Peterhead CCS Project

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Executive Summary

There are currently five suspended production wells on the Goldeneye platform, drilled and completed by the Maersk Innovator in 2003. For the carbon capture and storage project, it is planned to work these wells over prior to the start of CO_2 injection. The requirement for working over (re-completing) the wells and the proposed conceptual well design is described in the Conceptual Completion and Well Intervention Design Endorsement Report (Key Knowledge Deliverable 11.093) and the Well Completion Concept Select (Key Knowledge Deliverable 11.097).

At the end of field life, i.e. upon cessation of CO_2 injection, the Goldeneye field will be decommissioned. As part of the decommissioning process, the development wells will be permanently abandoned, and the proposed abandonment designs are detailed in this document.

The platform well abandonment designs are based on the following design premises, detailed description of which is available in the Dynamic Reservoir Modelling Report (Key Knowledge Deliverable 11.122) and the Well Integrity Assessment Report (Key Knowledge Deliverable 11.113)

- All the injected CO_2 is contained within the Captain reservoir.
  - However, a contingency design is supplied, should CO_2 leak from the Captain reservoir to the Balmoral formation.
  - The Plenus/Hidra Marl and Rodby Shale are the primary seal for Captain sand reservoir pressure containment.
- The Lista Shale is the primary seal for Balmoral sand containment.
- The most effective method of providing a permanent seal is to set cement plugs inside cemented casing. This type of abandonment barrier provides full cross-sectional coverage, and its position and integrity can be confirmed via tagging, pressure and inflow testing. The preferred concepts are based on this design premise.
  - However, in the event that there is poor annular cement coverage behind the production casing string, a contingency abandonment design, involving section milling a casing window to allow the placement of a "rock-to-rock" cement plug abandonment barrier, has been described.
  - It is planned to obtain cement bond logs for the 9 ⅝" [244.48mm] production casing strings when conducting the workovers required for conversion to CO_2 injection. The results from these will be used to assess the quality and position of the cement behind the 9 ⅝" production casing string, and will determine the abandonment design to be implemented.

The abandonment designs for the five development wells have been designed in accordance with the Oil & Gas UK, "Guidelines for the Suspension and Abandonment of Wells", Issue 4, July 2012 and Shell standards. The primary abandonment designs for each well are based on setting cement plugs inside well cemented casing and across the sealing Rodby Shale, Plenus/Hidra Marl and Lista Shale formations, with conventional abandonment techniques being employed. However, it is recognised that contingency designs may have to be applied in the event that poorly cemented casing is encountered, and these contingency designs are also described in this document.

In addition, the abandonment plugs are currently planned to be constructed using conventional cementing materials; however this will be re-evaluated at the time of abandonment, to ensure that the most appropriate materials available are used.

1. Introduction

1.1. Summary

The Goldeneye field is currently being evaluated as a potential store for CO_2 disposal, and following workover, the existing platform wells will be used for CO_2 injection. Upon cessation of CO_2 injection, the Goldeneye field will be decommissioned, during which the injection wells will be abandoned.

The purpose of this document is to detail the abandonment design concept for the Goldeneye platform wells.

2. Goldeneye Wells

The Goldeneye field currently consists of a normally unmanned platform with five gas production wells. The wells are similar in design and were drilled with the Maersk Innovator heavy-duty jack-up rig during 2003/2004. An intervention campaign was carried out in 2012 and suspension plugs were set in all the wells.

The existing wells have been constructed in the following manner:

- The 30" [762mm] conductors were driven to approximately 750ft [229m]. Slots were cut in the conductors at seabed level during well construction for surface casing cementing purposes.
  - The 20" x 13 ⅜" surface casing strings were set at approximately 4,000ft.
- The 10 ¾" x 9 ⅝" production casing strings were set either just above, or directly below the top of the Captain reservoir sands.
- The 7" slotted liners with 4 ½" screens and gravel packs were installed across the Captain reservoir sands for sand control purposes.
- The upper completions consist of 7", 13Cr tubing, with the following completion components included:
  - A 9 ⅝" production packer with perforated joint below.
  - A PBR and seal unit above the production packer.
  - A permanent downhole gauge.
  - A TRSSSV set at approximately 2,500ft
- The surface Xmas tree is a 6 ⅜" mono-bore system, rated to 5,000 psi.
- The surface wellhead is a Cameron compact design, rated to 5,000 psi.

Some of the existing wells will be selected for CO_2 disposal purposes, and these will be worked over in order to install a tapered 4-1/2" x 3-1/2") slim completion which shall include a safety valve, well monitoring package (permanent downhole gauge, DTS (Distributed temperature Sensing), DAS (Digital Acquisition system)), and a production packer with a stinger. The new upper completion shall sting into and seal in the existing lower completion screen packer. The proposed well construction including casing strings is discussed in the Conceptual Completion and Well Intervention Design Endorsement Report (Key Knowledge Deliverable 11.093)

In the worked over wells, the existing casing and lower completion shall not be changed. Therefore, for abandonment purposes, the status of these items will remain the same as when originally

constructed. Details of the existing well condition, field geology and reservoir characteristics are included in the Well Functional Specification (Key Knowledge Deliverable 11.098)

2.1. Goldeneye Stratigraphy

The stratigraphy encountered in the Goldeneye development wells is shown in Figure 2-1 below.

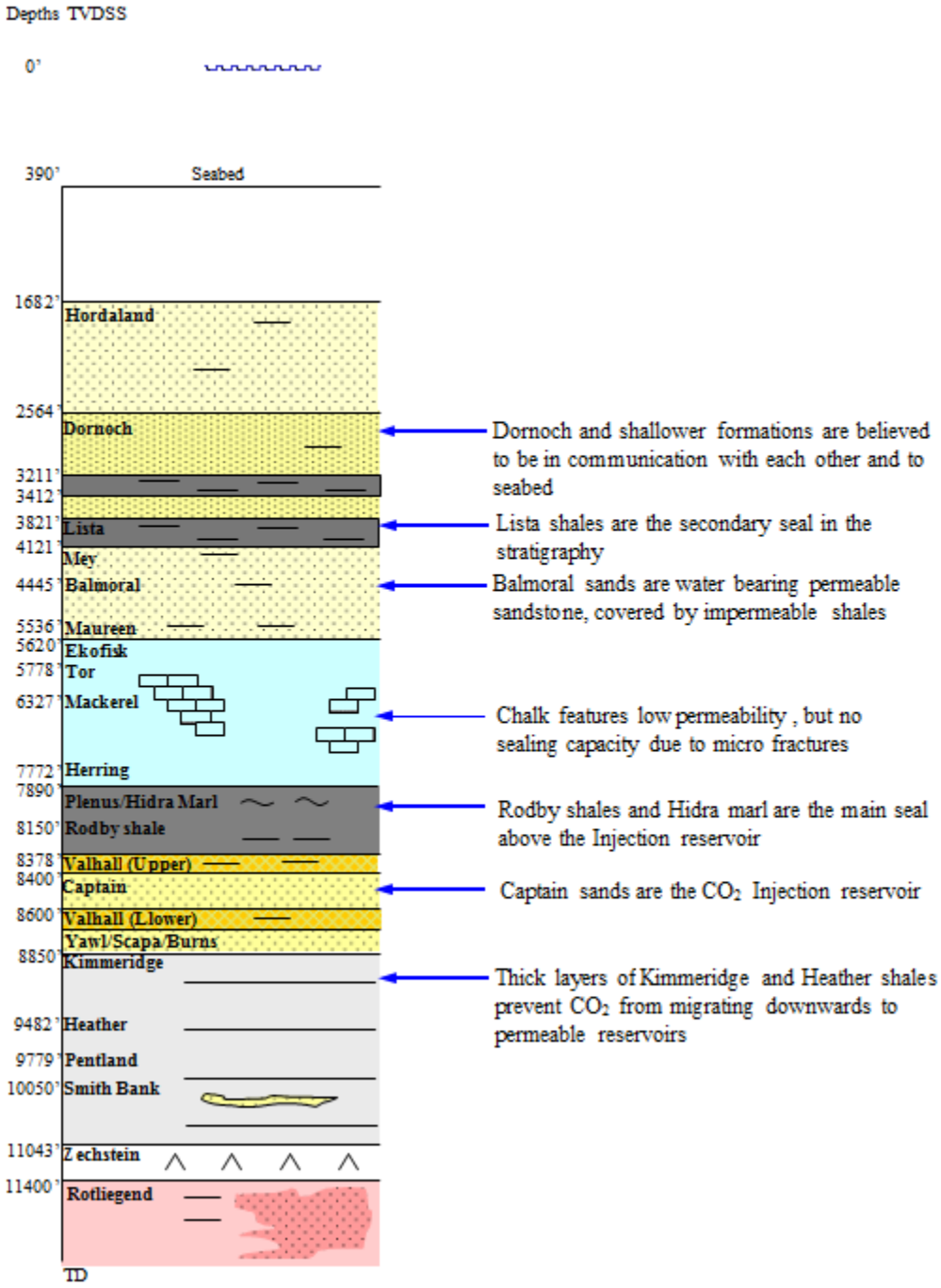


Figure 2-1: Main Stratigraphy for Goldeneye area, average depths of formation tops

The following stratigraphic facts have been taken into account when designing the abandonment concepts for each well:

- The Plenus/Hidra Marl and Rodby Shale directly overlying the Captain reservoir are sealing, and can be used for permanent abandonment integrity purposes.
- The Ekofisk, Tor, Mackerel and Herring are Chalk formations, which contain fractures. Therefore, these formations are not considered to be suitable for providing a permanent abandonment seal.
- The Mey, Balmoral and Maureen Sands are permeable, and are not considered to be suitable for providing a permanent abandonment seal.
- The Lista Shale is sealing, and can be used for permanent abandonment integrity purposes.
- The formations overlying the Lista are non-sealing and normally pressured, and are thought to be in communication with the seabed.

Therefore, the proposed abandonment concepts will be based on positioning permanent abandonment plugs opposite the sealing formations of the Plenus/Hidra Marl, Rodby and Lista Shales.

2.2. Goldeneye Wells: Current Well Status

The data relating to the current status of the existing five wells is described in the tables and figures provided in sections 2.2.1 to 2.2.5.

2.2.1. Goldeneye Well GYA01 (14/29a-A3)

Table 2-1: GYA01 (14/29a-A3) Well Details

Item	Data
Water Depth	395 ft
Rig Floor Elevation	152.5 ft
Wellhead System	Cameron SSMC Compact Spool
Xmas Tree	Cameron 5 ⅜" Monobore
Initial Reservoir Pressure	3,800 psi
Estimate Abandonment Reservoir Pressure	3,800 psi
Reservoir Temperature	180°F
Total Depth (TD)	9,166ft AHDBDF
Maximum Inclination	30.4° at 7,574ft AHDBDF
30" Conductor Setting Depth	750ft AHDBDF
30" Conductor Specification	1.5" WT, X52, Merlin (Internal Upset) 2" WT used for drive shoe

Item	Data
30" Cement Job	Conductor driven, N/A
20" x 13 ⅜" Casing Setting Depth	4,155ft AHDBDF
20" x 13 ⅜" Casing Specification	20", 202.7lb/ft, X80, Merlin (top joint) 20", 202.7lb/ft, X65, Merlin box x SR20 pin Crossover Joint 20", 202.7lb/ft, X65, SR20 13 ⅜", 68lb/ft, L80, Dino VAM 20" x 13 ⅜" XO at 704ft AHDBDF
30" x 20"/13 ⅜" Annulus Fluid	Seawater
20" x 13 ⅜" Cement Job	Single Slurry at 582pptf TOC at seabed
10 ¾" x 9 ⅝" Casing Setting Depth	9,066ft AHDBDF
10 ¾" x 9 ⅝" Casing Specification	10 ¾", 55.5lb/ft, L80, VAM Top 9 ⅝": 53.5lb/ft, L80, VAM Top 10 ¾" x 9 ⅝" XO at 3,130ft AHDBDF
20"/13 ⅜" x 10 ¾" /9 ⅝"Annulus Fluid	560 pptf LTOBM
10 ¾" x 9 ⅝" Cement Job	Single Class G Slurry at 728 pptf TTOC at 7506ft AHDBDF
7" Pre-drilled Liner Setting Depth	9,066ft AHDBDF
7" Pre-drilled Liner Specification	7", 29lb/ft, 13Cr L80, NK3SB
8 ½" x 7" Annulus Fluid	N/A
7" Cement Job	N/A

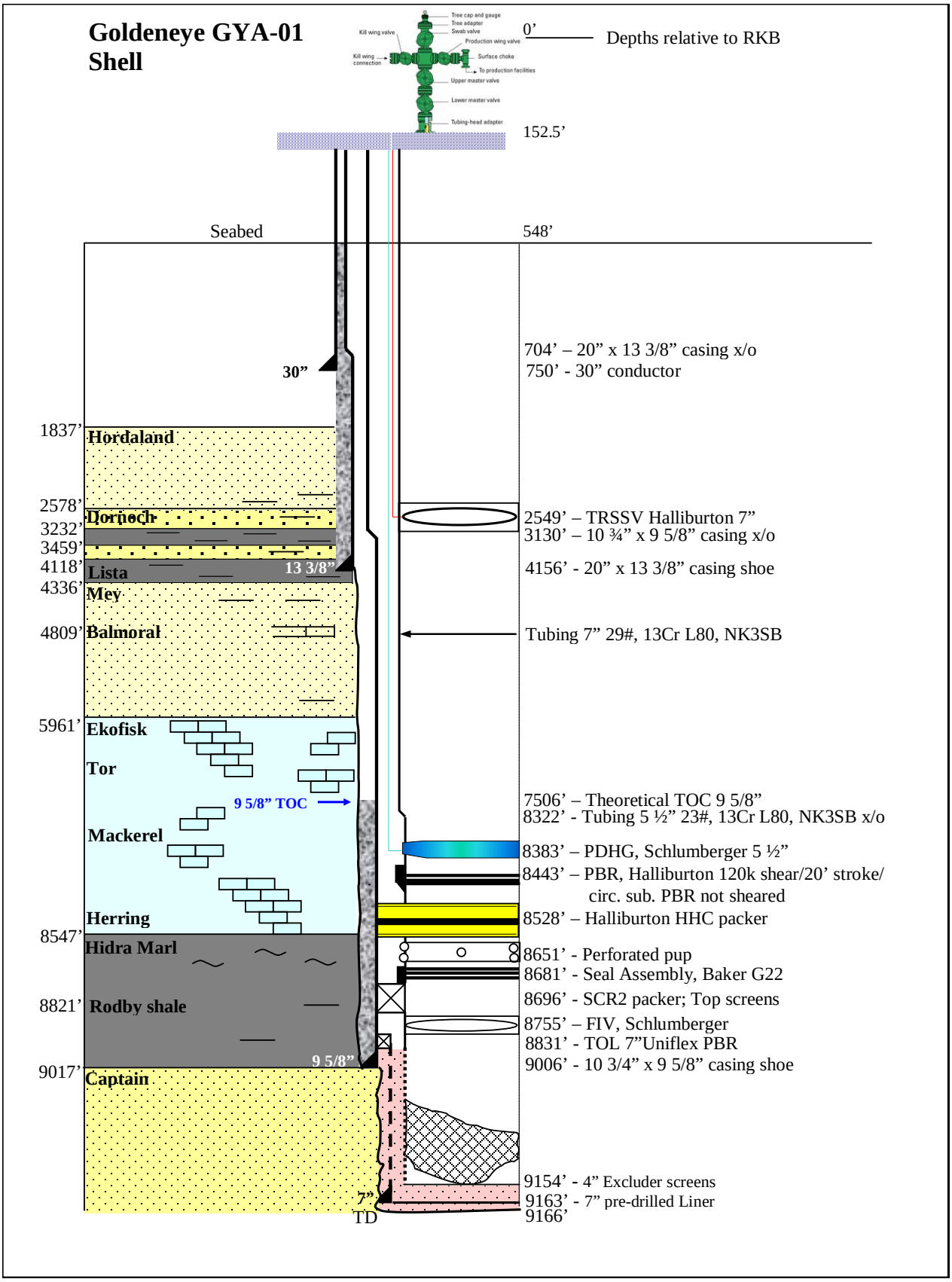


Figure 2-2: GYA01 (14/29a-A3)

2.2.2. Goldeneye Well GYA02s1 (14/29a-A4z)

Table 2-2: GYA02s1 (14/29a-A4z) Well Details

Item	Data
Water Depth	395 ft
Rig Floor Elevation	152.5 ft
Wellhead System	Cameron SSMC Compact Spool
Xmas Tree	Cameron 5 ⅜" Monobore
Initial Reservoir Pressure	3,811 psi
Estimate Abandonment Reservoir Pressure	3,800 psi
Reservoir Temperature	182°F
Total Depth (TD)	11,464ft AHDBDF
Maximum Inclination	60.5° at 10,622ft AHDBDF
30" Conductor Setting Depth	750ft AHDBDF
30" Conductor Specification	1.5" WT, X52, Merlin (Internal Upset) 2" WT used for drive shoe
30" Cement Job	Conductor driven, N/A
20" x 13 ⅜" Casing Setting Depth	4,154ft AHDBDF
20" x 13 ⅜" Casing Specification	20", 202.7lb/ft, X80, Merlin (top joint) 20", 202.7lb/ft, X65, Merlin box x SR20 pin Crossover Joint 20", 202.7lb/ft, X65, SR20 13 ⅜", 68lb/ft, L80, Dino VAM 20" x 13 ⅜" XO at 703ft AHDBDF
30" x 20"/13 ⅜" Annulus Fluid	Seawater
20" x 13 ⅜" Cement Job	Single Slurry at 582pptf TOC at seabed
10 ¾" x 9 ⅝" Casing Window Depth	10,990ft AHDBDF
10 ¾" x 9 ⅝" Casing Specification	10 ¾", 55.5lb/ft, L80, VAM Top 9 ⅝": 53.5lb/ft, L80, VAM Top 10 ¾" x 9 ⅝" XO at 3,155ft AHDBDF
20"/13 ⅜" x 10 ¾" /9 ⅝"Annulus Fluid	610 pptf LTOBM

Item	Data
10 ¾" x 9 ⅝" Cement Job	Single Class G Slurry at 728 pptf TTOC at 9,768ft AHDBDF
7" Pre-drilled Liner Setting Depth	11,462ft AHDBDF
7" Pre-drilled Liner Specification	7", 29lb/ft, 13Cr L80, NK3SB
8 ½" x 7" Annulus Fluid	N/A
7" Cement Job	N/A

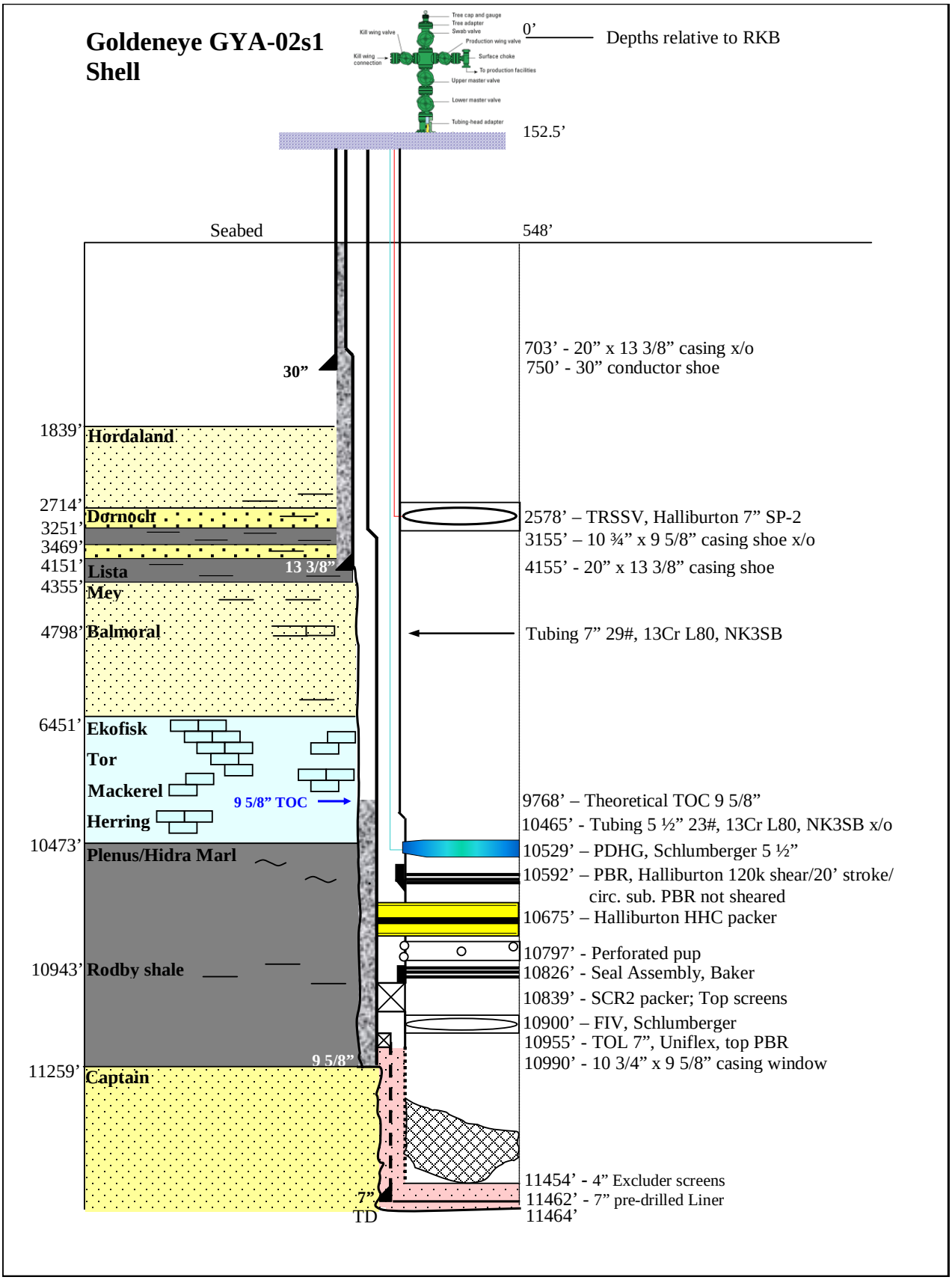


Figure 2-3: GYA02s1

2.2.3. Goldeneye Well GYA03 (14/29a-A5)

Table 2-3: GYA03 (14/29a-A5) Well Details

Item	Data
Water Depth	395 ft
Rig Floor Elevation	152.5 ft
Wellhead System	Cameron SSMC Compact Spool
Xmas Tree	Cameron 5 ⅜" Monobore
Initial Reservoir Pressure	3,820 psi
Estimate Abandonment Reservoir Pressure	3,800 psi
Reservoir Temperature	182°F
Total Depth (TD)	9,507ft AHDBDF
Maximum Inclination	40.1° at 5,983ft AHDBDF
30" Conductor Setting Depth	738ft AHDBDF
30" Conductor Specification	1.5" WT, X52, Merlin (Internal Upset) 2" WT used for drive shoe
30" Cement Job	Conductor driven, N/A
20" x 13 ⅜" Casing Setting Depth	4,143ft AHDBDF
20" x 13 ⅜" Casing Specification	20", 202.7lb/ft, X80, Merlin (top joint) 20", 202.7lb/ft, X65, Merlin box x SR20 pin Crossover Joint 20", 202.7lb/ft, X65, SR20 13 3/8", 68lb/ft, L80, Dino VAM 20" x 13 ⅜" XO at 703ft AHDBDF
30" x 20"/13 ⅜" Annulus Fluid	Seawater
20" x 13 ⅜" Cement Job	Single Slurry at 572pptf TOC at seabed
10 ¾" x 9 ⅝" Casing Window Depth	9,365ft AHDBDF
10 ¾" x 9 ⅝" Casing Specification	10 ¾", 55.5lb/ft, L80, VAM Top 9 5/8": 53.5lb/ft, L80, VAM Top 10 ¾" x 9 ⅝" XO at 3,013ft AHDBDF
20"/13 ⅜" x 10 ¾" /9 ⅝"Annulus Fluid	610 pptf LTOBM

Item	Data
10 ¾" x 9 ⅝" Cement Job	Single Class G Slurry at 728 pptf TTOC at 7,865ft AHDBDF
7" Pre-drilled Liner Setting Depth	9,503ft AHDBDF
7" Pre-drilled Liner Specification	7", 29lb/ft, 13Cr L80, NK3SB
8 ½" x 7" Annulus Fluid	N/A
7" Cement Job	N/A

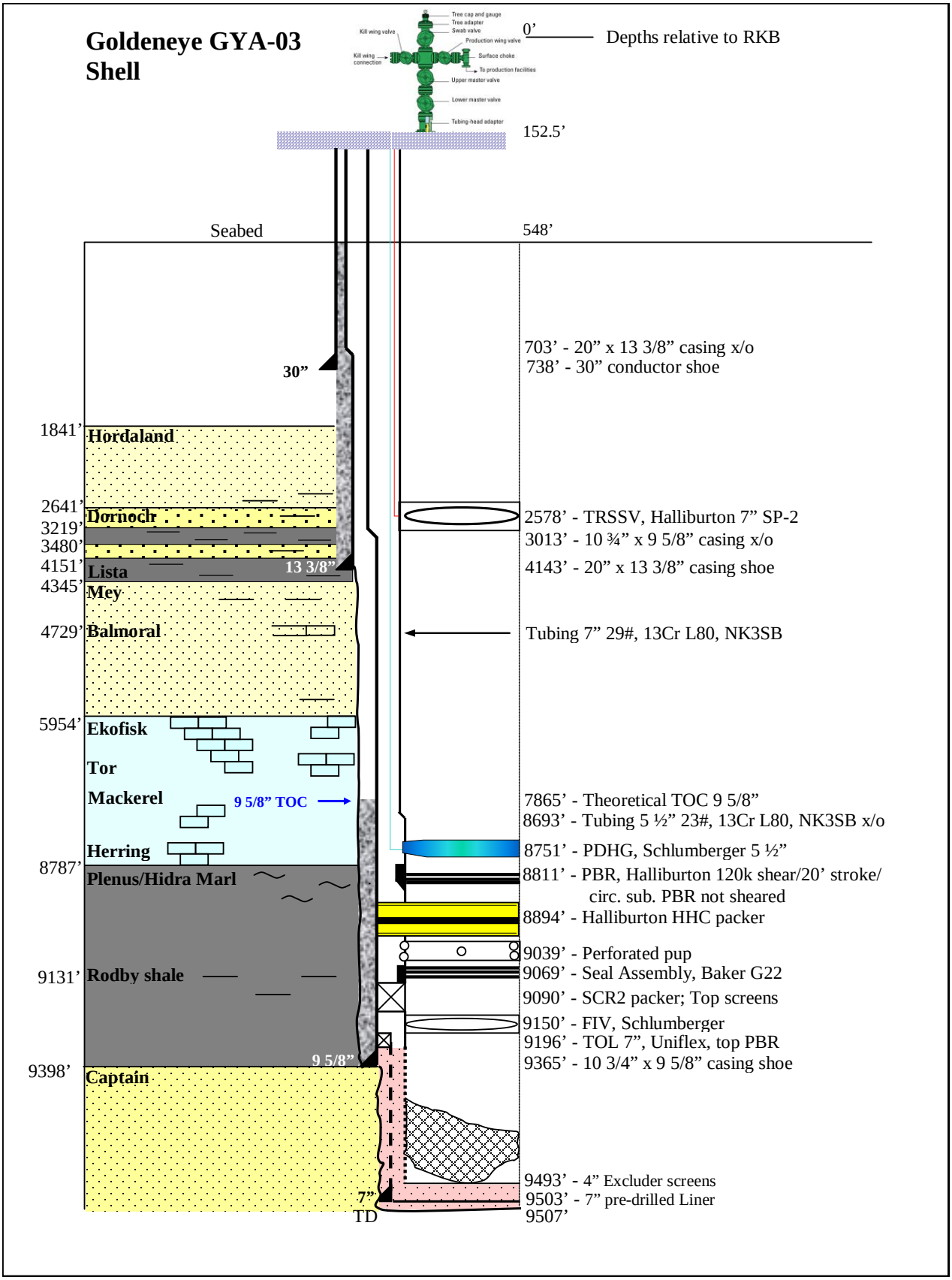


Figure 2-4: GYA03 (14/29a-A5)

2.2.4. Goldeneye Well GYA04 (14/29a-A1)

Table 2-4: GYA04 (14/29a-A1) Well Details

Item	Data
Water Depth	395 ft
Rig Floor Elevation	152.5 ft
Wellhead System	Cameron SSMC Compact Spool
Xmas Tree	Cameron 5 ⅜" Monobore
Initial Reservoir Pressure	3,820 psi
Estimate Abandonment Reservoir Pressure	3,800 psi
Reservoir Temperature	182°F
Total Depth (TD)	13,262ft AHDBDF
Maximum Inclination	68.1° at 6,020ft AHDBDF
30" Conductor Setting Depth	750ft AHDBDF
30" Conductor Specification	1.5" WT, X52, Merlin (Internal Upset) 2" WT used for drive shoe
30" Cement Job	Conductor driven, N/A
20" x 13 ⅜" Casing Setting Depth	4,224ft AHDBDF
20" x 13 ⅜" Casing Specification	20", 202.7lb/ft, X80, Merlin (top joint) 20", 202.7lb/ft, X65, Merlin box x SR20 pin Crossover Joint 20", 202.7lb/ft, X65, SR20 13 3/8", 68lb/ft, L80, Dino VAM 20" x 13 ⅜" XO at 705ft AHDBDF
30" x 20"/13 ⅜" Annulus Fluid	Seawater
20" x 13 ⅜" Cement Job	Single Slurry at 572pptf TOC at seabed
10 ¾" x 9 ⅝" Casing Shoe Depth	13,010ft AHDBDF
10 ¾" x 9 ⅝" Casing Specification	10 ¾", 55.5lb/ft, L80, VAM Top 9 5/8": 53.5lb/ft, L80, VAM Top 10 ¾" x 9 ⅝" XO at 2,768ft AHDBDF
20"/13 ⅜" x 10 ¾" /9 ⅝"Annulus Fluid	580 pptf LTOBM

Item	Data
10 ¾" x 9 ⅝" Cement Job	Single Class G Slurry at 728 pptf TTOC at 11,510ft AHDBDF
7" Pre-drilled Liner Setting Depth	13,255ft AHDBDF
7" Pre-drilled Liner Specification	7", 29lb/ft, 13Cr L80, NK3SB
8 ½" x 7" Annulus Fluid	N/A
7" Cement Job	N/A

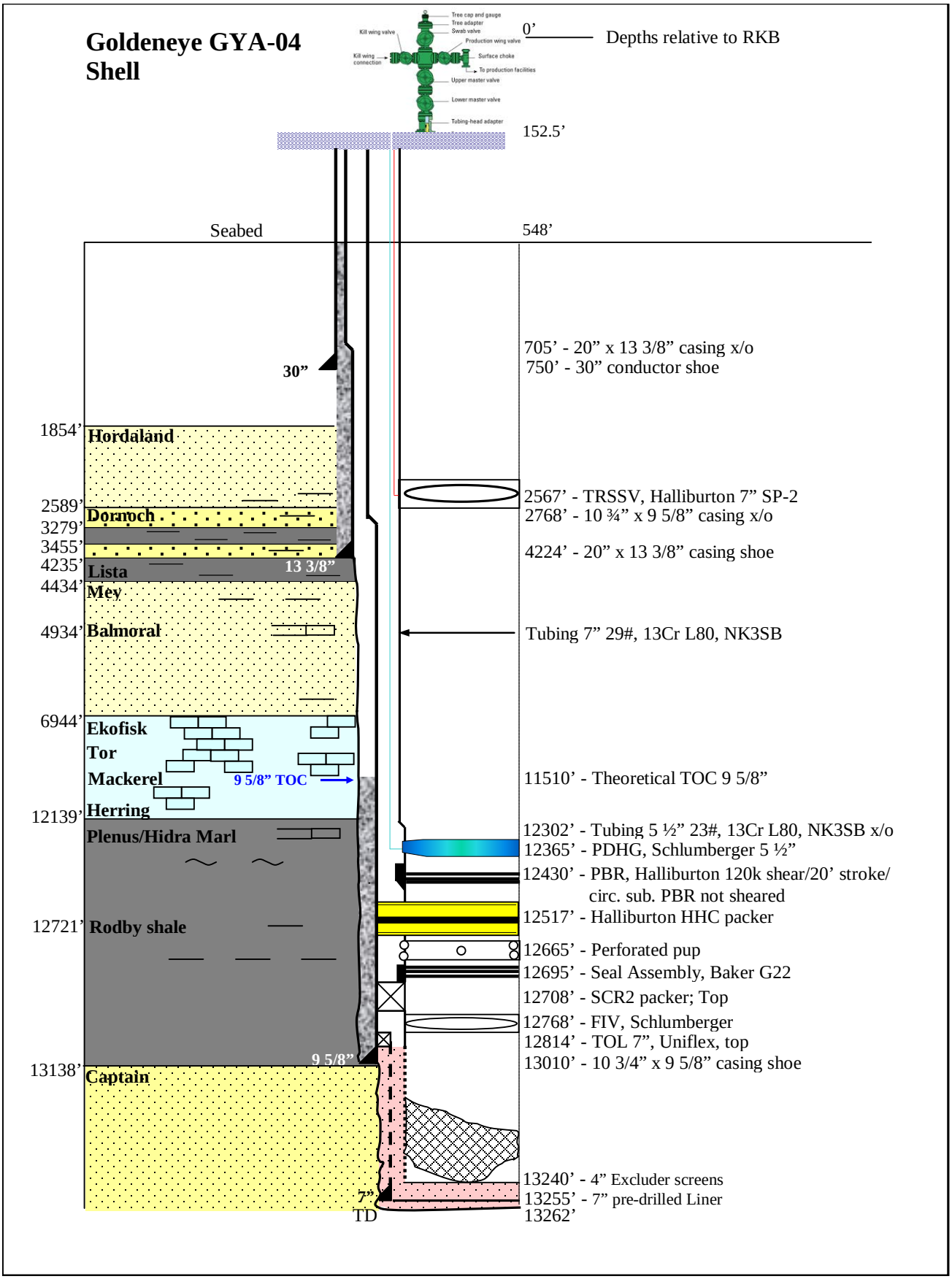


Figure 2-5: GYA04 (14/29a-A1)

2.2.5. Goldeneye Well GYA05 (14/29a-A2)

Table 2-5: GYA05 (14/29a-A2) Well Details

Item	Data
Water Depth	395 ft
Rig Floor Elevation	152.5 ft
Wellhead System	Cameron SSMC Compact Spool
Xmas Tree	Cameron 5 ⅜" Monobore
Initial Reservoir Pressure	3,820 psi
Estimate Abandonment Reservoir Pressure	3,800 psi
Reservoir Temperature	179°F
Total Depth (TD)	8,535ft AHDBDF
Maximum Inclination	7.2° at 1,785ft AHDBDF
30" Conductor Setting Depth	750ft AHDBDF
30" Conductor Specification	1.5" WT, X52, Merlin (Internal Upset) 2" WT used for drive shoe
30" Cement Job	Conductor driven, N/A
20" x 13 ⅜" Casing Setting Depth	4,107ft AHDBDF
20" x 13 ⅜" Casing Specification	20", 202.7lb/ft, X80, Merlin (top joint) 20", 202.7lb/ft, X65, Merlin box x SR20 pin Crossover Joint 20", 202.7lb/ft, X65, SR20 13 ⅜", 68lb/ft, L80, Dino VAM 20" x 13 ⅜" XO at 704ft AHDBDF
30" x 20"/13 ⅜" Annulus Fluid	Seawater
20" x 13 ⅜" Cement Job	Single Slurry at 577pptf TOC at seabed
10 ¾" x 9 ⅝" Casing Shoe Depth	8,395ft AHDBDF
10 ¾" x 9 ⅝" Casing Specification	10 ¾", 55.5lb/ft, L80, VAM Top 9 5/8": 53.5lb/ft, L80, VAM Top 10 ¾" x 9 ⅝" XO at 3,130ft AHDBDF
20"/13 ⅜" x 10 ¾" /9 ⅝"Annulus Fluid	560 pptf LTOBM

Item	Data
10 ¾" x 9 ⅝" Cement Job	Single Class G Slurry at 728 pptf TTOC at 6,295ft AHDBDF
7" Pre-drilled Liner Setting Depth	8,530ft AHDBDF
7" Pre-drilled Liner Specification	7", 29lb/ft, 13Cr L80, NK3SB
8 ½" x 7" Annulus Fluid	N/A
7" Cement Job	N/A

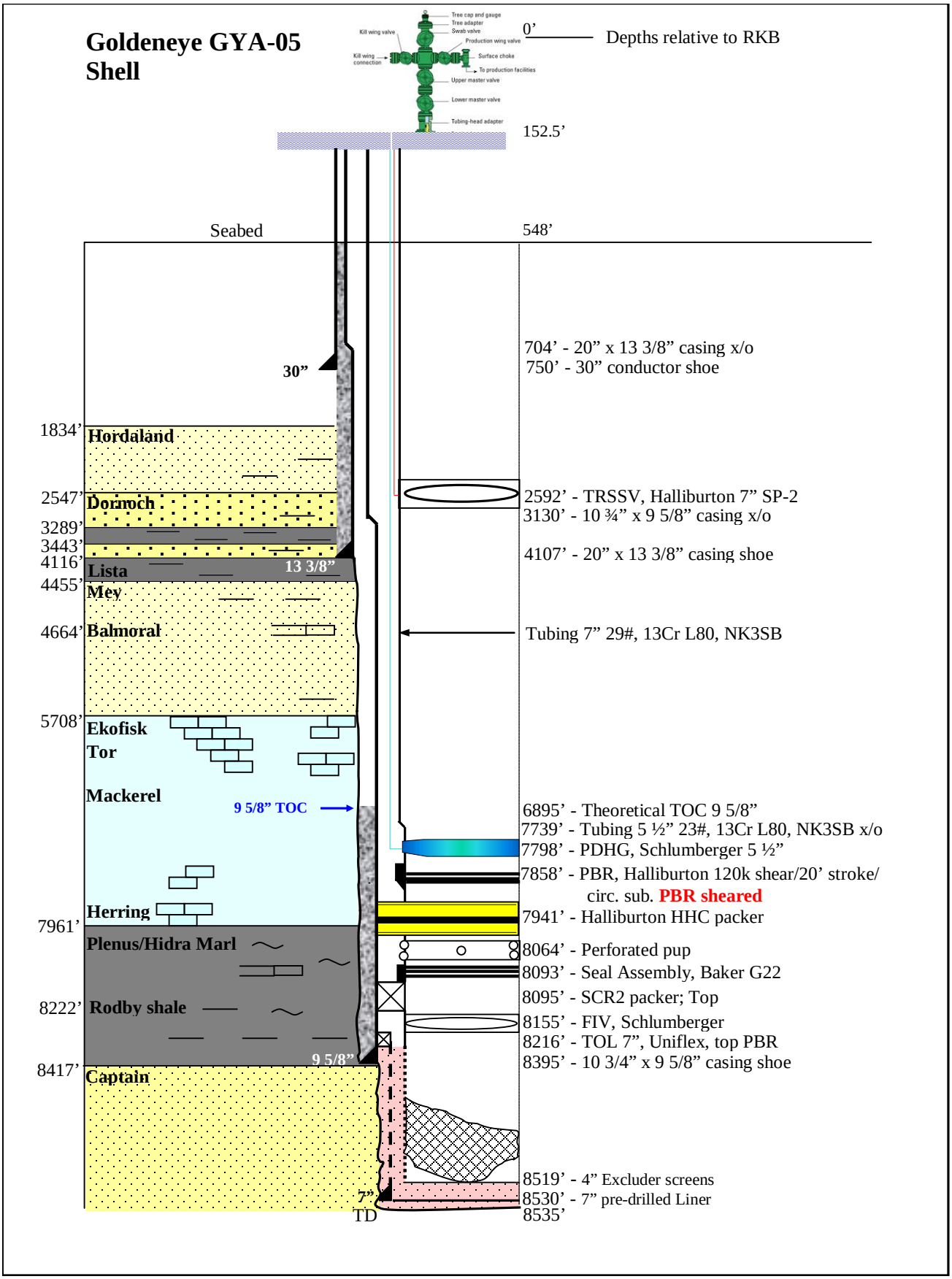


Figure 2-6: GYA05 (14/29a-A2)

3. Workover Design and Abandonment

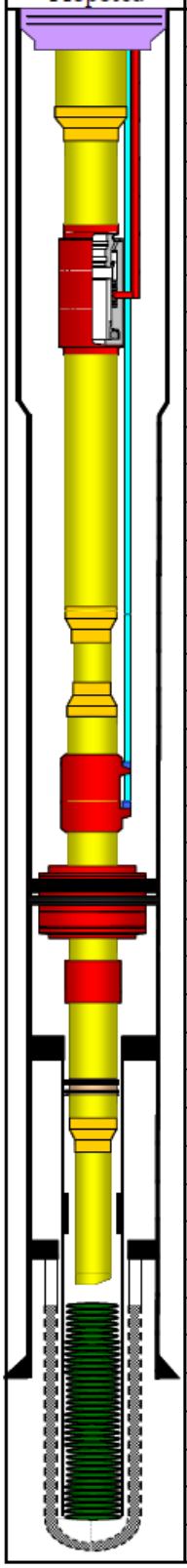
In order to use the existing wells for CO_2 injection, workovers will be required to replace the upper completions. Therefore, prior to CO_2 injection, each well will be worked over to install the upper completion shown in Figure 3-1.

It is planned to set the packers as deep as possible in the Plenus/Hidra Marl to ensure the integrity of the containment area. The table also shows the approximate available height to the top of the Plenus/Hidra Marl in relation to the various well components for setting a cement plug during final abandonment.

From the Table 3-1 it can be seen that the interval between the proposed packer setting depth and the top of the Plenus/Hidra Marl is relatively short. For this reason, each abandonment will require the production packer and possibly the SC-2R sand control packer and the tubing down to the FIV to be removed to provide the required interval to set the abandonment plugs.

Table 3-1: Well Component Depth, Top of Cement and Top Plenus/Hidra Marl

Well Component Depths vs. Top of Cement and Top Plenus/Hidra Marl					
	GYA-01 Depth ft, AHDBDF	GYA-02S1 Depth ft, AHDBDF	GYA-03 Depth ft, AHDBDF	GYA-04 Depth ft, AHDBDF	GYA-05 Depth ft, AHDBDF
Theoretical Top of Cement	7,506	9,490	7,865	11,510	6,895
Top Plenus/Hidra Marl	8,547	10,485	8,799	12,154	7,961
Proposed Packer Setting Depth	8,596	10,740	8,990	12,608	7,995
Cement to Top Plenus/Hidra	49	255	191	454	34
SC-2R Packer (sand control packer)	8,696	10,840	9,090	12,708	8,095
Cement to Top Plenus/Hidra	149	355	291	554	134
FIV (cut point)	8,755	10,900	9,150	12,768	8,155
Cement to Top Plenus/Hidra	208	415	351	614	194
Uniflex 7" Liner Hanger	8,831	10,955	9,196	12,832	8,237
Cement to Top Plenus/Hidra	284	470	397	678	276
9 ⅝" Casing Shoe	9,006	10,990	9,365	13,010	8,395
Cement to Top Plenus/Hidra	459	505	566	856	434
Proposed packer above 9 ⅝" Shoe	410	250	375	402	400



GYA 01 Proposed	Depth MD (ft)	Description of Item	ID (Inches)	Drift (Inches)
	79	Tubing Hanger	6.169	
		7.00 29# Tubing 13Cr/S13Cr	6.184	6.059
	139	XO 7.00" 29# x 4 1/2" 12.6#	3.958	3.833
		4 1/2" 12.6# Tubing 13Cr/S13Cr	3.958	3.833
	2500	SCTRSSSV 4 1/2" 13cr	3.813	
	3130	Casing XO 10 3/4" x 9 5/8"		
	6800	XO 4 1/2" 12.6# x 3 1/2"	2.922	
		3 1/2" Tubing	2.922	
	8430	X/O/Wire Finder Trip Sub 3 1/2" x 4 1/2" 12.6#	2.992	2.787
	8536	4 1/2" PDGM for PDG + DTS	3.958	3.833
		4 1/2" 12.6 # Tubing	3.958	3.833
	8596	9 5/8" x 4 1/2" Packer	3.818	
		4 1/2" Circulating/Pressure Relief Device	3.958	3.833
		4 1/2" Tubing		
	8696	Baker SC-2R packer/screen hanger 13Cr (existing)		
		G22 Seal Assembly	3.958	3.833
	8650	XO 4 1/2" 12.6# x 2 7/8" 6.4# FJ Tubing	2.441	2.347
	8755	Schlumberger FIV (existing)	2.94"	
	8850	2 7/8" Mule Shoe		
	8952	Top of 4.00" Screens (existing)	3.548	

Figure 3-1: Proposed completion schematic for CCS

4. Abandonment Options for Goldeneye Wells

As stated in section 3, upper completion workovers are required in order to make the Goldeneye wells suitable for CO_2 injection. The final abandonment of the five Goldeneye production wells will therefore be based on the well status after workover.

4.1. Zones Requiring Abandonment

Abandonment design within Shell is currently conducted in accordance with:

- Oil & Gas UK, "Guidelines for the Suspension and Abandonment of Wells", Issue 4 July 2012
- Shell Standards

These documents state that:

- Over-pressured permeable zones (both water and hydrocarbon bearing) and normally pressured permeable zones containing hydrocarbons require a minimum of two permanent (abandonment) barriers between the permeable zone and seabed/surface.
  - One composite cement plug may be used to meet the two permanent barriers requirement.
- Normally pressured permeable zones containing water require one permanent (abandonment) barrier between the permeable zone and seabed/surface.
- Permanent barriers must be set opposite formations with sufficient strength to contain "potential internal pressure" after abandonment. This means that the maximum reservoir pressure which can occur over time must be considered as the "potential internal pressure" value.
  - For Goldeneye, this has been assumed to be the virgin pressure of 3,800 psi.
- Permanent barriers must extend across the entire section of the wellbore. This may be achieved by overlapping components of barriers (for example setting a cement plug inside cemented casing will provide a barrier which extends across the entire wellbore).
- Provided that the requirement is met for setting cement opposite formations with sufficient strength to contain anticipated pressures, it is not necessary to abandon reservoir sections by setting cement plugs across sand screens.
- An annular column of 100ft of cemented casing is considered an acceptable barrier provided that top of cement has been verified.
- An annular column of 1,000ft of cemented casing is considered an acceptable barrier when top of cement has not been verified.
- A cement plug of a minimum 165ft length is considered an acceptable barrier provided that it is set inside casing using a mechanical plug as a foundation. However, where possible, for a single plug, at least 330ft of cement should be placed.
- For composite plugs, a minimum 660ft length is considered an acceptable barrier. However, where possible, 800ft of cement should be placed.

At present, permanent barriers normally consist of cement, as this material will retain integrity over time (i.e. cement does not corrode or perish). The type of cement to be used will be reviewed at the time of abandonment and may include CO_2 resistant additives. This will be influenced by the best practices and standards of the day at the time of abandonment.

For the Goldeneye well, the zones requiring abandonment are:

- Captain sands: Initially hydrostatically pressured, these reservoir sands are currently depleted to 2,500 psi. However, they are expected to re-pressurise to their original virgin pressure of 3,800 psi over time. This zone was originally hydrocarbon bearing (gas condensate) and will contain any remaining gas/condensate and injected CO_2 at the time of abandonment.
- Balmoral sands: This formation is a hydrostatically pressured, water bearing permeable zone. The Balmoral formation is contained by the Lista shales. The sandstones featured gas shows during drilling, however it is believed to be small amounts of background gas and not mobile gas that can flow and build up pressure. This zone was originally water bearing, but may contain some injected CO_2 at the time of abandonment.

The cap-rock for the Captain reservoir is the Plenus/Hidra Marl and Rodby Shale. These formations are impermeable, strong and approximately 500ft in vertical thickness. In Goldeneye, these formations are positioned directly above the Captain reservoir.

The Lista formation will act as the cap-rock for the Balmoral formation, and also provides a secondary seal for the Captain reservoir. The Lista formation strength is based on the data obtained when conducting 13 ⅜" casing shoe formation strength tests, and is estimated to be as follows:

Table 4-1: Goldeneye wells: 13 ⅜" casing shoe formation strength

		GYA-01	GYA-02s1	GYA-03	GYA-04	GYA-05
13 ⅜" shoe	AHD (ft)	4155	4155	4143	4224	4107
	TVD (ft)	4076	4085	4097.7	4073.2	4099.9
	EMW (psi/ft)	0.630	0.631	0.630	0.633	0.630
	Pressure (psi)	2568	2577	2580	2578	2583

The pressure from a CO_2 column to the 13 ⅜" casing shoe is as per Figure 4-1. As can be seen from Table 4-1, the formation strength pressure at the 13 ⅜" shoe is approximately 2,570 psi. The highest predicted pressure at the casing shoe based on the highest CO_2 injection pressure is approximately 2,200 psi. Therefore, a cement plug positioned opposite the Lista formation can also contain a CO_2 column, and will provide additional abandonment sealing capability to support the barriers positioned across the Plenus/Hidra Marl and Rodby Shale.

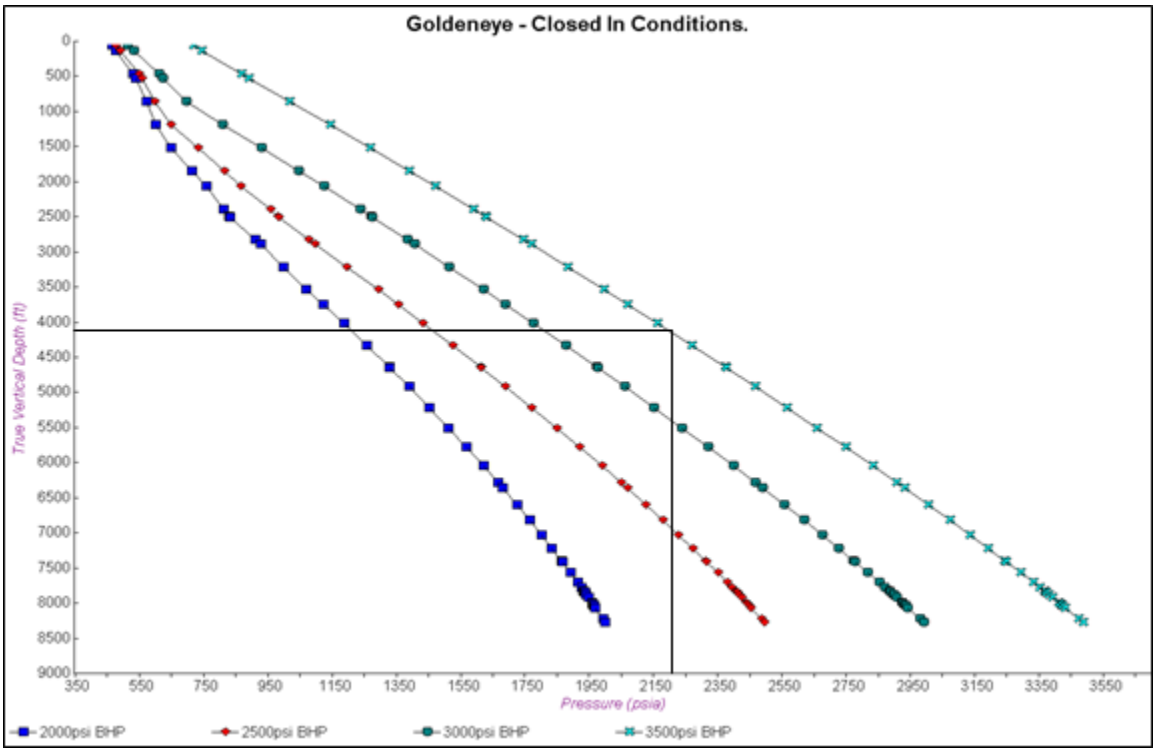


Figure 4-1: CO_2 pressure as function of depth, based on various reservoir pressures.

4.2. Well Abandonment Design: Concept 1

Concept 1 is the base case abandonment design for wells GYA-01 and GYA-05, and assumes that all injected CO_2 is contained within the Captain reservoir. As such, the Balmoral formation is water bearing and only requires a single barrier from surface.

In this concept, the 9 ⅝" production casing is well cemented, with top of cement being confirmed as being above top Plenus Marl via a cement bond log. However, the thickness of the Plenus/Hidra Marl and Rodby Shale is insufficient to allow a composite cement plug to be set inside the 9 ⅝" casing (which can act as two barriers). Therefore, two individual cement plugs will be set opposite the Plenus/Hidra Marl and Rodby Shale, to provide the required permanent barriers for the Captain reservoir sands. These cement plugs will be set on a mechanical plug inside cemented casing to provide cement and steel coverage across the full wellbore cross-section. In order to provide sufficient Plenus/Hidra Marl and Rodby formation length to set the base of the second abandonment plug below the top of the Plenus Marl, the production packer, sand screen hanger and lower completion to directly above the FIV will be removed from the well.

To isolate the Balmoral formation, the 9 ⅝" casing will be cut and pulled from the base of the Lista. A single cement plug will then be set opposite the Lista formation, to provide cement coverage across the full wellbore cross-section.

The operational steps required to deliver this concept are as follows:

- Pull the upper completion, including the production packer and tailpipe.
- Run a cement bond log (CBL) to confirm that top of 9 ⅝" annular cement is above the Plenus Marl, and that the annular cement quality is suitable for abandonment purposes.
  - If a CBL is obtained during workover operations, this data may be used for cement evaluation purposes.
  - If the 9 ⅝" casing is poorly cemented, concept 4 will be applied.

- Remove the sand screen hanger and lower completion down to the FIV.
- Set a bridge plug in the 9 ⅝" casing on top of the FIV, to act as a base for cement plug no.1.
- Set cement plug no.1 on top of the bridge plug, such that the top of the plug is below top Plenus Marl.
- Set cement plug no.2 on top of cement plug no.1.
- Set a bridge plug in the 9 ⅝" casing 10ft below the planned casing cut depth.
- Cut the 9 ⅝" casing 5ft below top Lista and pull the cut casing from the well.
- Set cement plug no.3 on the bridge plug, with top of cement placed inside cemented 13 ⅜" casing.
- Set a bridge plug in the 13 ⅜" casing at approximately 1,100ft.
- Set cement plug no.4 on the bridge plug, to act as an environmental barrier (i.e. to contain any residual oil-based mud from the open annuli generated when cutting casing).
- Cut the 30" conductor and 20" casing string 10ft below seabed, and pull both strings to surface.

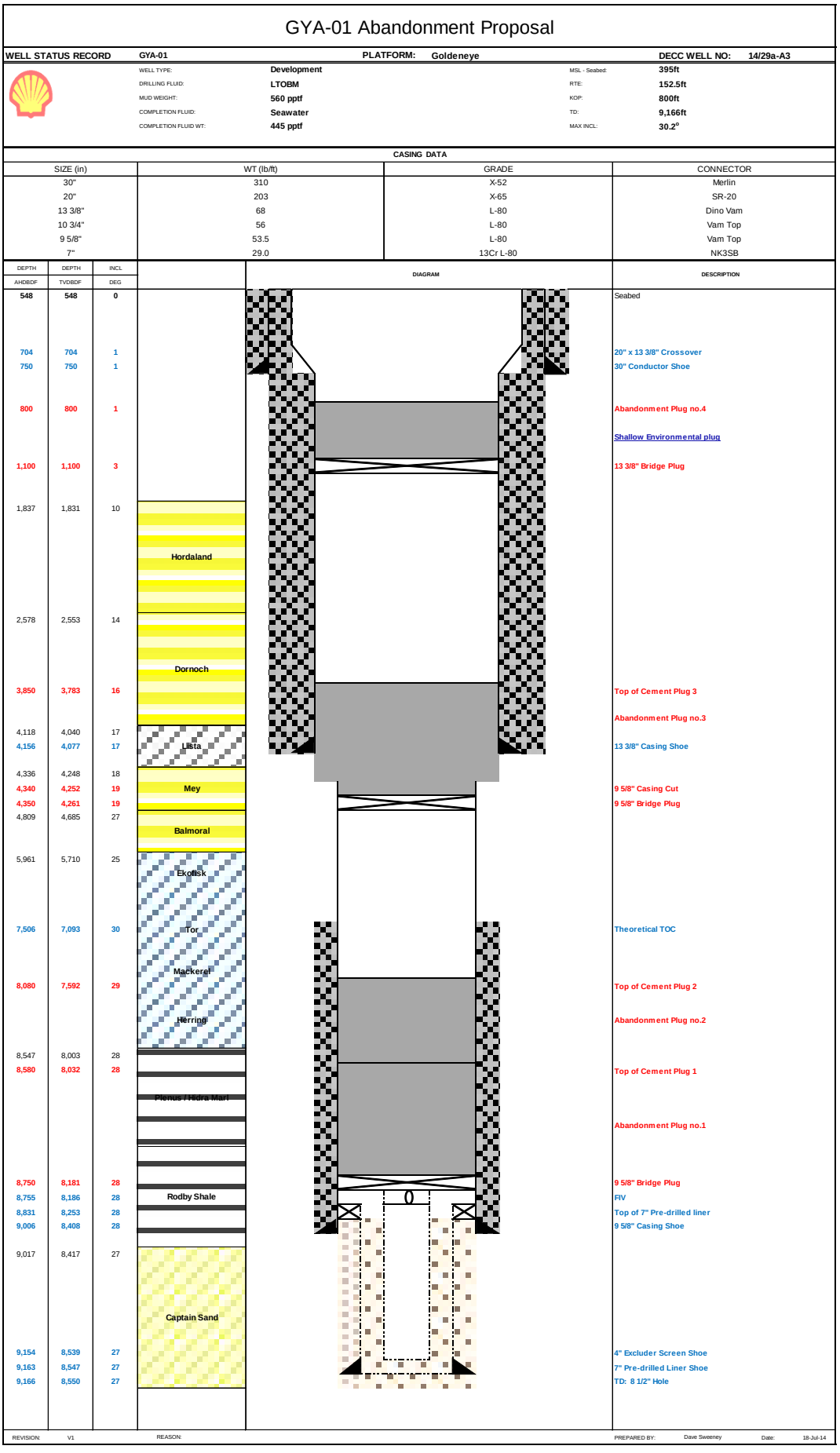


Figure 4-2: GYA01: Abandonment Proposal

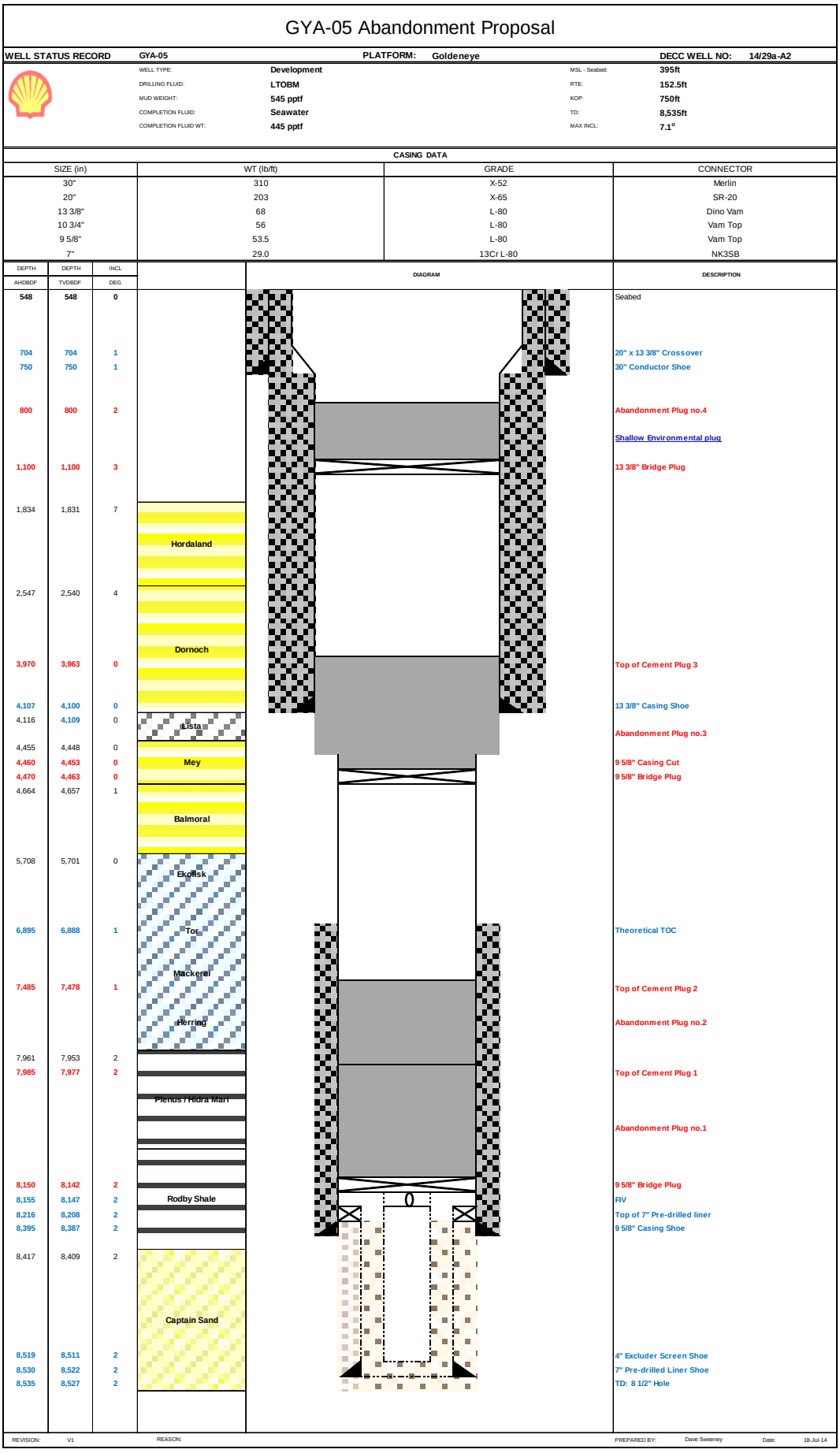


Figure 4-3: GYA05: Abandonment Proposal

4.3. Well Abandonment Design: Concept 2

Concept 2 is the base case abandonment design for wells GYA-02S1 and GYA-03, and assumes that all injected CO_2 is contained within the Captain reservoir. As such, the Balmoral formation is water bearing and only requires a single barrier from surface.

In this concept, the 9 ⅝" production casing is well cemented, with top of cement being confirmed as being above top Plenus Marl via a cement bond log. However, the thickness of the Plenus/Hidra Marl and Rodby Shale is insufficient to allow a composite cement plug to be set inside the 9 ⅝" casing (which can act as two barriers). Therefore, two individual cement plugs will be set opposite the Plenus/Hidra Marl and Rodby Shale, to provide the required permanent barriers for the Captain reservoir sands. These cement plugs will be set on a mechanical plug inside cemented casing to provide cement and steel coverage across the full wellbore cross-section. In order to provide sufficient Plenus/Hidra Marl and Rodby formation length to set the base of the second abandonment plug below the top of the Plenus Marl, the upper completion and production packer will be removed, but there is sufficient shale length to allow the sand screen hanger and lower completion to be left in situ.

To isolate the Balmoral formation, the 9 ⅝" casing will be cut and pulled from the base of the Lista. A single cement plug will then be set opposite the Lista formation, to provide cement coverage across the full wellbore cross-section.

The operational steps required to deliver this concept are as follows:

- Set a 5" bridge plug in the lower completion below the sand screen hanger and above the FIV to act as a base for cement plug no.1.
- Pull the upper completion, including the production packer and tailpipe.
- Run a cement bond log (CBL) to confirm that top of 9 ⅝" annular cement is above the Plenus Marl, and that the annular cement quality is suitable for abandonment purposes
  - If a CBL is obtained during workover operations, this data may be used for cement evaluation purposes.
  - If the 9 ⅝" casing is poorly cemented, concept 4 will be applied.
- Set cement plug no.1 on top of the 5" bridge plug and sand screen hanger, such that the top of the plug is below top Plenus Marl.
- Set cement plug no.2 on top of cement plug no.1.
- Set a bridge plug in the 9 ⅝" casing 10ft below the planned casing cut depth.
- Cut the 9 ⅝" casing 5ft below top Lista and pull the cut casing from the well.
- Set cement plug no.3 on the bridge plug, with top of cement placed inside cemented 13 ⅜" casing.
- Set a bridge plug in the 13 ⅜" casing at approximately 1,100ft.
- Set cement plug no.4 on the bridge plug, to act as an environmental barrier (i.e. to contain any residual oil-based mud from the open annuli generated when cutting casing).
- Cut the 30" conductor and 20" casing string 10ft below seabed, and pull both strings to surface.

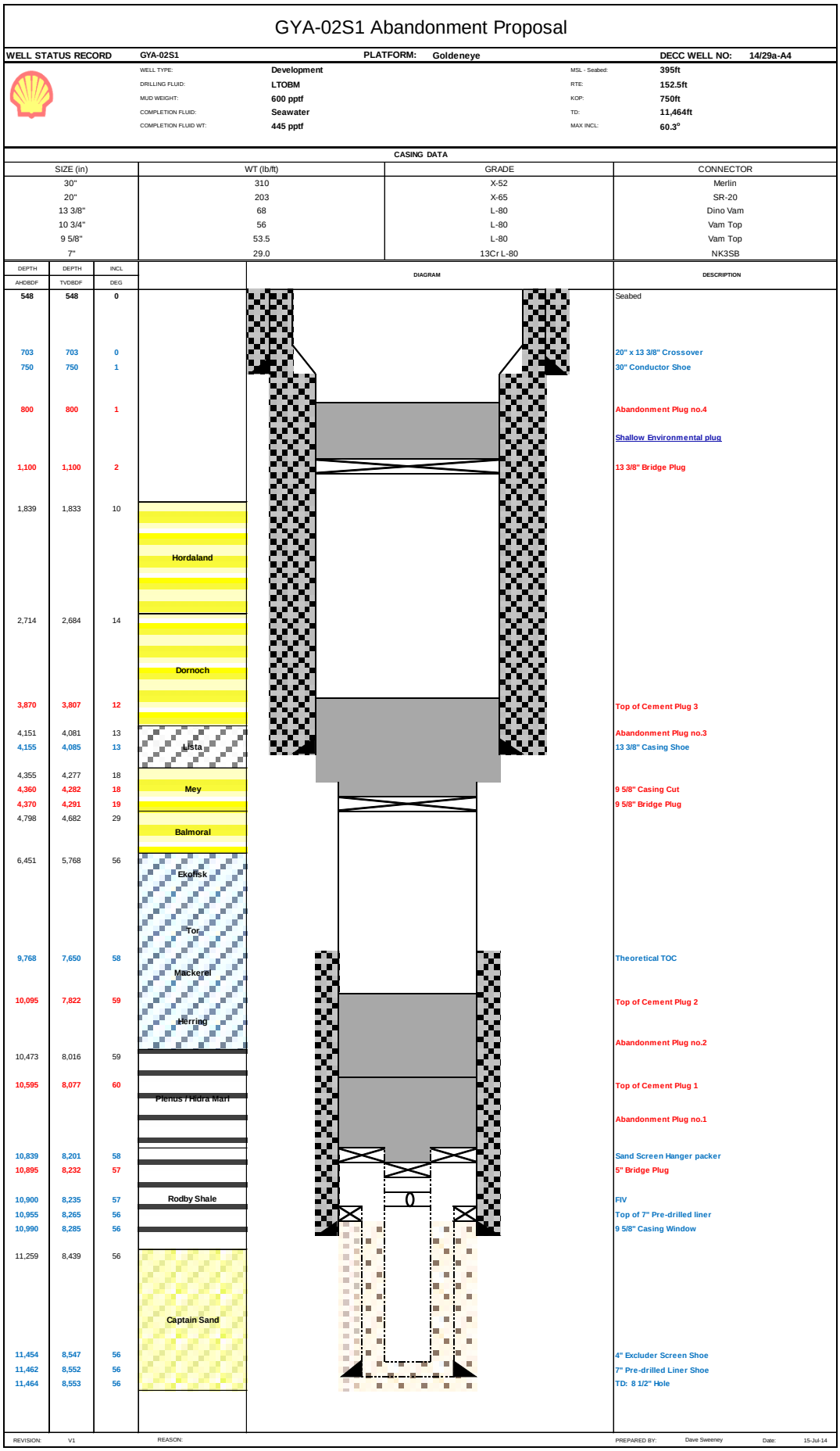


Figure 4-4: GYA02S1: Abandonment Proposal

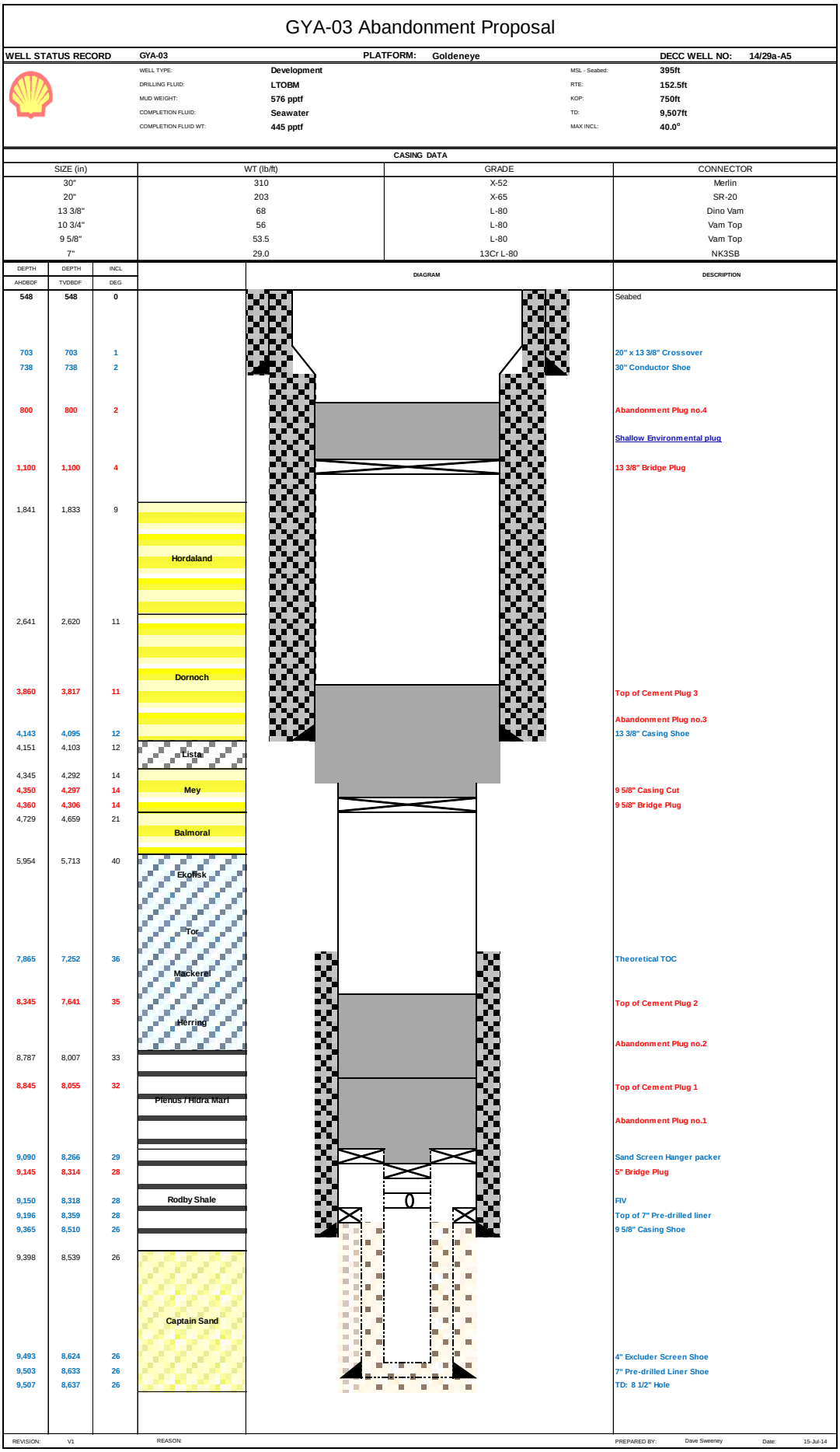


Figure 4-5: GYA03: Abandonment Proposal

4.4. Well Abandonment Design: Concept 3

Concept 3 is the base case abandonment design for well GYA-04, and assumes that all injected CO_2 is contained within the Captain reservoir. As such, the Balmoral formation is water bearing and only requires a single barrier from surface.

In this concept, the 9 ⅝" production casing is well cemented, with top of cement being confirmed as being above top Plenus Marl via a cement bond log. In addition, the thickness of the Plenus/Hidra Marl and Rodby Shale is sufficient to allow a composite cement plug to be set inside the 9 ⅝" casing (which can act as two barriers). The composite cement plug will be set inside cemented casing to provide cement and steel coverage across the full wellbore cross-section. In order to provide sufficient Plenus/Hidra Marl and Rodby formation length for the composite abandonment plug, the upper completion and production packer will be removed, but there is sufficient shale length to allow the sand screen hanger and lower completion to be left in situ.

To isolate the Balmoral formation, the 9 ⅝" casing will be cut and pulled from the base of the Lista. A single cement plug will then be set opposite the Lista formation, to provide cement coverage across the full wellbore cross-section.

The operational steps required to deliver this concept are as follows:

- Set a 5" bridge plug in the lower completion below the sand screen hanger and above the FIV to act as a base for combination cement plug no.1.
- Pull the upper completion, including the production packer and tailpipe.
- Run a cement bond log (CBL) to confirm that top of 9 ⅝" annular cement is above the Plenus Marl, and that the annular cement quality is suitable for abandonment purposes
  - If a CBL is obtained during workover operations, this data may be used for cement evaluation purposes.
  - If the 9 ⅝" casing is poorly cemented, concept 4 will be applied.
- Set combination cement plug no.1 on top of the 5" bridge plug and sand screen hanger.
- Set a bridge plug in the 9 ⅝" casing 10ft below the planned casing cut depth.
- Cut the 9 ⅝" casing 5ft below top Lista and pull the cut casing from the well.
- Set cement plug no.2 on the bridge plug, with top of cement placed inside cemented 13 ⅜" casing.
- Set a bridge plug in the 13 ⅜" casing at approximately 1,100ft.
- Set cement plug no.3 on the bridge plug, to act as an environmental barrier (i.e. to contain any residual oil-based mud from the open annuli generated when cutting casing).
- Cut the 30" conductor and 20" casing string 10ft below seabed, and pull both strings to surface.

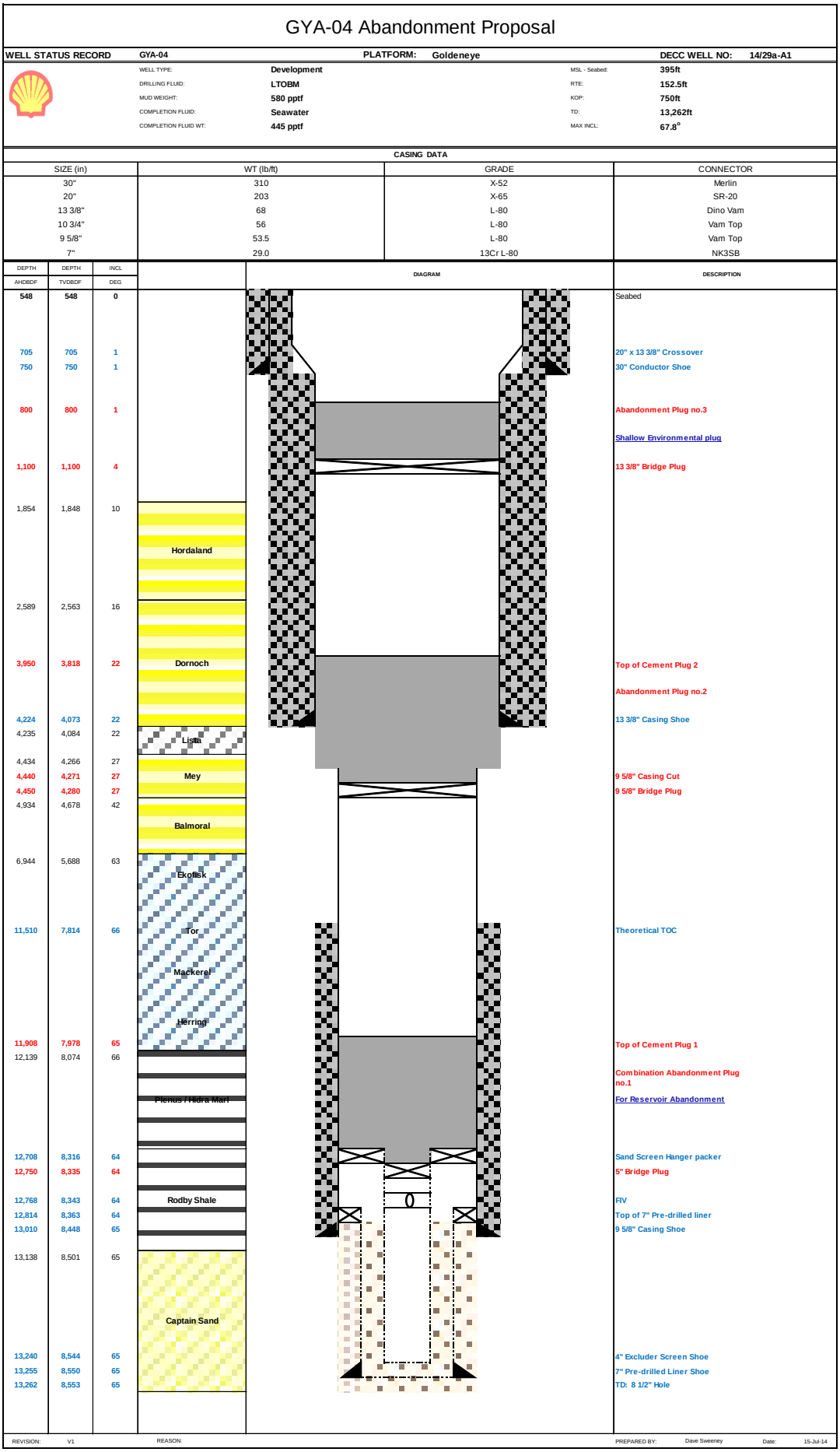


Figure 4-6: GYA04: Abandonment Proposal

4.5. Well Abandonment Design: Concept 4

Concept 4 is a contingency case abandonment design for concepts 1 to 3, and assumes that the 9 ⅝" production casing string has been poorly cemented (i.e. the annular cement is not of sufficient quality for abandonment barrier purposes).

The completion components which are removed pending abandonment will be the same as for concepts 1 to 3, and depends upon which well applies the contingency plan.

This concept delivers an acceptable abandonment barrier for the Captain reservoir by section milling the production casing and cement opposite the Rodby shales, and then setting a cement plug across the window to generate "rock-to-rock" cement coverage. Cuttings from the milling and associated retained milling fluid shall be collected in skips for transportation to shore and onshore disposal (the cuttings shall not be discharged to the marine environment). The second barrier (plug no.2) will be placed directly on top of plug no.1 in order to make best use of the Plenus Marl / Hidra cap-rock. The second barrier is supported on the outside of the production casing by annular cement from the primary cementation and partly by the cap-rock. Because only one abandonment barrier is set across the 9 ⅝" casing annulus, and verification of the seal in this annulus is problematic, the second Captain sand abandonment barrier is provided by the cement plug set across the Lista Shale (refer to Section 4.1 for the rationale behind being able to use the Lista Shale as a secondary Captain sand barrier).

The Balmoral formation will be isolated in the same manner as described in concepts 1 to 3.

An example of this contingency design, as applied to well GYA-01 is shown in **Figure 4-7** .

The operational steps required to deliver this concept are as follows:

- Pull the upper and lower completion (if required) as described in concepts 1 to 3.
- Set a bridge plug to act as a base for cement plug placement as described in concepts 1 to 3.
- Section mill a 150ft window in the 9 ⅝" casing opposite the Plenus/Hidra Marl and Rodby Shale.
- Under-ream the window, to ensure that the cement plug will be set against clean rock.
- Set cement plug no.1 on top of the bridge plug and across the window, placing top of cement above the window.
- Set cement plug no.2 on top of cement plug no.1.
- Set a bridge plug in the 9 ⅝" casing 10ft below the planned casing cut depth.
- Cut the 9 ⅝" casing 5ft below top Lista and pull the cut casing from the well.
- Set cement plug no.2 on the bridge plug, with top of cement placed inside cemented 13 ⅜" casing.
- Set a bridge plug in the 13 ⅜" casing at approximately 1,100ft.
- Set cement plug no.3 on the bridge plug, to act as an environmental barrier (i.e. to contain any residual oil-based mud from the open annuli generated when cutting casing).
- Cut the 30" conductor and 20" casing string 10ft below seabed, and pull both strings to surface.

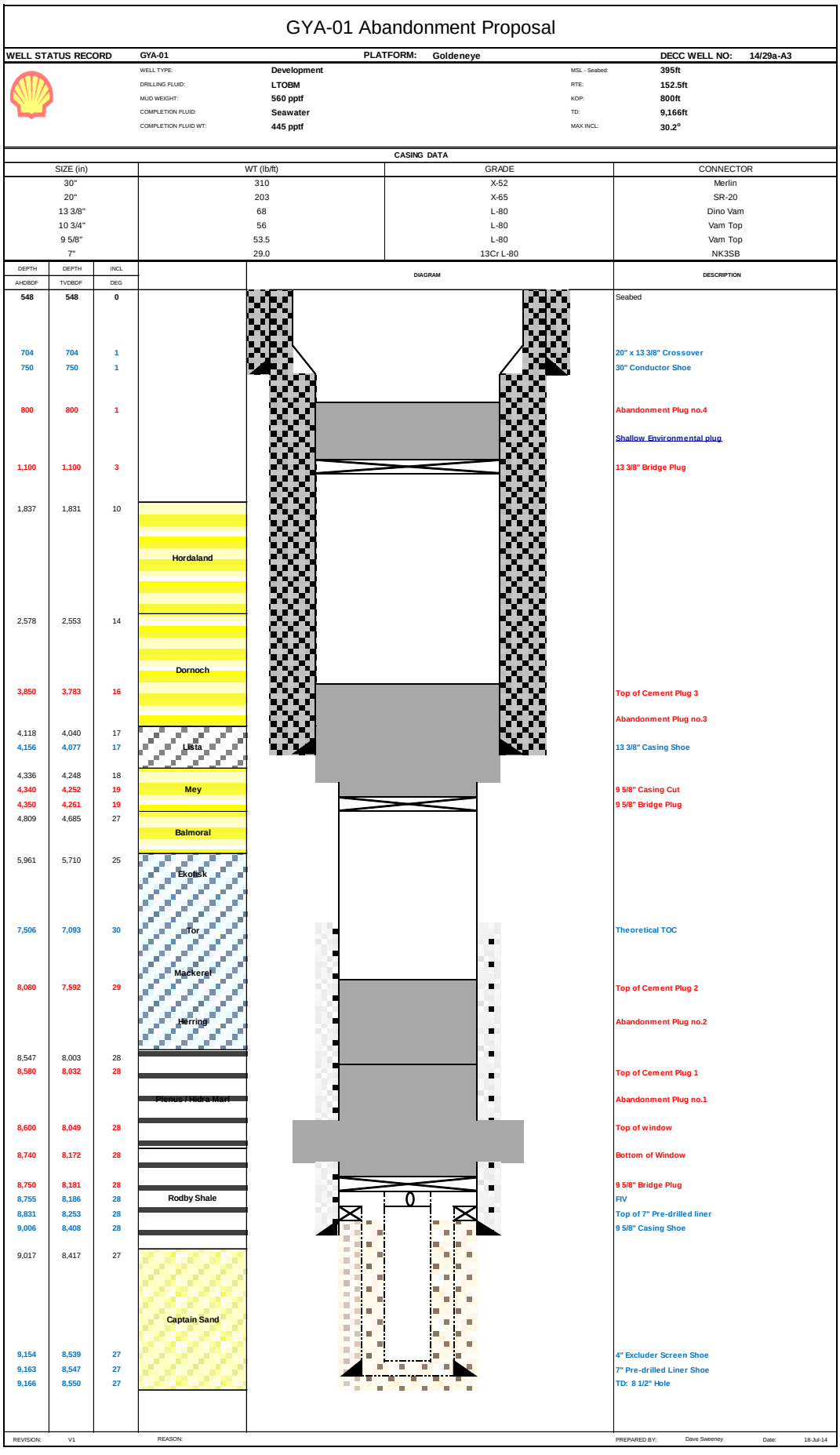


Figure 4-7: GYA01: Contingency Abandonment Concept for the Captain

4.6. Well Abandonment Design: Concept 5

Concept 5 is a contingency case abandonment design for concepts 1 to 3, and assumes that some CO_2 has migrated to the Balmoral formation and is therefore present in both the Captain reservoir and the Balmoral formations. Each formation will therefore require a minimum of two permanent barriers between the formation and seabed.

The Balmoral formation is assumed to have been charged with CO_2 and therefore requires two permanent barriers for containment. The Lista shales are the seal for the Balmoral formation, and since two permanent barriers are required, the second barrier will be set on top of the first Balmoral abandonment plug opposite the Dornoch shales.

An example of this contingency design, as applied to well GYA-01 is shown in .

The operational steps required to deliver this concept are as follows:

- Pull the upper and lower completion (if required) as described in concepts 1 to 3.
- Set a bridge plug to act as a base for cement plug placement as described in concepts 1 to 3.
- Run a cement bond log (CBL), which identifies poor cement outside the 9 ⅝" casing.
  - If a CBL is obtained during workover operations, this data may be used for cement evaluation purposes.
- Section mill a 150ft window in the 9 ⅝" casing opposite the Plenus / Hidra Marl and Rodby Shale.
- Under-ream the window, to ensure that the cement plug will be set against clean rock.
- Set cement plug no.1 on top of the bridge plug and across the window, placing top of cement above the window.
- Set cement plug no.2 on top of cement plug no.1.
- Set a bridge plug in the 9 ⅝" casing 10ft below the planned casing cut depth.
- Cut the 9 ⅝" casing 5ft below top Lista and pull the cut casing from the well.
- Set cement plug no.2 on the bridge plug, with top of cement placed inside cemented 13 ⅜" casing.
- Set a bridge plug in the 13 ⅜" casing at approximately 1,100ft.
- Set cement plug no.3 on the bridge plug, to act as an environmental barrier (i.e. to contain any residual oil-based mud from the open annuli generated when cutting casing).
- Cut the 30" conductor and 20" casing string 10ft below seabed, and pull both strings to surface.

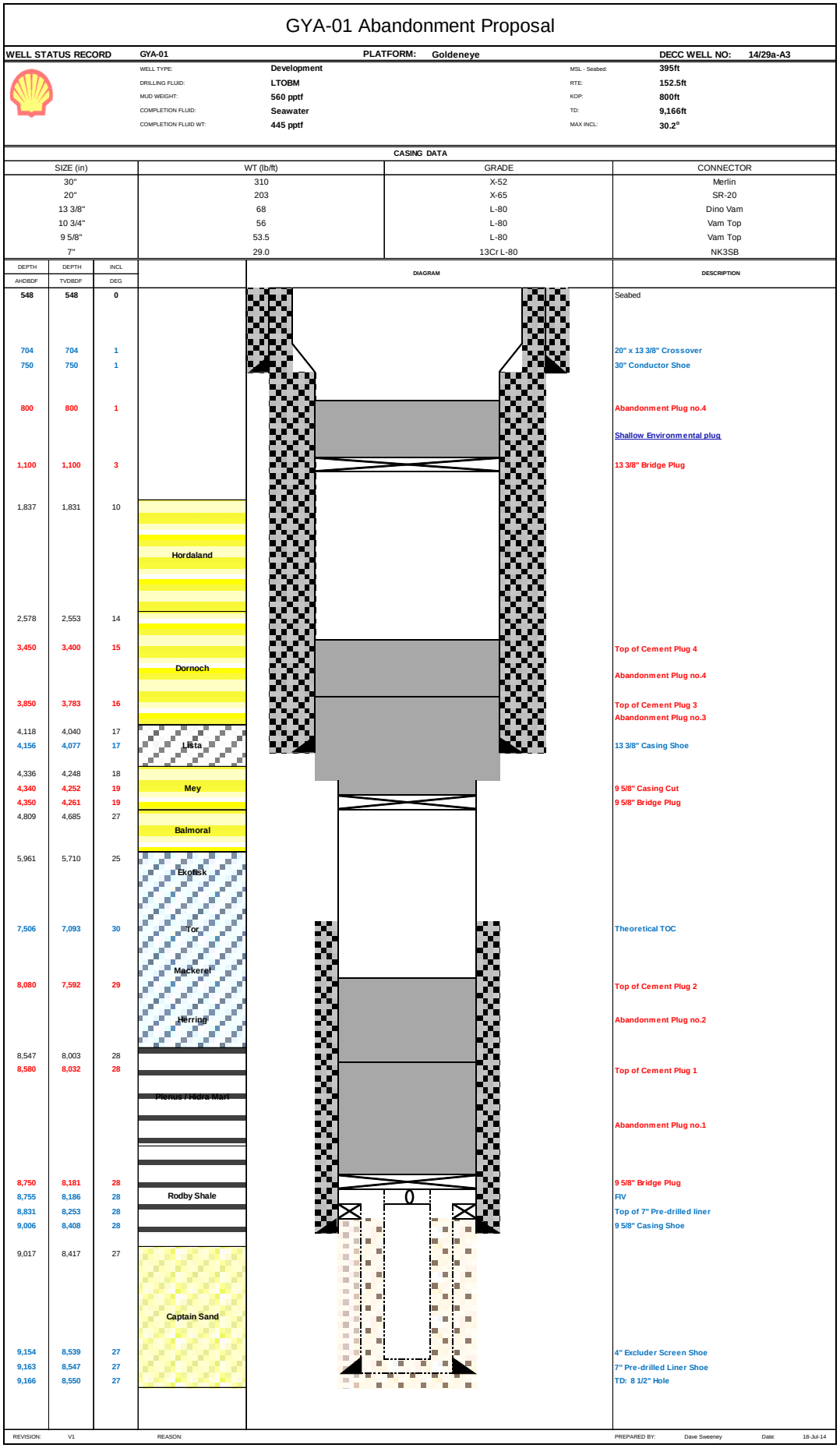


Figure 4-8: GYA01: Contingency Abandonment Concept for the Balmoral

5. Conclusions

Upon cessation of CO_2 disposal, the Goldeneye injection wells will be permanently abandoned. The abandonments will be based on the following conceptual basis of design:

- The Captain and Balmoral formations are the zones which will require isolation during abandonment.
- The abandonment design currently complies with the latest versions of Oil & Gas UK, "Guidelines for the Suspension and Abandonment of Wells" and Shell standards.
  - However, at the time of abandonment, the designs will be updated to comply with the prevailing legislative or industry standards.
- The Captain reservoir will be abandoned by setting two cement plugs opposite the Plenus/Hidra Marl and Rodby Shale.
- Where sufficient formation length exists, the two cement plugs will be set as a single combination plug.
- In all cases, the upper completion production packer will be removed prior to setting the abandonment plugs for plug length purposes.
- If required for plug length, the lower completion screen hanger and tubulars down to the FIV will be removed prior to setting the abandonment plugs.
- Cement bond logs will be run in each 9 ⅝" casing string to determine the position of top of cement behind the casing, and to evaluate cement quality.
  - The cement bod logs will be run either during workover or abandonment operations.
  - The expectation is that top of cement and cement quality will be acceptable, and if this is confirmed, then the abandonments will be conducted by setting cement plugs inside the 9 ⅝" casing and opposite logged cement.
  - In the event that either top of cement and cement quality are deemed to be unacceptable following log evaluation, the Captain reservoir will be abandoned by section milling a window in the 9 ⅝" casing opposite the Plenus/Hidra Marl and Rodby Shale and setting a "rock-to-rock" cement plug across the window. The abandonment plug set across the Lista will provide the secondary barrier to the 9 ⅝" casing annulus in this case.
- The Balmoral formation will be abandoned using a single cement plug, unless it is suspected that CO_2 has leaked into this formation.
  - If leakage is suspected, the Balmoral formation will be abandoned using two cement plugs.
- It is currently planned to use conventional cements with additives to maintain elasticity. However, at the time of abandonment, cement slurry design will be re-evaluated to ensure that any new products developed in the intervening period are incorporated into the abandonment plug design.

6. References In-Text

1) Oil & Gas UK, "Guidelines for the Suspension and Abandonment of Wells", Issue 4, July 2012

2) "Well Integrity for CO_2 storage in the fields Barendrecht and Barendrecht-Ziedewij" – TNO – June 2007

3) PCCS-05-PT-ZW-7180-00002 (Key Knowledge Deliverable 11.093) Conceptual Completions and Well Intervention Design Report. 2013. Peterhead Goldeneye CCS. 2013.

4) PCCS-05-PT-ZW-7180-00003 (Key Knowledge Deliverable 11.097) Well Completion Concept Select. 2013. Peterhead Goldeneye CCS. 2013.

5) PCCS-05-PT-ZR-3323-00002 (Key Knowledge Deliverable 11.122) Dynamic Reservoir Modelling Report. 2014. Peterhead Goldeneye CCS. 2014.

6) PCCS-05-PT-ZW-7180-00004 (Key Knowledge Deliverable 11.113) Well Integrity Assessment Report. 2014. Peterhead Goldeneye CCS. 2014.

7) PCCS-05-PT-ZW-7180-00005 (Key Knowledge Deliverable 11.098) Well Functional Specification. 2014. Peterhead Goldeneye CCS. 2014.

7. Glossary of Terms

Term	Definition
13Cr	13 percent chrome content metallurgy
AHD	Along Hole Depth
AHDBDF	Along Hole Depth, below drillfloor
Bbl	Blue Barrel – standard measurement
BHP	Bottom hole pressure
BPM	Barrel per minute
CBL	Cement Bond Log
CCS	Carbon Capture & Storage
CCS	Carbon Capture Sequestration
CO_2	Carbon Dioxide
DAS	Digital Acquisition system
DEG	Degrees
DTS	Distributed temperature Sensing
EMW	Equivalent mud weight
ft	feet
FIV	Formation Isolation Valve
ID	Inside Diameter
INCL	Inclination
LB/FT	Pounds per foot
LTOBM	Low toxicity oil-based mud
MD	Measured depth
MDT	Modular Formation Dynamics Tester
N/A	Not applicable
OBM	Oil based mud
OD	Outside Diameter
PBR	Polished Bore Receptacle
PDGM	Permanent downhole gauge mandrel
PDG	Permanent downhole gauge
PPTF	Pounds per thousand feet
PSI	Pounds per Square Inch
PSIA	Pounds per Square Inch, actual
PSI/FT	PSI per foot

RFT	Repeat Formation Tester
RKB	Rotary Kelly Bushing
ROV	Remotely Operated Vehicle
TD	Total Depth
TOC	Top of Cement
TOL	Top of Liner
TRSSSV	Tubing Retrievable Subsurface Safety Valve
TS	Technical Standard
TTOC	Theoretical Top of Cement
TVD	True Vertical Depth
TVDBDF	True Vertical Depth, below drillfloor
TVDSS	True Vertical Depth, Subsea
UTM	Universal Transverse Mercator
WH	Wellhead
WT	Weight
X/O	Cross Over

8. Glossary of Unit Conversions

Table 8-1: Unit Conversion Table

Function	Unit - Imperial to Metric conversion Factor
Length	1 Foot = 0.3048 metres 1 Inch = 25.4 millimetres
Pressure	1 Bara = 14.5psia
Temperature	°F=(1.8)(°C)+32 °R=(1.8)(K) (absolute scale)
Weight	1 Pound = 0.454 Kilogram

Table 8-2: Well Name Abbreviation Table

Full well name	Abbreviated well name
DTI 14/29a-A3	GYA01
DTI 14/29a-A4Z	GYA02S1
DTI 14/29a-A4	GYA02
DTI 14/29a-A5	GYA03
DTI 14/29a-A1	GYA04
DTI 14/29a-A2	GYA05