Cost Effective Alternative to Cased Hole Bond Logging: Full Waveform Capture using Open Hole Sonic Tool

With rig rental costs rising and attempts to minimize costs, the need for fast, efficient and accurate log acquisition is becoming more prevalent. Logging services are faced with the task of minimizing impact to rig time and cost of logging programs, thereby increasing the overall efficiency and economics of the drilling and completion process.

The following case study outlines the use of RECON's Full Waveform Sonic (FWS) function of the open hole Borehole Compensated Sonic tool (BHCS) to provide an operator with a cased hole bond log, requiring no additional passes, logging tools, drilling rig time or service rig rental.

Case History

Bond logging from acoustic tools serves several important functions to Operators in evaluating their wells and may have important production, regulatory or legal implications. Foremost is an evaluation of the integrity of the cement job, especially whether the cement is adhering solidly to the outside of the casing. In addition, a qualitative measure of hydraulic isolation surrounding the zone(s) of interest is determined. The most common form of bond logging is the Cement Bond Log (CBL) which is widely used since its introduction in the mid-1960s and continues to be one of the most popular forms of cement evaluation currently available.

The cased hole CBL and the open hole BHCS log essentially share the same measurement principles. Whereas a CBL relies on a centralized single transmitter and dual receiver configuration (3-ft and 5-ft), the BHCS is a centralized multiple-transmitter and multiple-receiver tool. A BHCS measures the *'first arrival' time* of the acoustic signal to produce a formation slowness value, whereas a standard CBL uses the *amplitude* of the 'first arrival' to indicate cement bond integrity.

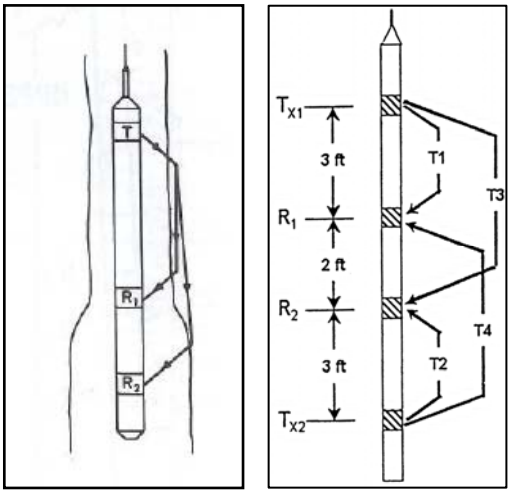


Figure 1: *Schematic representations of dual receiver (CBL, left) and multiple receiver (BHCS, right) sonic tools. An open hole BHCS tool is two dual receiver type sonic tools stacked inline. Dual and multiple receiver type sonic tools are compensated for the effects of mud path contribution, eccentralization, hole deviation and washout.*

The Variable Density Log (VDL) is a common display that accompanies bond logs. A VDL is created by transforming the acoustic waveform at each depth interval into a series of black and white lines that represent the amplitude of the waveforms' individual peaks (positive amplitudes) and valleys (negative amplitudes). Zero amplitude is represented with grey, negative amplitude with white and

positive amplitude with black. The visual representation of the waveform provides a simple evaluation method for cement integrity as bonded and free pipe can easily be differentiated.

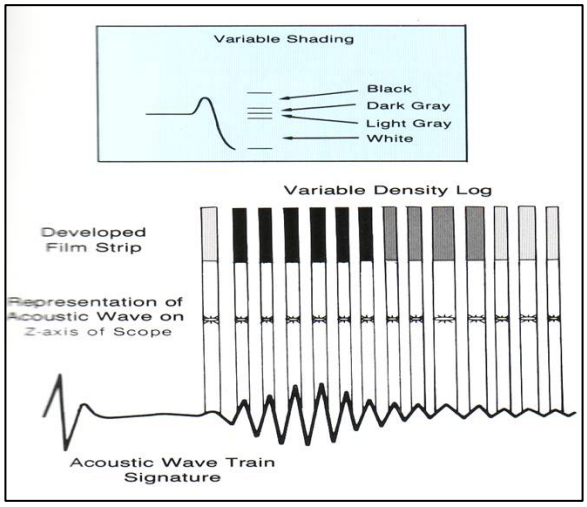


Figure 2: *Representation of the acoustic waveform (bottom) transformed into a Variable Density Log (VDL) display (top) Positive amplitudes are black while negative amplitudes are white. Low amplitudes (including zero amplitude) are represented in shades of grey.*

RECON has incorporated the Full Waveform Sonic (FWS) function into their open hole BHCS tool as a means of reducing analog to digital data conversion downhole while at the same time allowing for more effective analysis of sonic data uphole, including CBL-VDL displays of sonic data to be used in cement evaluation.

The advantage of maintaining full integrity analog acoustic data and not digitizing downhole is that the full unaltered waveform is available on surface for processing. Data that has been digitized downhole, i.e. the acoustic waveform data is converted from analog to digital; is sent uphole and then re-created at surface. During this process of conversion and reconversion, portions of acoustic data can be lost or filtered. By sending the full waveform uphole as analog data, no data is lost or compromised during transmission or through unnecessary conversion.

One of the most cost effective applications of FWS is the ability to produce a CBL and VDL from open hole BHCS log data. Since the acoustic data is not converted to a digital format prior to sending uphole, the full waveform is available uphole for processing and playback. With digital sonic tools, a separate pass with the sonic configured in a bond logging mode is required to obtain a CBL-VDL bond log. With FWS, creating a CBL-VDL bond log is a simple matter of data playback, using open hole acoustic data that is already being recorded; no open hole sonic data is compromised over any section of the wellbore to obtain this additional data. FWS also allows bond logs to be generated from previously logged wells, provided they were logged with FWS. All RECON BHCS tools employ full-time FWS when recording acoustic data in open or cased hole applications.

Cost Effective Economic Advantages

The RECON Full Waveform Sonic as part of the acoustic data acquisition process does not require additional logging passes, specialized set-up, tools or equipment. Acoustic logs are run at standard speeds (up to 3,000 ft/hr or 15 m/min in casing) without the need to slow down. This acoustic data can be acquired during completion of open hole logging operations, as part of the main pass log, requiring no additional passes and resulting in no additional rig time.

Since the Full Waveform Sonic (FWS) function of the open hole BHCS can be displayed as a bond log CBL-VDL, the cased hole cement evaluation can be completed during the open hole logging operation. This can potentially save the Operator from the additional costs incurred by bond logging the cased interval prior to completing and perforating the well.

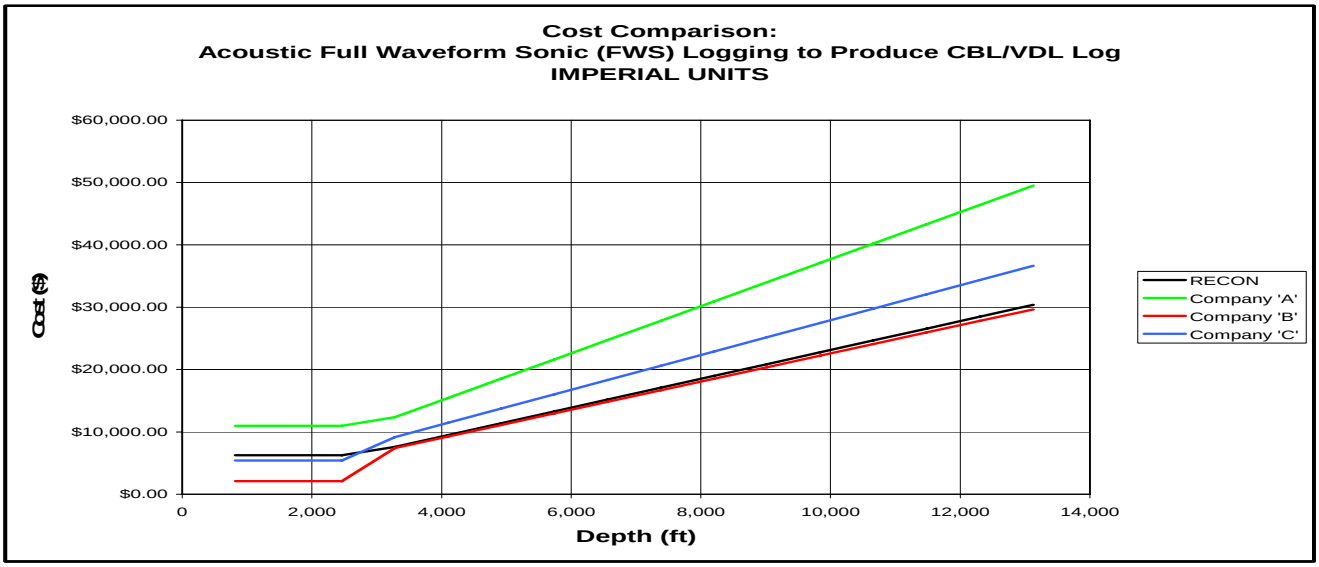
A comparison of various rates for FWS or equivalent service is presented below (Table 1) for a variety of open hole service companies. Key to this table is the differentiation between standard open hole BHCS logs and the FWS service or equivalent. The open hole BHCS is required in all cases; it provides the basic compressional acoustic data and a resulting depth and operations charge (subject to minimums). The FWS equivalent is either a specialized acquisition mode or reprocessing charge; therefore there is no depth charge in addition to the standard sonic depth rate, there is only an additional operations charge.

This same comparison is presented as a graph (Figure 3). While this figure takes minimum depth and operation charges into consideration, the service, truck, travel and crew rates are not included. The graph presents the FWS equivalent service only.

Comparison of Various Logging Rates for Full Waveform Sonic or Equivalent							
Company Name	**Service (FWS equivalent)**	**Depth (per ft)**	**Depth (per m)**	**Depth Minimum**	**Depth (per ft)**	**Operation (per m)**	**Operation Minimum**
RECON		**$0.89**	**$2.91**	**$2,461.86**	**$1.68**	**$5.51**	**$3,786.86**
– 0% Discount *	BHCS tool	$0.89	$2.91	$2,461.86	$0.89	$2.91	$2,461.86
	FWS	$0.00	$0.00	$0.00	$0.79	$2.60	$1,325.00
Company "A"		**$0.96**	**$3.15**	**$2,664.90**	**$3.30**	**$10.85**	**$8,333.10**
– 0% Discount *	BHCS tool	$0.69	$2.25	$1,903.50	$0.76	$2.50	$1,903.50
	Sonic Signature	$0.00	$0.00	$0.00	$0.76	$2.50	$1,903.50
	VDL	$0.00	$0.00	$0.00	$0.76	$2.50	$1,903.50
	CBL	$0.00	$0.00	$0.00	$0.76	$2.50	$1,903.50
	CCL	$0.27	$0.90	$761.40	$0.26	$0.85	$719.10
Company "B"		**$0.91**	**$3.00**	**$1,800.00**	**$2.20**	**$7.25**	**$3,625.00**
– 0% Discount *	BHC tool	$0.91	$3.00	$1,800.00	$0.91	$3.00	$1,500.00
	Waveform Rec	$0.00	$0.00	$0.00	$0.41	$1.35	$675.00
	CBL	$0.00	$0.00	$0.00	$0.88	$2.90	$1,450.00
Company "C"		**$0.78**	**$2.55**	**$1,530.00**	**$1.62**	**$5.30**	**$2,100.00**
– 0% Discount *	CST tool	$0.78	$2.55	$1,530.00	$0.78	$2.55	$1,275.00
	SWL	$0.00	$0.00	$0.00	$0.84	$2.75	$825.00

* Prices based on published data, subject to discount

Table 1: *Comparison of published open hole logging rates for various service companies for Full Waveform Sonic (FWS) equivalent service. These prices do not include additional service fees, truck, travel and crew fees.*

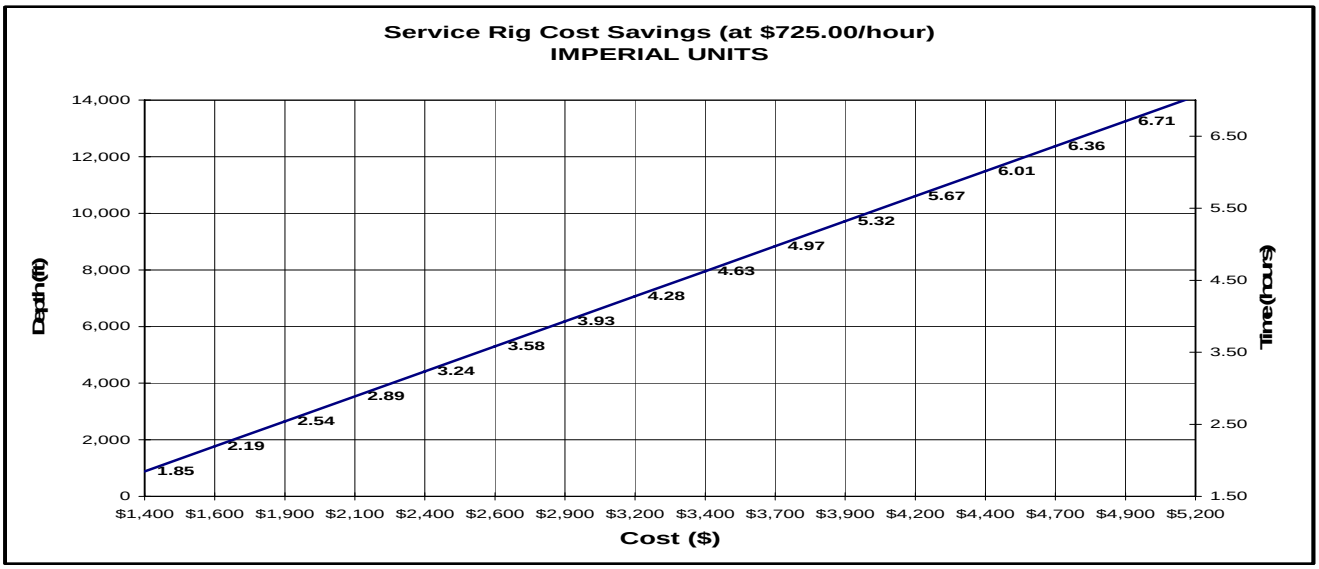


* Prices based on published data, subject to discount

Figure 3: *Resulting Cost Comparison of published open hole logging rates for various service companies for Full Waveform Sonic (FWS) equivalent service over a range of depths.*

Further to the base cost of the Full Waveform Sonic is the potential savings in Service Rig Costs. By reducing the amount of cased hole cement evaluation during the completion process, Operators can potentially save on service rig costs by performing all, or a portion of, the cement evaluation during open hole logging operations.

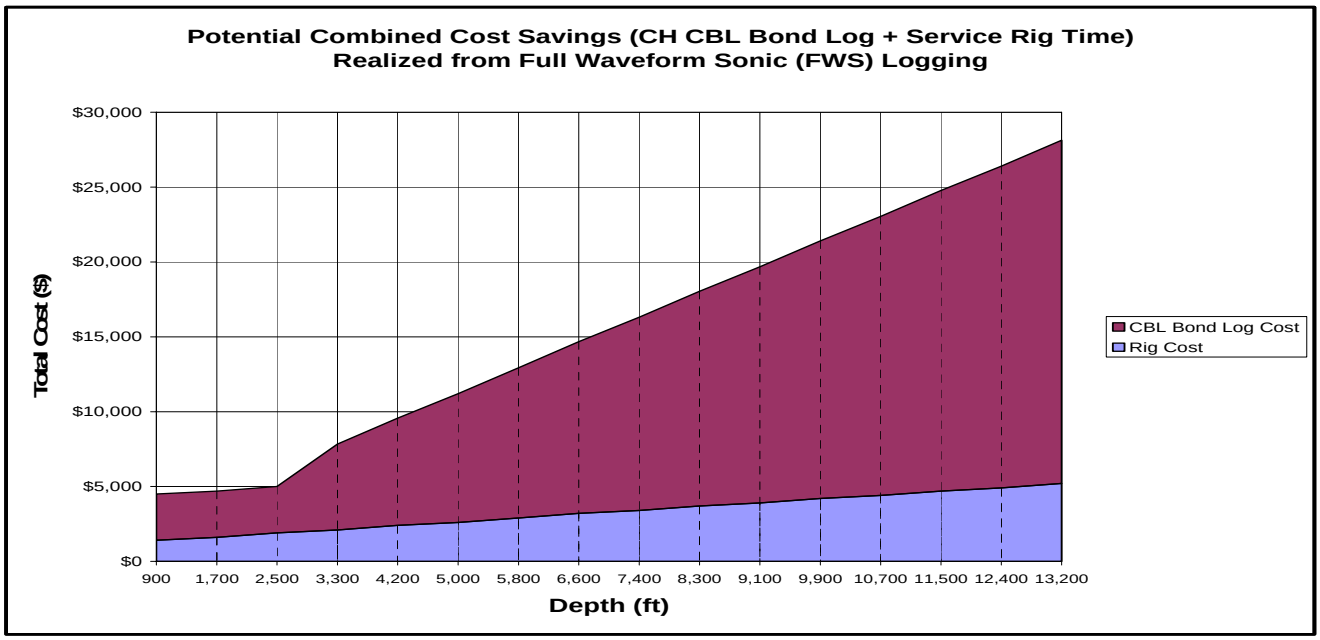
With the average service rig costs averaging around $700-725.00/hour ($17,500.00/day), savings incurred by evaluating cement prior to completions can be upwards of $5,000.00 on deeper wells.



* Prices based on published data, subject to discount

Figure 4: *Service Rig Cost Savings resulting from using OH Full Waveform Sonic (FWS) equivalent over a range of depths. Cost Savings based on time rate of $725.00/hour ("All-In" cost). Time based on 1.5 hours (Rig Up and Rig Down) + Run in speed of 200 ft/min (60 m/min) + Logging speed of 50 ft/min (15 m/min).*

By combining the potential cost benefits of reduced service rig times and reduced CH logging costs by replacing traditional CH CBL logs with OH FWS logs, Operators can potentially save almost $30,000.00 (see Figure 5).



* Prices based on published data, subject to discount

Figure 5: *Combined Cost Savings Realized from Full Waveform Sonic (FWS) Logging. The costs associated with traditional CH CBL logging and the associated Service Rig costs to perform cement evaluations are combined to maximize savings when utilizing Full Waveform Sonic (FWS) during open hole logging operations.*

Case Studies:

Both of these case studies demonstrate a cost effective alternative for obtaining cement bond logs for cement evaluation by using the Full Waveform Sonic function of RECON's open hole Borehole Compensated Sonic (BHCS) tool. The economic advantages of utilizing this RECON standard of acoustic data acquisition include: requiring no additional logging passes, no separate or specialized logging tools, no additional drilling rig time or service rig rental incurred costs.

Case Study #1:

Full suite open hole logging (Resistivity-SP-Sonic-Density-Neutron-GR-Calipers) was performed for an Operator in Alberta, Canada by RECON over the bottom section of a well that was drilled in two segments (intermediate and TD sections). Upon completion of open hole logging operations over the lower portion of the well, the Operator prepared to complete the well using basic cased hole logging evaluation services.

As per regulatory requirements in Alberta, the Operator was required to provide gamma ray and compensated neutron logs through both surface and intermediate strings of casing (GR-CNL). Surface casing GR-CNL logging is normally provided upon completion of open hole logging operations from surface casing shoe to surface by the open hole logging company. In addition to the standard GR-CNL through surface casing regulatory requirement, the regulatory body in the Province

of Alberta also requires GR-CNL logs across the intermediate portion of the well, in cases where open hole logs were not obtained. In addition to this requirement, a bond log across the intermediate casing of the well was required prior to completion. Rather than run a separate cased hole bond logging service on the well, the Operator took advantage of RECON's Full Waveform Sonic (FWS) function of the open hole BHCS to provide the regulatory body with all the requirements for the well including GR, CNL and CBL through intermediate casing. The following examples shown demonstrate both free and bonded pipe conditions in the intermediate casing:

Case Study #1, Example #1: Bonded Pipe

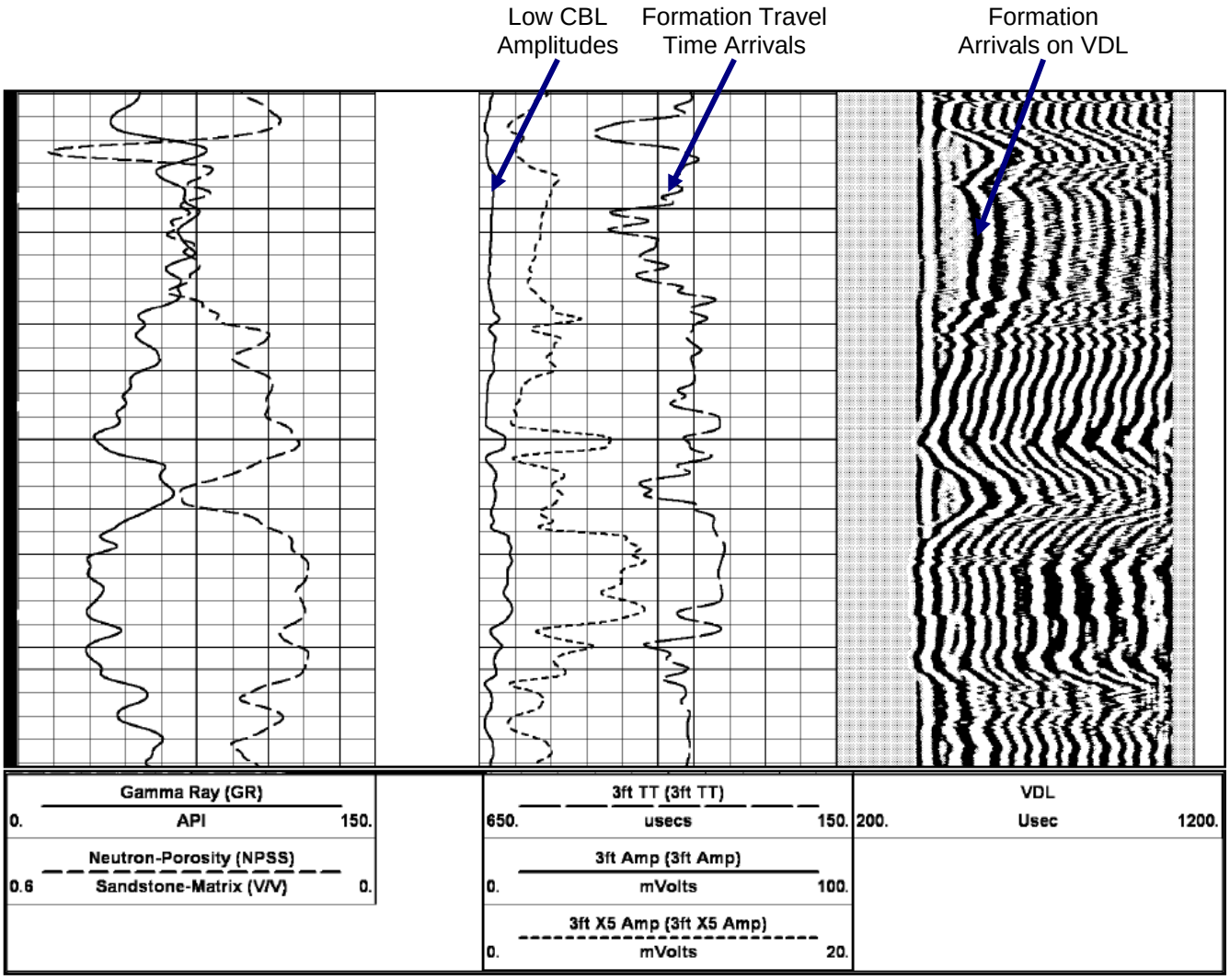


Figure 6: *CBL-VDL-CNL log presentation obtained from RECON open hole BHCS with FWS function. Compensated Neutron (CNL) porosity on a sandstone matrix is presented with GR in Track 1. CBL Amplitudes and Travel Time are displayed in Track 2 with the VDL in Track 3. This section of log shows pipe with good cement bond; CBL 3ft amplitudes are low and formation arrivals are clearly visible on the VDL.*

Case Study #1, Example #2: Free Pipe

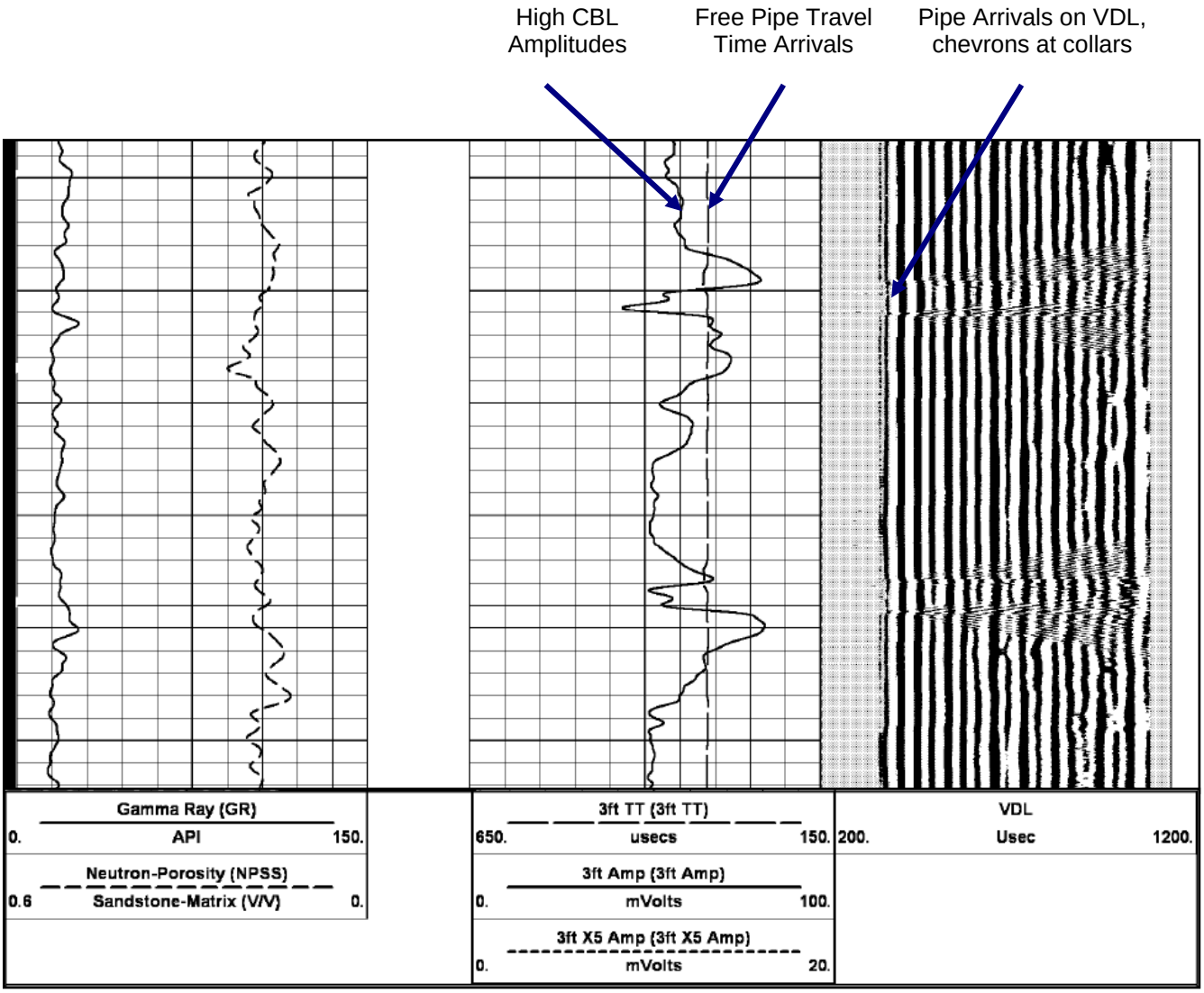


Figure 7: *CBL-VDL-CNL log presentation obtained from RECON Open Hole BHCS with Full Waveform Sonic (FWS) function. Compensated Neutron (CNL) porosity on a sandstone matrix is presented with GR in Track 1. CBL Amplitudes and Travel Time are displayed in Track 2 with the VDL in Track 3. This section of log shows pipe with little or no cement bond; CBL 3ft amplitudes are very high and only pipe and fluid arrivals are visible on the VDL (free pipe "ringing"). The presence of "chevrons" confirms the position of casing collar locations and verifies free pipe conditions over this section of log.*

Case Study #2:

Alberta Provincial Regulations required that an Operator obtain a GR-CNL log over the intermediate cased portion of a horizontal well. Intermediate casing was set at the heel of the horizontal section (~90° deviation) and regulations required that logs be obtained from point of refusal via gravity descent. The Operator chose to employ RECON's GR-CNL tool string with the addition of a casing collar locator (CCL) and a BHCS with FWS for cement evaluation.

Case Study #2, Example #1: Free and Bonded Pipe:

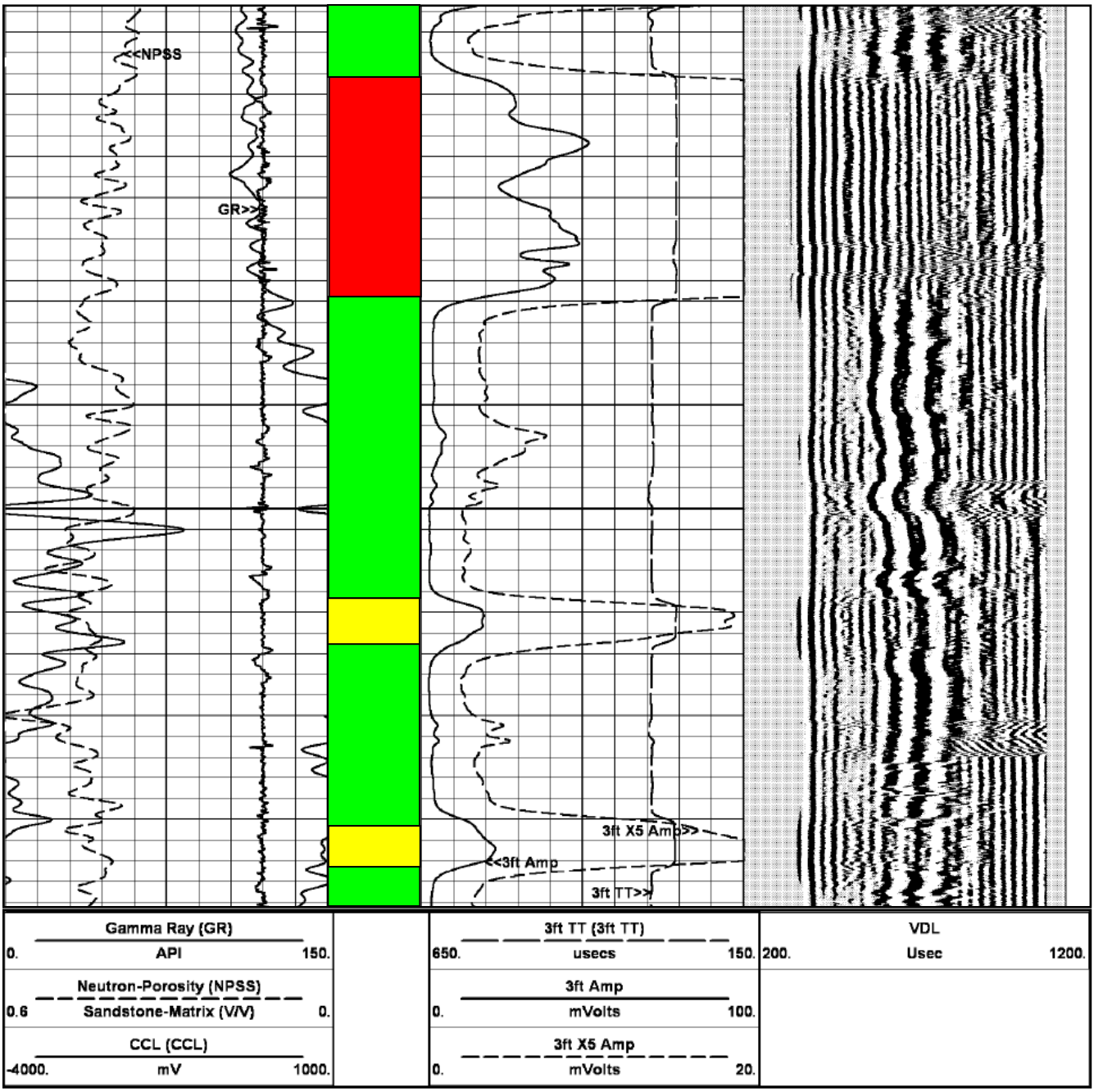


Figure 8: *CBL-VDL-CNL log presentation obtained from RECON Open Hole BHCS with Full Waveform Sonic (FWS) function. Compensated Neutron (CNL) porosity on a sandstone matrix is presented with GR and CCL in Track 1. CBL Amplitudes and Travel Time are displayed in Track 2 with the VDL in Track 3. This portion of log shows sections of intermediate casing with bonded and free pipe. Bonded pipe sections have been highlighted in green on the depth track; free pipe sections have been highlighted in red; sections with partial bond have been highlighted in yellow.*

Company Overview

RECON strives to obtain the most accurate data at the industry's highest STANDARD sampling rate (10 samples/ft, 33 samples/m), all the while having the lowest impact to Operator rig time and logging program costs. RECON is also the industry's only true provider of HDD™ (40 samples/ft, 132 samples/m) which offers unmatched reservoir characterization with substantially less economic impact than industry standard high resolution logging (12 samples/ft, 40 samples/m). When it comes to fast, accurate and superior well log data, RECON Petrotechnologies is the clear leader.

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References:

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2. Crain, E. R. (Ross)., "Crain's Petrophysical Handbook: Cement Integrity Logs – Part 1" http://www.spec2000.net/07-cementlog1.htm

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