

10TUNNEL 5: GEOLOGICAL & GEOTECHNICAL ASSESSMENT

10.1 Exploratory drillings

As per the requirement of scope of work outlined in the terms of reference, 61 bore holes were drilled with a cumulative length of 2307m at different locations along the proposed alignment. Necessary care has been taken during drilling operations by deploying good quality diamond drill machines to obtain good core recovery to obtain RQD values. The locations of the boreholes were selected in such a way, so that these holes intersect the envisaged ground/strata conditions at different depths. The location and details of boreholes drilled; total depth of drillings is shown in table below.

Chainage	BH	GL	FL	Depth
50177	BH-1	509.263	493.039	22.00
50227	BH-2	516.522	492.539	28.50
50277	BH-3	527.554	492.039	41.00
50327	BH-4	530.266	491.539	44.00
50377	BH-5	524.241	491.039	38.00
50427	BH-6	520.274	490.539	34.50
50477	BH-7	520.796	490.039	36.00
50527	BH-8	512.844	489.539	29.00
50577	BH-9	505.051	489.039	21.00
50627	BH-10	512.754	488.539	29.00
50677	BH-11	507.868	488.039	25.00
50727	BH-12	504.397	487.539	22.00
50777	BH-13	506.816	487.039	25.00
50827	BH-14	509.633	486.539	28.00
50877	BH-15	516.892	486.039	36.00
50927	BH-16	520.427	485.539	40.00
50977	BH-17	518.235	485.038	38.00
51027	BH-18	517.334	484.533	37.50
51077	BH-19	518.997	484.028	40.00
51127	BH-20	516.745	483.523	38.00
51177	BH-21	516.499	483.017	39.00
51227	BH-22	519.582	482.512	42.00
51277	BH-23	524.395	482.007	48.00
51327	BH-24	526.436	481.502	51.00
51377	BH-25	523.43	480.997	48.00
51427	BH-26	519.767	480.492	45.00

Chainage	BH	GL	FL	Depth
51477	BH-27	515.816	479.987	41.00
51527	BH-28	512.088	479.482	38.00
51577	BH-29	507.712	478.977	34.00
51627	BH-30	500.922	478.472	28.00
51677	BH-31	498.193	477.967	25.00
51727	BH-32	511.071	477.462	39.00
51777	BH-33	516.636	476.957	45.00
51827	BH-34	518.215	476.452	47.00
51877	BH-35	512.572	475.947	42.00
51927	BH-36	505.782	475.442	36.00
51977	BH-37	496.027	474.937	26.00
52027	BH-38	489.239	474.432	20.00
52077	BH-39	503.497	473.927	36.00
52127	BH-40	518.107	473.422	50.00
52177	BH-41	520.022	472.916	52.00
52227	BH-42	516.94	472.411	50.00
52277	BH-43	525.086	471.906	59.00
52327	BH-44	532.974	471.401	67.00
52377	BH-45	517.371	470.896	51.00
52427	BH-46	511.242	470.391	48.00
52477	BH-47	508.873	469.886	45.00
52527	BH-48	512.604	469.381	49.00
52577	BH-49	506.127	468.876	42.00
52627	BH-50	496.724	468.371	35.00
52677	BH-51	484.4	467.866	21.00
52727	BH-52	481.888	467.361	19.00
52777	BH-53	478.76	466.856	18.00
52827	BH-54	497.904	466.351	37.00
52877	BH-55	509.373	465.846	48.00
52927	BH-56	501.425	465.341	42.00
52977	BH-57	497.183	464.807	37.00
53027	BH-58	501.531	464.185	42.00
53077	BH-59	508.01	463.56	50.00
53127	BH-60	494.454	462.935	38.00
53177	BH-61	482.061	462.31	25.00

10.2 TUNNEL-5 SRT

10.2.1 Location:

Sr. No.	Chainage	Line	Spread	Location (T-05)		Length
				Start	End	In meter
1	50.177km to 53.177km	L1	S1 to S25	50.177km	53.177km	3000

10.2.2 Seismic survey results and conclusion

Table 10.1: Summery of Tunnel-1 SRT test

Variation of maximum range of thicknesses below EGL (M)			Avg. V_p (m/sec)	Calculated V_s (m/sec)	Dynamic Young's Modulus (MPa)	Shear Modulus (MPa)
Layer	From	To				
Layer-I	0.50	3.00	700	327	466	172
Layer-IIA	3.00	6.00	1700	837	3755	1401
Layer-IIB			2300	1183	8133	3081
Layer-IIIA	6.00	25.00	3000	1604	16046	6171
Layer-IIIB			3400	1879	22606	8831

Sample Calculation:

The Young's Modulus E is the uni-axial stress-strain ratio. Its dynamic value is expressed by the following equation:

$$E = \frac{\rho V_p^2 (1 + \mu)(1 - 2\mu)}{1 - \mu}$$

Where, E = Dynamic Young's Modulus in kN/m²

$$V_p = 700 \text{ m/sec}$$

$$\rho = 1.6 \text{ gm/cc} \approx 1.60 \text{ kN.s}^2/\text{m}^4 \text{ (mass density)}$$

$$\mu = 0.36$$

So, calculated E = 466480 kN/sqm \approx 466 MPa

The Shear Modulus G is the stress-strain ratio for simple shear. Its dynamic value is obtained by the following:

$$G = \frac{E}{2(1 + \mu)} = \rho V_s^2$$

So, Shear Modulus G comes out to be 171500 kN/sqm \approx 172 MPa

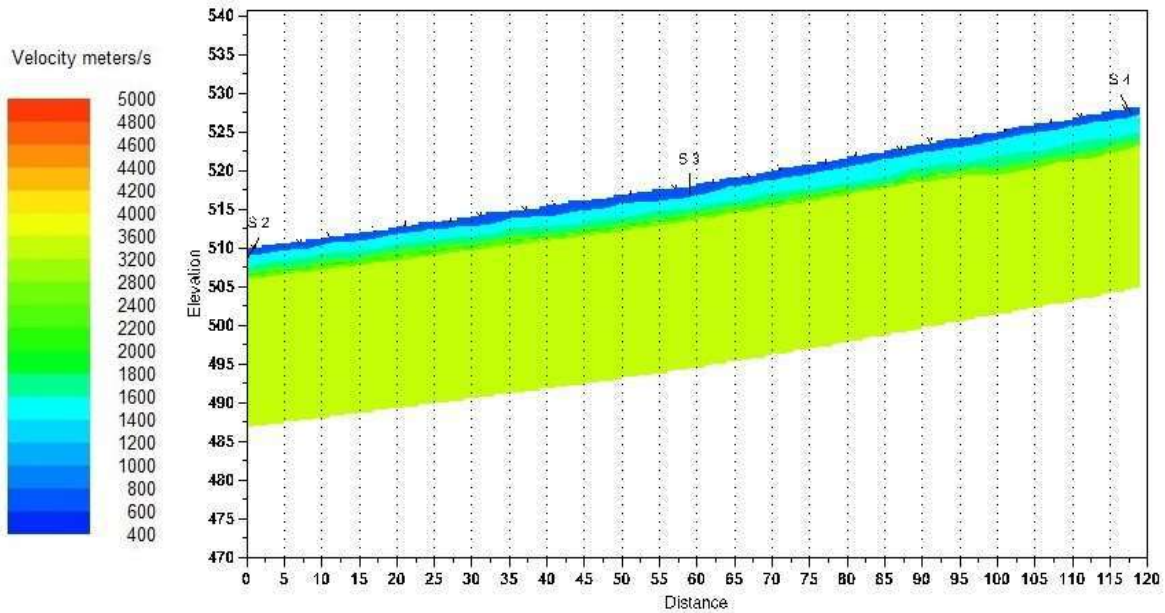
Again,

$$G = \rho V_s^2 \text{ giving } V_s = \sqrt{(G/\rho)}$$

So, calculated $V_s = 327.395 \text{ m/sec}$, say 327 m/sec

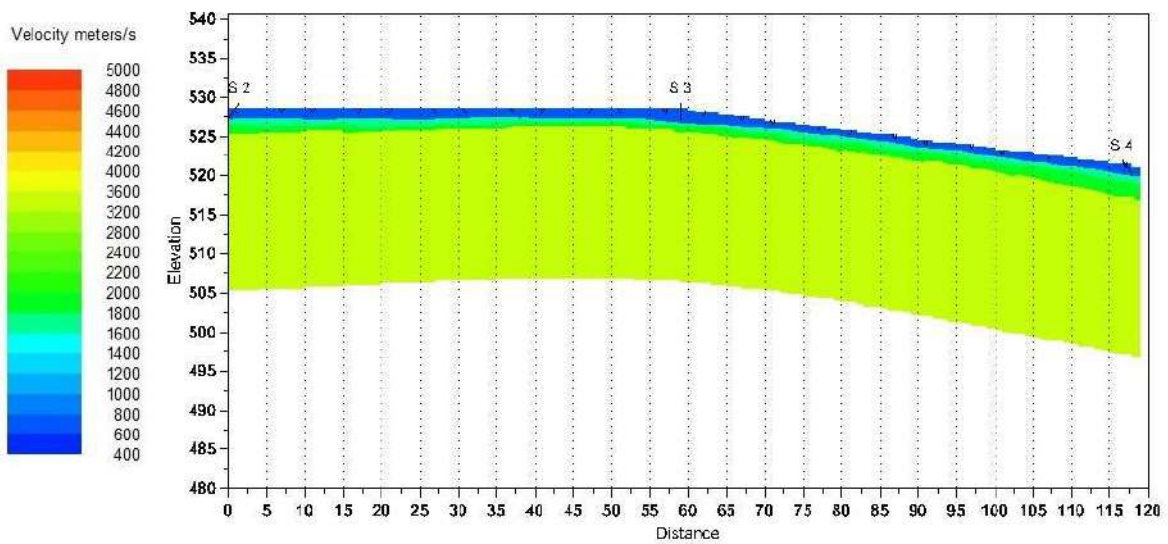
SEISMIC PROFILE(T05)

T5L1S1



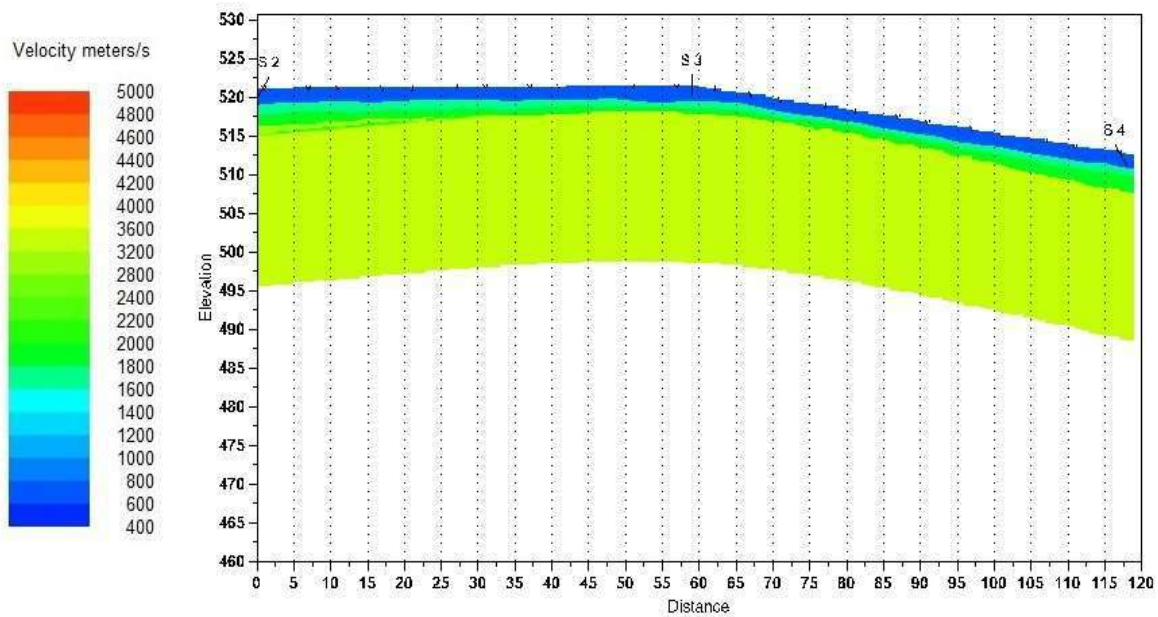
Shot point depth computation

T5L1S2

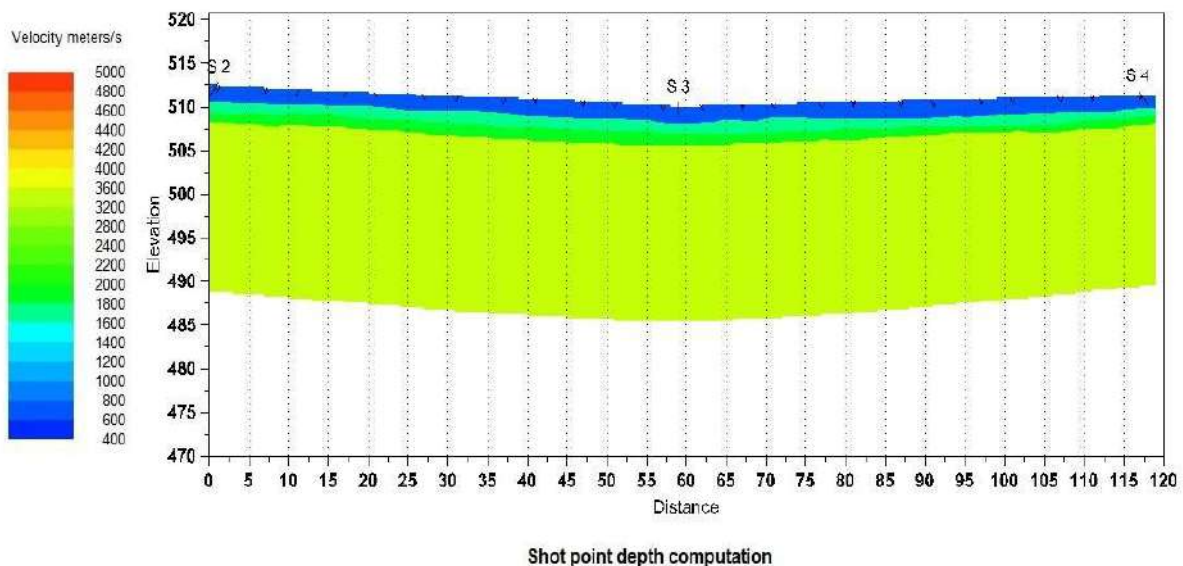


Shot point depth computation

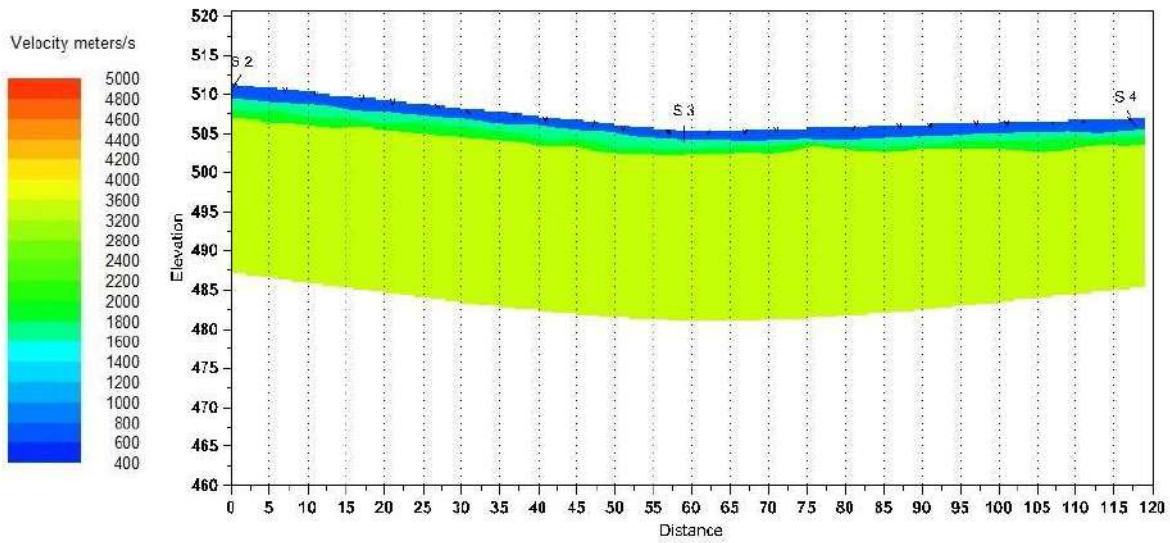
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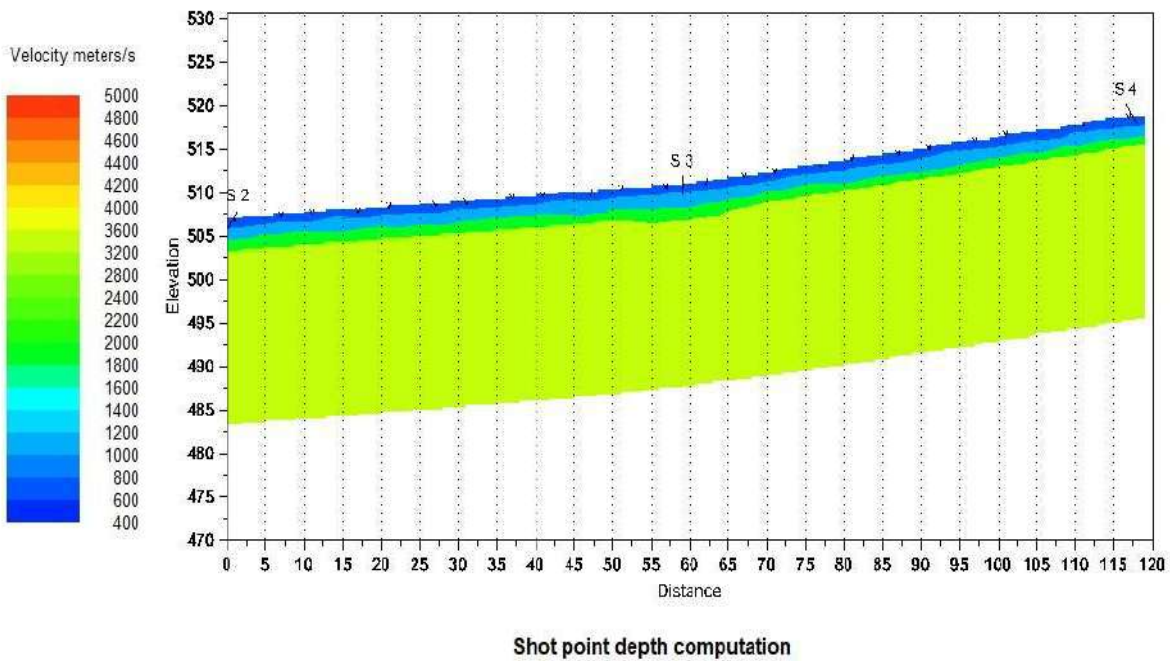
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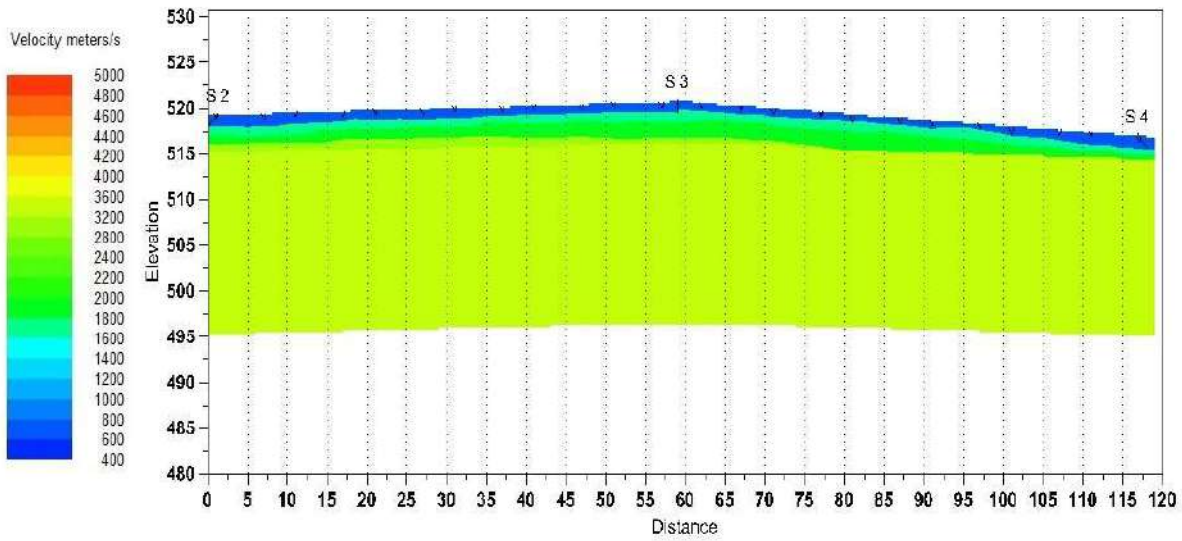
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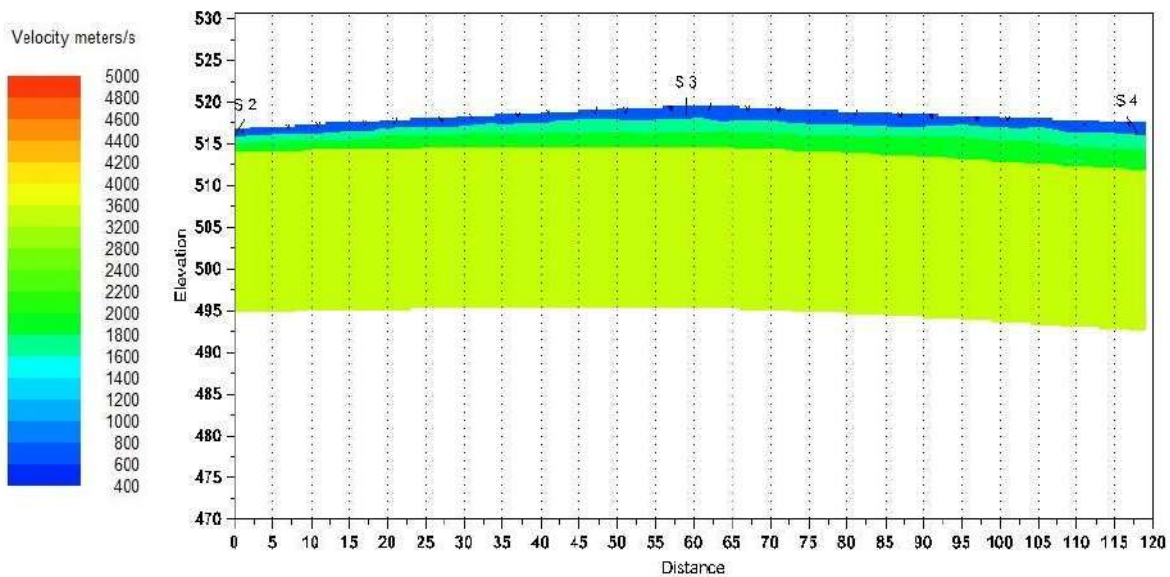
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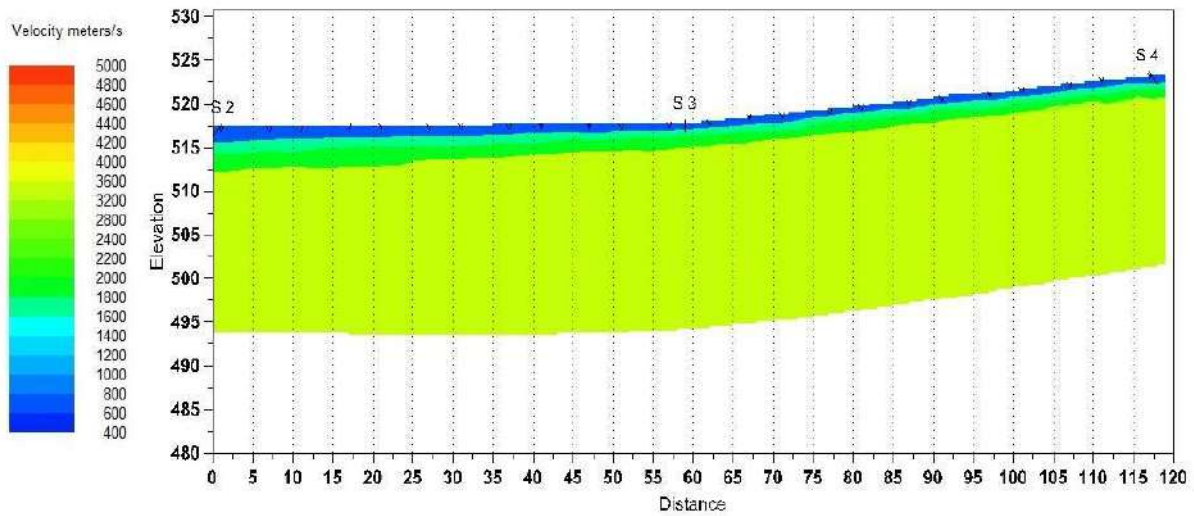
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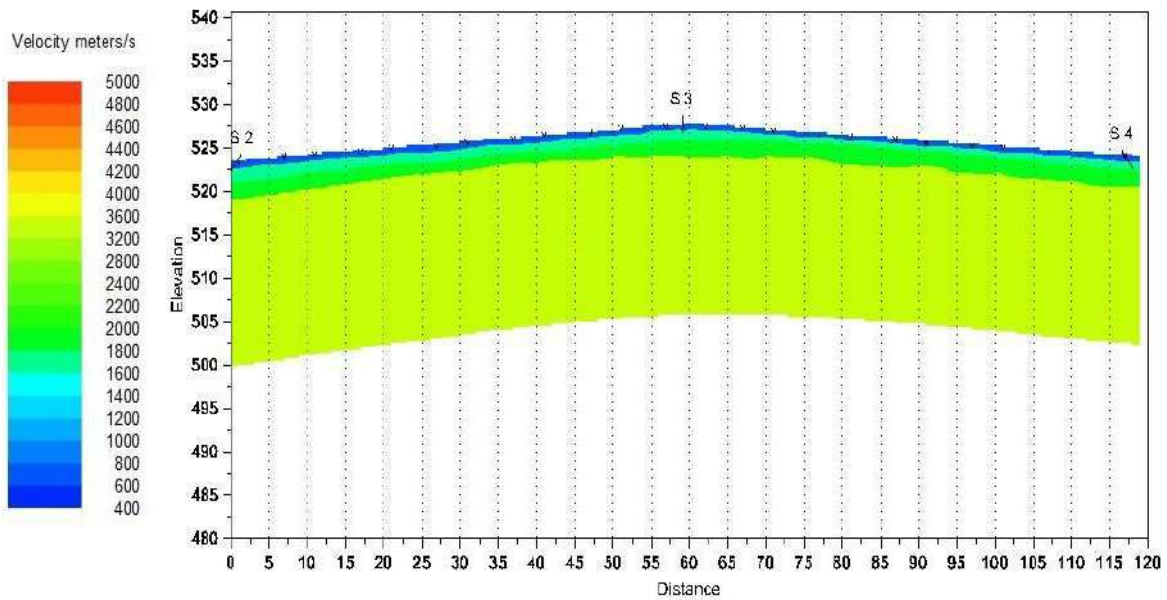
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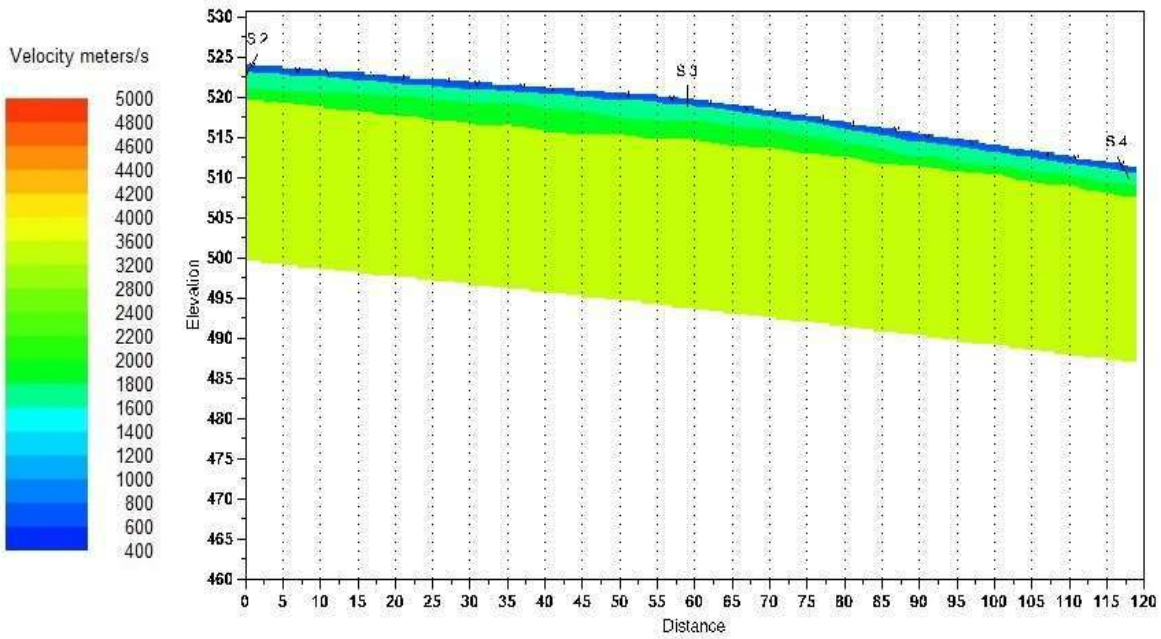
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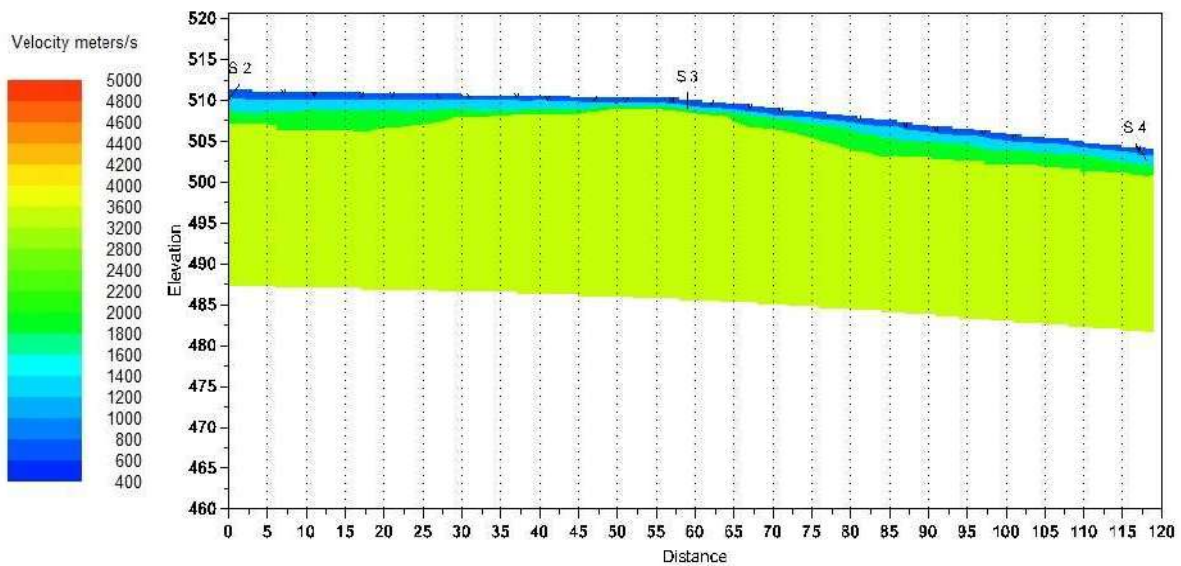
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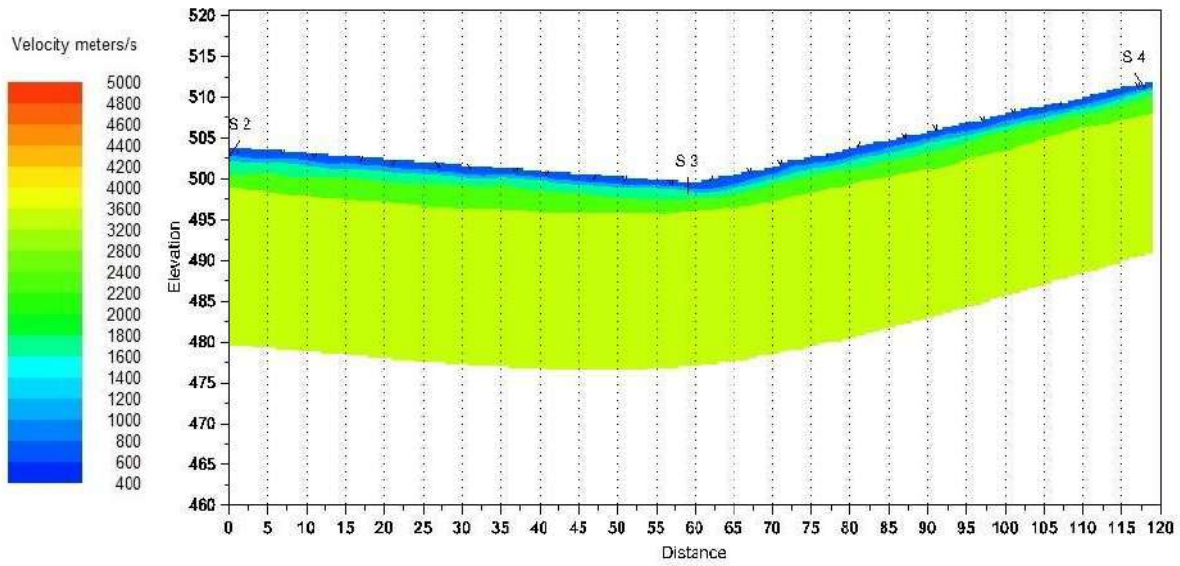
T5L1S11



T5L1S12

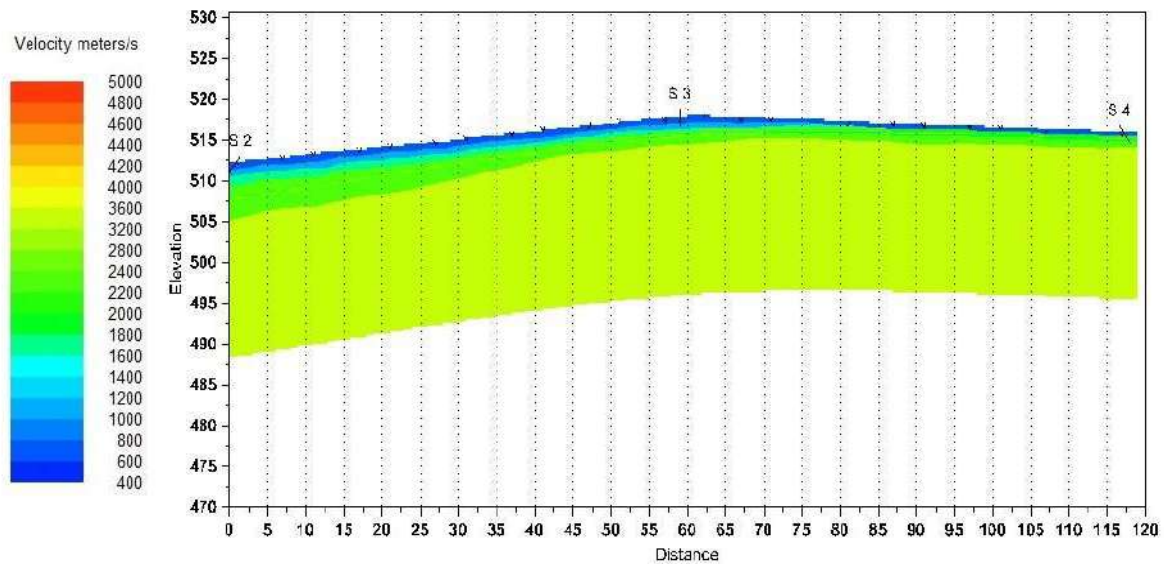


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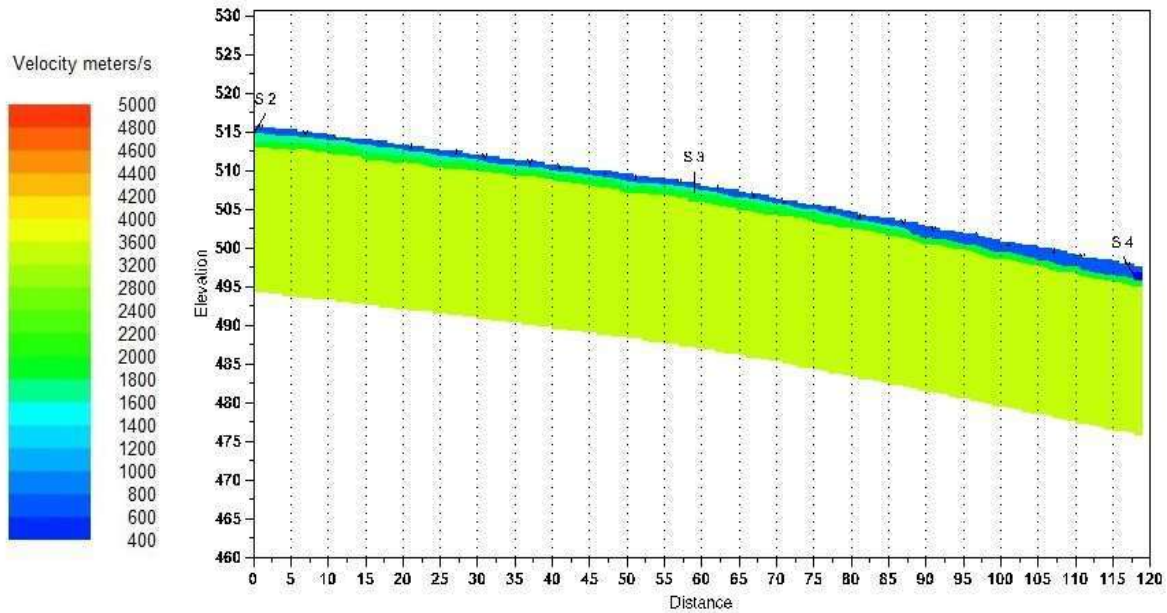
Shot point depth computation

T5L1S14



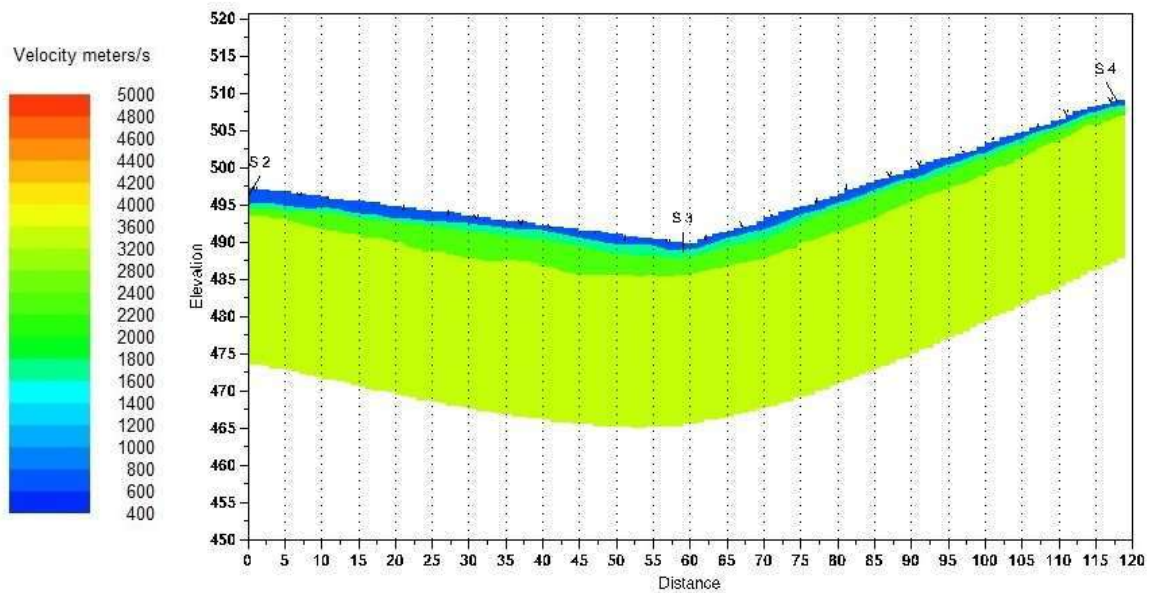
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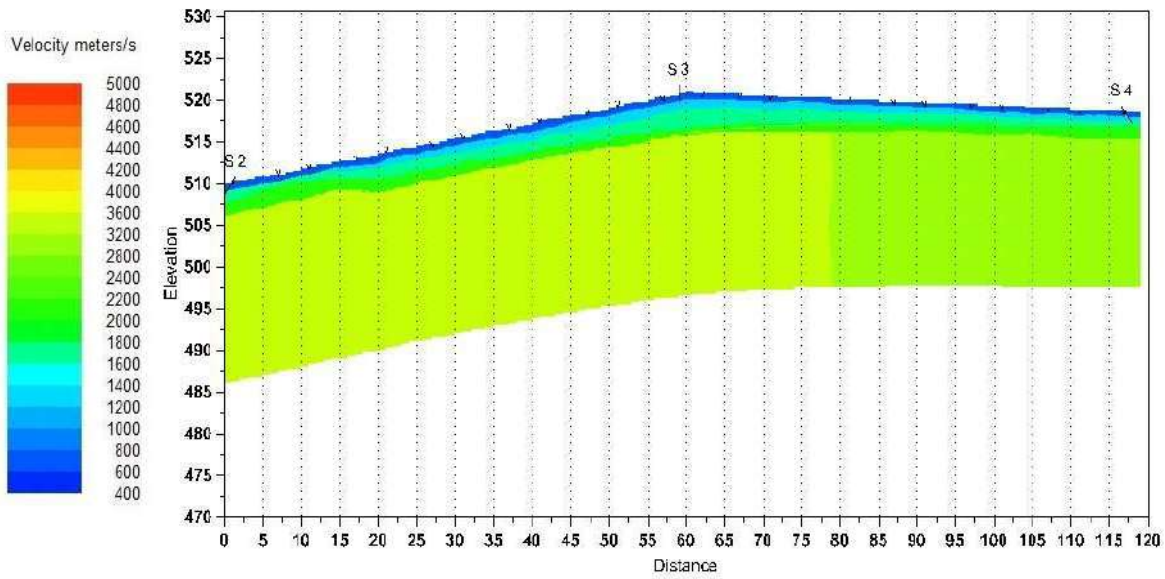
Shot point depth computation

T5L1S16



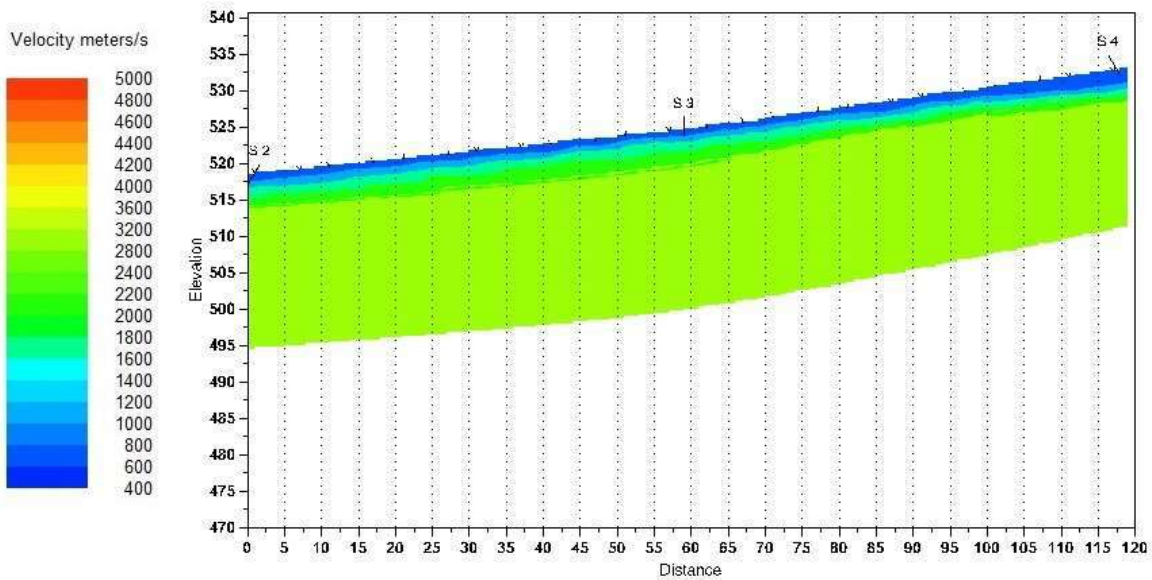
Shot point depth computation

T5L1S17



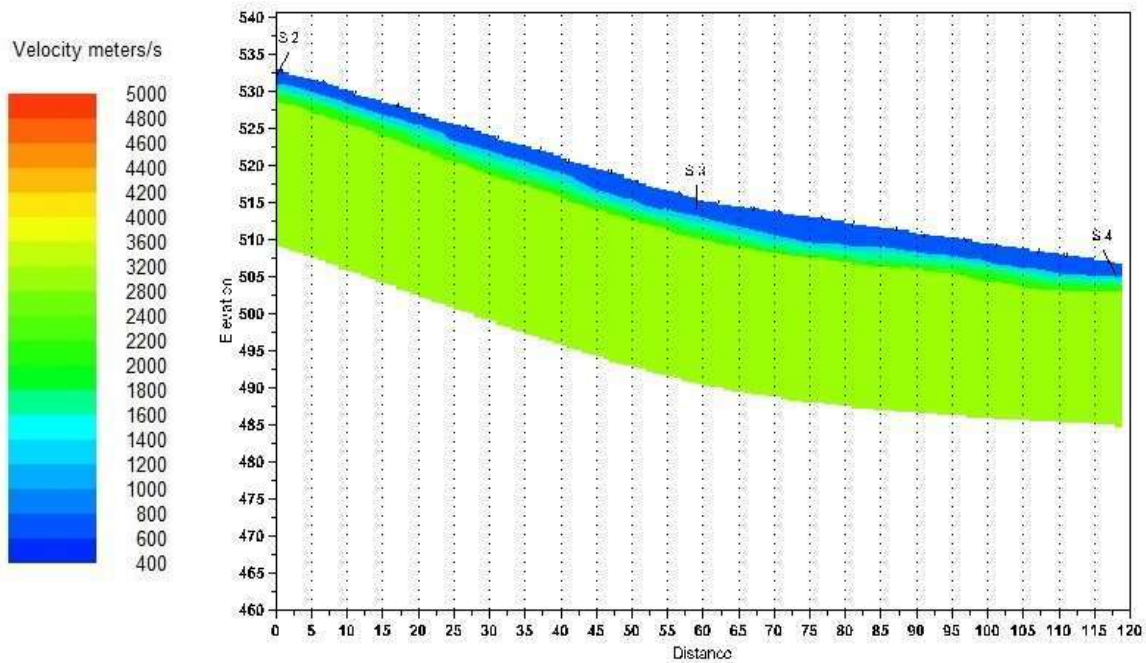
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T5L1S18



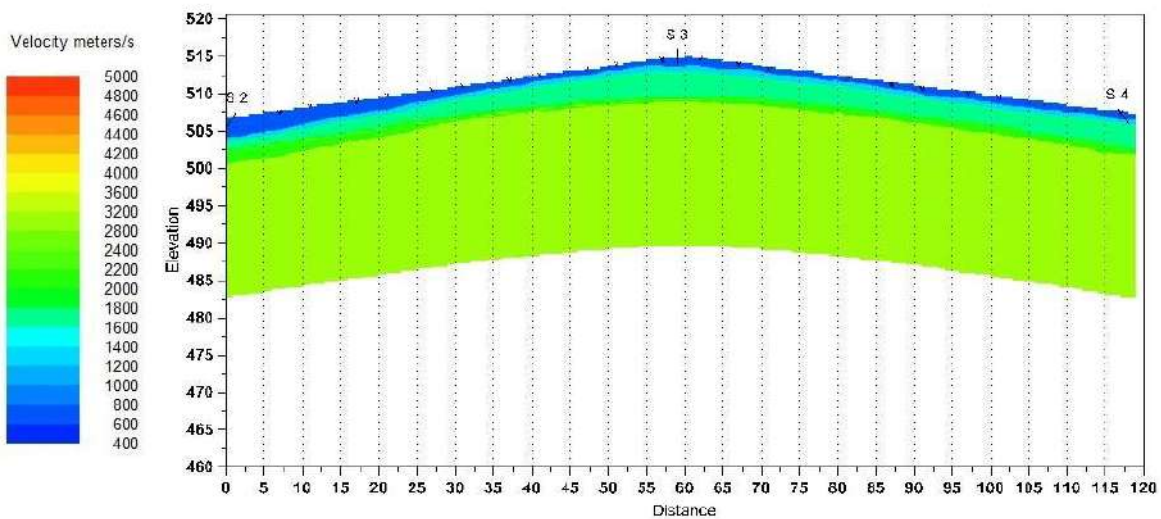
Shot point depth computation

T5L1S19



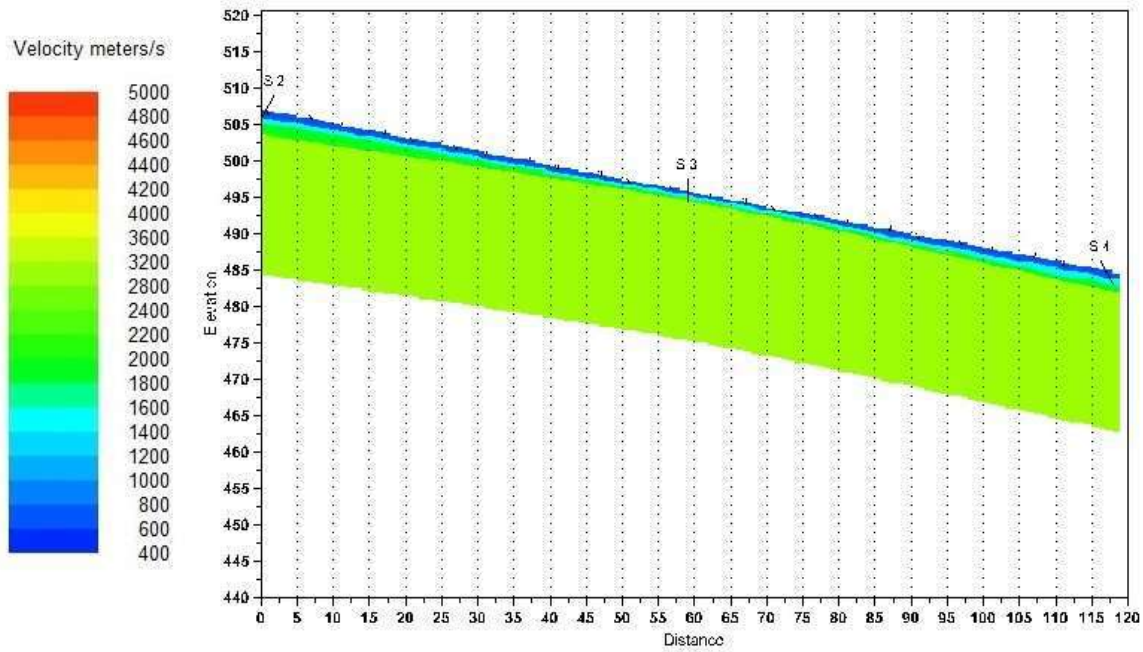
Shot point depth computation

T5L1S20



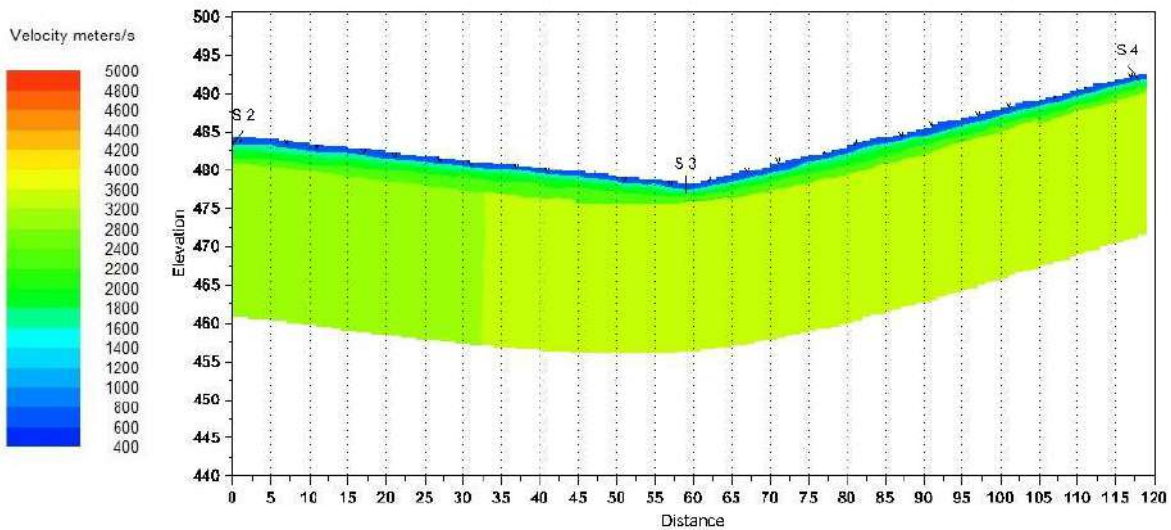
Shot point depth computation

T5L1S21



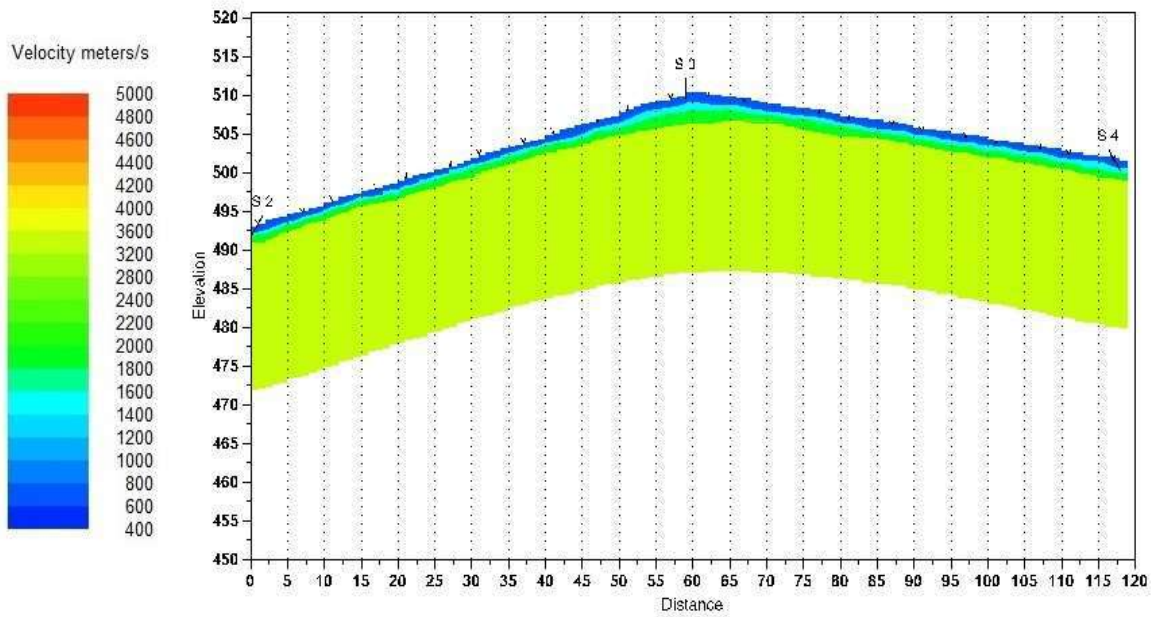
Shot point depth computation

T5L1S22



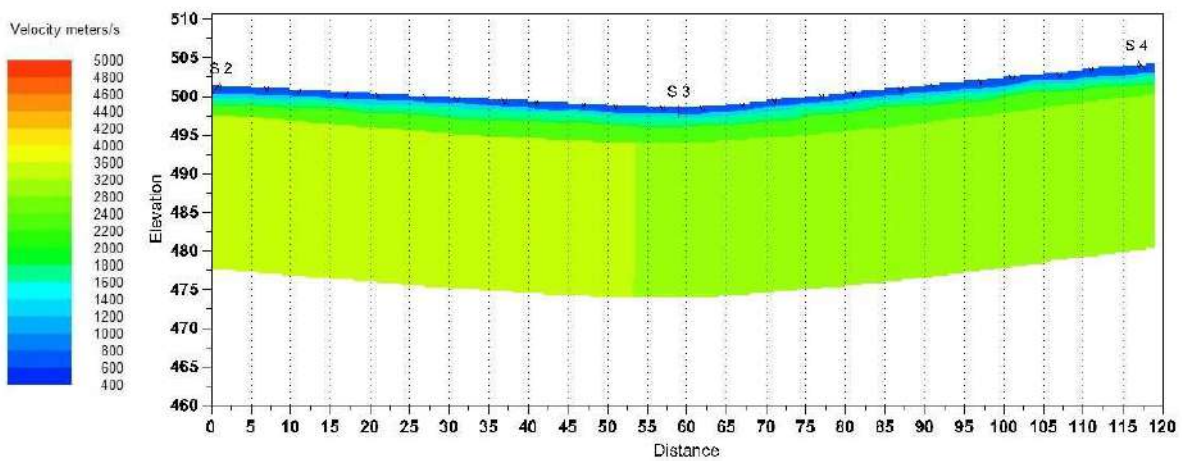
Shot point depth computation

T5L1S23



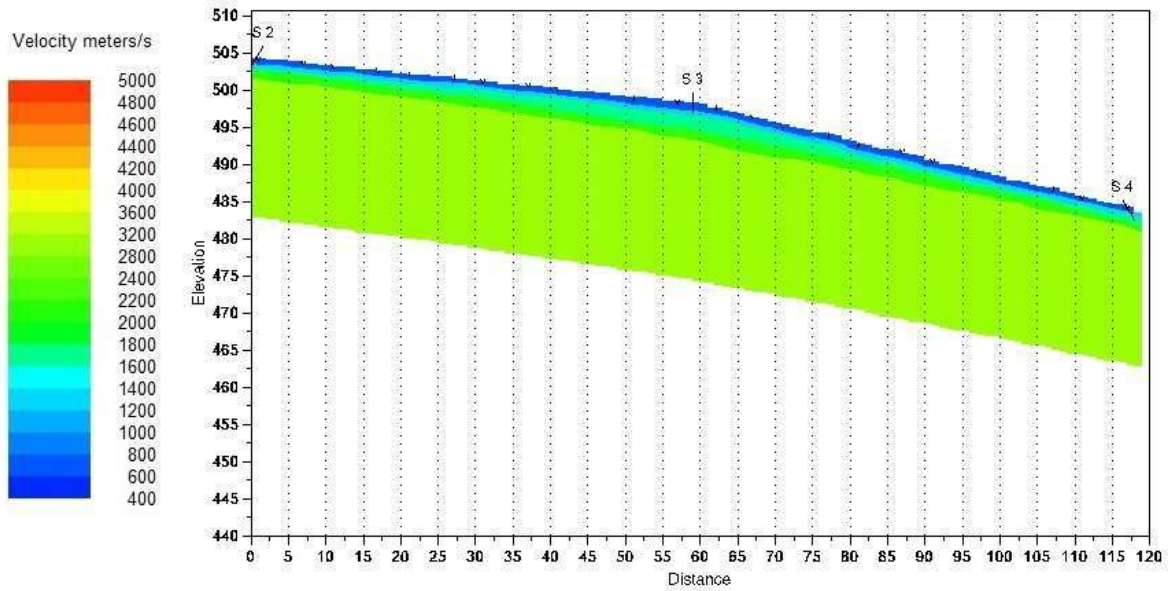
Shot point depth computation

T5L1S24



Shot point depth computation

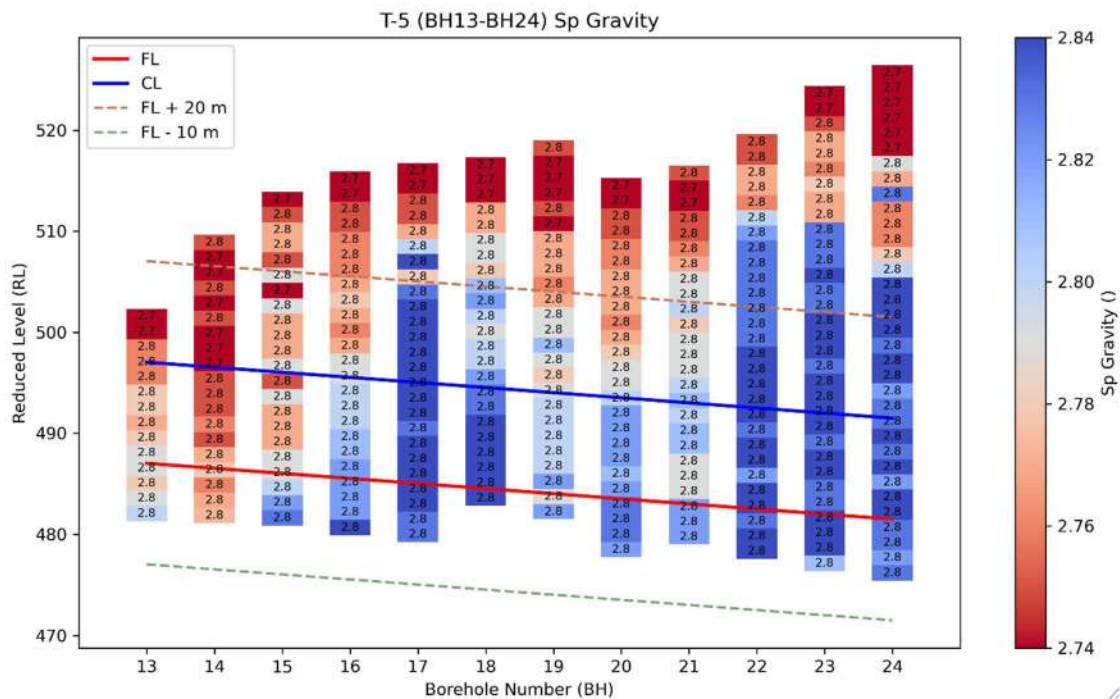
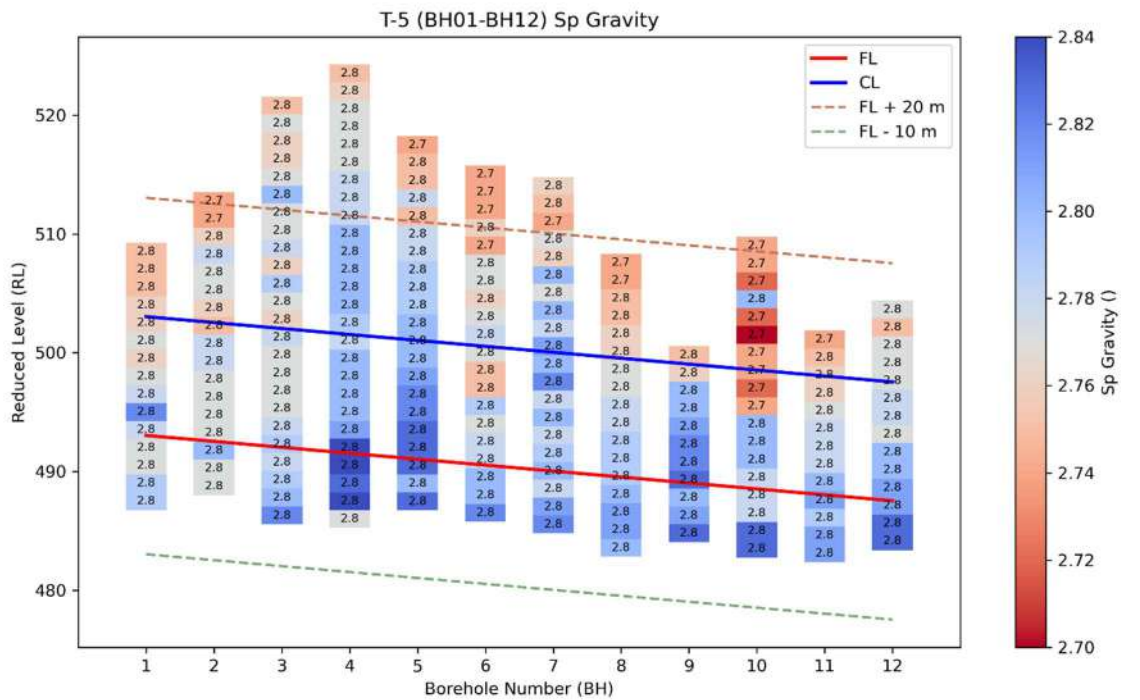
T5L1S25

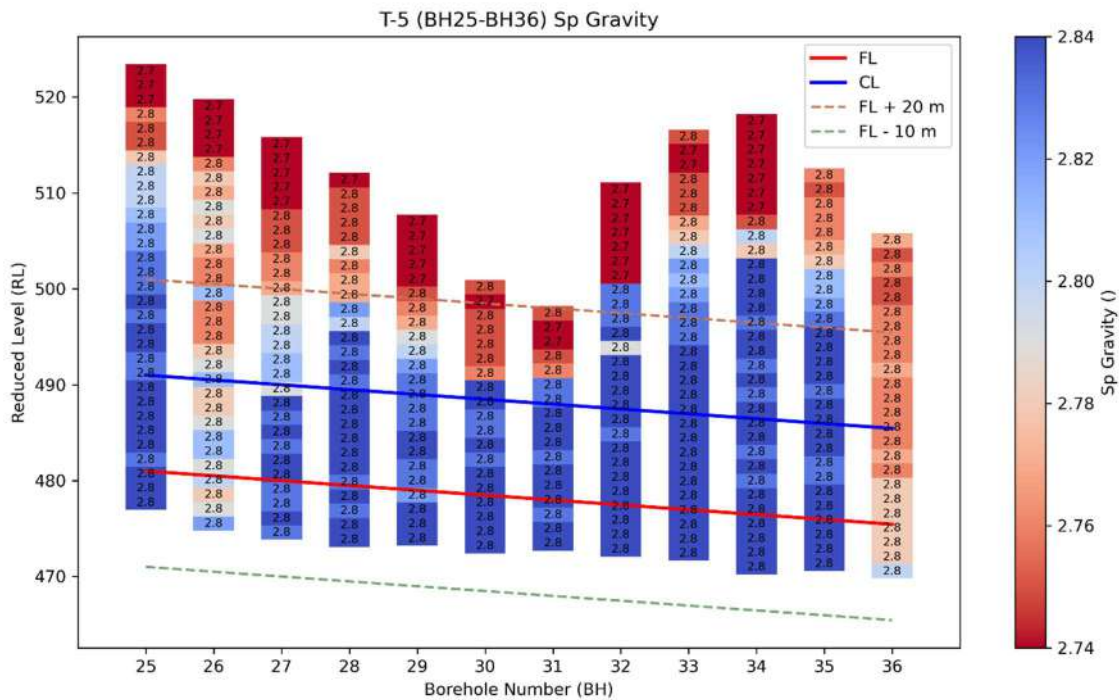
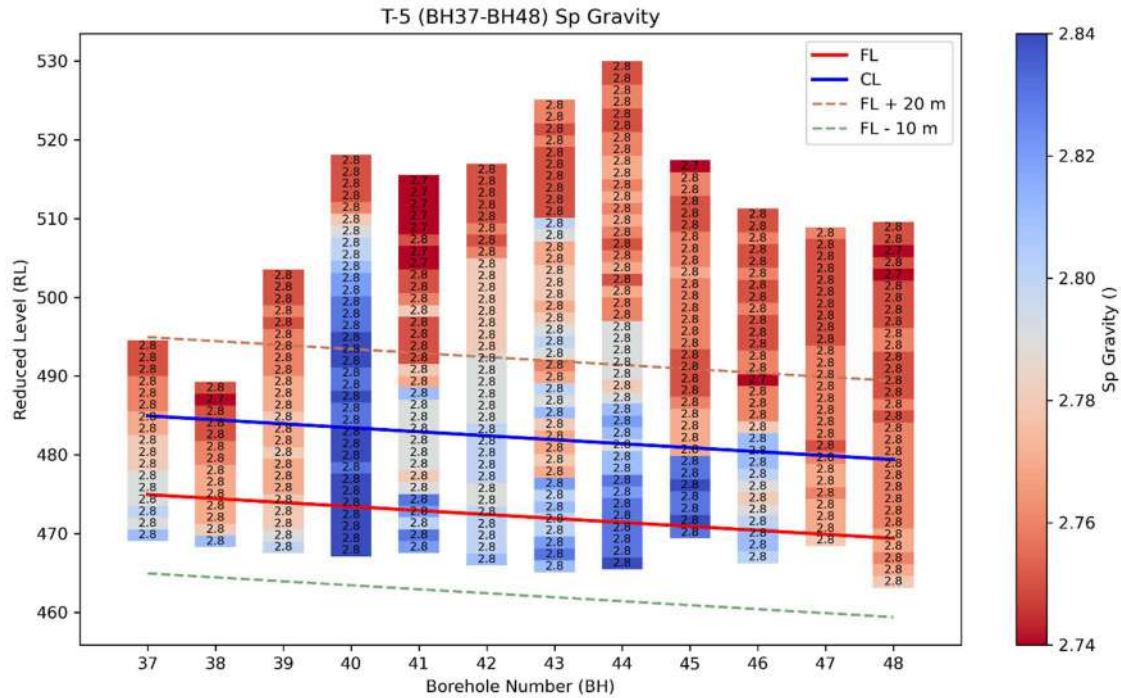


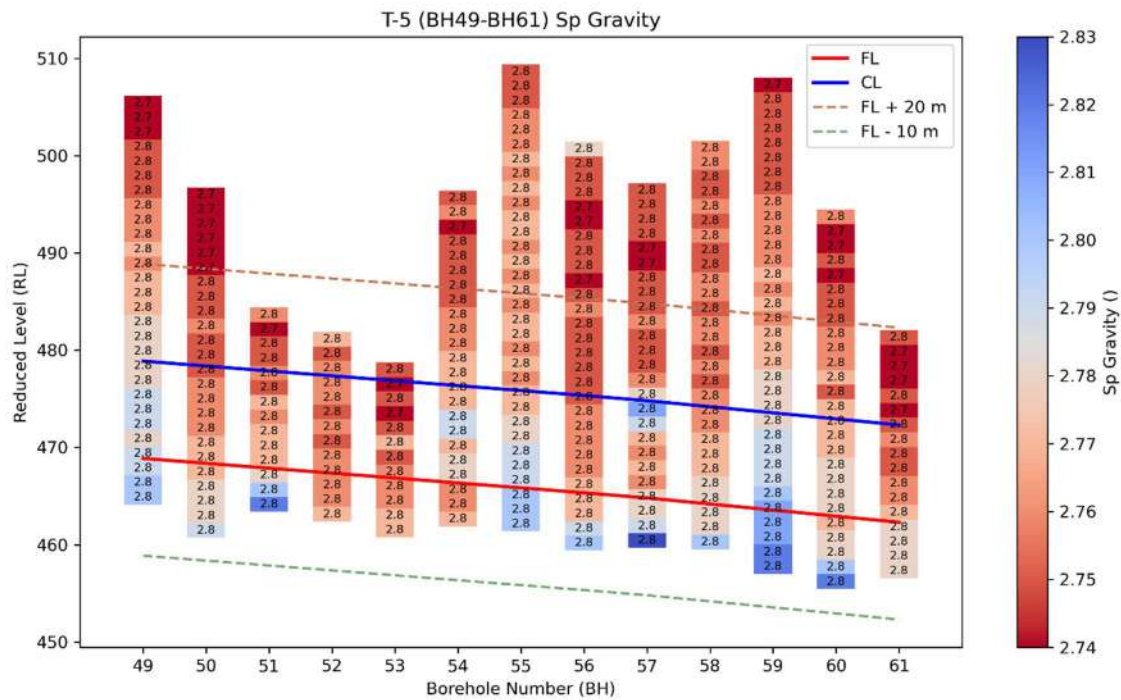
Shot point depth computation

10.3 Assessment of the engineering properties of rock sample:

10.3.1 Specific Gravity







10.3.1.1 Mean and Standard deviation Specific Gravity considering 1D zone of influence of each borehole:

BH No.	Chainage	Mean	Std
BH01	50177	2.8	0.02
BH02	50227	2.8	0.01
BH03	50277	2.8	0.02
BH04	50327	2.8	0.02
BH05	50377	2.8	0.01
BH06	50427	2.8	0.02
BH07	50477	2.8	0.02
BH08	50527	2.8	0.01

BH No.	Chainage	Mean	Std
BH09	50577	2.8	0.02
BH10	50627	2.8	0.04
BH11	50677	2.8	0.02
BH12	50727	2.8	0.02
BH13	50777	2.8	0.01
BH14	50827	2.8	0.01
BH15	50877	2.8	0.02
BH16	50927	2.8	0.01
BH17	50977	2.8	0.00
BH18	51027	2.8	0.01
BH19	51077	2.8	0.01
BH20	51127	2.8	0.01
BH21	51177	2.6	0.85
BH22	51227	2.8	0.01
BH23	51277	2.8	0.01
BH24	51327	2.8	0.01

BH No.	Chainage	Mean	Std
BH25	51377	2.8	0.00
BH26	51427	2.8	0.01
BH27	51477	2.8	0.01
BH28	51527	2.8	0.00
BH29	51577	2.8	0.01
BH30	51627	2.8	0.00
BH31	51677	2.8	0.00
BH32	51727	2.8	0.00
BH33	51777	2.8	0.00
BH34	51827	2.8	0.00
BH35	51877	2.8	0.00
BH36	51927	2.8	0.01
BH37	51977	2.8	0.01
BH38	52027	2.8	0.02
BH39	52077	2.8	0.01
BH40	52127	2.8	0.00

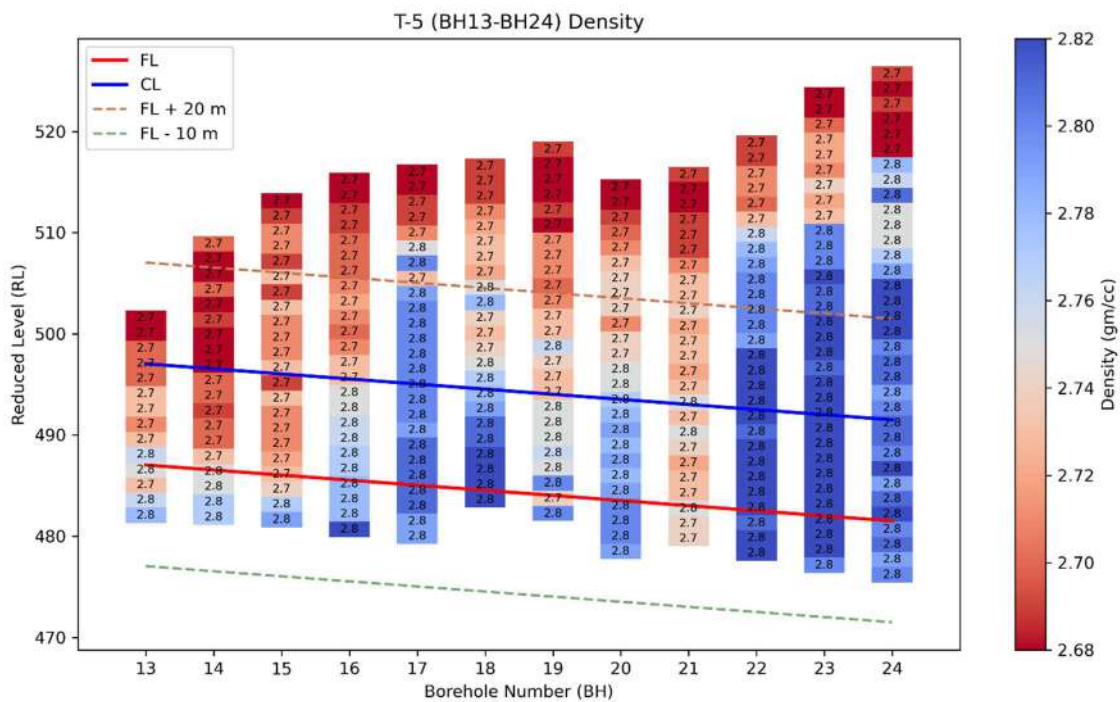
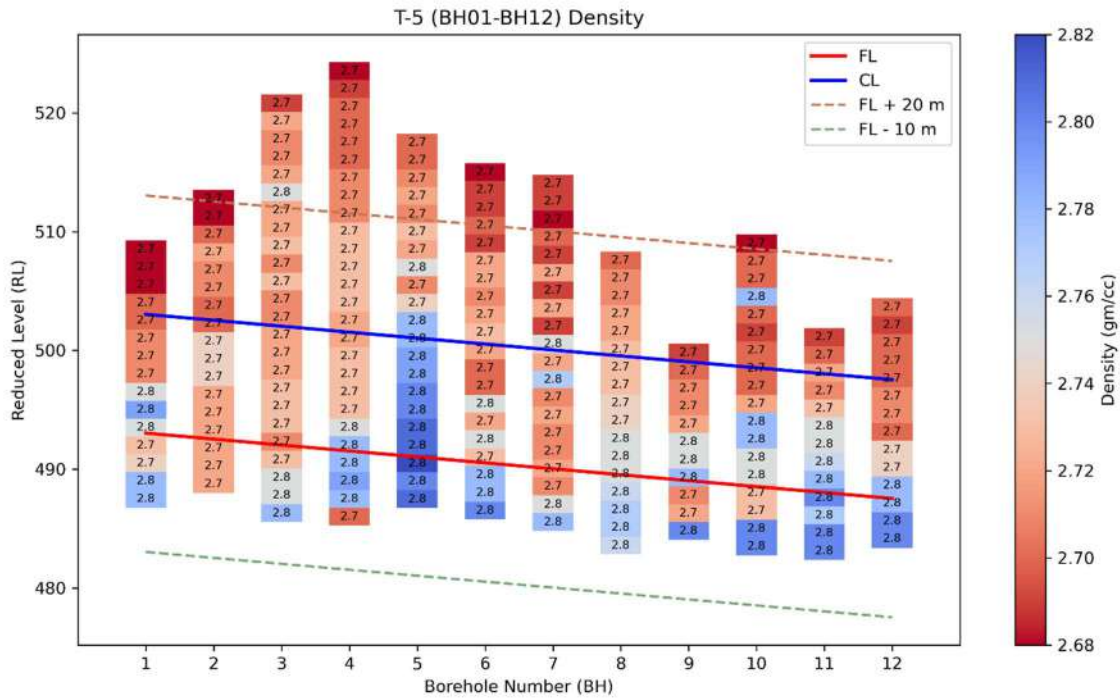
BH No.	Chainage	Mean	Std
BH41	52177	2.8	0.02
BH42	52227	2.8	0.01
BH43	52277	2.8	0.02
BH44	52327	2.8	0.01
BH45	52377	2.8	0.03
BH46	52427	2.8	0.01
BH47	52477	2.8	0.01
BH48	52527	2.8	0.01
BH49	52577	2.8	0.01
BH50	52627	2.8	0.01
BH51	52677	2.8	0.02
BH52	52727	2.8	0.01
BH53	52777	2.8	0.01
BH54	52827	2.8	0.01
BH55	52877	2.8	0.01
BH56	52927	2.8	0.01

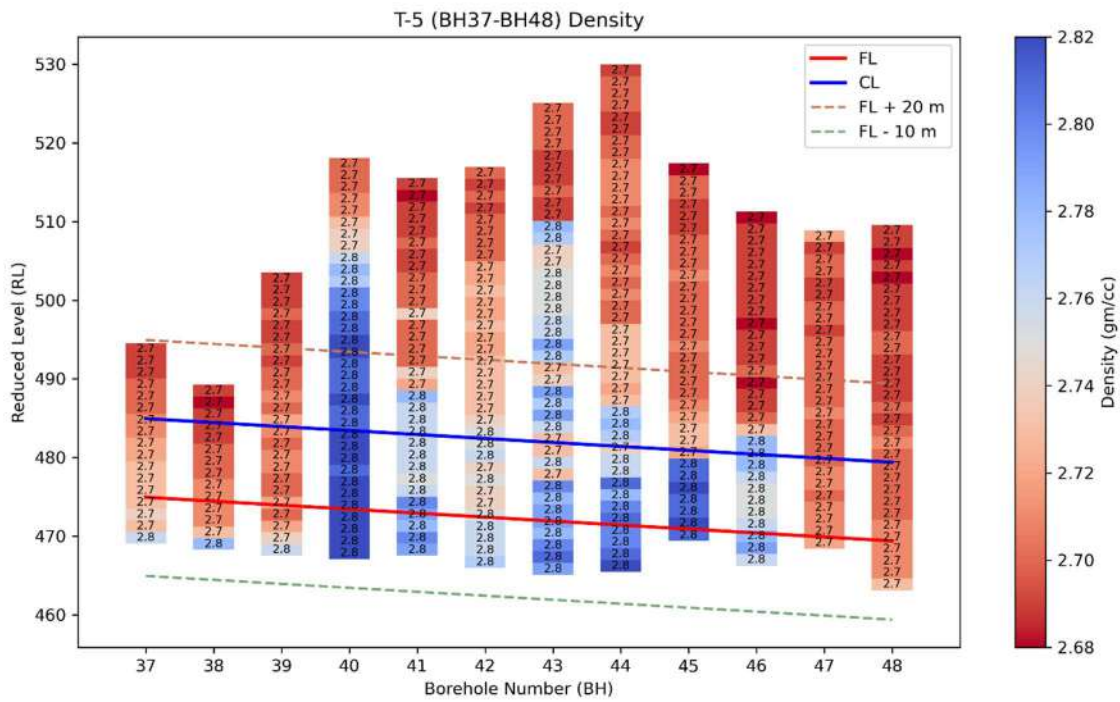
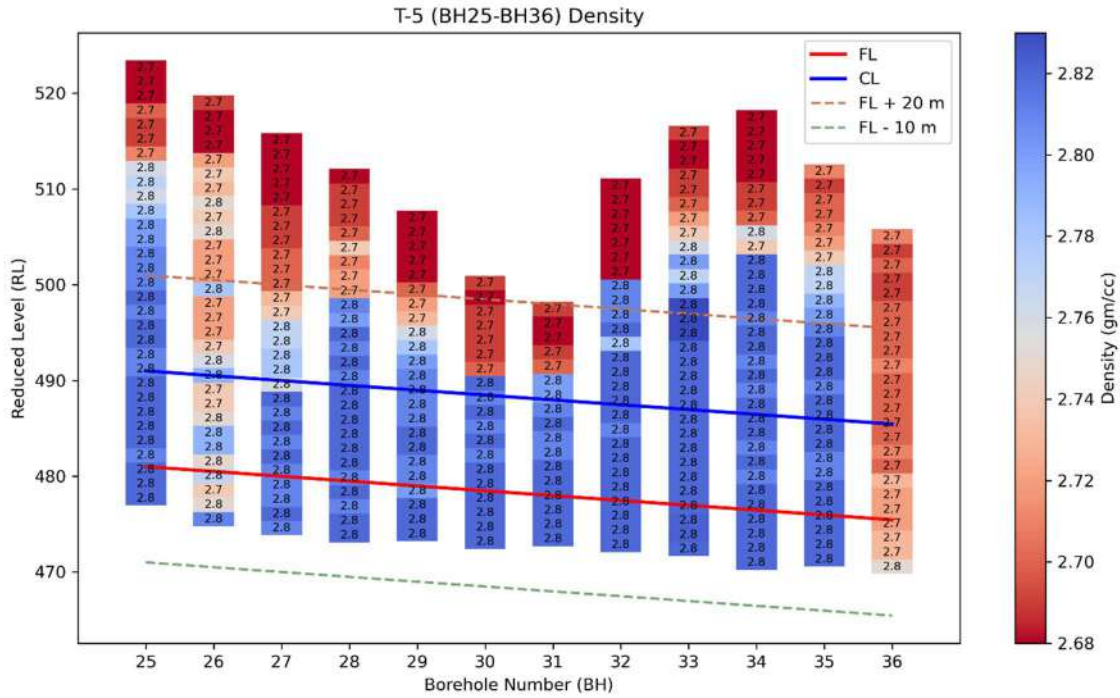
BH No.	Chainage	Mean	Std
BH57	52977	2.8	0.02
BH58	53027	2.8	0.01
BH59	53077	2.8	0.01
BH60	53127	2.8	0.01
BH61	53177	2.8	0.01

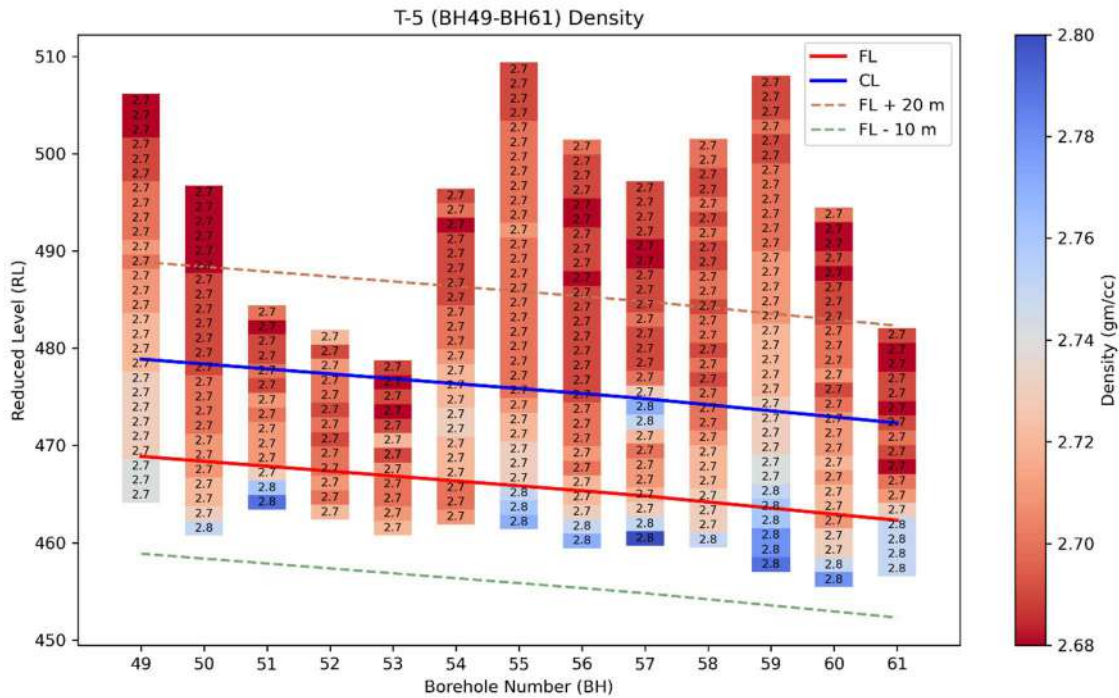
10.3.1.2 Recommended Specific Gravity considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($S_p = \mu - \sigma$ across boreholes within ± 10 m of FL and CL)	Reference Standards / Guidelines
50180 to 50880	2.8	IS 13030:1991; IS 1124:1974
50880 to 51920	2.8	
51920 to 53180 (P2)	2.8	

10.3.2 Dry Density







10.3.2.1 Mean and Standard Deviation in Density considering 1D zone of influence of each borehole:

BH No.	Chainage	Mean	Std
BH01	50177	2.74	0.032
BH02	50227	2.72	0.013
BH03	50277	2.73	0.020
BH04	50327	2.75	0.030
BH05	50377	2.80	0.012
BH06	50427	2.74	0.035
BH07	50477	2.73	0.027
BH08	50527	2.75	0.014

BH No.	Chainage	Mean	Std
BH09	50577	2.74	0.034
BH10	50627	2.75	0.037
BH11	50677	2.77	0.031
BH12	50727	2.76	0.041
BH13	50777	2.74	0.024
BH14	50827	2.73	0.032
BH15	50877	2.73	0.030
BH16	50927	2.77	0.020
BH17	50977	2.80	0.009
BH18	51027	2.80	0.025
BH19	51077	2.76	0.025
BH20	51127	2.79	0.010
BH21	51177	2.49	0.826
BH22	51227	2.82	0.004
BH23	51277	2.82	0.006
BH24	51327	2.81	0.010

BH No.	Chainage	Mean	Std
BH25	51377	2.82	0.004
BH26	51427	2.76	0.025
BH27	51477	2.81	0.017
BH28	51527	2.82	0.004
BH29	51577	2.81	0.007
BH30	51627	2.82	0.005
BH31	51677	2.82	0.005
BH32	51727	2.82	0.003
BH33	51777	2.82	0.001
BH34	51827	2.82	0.004
BH35	51877	2.82	0.004
BH36	51927	2.72	0.015
BH37	51977	2.73	0.014
BH38	52027	2.71	0.025
BH39	52077	2.72	0.019
BH40	52127	2.82	0.003

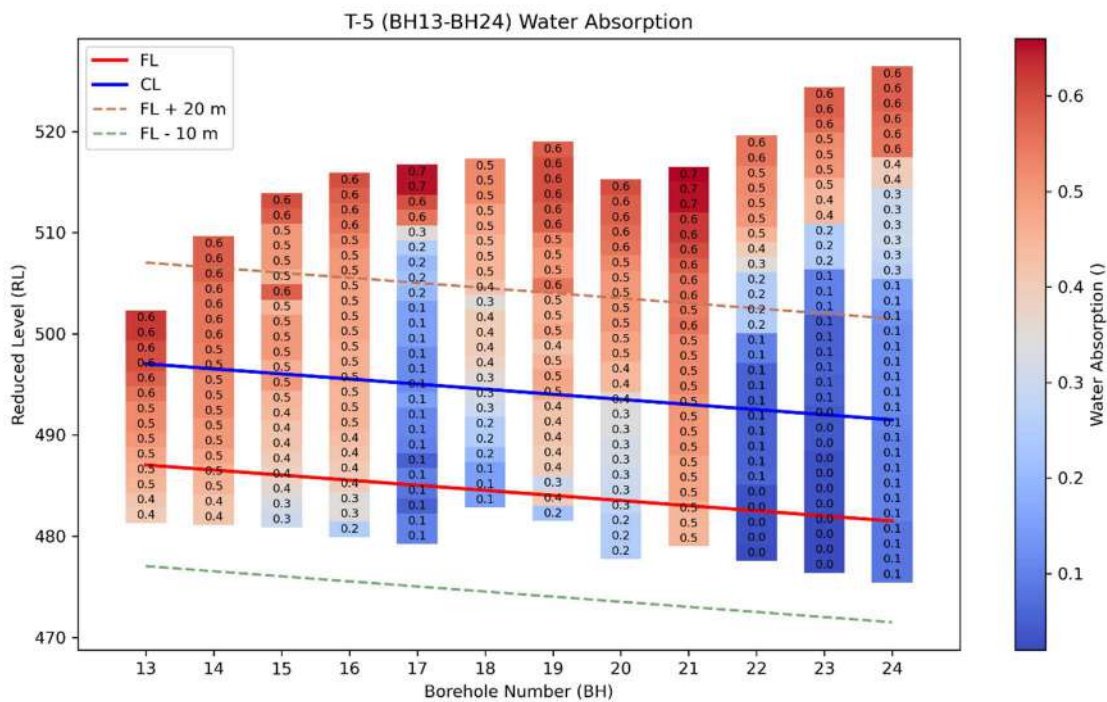
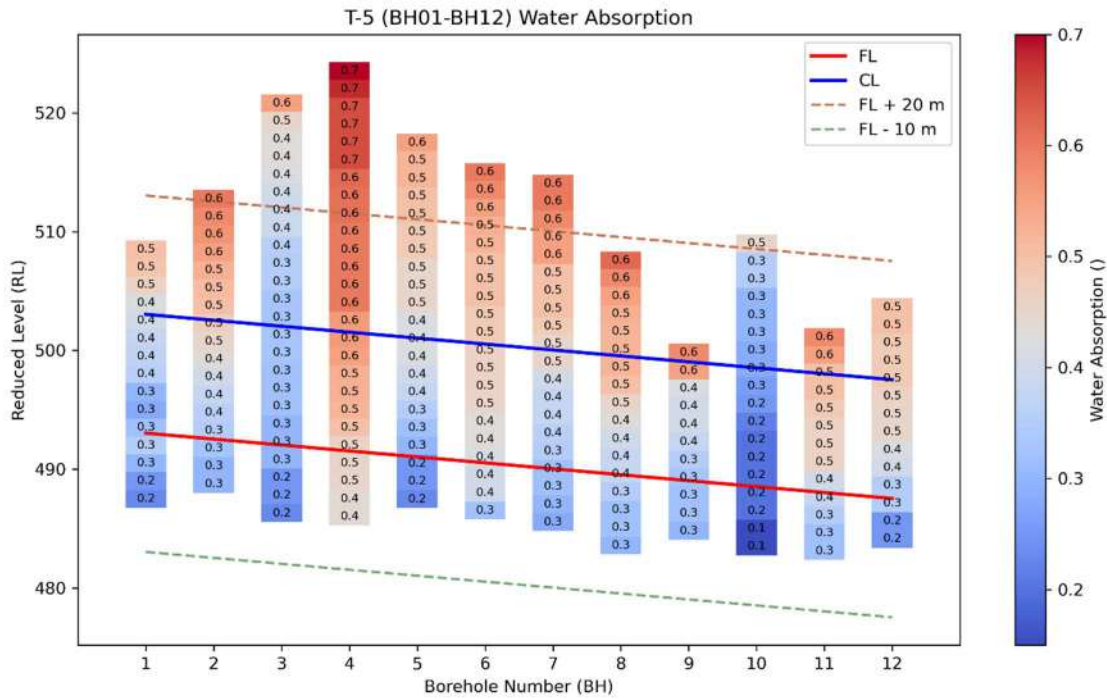
BH No.	Chainage	Mean	Std
BH41	52177	2.78	0.019
BH42	52227	2.75	0.010
BH43	52277	2.78	0.027
BH44	52327	2.79	0.026
BH45	52377	2.79	0.042
BH46	52427	2.77	0.015
BH47	52477	2.71	0.007
BH48	52527	2.71	0.009
BH49	52577	2.73	0.006
BH50	52627	2.71	0.016
BH51	52677	2.72	0.031
BH52	52727	2.70	0.009
BH53	52777	2.70	0.014
BH54	52827	2.72	0.010
BH55	52877	2.73	0.022
BH56	52927	2.72	0.025

BH No.	Chainage	Mean	Std
BH57	52977	2.74	0.031
BH58	53027	2.72	0.015
BH59	53077	2.75	0.022
BH60	53127	2.73	0.021
BH61	53177	2.72	0.028

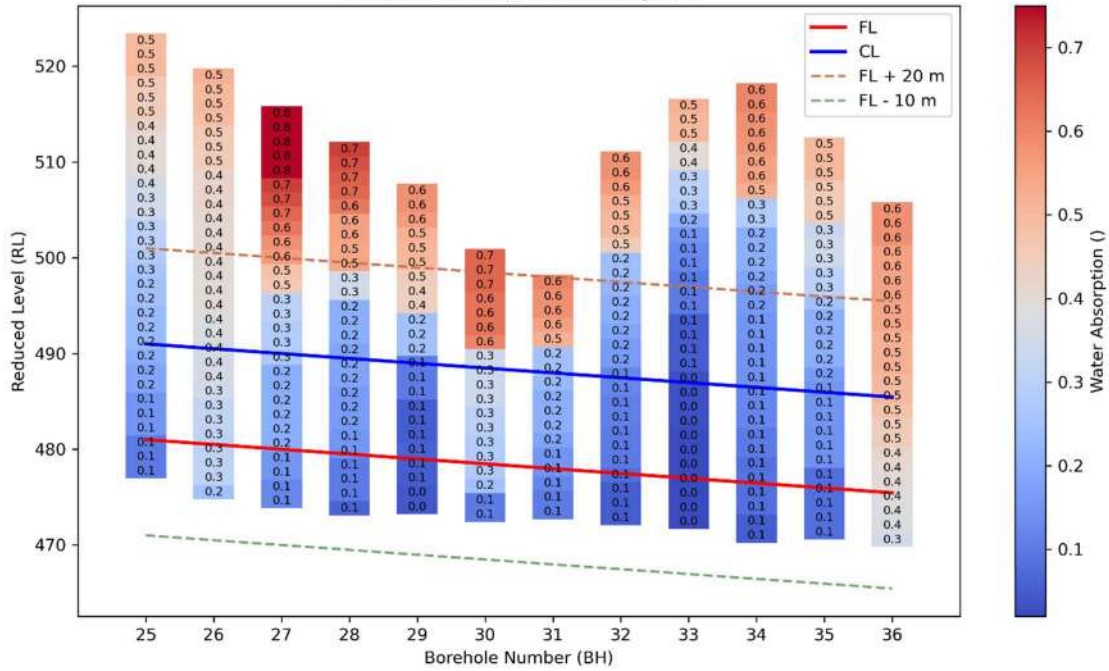
10.3.2.2 Recommended Density considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($d = \mu - \sigma$ across boreholes within ± 10 m of FL and CL)	Reference Standards / Guidelines
50180 to 50880	2.71	IS 13063:1991
50880 to 51920	2.59	
51920 to 53180 (P2)	2.70	

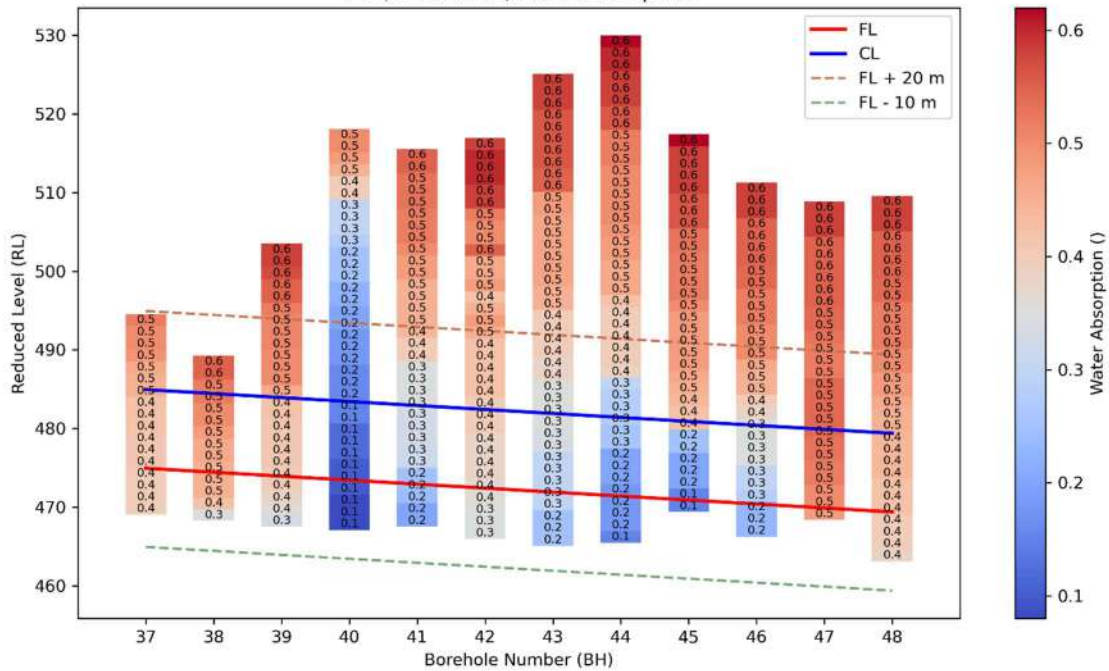
10.3.3 Water absorption Test

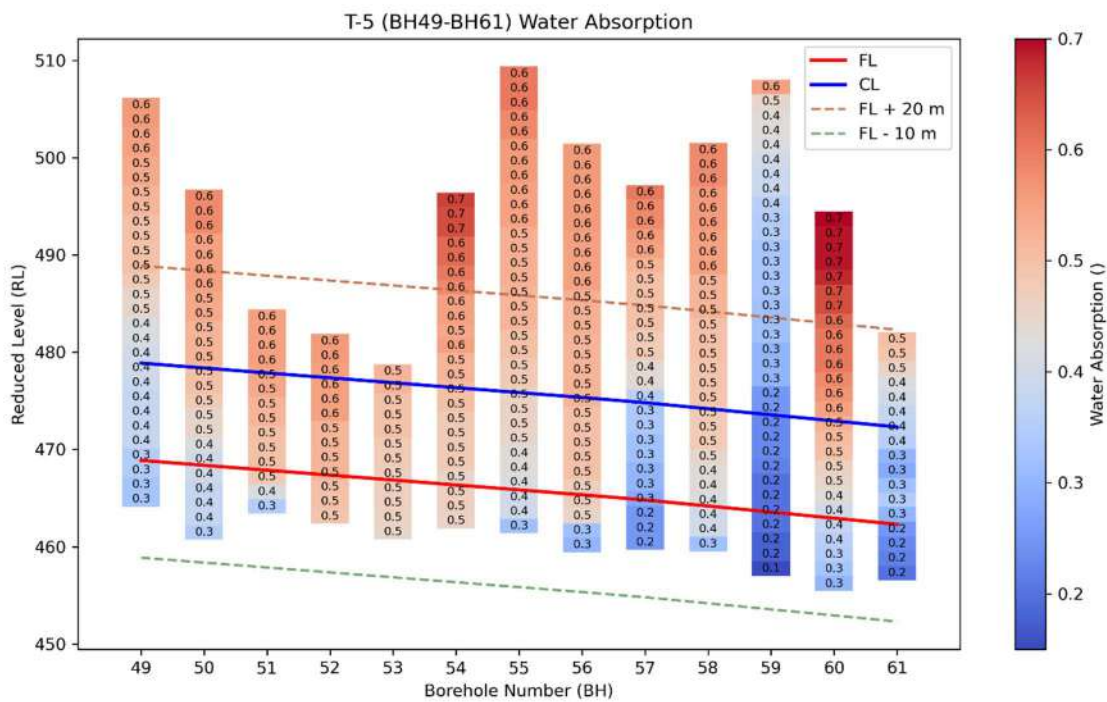


T-5 (BH25-BH36) Water Absorption



T-5 (BH37-BH48) Water Absorption





10.3.3.1 Mean and Standard Deviation in Water Absorption Value considering 1D zone of influence:

BH No.	Chainage	Mean	Std
BH01	50177	0.32	0.06
BH02	50227	0.38	0.06
BH03	50277	0.30	0.04
BH04	50327	0.49	0.05
BH05	50377	0.33	0.07
BH06	50427	0.42	0.04
BH07	50477	0.35	0.05
BH08	50527	0.40	0.07

BH No.	Chainage	Mean	Std
BH09	50577	0.38	0.07
BH10	50627	0.21	0.04
BH11	50677	0.41	0.07
BH12	50727	0.36	0.09
BH13	50777	0.49	0.06
BH14	50827	0.48	0.04
BH15	50877	0.40	0.06
BH16	50927	0.40	0.06
BH17	50977	0.10	0.03
BH18	51027	0.25	0.09
BH19	51077	0.39	0.08
BH20	51127	0.30	0.04
BH21	51177	0.44	0.15
BH22	51227	0.04	0.01
BH23	51277	0.03	0.01
BH24	51327	0.09	0.01

BH No.	Chainage	Mean	Std
BH25	51377	0.15	0.04
BH26	51427	0.32	0.03
BH27	51477	0.18	0.04
BH28	51527	0.14	0.04
BH29	51577	0.06	0.02
BH30	51627	0.26	0.09
BH31	51677	0.16	0.05
BH32	51727	0.09	0.03
BH33	51777	0.02	0.00
BH34	51827	0.09	0.03
BH35	51877	0.11	0.03
BH36	51927	0.41	0.04
BH37	51977	0.41	0.01
BH38	52027	0.46	0.05
BH39	52077	0.40	0.03
BH40	52127	0.11	0.03

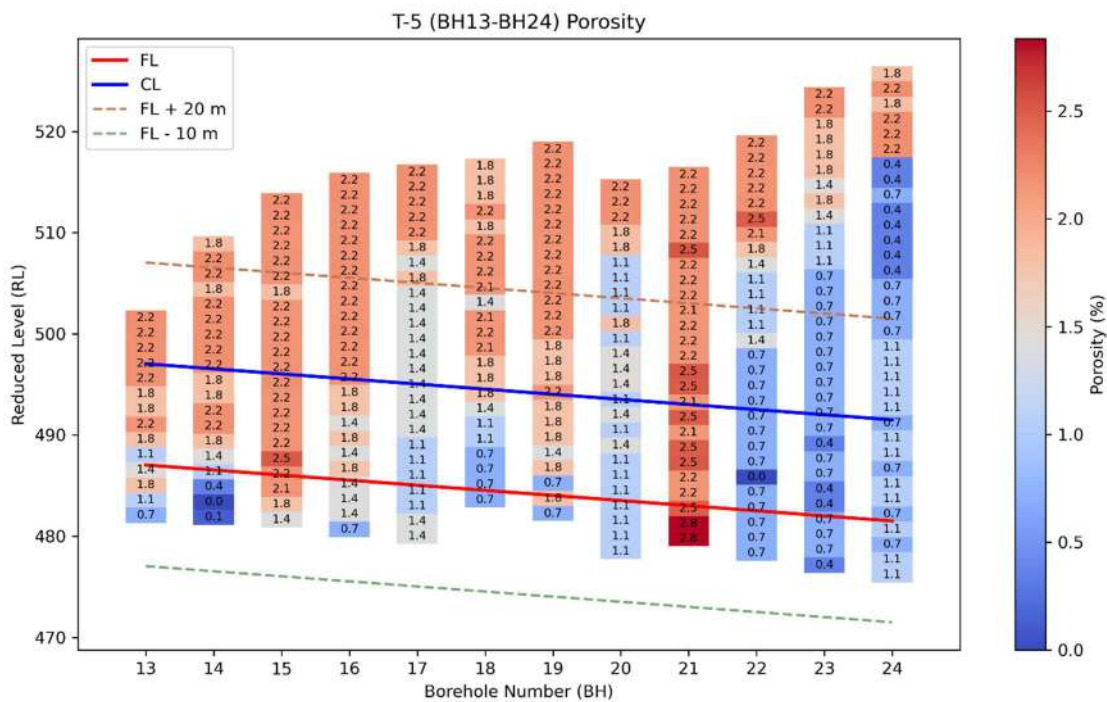
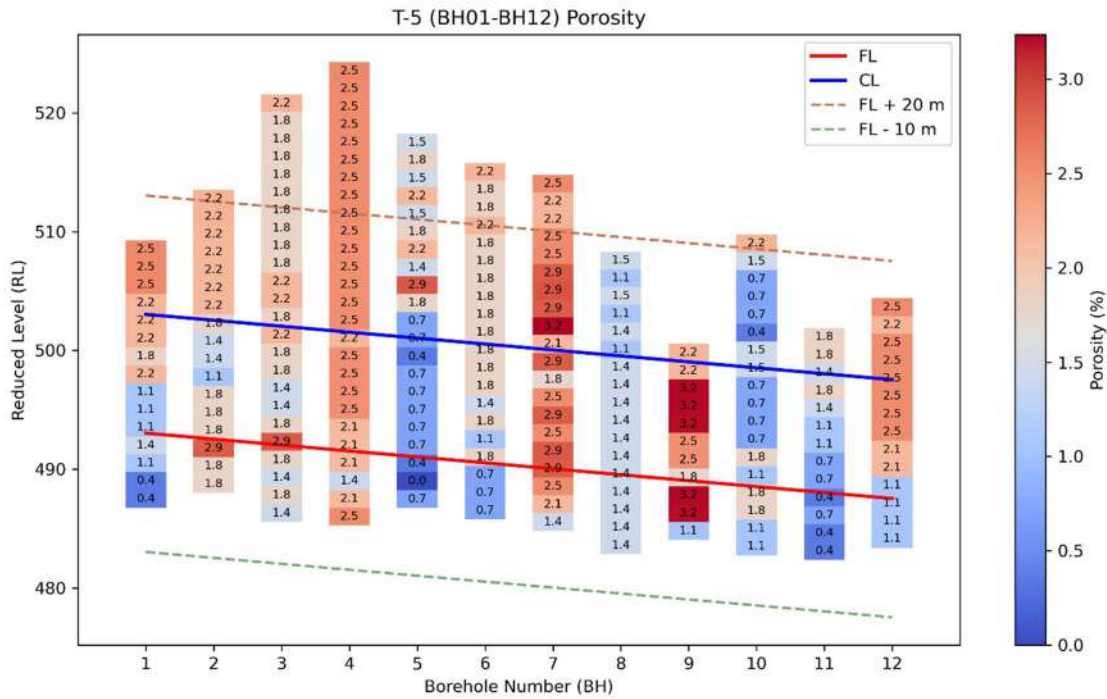
BH No.	Chainage	Mean	Std
BH41	52177	0.28	0.05
BH42	52227	0.37	0.02
BH43	52277	0.30	0.04
BH44	52327	0.21	0.04
BH45	52377	0.27	0.11
BH46	52427	0.30	0.06
BH47	52477	0.52	0.02
BH48	52527	0.42	0.02
BH49	52577	0.37	0.02
BH50	52627	0.42	0.05
BH51	52677	0.49	0.06
BH52	52727	0.52	0.02
BH53	52777	0.48	0.02
BH54	52827	0.48	0.02
BH55	52877	0.42	0.04
BH56	52927	0.46	0.08

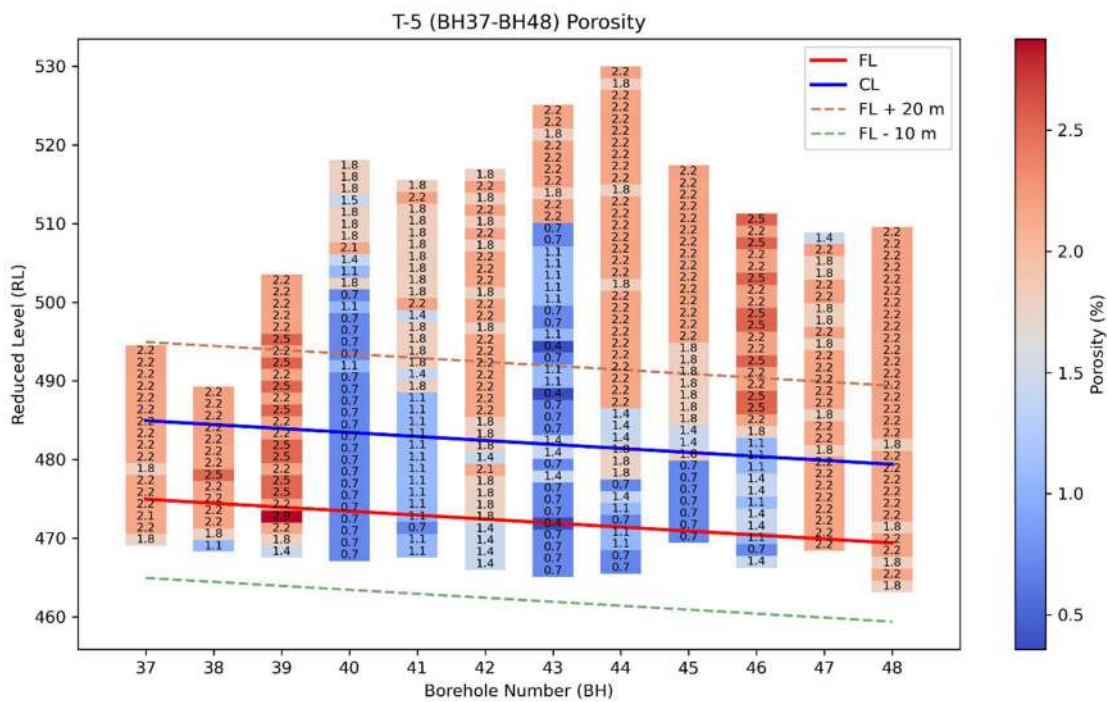
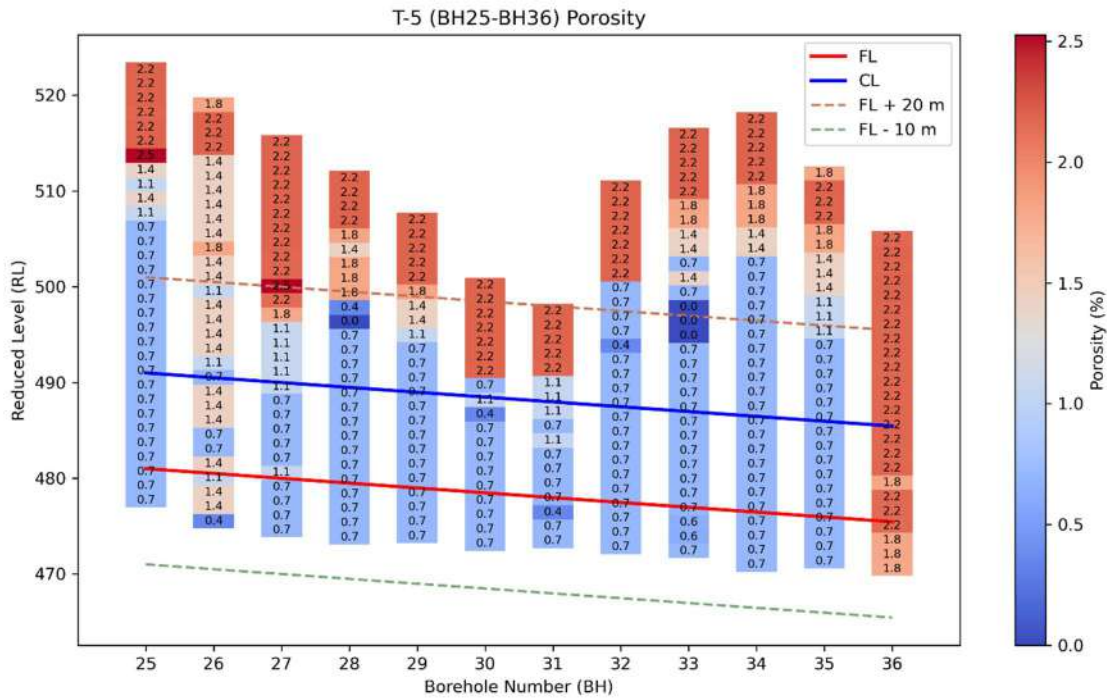
BH No.	Chainage	Mean	Std
BH57	52977	0.30	0.04
BH58	53027	0.43	0.05
BH59	53077	0.20	0.03
BH60	53127	0.42	0.08
BH61	53177	0.28	0.05

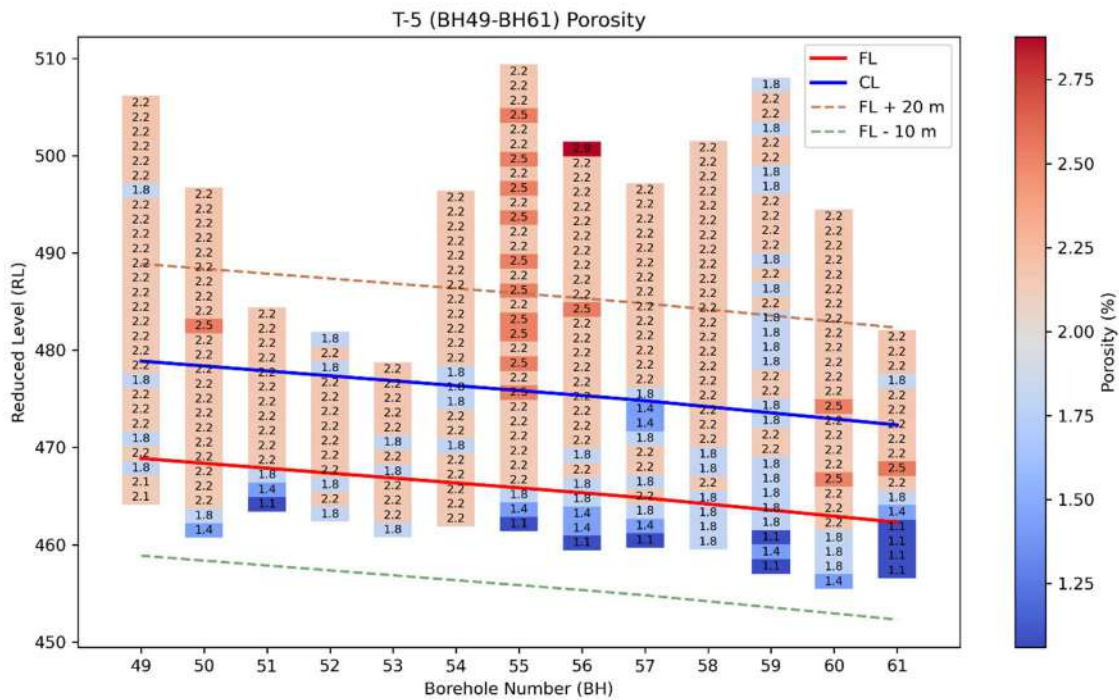
10.3.3.2 Recommended Water Absorption Value considering ID zone of influence:

Chainage	Statistical / Reduction Method ($A = \mu + \sigma$ across boreholes within ± 10 m of FL and CL)	Reference Standards / Guidelines
50180 to 50880	0.48	IS 13063:1991; IS 2386 (Part 3):1963
50880 to 51920	0.32	
51920 to 53180 (P2)	0.49	

10.3.4 Porosity







10.3.4.1 Mean And Standard Deviation in Porosity considering 1D zone of influence in each Borehole:

BH No.	Chainage	Mean	Std
BH01	50177	1.34	0.671
BH02	50227	1.77	0.457
BH03	50277	1.80	0.424
BH04	50327	2.23	0.332
BH05	50377	0.57	0.248
BH06	50427	1.37	0.511
BH07	50477	2.43	0.506
BH08	50527	1.43	0.007

BH No.	Chainage	Mean	Std
BH09	50577	2.60	0.755
BH10	50627	1.18	0.456
BH11	50677	0.86	0.491
BH12	50727	1.72	0.702
BH13	50777	1.58	0.491
BH14	50827	1.28	0.840
BH15	50877	2.08	0.292
BH16	50927	1.49	0.330
BH17	50977	1.25	0.185
BH18	51027	1.17	0.477
BH19	51077	1.57	0.486
BH20	51127	1.13	0.143
BH21	51177	2.20	0.776
BH22	51227	0.63	0.223
BH23	51277	0.56	0.181
BH24	51327	0.93	0.179

BH No.	Chainage	Mean	Std
BH25	51377	0.70	0.001
BH26	51427	1.15	0.410
BH27	51477	0.77	0.146
BH28	51527	0.70	0.001
BH29	51577	0.71	0.002
BH30	51627	0.70	0.157
BH31	51677	0.74	0.200
BH32	51727	0.70	0.001
BH33	51777	0.69	0.034
BH34	51827	0.70	0.001
BH35	51877	0.70	0.001
BH36	51927	2.02	0.191
BH37	51977	2.09	0.148
BH38	52027	2.07	0.370
BH39	52077	2.26	0.401
BH40	52127	0.70	0.001

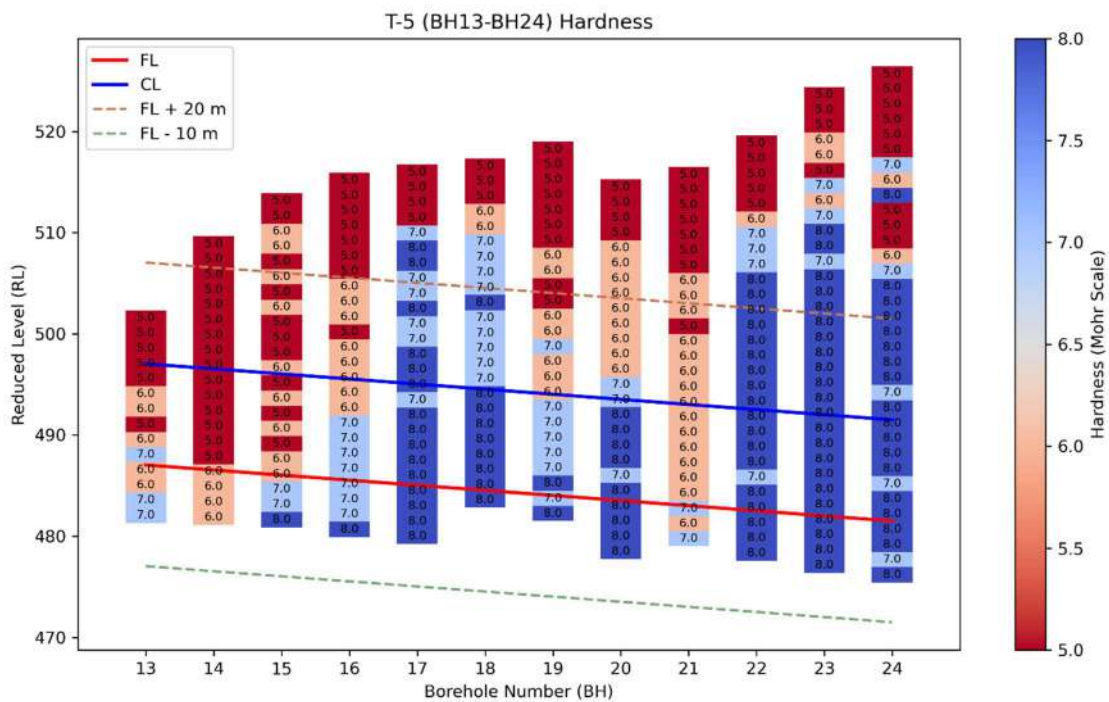
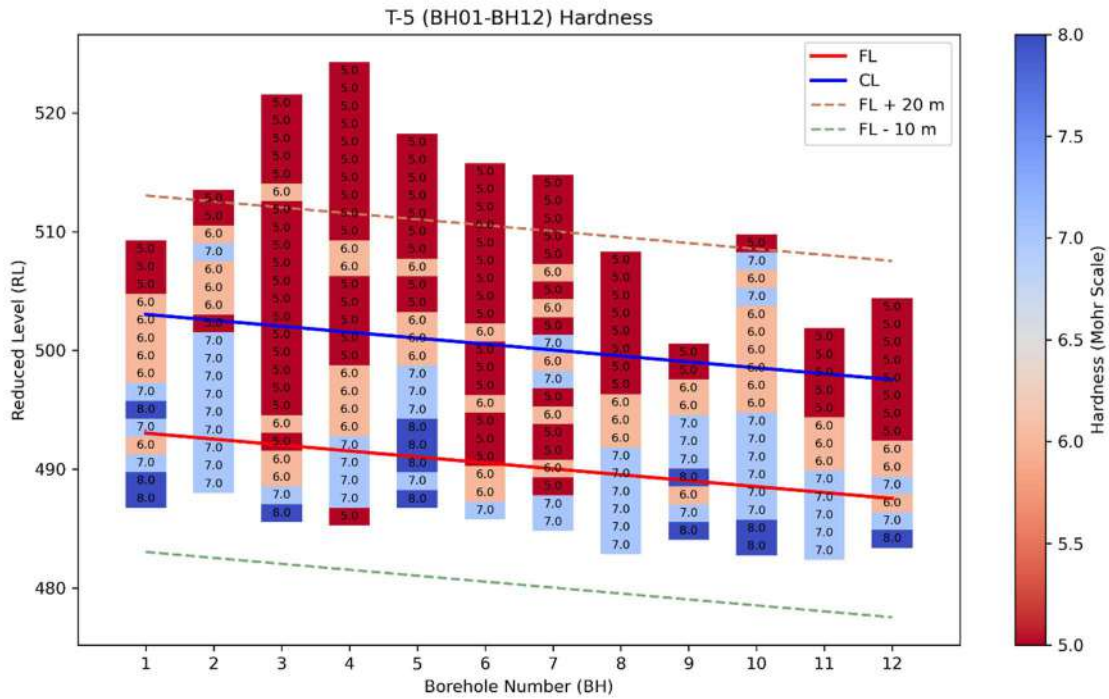
BH No.	Chainage	Mean	Std
BH41	52177	1.03	0.113
BH42	52227	1.66	0.242
BH43	52277	0.81	0.330
BH44	52327	1.16	0.457
BH45	52377	0.96	0.426
BH46	52427	1.20	0.243
BH47	52477	2.14	0.106
BH48	52527	2.07	0.170
BH49	52577	2.04	0.171
BH50	52627	2.08	0.229
BH51	52677	1.95	0.397
BH52	52727	2.10	0.155
BH53	52777	2.08	0.174
BH54	52827	2.03	0.180
BH55	52877	1.97	0.428
BH56	52927	1.84	0.385

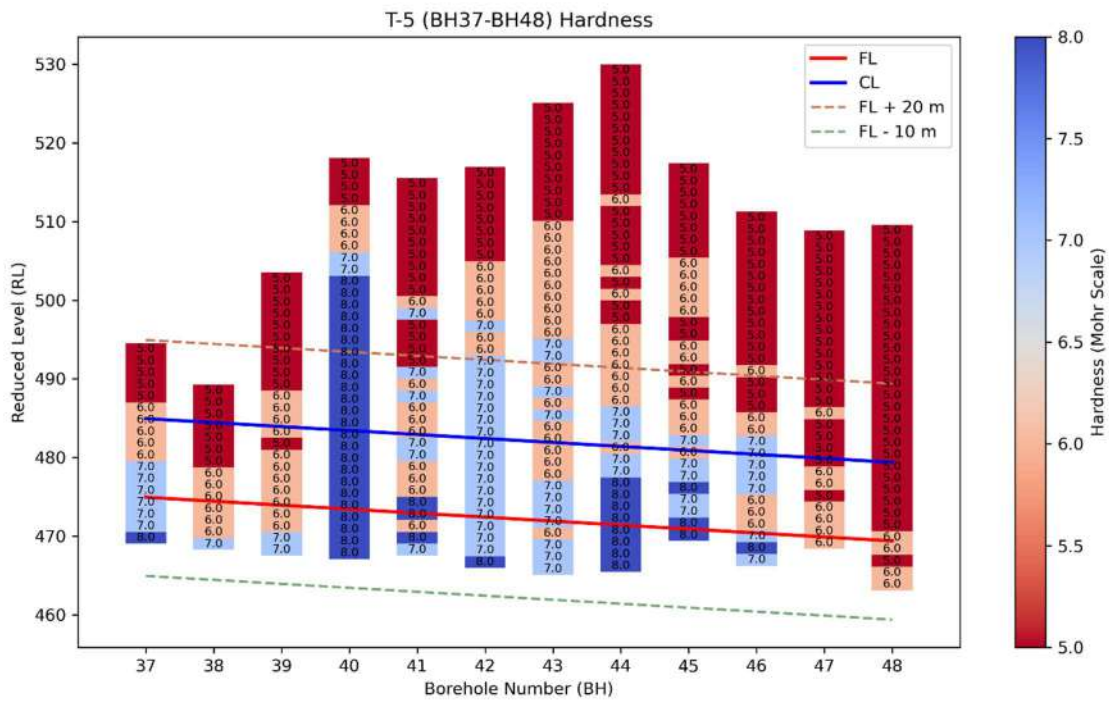
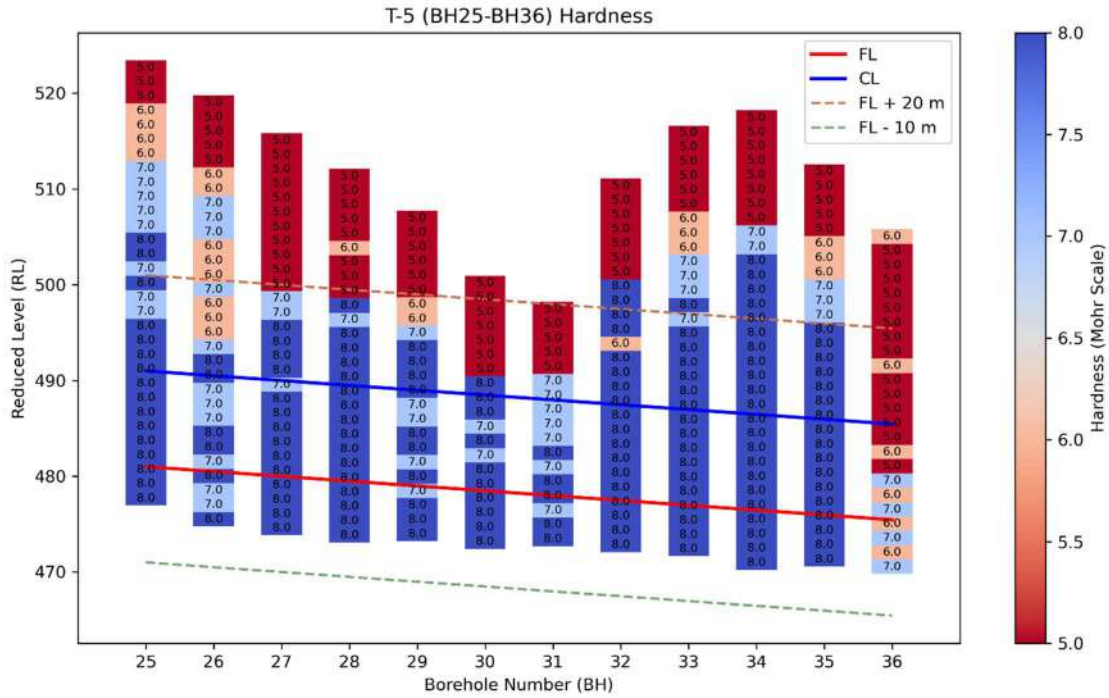
BH No.	Chainage	Mean	Std
BH57	52977	1.73	0.381
BH58	53027	1.95	0.191
BH59	53077	1.69	0.365
BH60	53127	2.04	0.286
BH61	53177	1.66	0.578

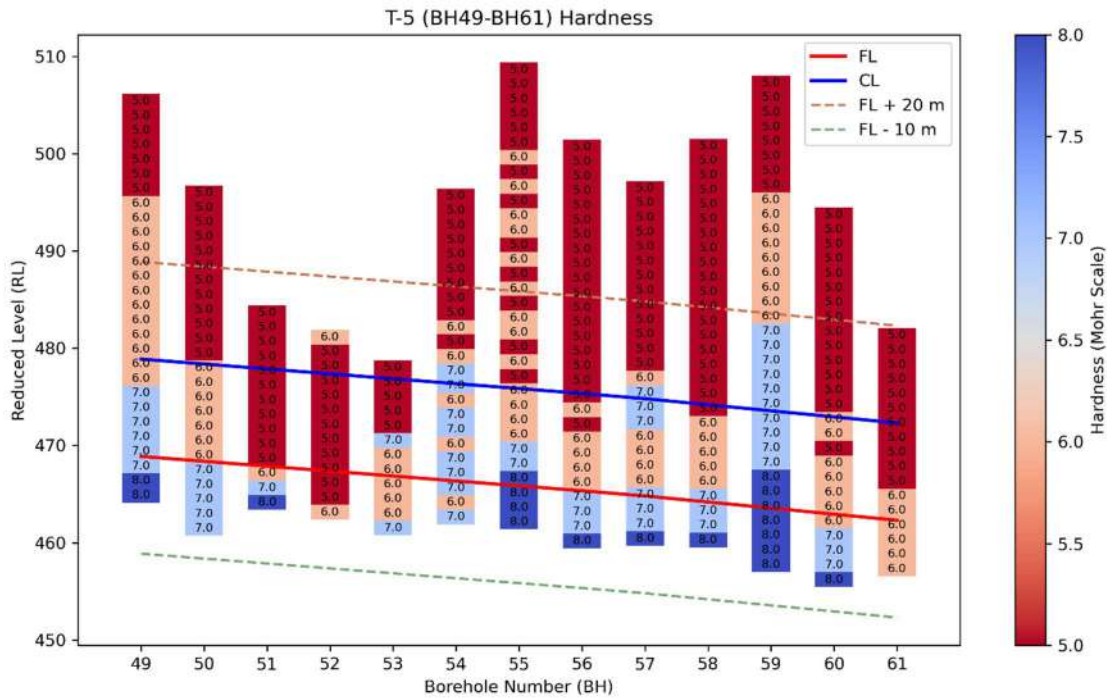
10.3.4.2 Recommended Porosity considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($n = \mu \pm \sigma$ across boreholes within ± 10 m of FL and CL)	Reference Standards / Guidelines
50180 to 50880	1.64 ± 0.74	IS 1124:1974; ISRM (1981)
50880 to 51920	0.96 ± 0.49	
51920 to 53180 (P2)	1.75 ± 0.54	

10.3.5 Hardness







10.3.5.1 Mean And Standard Deviation in Hardness considering 1D zone of influence in each Borehole:

BH No.	Chainage	Mean	Std
BH01	50177	7	1
BH02	50227	7	1
BH03	50277	6	1
BH04	50327	6	1
BH05	50377	7	1
BH06	50427	6	1
BH07	50477	6	1
BH08	50527	6	1

BH No.	Chainage	Mean	Std
BH09	50577	7	1
BH10	50627	7	1
BH11	50677	6	1
BH12	50727	6	1
BH13	50777	6	1
BH14	50827	5	1
BH15	50877	6	1
BH16	50927	7	1
BH17	50977	8	0
BH18	51027	8	0
BH19	51077	7	1
BH20	51127	8	0
BH21	51177	6	2
BH22	51227	8	0
BH23	51277	8	0
BH24	51327	8	0

BH No.	Chainage	Mean	Std
BH25	51377	8	0
BH26	51427	7	1
BH27	51477	8	0
BH28	51527	8	0
BH29	51577	8	1
BH30	51627	8	0
BH31	51677	8	1
BH32	51727	8	0
BH33	51777	8	0
BH34	51827	8	0
BH35	51877	8	0
BH36	51927	6	1
BH37	51977	7	1
BH38	52027	6	1
BH39	52077	6	1
BH40	52127	8	0

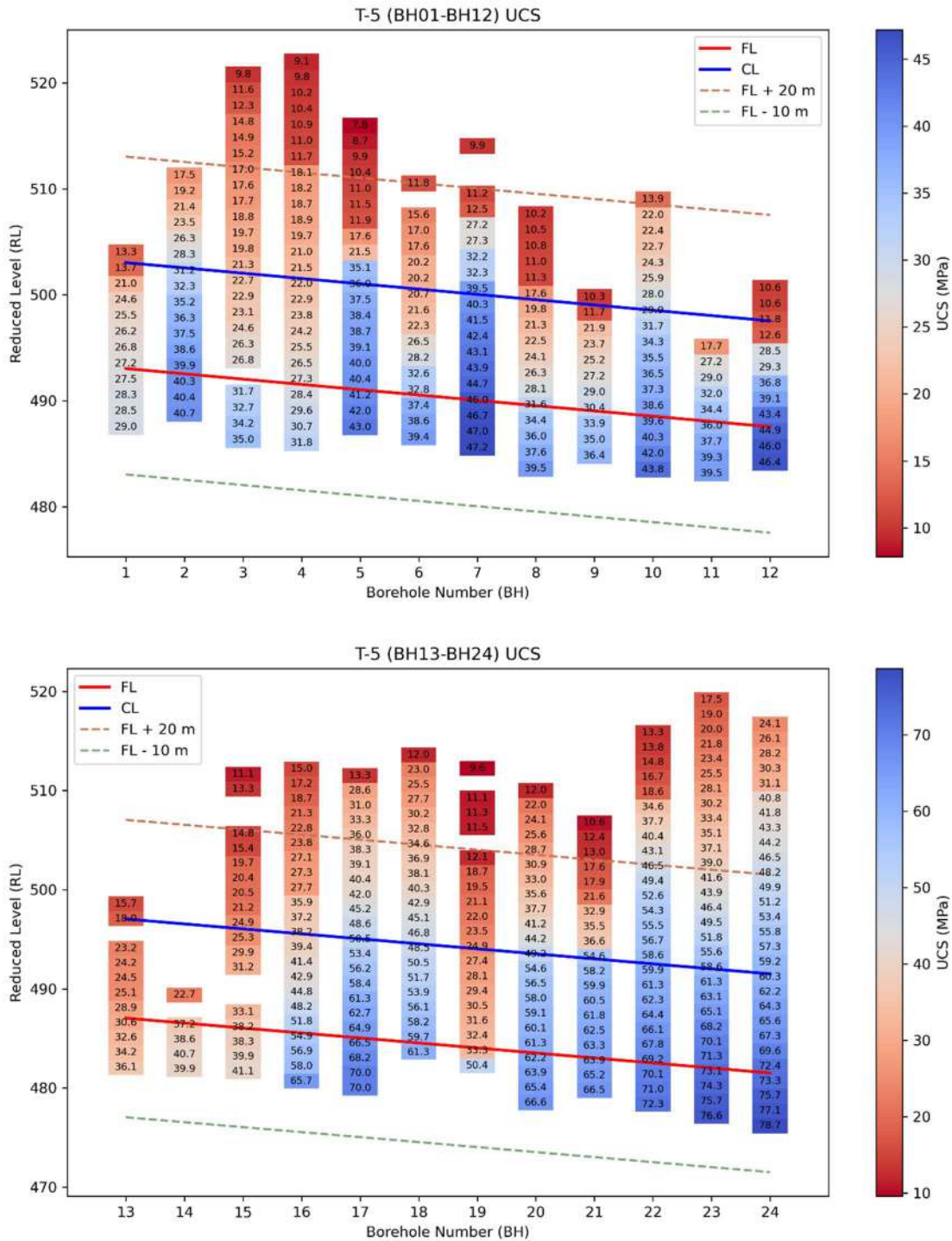
BH No.	Chainage	Mean	Std
BH41	52177	7	1
BH42	52227	7	0
BH43	52277	7	1
BH44	52327	8	1
BH45	52377	7	1
BH46	52427	7	1
BH47	52477	6	1
BH48	52527	5	1
BH49	52577	7	1
BH50	52627	6	1
BH51	52677	6	1
BH52	52727	5	0
BH53	52777	6	1
BH54	52827	7	0
BH55	52877	7	1
BH56	52927	6	1

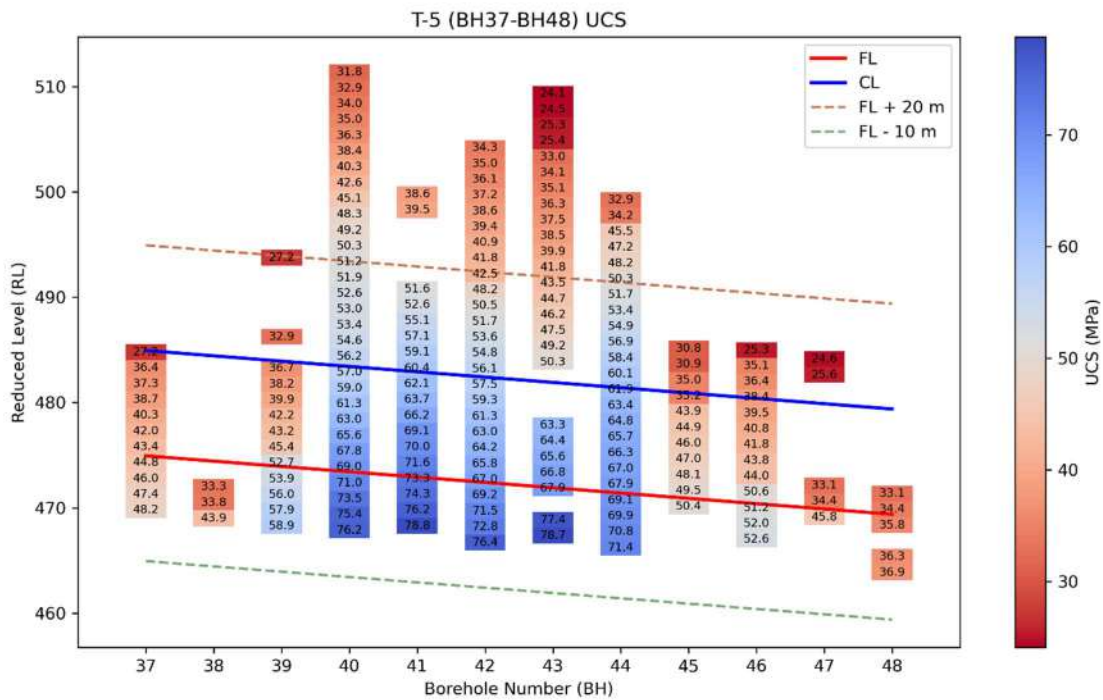
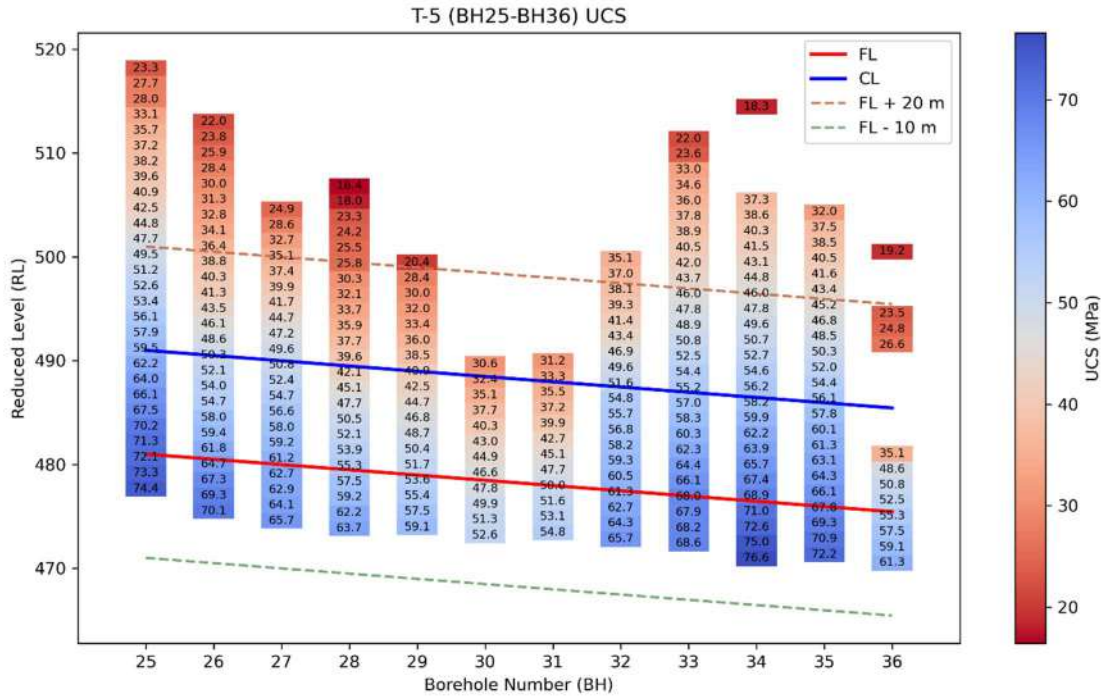
BH No.	Chainage	Mean	Std
BH57	52977	7	1
BH58	53027	6	1
BH59	53077	8	1
BH60	53127	6	1
BH61	53177	6	1

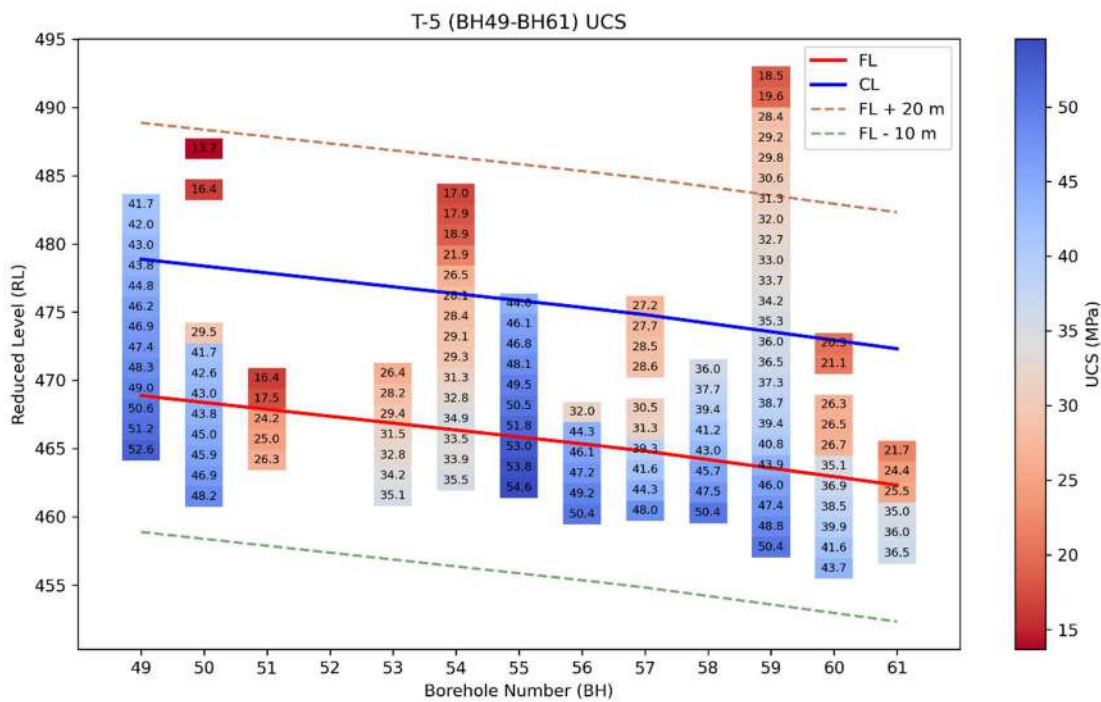
10.3.5.2 Recommended Hardness considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($H_i = \mu - \sigma$ across boreholes within ± 10 m of FL and CL)	Reference Standards / Guidelines
50180 to 50880	5	IS 13311 (Part 2):1992; ISRM 1978
50880 to 51920	7	
51920 to 53180 (P2)	6	

10.3.6 Compression Test







10.3.6.1 Mean And Standard Deviation in UCS considering 1D zone of influence in each Borehole:

BH No.	Chainage	Mean	Std
BH01	50177	25.30	4.45
BH02	50227	37.22	3.42
BH03	50277	27.99	4.91
BH04	50327	26.62	3.26
BH05	50377	39.63	2.12
BH06	50427	30.01	7.17
BH07	50477	44.28	2.43
BH08	50527	29.19	6.99

BH No.	Chainage	Mean	Std
BH09	50577	27.44	7.35
BH10	50627	37.22	4.24
BH11	50677	32.53	7.05
BH12	50727	37.33	11.03
BH13	50777	28.84	4.81
BH14	50827	35.79	7.46
BH15	50877	34.62	5.61
BH16	50927	50.39	8.49
BH17	50977	62.02	6.71
BH18	51027	53.19	5.55
BH19	51077	31.15	7.45
BH20	51127	59.71	5.06
BH21	51177	56.04	18.88
BH22	51227	66.42	4.33
BH23	51277	69.88	5.33
BH24	51327	69.67	6.23

BH No.	Chainage	Mean	Std
BH25	51377	68.05	5.04
BH26	51427	61.15	6.52
BH27	51477	58.94	4.91
BH28	51527	53.57	6.89
BH29	51577	50.11	6.02
BH30	51627	43.79	6.70
BH31	51677	45.77	6.77
BH32	51727	59.93	3.64
BH33	51777	64.11	4.36
BH34	51827	67.39	6.07
BH35	51877	65.30	4.79
BH36	51927	52.51	8.23
BH37	51977	41.07	6.08
BH38	52027	37.01	5.96
BH39	52077	47.73	8.31
BH40	52127	67.16	6.60

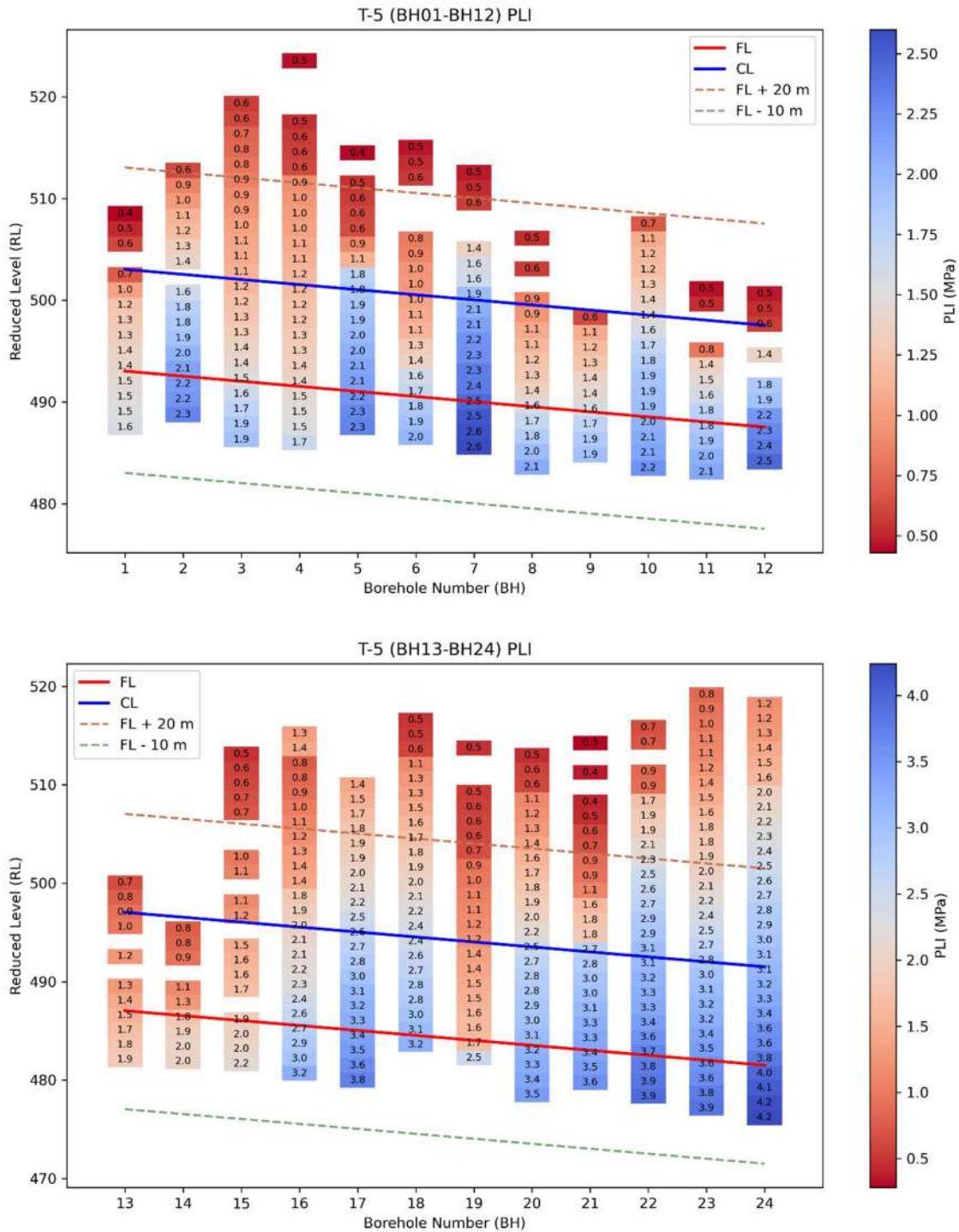
BH No.	Chainage	Mean	Std
BH41	52177	70.53	5.41
BH42	52227	66.19	5.89
BH43	52277	69.16	6.26
BH44	52327	67.09	3.06
BH45	52377	43.08	6.86
BH46	52427	44.64	5.94
BH47	52477	32.71	8.54
BH48	52527	35.30	1.56
BH49	52577	48.08	2.82
BH50	52627	42.95	5.49
BH51	52677	21.89	4.58
BH52	52727	31.10	3.22
BH53	52777	31.22	3.07
BH54	52827	49.81	3.55
BH55	52877	44.87	6.68
BH56	52927	35.53	7.79

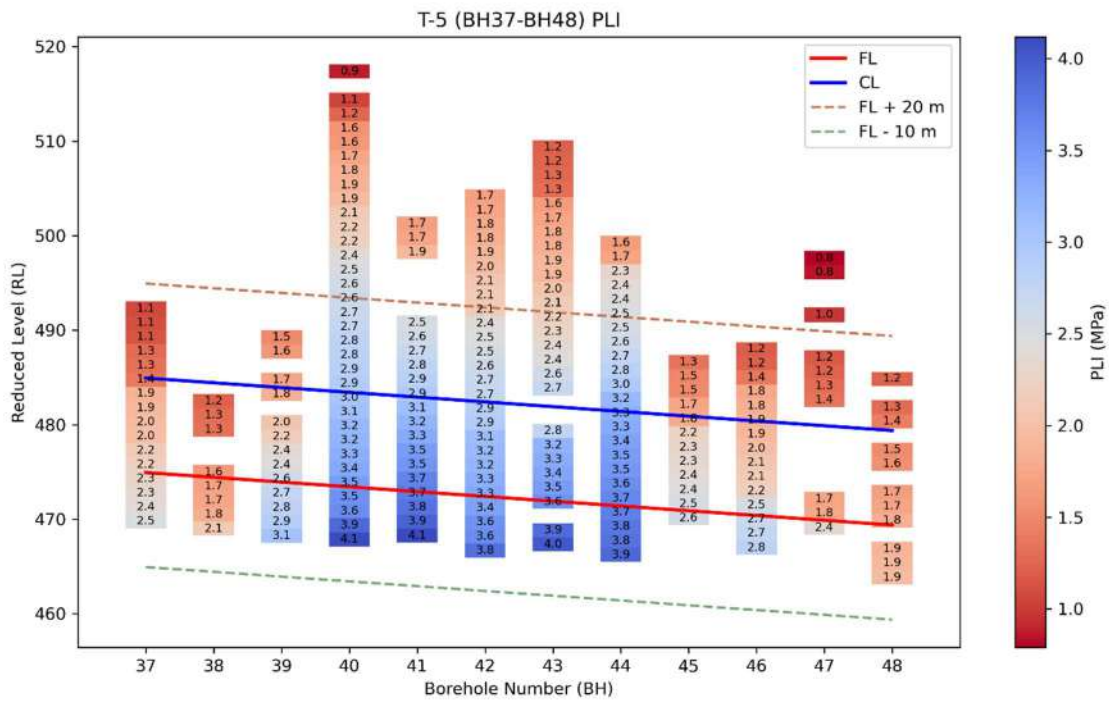
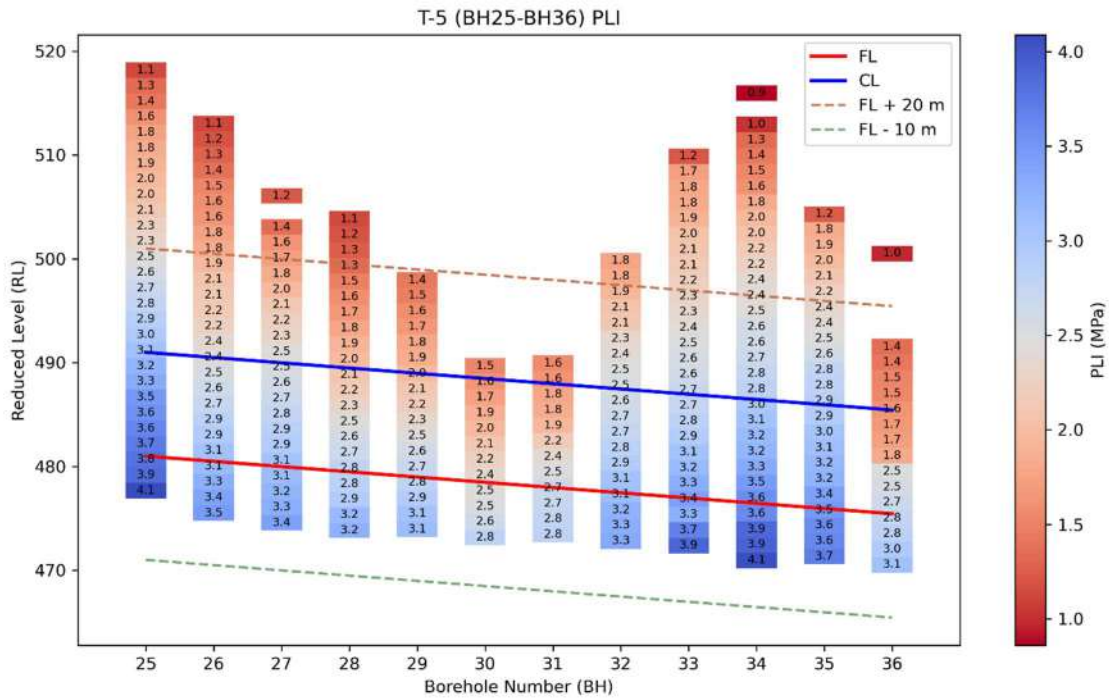
BH No.	Chainage	Mean	Std
BH57	52977	42.62	4.99
BH58	53027	42.29	5.23
BH59	53077	32.42	8.44
BH60	53127	29.84	6.68
BH61	53177	Mean	Std

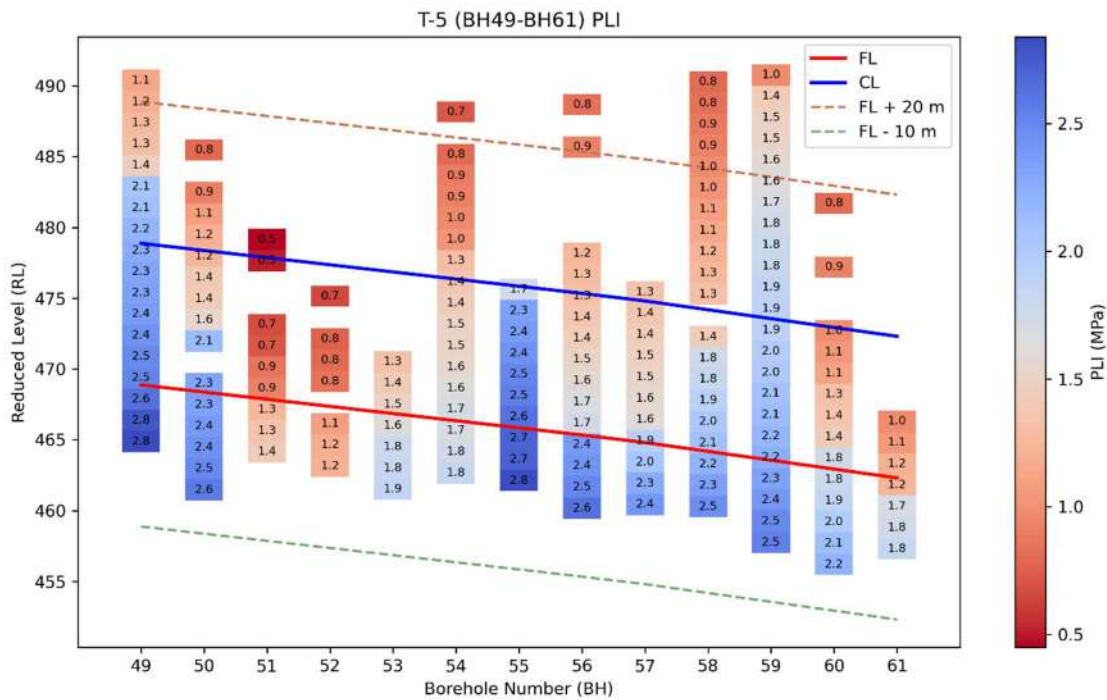
10.3.6.2 Recommended UCS considering 1D zone of influence:

Chainage	Statistical / Reduction Method	Recommended Design Value	Reference Standards / Guidelines
	(UCS _k = $\mu - \sigma$) across boreholes within ± 10 m of FL and CL)	(UCS _d = $(\mu - \sigma) \times f(\text{RMR})$), where $f(\text{RMR}) = 0.1-0.7$)	
50180 to 50880	25.60976	7.68	IS 9143:1979; IS 13365 (Part 2):1998; Hoek & Brown (2002, 2019)
50880 to 51920	45.93139	27.55	
51920 to 53180 (P2)	32.21954	3.22	

10.3.7 Point Load Test







10.3.7.1 Mean And Standard Deviation in PLI considering 1D zone of influence in each Borehole:

BH No.	Chainage	Mean	Std
BH01	50177	1.31	0.25
BH02	50227	2.00	0.23
BH03	50277	1.49	0.26
BH04	50327	1.38	0.15
BH05	50377	2.07	0.17
BH06	50427	1.50	0.36
BH07	50477	2.36	0.18
BH08	50527	1.47	0.38

BH No.	Chainage	Mean	Std
BH09	50577	1.41	0.39
BH10	50627	1.89	0.24
BH11	50677	1.66	0.40
BH12	50727	2.12	0.38
BH13	50777	1.48	0.30
BH14	50827	1.41	0.53
BH15	50877	1.82	0.25
BH16	50927	2.54	0.40
BH17	50977	3.17	0.38
BH18	51027	2.71	0.32
BH19	51077	1.56	0.38
BH20	51127	3.00	0.30
BH21	51177	2.87	0.99
BH22	51227	3.52	0.30
BH23	51277	3.41	0.30
BH24	51327	3.69	0.39

BH No.	Chainage	Mean	Std
BH25	51377	3.58	0.31
BH26	51427	3.00	0.32
BH27	51477	2.95	0.30
BH28	51527	2.66	0.38
BH29	51577	2.57	0.39
BH30	51627	2.21	0.38
BH31	51677	2.36	0.40
BH32	51727	2.98	0.27
BH33	51777	3.23	0.37
BH34	51827	3.48	0.36
BH35	51877	3.33	0.27
BH36	51927	2.45	0.52
BH37	51977	2.09	0.31
BH38	52027	1.60	0.30
BH39	52077	2.50	0.39
BH40	52127	3.43	0.34

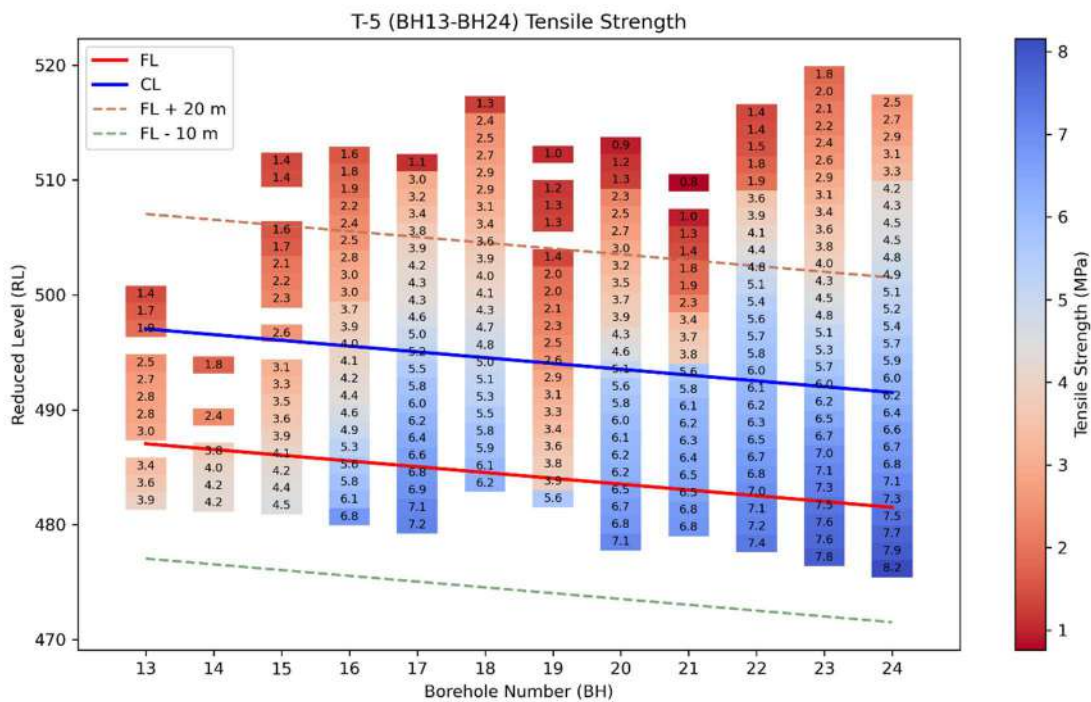
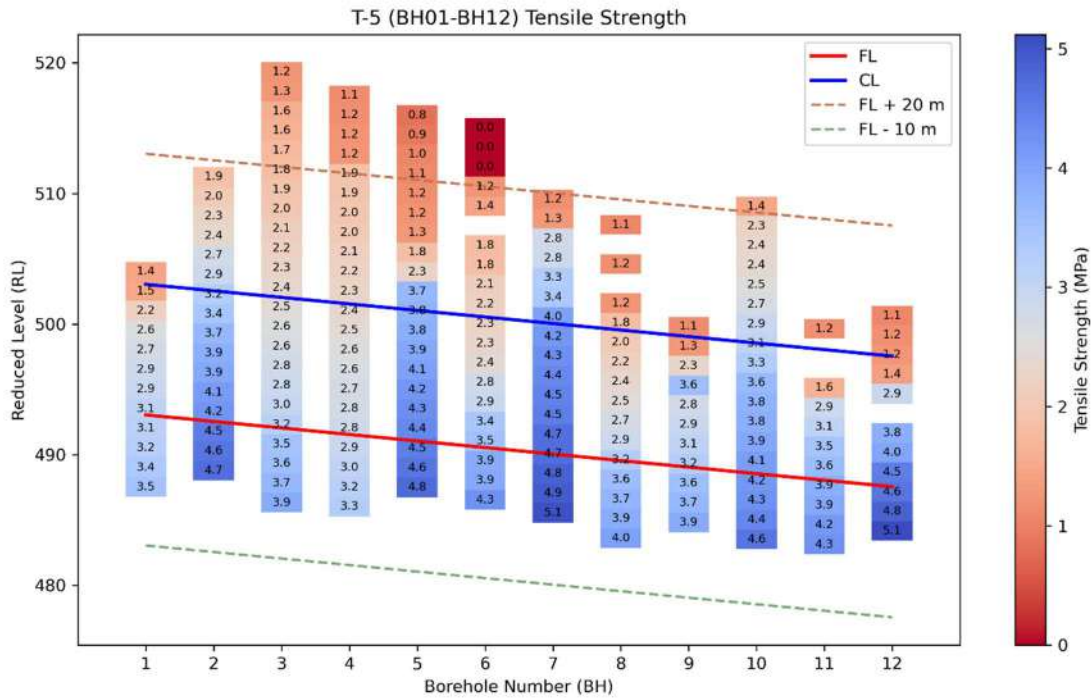
BH No.	Chainage	Mean	Std
BH41	52177	3.59	0.32
BH42	52227	3.30	0.29
BH43	52277	3.45	0.39
BH44	52327	3.58	0.21
BH45	52377	2.18	0.37
BH46	52427	2.25	0.37
BH47	52477	1.70	0.42
BH48	52527	1.76	0.16
BH49	52577	2.50	0.20
BH50	52627	2.02	0.51
BH51	52677	0.96	0.34
BH52	52727	0.93	0.22
BH53	52777	1.62	0.21
BH54	52827	1.57	0.16
BH55	52877	2.48	0.31
BH56	52927	1.87	0.51

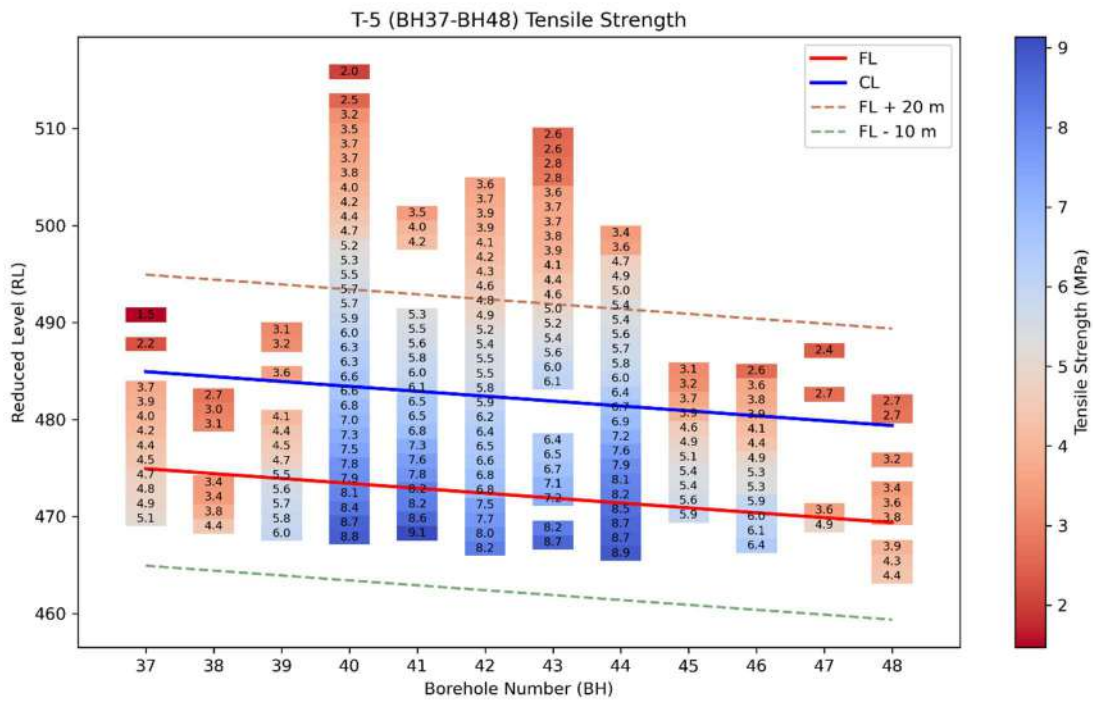
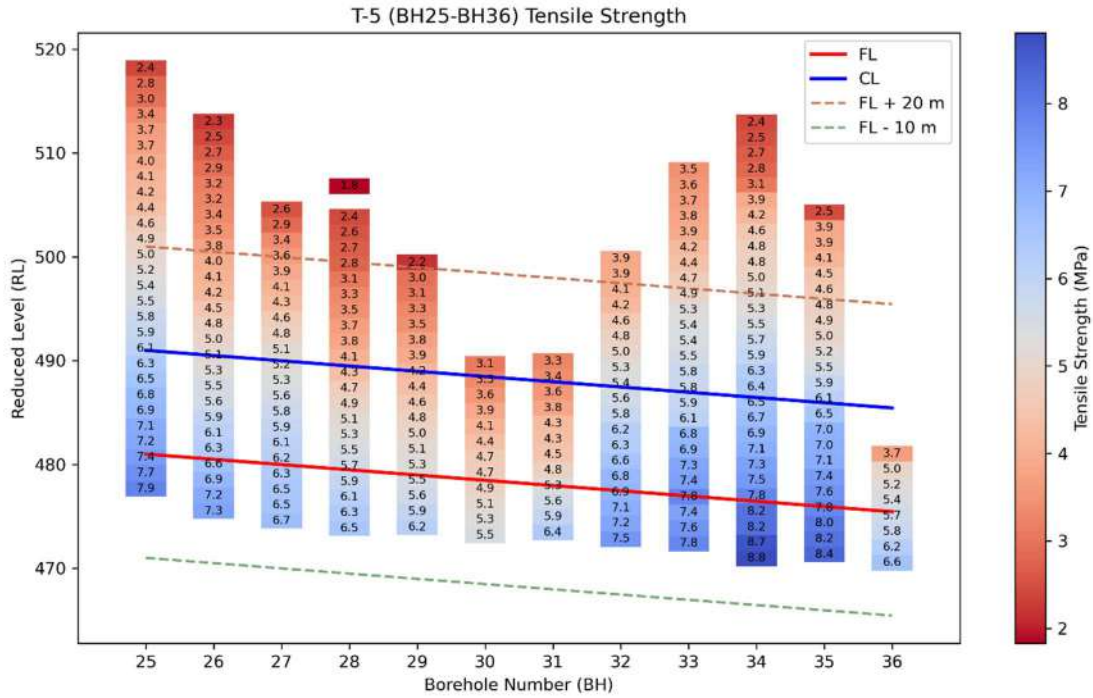
BH No.	Chainage	Mean	Std
BH57	52977	1.77	0.37
BH58	53027	2.01	0.32
BH59	53077	2.21	0.21
BH60	53127	1.58	0.42
BH61	53177	1.39	0.36

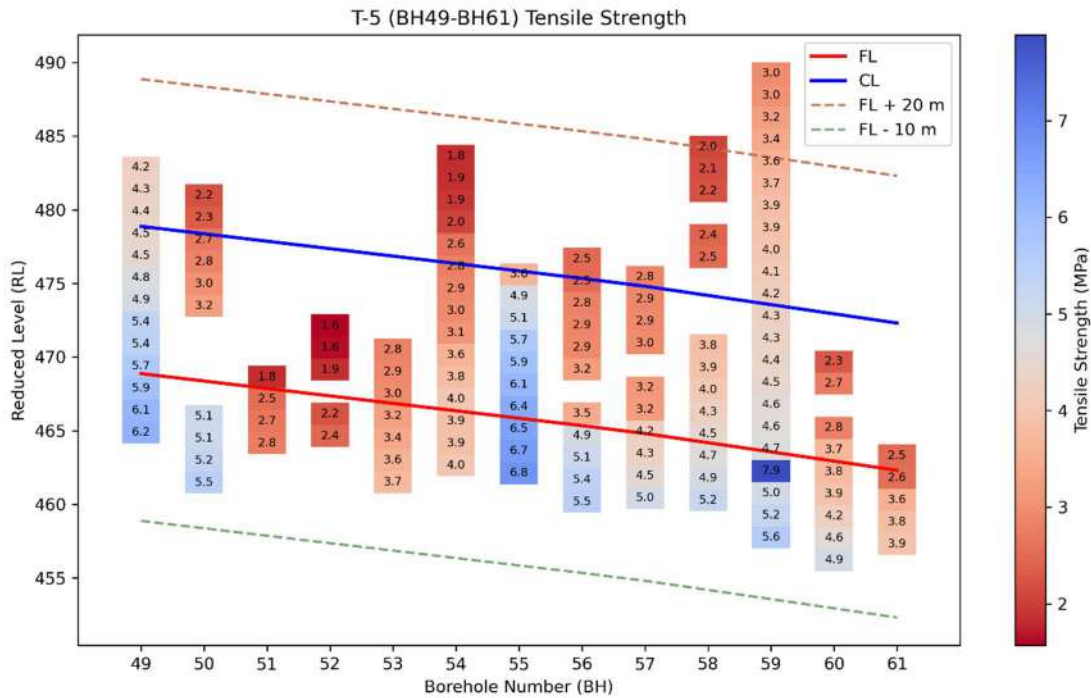
10.3.7.2 Recommended PLI considering 1D zone of influence:

Chainage	Statistical / Reduction Method	Recommended Design Value	Reference Standards / Guidelines
	(UCS _k = $\mu - \sigma$) across boreholes within ± 10 m of FL and CL)	(UCS _d = $(\mu - \sigma) \times f(\text{RMR})$), where $f(\text{RMR}) = 0.1-0.7$)	
50180 to 50880	1.28	0.38	IS 9143:1979; IS 13365 (Part 2):1998; Hoek & Brown (2002, 2019)
50880 to 51920	2.30	1.38	
51920 to 53180 (P2)	1.43	0.14	

10.3.8 Brazilian Test







10.3.8.1 Mean And Standard Deviation in Tensile Strength considering 1D zone of influence in each Borehole:

BH No.	Chainage	Mean	Std
BH01	50177	2.82	0.58
BH02	50227	4.03	0.50
BH03	50277	3.10	0.50
BH04	50327	2.79	0.29
BH05	50377	4.23	0.34
BH06	50427	3.17	0.73
BH07	50477	4.60	0.29
BH08	50527	3.01	0.71

BH No.	Chainage	Mean	Std
BH09	50577	3.03	0.78
BH10	50627	3.91	0.47
BH11	50677	3.43	0.83
BH12	50727	4.04	1.23
BH13	50777	3.08	0.51
BH14	50827	3.40	1.06
BH15	50877	3.84	0.51
BH16	50927	5.18	0.89
BH17	50977	6.32	0.67
BH18	51027	5.43	0.54
BH19	51077	3.46	0.90
BH20	51127	6.20	0.58
BH21	51177	5.73	1.94
BH22	51227	6.73	0.45
BH23	51277	7.13	0.54
BH24	51327	7.12	0.65

BH No.	Chainage	Mean	Std
BH25	51377	6.99	0.58
BH26	51427	6.26	0.70
BH27	51477	6.01	0.50
BH28	51527	5.48	0.70
BH29	51577	5.13	0.63
BH30	51627	4.49	0.70
BH31	51677	4.86	0.92
BH32	51727	6.61	0.62
BH33	51777	7.10	0.66
BH34	51827	7.62	0.78
BH35	51877	7.50	0.61
BH36	51927	5.45	0.89
BH37	51977	4.41	0.48
BH38	52027	3.41	0.58
BH39	52077	5.14	0.73
BH40	52127	7.73	0.75

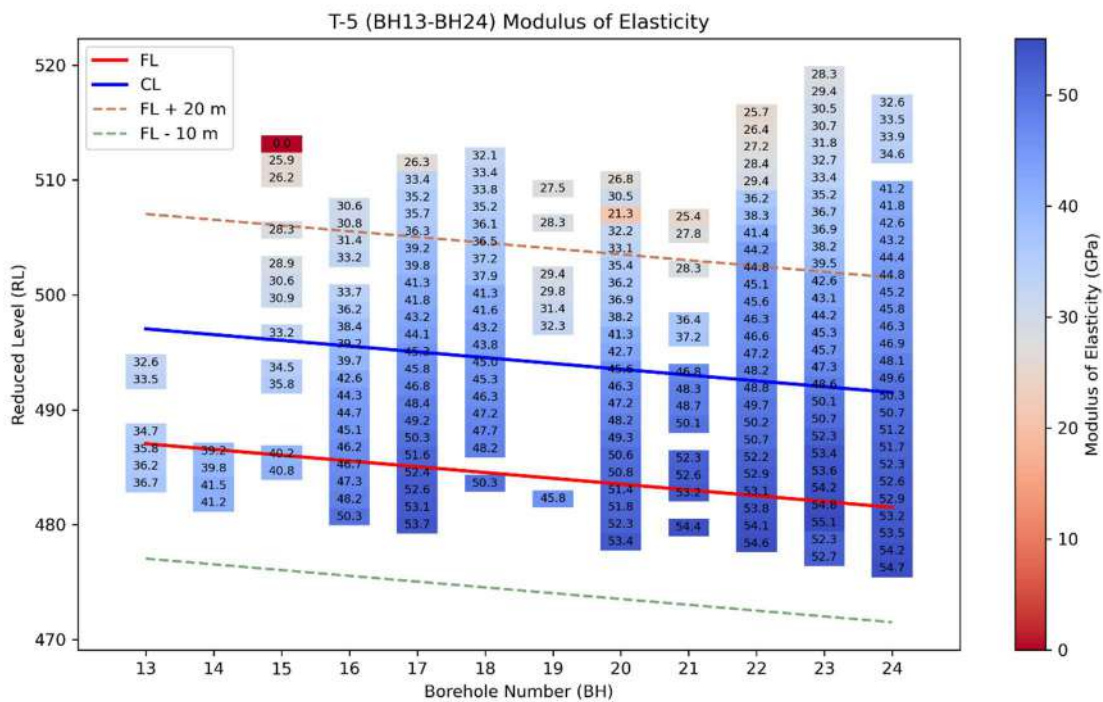
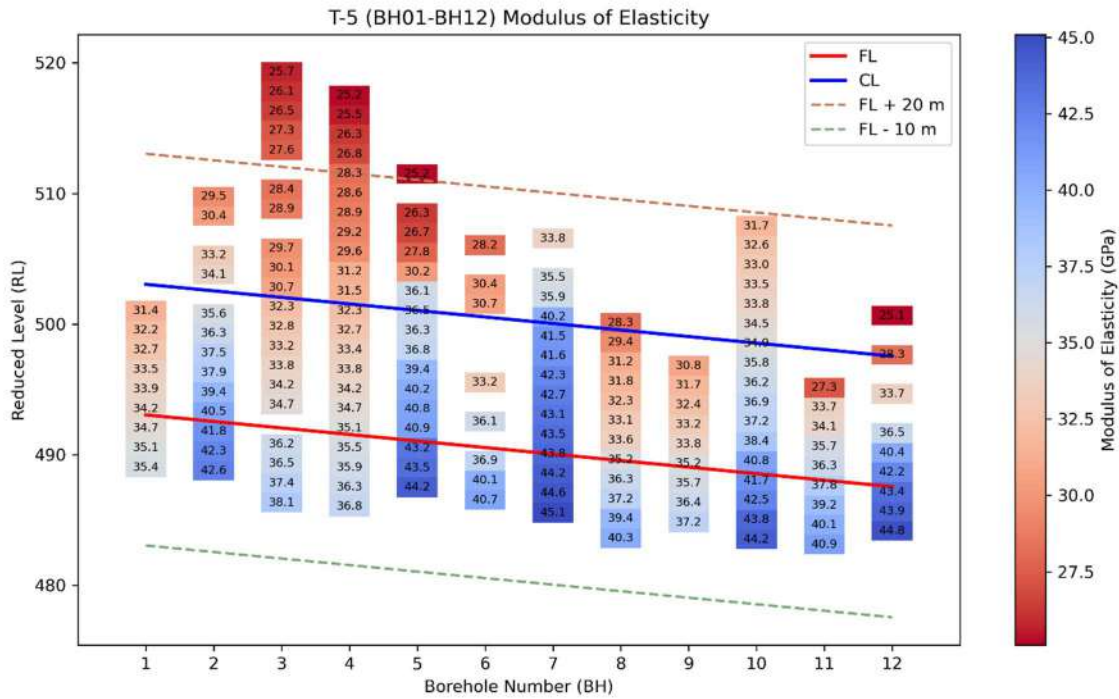
BH No.	Chainage	Mean	Std
BH41	52177	7.67	0.90
BH42	52227	6.96	0.77
BH43	52277	7.26	0.88
BH44	52327	7.95	0.74
BH45	52377	4.77	0.90
BH46	52427	5.10	0.95
BH47	52477	3.73	1.13
BH48	52527	3.80	0.43
BH49	52577	5.35	0.65
BH50	52627	4.09	1.23
BH51	52677	2.45	0.42
BH52	52727	1.94	0.38
BH53	52777	3.23	0.36
BH54	52827	3.41	0.54
BH55	52877	5.78	0.98
BH56	52927	3.87	1.20

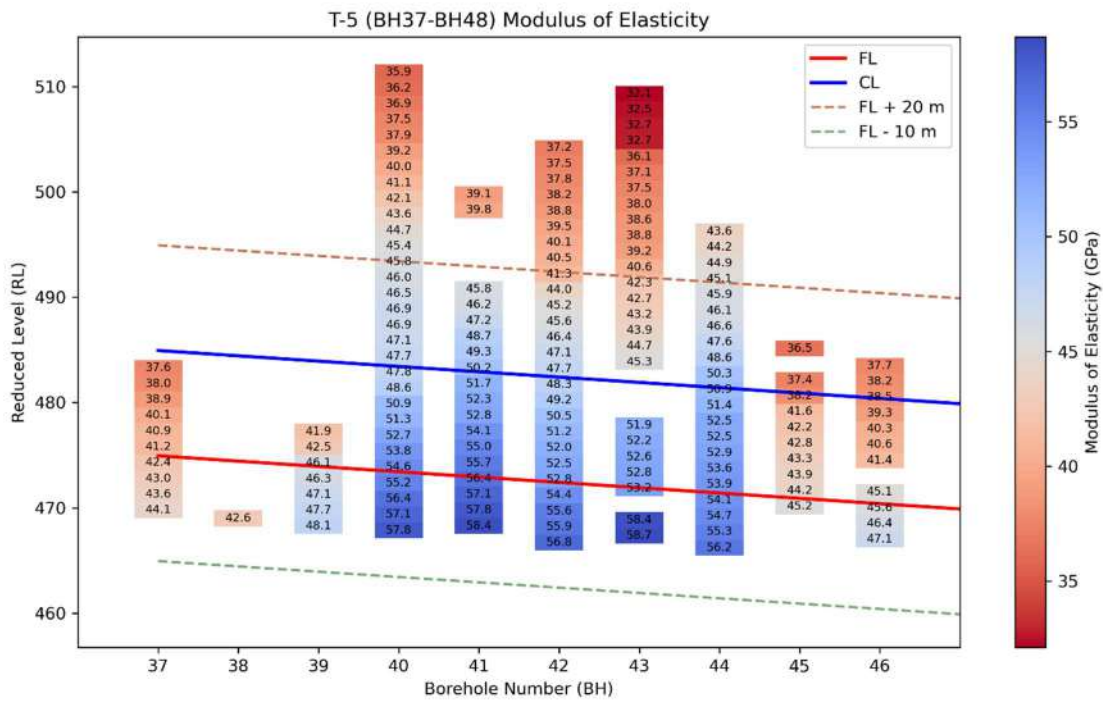
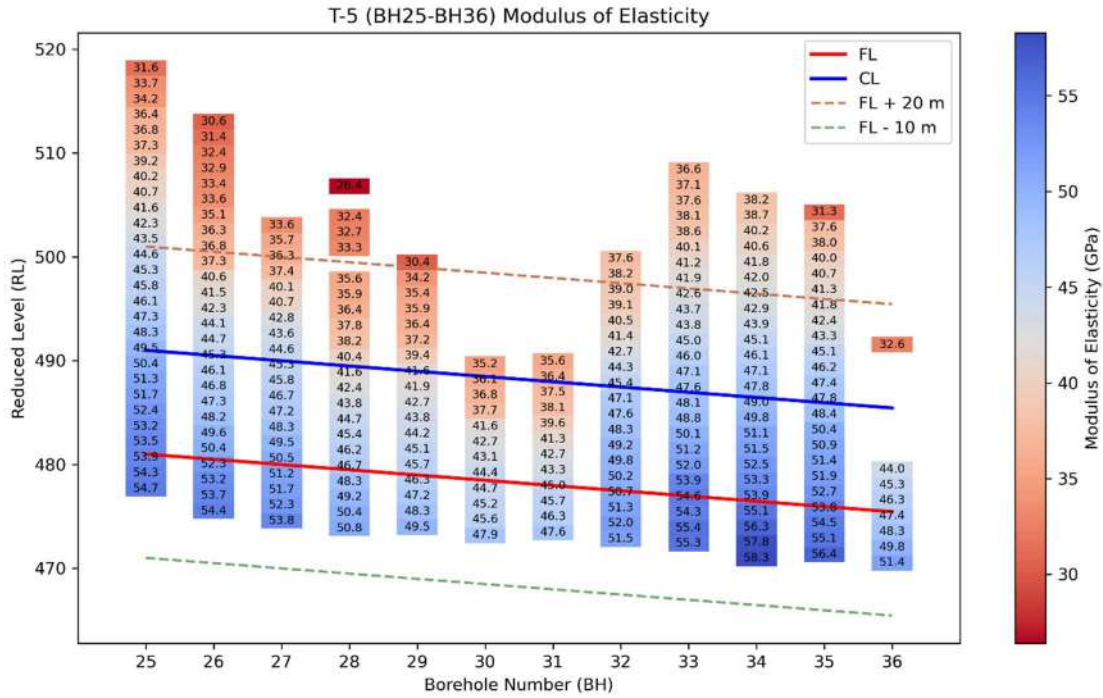
BH No.	Chainage	Mean	Std
BH57	52977	3.69	0.82
BH58	53027	4.41	0.50
BH59	53077	5.02	1.03
BH60	53127	3.66	0.89
BH61	53177	3.28	0.68

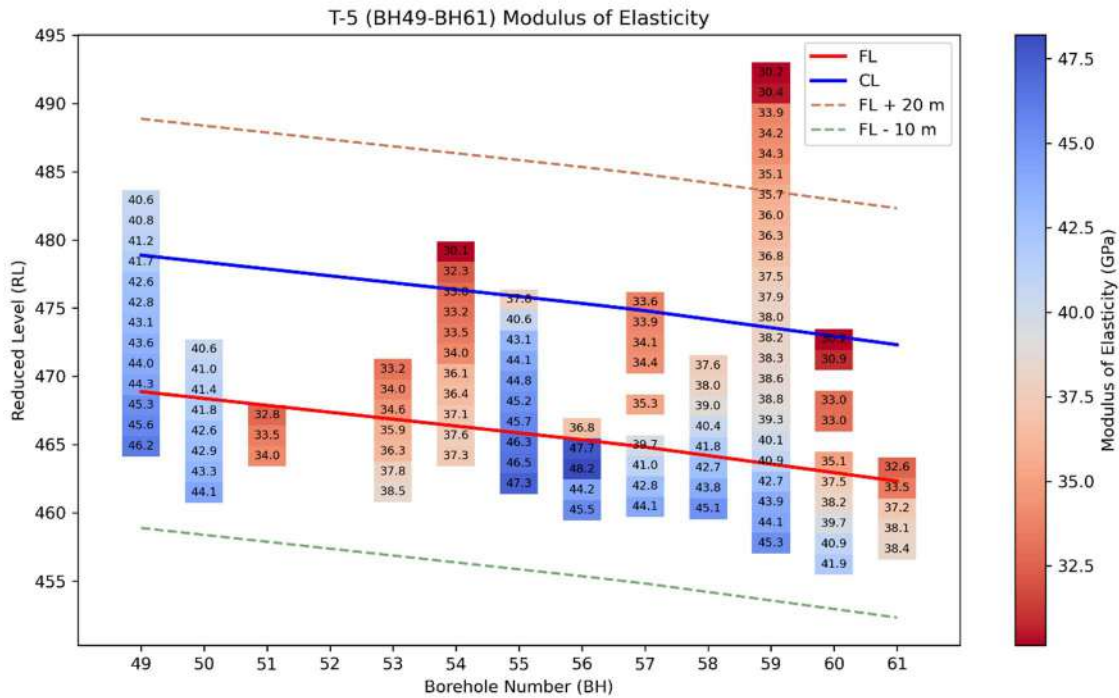
10.3.8.2 Recommended Tensile Strength considering 1D zone of influence:

Chainage	Statistical / Reduction Method (mean value across boreholes within ± 10 m of FL and CL \times 0.8 (account for anisotropy))	Recommended Design Value ($\mu - \sigma$)	Reference Standards / Guidelines
50180 to 50880	3.54	2.71	IS 10082:1982; Hoek & Brown (1997); ISRM Suggested Methods
50880 to 51920	6.07	4.76	
51920 to 53180 (P2)	5.01	3.23	

10.3.9 Modulus of elasticity test







10.3.9.1 Mean And Standard Deviation in Elasticity considering 1D zone of influence in each Borehole:

BH No.	Chainage	Mean	Std
BH01	50177	33.68	1.36
BH02	50227	39.33	2.64
BH03	50277	34.92	2.01
BH04	50327	34.61	1.47
BH05	50377	40.18	2.94
BH06	50427	37.40	3.07
BH07	50477	43.24	1.23
BH08	50527	34.53	3.47

BH09	50577	34.04	2.21
BH10	50627	39.31	3.39
BH11	50677	36.12	4.17
BH12	50727	41.22	4.11
BH13	50777	34.92	1.61
BH14	50827	40.43	1.10
BH15	50877	37.83	3.14
BH16	50927	45.51	2.98
BH17	50977	49.93	3.03
BH18	51027	46.33	2.26
BH19	51077	45.80	
BH20	51127	49.72	2.58
BH21	51177	45.16	17.12
BH22	51227	52.01	2.03
BH23	51277	52.92	1.64
BH24	51327	52.48	1.41
BH25	51377	52.49	1.73

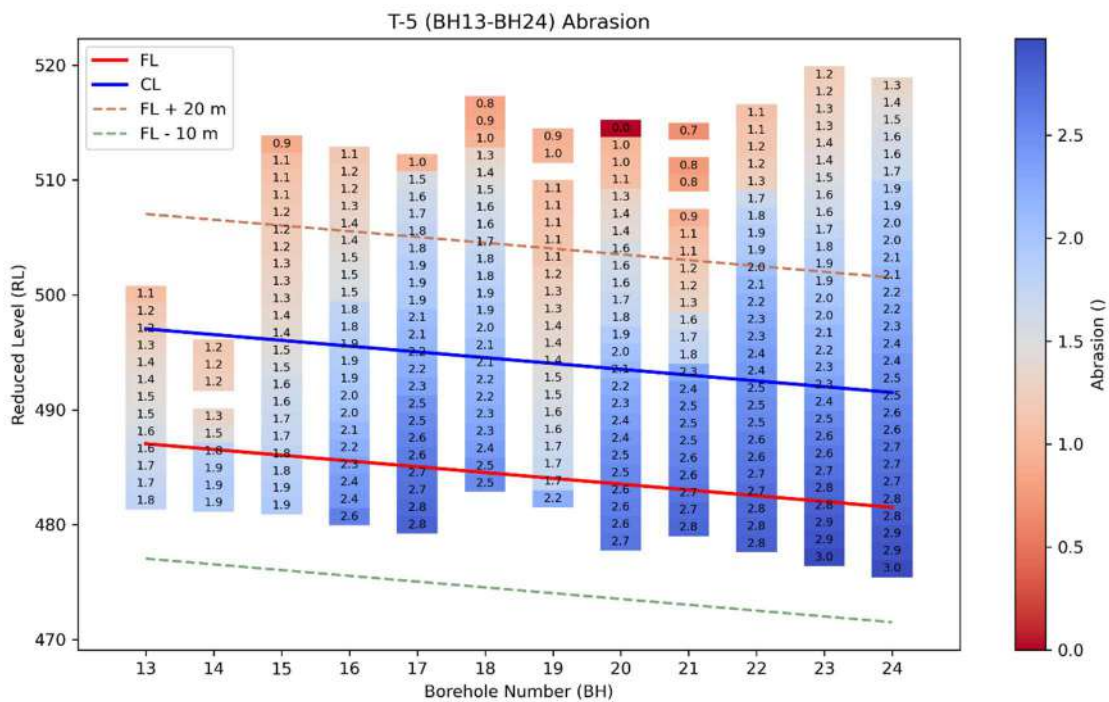
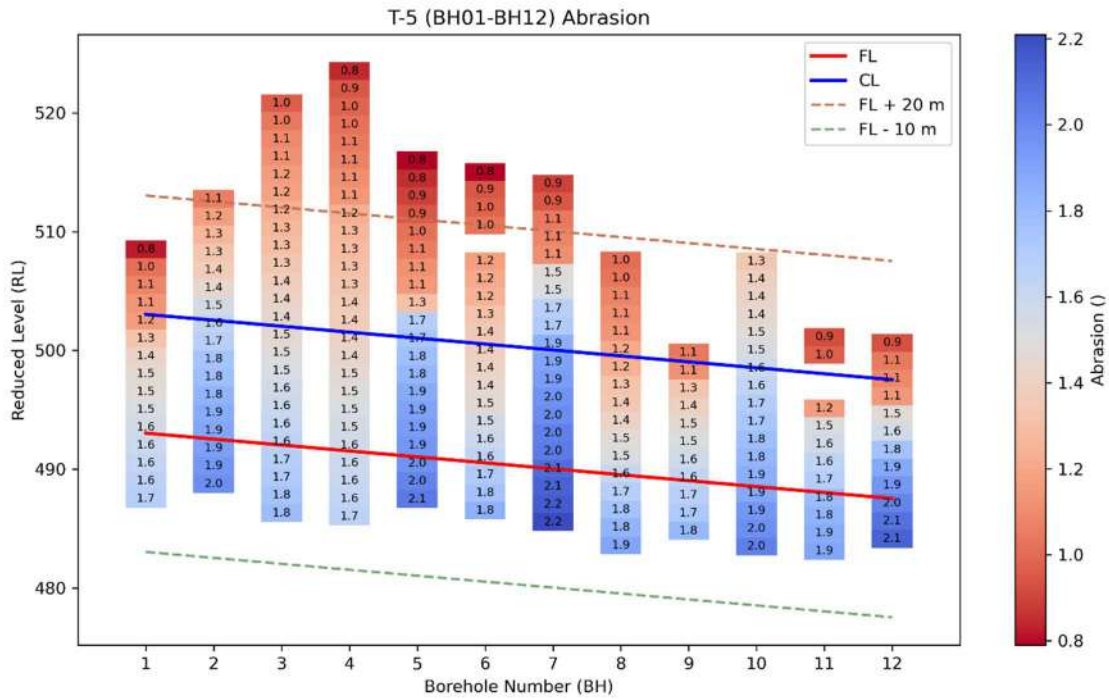
BH26	51427	50.20	3.06
BH27	51477	49.30	2.84
BH28	51527	46.32	3.11
BH29	51577	45.12	2.58
BH30	51627	42.35	3.90
BH31	51677	42.71	3.52
BH32	51727	49.78	1.69
BH33	51777	52.36	2.73
BH34	51827	53.51	3.12
BH35	51877	52.54	2.43
BH36	51927	47.48	2.58
BH37	51977	40.98	2.32
BH38	52027	42.63	
BH39	52077	45.67	2.49
BH40	52127	53.29	3.35
BH41	52177	55.12	2.36
BH42	52227	52.66	2.80

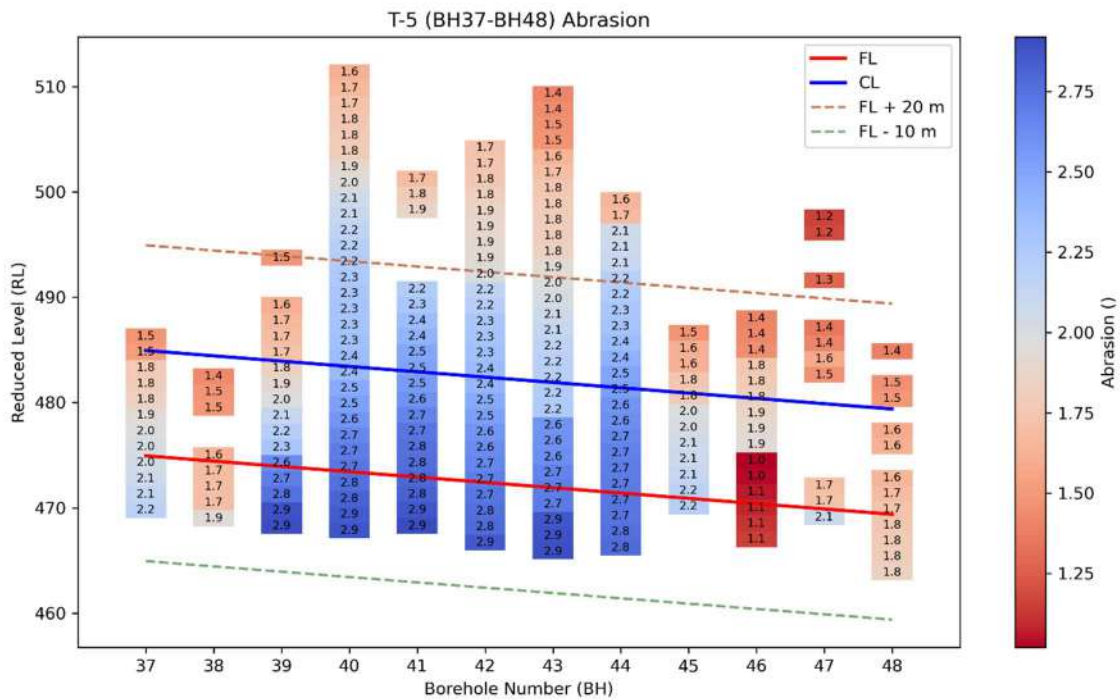
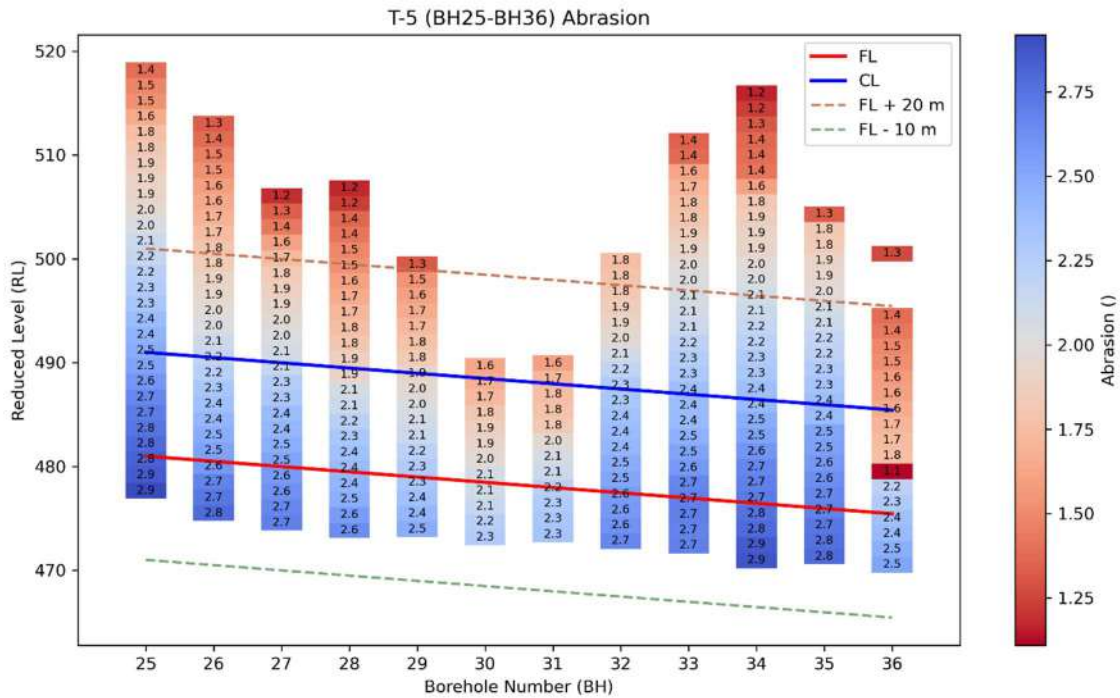
BH43	52277	54.24	2.97
BH44	52327	53.45	1.61
BH45	52377	42.09	2.65
BH46	52427	42.25	3.45
BH49	52577	43.91	1.44
BH50	52627	42.21	1.22
BH51	52677	33.42	0.61
BH53	52777	35.75	1.97
BH54	52827	35.32	2.15
BH55	52877	44.15	2.94
BH56	52927	44.47	4.59
BH57	52977	38.14	4.21
BH58	53027	41.05	2.75
BH59	53077	40.91	2.62
BH60	53127	36.03	4.18
BH61	53177	35.96	2.71

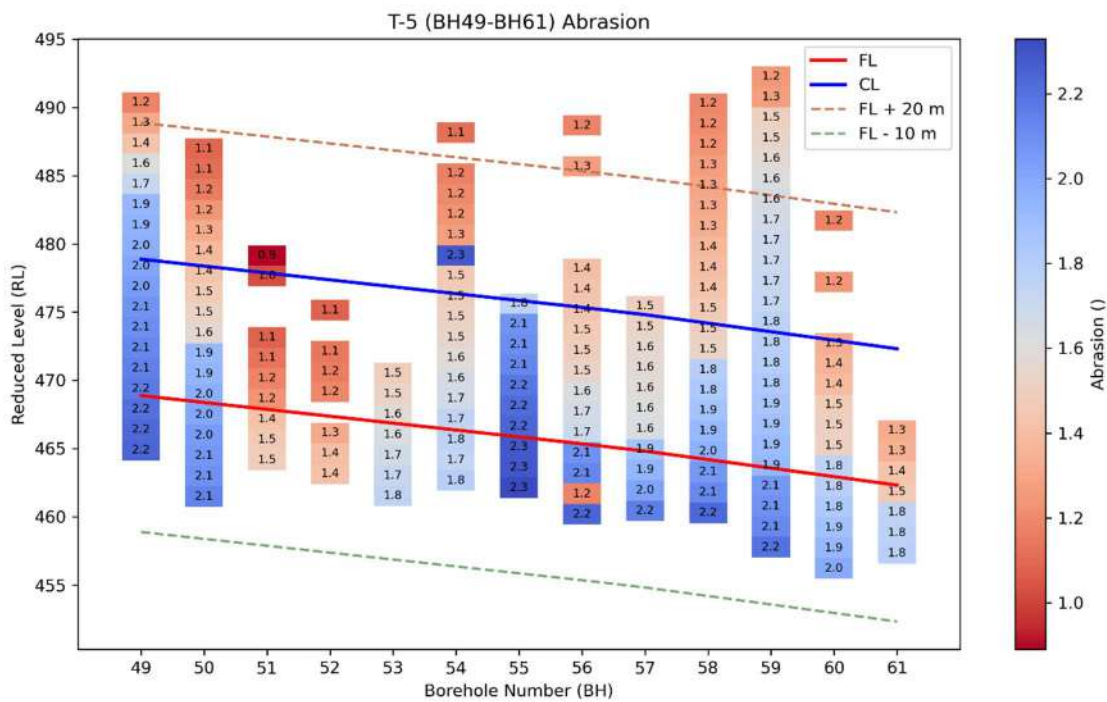
10.3.9.2 Recommended Modulus of Elasticity considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($E_i = \mu - \sigma$ across boreholes within ± 10 m of FL and CL $\times 0.8$ (account for anisotropy))	Recommended Design Value ($E_d = (\mu - \sigma) \times f(\text{RMR})$), where ($f(\text{RMR}) = 0.1 - 0.7$)	Reference Standards / Guidelines
50180 to 50880	33.62	10.09	IS 13365 (Part 2):1998; Hoek & Diederichs (2006)
50880 to 51920	43.44	26.07	
51920 to 53180 (P2)	37.14	3.71	

10.3.10 Abrasion test







10.3.10.1 Mean And Standard Deviation in Abrasion value considering 1D zone of influence in each Borehole:

BH No.	Chainage	Mean	Std
BH01	50177	1.50	0.15
BH02	50227	1.83	0.12
BH03	50277	1.62	0.11
BH04	50327	1.54	0.08
BH05	50377	1.90	0.10
BH06	50427	1.58	0.16
BH07	50477	2.05	0.10
BH08	50527	1.55	0.22

BH No.	Chainage	Mean	Std
BH09	50577	1.52	0.20
BH10	50627	1.81	0.15
BH11	50677	1.66	0.23
BH12	50727	1.82	0.33
BH13	50777	1.55	0.16
BH14	50827	1.55	0.32
BH15	50877	1.71	0.15
BH16	50927	2.20	0.24
BH17	50977	2.53	0.22
BH18	51027	2.24	0.18
BH19	51077	1.63	0.24
BH20	51127	2.45	0.18
BH21	51177	2.32	0.78
BH22	51227	2.66	0.13
BH23	51277	2.73	0.17
BH24	51327	2.74	0.14

BH No.	Chainage	Mean	Std
BH25	51377	2.71	0.14
BH26	51427	2.51	0.18
BH27	51477	2.46	0.17
BH28	51527	2.32	0.21
BH29	51577	2.20	0.19
BH30	51627	1.98	0.20
BH31	51677	2.07	0.22
BH32	51727	2.49	0.12
BH33	51777	2.58	0.13
BH34	51827	2.67	0.15
BH35	51877	2.63	0.12
BH36	51927	2.06	0.46
BH37	51977	1.93	0.19
BH38	52027	1.63	0.17
BH39	52077	2.38	0.40
BH40	52127	2.67	0.16

BH No.	Chainage	Mean	Std
BH41	52177	2.75	0.12
BH42	52227	2.64	0.14
BH43	52277	2.64	0.23
BH44	52327	2.68	0.08
BH45	52377	1.98	0.20
BH46	52427	1.44	0.42
BH47	52477	1.71	0.23
BH48	52527	1.72	0.09
BH49	52577	2.14	0.08
BH50	52627	1.85	0.27
BH51	52677	1.25	0.18
BH52	52727	1.24	0.13
BH53	52777	1.62	0.10
BH54	52827	1.63	0.12
BH55	52877	2.16	0.16
BH56	52927	1.68	0.33

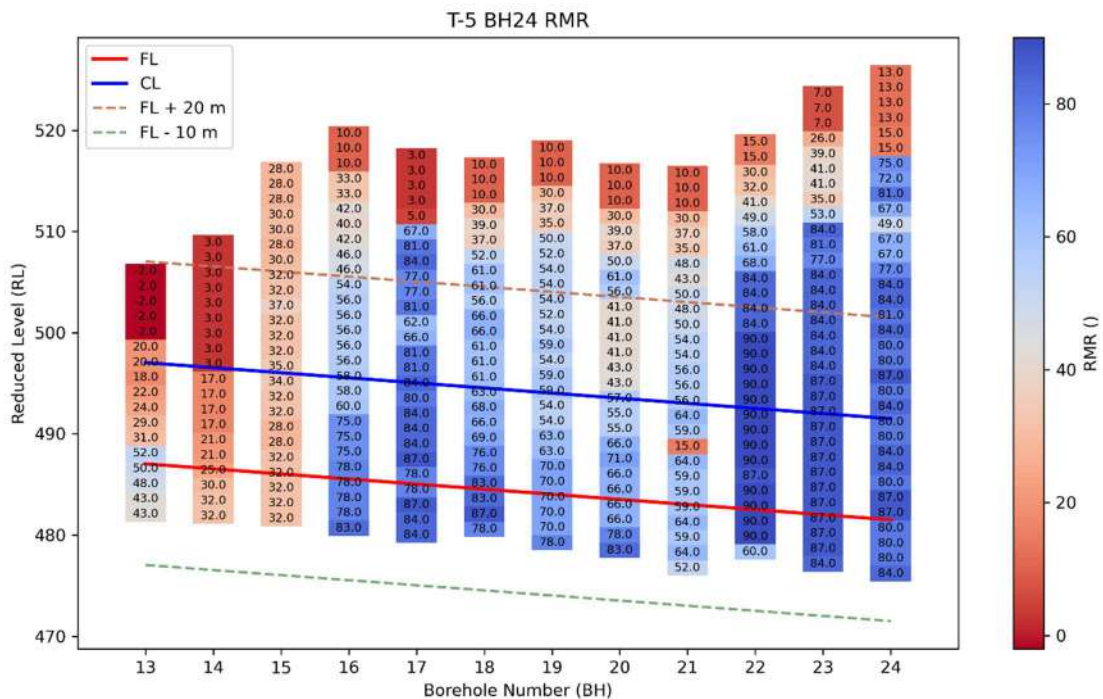
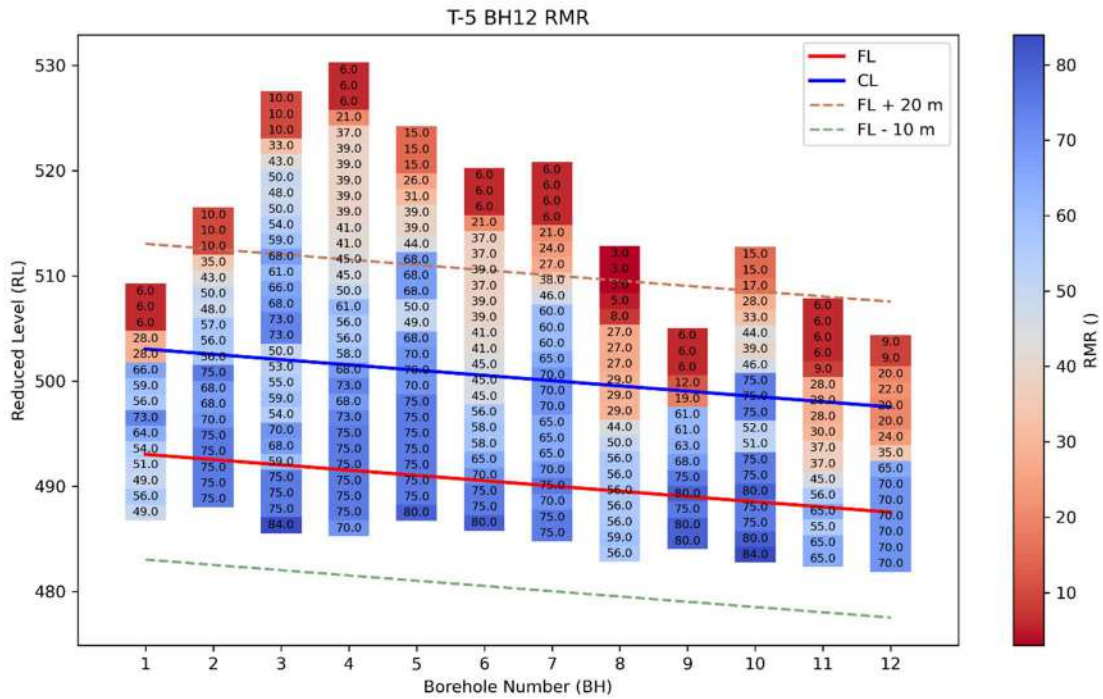
BH No.	Chainage	Mean	Std
BH57	52977	1.75	0.23
BH58	53027	1.88	0.24
BH59	53077	1.95	0.14
BH60	53127	1.65	0.24
BH61	53177	1.55	0.21

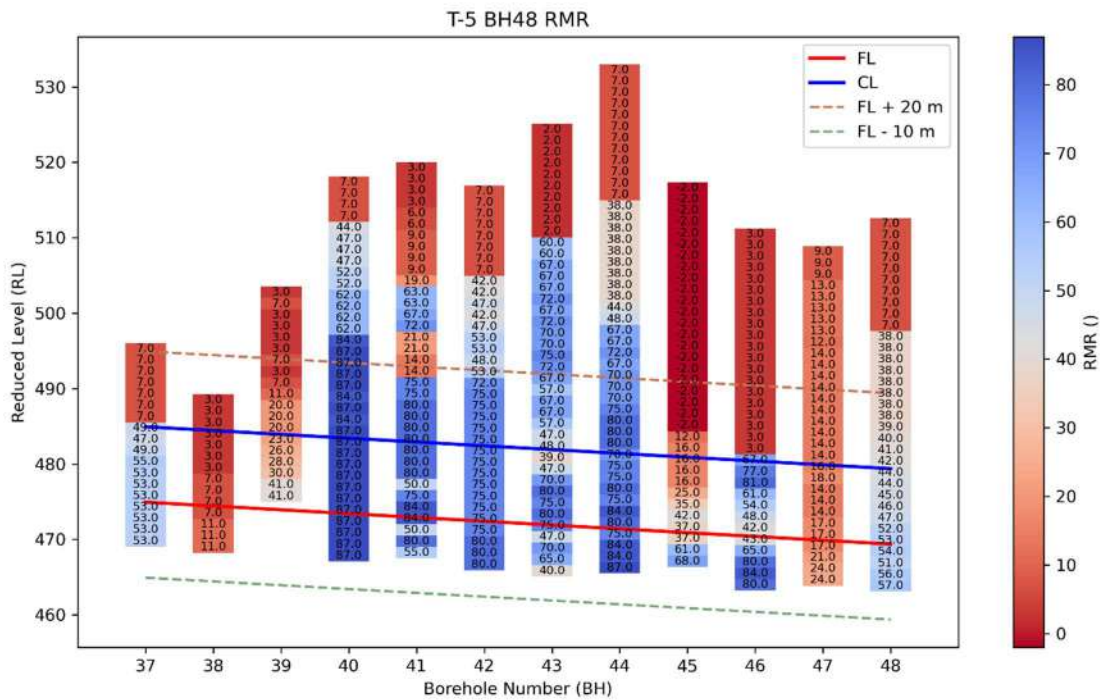
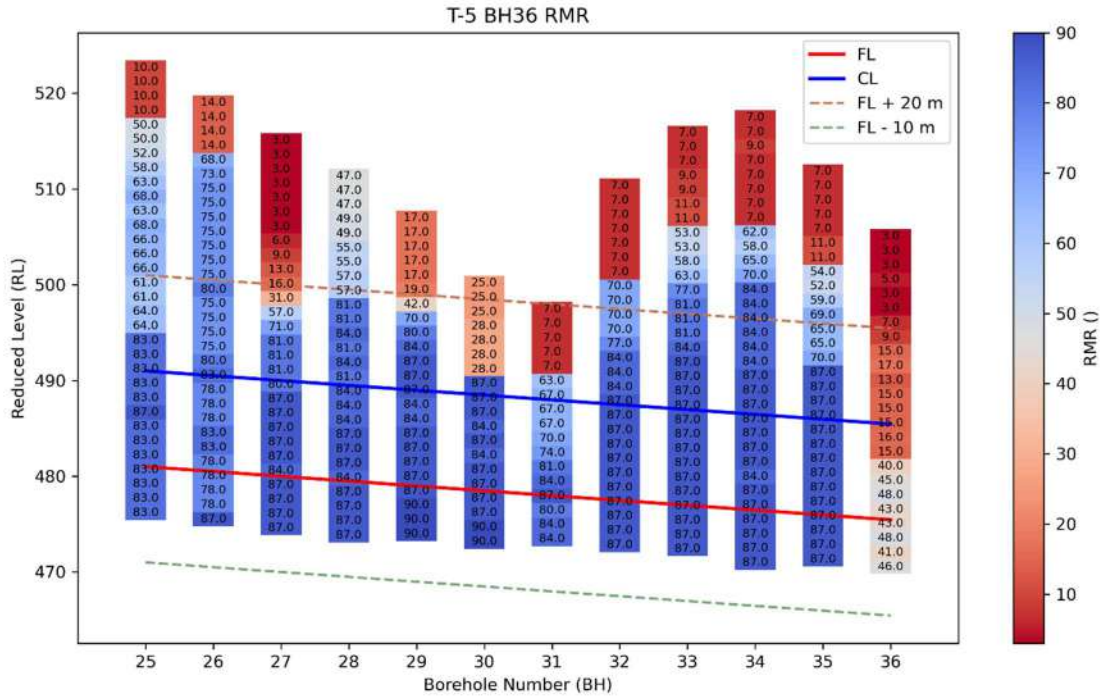
10.3.10.2 Recommended Abrasion Value considering ID zone of influence:

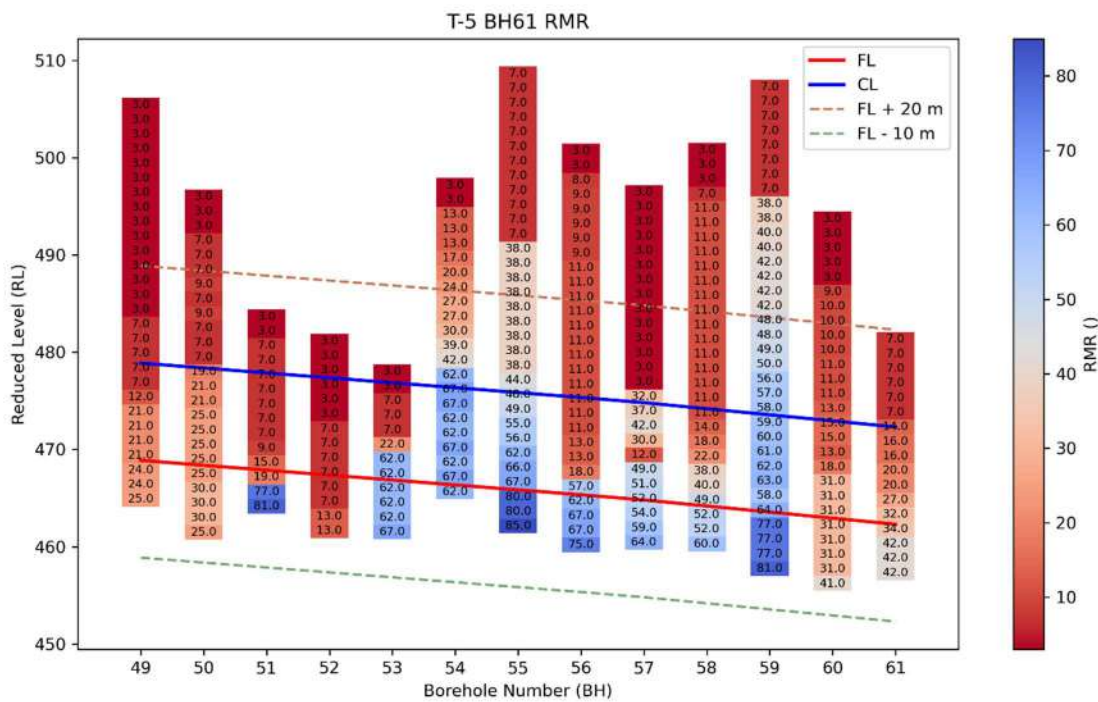
Chainage	Statistical / Reduction Method ($A = \mu + \sigma$ across boreholes within ± 10 m of FL and CL)	Recommended Design Value ($A_v < 25\%$): Slightly abrasive; 25–35%: Moderately abrasive; >35%: Highly abrasive. (CAI = 0.5–6).	Reference Standards / Guidelines
50180 to 50880	1.9	Slightly abrasive	IS 2386 (Part 4):1963; ISRM (2007); CERCHAR (1986)
50880 to 51920	2.8	Slightly abrasive	
51920 to 53180 (P2)	2.5	Slightly abrasive	

10.4 Geological assessment:

10.4.1 RMR:







10.4.1.1 Mean And Standard Deviation in RMR considering 1D zone of influence in each Borehole:

BH No.	Chainage	Mean	Std
BH01	50177	55	12
BH02	50227	71	6
BH03	50277	66	11
BH04	50327	73	3
BH05	50377	75	3
BH06	50427	63	12
BH07	50477	70	4
BH08	50527	50	11

BH No.	Chainage	Mean	Std
BH09	50577	66	18
BH10	50627	72	11
BH11	50677	48	15
BH12	50727	56	21
BH13	50777	36	13
BH14	50827	23	6
BH15	50877	31	2
BH16	50927	74	8
BH17	50977	83	3
BH18	51027	75	8
BH19	51077	66	8
BH20	51127	66	9
BH21	51177	56	14
BH22	51227	87	9
BH23	51277	87	1
BH24	51327	82	3

BH No.	Chainage	Mean	Std
BH25	51377	83	1
BH26	51427	80	3
BH27	51477	86	2
BH28	51527	86	2
BH29	51577	87	2
BH30	51627	87	2
BH31	51677	78	8
BH32	51727	87	0
BH33	51777	87	0
BH34	51827	87	1
BH35	51877	87	0
BH36	51927	39	12
BH37	51977	52	2
BH38	52027	7	3
BH39	52077	32	8
BH40	52127	87	0

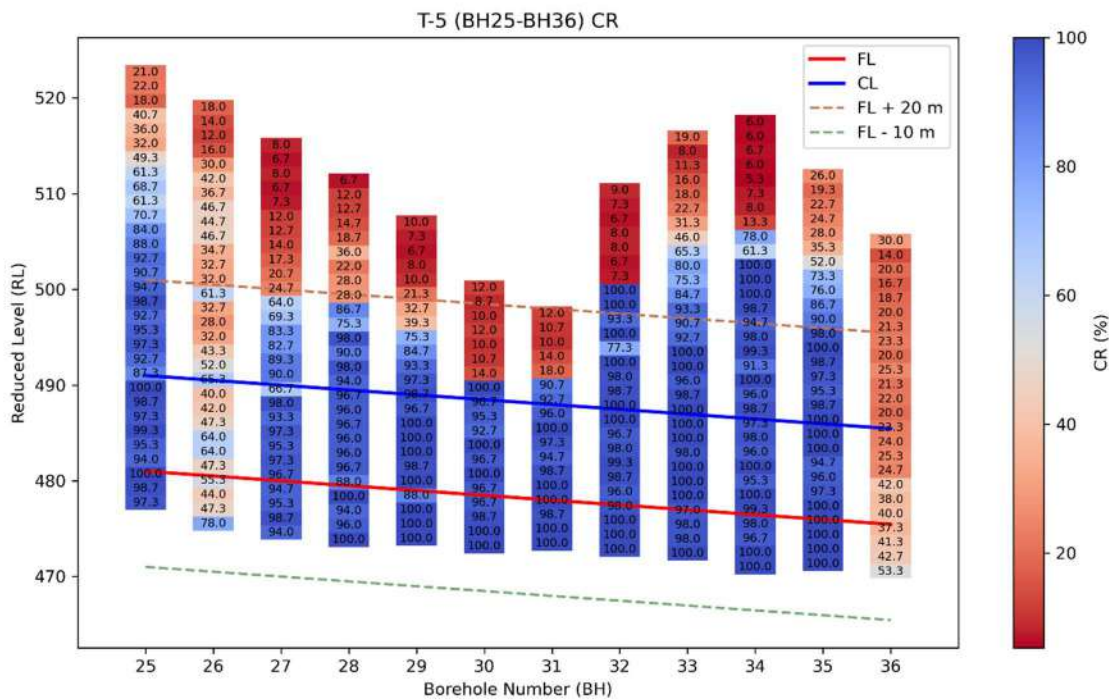
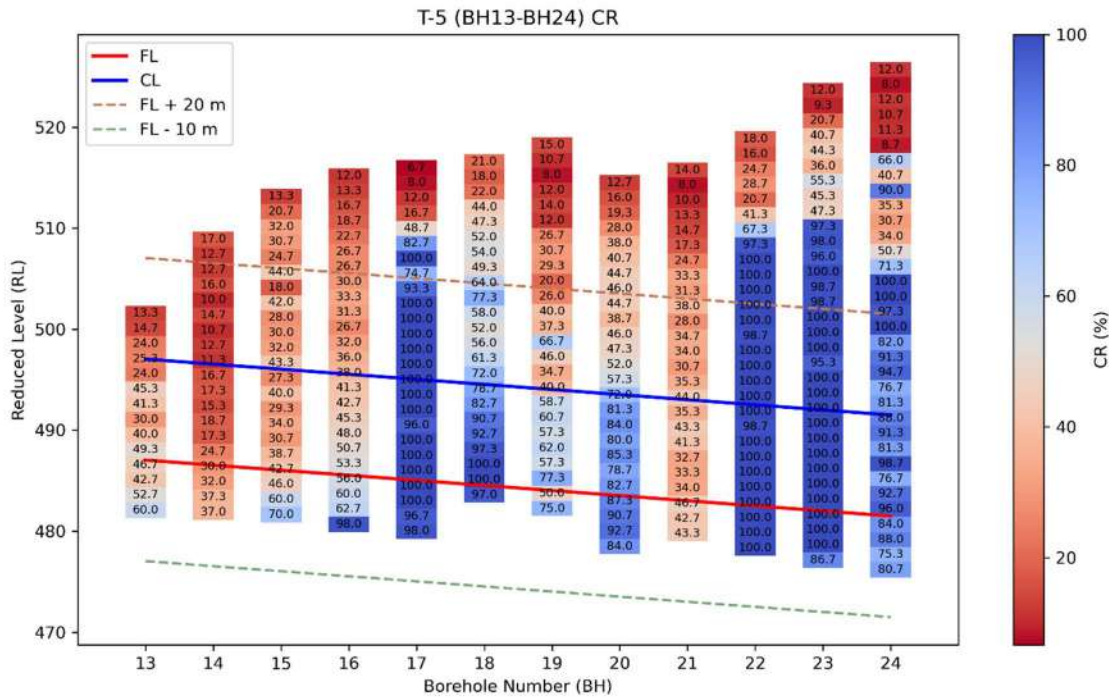
BH No.	Chainage	Mean	Std
BH41	52177	72	14
BH42	52227	76	2
BH43	52277	63	16
BH44	52327	79	5
BH45	52377	35	18
BH46	52427	65	16
BH47	52477	18	4
BH48	52527	50	5
BH49	52577	18	7
BH50	52627	25	4
BH51	52677	24	30
BH52	52727	7	3
BH53	52777	38	28
BH54	52827	65	3
BH55	52877	65	13
BH56	52927	37	28

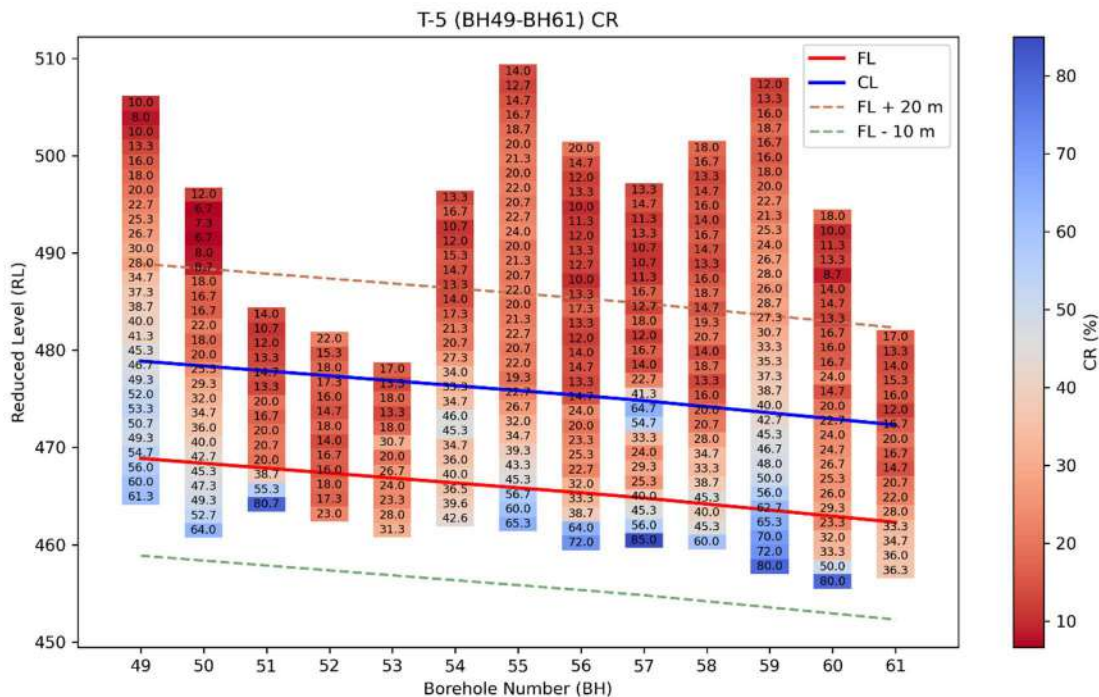
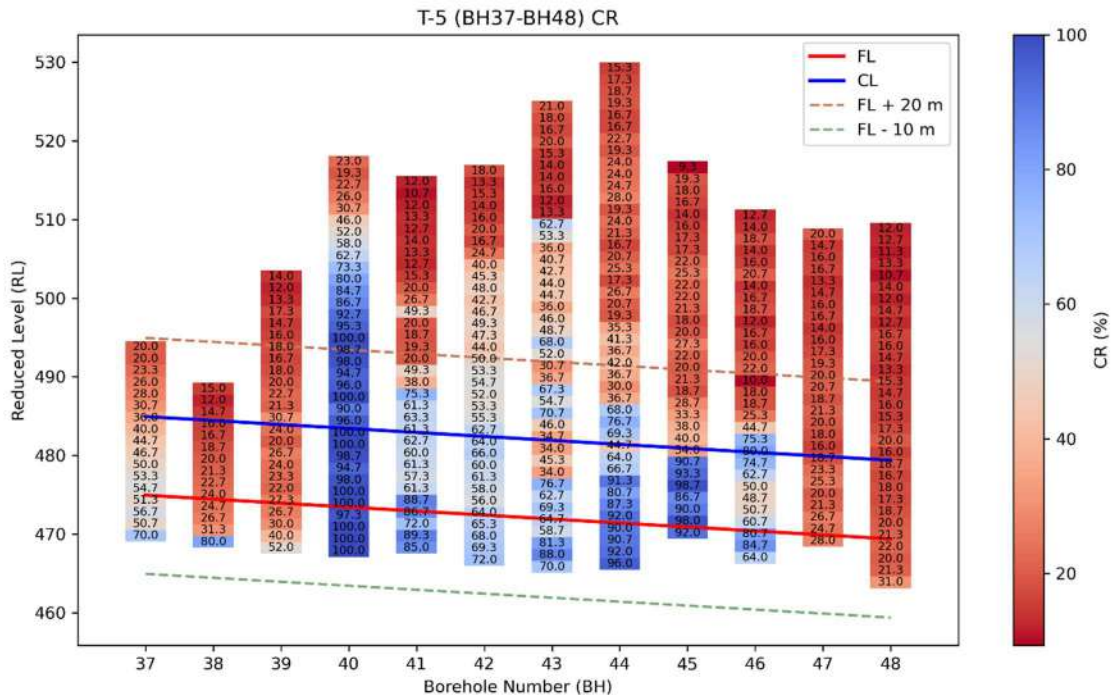
BH No.	Chainage	Mean	Std
BH57	52977	45	15
BH58	53027	36	18
BH59	53077	67	9
BH60	53127	27	9
BH61	53177	29	11

10.4.1.2 Recommended RQD considering 1D zone of influence:

Chainage	Statistical / Reduction Method	Recommended Design Value	Reference Standards / Guidelines
	(Average across boreholes within ± 10 m of FL and CL)	($RMR_d = \mu - \sigma$)	
50180 to 50880	57 (Class III)	38 (Class IV)	IS 13365 (Part 2): 1998, Cl. 5.1 + Note on “representative values”
50880 to 51920	81 (Class II)	70 (Class II)	
51920 to 53180 (P2)	44 (Class III)	18 (Class V)	

10.4.2 Core Recovery:





10.4.2.1 Mean And Standard Deviation in Core Recovery considering 1D zone of influence in each Borehole:

BH No.	Chainage	Mean	Std
BH01	50177	58.39	17.83
BH02	50227	50.37	8.34
BH03	50277	43.03	14.36
BH04	50327	45.64	11.29
BH05	50377	72.07	15.60
BH06	50427	35.27	13.52
BH07	50477	44.53	9.85
BH08	50527	50.61	10.15
BH09	50577	56.93	15.02
BH10	50627	65.39	10.54
BH11	50677	53.60	13.61
BH12	50727	54.02	18.50
BH13	50777	43.20	10.45
BH14	50827	24.63	8.75
BH15	50877	41.87	13.77

BH No.	Chainage	Mean	Std
BH16	50927	55.80	16.43
BH17	50977	99.15	1.52
BH18	51027	87.23	13.17
BH19	51077	57.30	13.39
BH20	51127	83.52	5.72
BH21	51177	36.06	12.95
BH22	51227	99.87	0.42
BH23	51277	98.67	4.22
BH24	51327	86.61	7.70
BH25	51377	96.80	3.86
BH26	51427	52.93	12.20
BH27	51477	93.39	9.02
BH28	51527	96.00	3.18
BH29	51577	98.36	3.59
BH30	51627	97.58	2.39
BH31	51677	98.53	1.93

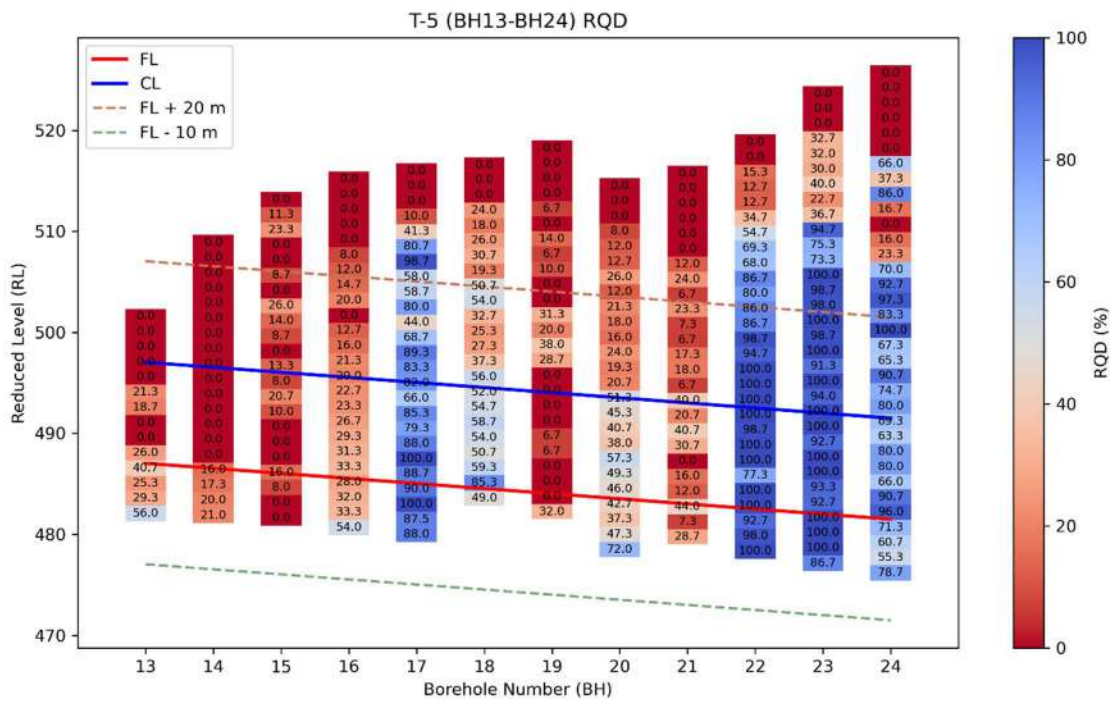
BH No.	Chainage	Mean	Std
BH32	51727	98.67	1.47
BH33	51777	99.10	1.20
BH34	51827	98.24	1.75
BH35	51877	98.80	2.03
BH36	51927	36.87	9.49
BH37	51977	50.36	9.02
BH38	52027	27.46	17.99
BH39	52077	28.73	9.36
BH40	52127	98.97	1.72
BH41	52177	72.43	13.48
BH42	52227	64.00	4.87
BH43	52277	62.24	18.02
BH44	52327	81.39	16.13
BH45	52377	76.13	27.05
BH46	52427	66.55	13.24
BH47	52477	22.00	3.86

BH No.	Chainage	Mean	Std
BH48	52527	20.45	3.90
BH49	52577	53.33	4.74
BH50	52627	41.56	10.96
BH51	52677	30.00	22.01
BH52	52727	17.10	2.46
BH53	52777	22.42	6.40
BH54	52827	38.42	4.58
BH55	52877	42.60	14.38
BH56	52927	33.64	18.32
BH57	52977	45.77	19.52
BH58	53027	36.60	12.17
BH59	53077	58.06	12.62
BH60	53127	33.11	16.54
BH61	53177	26.23	8.39

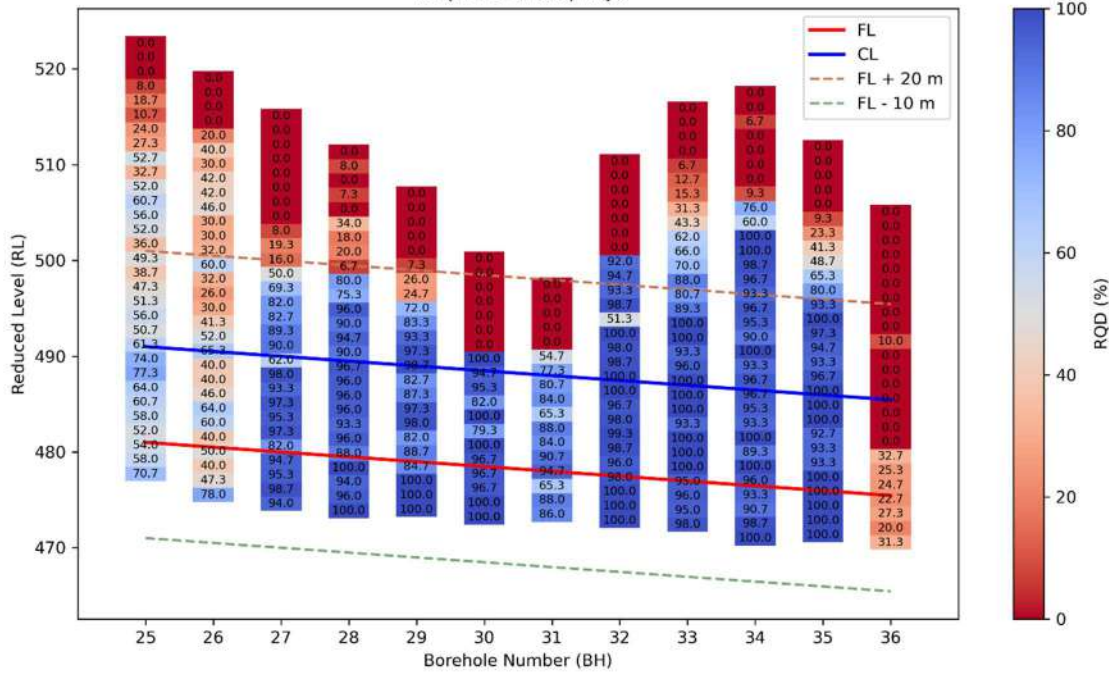
Chainage	Overall Mean	Std
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50180 to 50880	48.72347	16.67464
50880 to 51920	86.67478	20.38669
51920 to 53180 (P2)	45.64126	24.47483

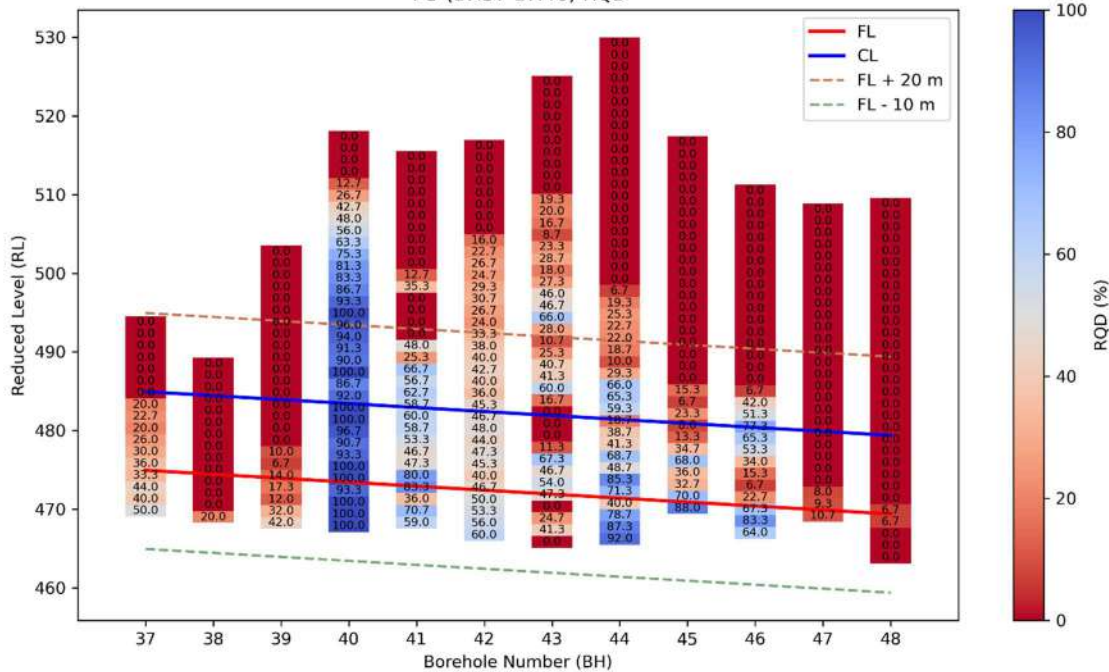
10.4.3 RQD:

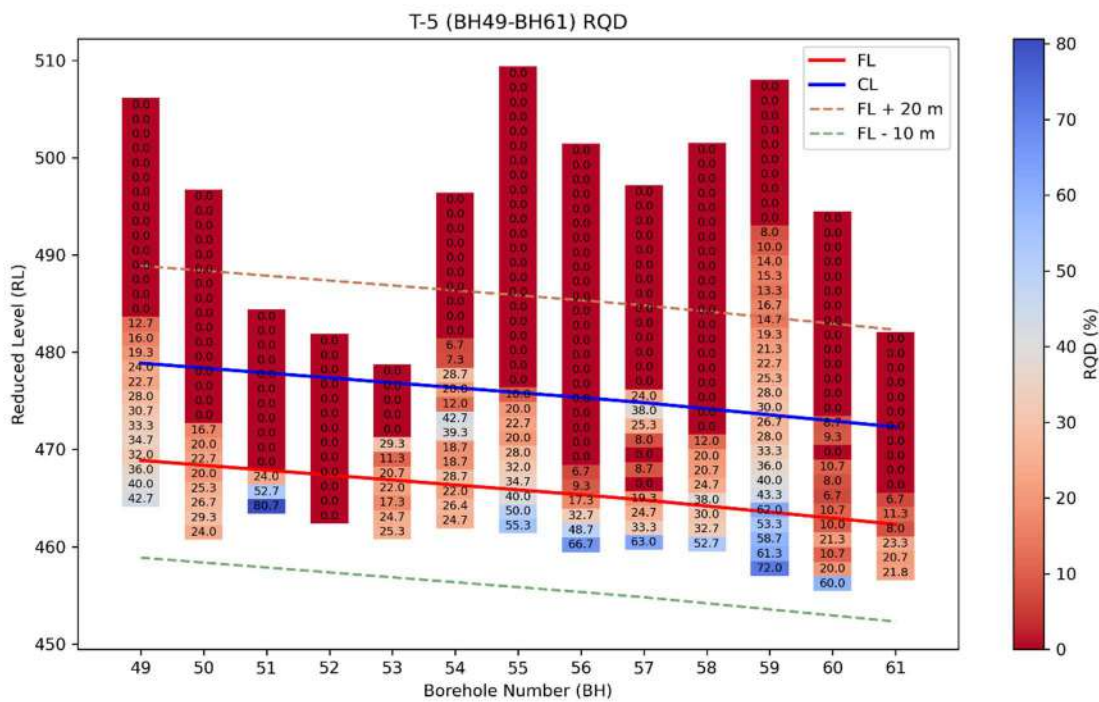


T-5 (BH25-BH36) RQD



T-5 (BH37-BH48) RQD





10.4.3.1 Mean And Standard Deviation in RQD considering 1D zone of influence in each Borehole

BH No.	Chainage	Mean	Std
BH01	50177	25.46	20.26
BH02	50227	29.07	12.80
BH03	50277	31.51	20.60
BH04	50327	29.46	8.93
BH05	50377	36.92	11.34
BH06	50427	17.73	19.56
BH07	50477	26.67	8.58

BH No.	Chainage	Mean	Std
BH08	50527	37.76	11.50
BH09	50577	44.60	17.52
BH10	50627	43.64	16.50
BH11	50677	33.70	21.08
BH12	50727	26.35	15.91
BH13	50777	21.73	18.40
BH14	50827	7.43	9.69
BH15	50877	6.27	7.59
BH16	50927	31.40	8.81
BH17	50977	86.80	9.38
BH18	51027	55.70	12.13
BH19	51077	4.53	10.04
BH20	51127	47.94	9.92
BH21	51177	21.82	16.11
BH22	51227	96.67	7.17
BH23	51277	96.53	4.82

BH No.	Chainage	Mean	Std
BH24	51327	73.76	12.60
BH25	51377	63.00	8.47
BH26	51427	50.53	12.91
BH27	51477	91.64	10.82
BH28	51527	95.64	3.26
BH29	51577	92.67	7.55
BH30	51627	94.67	7.22
BH31	51677	82.67	9.92
BH32	51727	98.67	1.47
BH33	51777	97.73	2.65
BH34	51827	95.76	3.78
BH35	51877	97.93	3.33
BH36	51927	18.40	13.23
BH37	51977	29.27	13.81
BH38	52027	1.82	6.03
BH39	52077	12.18	13.93

BH No.	Chainage	Mean	Std
BH40	52127	97.64	3.54
BH41	52177	59.50	14.97
BH42	52227	48.85	5.69
BH43	52277	26.61	25.55
BH44	52327	60.97	24.48
BH45	52377	38.07	28.23
BH46	52427	49.15	25.84
BH47	52477	2.55	4.40
BH48	52527	1.21	2.70
BH49	52577	32.40	6.41
BH50	52627	15.39	11.83
BH51	52677	15.73	28.64
BH52	52727	0.00	0.00
BH53	52777	13.70	11.78
BH54	52827	25.62	9.09
BH55	52877	31.27	14.18

BH No.	Chainage	Mean	Std
BH56	52927	16.49	23.07
BH57	52977	22.03	19.53
BH58	53027	23.07	16.48
BH59	53077	46.79	15.41
BH60	53127	14.67	15.33
BH61	53177	9.18	9.66

10.4.3.2 Recommended RQD considering 1D zone of influence:

Chainage	Statistical / Reduction Method	Recommended Design Value	Reference Standards / Guidelines
	(Average across boreholes within ± 10 m of FL and CL)	($RQD_d = \mu - \sigma$)	
50180 to 50880	28.27	10.04	IS 11315:1985; Deere (1963)
50880 to 51920	73.98	44.41	
51920 to 53180 (P2)	27.40	0.35	

10.5 Petrographic Assessments:

10.5.1 Description of Rock Masses

10.5.1.1 *Khondalite*

Typical khondalite assemblages in the EGMB are described as quartz–feldspar–garnet–sillimanite ± biotite gneisses, with quartz + feldspar together forming ~40–60 %, garnet ~20–30 %, and sillimanite + biotite ~10–20 % of the rock.

10.5.1.2 *Migmatite*

Migmatites of the Eastern Ghats consist of quartz- and feldspar-rich leucosome with garnet- and biotite-bearing melanosome/restite. Petrographic and modal descriptions are consistent with dominant quartz + feldspar (~60–70 %) and subordinate garnet and biotite.

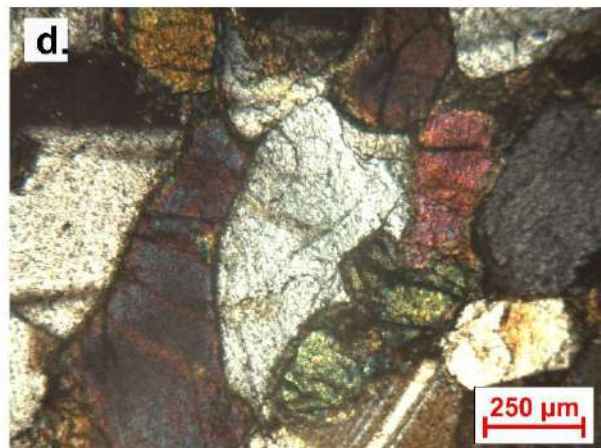
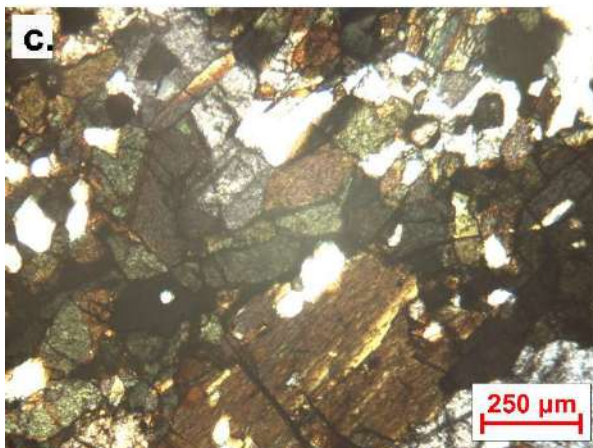
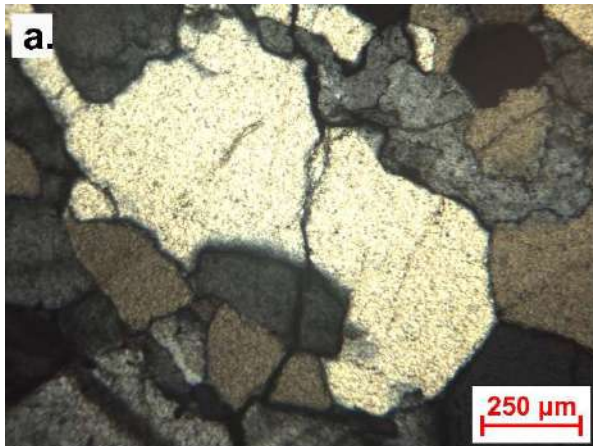
10.5.1.3 *Khondalite (Restite)*

Restites represent refractory residues after partial melting of metapelites, enriched in garnet and ferromagnesian minerals and depleted in felsic phases. Modal characteristics inferred from petrographic descriptions of residual granulites and restitic layers in the EGMB.

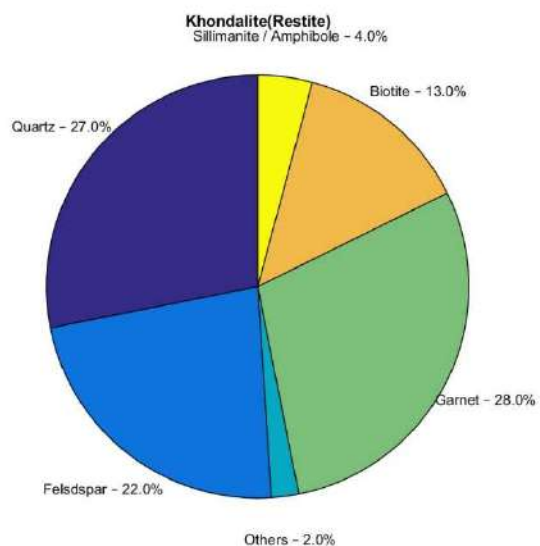
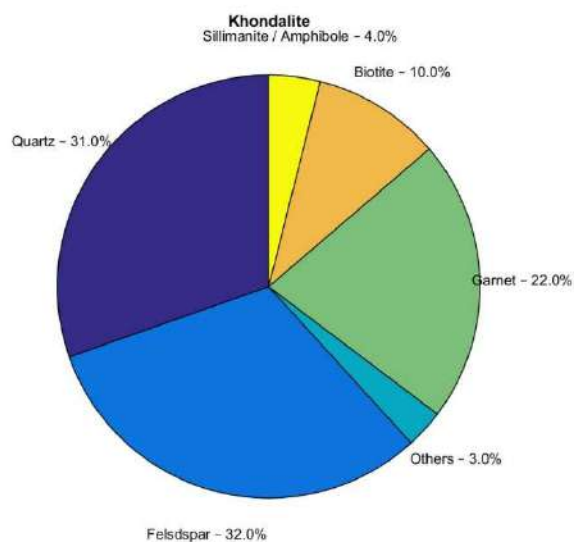
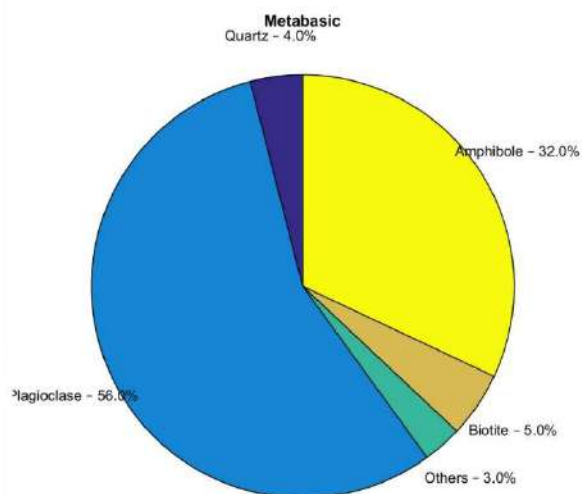
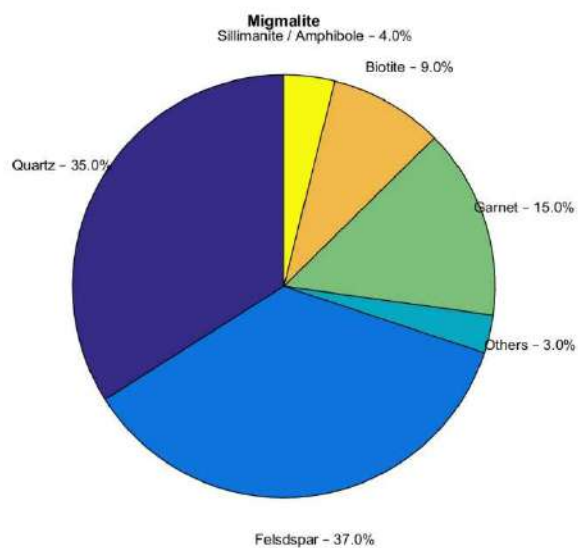
10.5.1.4 *Meta basic rock*

Metamorphosed doleritic rocks typically comprise plagioclase + amphibole as dominant phases, with minor quartz and accessory oxides. Modal proportions are consistent with amphibolite-facies metadolerites described from Indian Proterozoic terrains by Nanda et al. (2018) and comparable petrographic descriptions in Yellappa et al. (2019).

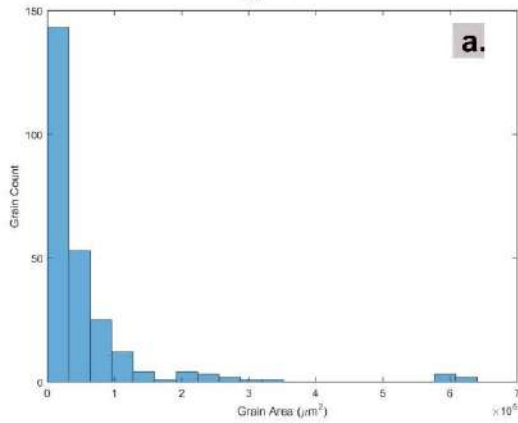
10.5.2 Micro Photographs



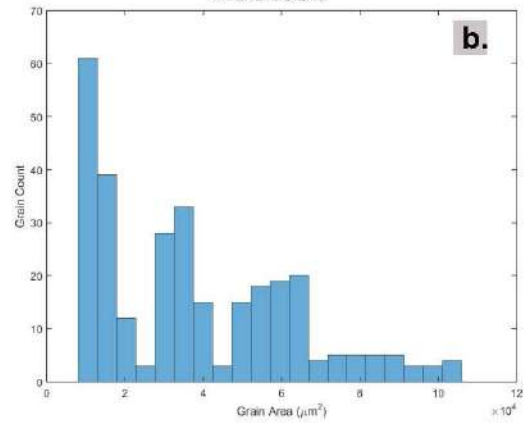
10.5.3 Mineral percentage and grain size distribution



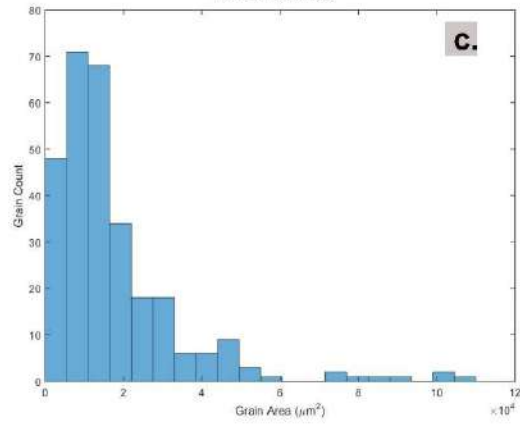
Migmatite



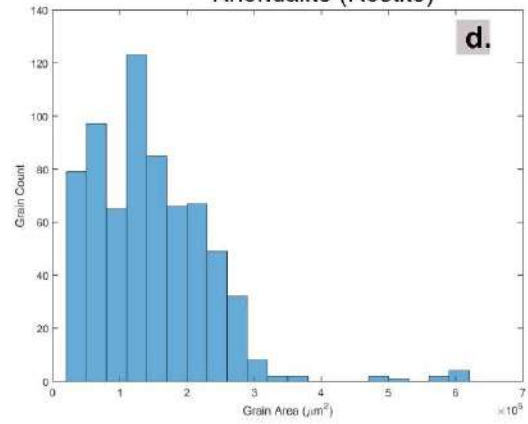
Metabasic



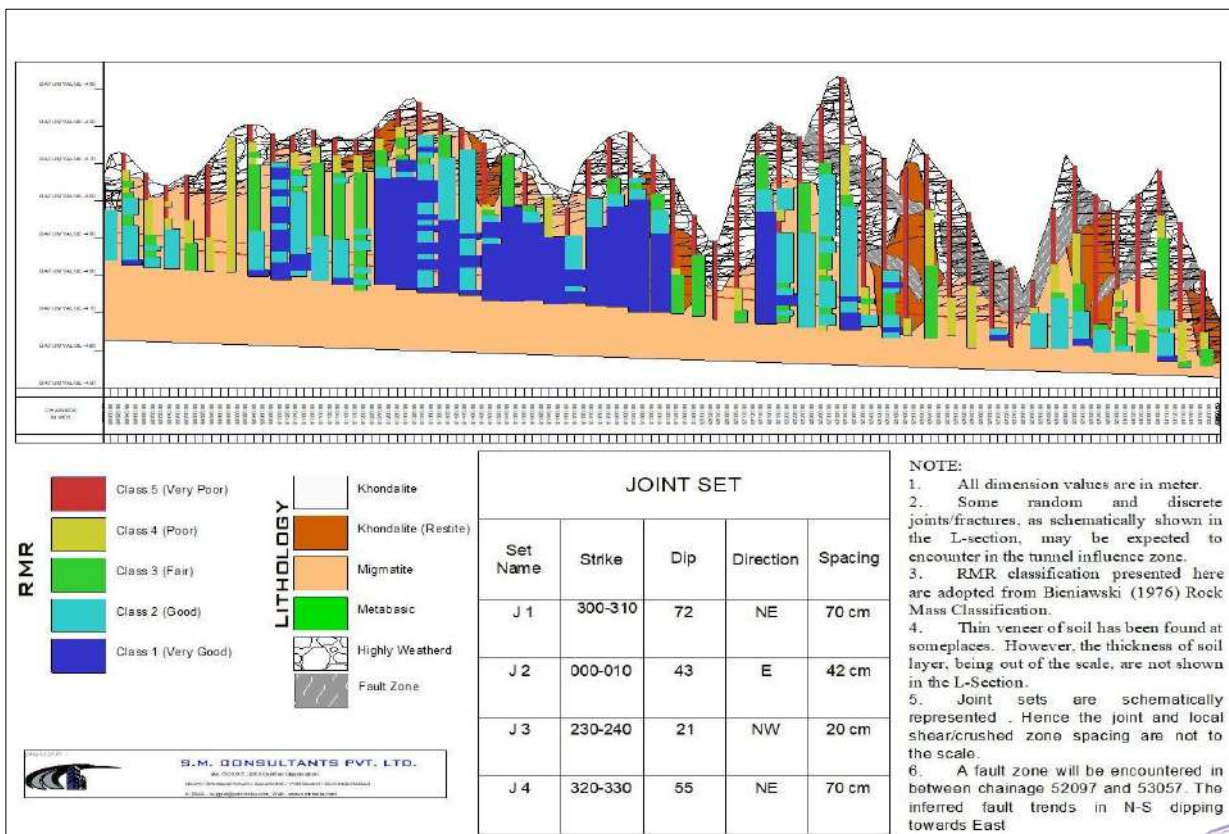
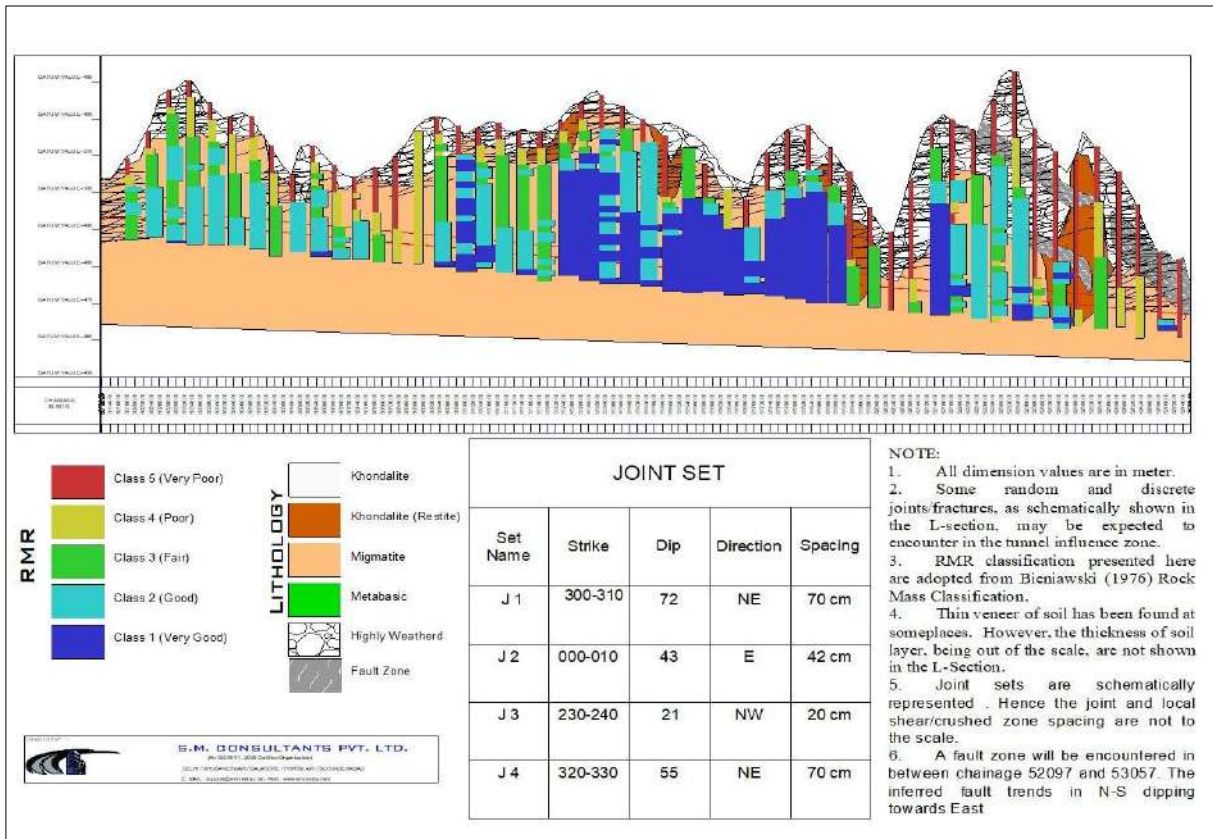
Khondalite



Khondalite (Restite)



10.6L section:



11 TUNNEL 6: GEOLOGICAL & GEOTECHNICAL ASSESMENT

11.1 Exploratory drillings

As per the requirement of scope of work outlined in the terms of reference, 36 bore holes were drilled with a cumulative length of 2493m at different locations along the proposed alignment. Necessary care has been taken during drilling operations by deploying good quality diamond drill machines to obtain good core recovery to obtain RQD values. The locations of the boreholes were selected in such a way, so that these holes intersect the envisaged ground/strata conditions at different depths. The location and details of boreholes drilled; total depth of drillings is shown in table below.

Chainage	BH	GL	FL	Depth
57503	BH-1	425.222	413.529	16.30
57553	BH-2	431.306	412.914	24.00
57603	BH-3	431.472	412.289	24.60
57653	BH-4	433.602	411.664	27.00
57703	BH-5	440.942	411.039	44.00
57753	BH-6	443.747	410.414	38.00
57803	BH-7	441.875	409.789	37.00
57853	BH-8	446.658	409.164	43.00
57903	BH-9	457.372	408.539	54.00
57953	BH-10	464.618	407.914	61.50
58003	BH-11	467.045	407.289	64.50
58053	BH-12	469.335	406.664	68.00
58103	BH-13	469.044	406.039	72.00
58153	BH-14	474.055	405.414	74.00
58203	BH-15	479.102	404.789	79.00
58253	BH-16	482.4	404.164	83.00
58303	BH-17	485.255	403.539	87.00
58353	BH-18	494.002	402.983	98.00
58403	BH-19	498.07	402.462	100.50
58453	BH-20	500.201	401.941	105.00
58503	BH-21	502.372	401.42	106.00
58553	BH-22	513.658	400.899	118.00
58603	BH-23	508.994	400.379	113.00
58653	BH-24	496.544	399.858	102.00
58703	BH-25	485.622	399.337	92.00
58753	BH-26	478.985	398.816	85.00

Chainage	BH	GL	FL	Depth
58803	BH-27	474.905	398.295	81.00
58853	BH-28	477.261	397.774	84.00
58903	BH-29	479.32	397.248	87.00
58953	BH-30	473.709	396.623	82.00
59003	BH-31	468.31	395.998	78.00
59053	BH-32	463.367	395.373	73.50
59103	BH-33	457.062	394.748	67.50
59153	BH-34	446.111	394.123	57.00
59203	BH-35	430.389	393.498	42.00
59253	BH-36	411.54	392.873	24.00

11.2 TUNNEL-6 SRT

11.2.1 Location:

Sr. No.	Chainage	Line	Spread	Location (T-06)		Length
				Start	End	In meter
1	57.503km to 59.253km	L1	S1 to S15	57.503km	59.253km	1750

11.2.2 Seismic survey results and conclusion

Table 11.1: Summary of Tunnel-1 SRT test

Variation of maximum range of thicknesses below EGL (M)			Avg. V_p (m/sec)	Calculated V_s (m/sec)	Dynamic Young's Modulus (MPa)	Shear Modulus (MPa)
Layer	From	To				
Layer-IA	0.50	6.00	500	227	212	77
Layer-IB			700	327	466	172
Layer-IIA	6.00	12.00	1700	837	3755	1401
Layer-IIB			2300	1183	8133	3081
Layer-III	12.00	25.00	3400	1879	21702	8477

Sample Calculation:

The Young's Modulus E is the uni-axial stress-strain ratio. Its dynamic value is expressed by the following equation:

$$E = \frac{\rho V_p^2 (1 + \mu)(1 - 2\mu)}{1 - \mu}$$

Where, E = Dynamic Young's Modulus in kN/m²

$$V_p = 700 \text{ m/sec}$$

$$\rho = 1.6 \text{ gm/cc} \approx 1.60 \text{ kN.s}^2/\text{m}^4 \text{ (mass density)}$$

$$\mu = 0.36$$

So, calculated E = 466480 kN/sqm \approx 466 MPa

The Shear Modulus G is the stress-strain ratio for simple shear. Its dynamic value is obtained by the following:

$$G = \frac{E}{2(1 + \mu)} = \rho V_s^2$$

So, Shear Modulus G comes out to be 171500 kN/sqm \approx 172 MPa

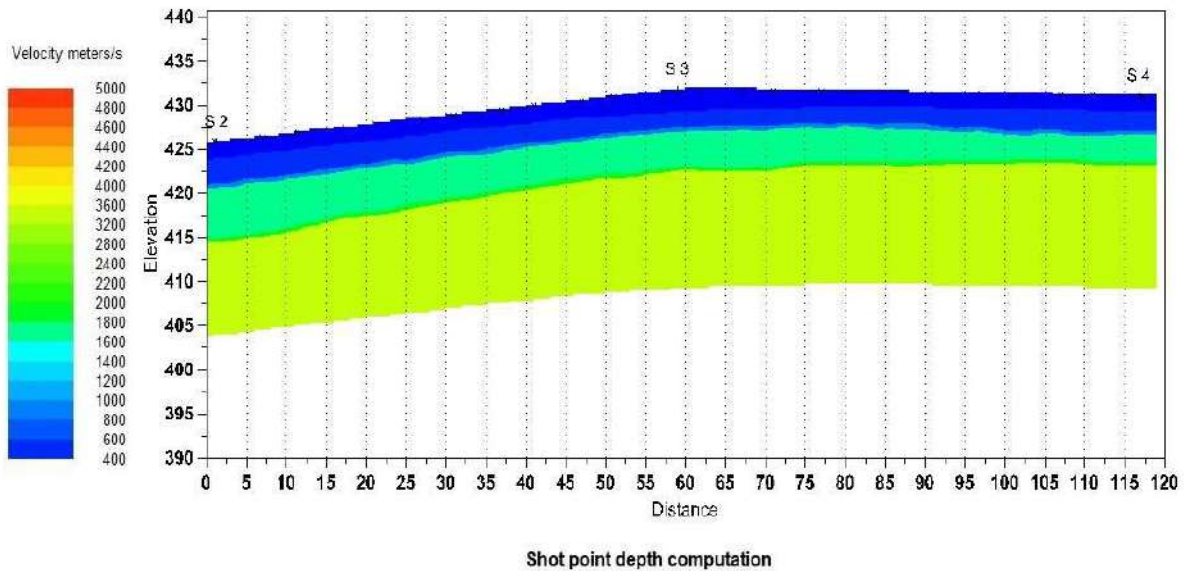
Again,

$$G = \rho V_s^2 \text{ giving } V_s = \sqrt{(G/\rho)}$$

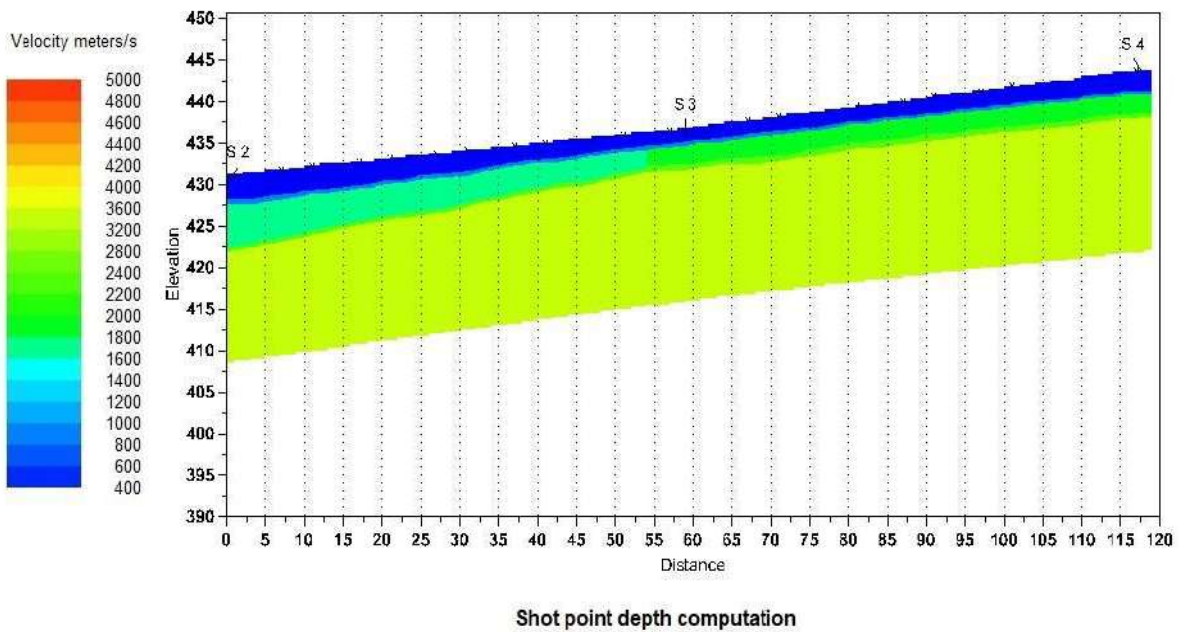
So, calculated V_s = 327.395 m/sec, say 327 m/sec

SEISMIC PROFILE(T06)

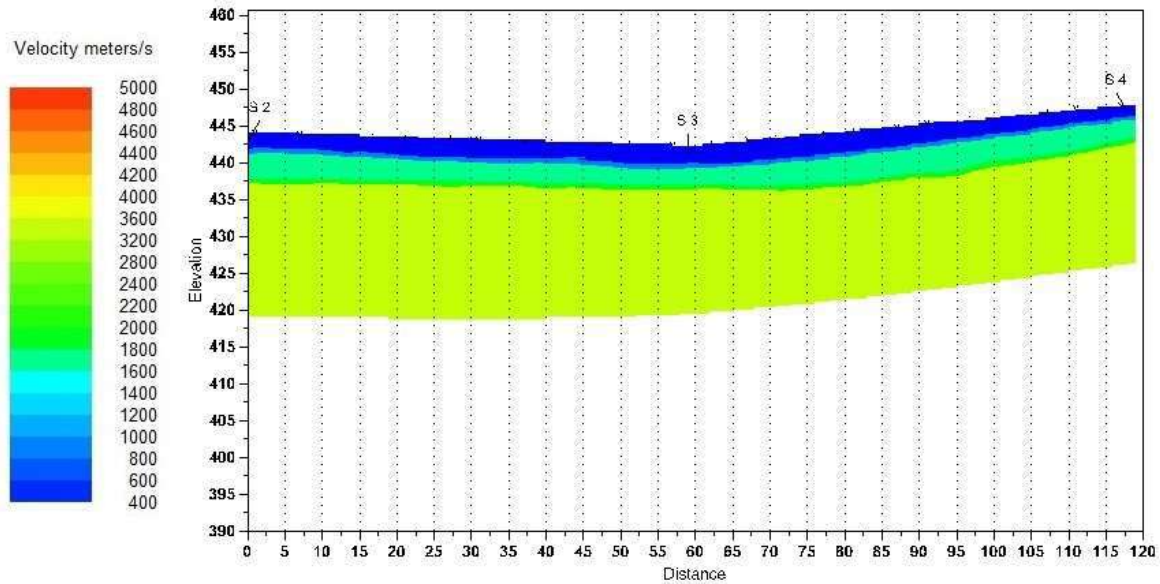
T6L1S1



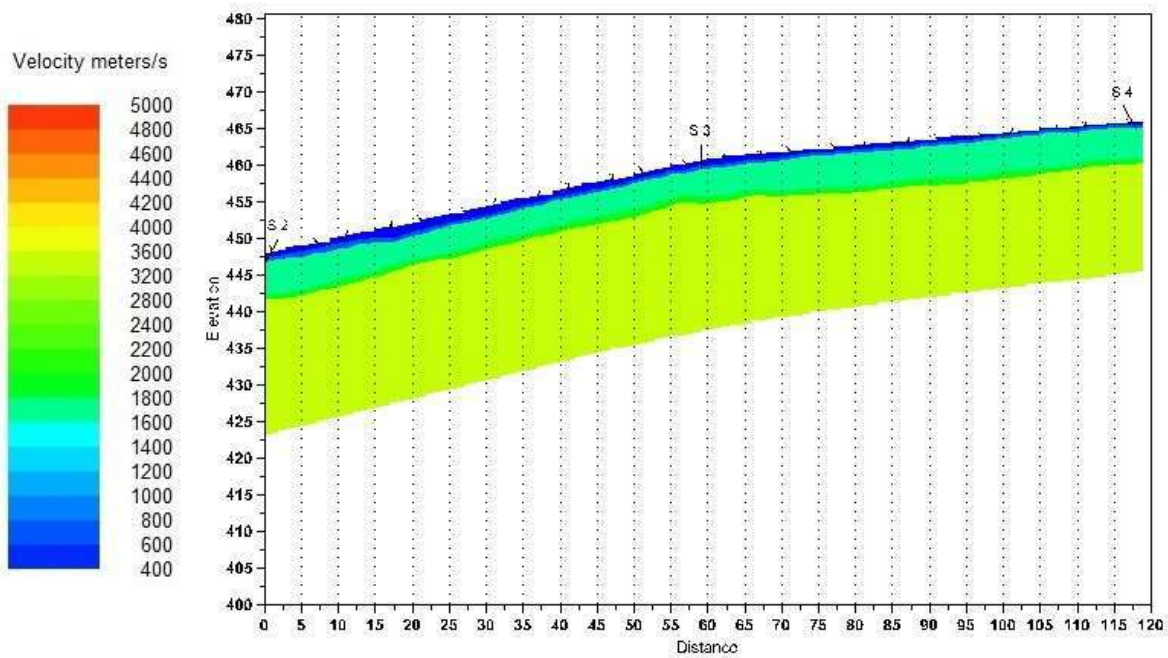
T6L1S2



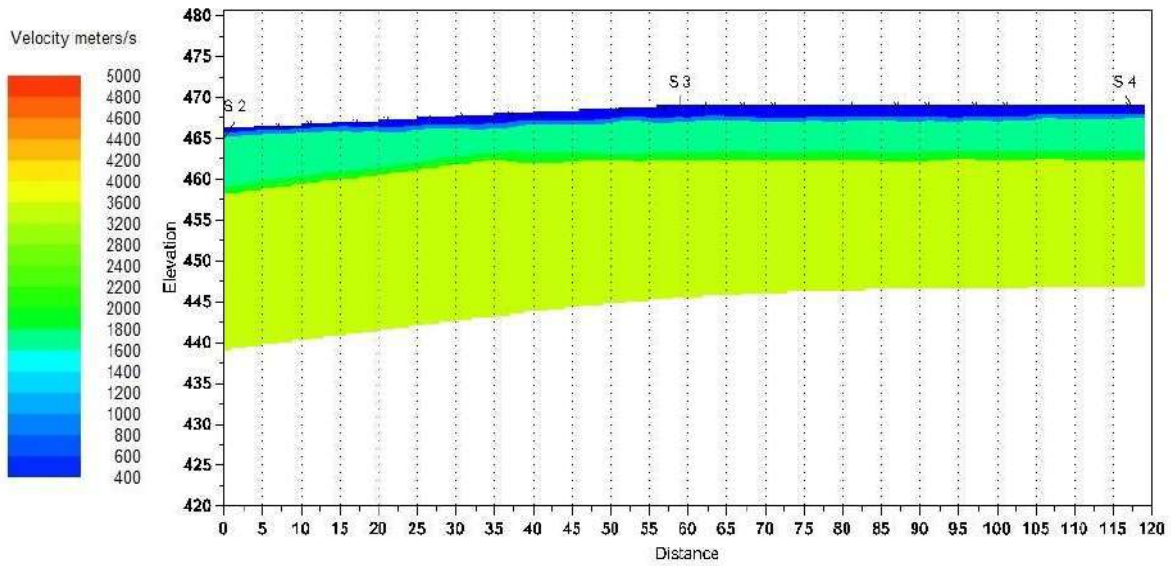
T6L1S3



T6L1S4

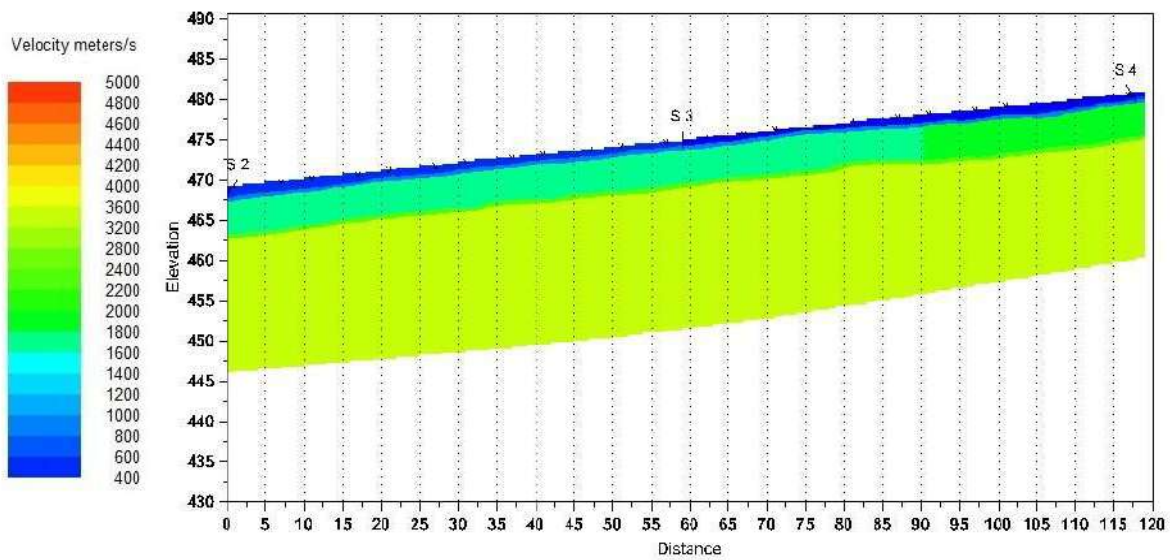


T6L1S5



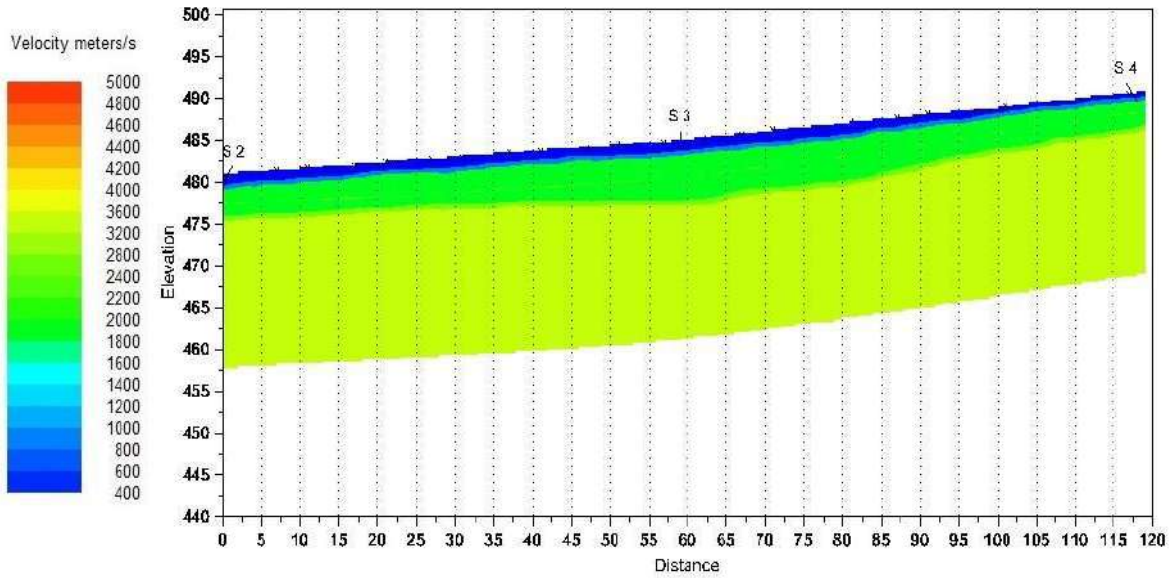
Shot point depth computation

T6L1S6



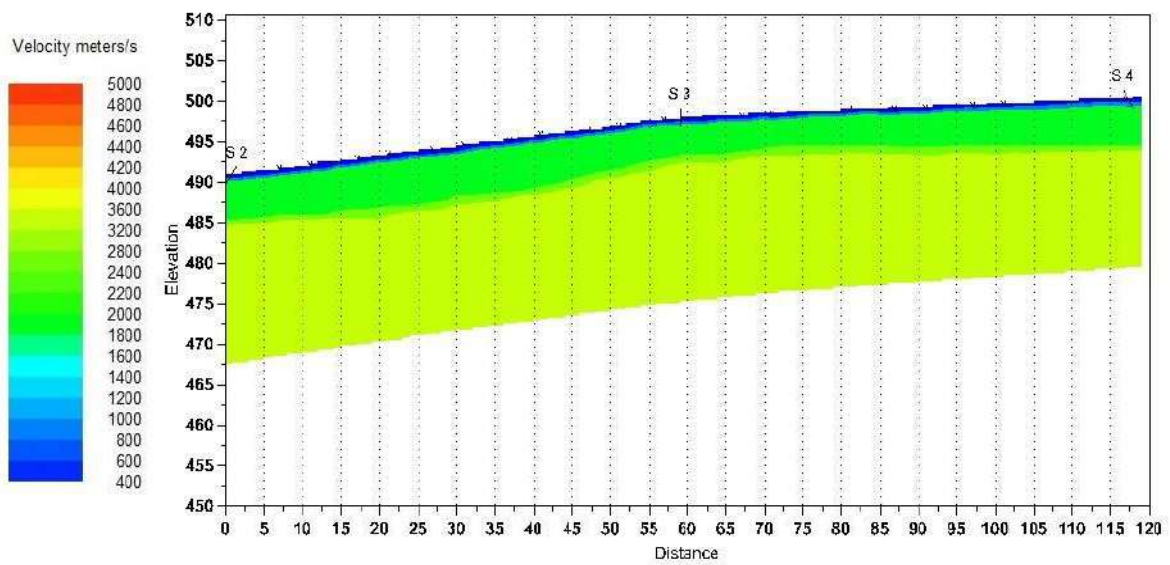
Shot point depth computation

T6L1S7



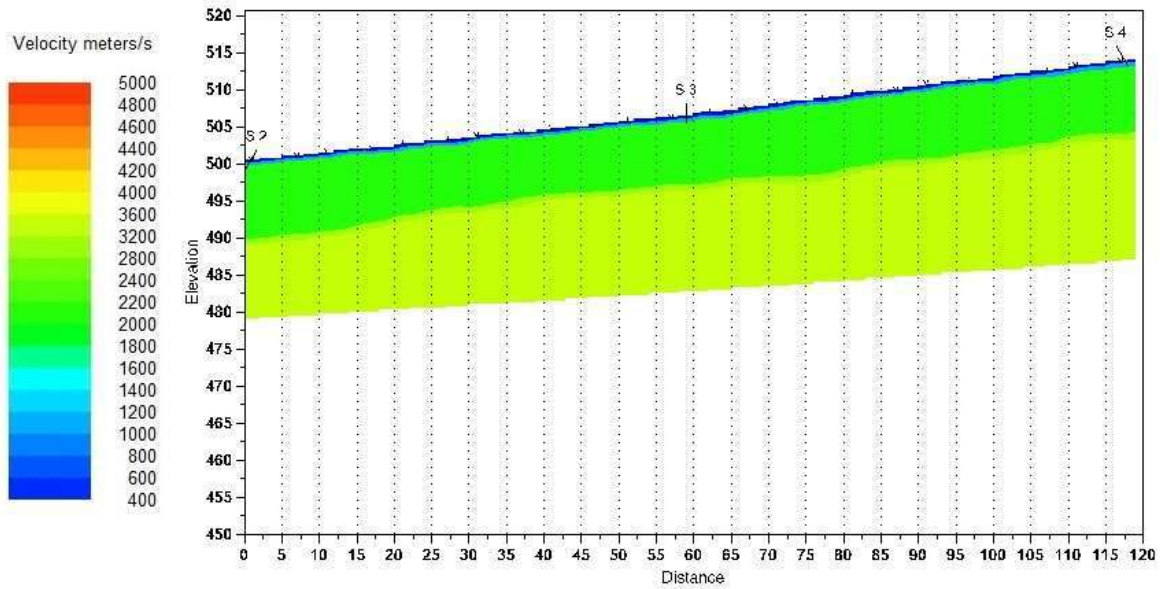
Shot point depth computation

T6L1S8



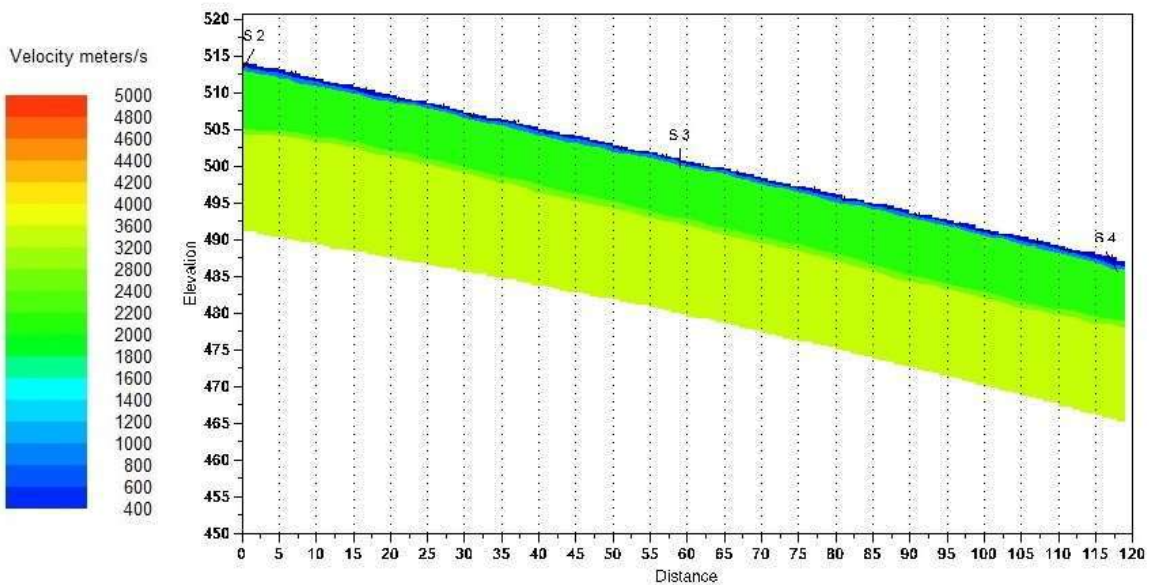
Shot point depth computation

T6L1S9



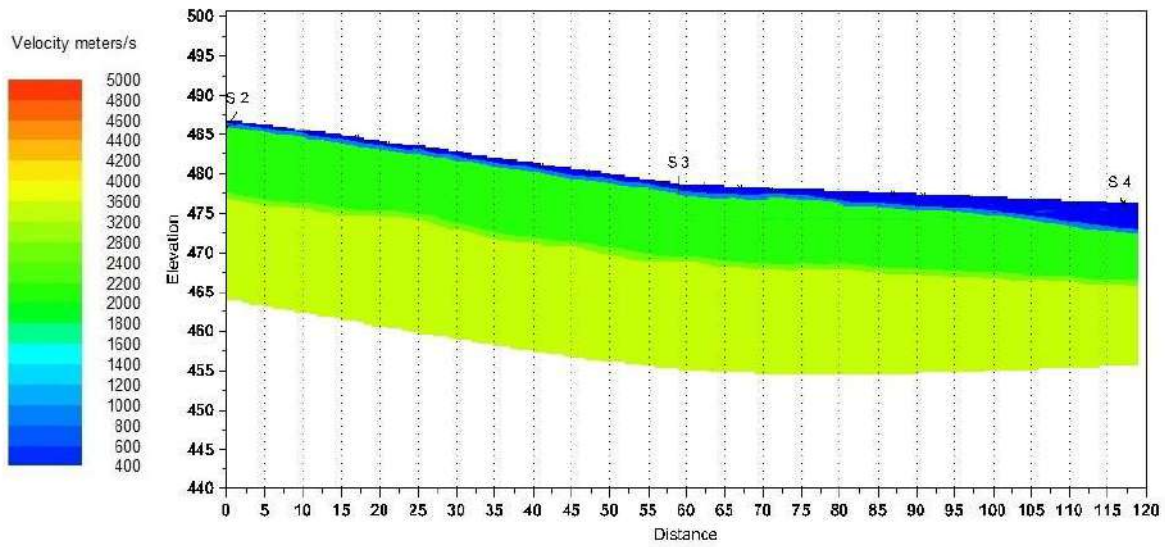
Shot point depth computation

T6L1S10

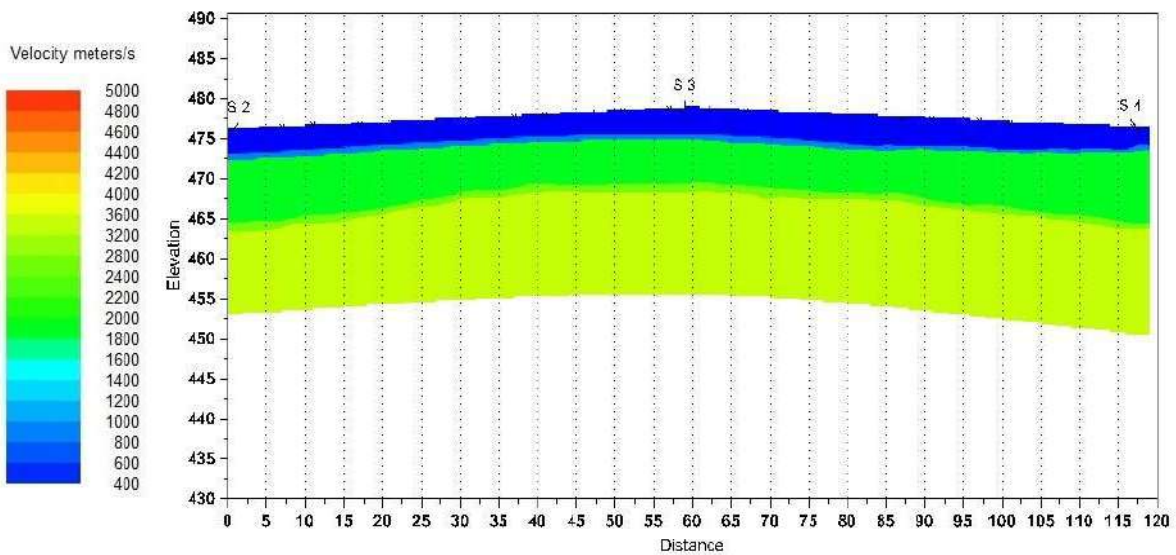


Shot point depth computation

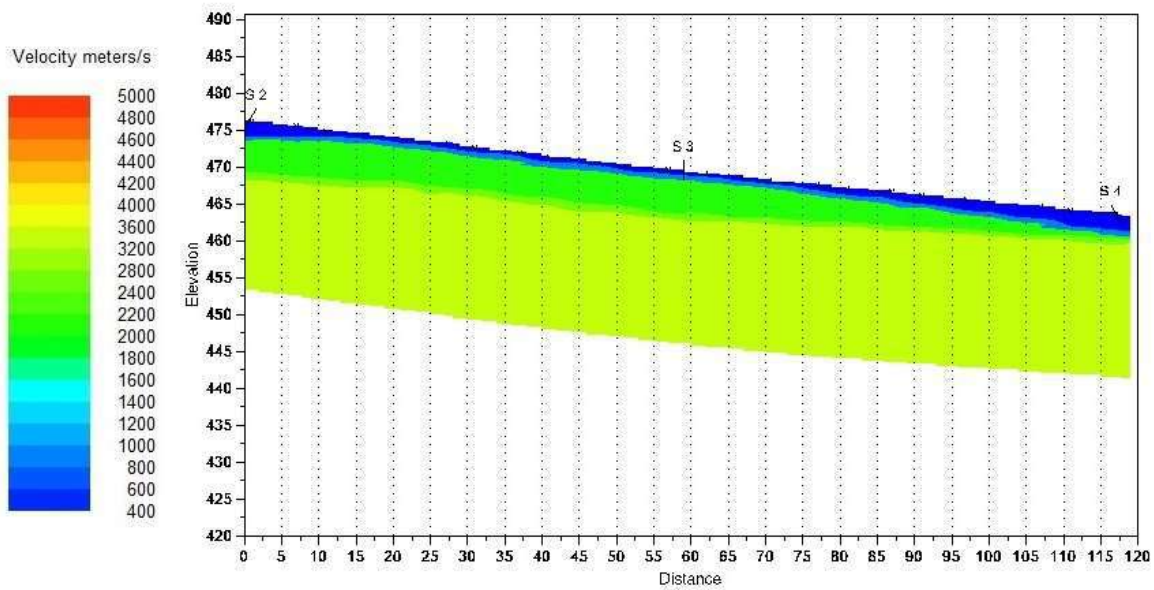
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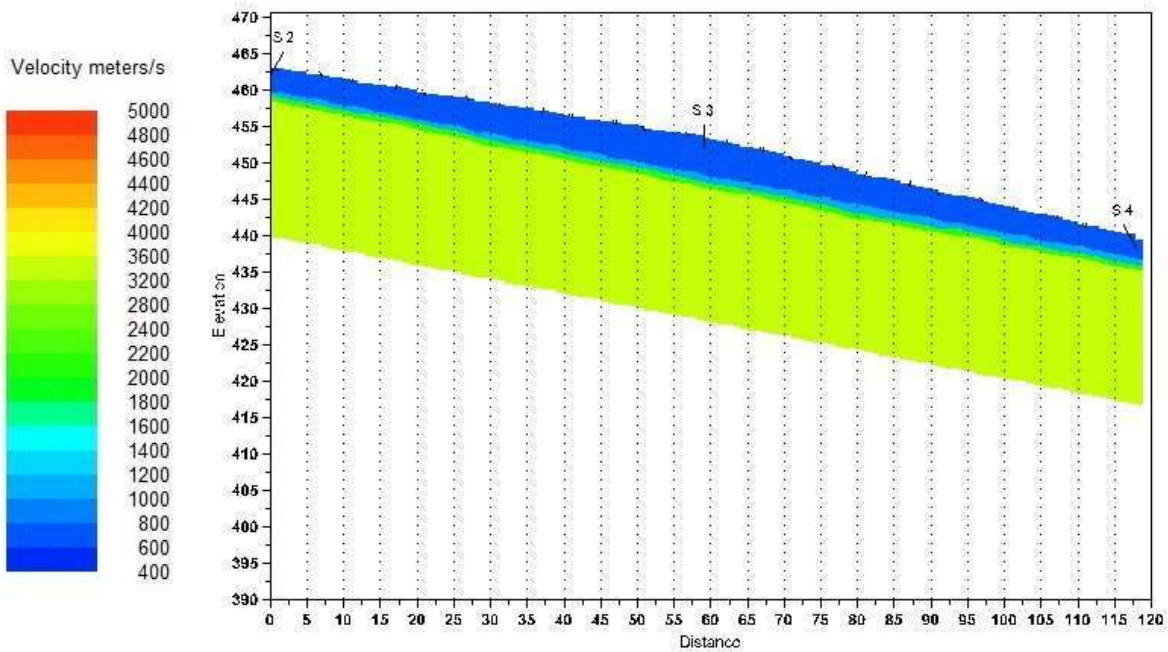
T6L1S12



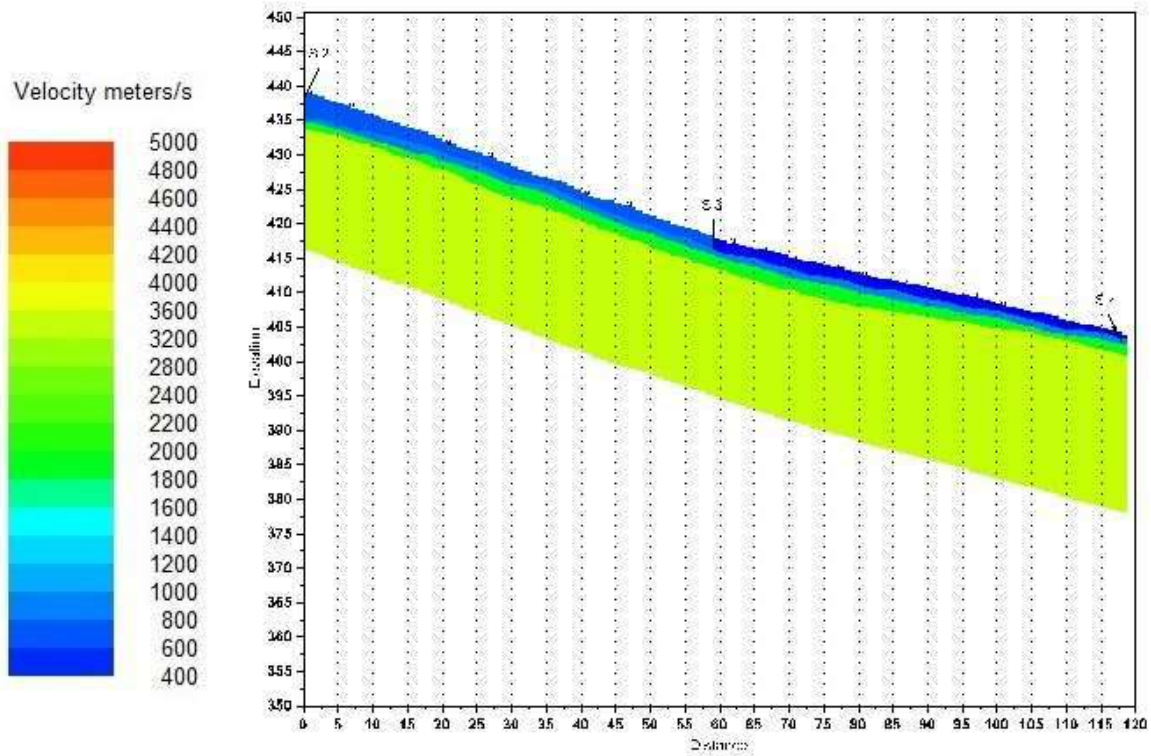
T6L1S13



T6L1S14



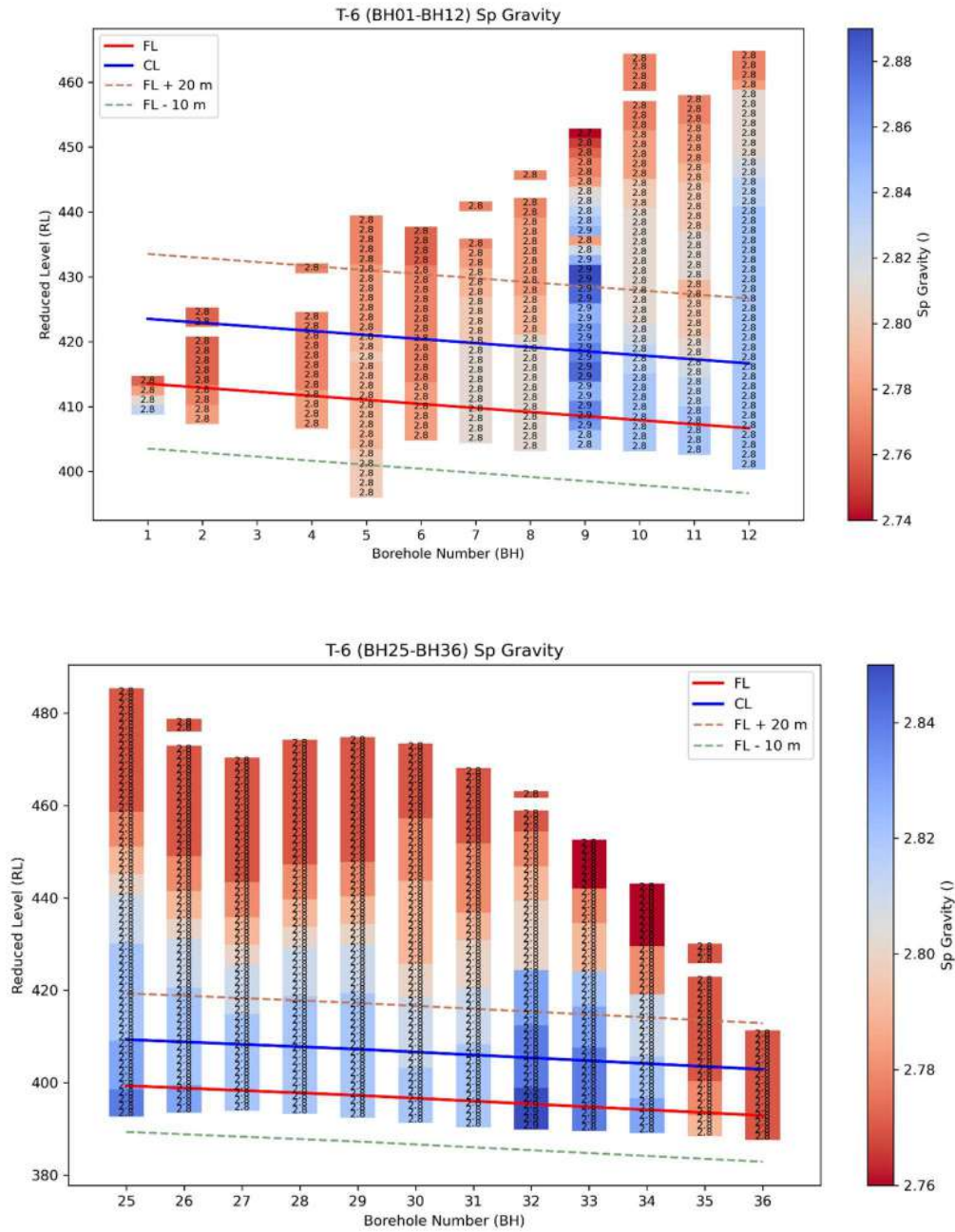
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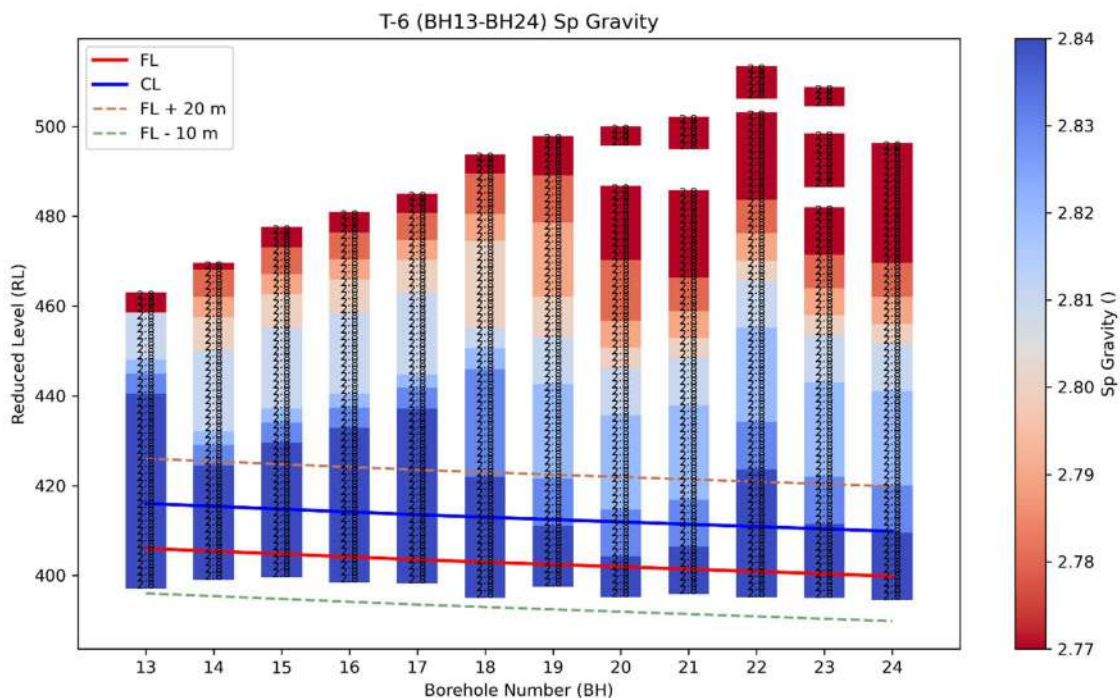


Shot point depth computation

11.3 Assessment of the engineering properties of rock sample:

11.3.1 Specific Gravity





11.3.1.1 Mean and Standard deviation Specific Gravity considering 1D zone of influence of each borehole:

BH No	Chainage	Mean	Std
BH01	57503	2.80	0.031
BH02	57553	2.77	0.009
BH04	57653	2.77	0.005
BH05	57703	2.79	0.004
BH06	57753	2.78	0.005
BH07	57803	2.81	0.000

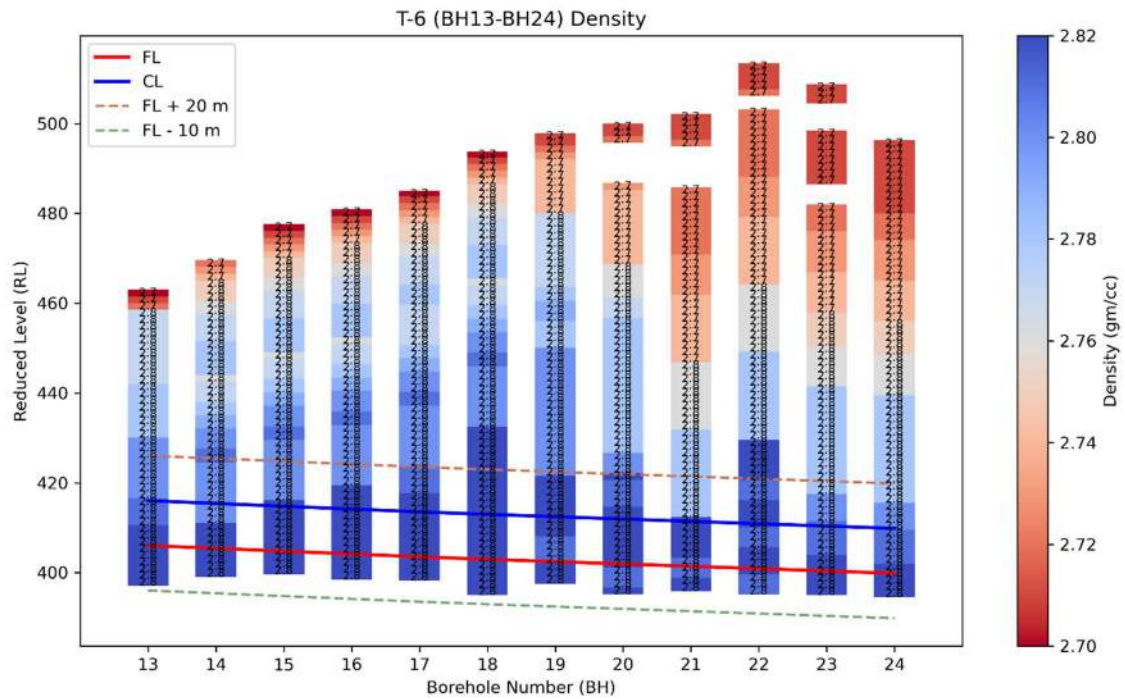
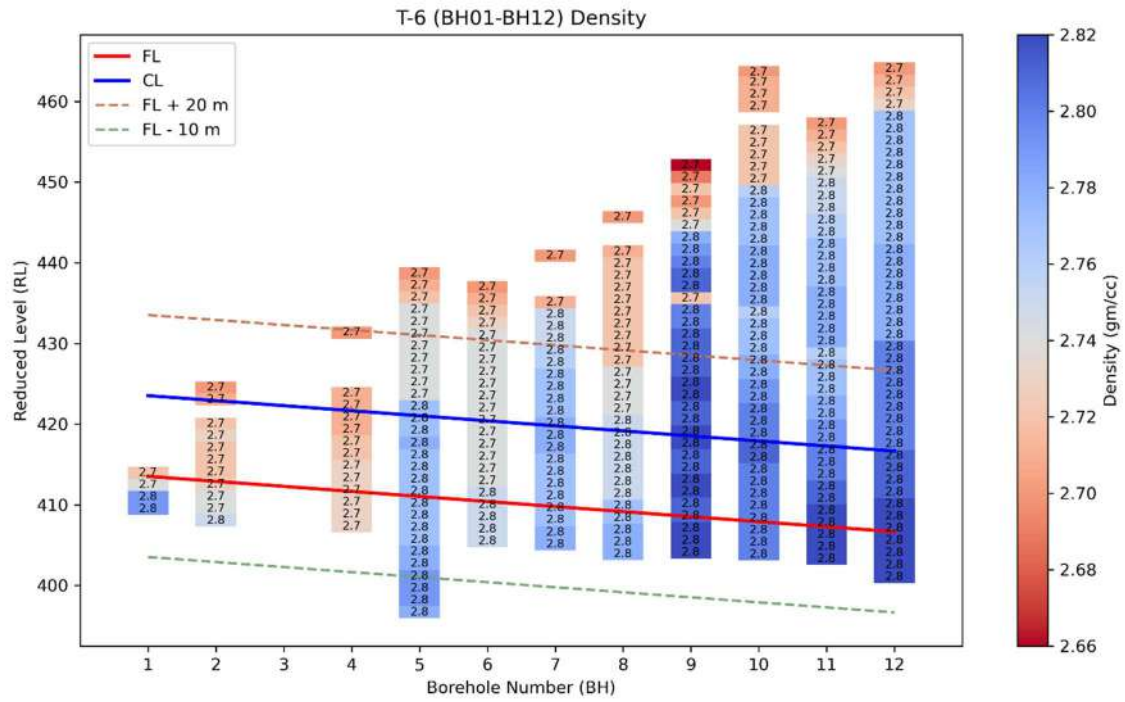
BH No	Chainage	Mean	Std
BH08	57853	2.81	0.000
BH09	57903	2.86	0.015
BH10	57953	2.84	0.004
BH11	58003	2.83	0.008
BH12	58053	2.84	0.000
BH13	58103	2.84	0.000
BH14	58153	2.84	0.000
BH15	58203	2.84	0.000
BH16	58253	2.84	0.000
BH17	58303	2.84	0.000
BH18	58353	2.84	0.000
BH19	58403	2.84	0.003
BH20	58453	2.84	0.005
BH21	58503	2.84	0.005
BH22	58553	2.84	0.000
BH23	58603	2.84	0.000

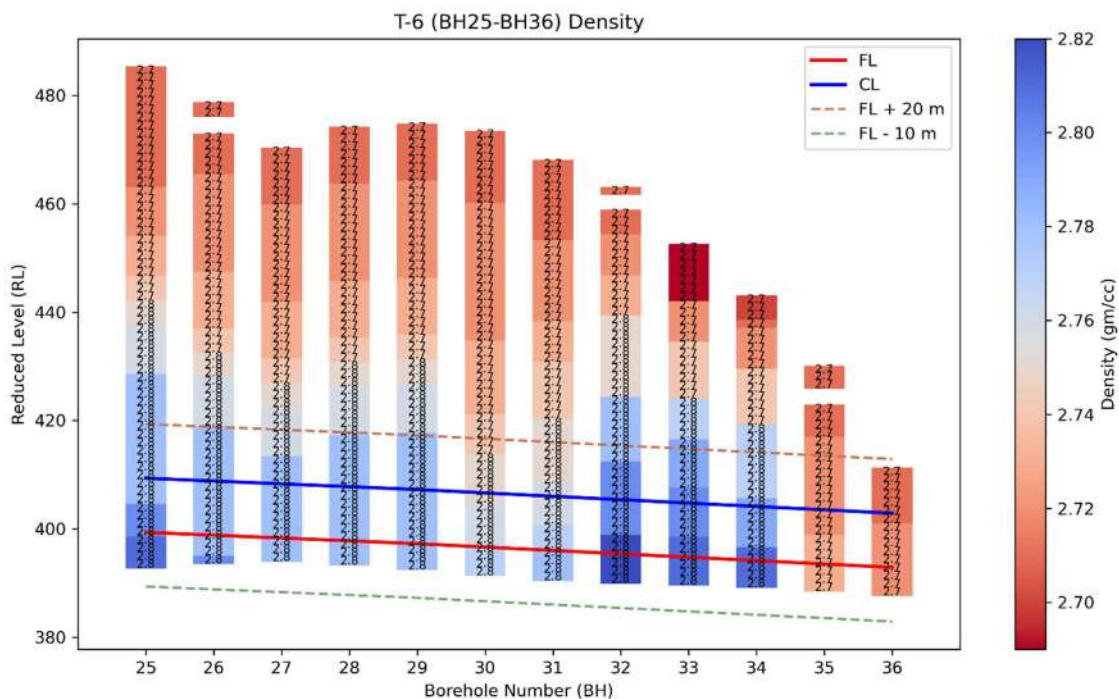
BH No	Chainage	Mean	Std
BH24	58653	2.84	0.000
BH25	58703	2.83	0.005
BH26	58753	2.82	0.005
BH27	58803	2.82	0.000
BH28	58853	2.82	0.000
BH29	58903	2.82	0.000
BH30	58953	2.82	0.004
BH31	59003	2.82	0.000
BH32	59053	2.85	0.005
BH33	59103	2.84	0.000
BH34	59153	2.83	0.005
BH35	59203	2.78	0.007
BH36	59253	2.77	0.000

11.3.1.2 Recommended Specific Gravity considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($S_p = \mu - \sigma$ across boreholes within ± 10 m of FL and CL)	Reference Standards / Guidelines
57500 to 57900	2.77	IS 13030:1991; IS 1124:1974
57900 to 59260	2.81	

11.3.2 Dry Density





11.3.2.1 Mean and Standard Deviation in Density considering 1D zone of influence of each borehole:

BH No	Chainage	Mean	Std
BH01	57503	2.76	0.036
BH02	57553	2.73	0.011
BH04	57653	2.72	0.008
BH05	57703	2.77	0.006
BH06	57753	2.75	0.005
BH07	57803	2.77	0.005
BH08	57853	2.76	0.014
BH09	57903	2.82	0.005

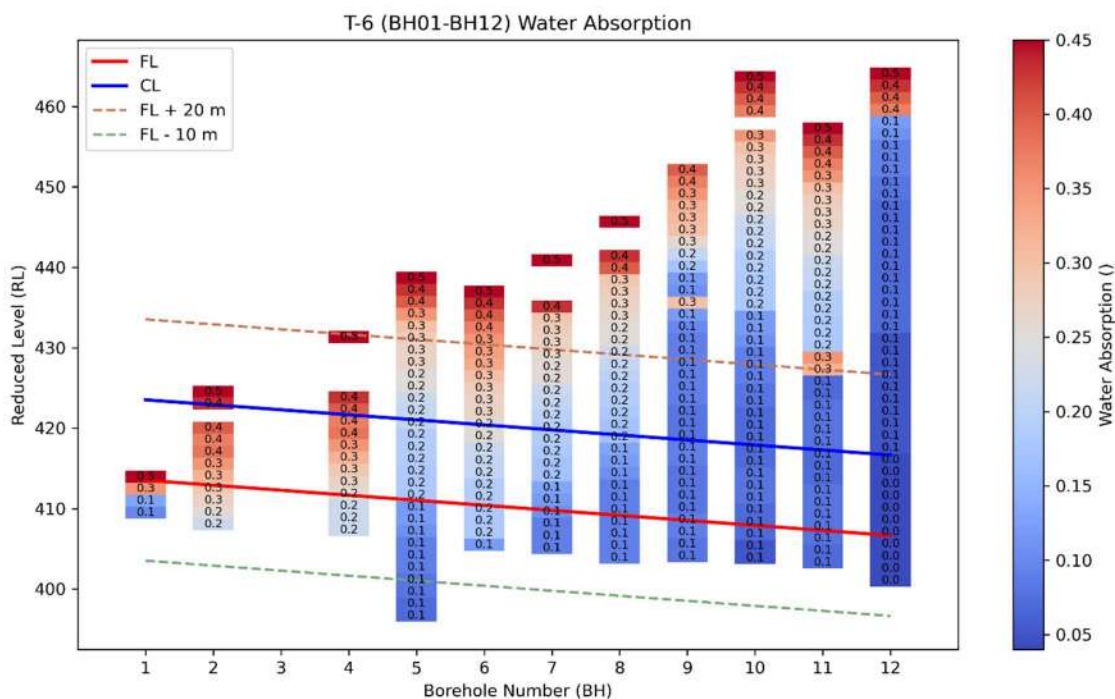
BH No	Chainage	Mean	Std
BH10	57953	2.80	0.004
BH11	58003	2.81	0.009
BH12	58053	2.82	0.005
BH13	58103	2.82	0.005
BH14	58153	2.81	0.009
BH15	58203	2.82	0.000
BH16	58253	2.82	0.000
BH17	58303	2.82	0.000
BH18	58353	2.82	0.000
BH19	58403	2.82	0.005
BH20	58453	2.82	0.005
BH21	58503	2.82	0.005
BH22	58553	2.81	0.005
BH23	58603	2.82	0.005
BH24	58653	2.82	0.005
BH25	58703	2.80	0.013

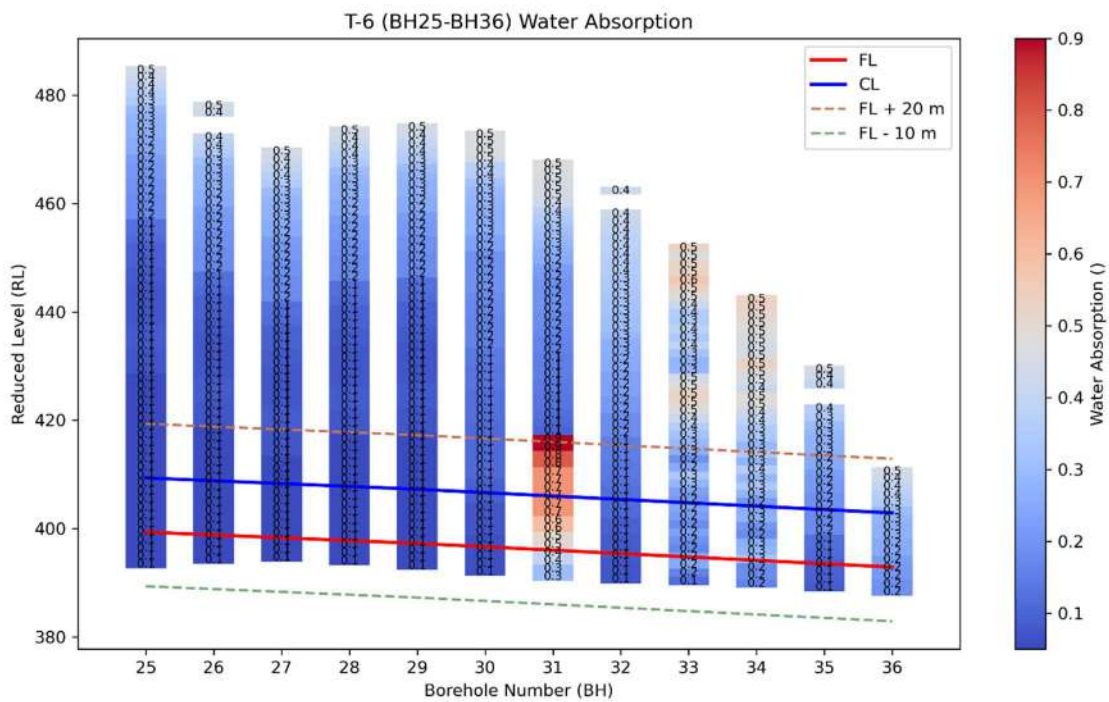
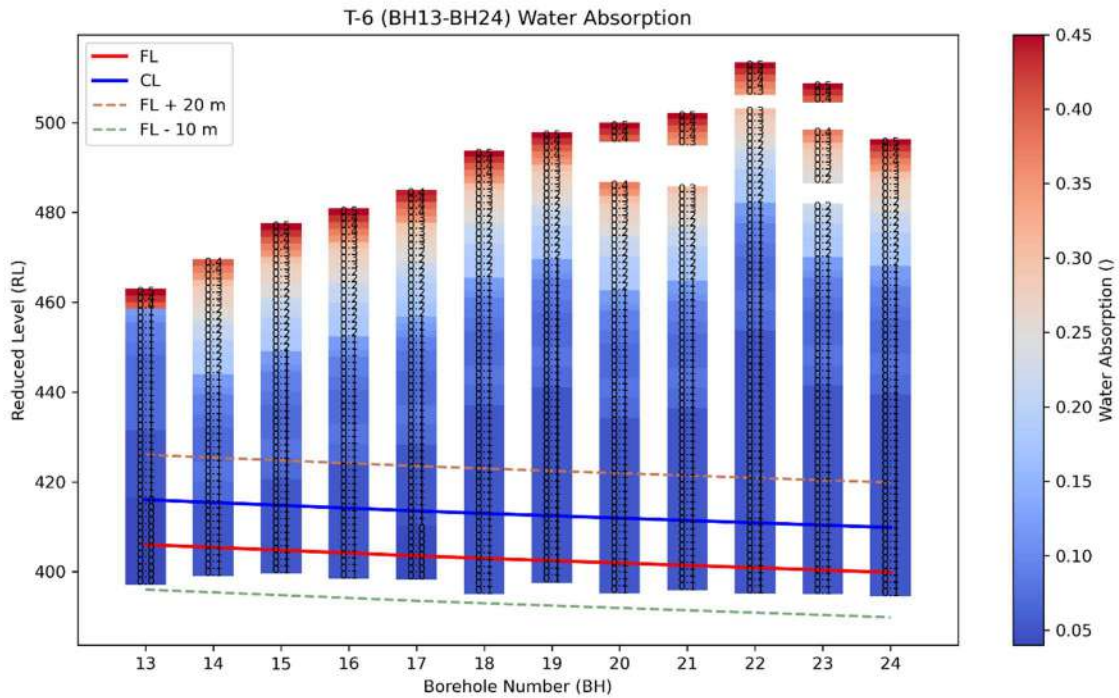
BH No	Chainage	Mean	Std
BH26	58753	2.78	0.006
BH27	58803	2.78	0.000
BH28	58853	2.78	0.000
BH29	58903	2.78	0.000
BH30	58953	2.76	0.007
BH31	59003	2.77	0.009
BH32	59053	2.81	0.010
BH33	59103	2.81	0.005
BH34	59153	2.80	0.011
BH35	59203	2.73	0.005
BH36	59253	2.72	0.003

11.3.2.2 Recommended Density considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($d = \mu - \sigma$ across boreholes within ± 10 m of FL and CL)	Reference Standards / Guidelines
57500 to 57900	2.73	IS 13063:1991
57900 to 59260	2.77	

11.3.3 Water absorption Test





11.3.3.1 Mean and Standard Deviation in Water Absorption Value considering 1D zone of influence:

BH No	Chainage	Mean	Std
BH01	57503	0.258	0.170
BH02	57553	0.317	0.063
BH04	57653	0.289	0.063
BH05	57703	0.144	0.048
BH06	57753	0.193	0.034
BH07	57803	0.134	0.040
BH08	57853	0.105	0.026
BH09	57903	0.084	0.005
BH10	57953	0.069	0.011
BH11	58003	0.075	0.005
BH12	58053	0.040	0.000
BH13	58103	0.040	0.000
BH14	58153	0.050	0.000
BH15	58203	0.050	0.000
BH16	58253	0.050	0.000

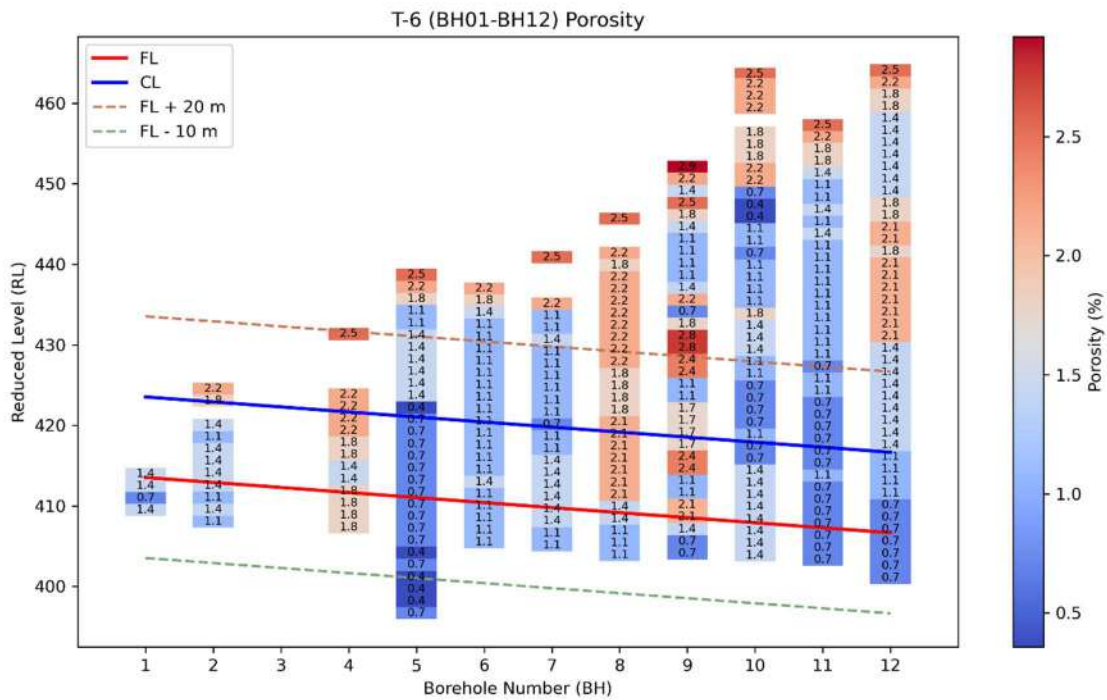
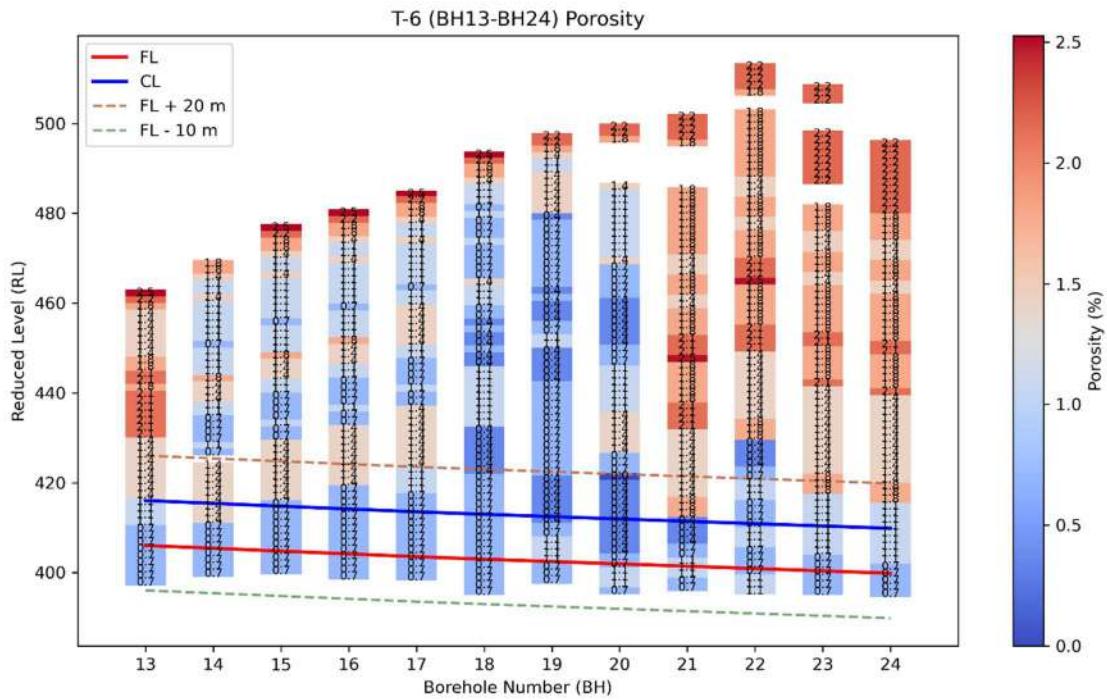
BH No	Chainage	Mean	Std
BH17	58303	0.042	0.004
BH18	58353	0.050	0.000
BH19	58403	0.050	0.000
BH20	58453	0.050	0.000
BH21	58503	0.050	0.000
BH22	58553	0.050	0.000
BH23	58603	0.050	0.000
BH24	58653	0.050	0.000
BH25	58703	0.050	0.000
BH26	58753	0.050	0.000
BH27	58803	0.050	0.000
BH28	58853	0.050	0.000
BH29	58903	0.050	0.000
BH30	58953	0.067	0.009
BH31	59003	0.500	0.149
BH32	59053	0.085	0.015

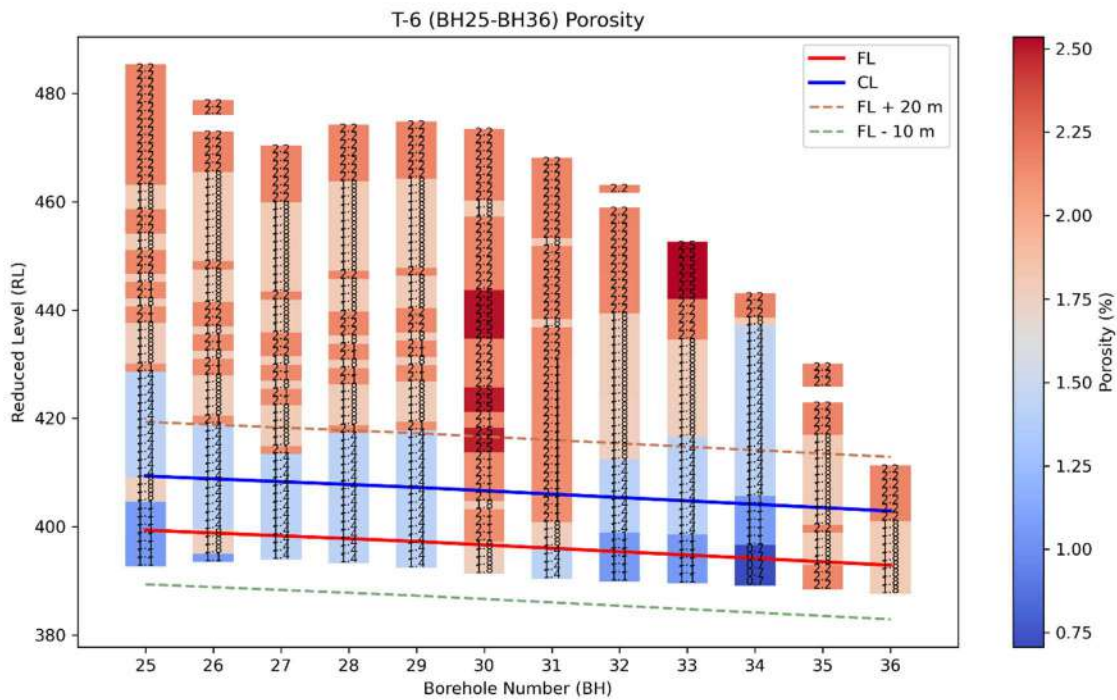
BH No	Chainage	Mean	Std
BH33	59103	0.200	0.043
BH34	59153	0.230	0.057
BH35	59203	0.124	0.041
BH36	59253	0.234	0.034

11.3.3.2 Recommended Water Absorption Value considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($A = \mu + \sigma$ across boreholes within ± 10 m of FL and CL)	Reference Standards / Guidelines
57500 to 57900	0.29	IS 13063:1991; IS 2386 (Part 3):1963
57900 to 59260	0.19	

11.3.4 Porosity





11.3.4.1 Mean And Standard Deviation in Porosity considering 1D zone of influence in each Borehole:

BH No	Chainage	Mean	Std
BH01	57503	1.25	0.361
BH02	57553	1.33	0.182
BH04	57653	1.80	0.241
BH05	57703	0.67	0.130
BH06	57753	1.12	0.113
BH07	57803	1.28	0.184
BH08	57853	1.71	0.499
BH09	57903	1.57	0.676

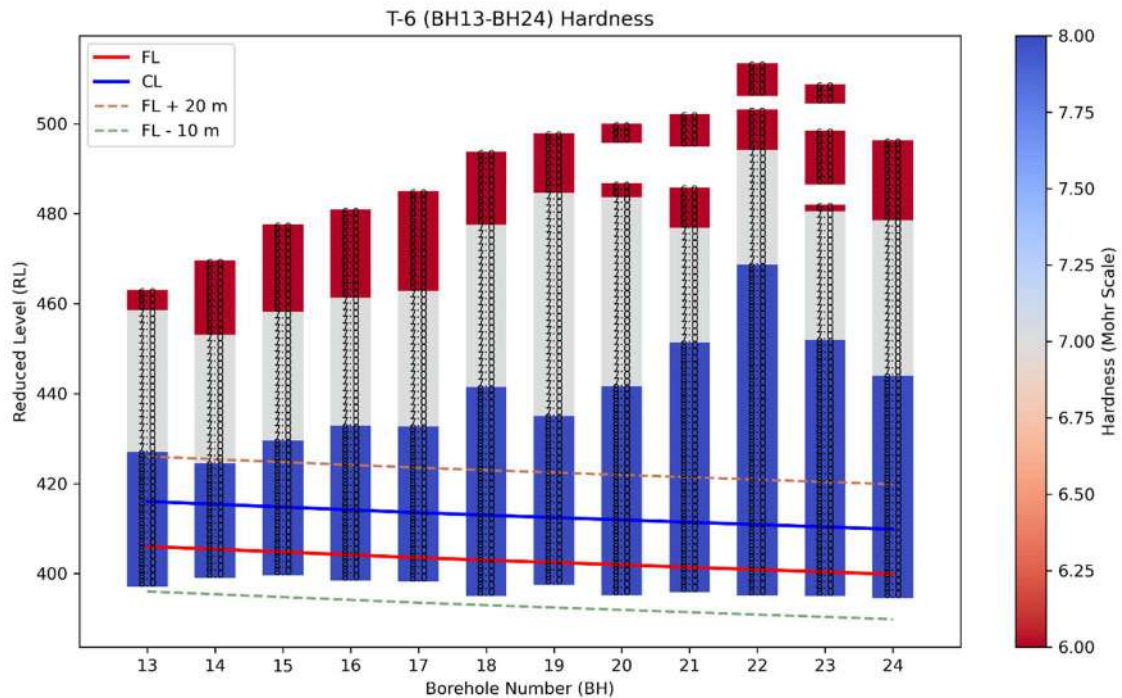
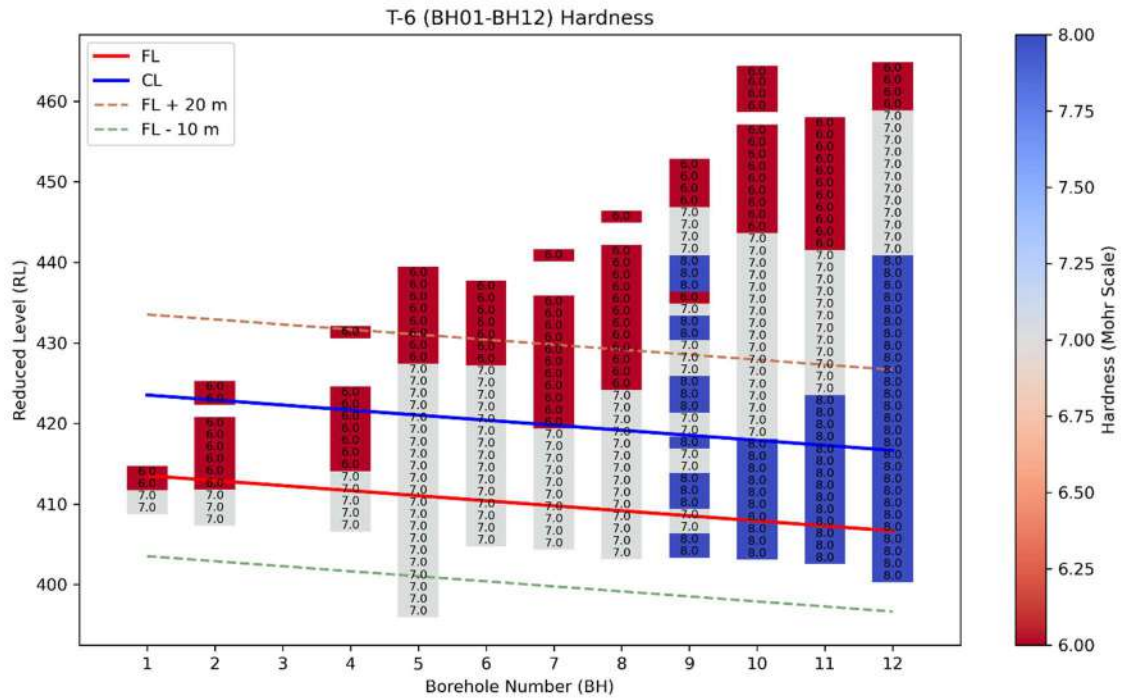
BH No	Chainage	Mean	Std
BH10	57953	1.27	0.296
BH11	58003	0.74	0.112
BH12	58053	0.83	0.178
BH13	58103	0.81	0.169
BH14	58153	0.90	0.329
BH15	58203	0.70	0.000
BH16	58253	0.70	0.000
BH17	58303	0.70	0.000
BH18	58353	0.70	0.000
BH19	58403	0.81	0.237
BH20	58453	0.64	0.307
BH21	58503	0.70	0.287
BH22	58553	0.92	0.182
BH23	58603	0.85	0.182
BH24	58653	0.88	0.186
BH25	58703	1.25	0.331

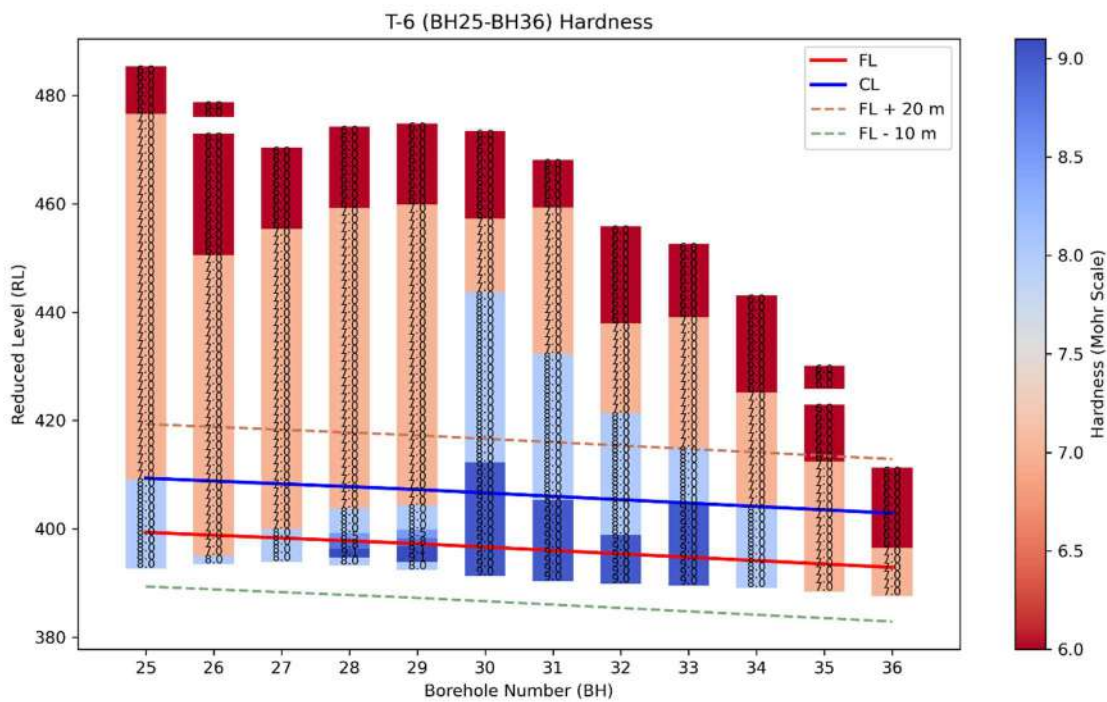
BH No	Chainage	Mean	Std
BH26	58753	1.49	0.222
BH27	58803	1.42	0.000
BH28	58853	1.42	0.000
BH29	58903	1.42	0.000
BH30	58953	1.95	0.187
BH31	59003	1.74	0.310
BH32	59053	1.19	0.184
BH33	59103	1.20	0.182
BH34	59153	0.89	0.188
BH35	59203	1.94	0.182
BH36	59253	1.84	0.114

11.3.4.2 Recommended Porosity considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($n = \mu \pm \sigma$ across boreholes within ± 10 m of FL and CL)	Reference Standards / Guidelines
57500 to 57900	1.28 \pm 0.47	IS 1124:1974; ISRM (1981)
57900 to 59260	1.11 \pm 0.46	

11.3.5 Hardness





11.3.5.1 Mean And Standard Deviation in Hardness considering 1D zone of influence in each Borehole:

BH No	Chainage	Mean	Std
BH01	57503	7	0.577
BH02	57553	6	0.500
BH04	57653	7	0.527
BH05	57703	7	0.000
BH06	57753	7	0.000
BH07	57803	7	0.000
BH08	57853	7	0.000
BH09	57903	8	0.516

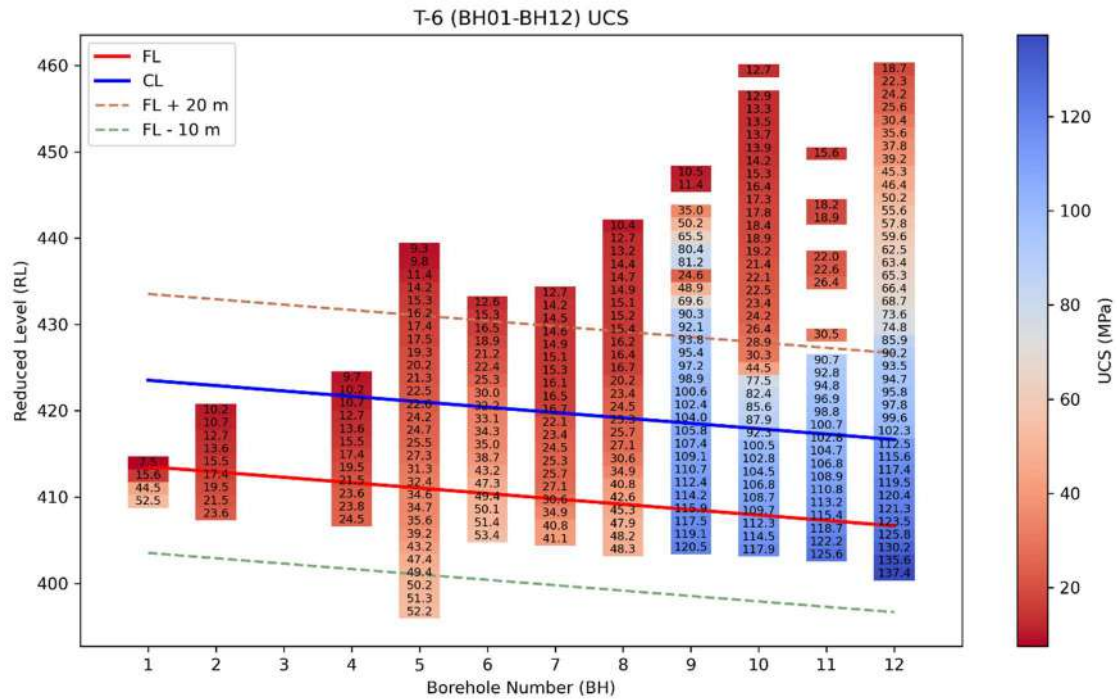
BH No	Chainage	Mean	Std
BH10	57953	8	0.000
BH11	58003	8	0.000
BH12	58053	8	0.000
BH13	58103	8	0.000
BH14	58153	8	0.000
BH15	58203	8	0.000
BH16	58253	8	0.000
BH17	58303	8	0.000
BH18	58353	8	0.000
BH19	58403	8	0.000
BH20	58453	8	0.000
BH21	58503	8	0.000
BH22	58553	8	0.000
BH23	58603	8	0.000
BH24	58653	8	0.000
BH25	58703	8	0.000

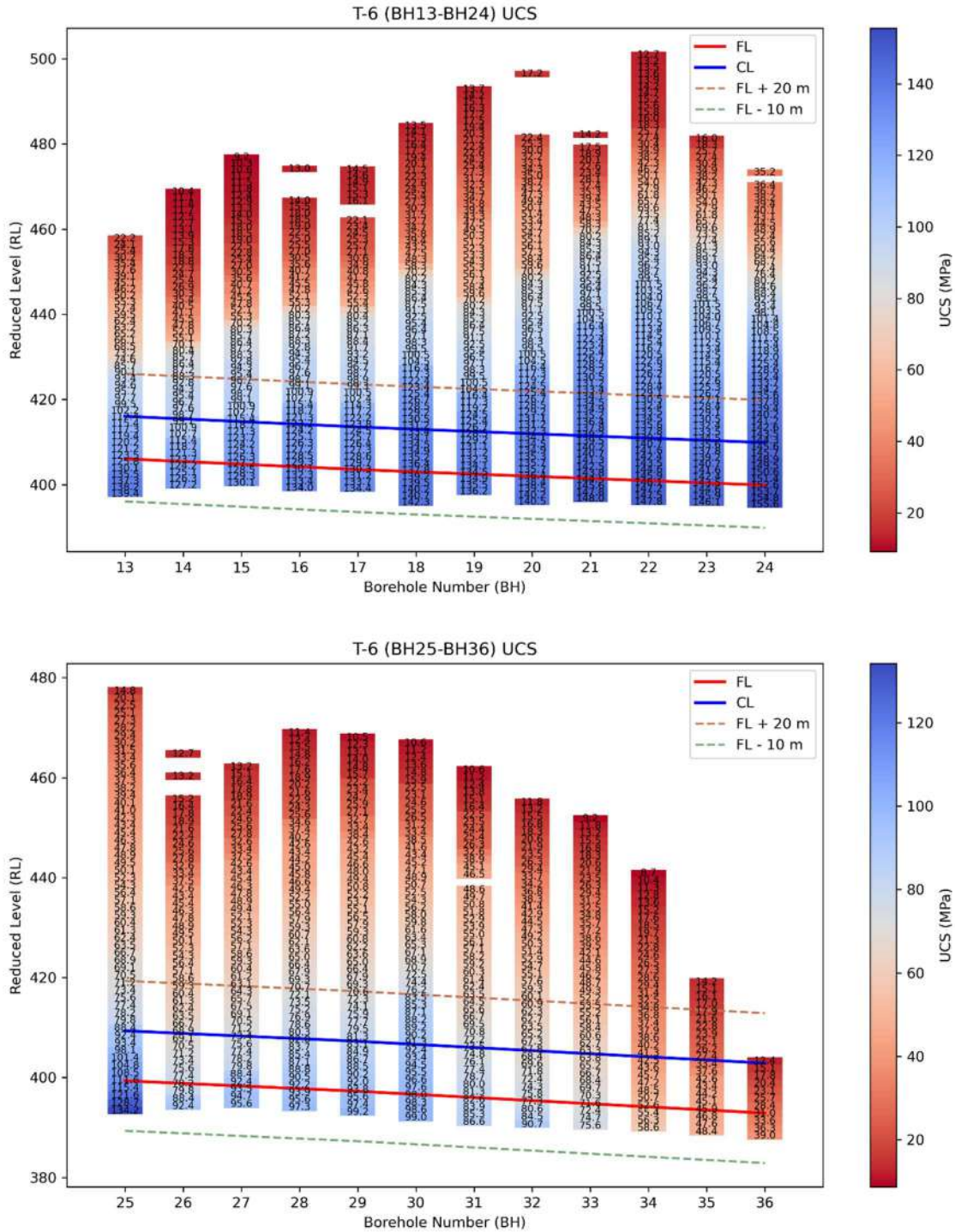
BH No	Chainage	Mean	Std
BH26	58753	7	0.316
BH27	58803	7	0.516
BH28	58853	8	0.750
BH29	58903	8	0.752
BH30	58953	9	0.000
BH31	59003	9	0.000
BH32	59053	9	0.516
BH33	59103	9	0.000
BH34	59153	8	0.000
BH35	59203	7	0.000
BH36	59253	7	0.516

11.3.5.2 Recommended Hardness considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($H_i = \mu - \sigma$ across boreholes within ± 10 m of FL and CL)	Reference Standards / Guidelines
57500 to 57900	6	IS 13311 (Part 2):1992; ISRM 1978
57900 to 59260	7	

11.3.6 Compression Test





11.3.6.1 Mean And Standard Deviation in UCS considering 1D zone of influence in each Borehole:

BH No	Chainage	Mean	Std
BH01	57503	30.03	21.83

BH No	Chainage	Mean	Std
BH02	57553	16.08	4.75
BH04	57653	18.27	5.03
BH05	57703	33.72	8.64
BH06	57753	43.59	7.76
BH07	57803	29.55	7.05
BH08	57853	37.88	9.41
BH09	57903	113.26	5.02
BH10	57953	107.00	7.42
BH11	58003	112.91	7.56
BH12	58053	123.56	8.01
BH13	58103	125.82	9.32
BH14	58153	116.78	10.77
BH15	58203	125.44	3.61
BH16	58253	128.55	3.63
BH17	58303	129.18	3.31
BH18	58353	137.35	2.98

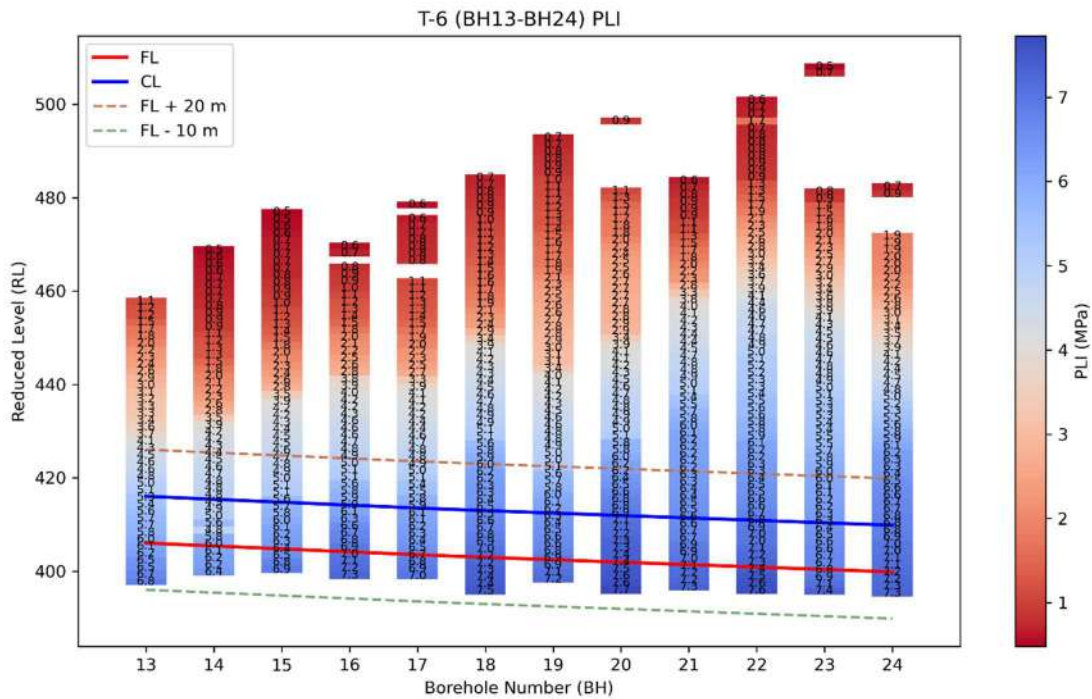
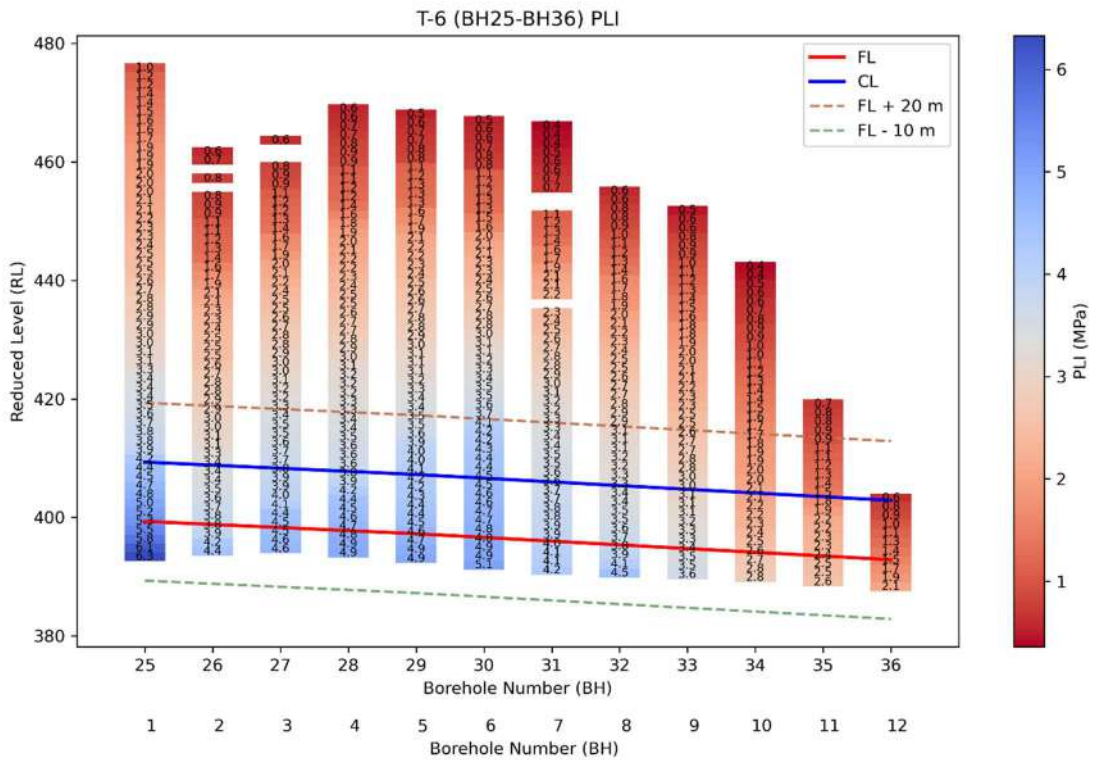
BH No	Chainage	Mean	Std
BH19	58403	132.75	2.69
BH20	58453	136.84	2.37
BH21	58503	143.39	3.07
BH22	58553	144.73	2.57
BH23	58603	141.74	3.48
BH24	58653	150.84	3.49
BH25	58703	110.01	13.90
BH26	58753	77.60	7.65
BH27	58803	84.90	8.81
BH28	58853	89.65	5.15
BH29	58903	91.14	5.42
BH30	58953	96.38	2.34
BH31	59003	80.67	3.97
BH32	59053	76.54	7.00
BH33	59103	69.84	3.90
BH34	59153	50.11	5.54

BH No	Chainage	Mean	Std
BH35	59203	43.50	4.69
BH36	59253	27.03	8.02

11.3.6.2 Recommended UCS considering 1D zone of influence:

Chainage	Statistical / Reduction Method	Recommended Design Value	Reference Standards / Guidelines
	(UCS _k = $\mu - \sigma$) across boreholes within ± 10 m of FL and CL)	(UCS _d = $(\mu - \sigma) \times f(\text{RMR})$), where $f(\text{RMR}) = 0.1-0.7$)	
57500 to 57900	17.88	5.36	IS 9143:1979; IS 13365 (Part 2):1998; Hoek & Brown (2002, 2019)
57900 to 59260	74.13	37.06	

11.3.7 Point Load Test



11.3.7.1 Mean And Standard Deviation in PLI considering 1D zone of influence in each Borehole:

BH No	Chainage	Mean	Std
BH01	57503	1.50	1.08
BH02	57553	1.13	0.22
BH04	57653	1.25	0.22
BH05	57703	1.70	0.42
BH06	57753	2.17	0.42
BH07	57803	1.54	0.34
BH08	57853	1.90	0.48
BH09	57903	5.70	0.39
BH10	57953	5.23	0.36
BH11	58003	5.63	0.44
BH12	58053	5.89	0.41
BH13	58103	6.03	0.49
BH14	58153	5.63	0.61
BH15	58203	6.27	0.38
BH16	58253	6.72	0.43

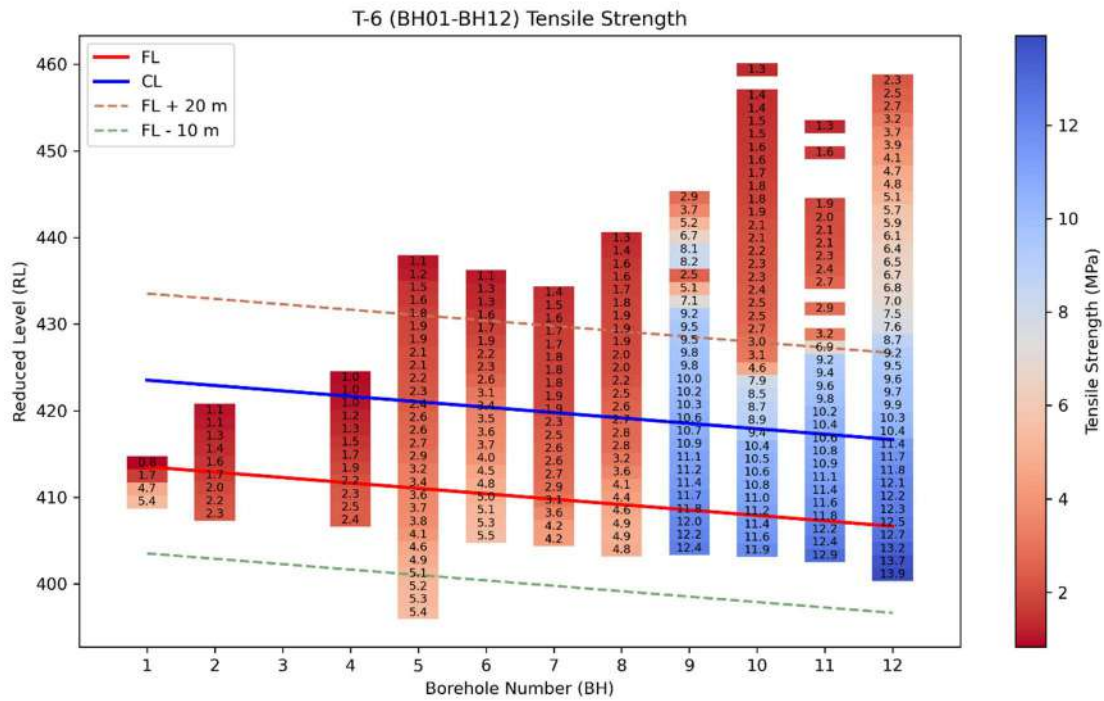
BH No	Chainage	Mean	Std
BH17	58303	6.50	0.34
BH18	58353	7.06	0.32
BH19	58403	6.73	0.28
BH20	58453	7.38	0.21
BH21	58503	6.97	0.25
BH22	58553	7.27	0.26
BH23	58603	6.76	0.30
BH24	58653	7.09	0.16
BH25	58703	5.23	0.63
BH26	58753	3.76	0.35
BH27	58803	4.23	0.33
BH28	58853	4.46	0.41
BH29	58903	4.51	0.27
BH30	58953	4.76	0.17
BH31	59003	3.91	0.18
BH32	59053	3.74	0.35

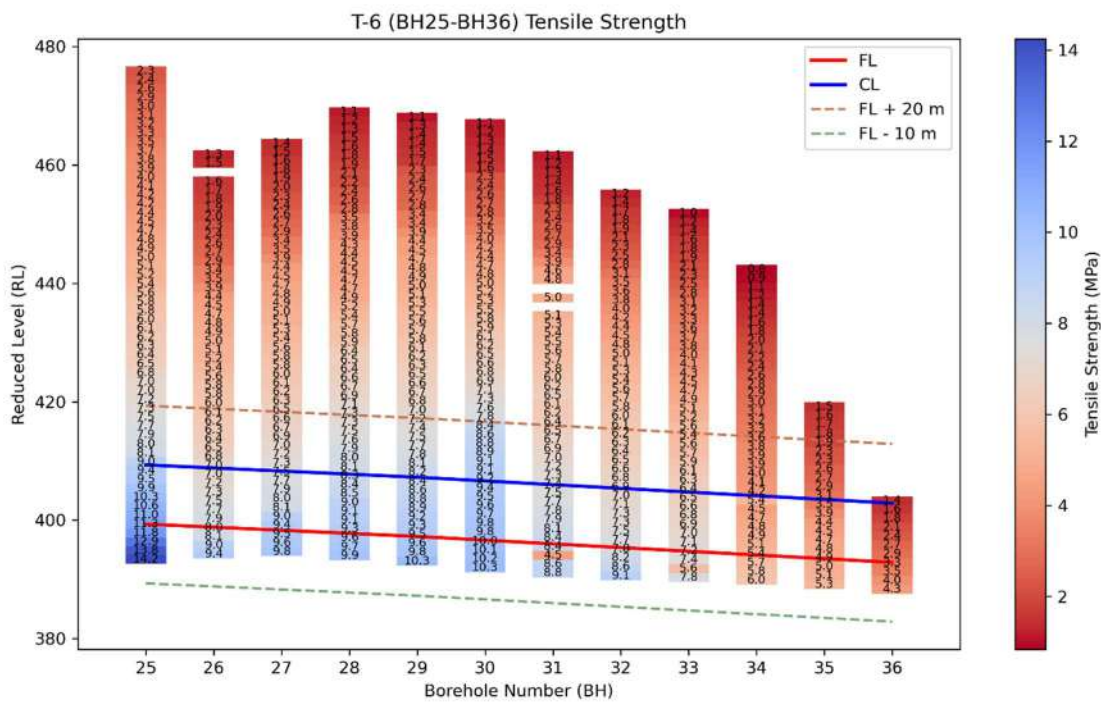
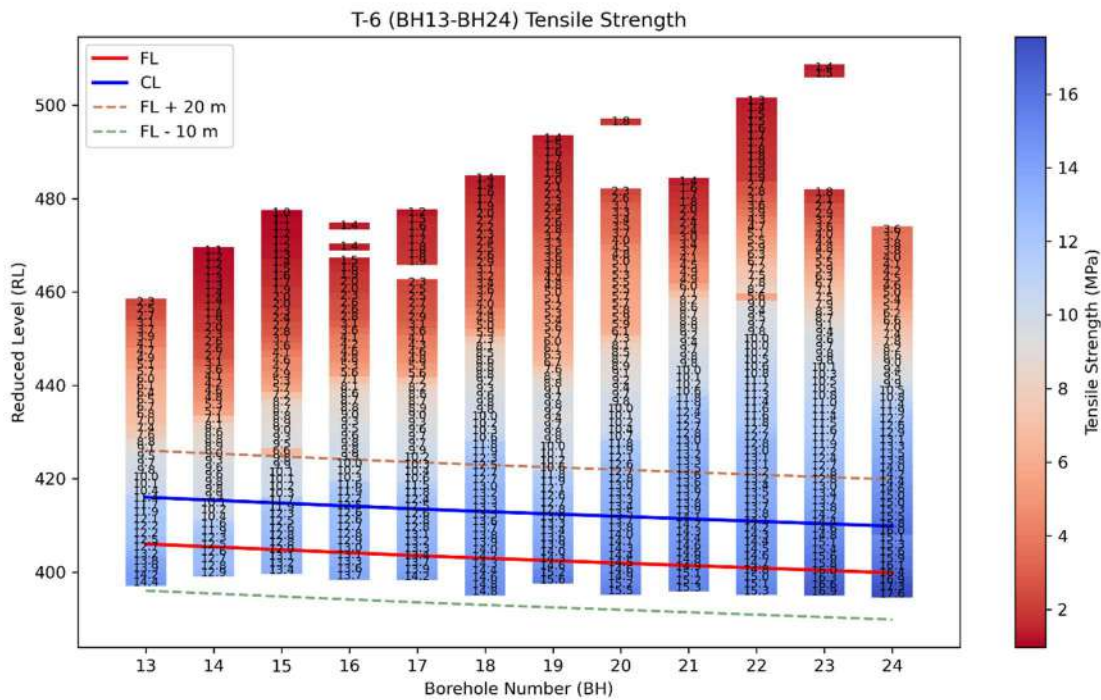
BH No	Chainage	Mean	Std
BH33	59103	3.31	0.18
BH34	59153	2.45	0.25
BH35	59203	2.26	0.26
BH36	59253	1.37	0.43

11.3.7.2 Recommended PLI considering 1D zone of influence:

Chainage	Statistical / Reduction Method	Recommended Design Value	Reference Standards / Guidelines
	($PLI_k = \mu - \sigma$) across boreholes within ± 10 m of FL and CL)	($PLI_d = (\mu - \sigma) \times f(RMR)$), where ($f(RMR) = 0.1-0.7$)	
57500 to 57900	1.09	0.32	IS 9143:1979; IS 13365 (Part 2):1998; Hoek & Brown (2002, 2019)
57900 to 59260	3.64	1.82	

11.3.8 Brazilian Test





11.3.8.1 Mean And Standard Deviation in Tensile Strength considering 1D zone of influence in each Borehole:

BH No	Chainage	Mean	Std
BH01	57503	3.15	2.23
BH02	57553	1.62	0.46
BH04	57653	1.81	0.52
BH05	57703	3.54	0.87
BH06	57753	4.50	0.74
BH07	57803	3.07	0.70
BH08	57853	3.89	0.90
BH09	57903	11.54	0.56
BH10	57953	10.88	0.70
BH11	58003	11.59	0.77
BH12	58053	12.49	0.82
BH13	58103	12.78	1.01
BH14	58153	11.82	1.10
BH15	58203	12.76	0.45
BH16	58253	12.98	0.42

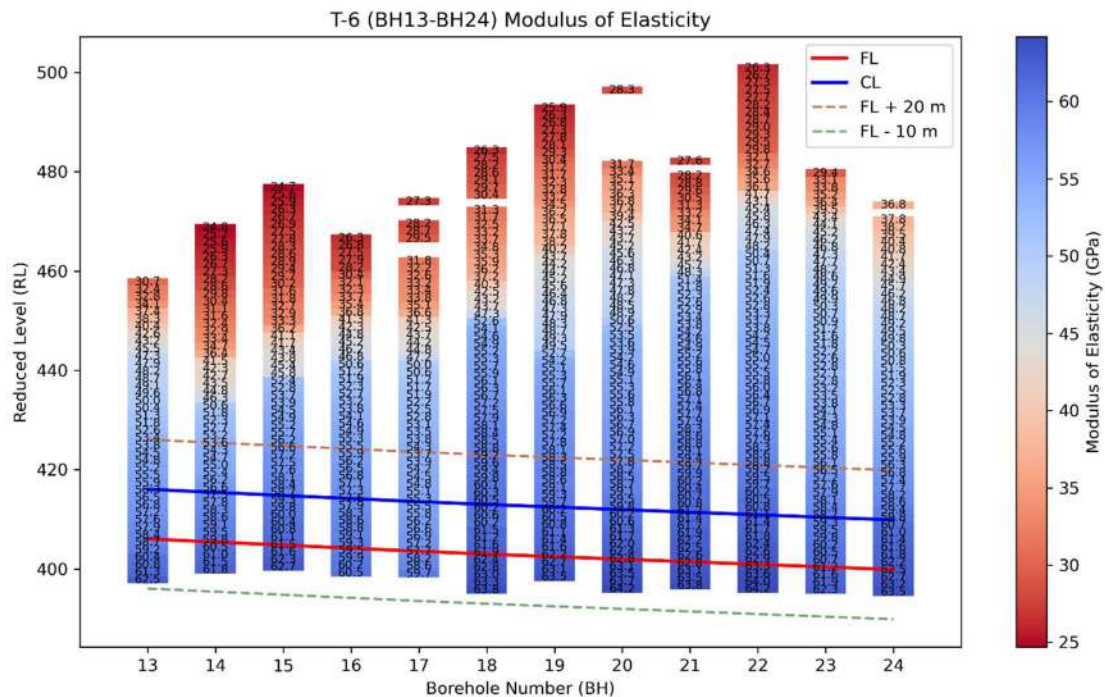
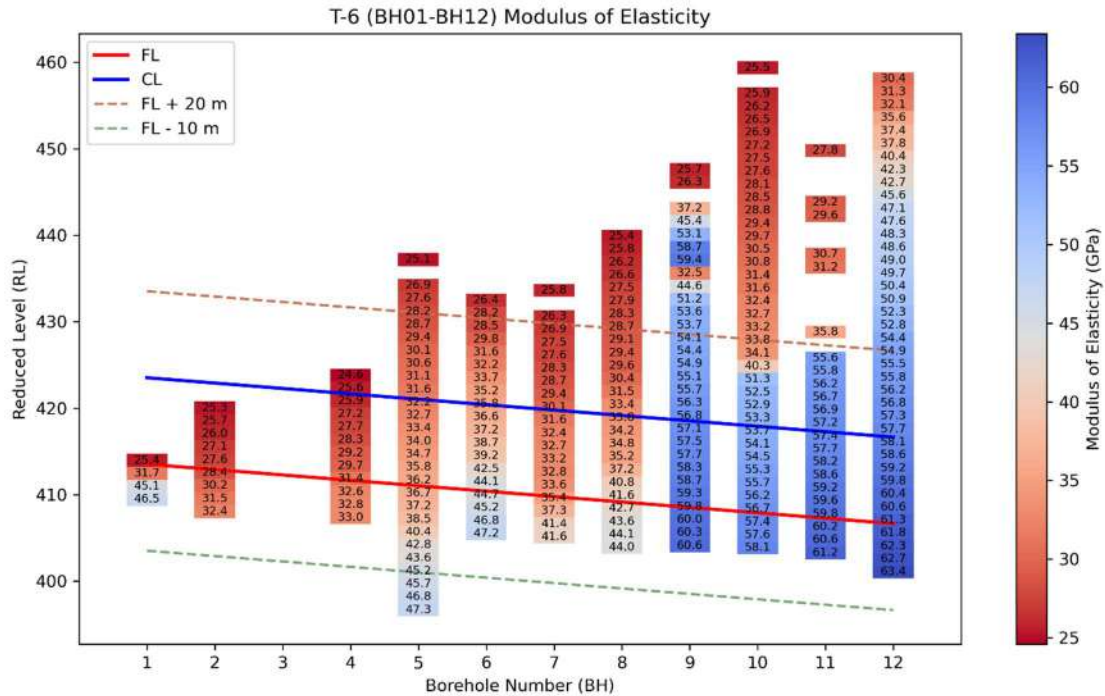
BH No	Chainage	Mean	Std
BH17	58303	13.30	0.52
BH18	58353	14.12	0.47
BH19	58403	14.09	0.84
BH20	58453	14.46	0.55
BH21	58503	14.74	0.39
BH22	58553	14.70	0.36
BH23	58603	15.72	0.76
BH24	58653	16.20	0.82
BH25	58703	11.34	1.68
BH26	58753	7.90	0.76
BH27	58803	8.64	0.90
BH28	58853	9.10	0.56
BH29	58903	9.24	0.59
BH30	58953	9.81	0.30
BH31	59003	7.79	1.22
BH32	59053	7.76	0.69

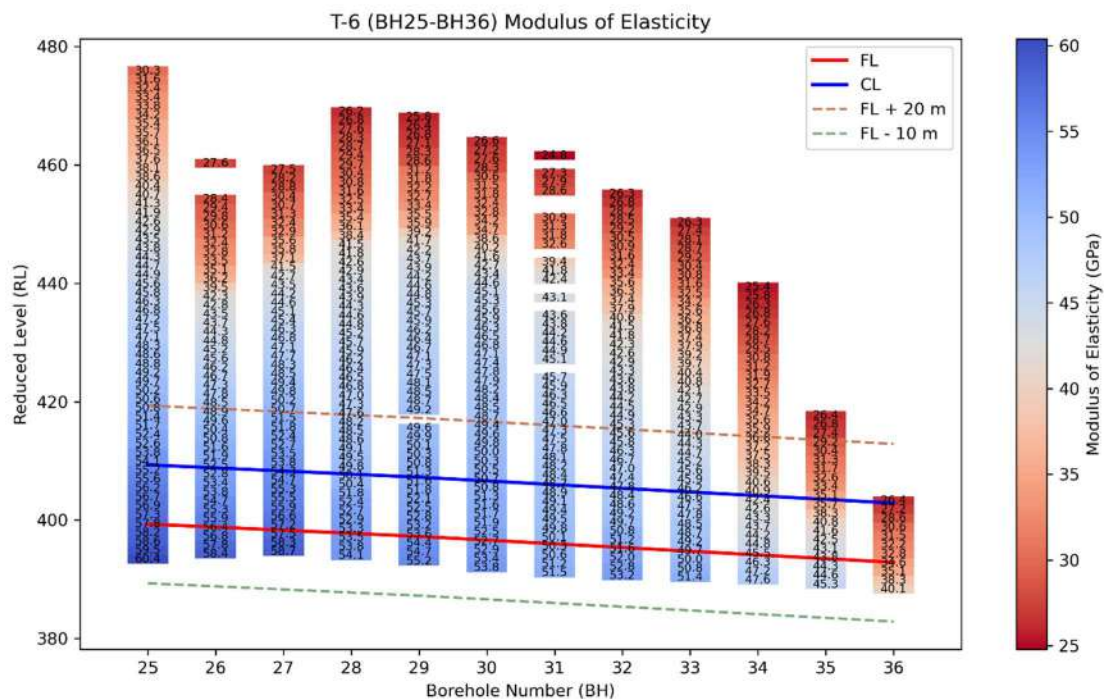
BH No	Chainage	Mean	Std
BH33	59103	6.89	0.60
BH34	59153	5.22	0.50
BH35	59203	4.61	0.57
BH36	59253	2.86	0.91

11.3.8.2 Recommended Tensile Strength considering 1D zone of influence:

Chainage	Statistical / Reduction Method (mean value across boreholes within ± 10 m of FL and CL $\times 0.8$ (account for anisotropy))	Recommended Design Value ($\mu - \sigma$)	Reference Standards / Guidelines
57500 to 57900	3.14	1.84	IS 10082:1982; Hoek & Brown (1997); ISRM Suggested Methods
57900 to 59260	10.98	7.50	

11.3.9 Modulus of elasticity test





11.3.9.1 Mean And Standard Deviation in Elasticity considering 1D zone of influence in each Borehole:

BH No	Chainage	Mean	Std
BH01	57503	37.175	10.302
BH02	57553	28.244	2.589
BH04	57653	29.782	2.555
BH05	57703	37.386	4.180
BH06	57753	42.220	3.982
BH07	57803	35.198	3.696
BH08	57853	39.275	4.251
BH09	57903	58.930	1.250

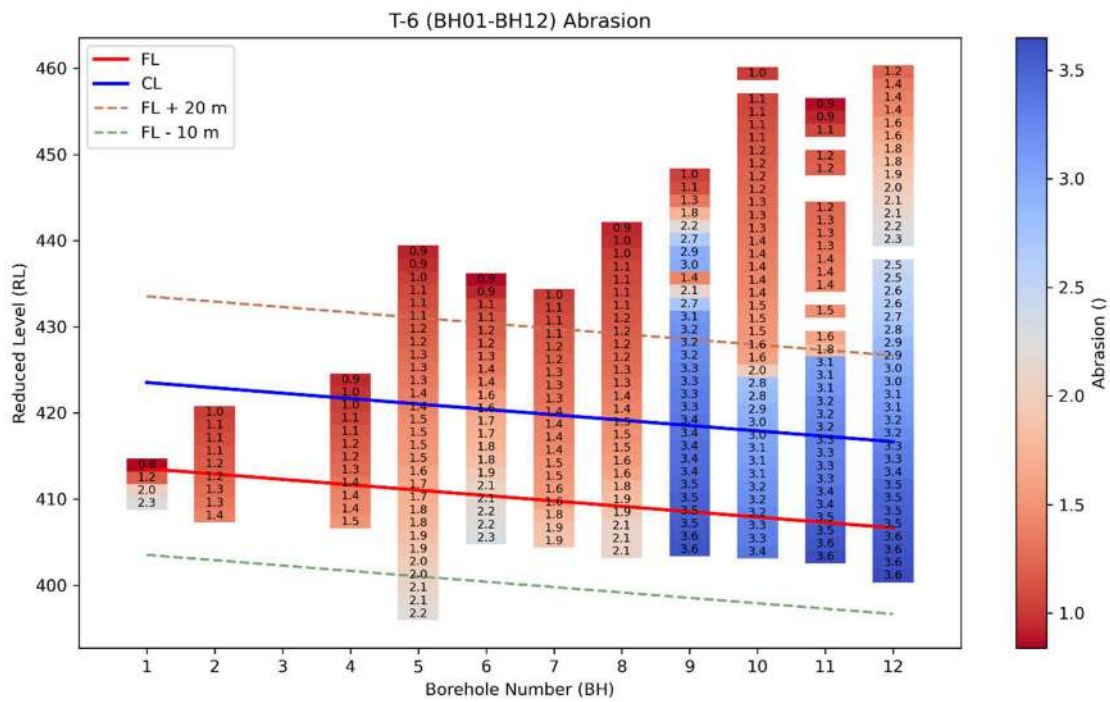
BH No	Chainage	Mean	Std
BH10	57953	55.930	1.533
BH11	58003	59.250	1.261
BH12	58053	60.745	1.724
BH13	58103	58.738	1.982
BH14	58153	59.582	1.478
BH15	58203	60.950	1.101
BH16	58253	59.064	0.931
BH17	58303	57.240	1.323
BH18	58353	61.875	1.208
BH19	58403	61.710	1.126
BH20	58453	62.318	1.291
BH21	58503	62.550	0.776
BH22	58553	62.790	0.981
BH23	58603	60.700	1.031
BH24	58653	62.060	0.924
BH25	58703	57.491	1.607

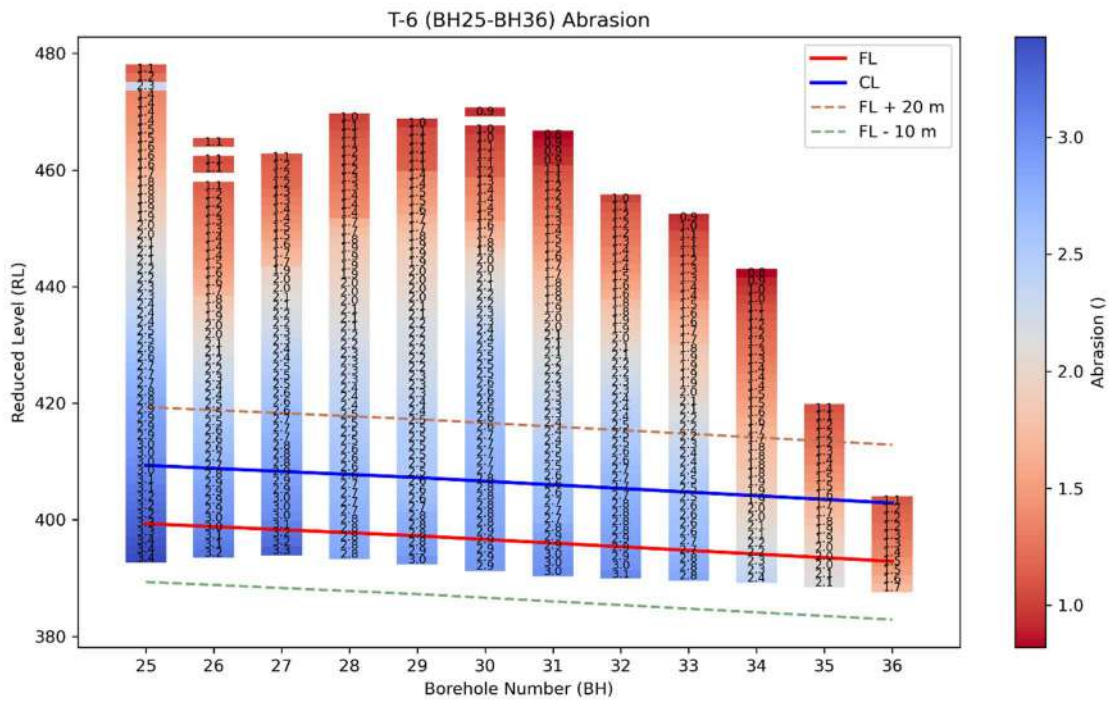
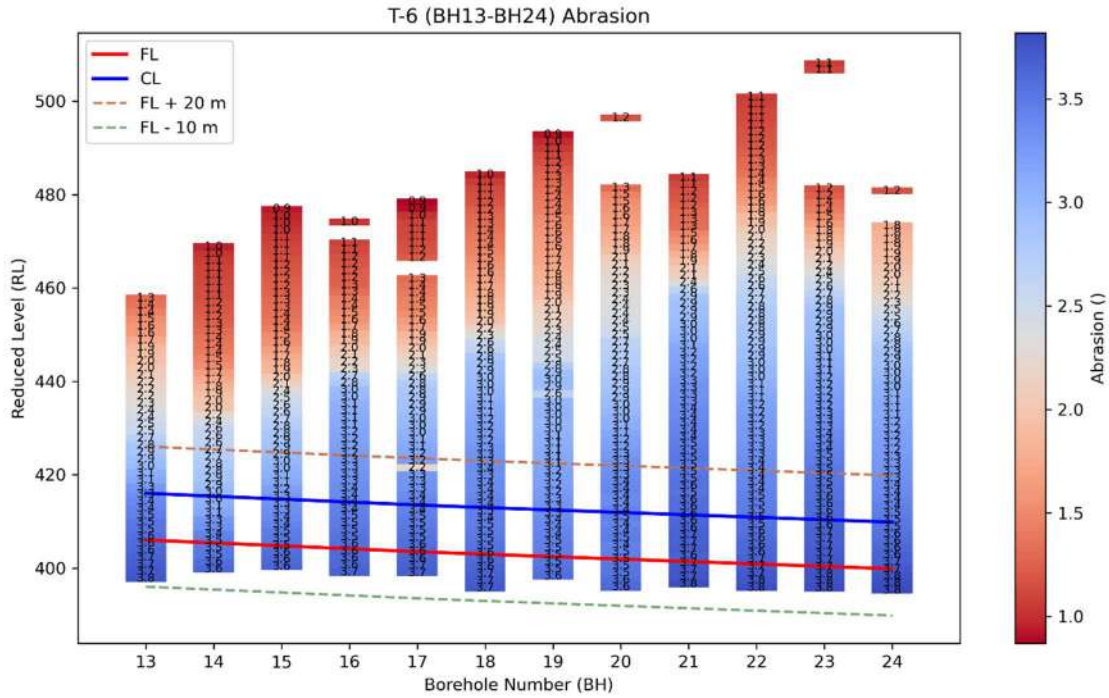
BH No	Chainage	Mean	Std
BH26	58753	55.530	1.874
BH27	58803	56.400	1.504
BH28	58853	52.500	1.365
BH29	58903	53.190	1.257
BH30	58953	52.260	0.958
BH31	59003	50.040	0.869
BH32	59053	50.750	1.711
BH33	59103	49.000	1.526
BH34	59153	44.760	1.848
BH35	59203	42.000	3.030
BH36	59253	33.100	4.042

11.3.9.2 Recommended Modulus of Elasticity considering 1D zone of influence:

Chainage	Statistical / Reduction Method ($E_i = \mu - \sigma$ across boreholes within ± 10 m of FL and CL $\times 0.8$ (account for anisotropy))	Recommended Design Value ($E_d = (\mu - \sigma) \times f(\text{RMR})$), where $f(\text{RMR}) = 0.1 - 0.7$)	Reference Standards / Guidelines
57500 to 57900	29.54	8.86	IS 13365 (Part 2):1998; Hoek & Diederichs (2006)
57900 to 59260	48.86	24.43	

11.3.10 Abrasion test





11.3.10.1 Mean And Standard Deviation in Abrasion value considering 1D zone of influence in each Borehole:

BH No	Chainage	Mean	Std
BH01	57503	1.58	0.682
BH02	57553	1.20	0.121
BH04	57653	1.25	0.164
BH05	57703	1.70	0.204
BH06	57753	1.99	0.221
BH07	57803	1.59	0.184
BH08	57853	1.77	0.249
BH09	57903	3.48	0.071
BH10	57953	3.19	0.114
BH11	58003	3.43	0.126
BH12	58053	3.49	0.119
BH13	58103	3.56	0.130
BH14	58153	3.36	0.200
BH15	58203	3.48	0.116
BH16	58253	3.54	0.082

BH No	Chainage	Mean	Std
BH17	58303	3.56	0.087
BH18	58353	3.57	0.099
BH19	58403	3.45	0.081
BH20	58453	3.49	0.064
BH21	58503	3.69	0.049
BH22	58553	3.66	0.080
BH23	58603	3.72	0.051
BH24	58653	3.67	0.100
BH25	58703	3.24	0.124
BH26	58753	2.97	0.124
BH27	58803	3.04	0.147
BH28	58853	2.74	0.065
BH29	58903	2.75	0.125
BH30	58953	2.86	0.056
BH31	59003	2.83	0.139
BH32	59053	2.87	0.102

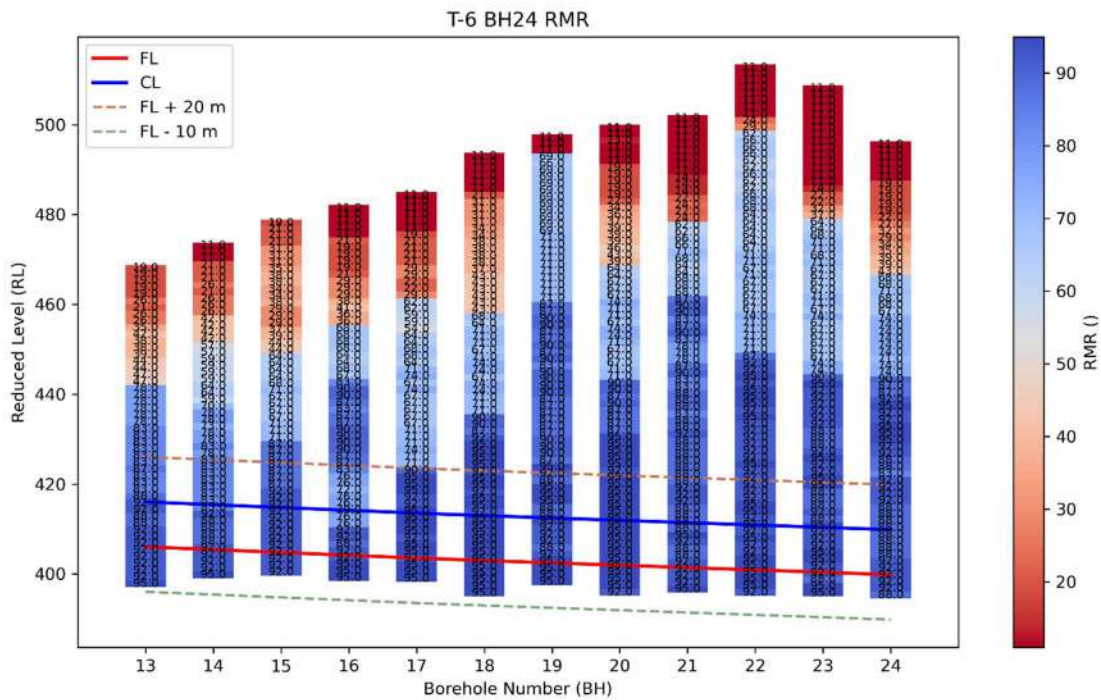
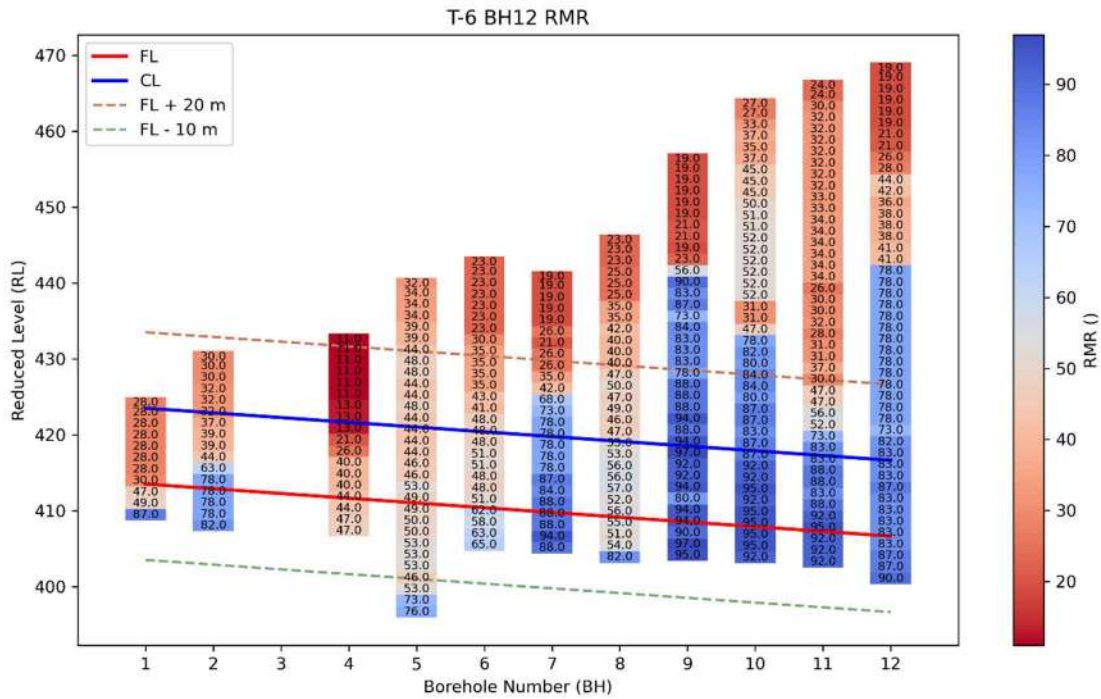
BH No	Chainage	Mean	Std
BH33	59103	2.67	0.097
BH34	59153	2.14	0.153
BH35	59203	1.92	0.154
BH36	59253	1.39	0.190

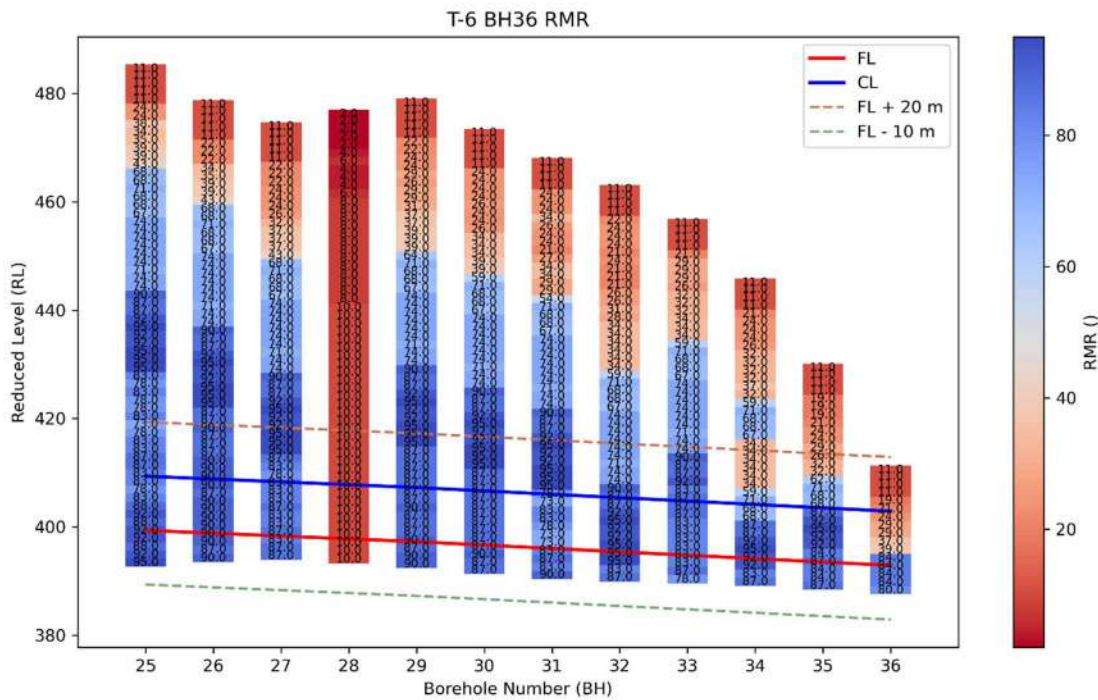
11.3.10.2 Recommended Abrasion Value considering 1D zone of influence:

Chainage	Statistical / Reduction Method	Recommended Design Value	Reference Standards / Guidelines
	($A = \mu + \sigma$ across boreholes within ± 10 m of FL and CL)	($A_v < 25\%$): Slightly abrasive; 25–35%: Moderately abrasive; >35%: Highly abrasive. (CAI = 0.5–6).	
57500 to 57900	1.95	Slightly abrasive	IS 2386 (Part 4):1963; ISRM (2007); CERCHAR (1986)
57900 to 59260	3.72	Highly abrasive	

11.4 Geological assessment:

11.4.1 RMR:





11.4.1.1 Mean And Standard Deviation in RMR considering 1D zone of influence in each Borehole:

BH No	Chainage	Mean	Std
BH01	57503	38	19.05
BH02	57553	62	19.52
BH04	57653	36	11.89
BH05	57703	49	3.57
BH06	57753	55	6.79
BH07	57803	85	5.47
BH08	57853	57	8.57
BH09	57903	93	4.90

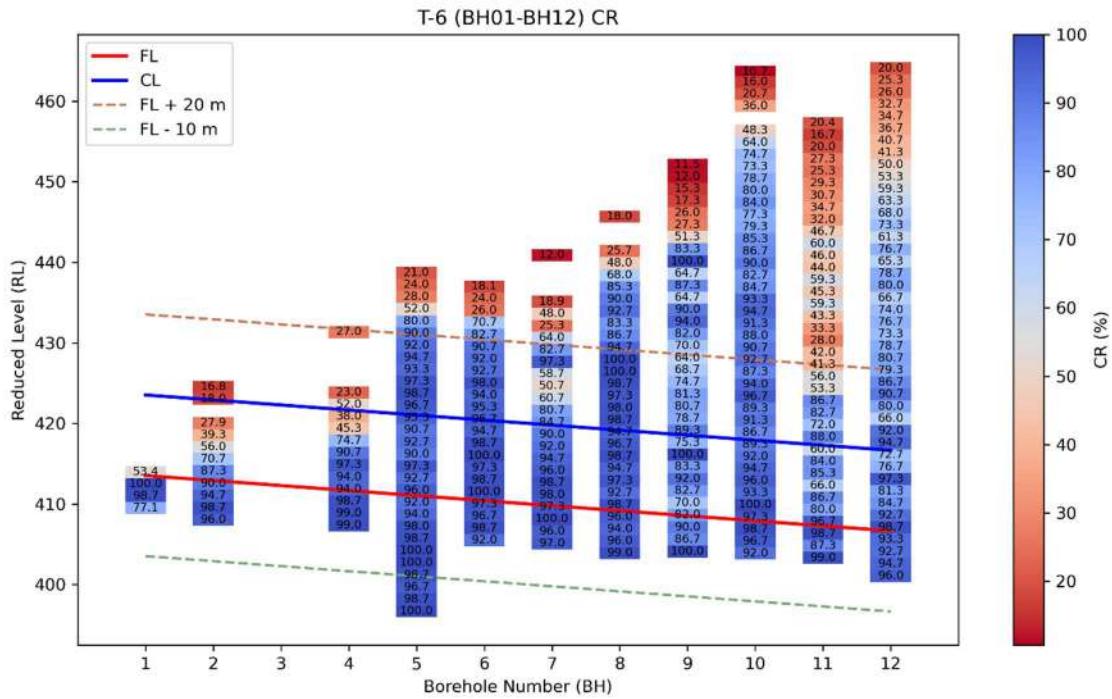
BH No	Chainage	Mean	Std
BH10	57953	93	2.58
BH11	58003	89	4.03
BH12	58053	85	2.53
BH13	58103	92	1.80
BH14	58153	90	3.32
BH15	58203	92	0.00
BH16	58253	88	7.61
BH17	58303	94	1.26
BH18	58353	95	0.00
BH19	58403	93	2.33
BH20	58453	95	0.90
BH21	58503	91	2.63
BH22	58553	94	1.55
BH23	58603	93	2.25
BH24	58653	90	2.11
BH25	58703	88	5.12

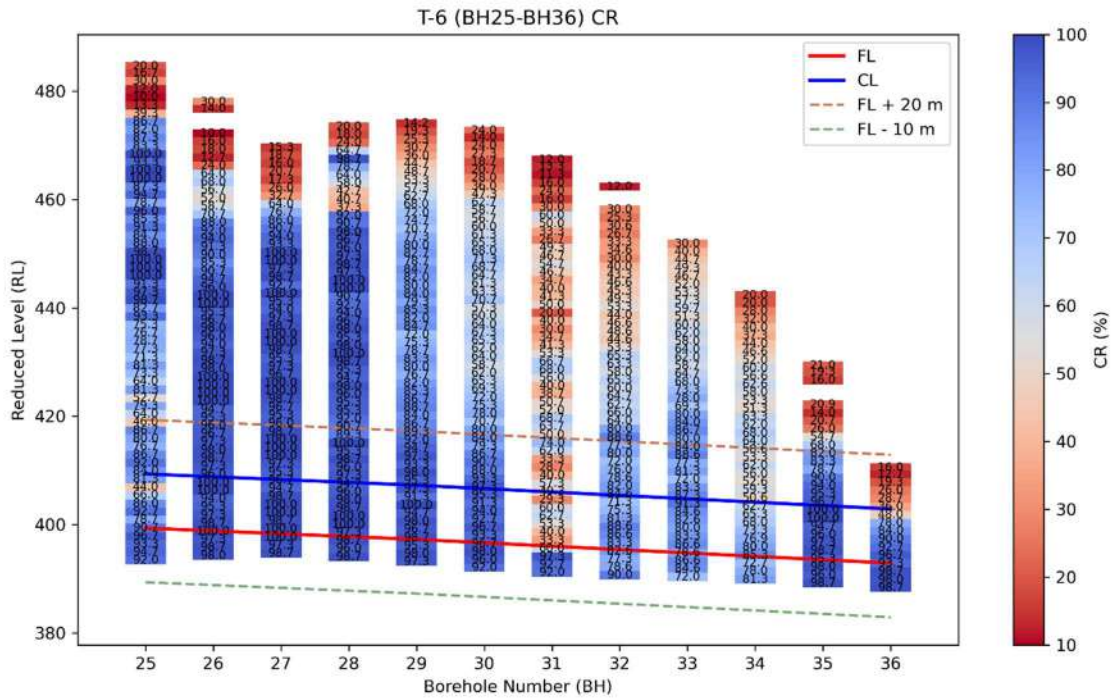
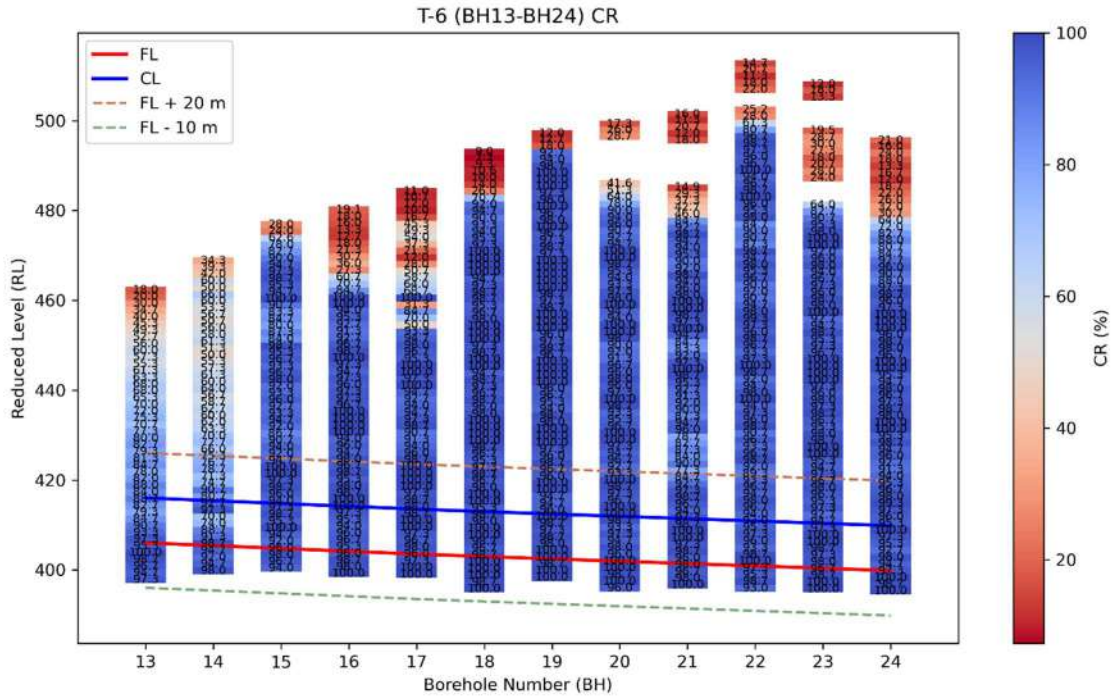
BH No	Chainage	Mean	Std
BH26	58753	89	1.26
BH27	58803	85	2.07
BH28	58853	10	0.00
BH29	58903	88	1.55
BH30	58953	87	0.95
BH31	59003	81	6.08
BH32	59053	91	4.24
BH33	59103	84	2.75
BH34	59153	85	9.67
BH35	59203	88	4.03
BH36	59253	57	27.54

11.4.1.2 Recommended RQD considering 1D zone of influence:

Chainage	Statistical / Reduction Method (Average across boreholes within ± 10 m of FL and CL)	Recommended Design Value ($RMR_d = \mu - \sigma$)	Reference Standards / Guidelines
57500 to 57900	54 (Class IV)	35 (Class IV)	IS 13365 (Part 2): 1998, Cl. 5.1 + Note on “representative values”
57900 to 59260	86 (Class I)	69 (Class II)	

11.4.2 Core Recovery:





11.4.2.1 Mean And Standard Deviation in Core Recovery considering 1D zone of influence in each Borehole:

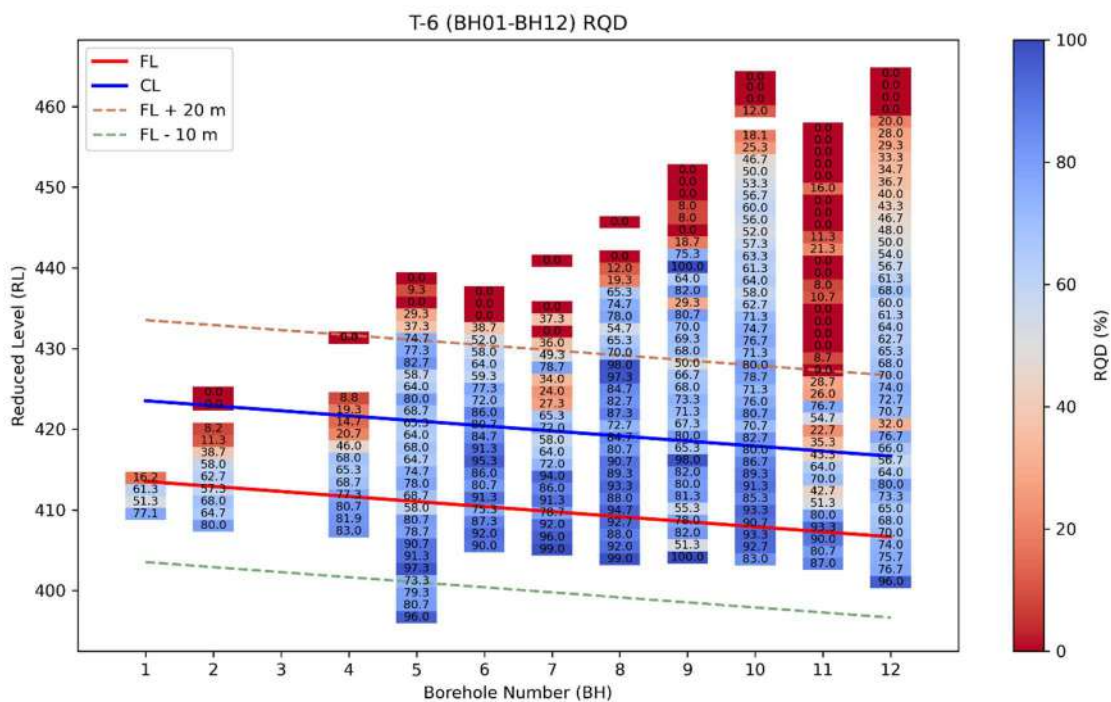
BH No	Chainage	Mean	Std
BH01	57503	82.29	21.94
BH02	57553	73.40	26.49
BH04	57653	83.07	23.04
BH05	57703	95.43	3.45
BH06	57753	97.40	2.48
BH07	57803	95.97	3.05
BH08	57853	96.21	2.09
BH09	57903	86.20	9.71
BH10	57953	95.00	3.35
BH11	58003	84.37	13.06
BH12	58053	89.15	8.86
BH13	58103	92.26	6.59
BH14	58153	90.18	9.52
BH15	58203	96.27	2.38
BH16	58253	97.03	1.96

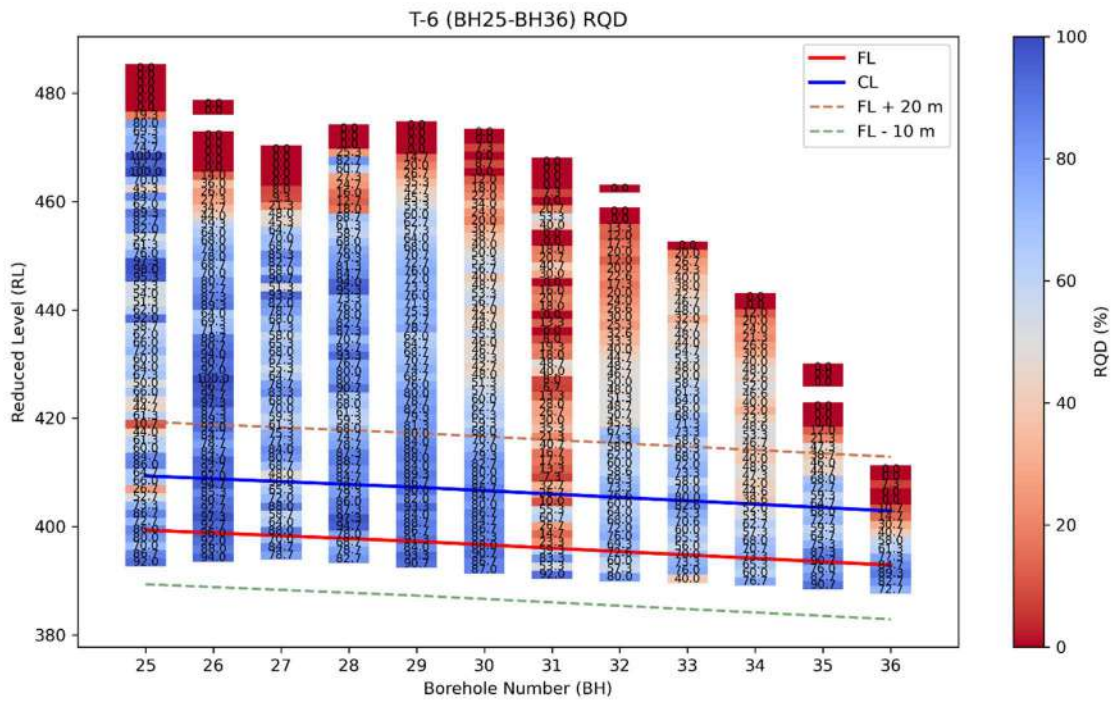
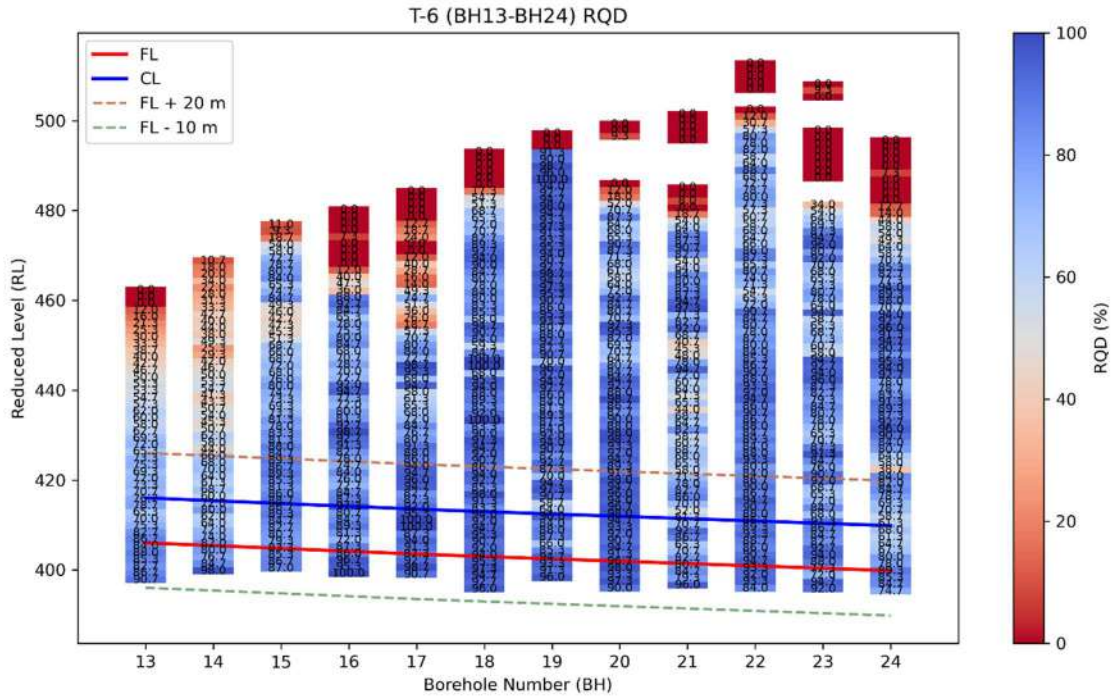
BH No	Chainage	Mean	Std
BH17	58303	98.40	1.55
BH18	58353	99.11	1.08
BH19	58403	99.13	1.00
BH20	58453	97.52	2.27
BH21	58503	98.33	1.41
BH22	58553	96.50	2.32
BH23	58603	98.67	1.30
BH24	58653	97.40	2.50
BH25	58703	83.27	15.82
BH26	58753	97.93	2.02
BH27	58803	98.47	1.78
BH28	58853	97.80	1.78
BH29	58903	96.73	2.44
BH30	58953	94.60	2.26
BH31	59003	62.07	24.82
BH32	59053	81.49	5.98

BH No	Chainage	Mean	Std
BH33	59103	83.02	5.27
BH34	59153	74.35	7.33
BH35	59203	97.47	1.91
BH36	59253	87.80	15.54

Overall Mean	Std
91.58	12.44

11.4.3 RQD:





11.4.3.1 Mean And Standard Deviation in RQD considering 1D zone of influence in each Borehole:

BH No	Chainage	Mean	Std
BH01	57503	51.50	25.80
BH02	57553	49.87	25.23
BH04	57653	60.63	25.16
BH05	57703	75.24	11.66
BH06	57753	87.40	5.98
BH07	57803	83.10	14.26
BH08	57853	90.27	4.99
BH09	57903	77.33	16.03
BH10	57953	88.57	4.63
BH11	58003	70.23	19.12
BH12	58053	72.67	10.22
BH13	58103	80.98	7.43
BH14	58153	76.85	9.98
BH15	58203	84.57	3.09
BH16	58253	88.24	8.55

BH No	Chainage	Mean	Std
BH17	58303	93.73	4.76
BH18	58353	94.06	1.92
BH19	58403	88.20	8.94
BH20	58453	93.82	2.72
BH21	58503	80.94	9.84
BH22	58553	90.53	3.51
BH23	58603	86.47	7.50
BH24	58653	75.33	9.66
BH25	58703	72.06	18.87
BH26	58753	92.33	3.61
BH27	58803	72.73	11.54
BH28	58853	83.07	8.54
BH29	58903	88.40	4.05
BH30	58953	86.04	2.75
BH31	59003	47.87	28.23
BH32	59053	67.92	7.49

BH No	Chainage	Mean	Std
BH33	59103	66.91	12.28
BH34	59153	63.93	8.36
BH35	59203	76.73	10.95
BH36	59253	61.20	25.22

11.4.3.2 Recommended RQD considering 1D zone of influence:

Chainage	Statistical / Reduction Method (Average across boreholes within ± 10 m of FL and CL)	Recommended Design Value ($RQD_d = \mu - \sigma$)	Reference Standards / Guidelines
57500 to 57900	73.71	52.01	IS 11315:1985; Deere (1963)
57900 to 59260	79.49	63.85	

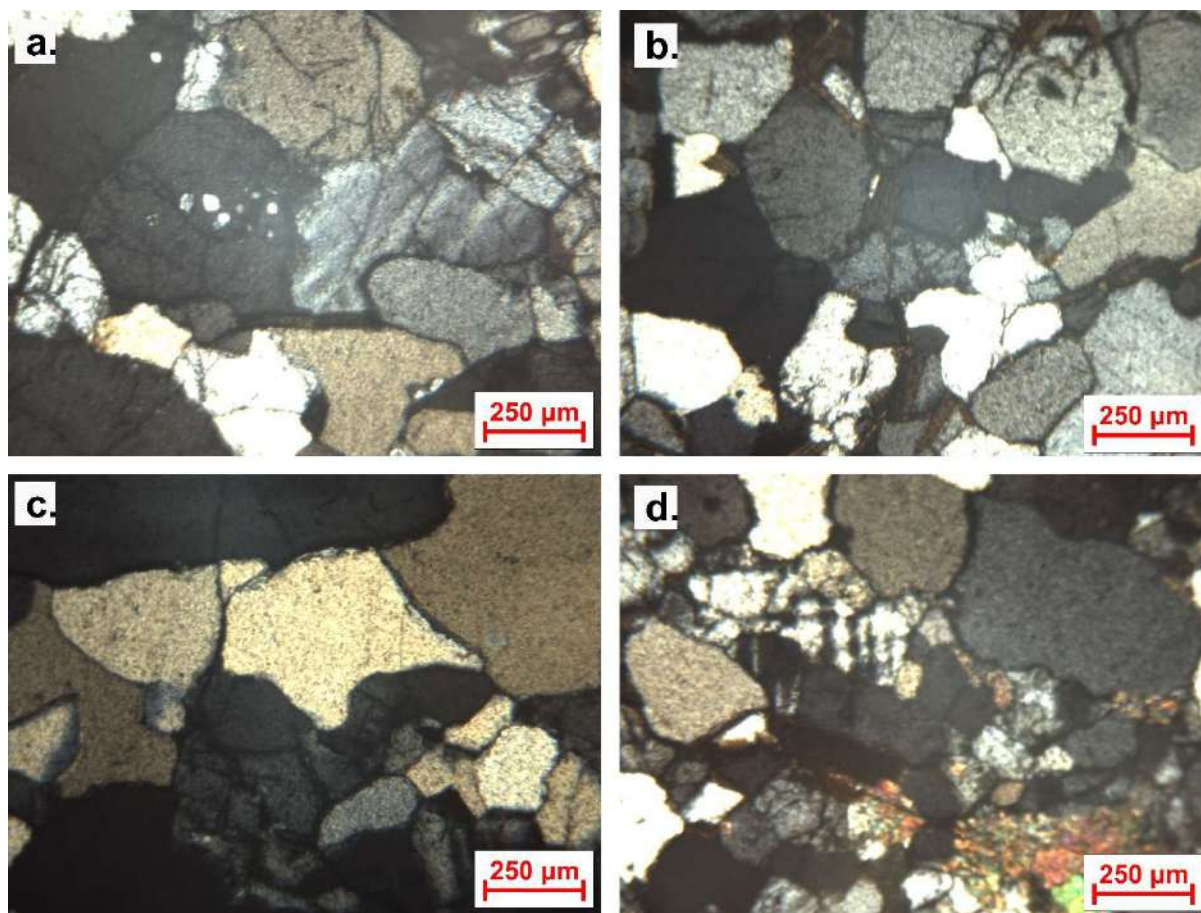
11.5 Petrographic Assessments:

11.5.1 Description of rock Masses

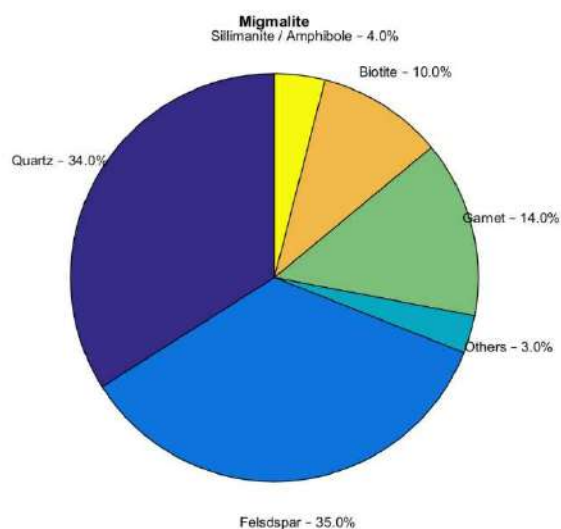
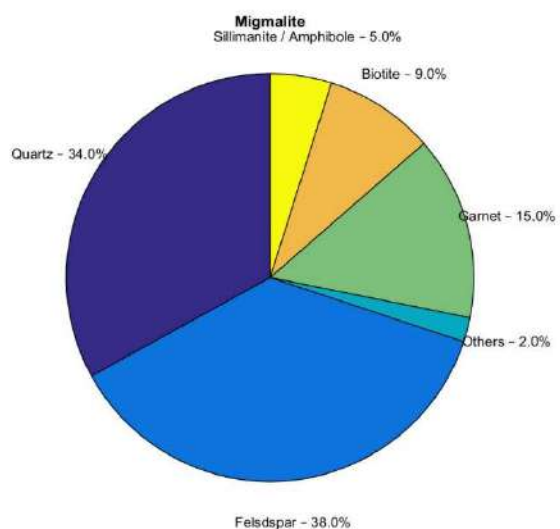
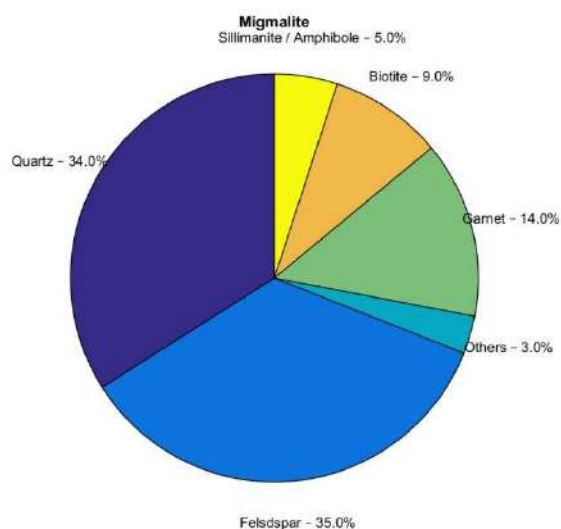
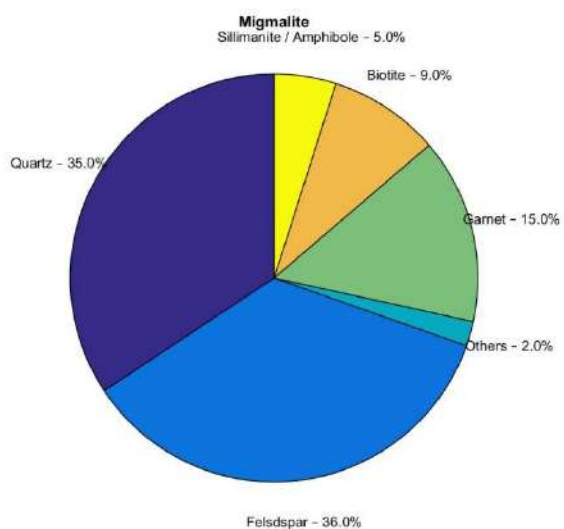
11.5.1.1 Migmatite

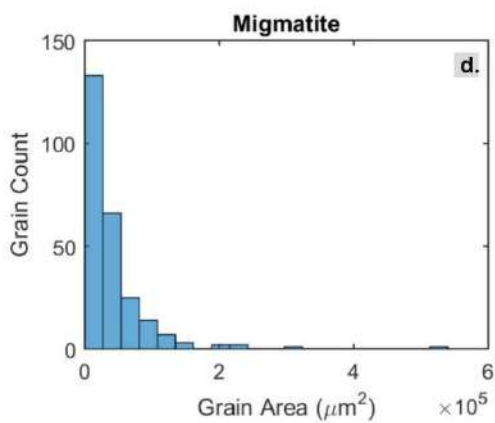
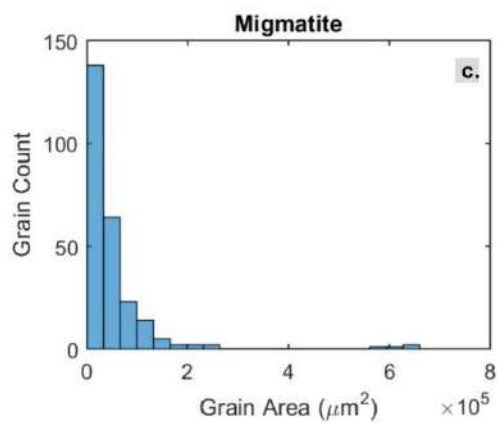
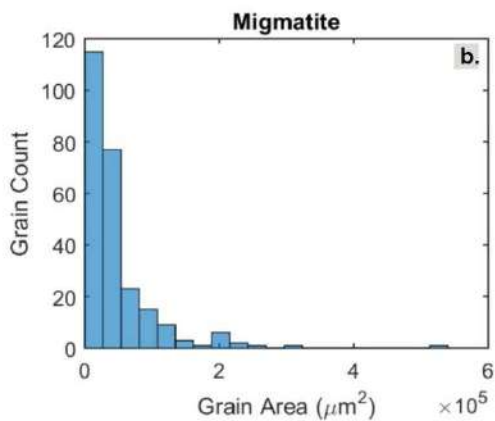
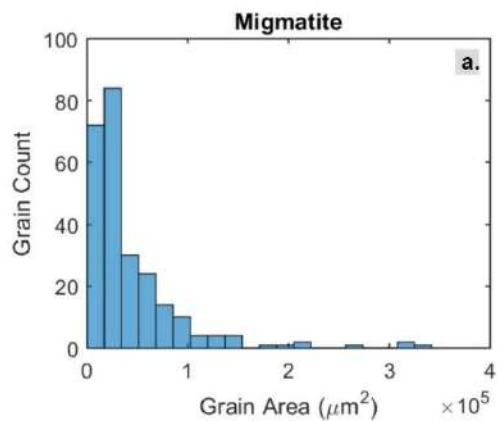
Migmatites of the Eastern Ghats consist of quartz- and feldspar-rich leucosome with garnet- and biotite-bearing melanosome/restite. Petrographic and modal descriptions are consistent with dominant quartz + feldspar (~60–70 %) and subordinate garnet and biotite as reported by Sarkar et al. (2007) and Sengupta et al. (2011).

11.5.2 Micro Photographs



11.5.3 Mineral percentage and grain size distribution





11.6 L section

