Green Well Westland

Detailed design

HON-GT-01-S2

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Revision change notice

Rev	*Brief Description of Change*
1.0	*Issued to client*
1.1	*Updated for comments*
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1.3	*Updated for comments*
1.4	*Updated for comments*

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1 Introduction

The well HON-GT-01 is drilled in 2011/2012. During drilling operations a technical sidetrack (S1) was required as a result of hole problems in the 6 ⅛" reservoir section. While running in the wire wrapped screen section the assembly got stuck. Attempts to fish & retrieve the lower completion were unsuccessful. The lower half of the assembly was therefore left in the hole and a sidetrack was drilled. The sidetrack was successfully completed with a wirewrapped screen section through the reservoir.

More details on the likely cause and can be found in the blockage investigation report:
HON-GT-01-S1; Blockage investigation v1.4 (26-03-2015)

The produced warmth from the geothermal well is used to heat the connected greenhouses. After ca. 2 years production a marked increase in required production pump power was noted. This was further investigated and a blockage was found inside the upper section of the 4 ½" lower completion: 20 meters below the liner hanger and 50m above the 7" casing shoe.

Attempts to remove the blockage in December 2014 with coiled tubing have been unsuccessful.

This detailed design document discusses the options for drilling a sidetrack HON-GT-01-S2 with the goal to reduce the chances of a similar type well failure in the future. The lessons from the blockage investigation included in the design are:

- Remove internal ledges in production tubing/liner
  - Use premium, internally flush, connections
- Use largest tubing ID possible
  - Reduce fluid velocities at high flowrates

From the report it is expected that the liner is severely damaged at a casing connection. Due to the uncertainties in the place of damage in the liner and the internal blockage, no liner cleaning and/or cutting operations are planned. One fishing trip is planned to attempt to retrieve the liner hanger and the section of liner above the damaged connection.

Address of the mining location:
Van Ockenburglaan 20
2675 SB
Honselersdijk

All depths are from **groundlevel**, unless otherwise specified.

2 Current well status

The well HON-GT-01-S1 has a blockage inside the 4 ½" liner at 2422m, 20m below the 7" x 4 ½" liner hanger and 50m above the 7" casing shoe. The location of the blockage is marked below in the well schematic (Figure 11). 7 meters of the blockage were milled out by CT. The remaining thickness of the blockage is unknown, but is expected to extend to at least several meters thick. After the injection/pressure test to 30bar it was confirmed that a clay plug would likely >10m in thickness to hold such pressure (Panterra Geoconsultants, verbal)

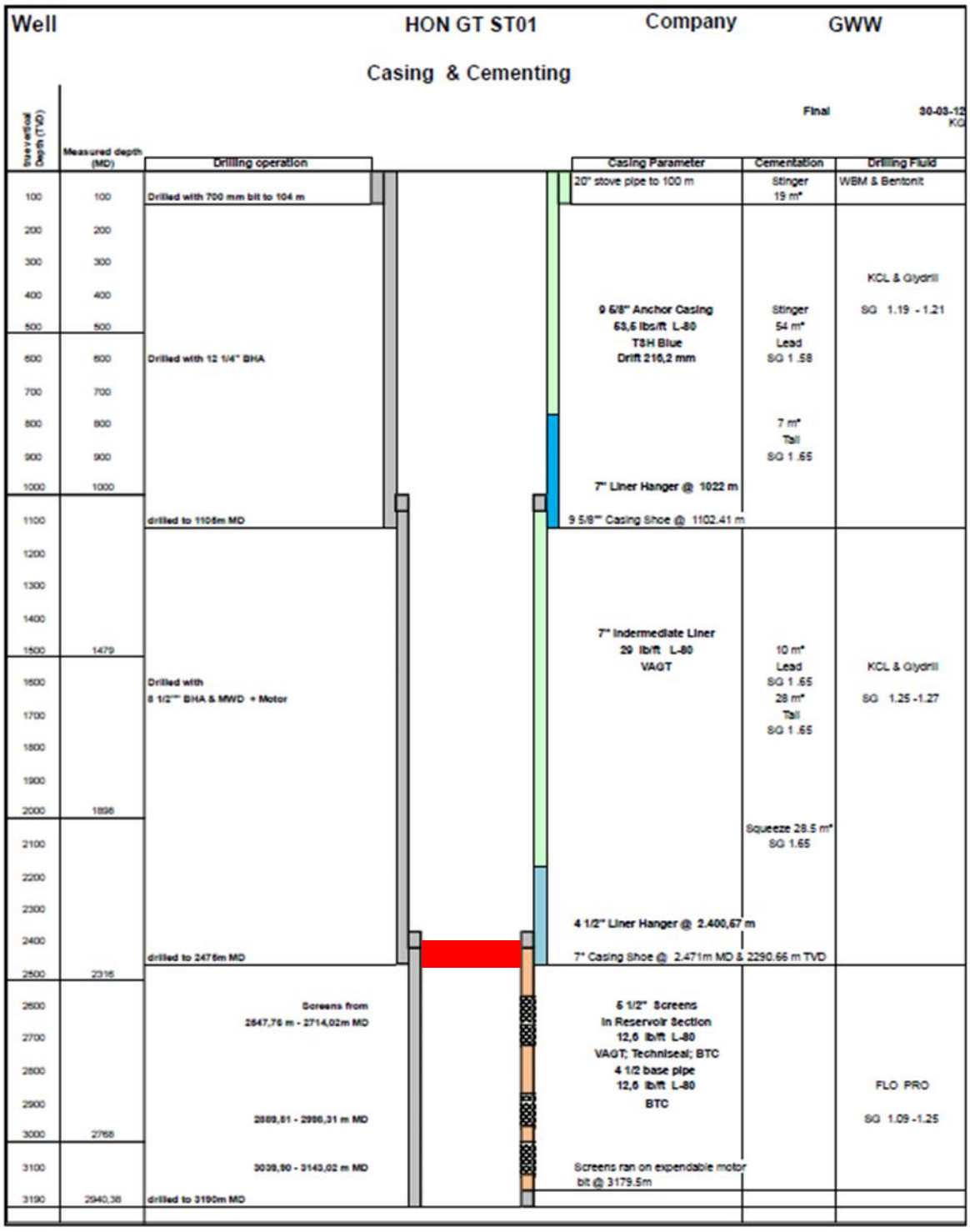

Figure 1: HON-GT-01ST1 well diagram. Plug marked in Red (thickness unknown).

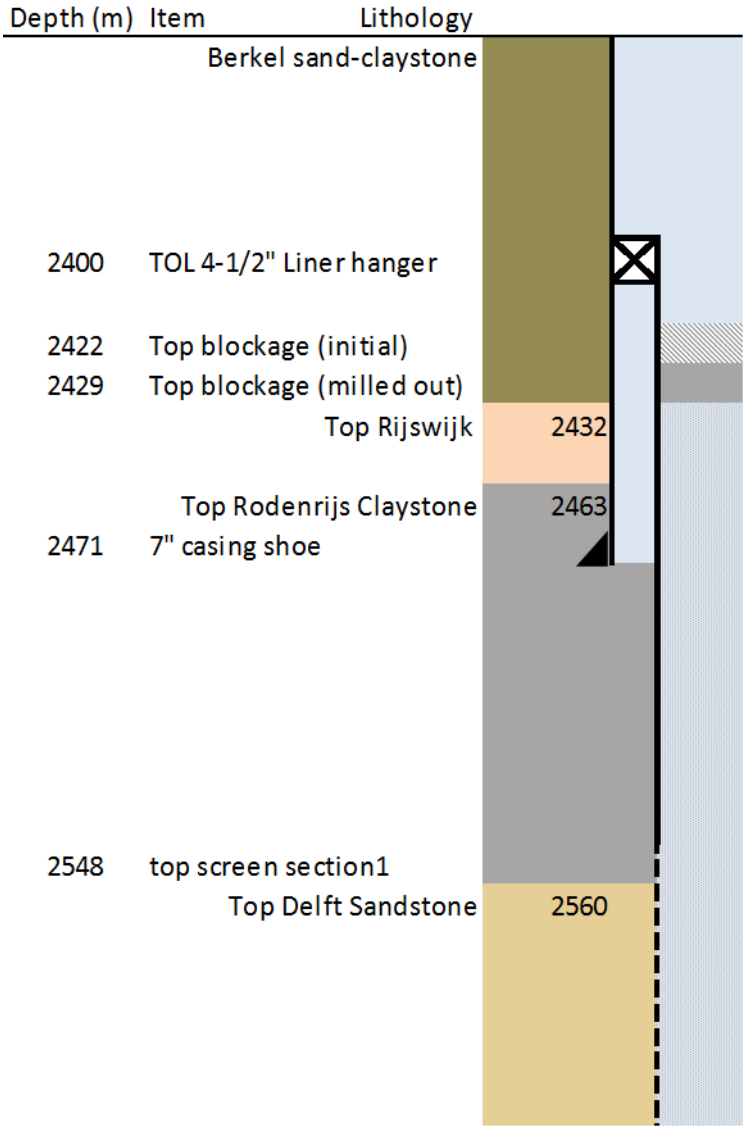

Figure 2: Zoomed in section of well schematic at area of interest(vertically approximately to scale)

3 Offset summary

The offset summary, due to its close vicinity is limited to the wells HON-GT-01(S1) and the adjacent injection well HON-GT-02. Both wells were drilled in the same campaign from December 2011 to April 2012.

3.1 List of available data

The following data has been provided for review
HON-GT-01(S1):

- End of well report T&A survey
- Final well report Geoservices
- Daily drilling reports
- 2014 slickline reports
- 2014 coiled tubing reports
- Liner hanger drawings

HON-GT-02:

- Final well report Geoservices
- Daily drilling reports

Since the obstruction in the well is situated in the lower part of the well, the new sidetrack is aimed to exit the existing wellbore as deep as possible. The offset review will therefore be limited to the lower section of the wells.

3.2 Geological summary

Below the geological summary of the well HON-GT-01 and the gas readings encountered in both offset wells.

Table 1: Geological summary HON-GT-01S1

Lithostratigraphic Column GreenWell				HON-GT-01	Total gas ppm	
Era	Group	Member	Lithology	*AH-GL Depth (m)*	HON-GT-01	HON-GT-02
Mesozoicum	Rijnland KN	Vlieland Clay KNNCM	Dark brownish-grey to grey claystone. Mica and very fine lignitic matter are common. The formation can be very silty to sandy. It's also slightly calcareous.	1920	200 - 10,000 CG up to 77,000	1000 - 6000 CG up to 29,000
		Berkel Sandstone KNNSB	Sandstone, light-grey, very fine- to coarse-grained, locally gravelly, lignitic, locally glauconitic or with sideritic concretions. Especially in the upper part calcareous cemented beds are common.	2227	1000 - 10,000 CG up to 51,000	3000 - 7000 CG up to 49,000
		Berkel Sand/Claystone KNCC	Alternation of fine-grained, argillaceous sandstones and brown-grey silty to sandy claystones. Locally sideritic concretions are present.	2270	0 - 9000 CG up to 40,000	1500 - 7000 CG up to 45,000
		Rijswijk Sandstone KNNSR	Light- to medium-grey sandstones with a very fine to medium and locally gravelly grain size; mica, lignitic matter and siderite concretions are common.	2434	0 - 9000 CG up to 22,000	2000 - 6000 CG up to 34,000
	Schieland SL	Rodenrijs Claystone SLDNR	Medium- to dark-grey and dark brown, silty to sandy lignitic claystones with laminated or contorted bedding, and lignite/coal beds. Traces of mollusc shells, pyrite and siderite.	2466	0 - 2000 CG up to 15,000	150 - 6000 CG up to 11,000
		Delft Sandstone SLDND	Light-grey massive sandstone sequence, fine to coarse-gravelly, fining upward, lignitic.	2553	200- 2700	150 - 3400
		Alblasserdam SLDNA	The upper part consists of grey to greyish brown, soft claystone with some intercalated red bands and well sorted, very fine loose sand, sandstone & siltstone.	2611	200 - 7400	150 - 17,000
				TD 3190		

3.3 Technical summary

HON-GT-01

8 1/2" section	1103m to 2470m shoe MD (base Ommelanden Fm to top Rodenrijs Claystone Mb)	
Mud type	KCl Polymer	
Mud Weight	1.24 sg	
F.V.	61	
Y.P.	23	
Several high-vis pills used in Holland Formation		
Losses (30m3/h) in Vlieland Claystone Mb between 2000 and 2010m MD, conditioned mud to 1.28sg.		
Now MW: 1.29sg, PV: 26, FV: 81, YP: 33, PH 8.8		
Losses (36m3/h) in Vlieland Claystone Mb at 2095m MD, conditioned mud to 1.28sg.		
Now MW: 1.25sg, PV: 19, FV: 68, YP: 20, PH 9.2		
6 1/8"section	2470m to 3190m MD (top Rodenrijs Claystone to Altena Gr)	
Mud type	Flo Pro	
Mud Weight	1.24 sg	
F.V.	41	
Y.P.	16	
Losses between 2478m to 2562m (Rodenrijs Clst to top Delft Sandstone Mb)		
Displaced mud system to FloPro WBM		
2495m	MW: 1.09 FV: 41, PV: 7, YP: 13, PH 9.7	
2515m	MW: 1.09 FV: 39, PV: 7, YP: 13, PH 9.5	Rodenrijs
2540m	MW: 1.13 FV: 41, PV: 7, YP: 12, PH 9.0	
2575m	MW: 1.14 FV: 37, PV: 6, YP: 11, PH 8.8	Delft Sst
2605m	MW: 1.14 FV: 39, PV: 8, YP: 12, PH 9	
2615m	MW: 1.14 FV: 40, PV: 8, YP: 12, PH 9.3	Alblasserdam
2690m	MW: 1.14 FV: 40, PV: 7, YP: 12, PH 9.3	

HON-GT-02

8 1/2" section	1172m to 2535m shoe MD (top Texel Fm to mid Rodenrijs Claystone Mb)	
Mud type	KCl Polymer	
Mud Weight	1.26 sg	
F.V.	61	
Y.P.	23	
Losses @ 2087m in Vlieland Claystone Mb up to 6m3/hr, dropped MW to 1.27, static losses 2m3/hr.		
At 2140m	MW: 1.26 FV: 59, PV: 21, YP: 17, PH 9.0	
Losses @ 2188m in Vlieland Claystone Mb up to 12m3/hr, dropped MW to 1.26, static losses 3m3/hr		
Balooning in base Vlieland Claystone Berkel Sandstone and top Berkel Sand-Claystone, POOH		
6 1/8"section	2535m to 3041m MD (mid Rodenrijs Claystone to Alblasserdam Mb)	
Mud type	Flo Pro	
Mud Weight	1.10 sg	
F.V.	45	
Y.P.	5	
2595m	MW: 1.11 FV: 48, PV: 9, YP: 17, PH 9.3	base Rodenrijs Clst

4 General well design considerations

The items listed below are taken into consideration

4.1 Production & commercial considerations

In order to optimize the production capacity/running cost and the repair costs the following are taken into consideration for the well design:

- Largest size lower completion as practically possible.
  - Minimize pressure losses during production as result from ID
- Perform sidetrack at lowest exit-point from wellbore as possible
  - Minimize length of new hole
  - Minimize pressure losses in small ID lower completion length
- Sidetrack length is not required to extend much into the Alblasserdam member
  - >80% of current production contribution is from Delft Sandstone
  - Drill to first claystone within Alblasserdam member
  - Minimize sidetrack cost by length reduction.
- Reservoir characteristics
  - Reservoir properties (permeability) are reducing towards the east
    - Best target reservoir found to west of original target.

The production should be limited to 170 m^3/hr to not exceed the API recommended fluid velocity in the injection well.

4.2 Anti-collision

Due to the presence of the well HON-GT-01 and S1 in the reservoir section of the well, the new sidetrack will be required to keep sufficient distance from the existing wellbores. HON-GT-01S1 was kicked off from HON-GT-01 to the bottom right (east) at 2488m (Figure 3). Special care is required when making a new sidetrack below 2488m.
To minimize the risk of collision the plan is to kick off from the well (either with sidetrack, or in open hole) and keep tangent, away from the existing wellbore(s)

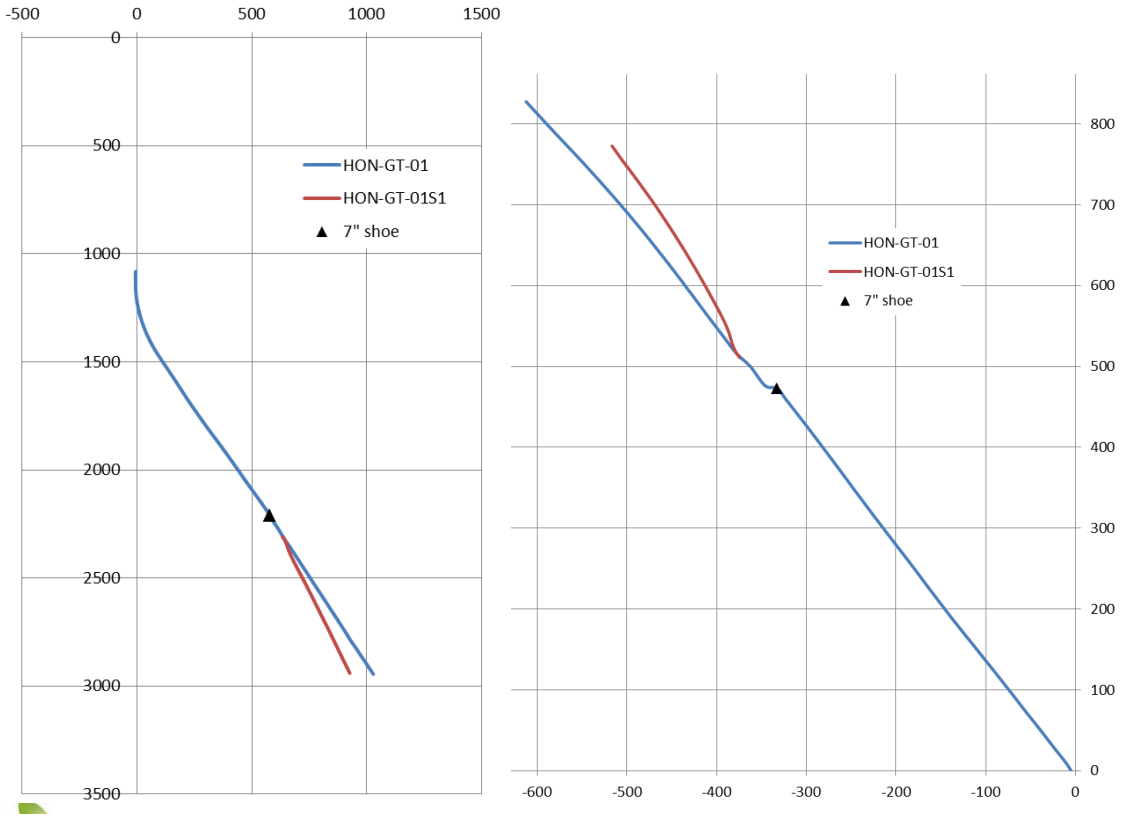

Figure 3: Well path plots HON-GT-01(S1). Vertical section (325 azimuth) left & horizontal section (right)

4.3 Pore pressures

Hydrostatic pressures are expected from the original well and S1.

Losses have been encountered in two intervals:

- Vlieland Claystone (2000-2200m both wells)
- Rodenrijs Claystone (Below 7" shoe – HON-GT-01)

The losses in the Vlieland Claystone have occurred at depths above the highest foreseen sidetrack point, so are not considered relevant.

Losses in the Rodenrijs Claystone from 2478 to 2522m in the well HON-GT-01 while drilling with a 1,24 sg mud. In HON-GT-01S1 no losses were encountered with 1,09 sg, which was later increased to 1,16sg while RIH screen section without losses.
Partial losses, as encountered in a dense claystone like the Rodenrijs are most likely related to (small) local fractures.
In HON-GT-02 this section was drilled with 1,10 sg mud without losses.

4.4 Formation strength

An FIT (limit test) was performed in the Rodenrijs claystone below the 7" shoe to 1,57 sg.

4.5 Temperatures

The reservoir fluid temperature from the Delft Sandstone is measured at 86ºC during production tests.

4.6 Hydrocarbons

Gas readings have been monitored while drilling the wells HON-GT-01 S1 & 02. An overview of the gas readings can be found in Table 1.
Highest gas readings have been reported in the Rodenrijs Claystone, above the Delft Sandstone:

- Background gas
  - <2.000 (HON-GT-01)
  - <6.000 (HON-GT-02)
- Connection gas
  - Up to 15.000 (HON-GT-01)
  - Up to 11.000 (HON-GT-02)

5 Well design

With the above considerations (Chapter 4) the design has been set up for the sidetrack. Three variations are discussed per item based on the ability to retrieve the current lower completion:

- Full retrieval
- Partial retrieval (to ca. 20m below 7" shoe)
- Partial/no retrieval (< 20m free below 7" shoe)

In all cases a 6 ⅛" hole section is planned to be drilled from either below the 7" casing shoe, or through a window in the 7" casing shoe.

5.1 P&A HON-GT-01-S1

The old section of the well (HON-GT-01-S1) will be required to be sealed off to prevent interference from the damaged wellbore into the new well. Depending on the retrieval success the following is planned:

- Cased hole exit:
  - Bridgeplug installed below whipstock to seal off S1
- Open hole exit:
  - Cement plug below 7" shoe to seal off S1 & accommodate open hole sidetrack

5.2 Trajectory

In case of full retrieval of the entire lower completion the original well trajectory can be re-used. This is however very unlikely since the screens will likely separate from the base pipe while POOH. This as result of the expected high strength of the bond between screens and the reservoir rock (sandstone) and the relative weak welds between the screens and base pipe.

In case of partial or no retrieval a kick off will be required from the original well to sidetrack past the old lower completion. To prevent hole collapse at the kick-off point the kick-off is made towards a side of the well (left or right along azimuth).
Based on the geological data it was found that reservoir properties (permeability) towards the east of the well decrease. Therefore a kick off from the main bore towards the west (left) is planned. In case of a whipstock exit the whipstock will need to be positioned such that the ledge side is stable on the borehole wall, thus requiring an exit to the upper left of the well.

From the kick off angle is built for a short section to ensure the trajectory of S2 does not intersect the original well HON-GT-01.

Well azimuth is planned at ca. 315º
Hole inclination will be similar to existing well: 25-30º

Well TD is planned 10m below base Delft Sandstone.

5.3 Drilling fluids

The following type drilling fluid is required to drill the hole section through both Rodenrijs Claystone and Delft Sandstone.

- 1,10 sg
  - Prevent losses in Rodenrijs Claystone
- KCl/glycol inhibition
  - Hole stability through claystones
- Solids free/low solids
  - Minimize reservoir damage

5.4 Logging

Logging will be limited to the following MWD tools:

- Directional
- GR,

5.5 Completion

Lower completion is planned with WireWrappedScreen liner on 4 ½" base pipe, as this is already in stock with GreenWell. Between the screen section and the liner hanger 5" pipe is planned to reduce friction losses while producing. Alternatively 5 ½" flush casing could be used, if readily available.
Alternatively 5" base pipe with 5 ½" OD screens can be used.

Larger size base pipe (5 ½") with screens (6" OD) should not be used due to the limited ID (6.184) of the 29ppf 7" (special drift) casing installed in the well.

5.6 Testing

Well testing will be performed on the well after installation of the lower completions (WWS)

5.7 Well schematic

The three options are shown below in detail for the reservoir section.
The final design for the first options will be the same, however partial retrieval will require the drilling of a new 6 ⅛" hole to 2620m. In case no, or insufficient, retrieval a whipstock will be required above the original liner hanger, thus the new liner hanger will be positioned higher.

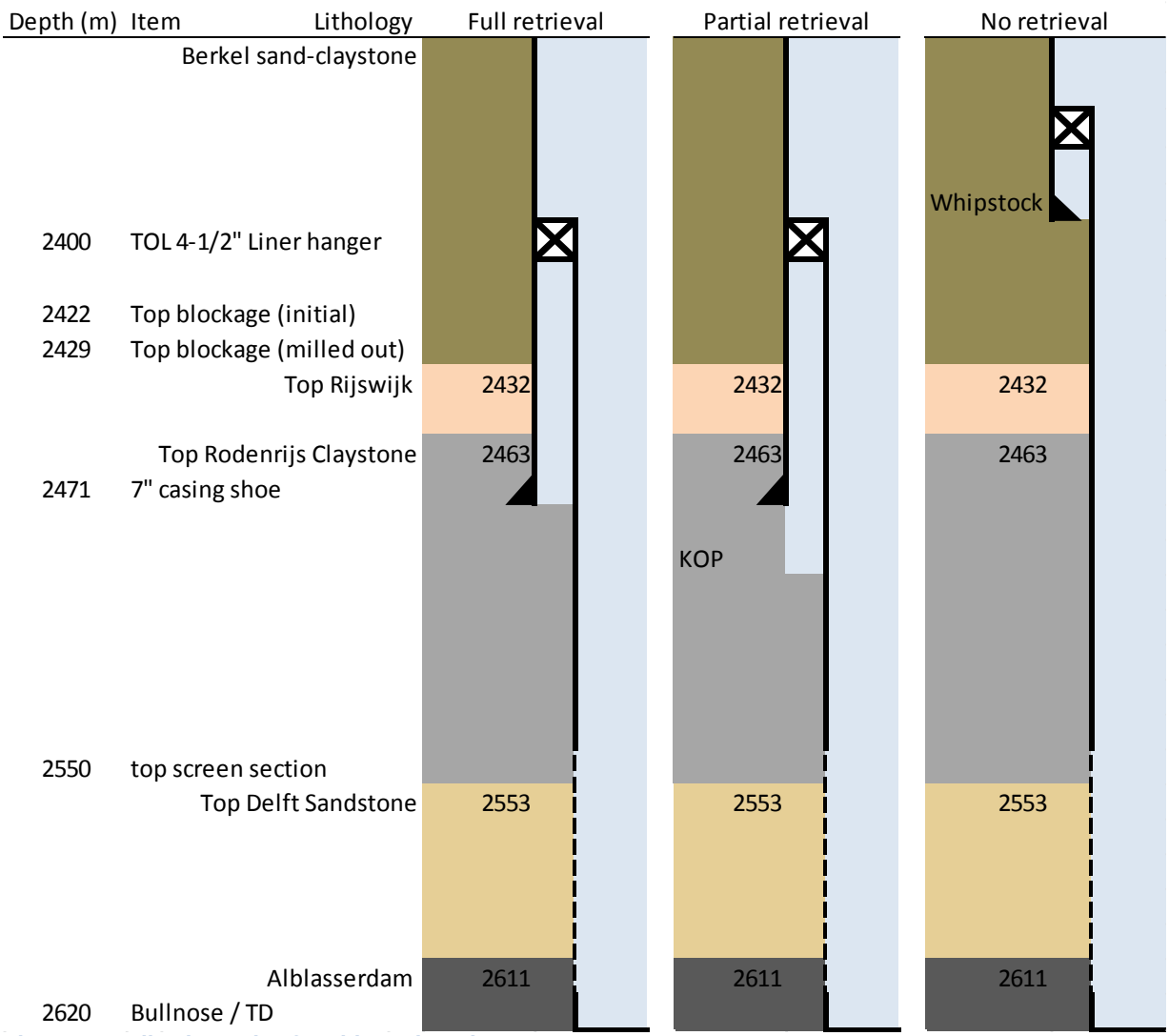

Figure 4: Well schematics for sidetrack options

5.8 Completion length

The Delft Sandstone extends over 60m, requiring 60m of WireWrappedScreens (WWS)
The shortest option (full or sufficient partial retrieval) requires total 220m liner, of which 60m screens, thus 160m blind pipe
In case of a cased hole exit (no or insufficient retrieval) an additional 60m as a minimum will be required to accommodate setting of the whipstock at a suitable place above the liner hanger and create sufficient liner lap for the installation of a new Liner Hanger. Thus minimum 220m blind pipe total.
NB. Above lengths are not accounting for potential rejects while RIH.

6 Loads & casing design

6.1 Drilling loads

6-1/8" hole requires 4" or 3 ½" drillpipe.
3 ½" DP @ 15,5 ppf weighs 23,07 kg/m.
This gives a string weight in air @ 3000m of 69t.
BHA weight is estimated at ca. 6t,
Total minimum capacity (excluding overpull) is therefore 75t.

Maximum actual hookload while RIH the screen section to below 2972m was 55t. In case of a longer open hole section (window in 7" casing) this could vary, but would be similar or less than the drilling string.

Based on the above it is recommended to have a rig/pulling unit with at least 100t safe working load available. This will allow some overpull capacity in case of hole problems & retrieving the lower completion.

6.2 Hydraulics

For hole cleaning the worst case is calculated: 3 ½" drillpipe inside the 9 ⅝" casing while drilling 6 ⅛" hole at 2650m (expected well TD for S2)
Minimum flow required is 1070lpm, with 220bar pump pressure. This is equivalent to ca. 1000HP.

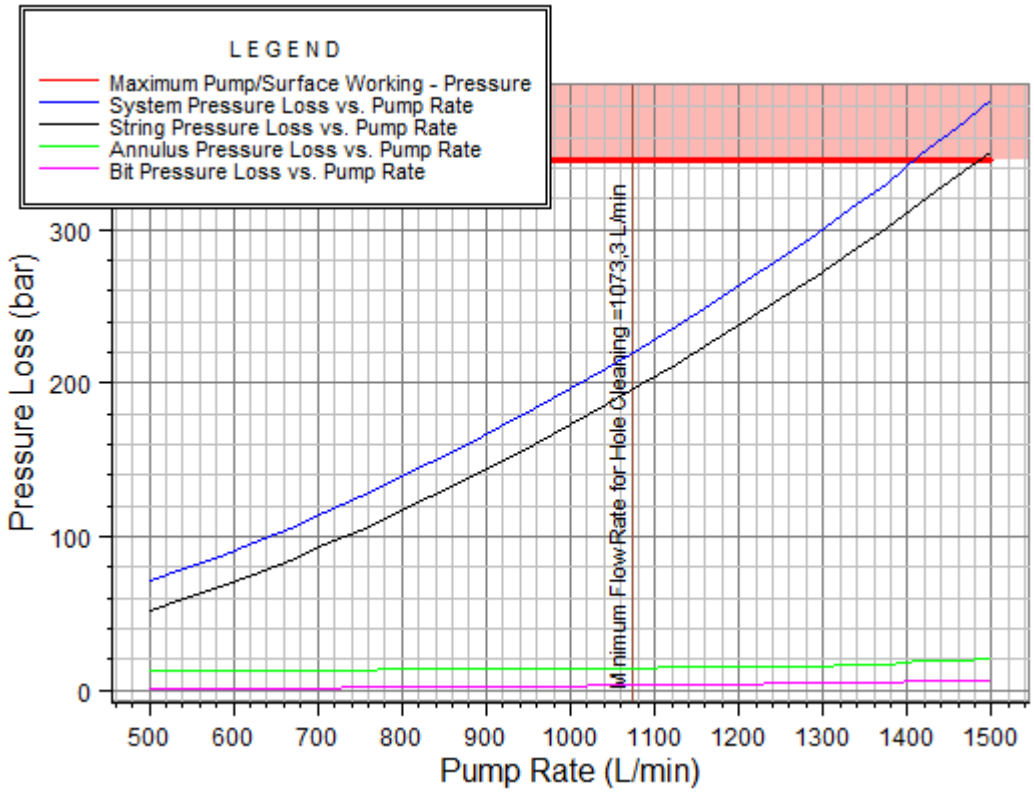

Figure 5: Pump rate vs pressure loss while drilling 6-1/8" hole section with 3-1/2" DP at S2 TD (2650m MD)

6.3 Casing design

Both screen section and blind pipe will require to fit inside a 6 ⅛" hole.

Blind pipe:

- Regular casing couplings on 5 ½" casing are 6,05" OD.
  - Due to the limited clearance this options is not further considered
- Flush 5 ½" casing has a 5 ½" connection OD
  - Depends on availability
- Regular 5" casing couplings have 5,563" OD
  - ¼" annular clearance available

Screen section

- Screens on 5" blind pipe have 5 ½" OD.
  - Depends on availability
- Intalled screens on 4 ½" blind pipe have 127mm (4,99") OD
  - Readily available

Burst and collapse loads are not considered for the well design, since the liner will be pre-perforated.

Tension loads in the liner string are:
Length: <400m
String weight (5" 15ppf – 22,32kg/m)
Total liner weight: 8,9t

Tension limit of 5" 15ppf L80 casing is 158t
Pre-perforated pipe has ca. 72% of the strength of blind pipe: 114t

7 Equipment

In order to repair well HON-GT-01 the following equipment and services are required:

- 100t rig or workover unit
    - Complete with >1000HP pumps, mud mixing & solids control equipment
- >60m screen section
    - 4 ½" or 5" base pipe
    - To cover the Delft Sandstone
- >220m 5" blind pipe (or 5 ½" flush)
- Mud services
- Cutting disposal
- Whipstock for 6 ⅛" sidetrack in 7" casing
    - To facilitate cased hole exit
- 6 ⅛" bit
- Directional drilling services
- Fishing spear for 4 ½" lower completion
    - Attempt to retrieve lower completion

8 Project planning

The project execution is depending on equipment & rig availability. It is however planned to be performed in June 2015.

Below in Table 2 a breakdown of the planned operations is included, based on execution of the operations with a hydraulic workover unit (HWU).

Table 2: time breakdown for Open hole (left) and Cased hole (right) sidetrack operations.

Open hole sidetrack	hrs	day
Rig up	78,0	3,3
Attempt fish liner	38,8	1,6
Set cementplug	35,9	1,5
Drill OH sidetrack	72,1	3,0
RIH liner	43,2	1,8
RIH ESP assembly	11,7	0,5
Install wellhead	12,0	0,5
Rig down	64,0	2,7
Total	**355,6**	**14,8**
Contingency	**15%**	**2,2**
Total		**17,0**

Cased hole sidetrack	hrs	day
Rig up	78,0	3,3
Attempt fish liner	38,8	1,6
Set mechanical bridgeplug on wireline	16,3	0,7
Set whipstock & mill window	48,6	2,0
Drill cased hole sidetrack	81,2	3,4
RIH liner	43,2	1,8
RIH ESP assembly	11,7	0,5
Install wellhead	12,0	0,5
Rig down	64,0	2,7
Total	**393,8**	**16,4**
Contingency	**15%**	**2,5**
Total		**18,9**