



Needle's Eye Tunnel Repair Feasibility Study

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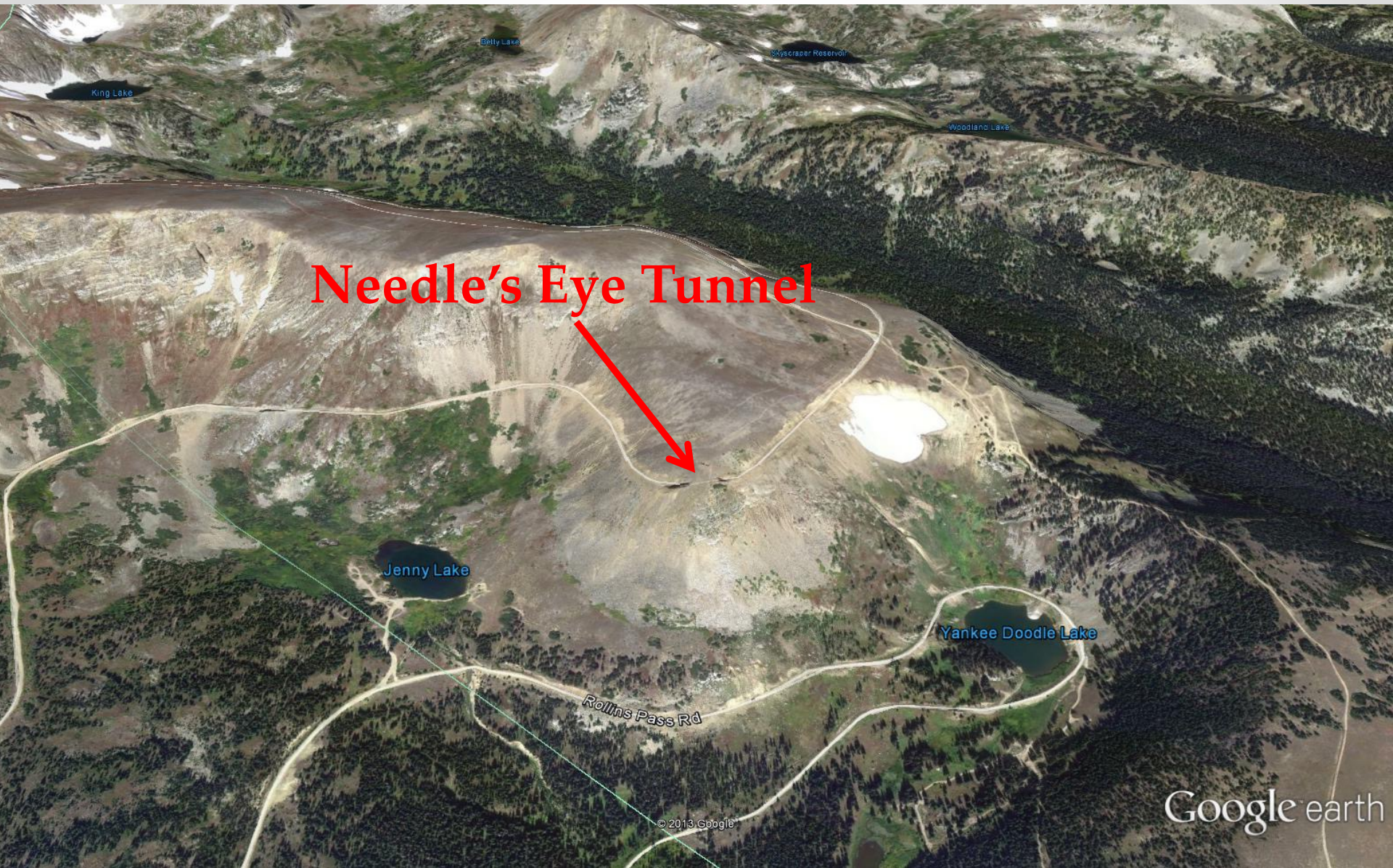


Tunnel Stats

- 11,600 ft elevation on Rollins Pass
- 19.4 mi west of Rollinsville on CR117/USFS Rd149
- 150 feet long
- 19-22 feet wide
- 22-30 feet tall (24 ft typical)
- Rock dowel and wire mesh support







Needle's Eye Tunnel

Google earth

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Needle's Eye



Tunnel History

- Part of Moffat Railroad “Hill Route”
- 1903-1905 Constructed
- 1905-1928 In operation, replaced by Moffat Tunnel
- 1935 Abandoned
- 1937-1955 Primitive Road
- 1955-1979 Car road
- 1979 Closed due to rock fall



Repair History

- 1981 Amuedo & Ivey Engineering Study
- 1985 MSHA Study
- 1986 Centennial Engineering Design
- 1987 Rock dowel and steel mesh repair
- 1988 Tunnel Re-opens
- 1990 Rock fall with injury, tunnel closed
- 1992 Repair Alternatives Study by PB



Engineering Reports

- **Heuer 1990**
 - Spacing of bolts was too wide (main cause of rock fall)
 - Ice wedging loosens rock
 - Recommends additional bolting to achieve 1986 design spacing and consider adding shotcrete
- **Parsons Brinkerhoff 1992**
 - Evaluation of 5 repair alternatives
 - Very conservative risk analysis
 - Dowels and mesh with 1 injury every 10 years
 - Expensive Concrete lining with less than 1 injury every 100 years
 - Effectively stopped further consideration of repairs
- **2012 Deere & Ault Feasibility Study**



NE Portal View SW



View Southwest



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Shear at NE Portal



North Wall Shear at NE Portal with Failed Mesh



Shear



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North Wall Shear in Middle of Tunnel



Shear

New Rock Fall



New Rock Fall Source and Failed Mesh



Shear

Rock Dowels & Mesh in Crown



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Rock Dowels & Mesh on North Wall



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SW Portal View NE



Observations

- **Shallow cover**
 - Rock blocks are de-stressed and more prone to sliding
 - Susceptible to freeze-thaw damage & ice wedging
- **Geology**
 - Igneous metamorphosed migmatite/granite gneiss
 - Fresh to moderately weathered
 - Joint sets per Amuedo & Ivey
- **Shear on north wall parallel to tunnel**
 - Amuedo & Ivey joint set #2
 - Strikes northeast & dips sharply southwest
 - Local hydrothermally altered shears
 - Forms smooth north wall and controls shape of south wall



Observations

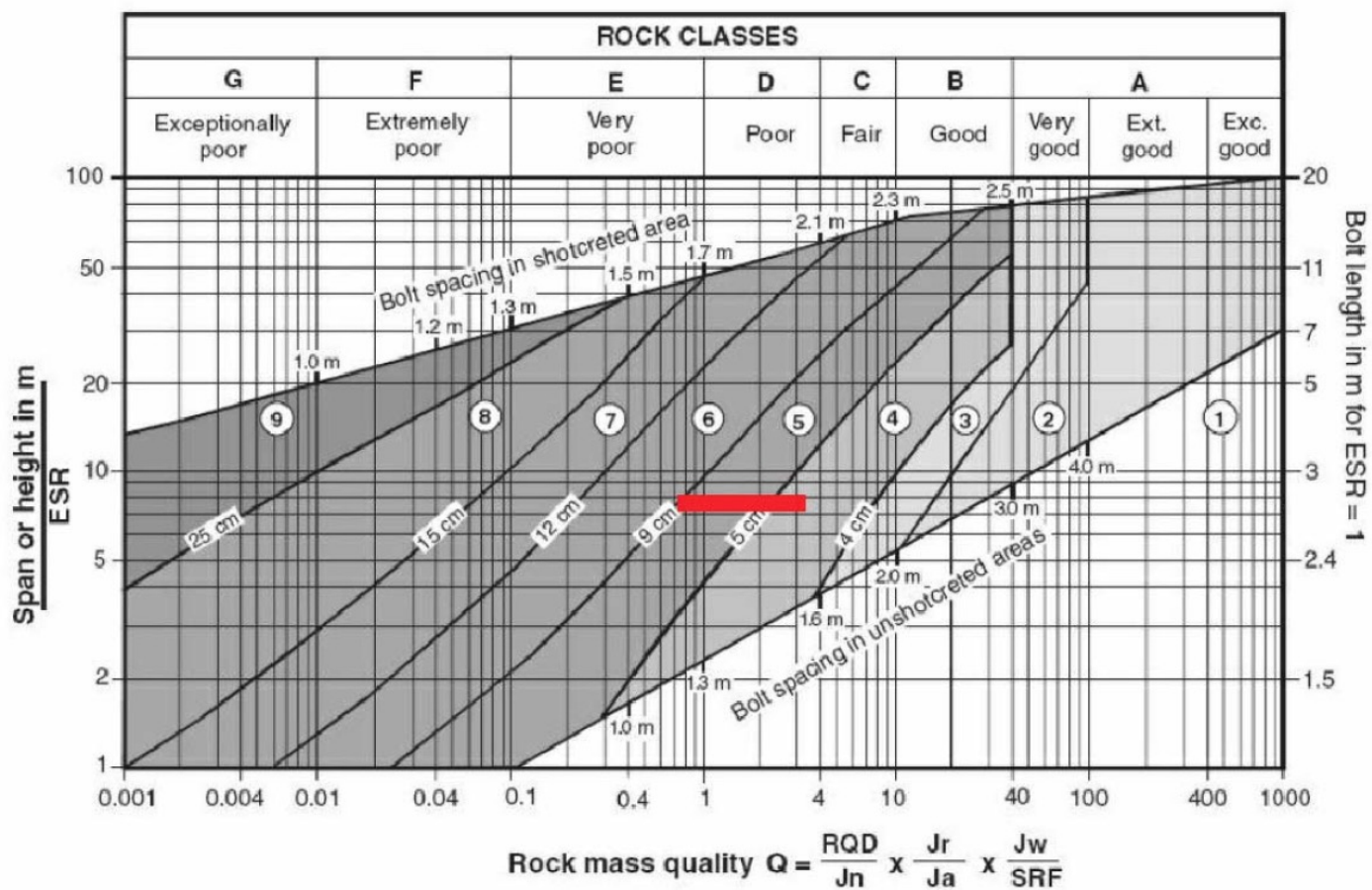
- 2 significant rock falls
- 1990 rock fall at NE portal shows additional raveling
- New rock fall near middle of tunnel
 - Two sources of rock, both in north wall shear
 - Upper crown where mesh failed
 - Wall below dowels and mesh
- Confirmed that tunnel is not stable with existing support



Q Analysis

- Rock mass classification system developed from case histories
- Used to evaluate various rock parameters

Parameter	Value	Description
Rock Quality Designation (RQD)	75-90	Fair-Good
Joint Set Number J_n	9-12	3 joint sets to 3 joint sets + random
Joint Roughness Number J_r	1-1.5	Smooth planar-rough planar
Joint Alteration Number J_a	1-2	Unaltered joints-slightly altered joints
Joint Water Reduction J_w	1	Dry or minor inflow
Stress Reduction Factor (SRF)	5	Single shear zone in shallow rock or loose open joints
$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$	Q=	0.6-3



REINFORCEMENT CATEGORIES:

- | | |
|---|---|
| <ul style="list-style-type: none"> 1) Unsupported 2) Spot bolting 3) Systematic bolting 4) Systematic bolting, (and unreinforced shotcrete, 4 - 10 cm) 5) Fibre reinforced shotcrete and bolting, 5 - 9 cm | <ul style="list-style-type: none"> 6) Fibre reinforced shotcrete and bolting, 9 - 12 cm 7) Fibre reinforced shotcrete and bolting, 12 - 15 cm 8) Fibre reinforced shotcrete, > 15 cm, reinforced ribs of shotcrete and bolting 9) Cast concrete lining |
|---|---|

RANGE OF ROCK MASS QUALITY IN NEEDLE'S EYE TUNNEL

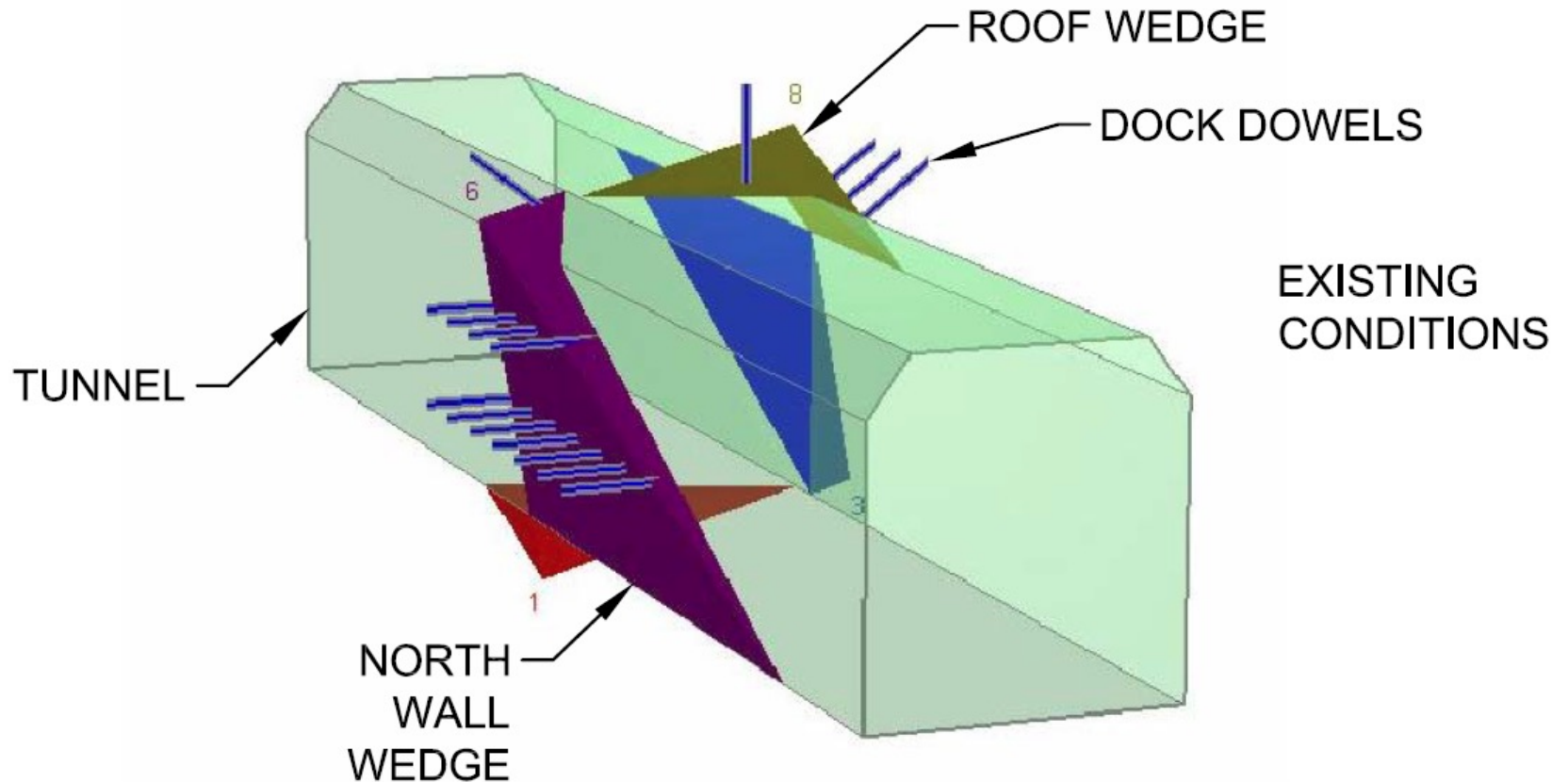
RMR Analysis

- Rock Mass Rating
- Recommends rock bolts on 5 foot spacing with 2-4 inches of shotcrete

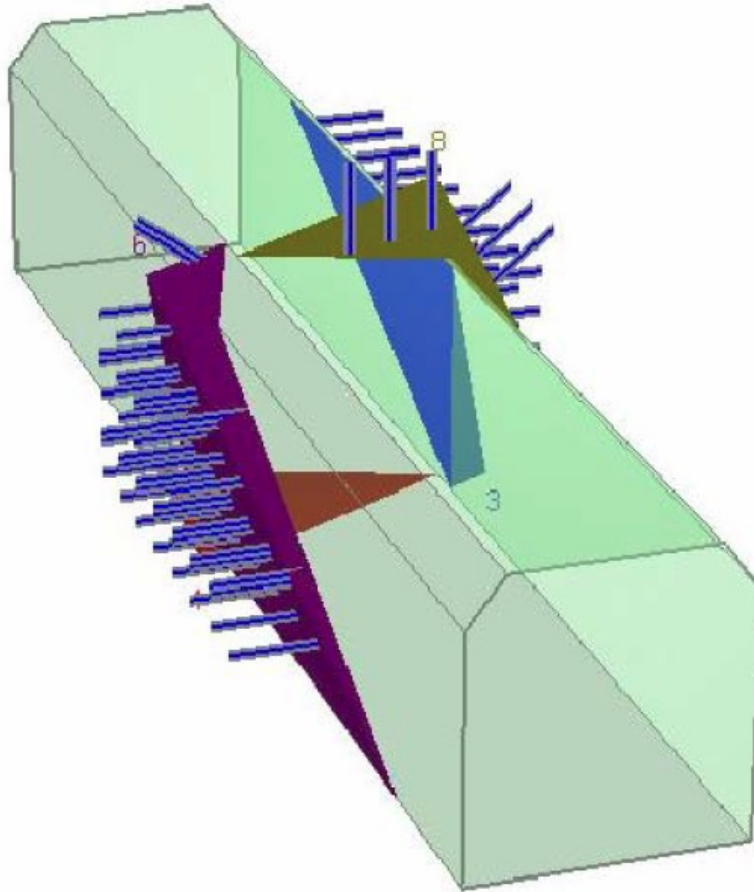
Parameter	Value	Description
Intact Rock Strength	7	50-100 MPA (7250-14,500 psi); medium strength
Rock Quality Designation (RQD)	17	75-90%; Fair-Good
Discontinuity Spacing	10	20-60cm (0.7-2 ft)
Discontinuity Condition	20	Slightly rough surface, highly weathered walls
Groundwater Inflow	10	Damp
Strike & dip orientation	-12	Very unfavorable; steep shear parallel to tunnel
RMR	52	Class III Fair Rock



Key Block Analysis



Key Block Analysis



ROCK DOWEL
REPAIR
ALTERNATIVE

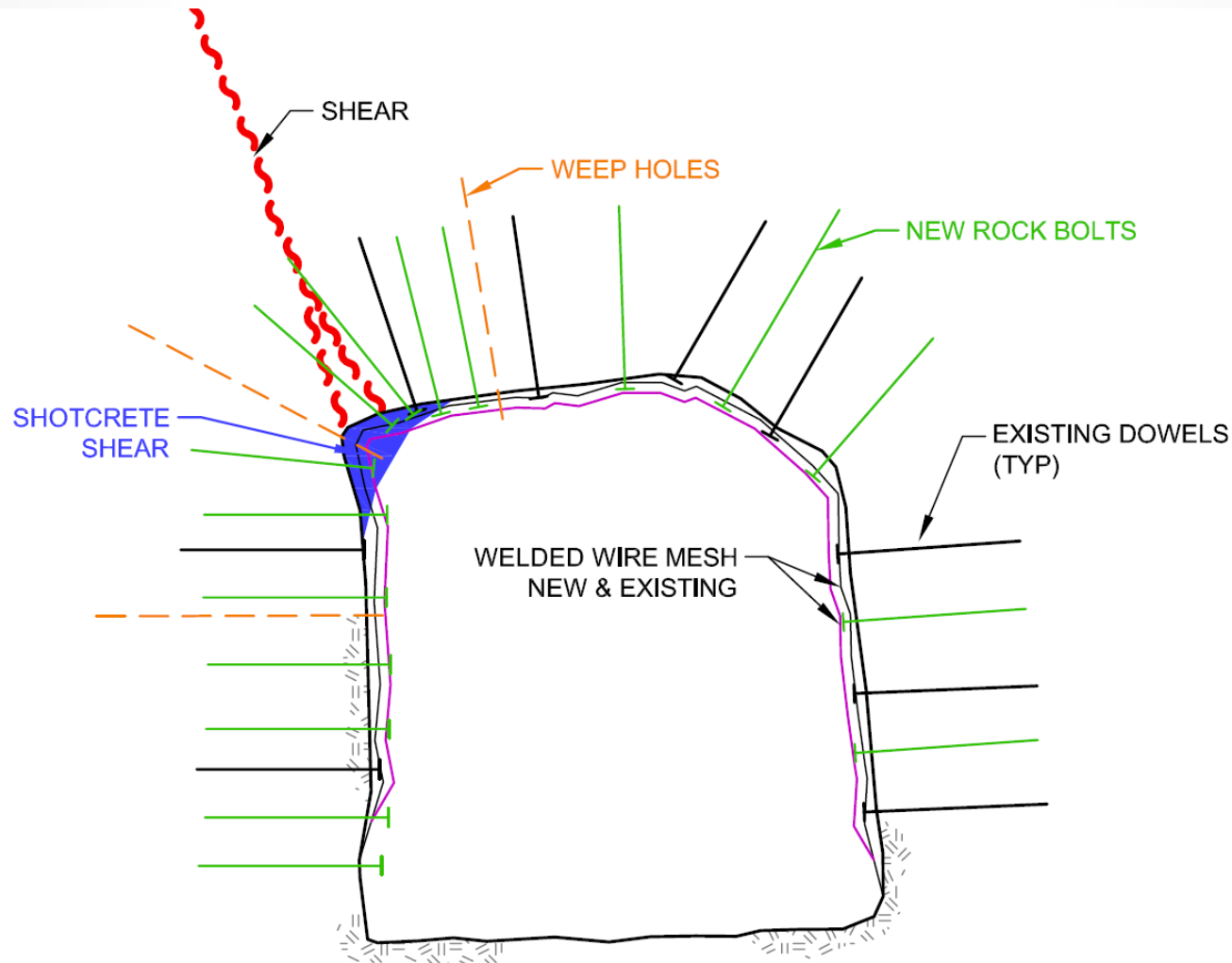
Findings From Analysis

- Tunnel currently not safe for public access
- Rock falls likely in future
- Repairs required to re-open tunnel
- Two repair options evaluated



Repair Option 1

Rock Bolts & Mesh with Minor Shotcrete



Repair Option 1 Cost

Option 1: Rock Bolts and Mesh

Item	Quantity	Unit	Unit Price	Price
Mobilization	1	Lum Sum	\$ 50,000	\$ 50,000
Road Improvements	1	Lump Sum	\$ 50,000	\$ 50,000
Scaling/Prep	1	Lum Sum	\$ 30,000	\$ 30,000
Muck Removal	30	CY	\$ 500	\$ 15,000
Rock Bolts	600	Each	\$ 200	\$ 120,000
Weep Holes	85	Each	\$ 100	\$ 8,500
Wire Mesh	12000	Square Foot	\$ 2	\$ 24,000
Shotcrete	20	Cubic Yard	\$ 2,000	\$ 40,000

Total \$ 337,500

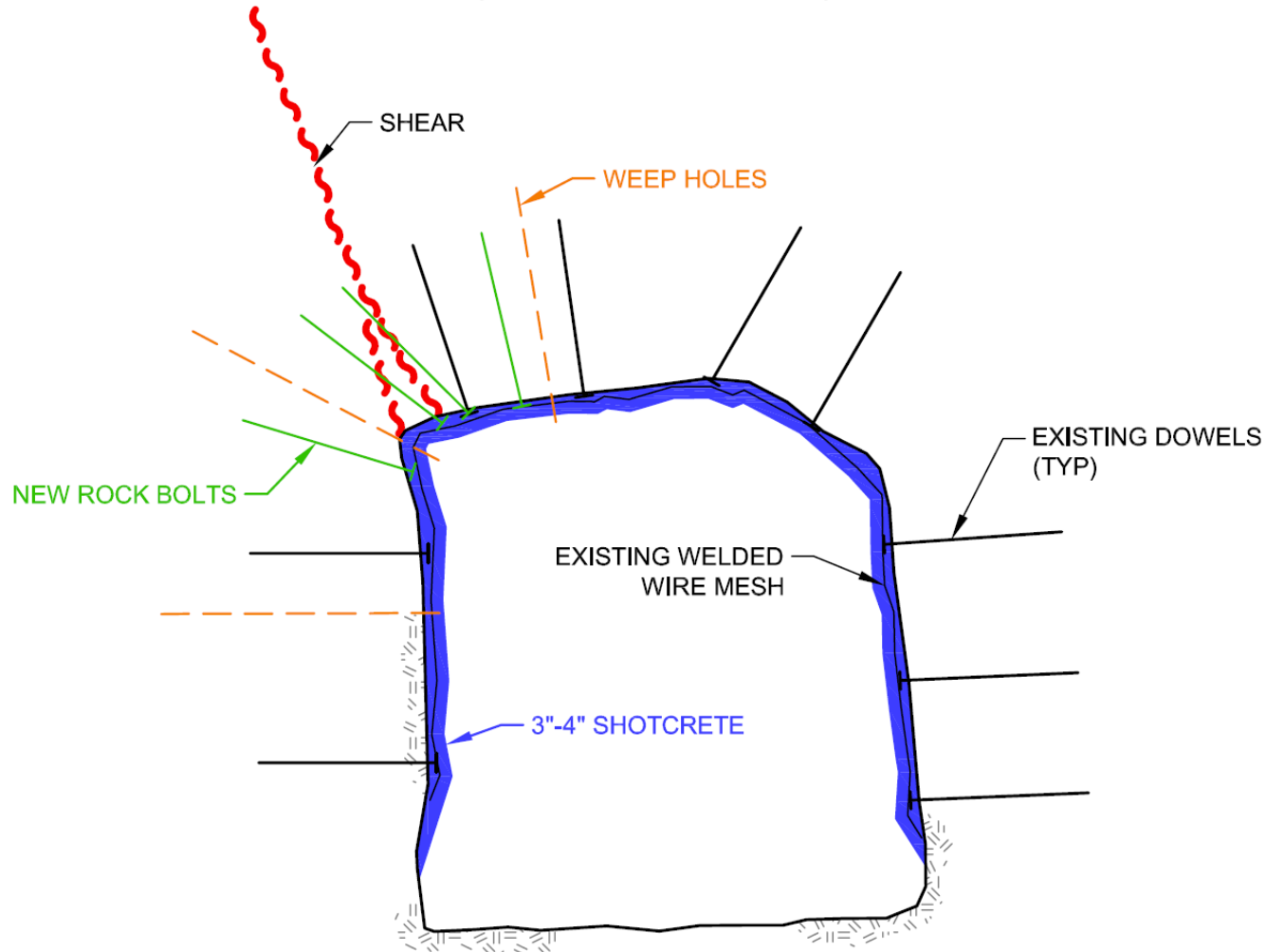
Contingency at 20% \$ 67,500

Total with Contingency \$ 405,000



Repair Option 2

Shotcrete with Some Rock Bolts



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Repair Option 2 Cost

Option 2: Shotcrete & Limited Bolting

Item	Quantity	Unit	Unit Price	Price
Mobilization	1	Lum Sum	\$ 50,000	\$ 50,000
Road Improvements	1	Lump Sum	\$ 50,000	\$ 50,000
Scaling/Prep	1	Lum Sum	\$ 30,000	\$ 30,000
Muck Removal	30	Cubic Yard	\$ 500	\$ 15,000
Rock Bolts	240	Each	\$ 200	\$ 48,000
Weep Holes	75	Each	\$ 100	\$ 7,500
Wire Mesh	2000	Square Foot	\$ 2	\$ 4,000
Shotcrete	122	Cubic Yard	\$ 1,600	\$ 195,200

Total \$ **399,700**
 Contingency at 20% \$ 79,940
Total with Contingency \$ **479,640**



Repair Summary

- **Option 1: Rock Bolts & Mesh with Some Shotcrete**
 - Estimated construction cost \$405,000
 - More difficult to construct due to tight bolt spacing
 - Regular maintenance required
- **Option 2: Shotcrete with Some Rock Bolts**
 - Estimated construction cost \$480,000
 - Easier to construct
 - Low maintenance
 - More typical for public structures
 - Will cover soot marks
- **Engineering (either option)**
 - Design: \$60,000
 - Construction Engineering: \$70,000



Boulder Canyon Tunnel



Boulder Canyon Tunnel



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Laramie-Poudre Tunnel



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Standley Lake Tunnel



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Esti Hydrotunnel



Conclusion

- The Needle's Eye Tunnel can be safely repaired for public access using shotcrete and rock bolts.





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