVATION

SCALE: 1/2" = 1'-0"

6

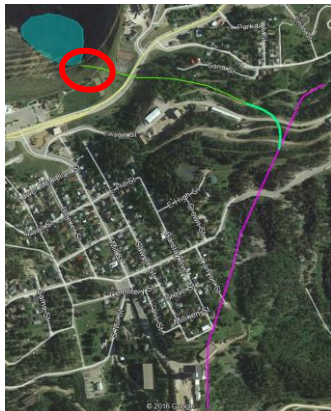
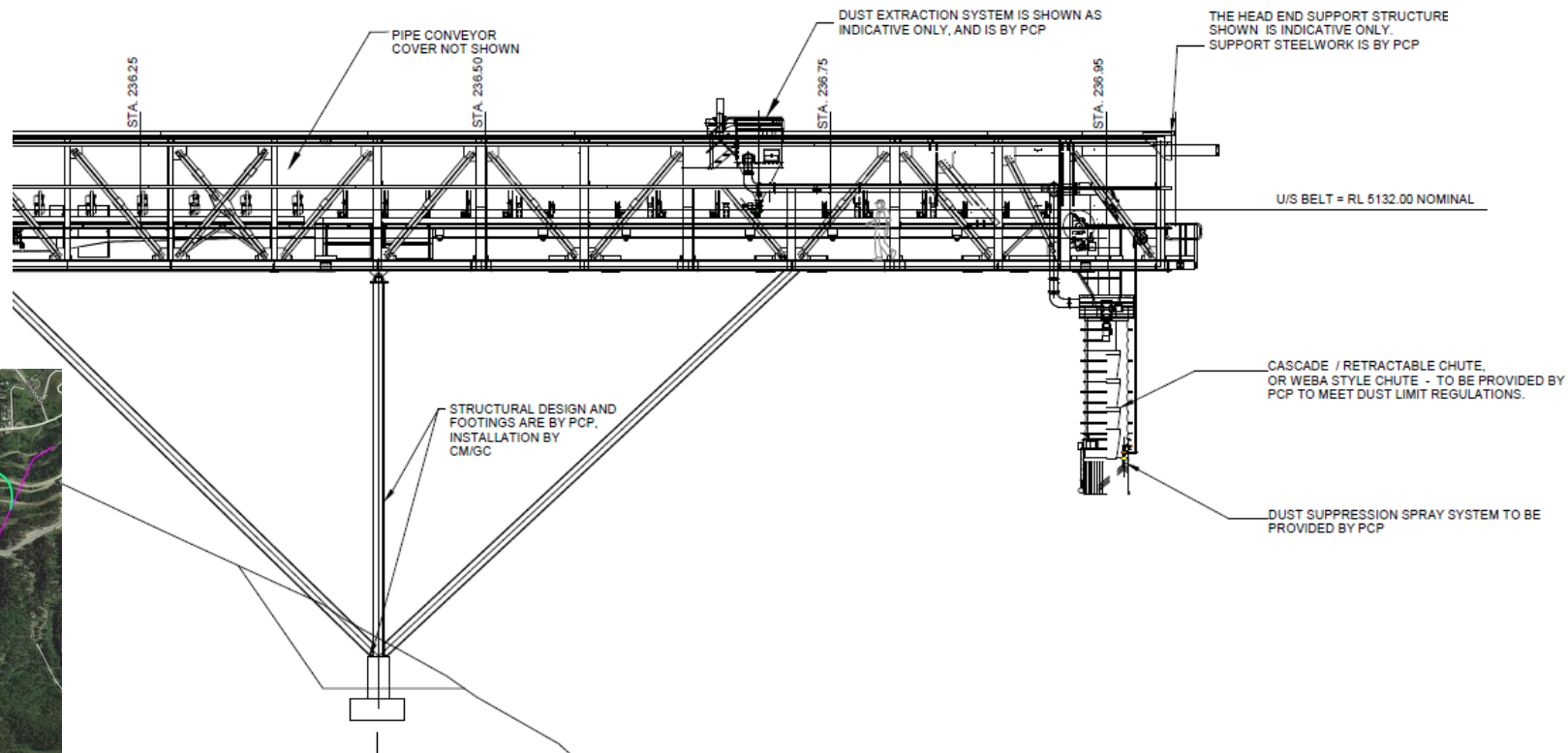
Conveyor General Appearance



Pipe Conveyor Discharge

The discharge cantilevers to allow for the entire volume of excavated rock to free flow down the high wall without any “working” of the pile.

A key element of this is to provide a combination of chute, dust collection, and dust suppression to control dust generation.

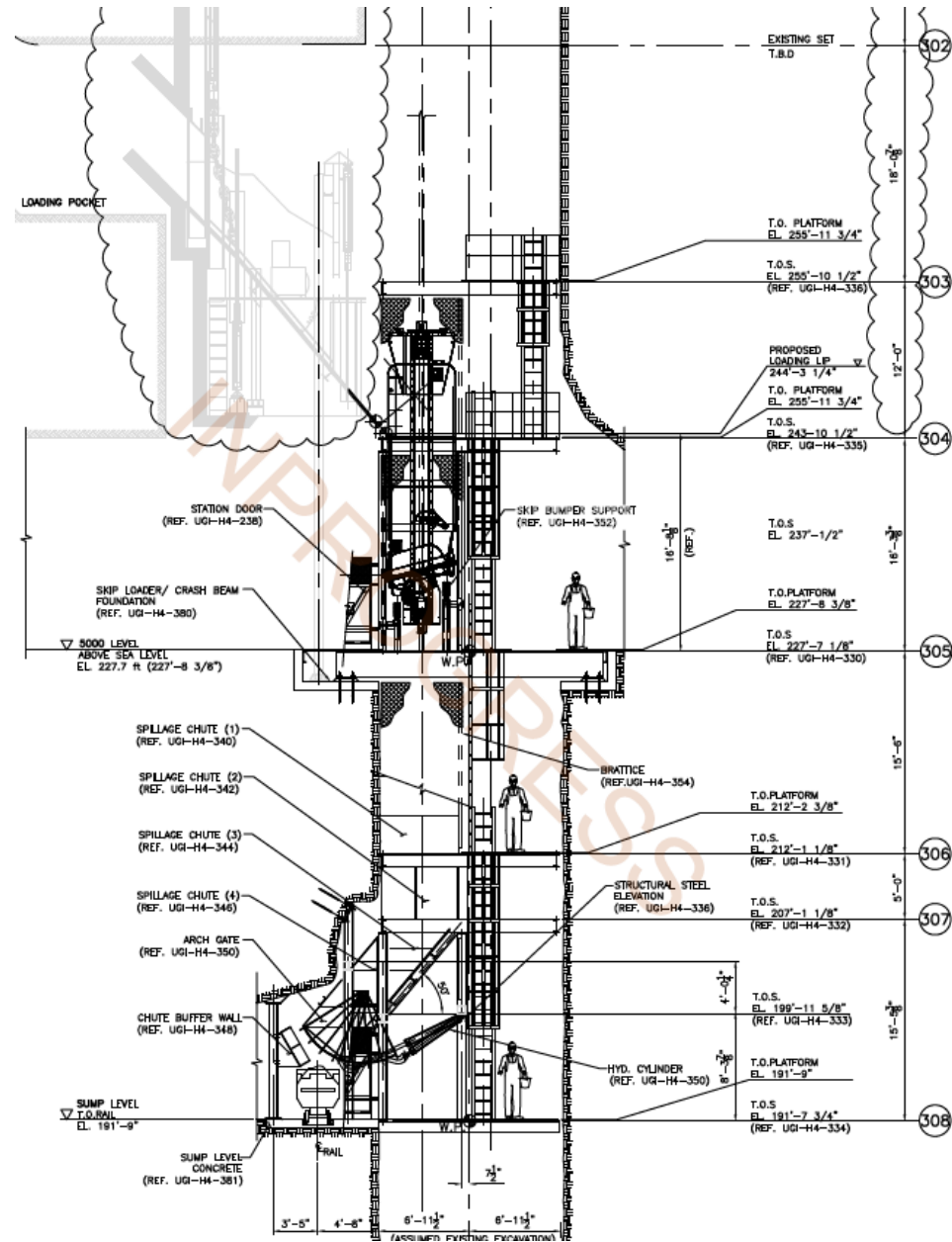


Other near term (next couple of years) projects

- Rebuilding the centrifugal fan at the Oro Hondo shaft in Kirk Canyon
 - This means running the vane-axial fan during the rebuild
- Rebuilding the Ross shaft hoists (motors, clutches, brakes)
- New cage and skips for the Ross shaft
- Rebuilding the skip loading system underground (next slide)
- Rebuilding the crushing system at surface

Skip Loading System

- Skips are essentially big buckets to bring rock to the surface
- A bin feeds a measuring chute that keeps the skip from overfilling
- Some material inevitably spills, so a collection system will also be restored.



Some Other Topics

Environmental Assessment Updates

- Any approach changes are sent to the Department of Energy environmental compliance officer for review on whether it affects the “FONSI” for the project. The change is reviewed relative to the approach described in the EA.
- Responses are submitted to the project. So far, 4 such reviews have been performed and none have been found to change the EA result:
 - Rock placement in south end of the open cut
 - Rock placement moved 200’ West (still south end)
 - LAr volume higher than stated
 - Excavation of new tunnel for conveyor

Construction Manager/General Contractor Update

- We had an excellent response from world class firms to help build this project
- Firms all indicated a desire to hire locally wherever practical
- A selection will be made mid-year

Recent City Involvement

We've been working with the City on several topics:

- Alternate methods to meet code (building code doesn't address working a mile underground very well in a few areas)
 - Elevator lobbies, elevator for egress, drifts for ventilation, standpipe use, occupancy levels.
- Easements and zoning
- Utility supply (e.g. water for dust suppression)
- Noise compliance
- Historic Preservation input
- Community involvement (like this meeting)

Questions?