Using Pressure While Drilling to Calculate Injectivity Index

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ABSTRACT

Pressure While Drilling (PWD) data was collected on several wells drilled in Nevada, USA in 2025, and was used to calculate injectivity index in real time and to do injection tests. This provided real time injection capacity estimates while saving rig time. This paper will cover (a) a description of the PWD technology, (b) a number of examples where comparison between PWD injectivity calculations versus injection test results after the wells were completed, and (c) a brief discussion on future optimization of the approach.

1. INTRODUCTION

Historically indications of permeability whilst drilling were determined through looking at the loss rate of drilling fluids and coupling this with the observation of drilling breaks. Injectivity Index can be estimated with partial losses by calculating downhole pressure from the surface. Total losses of drilling fluids indicated sufficient permeability for a commercial well, however this can be impacted by other variables such as deep water tables such that total losses may not indicate commercial permeability. An open-hole stage test is commonly undertaken to increase relative confidence of sufficient permeability to run a slotted liner and complete the well, often with a pressure-temperature (PT) tool run downhole which typically sat within the casing shoe.

Mercury used Injectivity Index (II) calculated from Pressure While Drilling (PWD) to make real-time drilling decisions for four geothermal wells at the Kawerau (Milicich et al., 2016) and Rotokawa (McNamara et al., 2016) fields in New Zealand (Le Brun et al., 2021). This approach provided continuous monitoring of downhole pressure and was able to provide more quantitative measures of injectivity and therefore a likely well performance. This assisted Mercury through reduced waiting time for data analysis, and supported critical decisions including total depth determination, sidetrack planning, and drilling continuation.
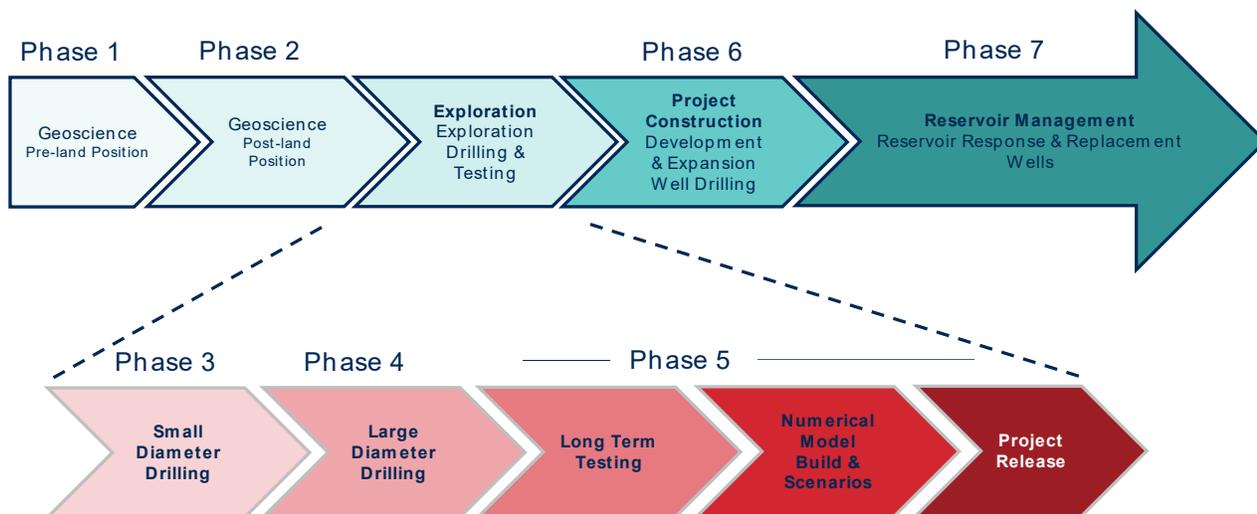

Figure 1: Ormat Development Workflow (Webbison et al., 2026)

Following the work conducted by Mercury, Ormat in 2023 commenced to trial the collection of PWD data across select wells being actively drilled in higher temperature resources and proved the viability of the approach. With the commencement of significant full-size exploration drilling as part of Ormat's growth plans, with a high focus on the Great Basin where many low-medium enthalpy geothermal fields occur, Ormat decided to test the viability of using PWD as part of its exploration drilling to improve real-time decision making. When exploring for low-medium enthalpy geothermal fields, the permeability requirements of a successful well are significantly higher than traditional high enthalpy geothermal fields. This can be seen in Figure 2.
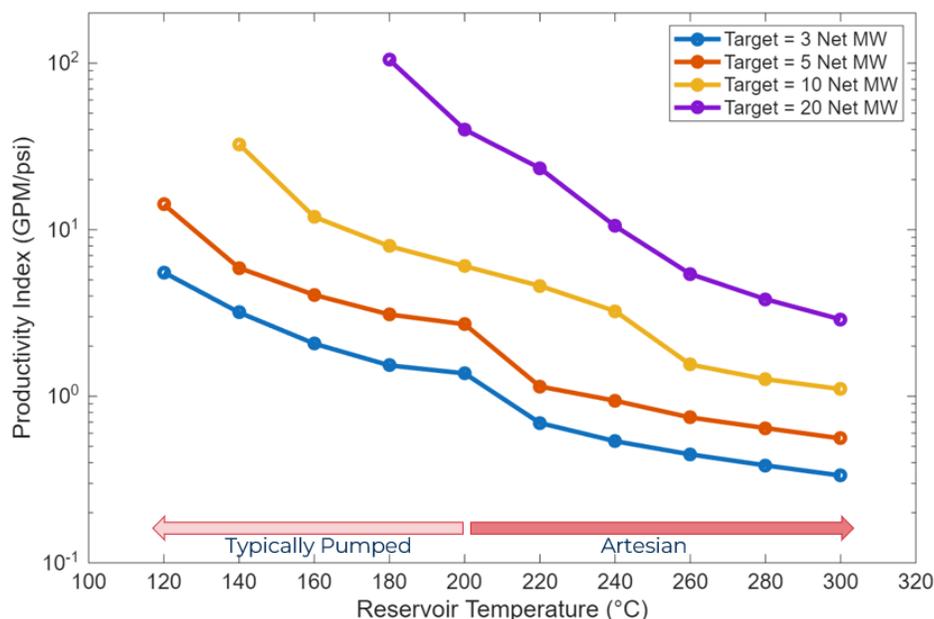
Figure 2. Productivity Index versus production temperature for several output targets.

Ormat collected PWD data on several wells drilled in the Great Basin with a campaign that commenced in late 2024 and has continued through 2025 and will continue thereafter. These wells are the basis of the technical results presented in this paper. The data was used to calculate injectivity index in real time and was sometimes utilized to do injection tests prior to a final decision to complete the well or to continue drilling, as the PWD tool was within the open-hole section with potential concerns of running wireline pressure-temperature (PT) tools within an open hole section. This provided real time injection capacity estimates while saving rig time from a traditional testing approach of pulling the drilling string out of the hole and running a downhole PT tool. In all scenarios step rate injection tests were conducted with downhole PT tools after the wells were completed and compared to the PWD injectivities, with the PT tool being located within the reservoir section of the well for the completion testing.

Comparison of injectivity measurements indicated that Injectivity Index (II) values obtained from final injection tests were higher than those derived from PWD data for most wells. Specifically, four wells exhibited final injectivity values that were 18% to 80% greater than the corresponding PWD-based estimates. Two wells showed significant deviation, which were attributed to fill-related issues occurring either before or after the tests, affecting flow capacity and pressure response. Lower II estimates from PWD are probably due to mud and cuttings in the fractures that were cleaned out by flowing the wells before the final injection test. Ormat has on recent wells been engaging with open hole cleanouts prior to running casing if the hole stability allows for this, and through time with further tests additional insights will be gained around the difference between running short-term cleanout flows with and without the liner installed.

2. PRESSURE WHILE DRILLING (PWD)

Measurement While Drilling (MWD) systems transmit directional and drilling motor data to the surface in real time, enabling continuous monitoring of well trajectory and drilling performance. PWD, typically integrated as a sub within the MWD tool string, provides downhole pressure (DHP) measurements near the bit. Lost circulation events serve as indicators of formation permeability; partial losses can be leveraged to estimate the Injectivity Index (II) by calculating downhole pressure from surface measurements, whereas total losses suggest high permeability but preclude accurate pressure estimation due to unknown fluid level. The II is defined as the ratio of mud loss rate to the pressure differential between DHP and static pressure (II = Mud Loss Rate / (DHP – Static P)). PWD enables dynamic injection testing without interrupting drilling operations, offering significant operational efficiency. However, limitations exist: the Productivity Index may differ from the Injectivity Index, mud and cuttings can obstruct shallower permeable zones, and accurate static pressure estimation is essential for reliable II calculations. In some instances, the transmission of data to the surface may be disrupted depending on the method utilized (either mud pulse or electric signal through casing).
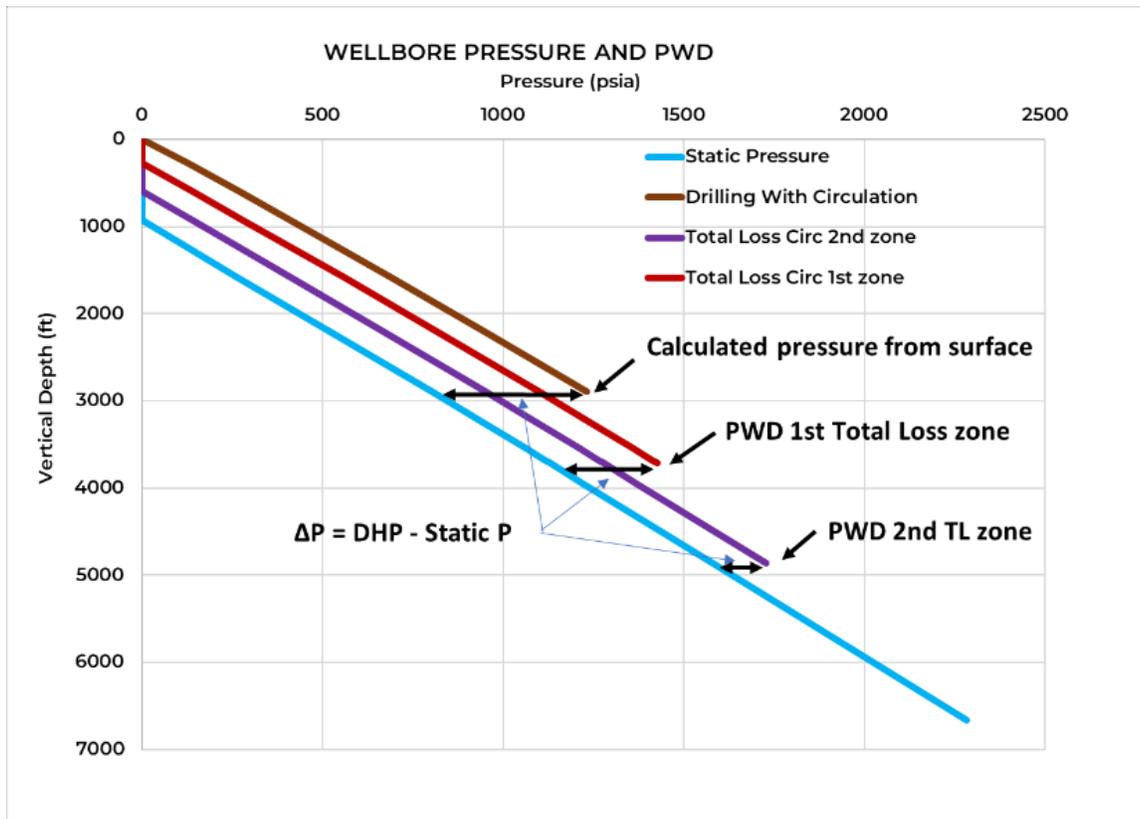
Figure 3. Wellbore pressures, PWD measurements, and static pressure.

Figure 4. Pressure While Drilling tool.

3. HOW TO CALCULATE II FROM PWD

The Injectivity Index (II) is defined as the ratio of injection rate to the pressure differential (ΔP), where the injection rate corresponds to the mud loss rate during drilling operations. Surface measurements from electronic drilling recorder provide the "Total Pump Rate," which represents the flow rate down the drillpipe in gallons per minute (gpm), and "Flow," which indicates the percentage level in the mud return line. To determine the actual mud return rate in gpm, the flow percentage is corrected using full circulation calibration values (Flow$_{fc}$ and Total Pump Rate$_{fc}$) according to the relation: Mud Return Rate = Flow × (Pump Rate$_{fc}$ / Flow$_{fc}$). The mud loss rate is then calculated as the difference between the total pump rate and the mud return rate. This relationship is further calibrated to mud loss rates determined from pit levels, inflows, and outflows. The ΔP is obtained by subtracting the static formation pressure from the injecting pressure at the same depth, where injecting pressure is measured by the PWD tool. Accurate depth correction is essential; measured depth is derived from the bit depth minus the distance of the PWD sub above the bit and subsequently converted to true vertical depth (TVD) or elevation using directional survey data. Static pressure is estimated from a pressure survey in a nearby well, corrected for elevation and KB differences. These calculations enable real-time estimation of injectivity without interrupting drilling operations, provided depth and pressure corrections are rigorously applied. Following are case studies from wells drilled in Nevada by Ormat in 2025.

4. WELL A

Mud losses during drilling were minimal initially but began at a measured depth of approximately 4,100 ft. Based on observed losses, the calculated Injectivity Index (II) ranged between 0.2 and 0.4 gpm/psi. A final injection test with PT tools confirmed an II value of 0.47 gpm/psi, indicating slightly higher injectivity than estimated from PWD.
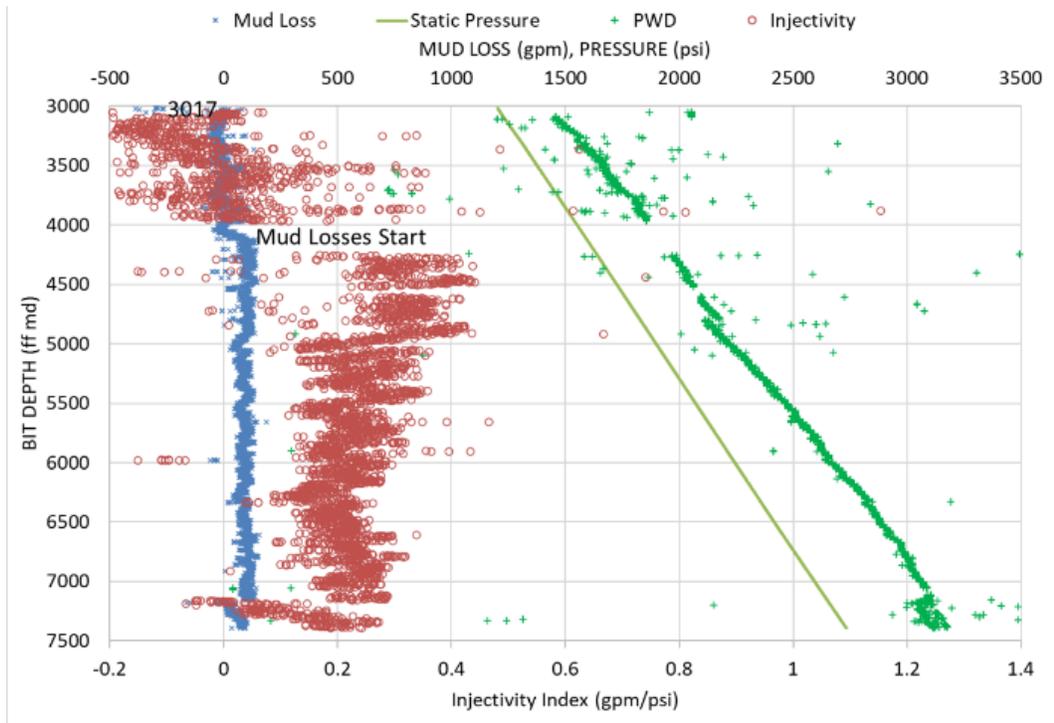
Figure 5. Well A mud losses, PWD measurements and calculated II.

5. WELL B

Partial mud losses were observed at a drill break at 4,450 ft, accompanied by a decline in PWD readings, resulting in an estimated Injectivity Index (II) of approximately 1.2 gpm/psi. A subsequent drill break at 4,650 ft led to total losses, with PWD continuing to decline and II increasing to about 7.5 gpm/psi. At 4,750 ft, PWD dropped to static pressure, indicating very high injectivity; the calculated II was approximately 100 gpm/psi, while a final injection test with PT tools measured 135 gpm/psi. It is important to note that uncertainty in static pressure significantly affects high II calculations because the pressure differential becomes very small at these conditions.
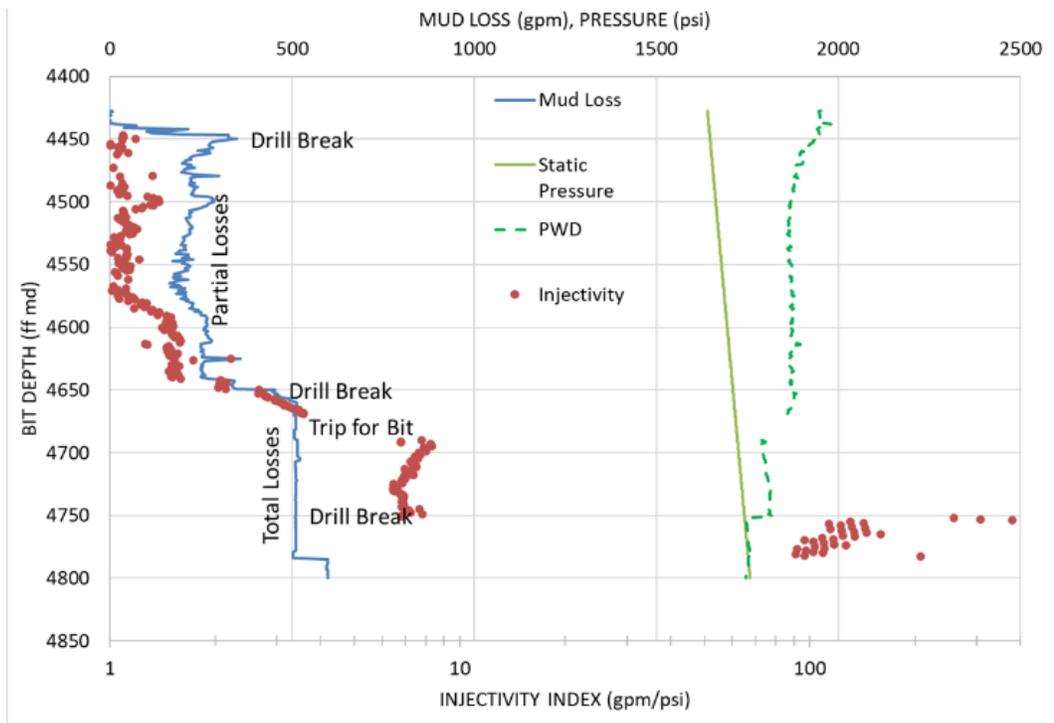

Figure 6. Well B mud losses, PWD measurements and calculated II.

6. WELL C

Lost circulation was observed at a depth of 6,487 ft, coinciding with a drill break at the same depth. The Injectivity Index (II) initially increased to 3.6 gpm/psi but subsequently declined, suggesting a limited-volume zone. Air drilling was conducted from 6,500 to 6,760 ft, during which PWD data was not available. Drilling without air resumed to a depth of 6,800 ft, where initial injectivity was approximately 30 gpm/psi while circulating above total depth. This high II most likely resulted from pressure drawdown following air-lift flow. Injectivity then declined to 0.5 gpm/psi, accompanied by intermittent returns. A final injection test with PT tools measured an II of 0.9 gpm/psi, confirming the reduced injectivity at final conditions.
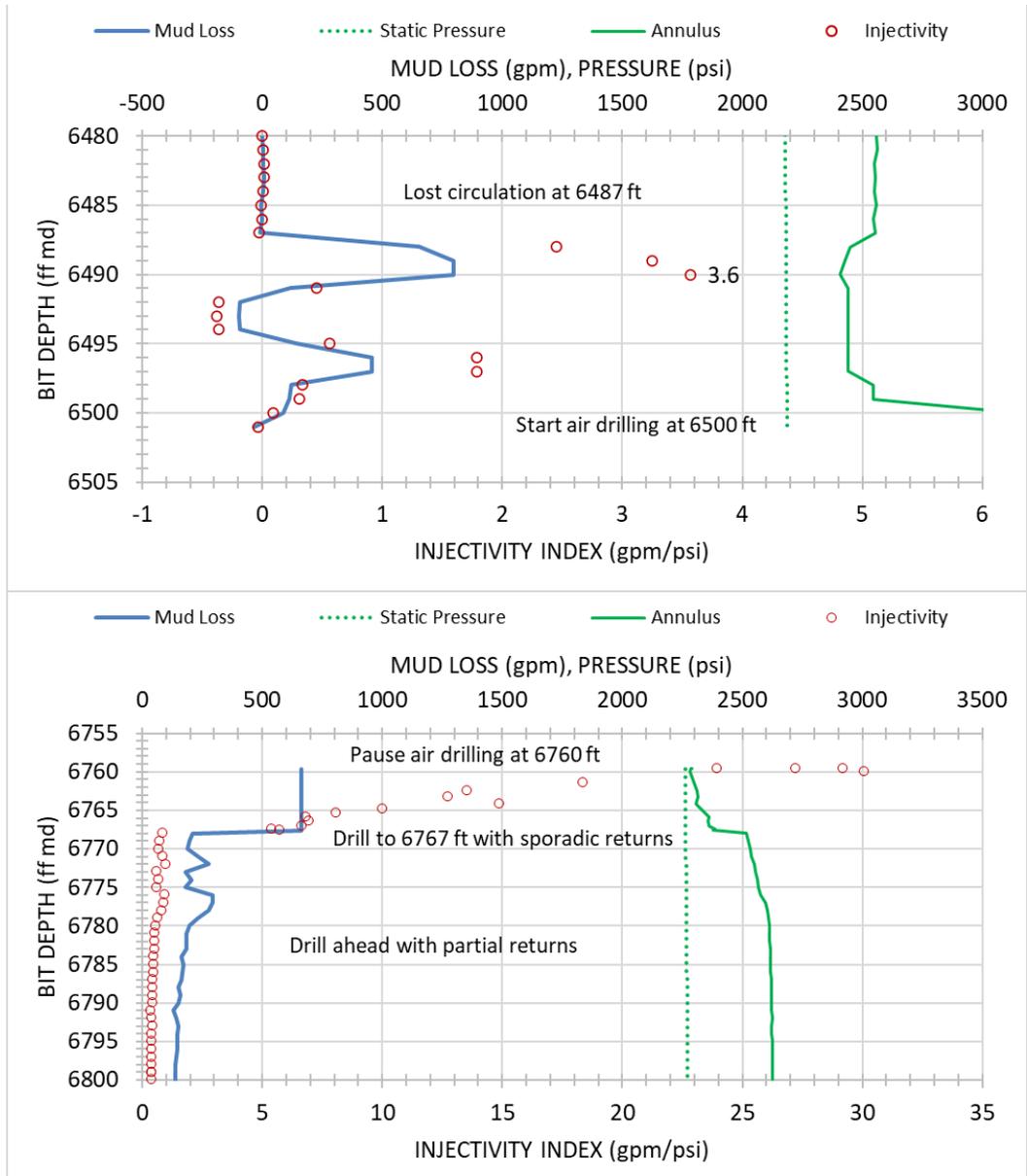

Figure 7. Well C mud losses, PWD measurements and calculated II.

7. WELL D

Total lost circulation occurred while drilling the 17-1/2-inch hole without PWD instrumentation. Following this event, the drilling assembly was pulled, and PWD was run in hole to a depth of 778 ft. A PWD Injection Test was then performed, yielding an injectivity of 48 gpm/psi. After installing a slotted liner, a final injection test with PT tools measured an injectivity of 10 gpm/psi, with a skin of 20. The reduction in injectivity is attributable to fill behind the liner restricting flow into the formation. Injectivity improved during long term testing suggesting that injection washed away the fill.
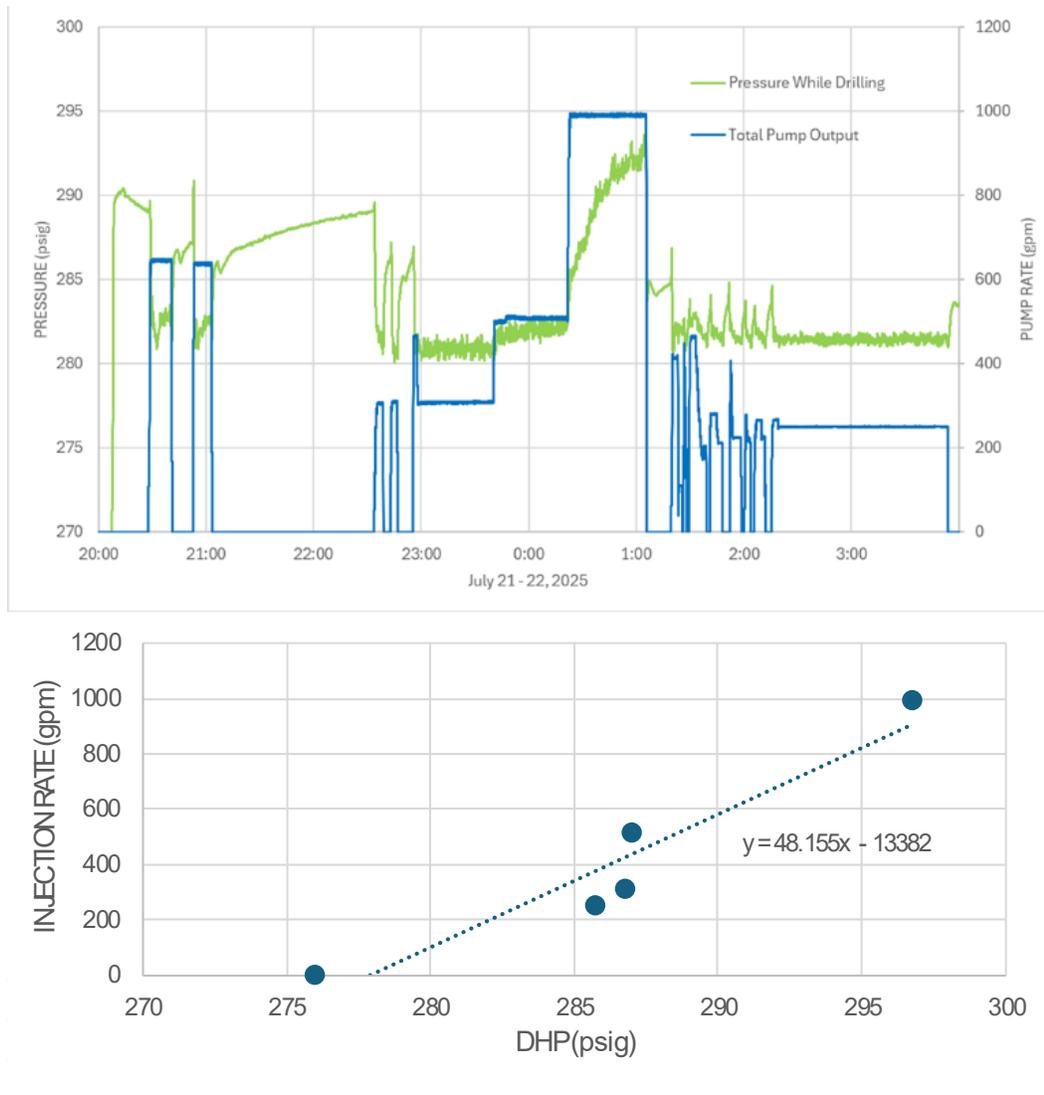
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Figure 8. Well D PWD injection test results.

8. WELL E

A PWD injection test was conducted after drilling reached 5,473 ft. The injectivity was measured at approximately 16 gpm/psi during two lower-rate steps and 15 gpm/psi during the final step and falloff, although a 20 psi offset was observed, and Pressure Transient Analysis indicated a high skin factor. Drilling continued to 5,700 ft, after which a final injection test with PT tools recorded a significantly higher injectivity of 503 gpm/psi. The discrepancy between the two tests suggests that fill present during the PWD injection test was covering deeper zones, which were subsequently cleaned out before or during the final injection test.
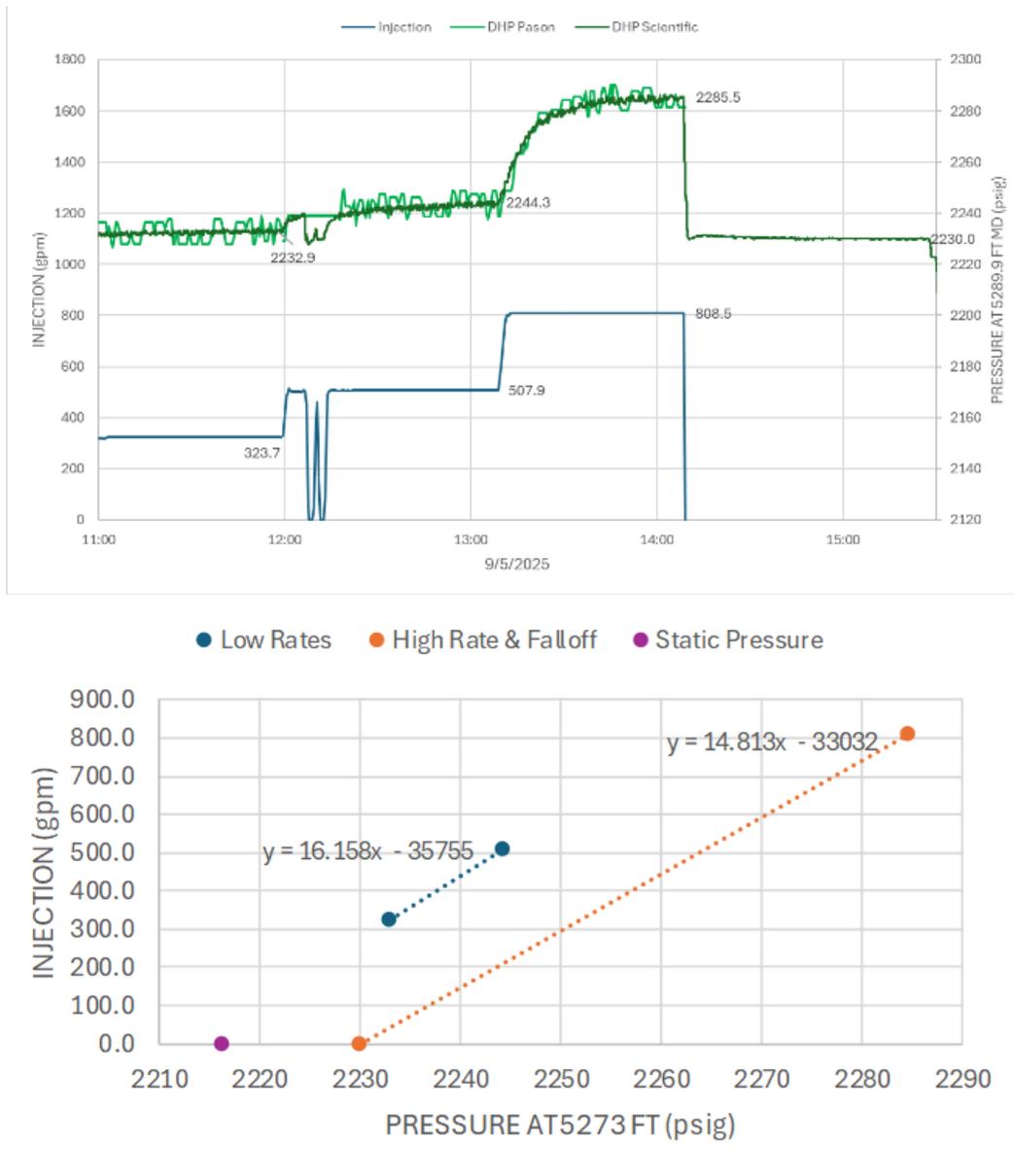
Figure 9. Well E PWD injection test results.

9. WELL F

Lost circulation was first observed at a depth of approximately 1,500 ft, followed by partial losses as drilling progressed. PWD data indicated that the Injectivity Index (II) peaked at 1,900 ft with a maximum value of 3.8 gpm/psi before declining. A second zone was encountered at 3,900 ft, where a momentary total loss occurred, accompanied by a small drop in PWD readings. The estimated II for this zone was approximately 2.6 gpm/psi. A final injection test with PT tool confirmed an II of 3.2 gpm/psi, consistent with the earlier PWD-based estimates.
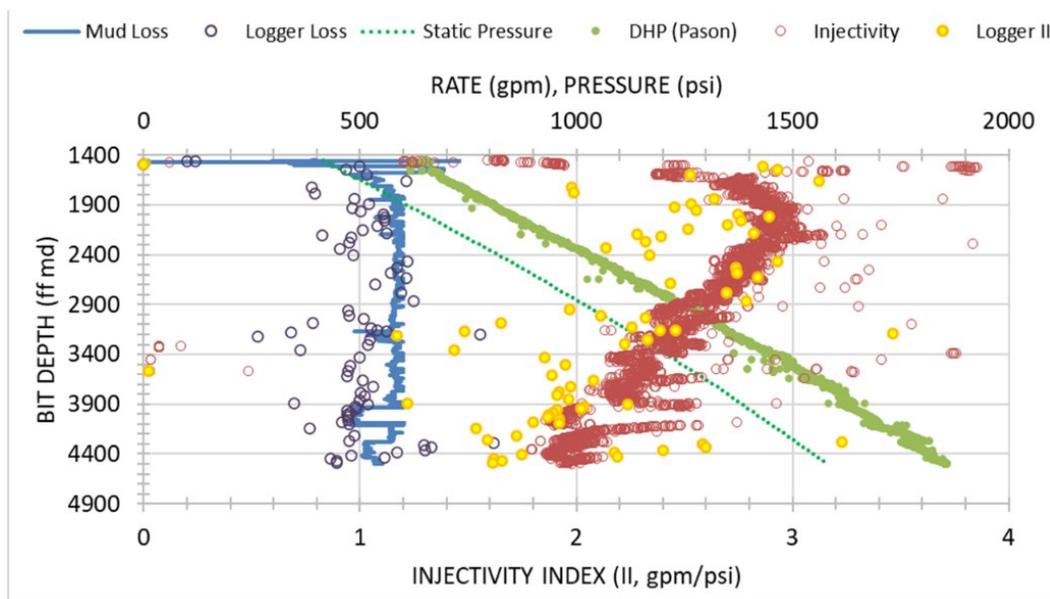
Spielman et al.

Figure 10. Well F mud losses, PWD measurements and calculated II.

10. CONCLUSION

Comparison of injectivity measurements indicate that Injectivity Index (II) values obtained from injection tests with PT tool after completion were higher than those derived from PWD data for most wells. Four wells exhibited final injectivity values after completion that were 18% to 80% greater than the corresponding PWD-based estimates. Two wells showed much lower or higher injectivity values, which were attributed to fill-related issues occurring either before or after the tests, affecting flow capacity and pressure response. Lower II estimates from PWD are probably due to mud and cuttings in the fractures that were cleaned out by flowing the wells before the final injection test.

Table 1. PWD to Step Rate Test I.I. Comparison

Well (gpm/psi)	PWD low	PWD high	Final Test	(Final - high) /high	Flow cleanout vs Liner	Comments
Well A	0.2	0.4	0.47	18%	After	
Well B	8	100	135	35%	After	
Well C	0.5	30	0.9	*80%	Prior	high II right after flow, *(Final - lo)/lo
Well D	48	48	10	-79%	After	open hole step rate test with PWD, fill behind liner
Well E	15	16	503		After	fill problems while drilling
Well F	2.6	3.8	3.2	23%	Prior	

As more wells are drilled and tested we will gain a greater understanding around the importance of well flowing for improving the final permeability of wells drilled and the differences between open hole cleanout flows and cased hole (behind slotted liner) cleanout flows.

ACKNOWLEDGEMENTS

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