Monitoring Aquifer Integrity in a Multi-Zone Environment - A Fit-for-Purpose Single-Trip Solution

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Abstract

Oil and Gas Operators are authorized to produce associated water under the Petroleum and Gas Act 2004 as a necessary activity in oil and gas production. With this authorization comes the obligation to monitor and manage the impacts for the removal of the water in compliance with the Queensland Water Act 2000 (current as of 1 October 2014). Many required monitoring sites have multiple/stacked aquifers that must be independently monitored and reported.

Single Zone vs. Multi-Zone Monitoring Wells

The completion design for a well that will monitor a single aquifer is relatively simple while completion designs for wells that will discreetly monitor multiple aquifers are necessarily more complex. Single-zone monitoring well designs simply involves positioning a suitable pressure gauge downhole at or near the aquifer. This gauge can be mounted outside the casing and cemented in place if fluid samples from the aquifer are not required, or it can be secured on the outside of the production tubing near the aquifer perforations if periodic water sampling is required. The problem with single-zone monitoring wells in a location where there are multiple/stacked aquifers is the costs associated with drilling and completing multiple, single-zone wells. As a result, there is a strong desire for a cost effective completion system that will allow multiple aquifers to be adequately monitored and sampled from a single well.

Monitoring System Considerations

The Queensland Water Act 2000 sets trigger thresholds for borehole water level changes. For a consolidated aquifer (e.g., sandstones, limestones, and coals), the threshold is 5 metres and for an unconsolidated aquifer (e.g., sand and gravel) the threshold is just 2 metres. These water level changes equate to a 7.1 psi and 2.8 psi variation in hydrostatic head respectively. A pressure gauge must therefore be capable of monitoring long term fluctuations in hydrostatic head to determine if these thresholds are exceeded at any time within the first three years of CSG operations (classified as an “Immediate Affect”) or at any time thereafter (classified as a “Long-Term Affect”) while CSG operations are ongoing around the monitoring wells. This highlights the need for the selection of an appropriate pressure gauge type, particularly with respect to measurement drift.

In addition, in selecting the optimal gauge type for multi-zone aquifer monitoring, consideration must be given to the number of pressure gauges to be connected per instrument cable, the number of available tubing hanger ports and the number of cable connections required for the entire downhole monitoring system. Generally, one gauge per cable will provide the highest level of reliability, since any loss of electrical, mechanical or pressure integrity in one deployed gauge system will not affect any others in the same well. However, in a multi-zone monitoring

system, having just one downhole connection per gauge system, and/or one gauge per instrument cable, may not be possible for the following reasons:

- Since multi-zone aquifer monitoring systems will have packers separating the zones, then at least one splice will be required for each packer unless reactive element packers with “self-healing cable slots” cut on the OD of the elements are employed.
- If more than one cable is used, then the tubing hanger and wellhead will require additional hanger ports and wellhead outlet ports (one for each cable).

As a result, a monitoring system that can accommodate more than one gauge on a single cable is desirable. Such gauge systems are available in two different configurations:

- With a built-in Y-Block (internal to the gauge body or integral to the cable head)
- Without a built-in Y-Block

The former has the advantage of fewer connections – one at the top of the gauge and one connected to the cable continuing downhole to subsequent gauges. The latter requires an additional electrical connection for each gauge, except the bottom gauge, i.e., three connections:

- One to the cable going uphole
- One to the adjacent gauge
- One to the cable going downhole to the next gauge or Y-Block

Another advantage of using gauges that have a built-in Y-Block is that it may be possible to position the gauges such that the gauge connections also serve as cable splices at packers.

Packers for Zonal Isolation

Several factors need to be considered in selecting an appropriate type of packer for a multi-zone aquifer monitoring system. There is a broad range of packers available in the oil and gas industry, including mechanically set, hydraulically set and re-active element packers. Theoretically, the optimum packer for this application might be a re-active element packer with “self-healing cable slots” cut on the OD of the element so that cable splices can be reduced or eliminated. From a practical standpoint, installing the cable in the pre-cut slots can be a challenge and time consuming on the rig floor. In addition, there are concerns over seal integrity around the cables, and re-active element packers generally cost more than hydraulically set and mechanically set packers suitable for this application.

Generally, it is recommended to avoid or minimize rotating the tubing when running completions that have control lines or electrical cables. As a result, hydraulically set packers are preferred for multi-zone aquifer monitoring systems over mechanically set packers. Consideration should be given to utilizing a hydraulically set packer with pass-through ports that make it relatively easy to route the gauge cable through the packer

during the installation process, and thereby eliminate or reduce the need for cable splices – some packer types require pre-installation of a cable pigtail prior to equipment mobilisation, and thus require a cable splice above and below the packer.

In selecting a suitable hydraulically set packer, it will also be necessary to consider the rated maximum working pressure for the entire completion system, as well as the rig's available pump pressure, when determining a suitable packer setting pressure. Similarly, the rigs available lifting/pulling capacity should be considered in setting the packers shear/release force.

Water Quality Monitoring

The Queensland Water Act 2000 also specifies requirements for periodic monitoring of water quality, but it does not state exactly how that monitoring should be accomplished. One monitoring method would be to install an array of downhole monitoring sensors to measure parameters like conductivity, while another option would be to periodically take water samples for more thorough ex-situ water analysis. In a multi-zone aquifer, monitoring well the casing is perforated in each aquifer to allow communication with the aquifer. Individual aquifer zones are then isolated from each other by packers and the production tubing; the aquifer pressure monitoring gauges are mounted on the outside of the production tubing to measure annulus pressure between the tubing and casing. As a result, a device like a sliding sleeve must be installed in the production tubing between each packer to facilitate sampling of fluids from that specific zone. The device must be capable of being opened to capture a fluid sample and then closed to provide zonal isolation.

The sliding sleeve for any specific zone can also be opened and a suspended gauge can be run-in-hole to the depth of the sliding sleeve to monitor aquifer pressure either temporarily, as a "drift check" of the permanently installed gauge, or on a long-term basis if the permanently installed gauge should fail. The suspended gauge is simply a pressure gauge connected to an instrument cable that is run inside the production tubing and suspended from the wellhead.

Summary

This paper will review the pros and cons of various completion design options to adequately and efficiently meet the requirements of the Queensland Water Act 2000 in a multi-zone monitoring environment.