



Torkild Åndal – Ingeniørgeolog SVV utbygging

17.03.2021

Lange styrte kjerne hull

Erfaringer fra boring av lange retningsstyrte kjerne hull på prosjektet kryssing av Romsdalsfjorden

- Bakgrunn for prosjektet
- Plassering
- Anskaffelsen
- Boreproblemer
- Oppnådd resultater



Statens vegvesen

17.08.2021

Vedtatt konsept

- Romsdalsfjordkryssinga
- Møre-aksen
- Tautratunnelen
- Romsdalsfjordtunnelen
- Vik- Julbøen

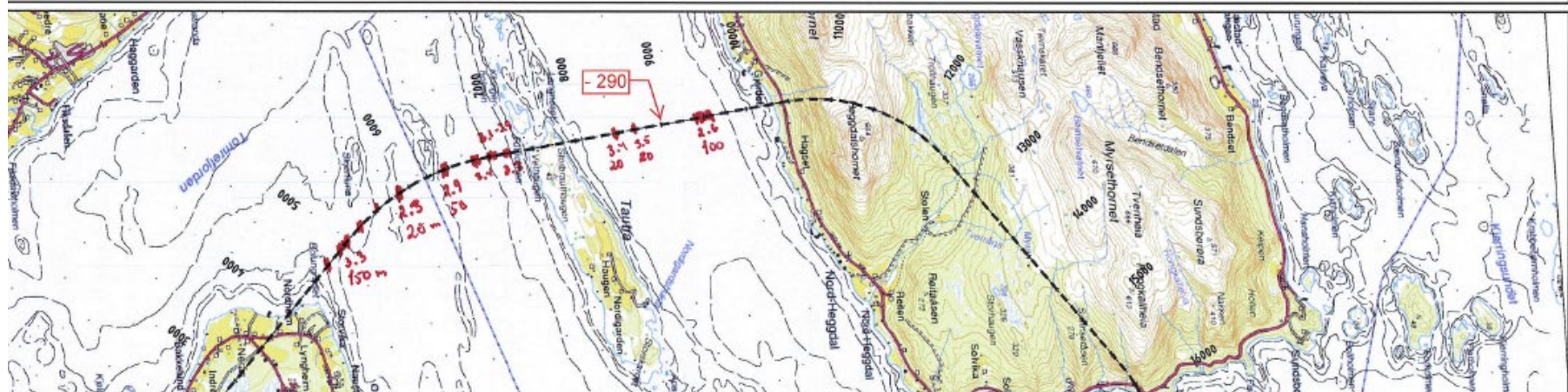
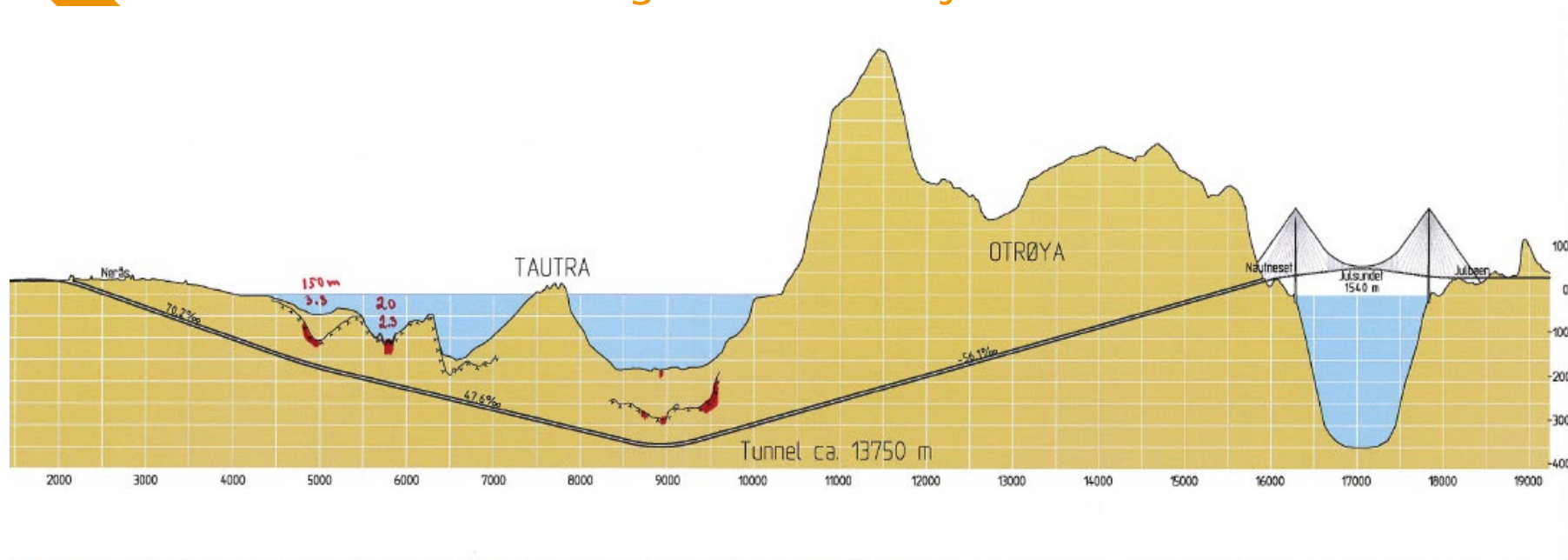




E39 Vik-Julbøen – kryssing Romsdalsfjorden



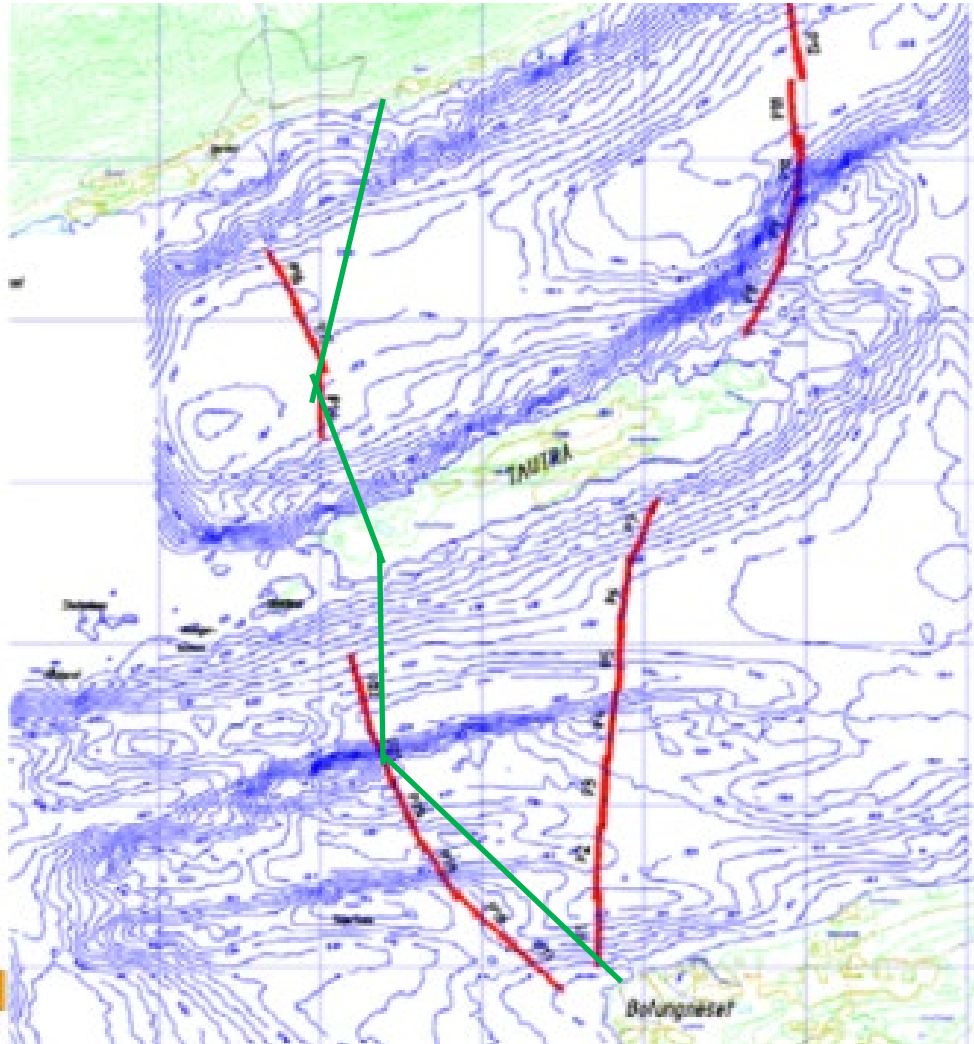
Svakhetssoner kartlagt med refraksjonsseismikk





Statens vegvesen

Boring av lange NQ-kjerneborhull



- Borehull 1 Heggdal 1141 m av 1535m
- Borehull 2 Tautra nord 1651 m av 1464m.
- Borehull 3 Tautra sør 1202 m av 1260m.
- Borehull 4 Bolungsneset 1602 m av 2153m.



Statens vegvesen

Anskaffelse

- Utlyst TED
- Faveo
- Devico direkte anskaffelse
- Pris 50%, kompetanse 20%, gjennomføringsevne 30%.
- Mange interessenter
- 3 tilbud





Tre tilbud

- Rockma AB, Sverige, 37 mill. NOK
- Entreprenørservice AS (Norge) med underentreprenør Asera mining AB, Sverige, 65 mill. NOK
- Fellesskap Zublin Spezialtiefbau Ges.m.b.H og Foralith Drilling Support AG, Tyskland, 225 mill. NOK
- Tillegg styring
 - Devico AS 20 mill. NOK

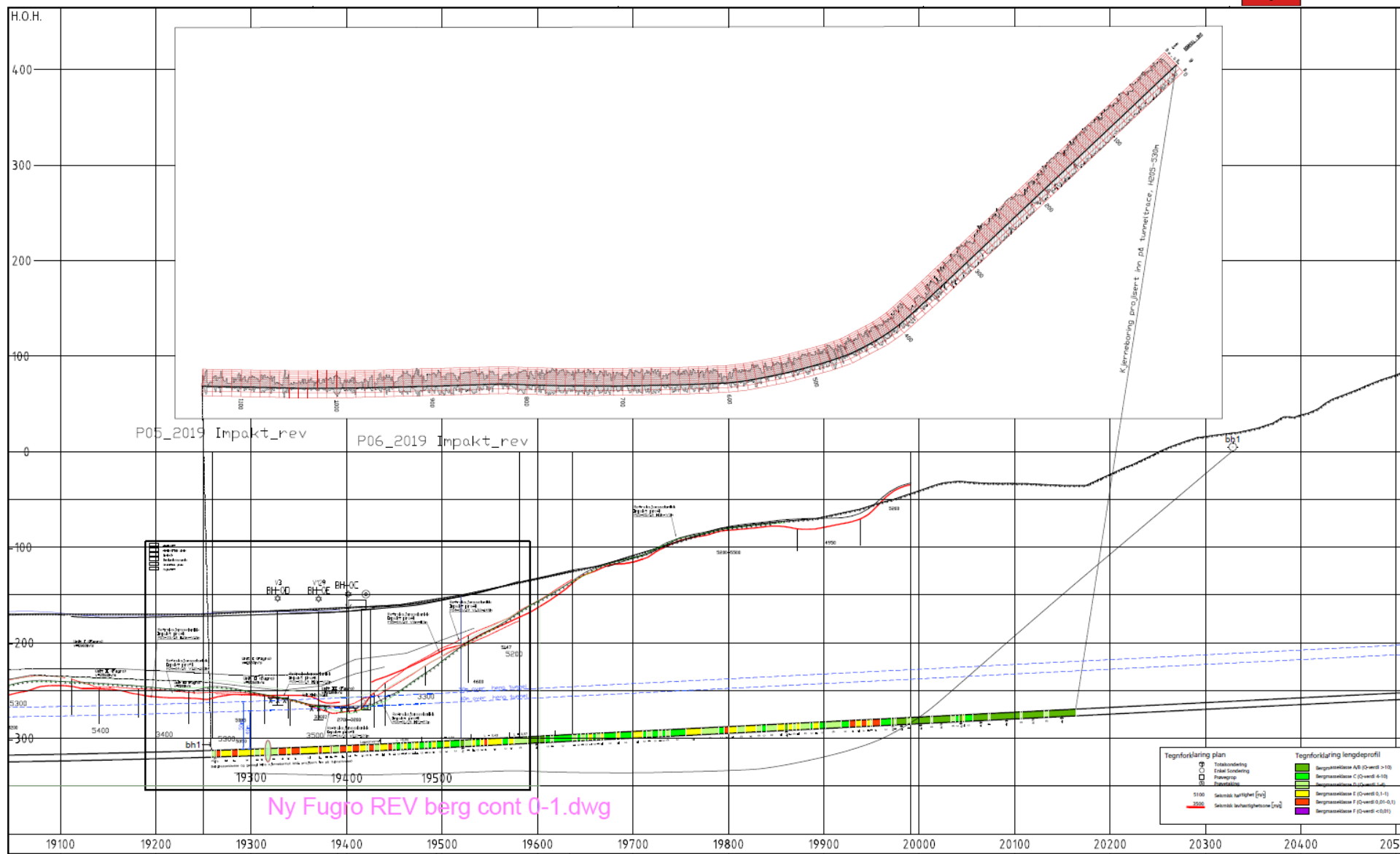


ens vegvesen



17.03.2021

Nord for Tautra



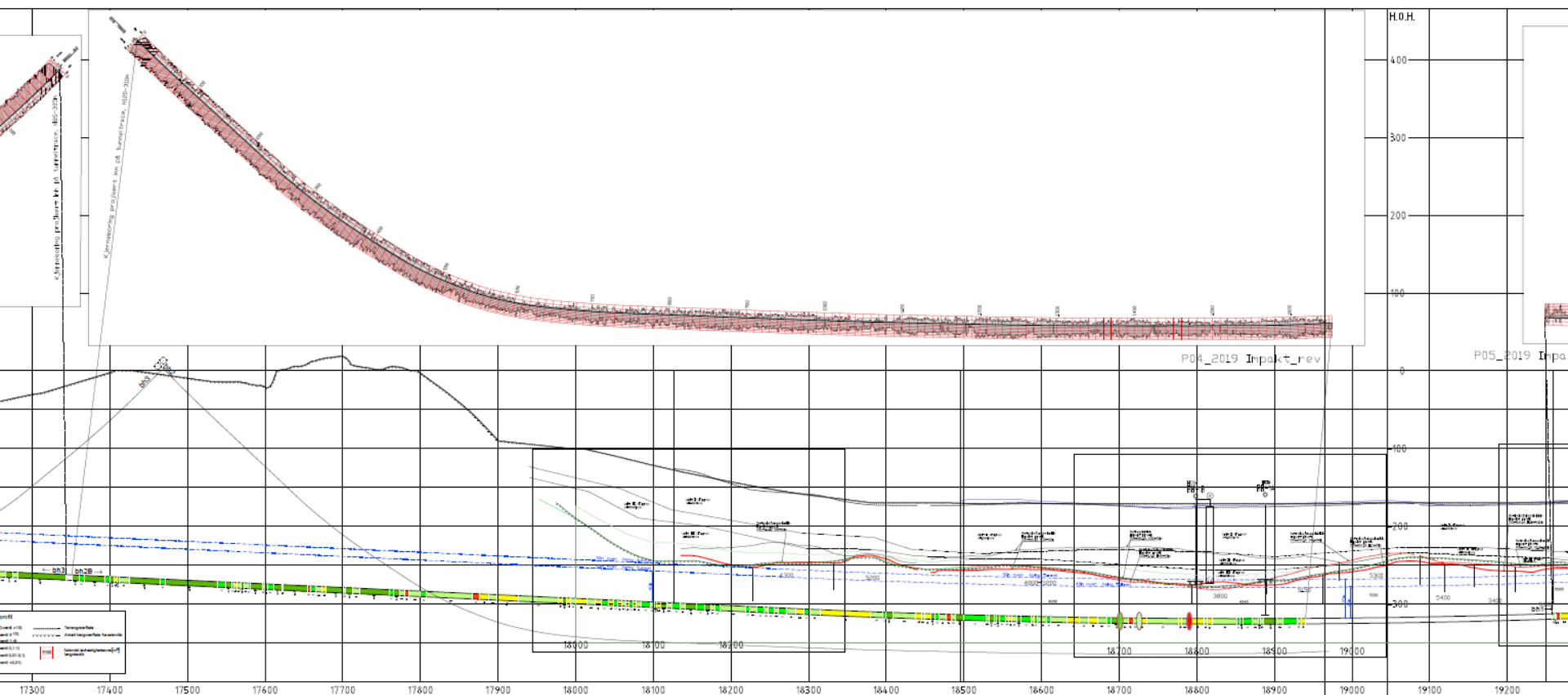
17.03.2021

Lange styrte kjernehull



Statens vegvesen

Nord for Tautra



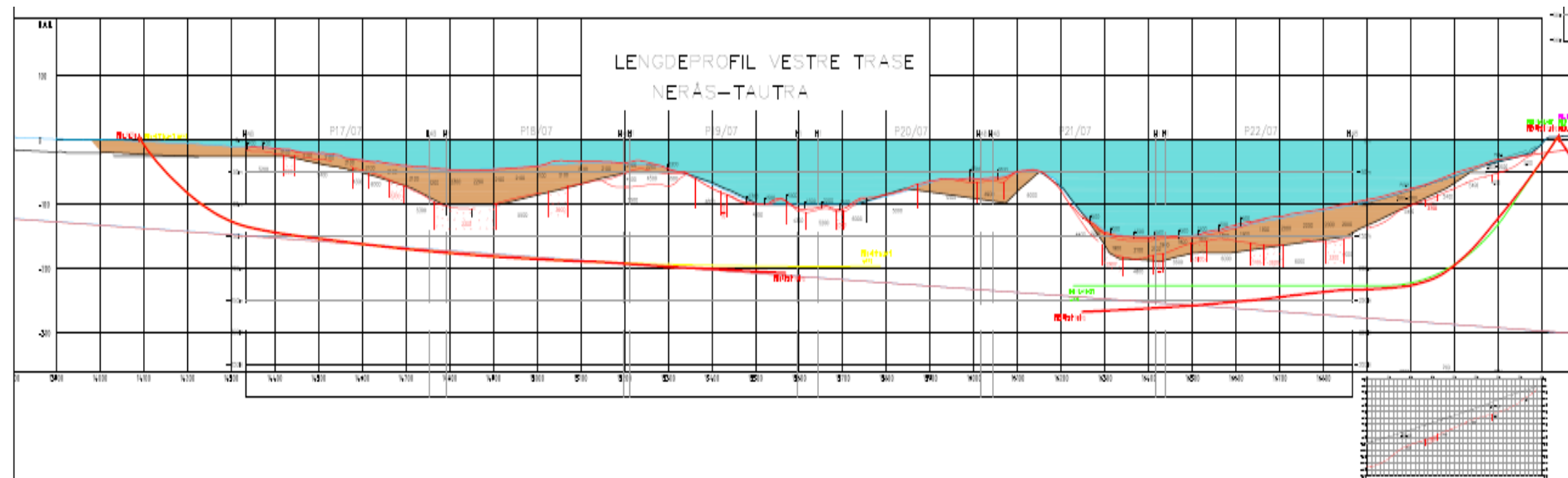
17.03.2021

Lange styrte kjerne hull



Statens vegvesen

Sør for Tautra



			Initial risk			Final risk					Resp.	
Ref.	Hazard description	Consequence description	Cons	Freq	RF	Risk reducing measures		Cons	Freq	RF		Actions / comments.
General risks												
1	Personal injury when handling drill string components.	Medical treatment of workshop, coring and rig personnel	4	3	15	Minimize risk by premaking assemblies offsite and by having makeup manual and proper handling equipment and facilities		4	4	10	Plan to assemble corebarrels offsite and have proper handling and transportation to site	Coring Personnel and Drilling Site/Workshop Personnel
2	Personal injury due to falling objects.	Medical treatment of workshop, coring and rig personnel	4	3	15	Maintain high awareness when handling tubulars and subs. Minimize number of personnel on drill site.		4	5	5	Follow detailed procedures for handling, lifting and securing, ensure all subs torqued up properly	Logistics, Coring and Drilling Personnel
3	Unplanned discharges, equipment malfunction, incorrect operations	Risk of injury to personnel, damage to Environment and reputation of Client and Operators.	3	5	10	Follow procedures, pay close attention to gauges, alarms, hydraulic and other flexibles		4	5	5	Use tested equipment and procedures, keep all planned maintenance to schedule, renew suspect equipment and avoid overpressure	Drilling Supervisor, Rig Personnel, Coring Personnel
4	Availability of equipment/ logistics.	Equipment is not on rig on time; delayed operations.	4	4	10	Programme logistics and verify schedules and equipment lists		4	5	5	Ensure all deliveries and assemblies are completed well ahead of required time	Drilling supv / Program Engineer / Logistics
5	Missing or lack of correct equipment due to wrong assembly or delivery.	Equipment is not on rig on time; delayed or revised operations.	5	3	3	Tool preparation prior to startup, spares inventory checked for fit before startup, inventory stocklist checked against requirements.		5	4	2	Full assembly and spares check of corebarrels, lifting and handling equipment at site and prior to operation	Drilling supv / Program Engineer / Logistics
6	Potential errors due to new equipment on rig (DeviDrill core barrel handling and operation)	Delayed operations, damage to equipment, debris downhole	4	2	20	Minimise Risks by using written procedures, familiarising personnel with procedures and constant experienced supervision by Devico service technician		4	3	15	pre-drilled hole needs to be as clean as possible and of correct diameters for planned assembly and operation.	Drilling superintendent, drilling and coring personnel
Continuous Coring Section												
7	Danger of wearing corebit prematurely due to use of incorrect coring/drilling procedures	Unable to make proper spud-in and coring progress in borehole, potentially have to trip string	4	3	15	Follow operational procedures for landing corebit, starting rotation and building up weight. Ensure all rig personnel have attended 'Tool box talk'.		4	4	10	Follow detailed procedures for core barrel operations	Drilling superintendent, drilling and coring personnel
8	Lack of Water Flush/Circulation in hole	Bit burning, corebarrel/pipe sticking, potential core run abandonment, trip string	4	3	15	Ensure sufficient back-up flushing capacity, monitor pump strokes and borehole discharge		4	4	10	Follow detailed procedures for corebarrel operations	Drilling superintendent, drilling and coring personnel
9	Insufficient hole cleaning	Hole problems, corebarrel sticking, core jamming due to blockage or lifting off base of hole. Abandonment of core run	4	4	10	Continuously monitor pump pressures, string torque and WOB.		4	4	10	Follow detailed procedures for corebarrel operations	Drilling superintendent, drilling and coring personnel

Lange styrte kjerne hull

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			Initial risk			Final risk					Resp.
Ref.	Hazard description	Consequence description	Cons	Freq	RF	Risk reducing measures	Cons	Freq	RF	Actions / comments.	
10	Lack of Penetration	Slow drilling rate, probably bit blocking, unable to complete core run, trip string	4	3	15	Maintain correct operating parameters, vary rpm and flush to try to increase penetration and core flow.	4	4	10	Follow detailed procedures for corebarrel operations	Drilling superintendent, drilling and coring personnel
11	Bit failure during directional section	No progress, possible erratic torque flush flow. Trip string	4	2	20	Bit has to be optimised for specific work and needs to be operated within specified parameters under devico service technician	4	3	15	Follow detailed procedures for directional corebarrel operations	Drilling superintendent, drilling and coring personnel
12	Over-/Underpressure in borehole due to water in/outflow (especially in weak rock zones)	pressure in/decrease in borehole	4	4	10	Control valve in corebarrel head to contain pressure while tripping out. WD-test, cementation of weak zone, redrill	4	4	10	Driller and directional coring consultant to continuously monitor operation and maintain acceptable operating	Drilling superintendent, drilling and coring personnel
13	Stuck String	Unable to continue coring if have to lift off bottom to allow rotation. End of coring run and string trip.	4	3	15	Optimize coring parameters, constantly monitor flush, torque, rpm and WOB. Continuously vary to maximise ROP with minimum	4	5	5	Follow detailed procedures for corebarrel operations	Drilling superintendent, drilling and coring personnel
Hole opening and coring from pre-drilled borehole											
14	Unable to reach desired borehole depth due to geology, weak rock zones (especially for boreholes exceeding 1600 m length)	Unable to continue coring with NQ size equipment	2	3	75	Use hole opener and redrill with bigger diameter, case upper section. Ensure completion is compatible with coring operation of bigger diameter	2	5	25	pre-drilled hole needs to be as clean as possible and of correct diameters for planned assembly and operation.	Drilling superintendent, drilling and coring personnel
15	Unable to spud corebit at base of pre-drilled section	Unable to continue coring	4	2	20	Ensure pre-drilled completion is compatible with coring operation of bigger diameter	3	5	10	pre-drilled hole needs to be as clean as possible and of correct diameters for planned assembly and operation.	Drilling superintendent, drilling and coring personnel
16	Danger of stripping corebit while spudding in at base of pre-drilled hole	Debris or sharp steel liner edges left at base of hole could damage or prematurely wear the core bit. No coring penetration, trip string	4	2	20	Ensure hole is as clean and free of obstruction as is possible	4	4	10	pre-drilled hole needs to be as clean as possible and of correct diameters for planned assembly and operation.	Drilling superintendent, drilling and coring personnel
17	Danger of wearing corebit prematurely due to use of incorrect coring/drilling procedures	Unable to make proper spud-in and coring progress in borehole, potentially have to trip string	3	4	20	Follow operational procedures for landing corebit, starting rotation and building up weight. Ensure all rig personnel have had a 'tool box talk'.	2	5	25	Driller and directional coring consultant to continuously monitor operation and maintain acceptable operating parameters	Drilling superintendent, drilling and coring personnel
18	Lack of Water Flush/Circulation in hole	Bit burning, corebarrel/pipe sticking, potential core run abandonment, trip string	4	3	15	Ensure sufficient back-up flushing capacity, monitor pump strokes and borehole discharge	4	4	10	Driller and directional coring consultant to continuously monitor operation and maintain acceptable operating	Drilling superintendent, drilling and coring personnel
19	Bit failure	Trip	4	3	15	Bit has to be optimised for specific work and needs to be operated within specified parameters by devico service technician	4	4	10	Driller and directional coring consultant to continuously monitor operation and maintain acceptable operating parameters	Drilling superintendent, drilling and coring personnel



Ref.	Hazard description	Consequence description	Initial risk			Risk reducing measures	Final risk			Actions / comments.	Resp.
			Cons	Freq	RF		Cons	Freq	RF		
20	Insufficient hole cleaning	Hole problems, corebarrel sticking, core jamming due to blockage or lifting off base of hole. Abandonment of core run	4	3	15	Continuously monitor pump pressures, string torque and WOB.	4	4	10	Do not lift bit of bottom of hole during core run or core catcher will lock and core run will have to be abandoned.	Drilling superintendent, drilling and coring personnel
21	Buckling of drillpipe	Damaged drillpipe	5	4	2	Establish max allowable WOB. When coring this will be a small percentage of maximum allowable to unacceptable string deflections	4	4	10	Provided procedures are adhered to and gauges are reading correctly this situation should not arise while coring	Drilling superintendent, drilling and coring personnel

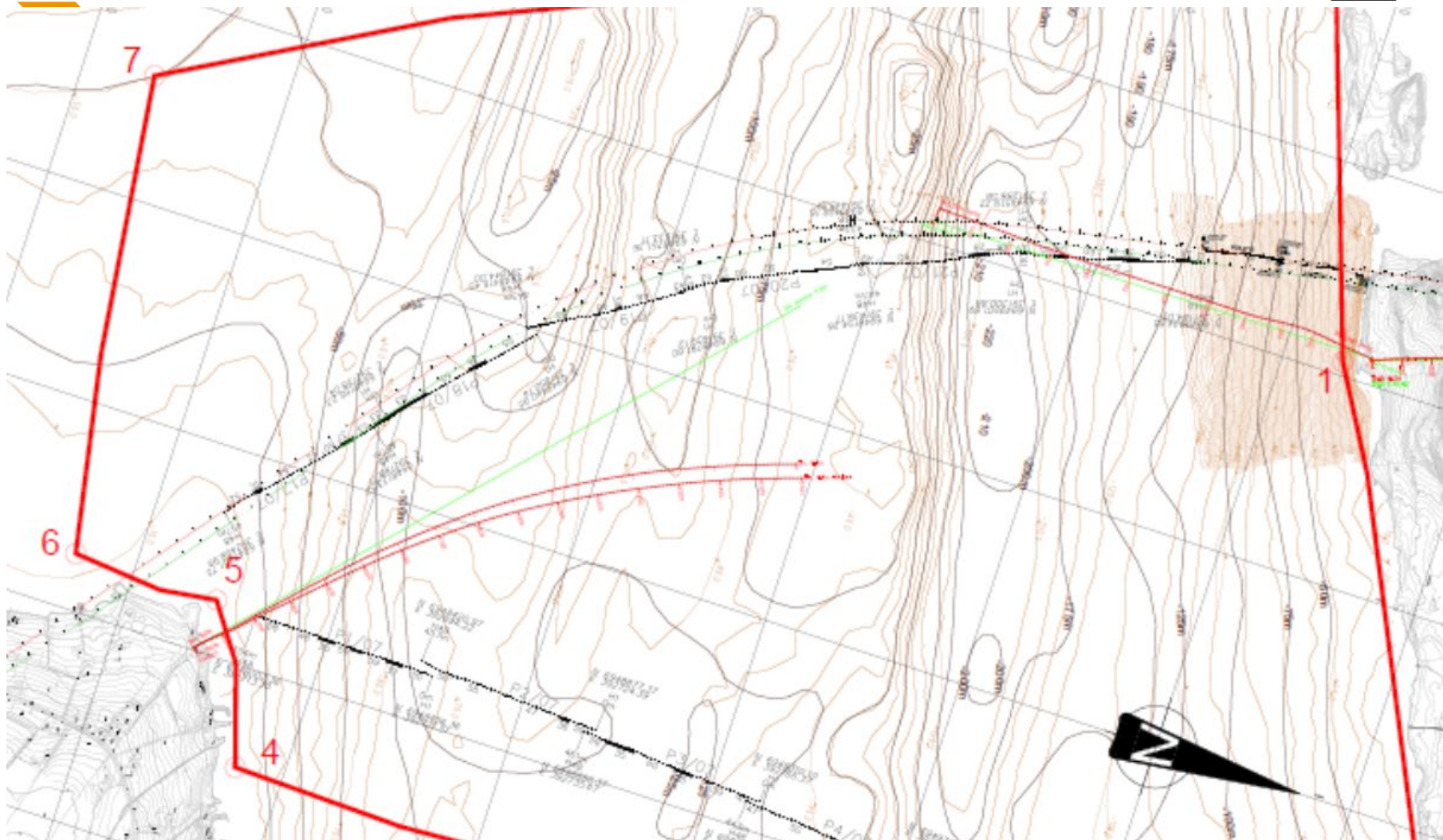
Comments and evaluation of the risk assessment

This risk assessment is based on the operations carried out for the geotechnical investigation by diamond core drillings for the tunnel project at Romsdalsfjorden. It does not cover any of the drill pad works or contractual issues of the boreholes 'per se' and only covers the operation of the core drilling part. The risk evaluation can be further assessed with regard to the whole project and any connected installations to ensure full compatibility in as risk-free a manner as practicable if the client wants to do so.



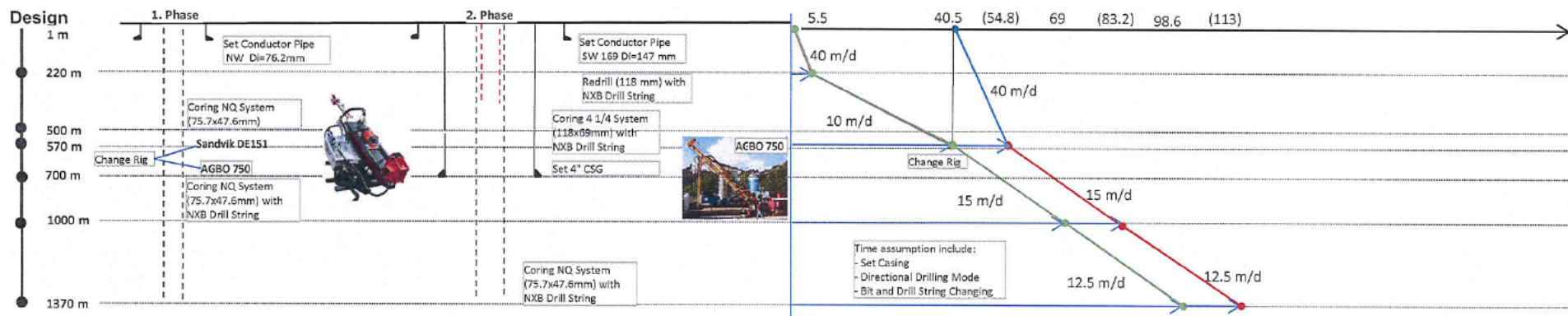
problemer underveis

- Borestreng ryker
 - Slitt
 - Ny maskin
 - Ustabil plattform
 - Famle i blinde
- Støper
- Vanntrykk forsvinner
- Borstreng går
- Retning/posisjon





No_3_Tautra_towards_south



Borehole Test [days]

	Hydraulic Permeability	Injection Ahead Drill Bit	Cementation of sections	Stabilizing	Install CSG guide	Standby	Sidetrack	Total
500 m	Single Packer: 50 x 2 h 4	0,5		5/4 x 1 d 1,25				
	Double Packer: 50 x 2 h 4							
1000 m	Double Packer: 50 x 4 h 8	0,75		5/4 x 1.5 d 1,9				
	Double Packer: 50 x 5 h 10,4			10/4 x 1.5 d 3,8				
1500 m								35



Statens vegvesen

Kjerne logging



17.03.2021

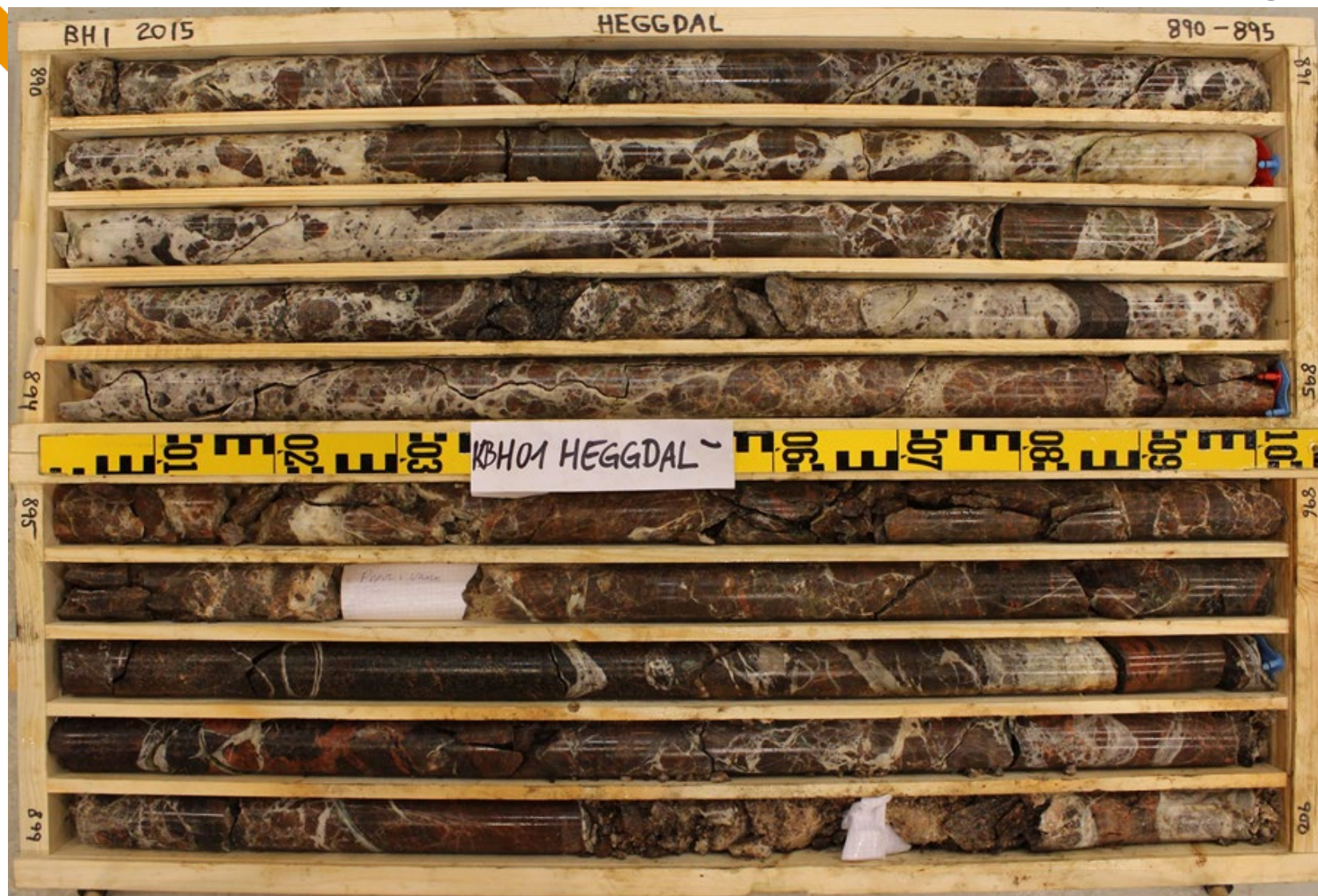
Lange styrte kjerne hull



- Heggdal 890-900



Statens vegvesen



Kjernelogging



Statens vegvesen

Kjernelogg E136 Vik – Julbøen

Borhull: KBH 04 Vik

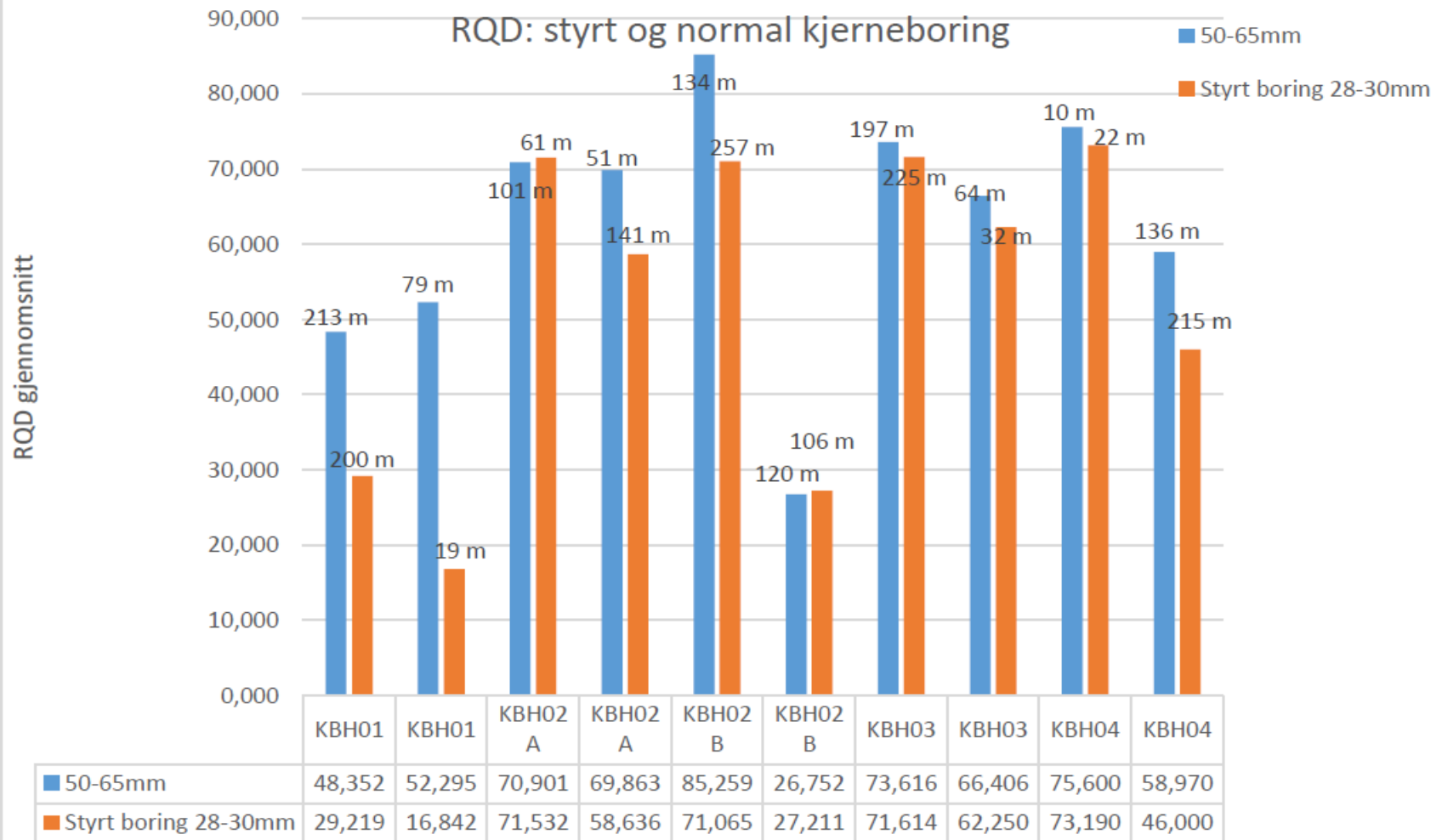
Dybde, m	Bergart	RQD	Jn	Jr	Ja	Jw	Q-verdi (SRF = 1)	Q-verdi - 0 1 100	støp	Lugeon	Merknad	Foto
281	Am.gn	72	5,0	2,0	2,0	1,0	14,4				Ø28 Granittisk gneis. Kornete	
282	Am.gn	52	4,0	1,5	2,0	1,0	9,8				Ø28 Amfibiolittisk gneis. Kornete (granittisk). Går over til linjete	
283	Am.gn	11	15,0	2,5	2,0	1,0	0,9				Ø28 Amfibiolittisk gneis. Linjete. Kjernetap (15cm) ca midten. "sukkerbit" start + slutt	
284	Am.gn	10	15,0	2,0	2,0	1,0	0,7				Ø28 Amfibiolittisk gneis. Linjete. Kjernetap i starten (15cm) noe "sukkerbit" sluttet.	
285	Am.gn	7	15,0	3,0	2,0	1,0	0,7				Ø28 Amfibiolittisk gneis. Linjete. Kjernetap i starten (15cm)	
286	Am.gn	15	15,0	1,0	10,0	1,0	0,1				Ø28. Amfibiolittisk sliregneis. Grålig farge. Noe rødt	
287	Am.gn	21	12,0	3,0	2,0	1,0	2,6				Ø28. Amfibiolittisk sliregneis. Grålig farge. Noe rødt	
288	Am.gn	51	9,0	2,0	1,5	1,0	7,6				Ø28. Amfibiolittisk sliregneis. Grålig farge. Noe rødt	
289	Am.gn	56	6,0	2,5	2,5	1,0	9,3				Ø28. Amfibiolittisk sliregneis. Grålig farge. Noe rødt	
290	Am.gn	32	15,0	1,0	10,0	1,0	0,2				Ø28. Amfibiolittisk sliregneis. Litt grønnskjær.	
291	8/Ø.gn	10	12,0	1,5	1,0	1,0	1,3				Ø28 (styring 28mm) Båndgneis. Folasjon 30°. Mange sprekker pga. skifting fra Ø50–Ø28. Tynne sprekker fylt av kalsitt.	
292	8/Ø.gn	13	12,0	1,5	1,0	1,0	1,6				Ø28 (styring 28mm) Båndgneis. Folasjon 30°. Mange sprekker pga. skifting fra Ø50–Ø28. Tynne sprekker fylt av kalsitt.	
293	8/Ø.gn	55	9,0	1,5	1,0	1,0	9,2				Ø28 (styring 28mm) Båndgneis. Folasjon 30°. Mange sprekker pga. skifting fra Ø50–Ø28. Tynne sprekker fylt av kalsitt.	
294	8/Ø.gn	56	9,0	1,5	1,0	1,0	9,3				Ø28 (styring 28mm) Båndgneis. Folasjon 30°. Mange sprekker pga. skifting fra Ø50–Ø28. Tynne sprekker fylt av kalsitt.	
295	8/Ø.gn	38	6,0	3,0	1,0	1,0	19,0				Ø28 (styring 28mm) Båndgneis. Folasjon 30°. Mange sprekker pga. skifting fra Ø50–Ø28. Tynne sprekker fylt av kalsitt.	
296	8/Ø.gn	32	9,0	3,0	2,0	1,0	5,3				Ø28. Båndgneis med folasjon 30°. Noen kvartsårer. Tynne sprekker fylt av kalsitt og leirbelegg og sandpartikler.	
297	8/Ø.gn	35	9,0	3,0	1,0	1,0	11,7				Ø28. Båndgneis med folasjon 30°. Noen kvartsårer. Tynne sprekker fylt av kalsitt og leirbelegg og sandpartikler.	
298	8/Ø.gn	52	9,0	3,0	1,0	1,0	17,3				Ø28. Båndgneis med folasjon 30°. Noen kvartsårer. Tynne sprekker fylt av kalsitt og leirbelegg og sandpartikler.	
299	8/Ø.gn	70	6,0	3,0	1,0	1,0	35,0				Ø28. Båndgneis med folasjon 30°. Noen kvartsårer. Tynne sprekker fylt av kalsitt og leirbelegg og sandpartikler.	
300	8/Ø.gn	47	6,0	3,0	1,0	1,0	23,5				Ø28. Båndgneis med folasjon 30°. Noen kvartsårer. Tynne sprekker fylt av kalsitt og leirbelegg og sandpartikler.	

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Lange styrte kjerne hull

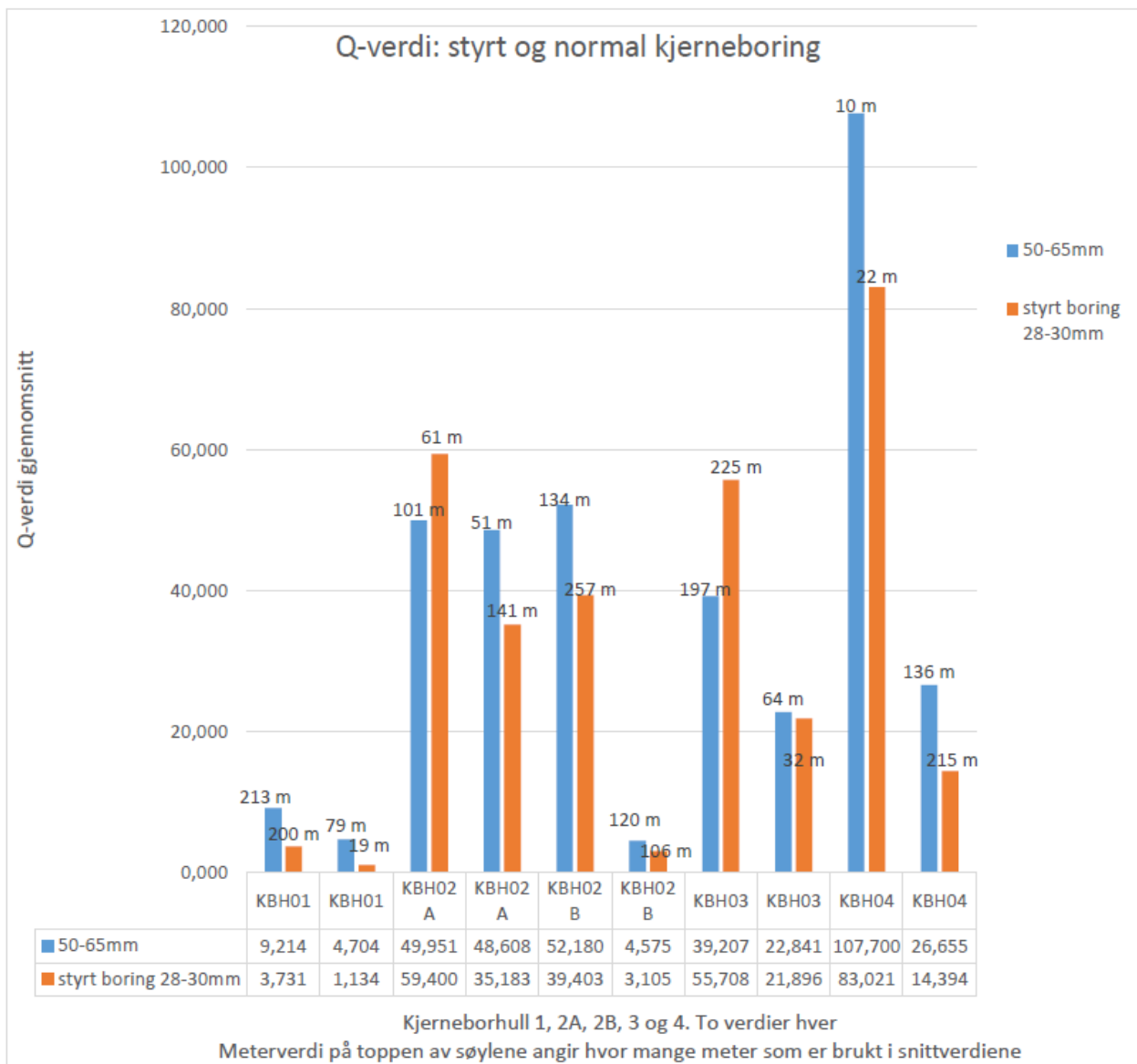


RQD: styrt og normal kjerneboring



kjerneborhull 1, 2A, 2B, 3 og 4. to verdier hver.

Meterverdi på toppen av søylene angir hvor mange meter som er brukt i snittverdiene

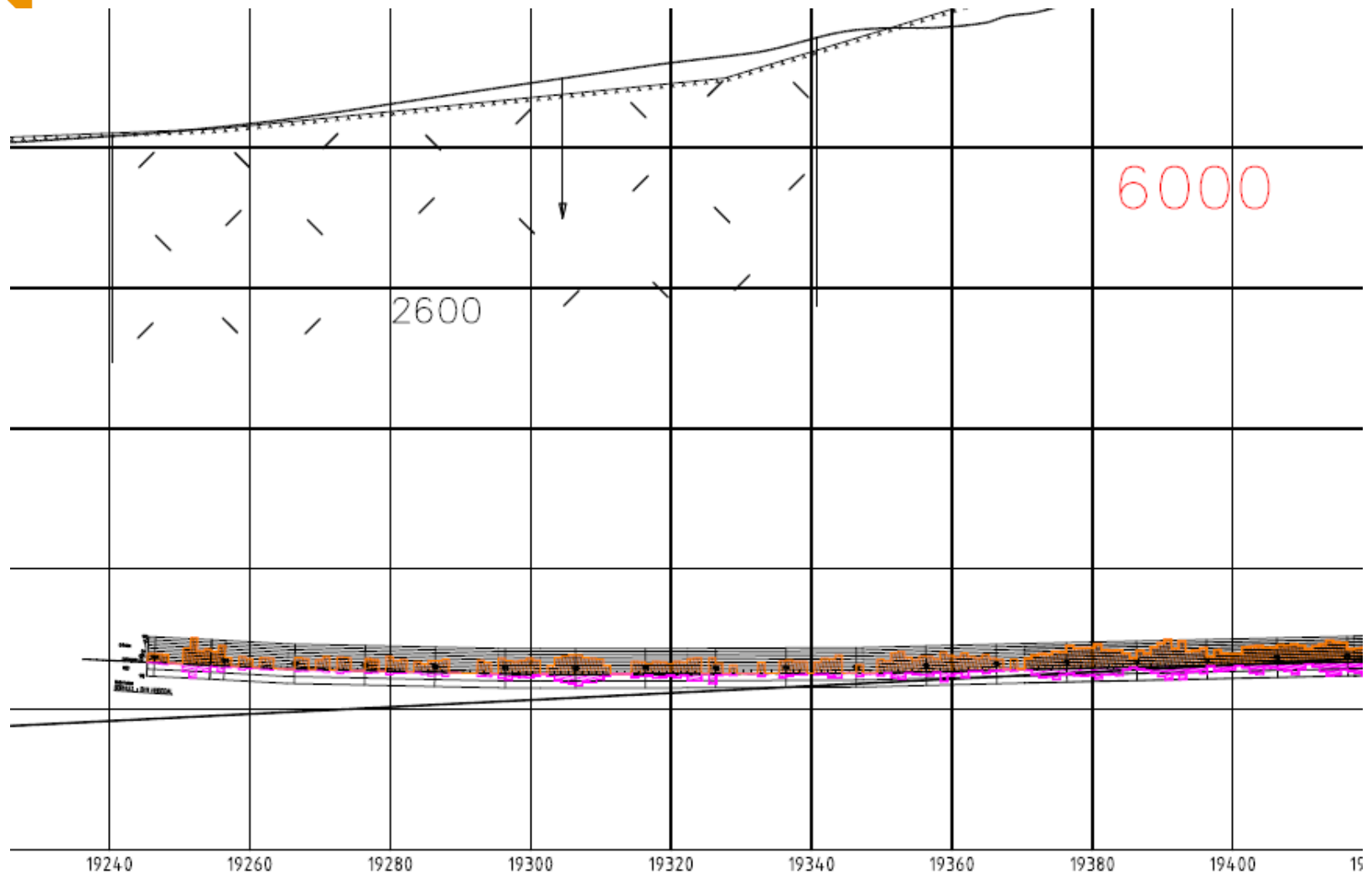




Kjerneboring og logging

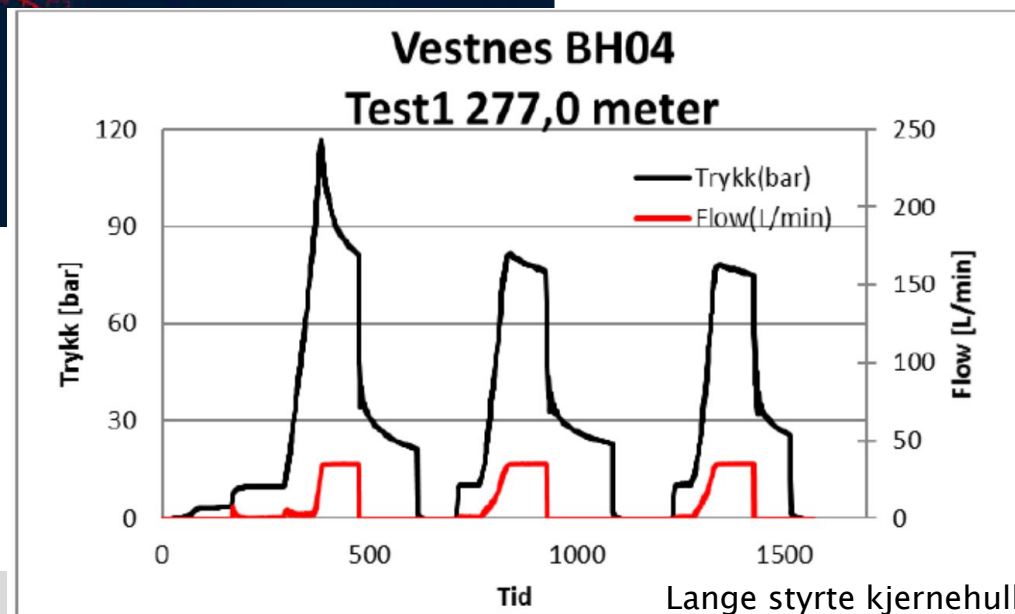
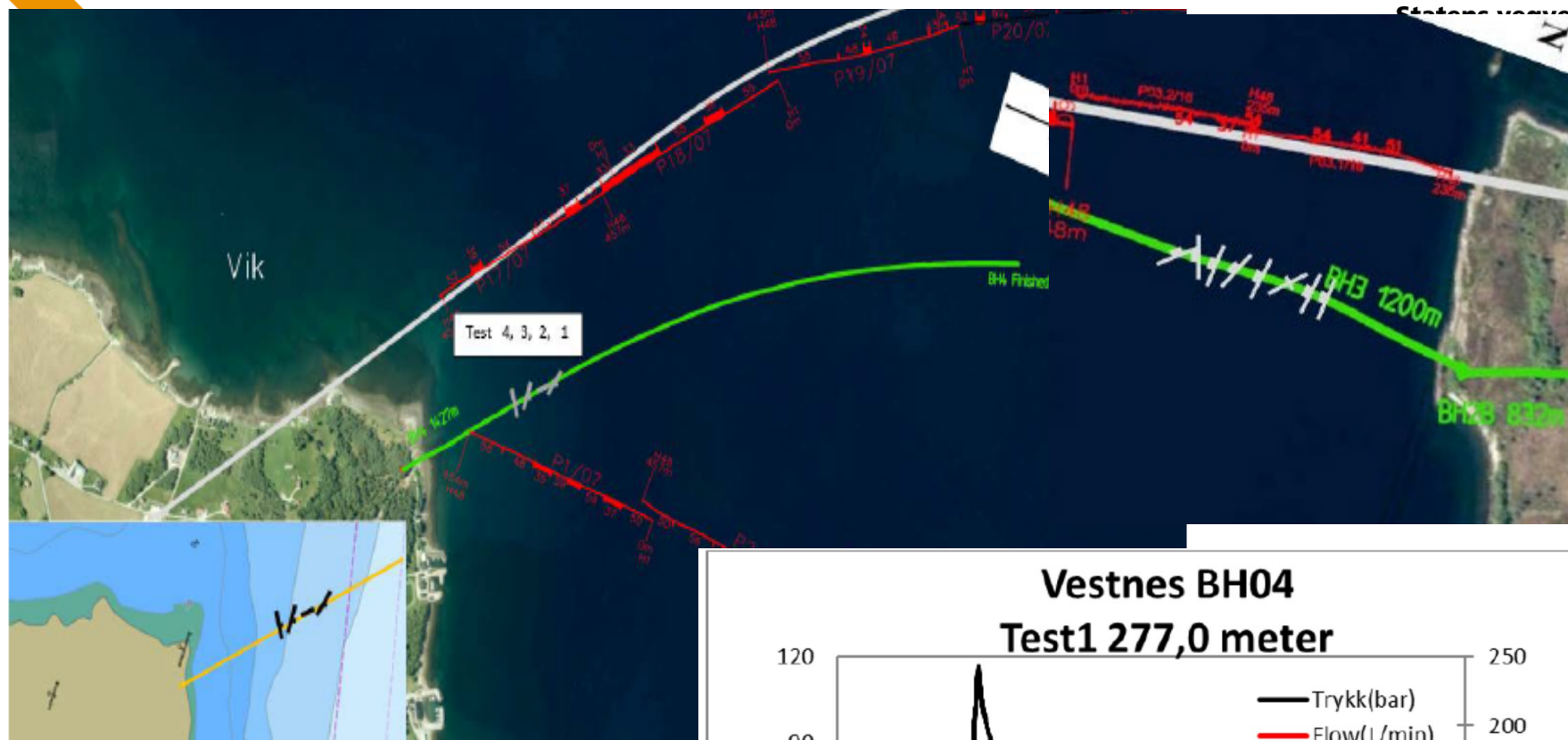


Statens vegvesen





Statens vassvesen



Figur 7 Splittekurve for test 1 277 m i BH04 som viser trykk og vannstrøm (flow) som funksjon av tid logget fra overflaten (tidsenhet i 0,25 s, 1000=250 s)

Borehullstomografi



Statens vegvesen

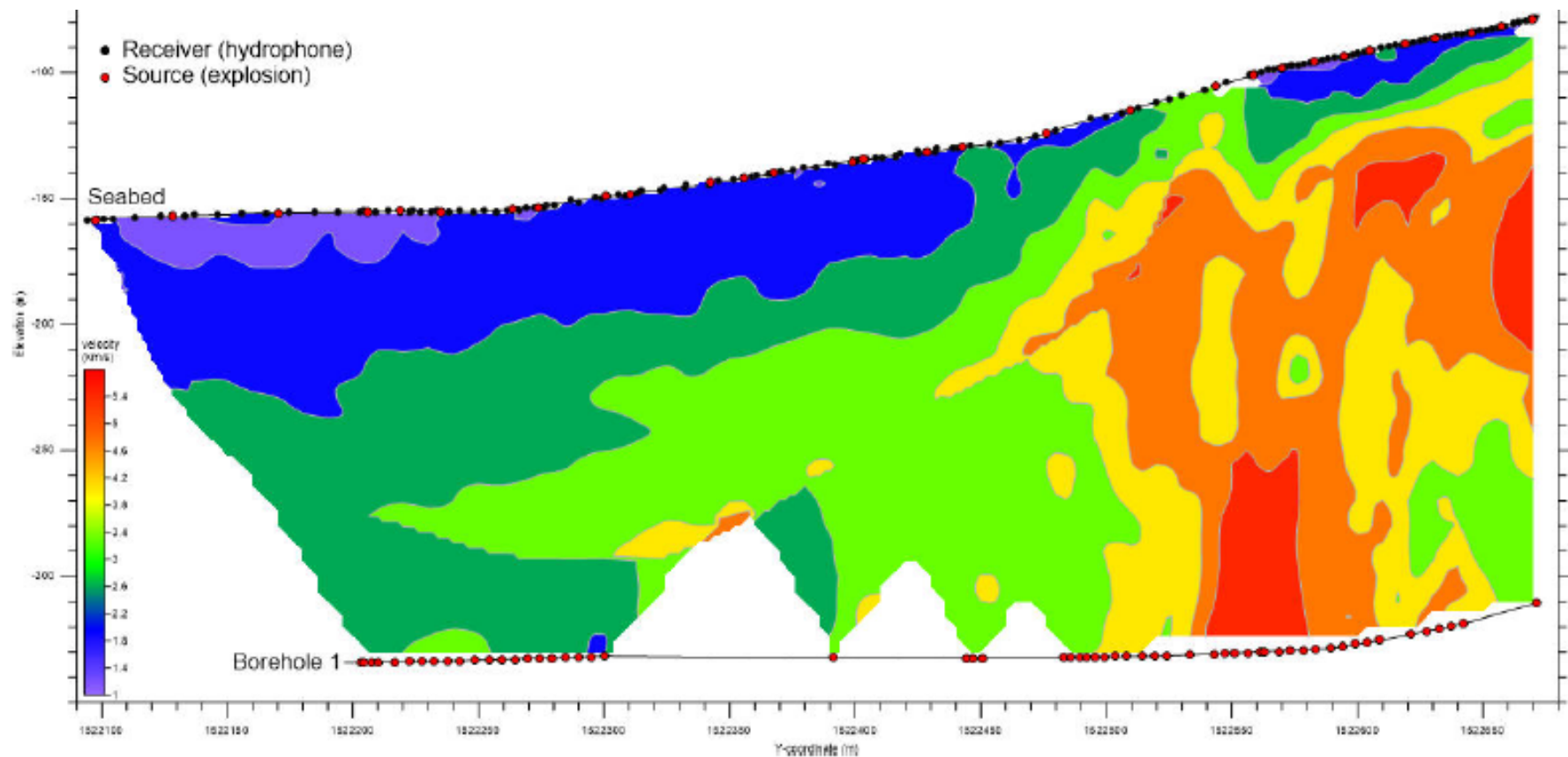


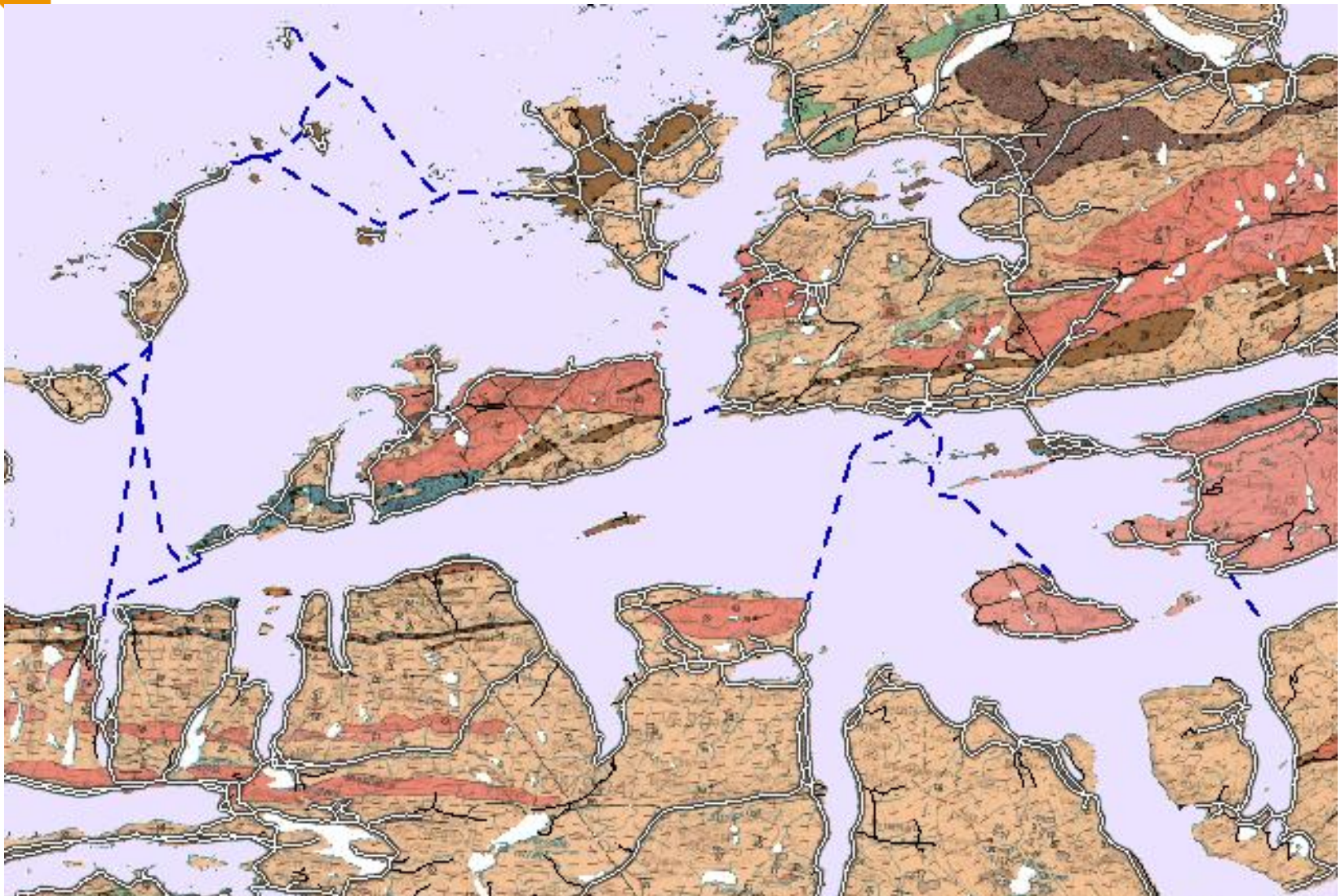
Figure 8. BH1 inversion models, section plots (Y, Z). Top: cross-hole model complete data



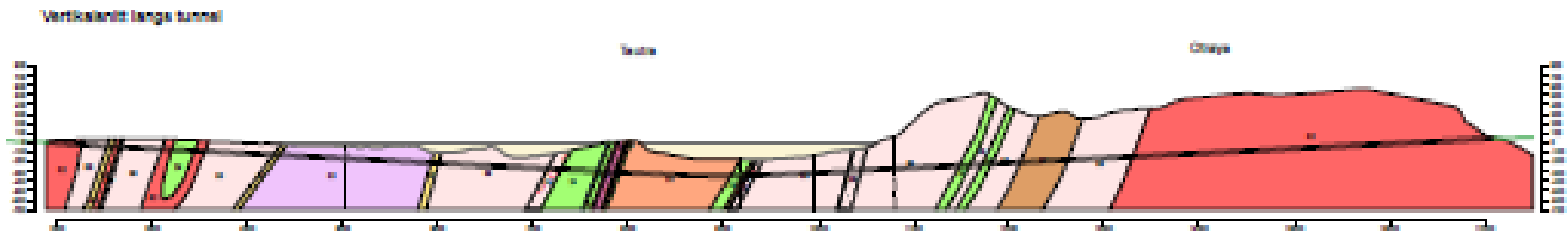
Foreliggende geologiske kart 1:250 000



Statens vegvesen



Mer detaljert geologisk kart 1:50 000 basert på ny feltkartlegging og magnetogrametri



Oppsummering

- Riktig i forhold til retningsstyrt boring fra skip?
 - Nesten 100% kjerner
 - Viktig info, men fortsatt usikkerheter
- Konkurranses grunnlag kunne helt klart vært bedre?
 - Hva kan vi få/tilby?
 - Hva kan etterspørres?
 - NGU stått for innkjøp? egen gruppe i SVV? Bransjen hatt egen innkjøpskontrakt?
 - Sjeldne konkurranser, vi er amatører.
 - Tilknyttet kompetanse er viktig
- Studentoppgaver: prosjekt og master
 - Overføring teknologi fra olje industrien
 - Kan hente ut mye mer info, MWD, tomografi, borehullslogging
- Obligatorisk på alle landtunneler (vann)? Skjer en del på bore fronten, DHM.
- Plexiglass
- Kostnader



Kostnader

- $1141\text{m} + 1653\text{m} + 1202\text{m} + 1602\text{m} + (656\text{m}) = 6251\text{m} + 200\text{ m}$ for brua.
- 140 mill.kr
- 21 700 kr/m
- 4 242 kr/m tunnel

- Spørsmål?



Statens vegvesen

Gamma Ray, kaliper, resistivitet, formasjonshastighet, sprekketetthet, sprekke åpning, RQD, +++

B1 Julbøen - Composite Log Image

VEDLEGG 6A

Lange styrte kjerne hull

