Sampling Method/Media: **Step-Drawdown Pump Test / Groundwater**	Title: **Standard Operating Procedure for Step-Drawdown Pump Testing**
Revision No: 1.0 **Revision Date: 31 March, 2018**	**Reference No: SOP-E2-10** **Parent Document: BC Field Sampling Manual – Part E2**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instruction for performing single well step-drawdown pumping tests. Step-drawdown tests are most often completed to aid in planning full-scale pump tests by determining a well's efficiency and providing an initial assessment of aquifer hydraulic properties.

This SOP provides a field procedure for the performance of a single well step-drawdown test only; analytical solutions are described in Kruseman and de Ridder (1994) which is briefly described below.

This SOP forms part of the British Columbia Field Sampling Manual (BCFSM). Additional information on step-drawdown pump testing is provided in Part E2 – Groundwater, which must be used in conjunction with the information provided in this SOP. Further guidance regarding groundwater is provided in the Water Sustainability Act (WSA) and the Groundwater Protection Regulation (GPR) which are available at:

https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules/groundwater-protection-regulation.

The Environmental Management Act (EMA), the Contaminated Sites Regulation (CSR) and associated guidance documents provide information specific to groundwater monitoring wells installed to investigate and remediate contaminated sites; these documents are available at:

https://www2.gov.bc.ca/gov/content/environment/air-land-water/site-remediation/contaminated-sites.

Groundwater well installations, sampling, monitoring and decommissioning conducted for regulatory purposes within the provincial jurisdiction of BC must be carried out with consideration to the WSA, the GPR, the EMA, and the CSR, all as applicable, Part E2 of the BC Field Sampling Manual, and this document.

2. Document Control

This Standard Operating Procedure (SOP) is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

3. Principle of Step Drawdown-Pump Testing

Well drawdown results from aquifer losses such as linear loss due to groundwater pumped from the aquifer and well losses such as linear losses during drilling and/or other permeability related effects near the borehole, and non-linear losses due to turbulent flow in the well. The combination of aquifer and well loses result in the drawdown measured in the pumped well being greater than the expected drawdown based on theoretical determinations and the drawdown in the aquifer as recorded at observation wells. Data obtained from a step-drawdown pumping test is used to provide estimates of these losses using the Hantush (1964)-Bierschenck (1963) method.

A step-drawdown test monitors pumping well performance by varying the pumping rate in a controlled manner. Specifically, a low constant pumping rate is selected, which is increased in progressive steps of higher pumping rates, with each step conducted over an equal interval (from 30 minutes to 2 hours). Each step should be of long enough duration to allow wellbore storage effects to dissipate. Step tests can be used to estimate transmissivity,

hydraulic conductivity, well loss, well efficiency and the effective well radius. The test also allows estimates of expected drawdown at specified pumping rates for a full-scale constant rate pumping test.

4. Quality Control

- Ensure that instruments are functioning and properly calibrated before starting and that all required information is recorded in the field.
- Ensure that field notes are legible (recorded in ink where possible) and complete.
- Retain all field notes to ensure the information reported is accurate and defensible.
- If pressure transducers are used to measure water levels, ensure the data is complete and satisfactory before leaving the field.

5. Recommended Equipment and Materials

Field equipment should include the following:

- Pump and control box,
- Generator with outlets for pump controller, and extra fuel for the generator,
- Perforated spacer rod for straddle zone tests,
- Electronic water level probe,
- Pressure transducer(s),
- Watch, stopwatch or other device to record elapsed time during the test,
- pH, temperature, and electrical conductivity meter/s,
- Field book/forms to record test details and measurements; and,
- Discharge equipment, including adequate discharge piping, in-line flow meter and/or circular orifice weir.

6. Procedures

1) *Authorization:* Obtain authorization from the landowner for site access if needed. Obtain temporary discharge permits if required.
2) *Test design and preparation:* The following should be considered and decided prior to arrival at the site: equipment (including selection of pump and generator, pressure transducers, water level probe), test duration (generally less than 6 hours), step duration (typically 1 hour), number of steps (between 3 and 5 is common), discharge rates (typically start at 50% of the anticipated final rate and increase discharge between 20 and 25% with each step), estimated expected drawdown, and disposal of discharge.
3) *Pretest monitoring.* Measure the static water level in the pump well and any wells within the anticipated radius of influence that may be used as observation wells. Note that static and drawdown water level measurements are not necessary at observation wells for the analysis of a step drawdown test to determine well and aquifer losses but may be desired for a preliminary assessment of the radius of influence and aquifer parameters.
4) *Test and synchronize water level transducers.* The transducers should be tested and all watches and transducers should be synchronized.
5) *Install the pump and transducers:* For a confined aquifer, install the pump above the top of the screen or the aquifer (whichever is shallower). For an unconfined aquifer, install the pump at 2/3 of the saturated depth (or shallower if local regulations require). For a shallow well, install the pump above the screen to maximize available drawdown during testing. Install a check valve on the discharge pipe above the pump. If the discharge line runs directly to a tank or stream, ensure an air break exists so that a siphon is not created when the pump is shut down. Ensure the water level in the pump well has returned to static prior to starting the test.
6) *Setup the discharge system:* Make sure a gate valve (recommended) or ball valve is available to control the discharge during the test by maintaining some back pressure on the discharge line. The discharge during the constant rate test should be maintained within ±5% of the target value. The discharge location should be pre-approved, downgradient from the pumping well and a suitable distance from the pumping well if there is a

potential for the discharged water to infiltrate back into a monitored unit during the test (i.e., unconfined shallow aquifers).

7) *Prepare field notes.* Record all required information including the date, pump well, pump well details, and pump and transducer installation details in a field book or appropriate test form.

8) *Begin the step test:* Generally, a step-drawdown test comprises 3 to 5 steps of 60 minutes duration. The first discharge rate is approximately 50% of the desired rate, and each subsequent step increases the discharge between 20 and 25% above the previous. The test should be started at a defined time (e.g., 10:00 AM) so that all observations are relative to the same start time. Ideally, two field crew are assigned to conduct the test. One person should verify that the water discharge rates are consistent or similar to planned values, and the second person will measure manual water levels at the pumping well. As guidance, manual water level measurements should be made for each step approximately every minute for the first 10 minutes, every 5 minutes between minutes 10 and 30, and every 30 minutes between minutes 30 and 90. However, more frequent measurements may be required depending on the setting. Manual water level measurements should be taken for backup data even if pressure transducers were installed.

9) *Measure and maintain the discharge rate during each step*: Fluctuations in discharge rates are most likely to occur at the start of the test when drawdown is rapid. Therefore, it is recommended to check the flow rate, and make adjustments if needed, once every ten minutes for the first 60 minutes of the pumping test. The discharge rate and total volume discharged should be recorded periodically through the remainder of the test.

10) *Confirm water quality parameters*: During the test, the water quality parameters pH, temperature, and electrical conductivity, should be monitored. The measurement of additional field parameters might be required depending on the site and project scope (e.g. chloride and turbidity are sometimes measured). If at any time the water quality parameters indicate that the quality of the groundwater does not meet local surface water quality requirements (i.e., pH or chloride are outside acceptable limits), the test should cease until appropriate discharge plans and developed.

11) *Advancing to the next step*: After 60 minutes the pumping rate is increased by opening the gate or ball valve slightly; thus the next step begins without interruption. When all steps are completed the pump is shut down. Monitor the recovery or leave transducers in the well to monitor recovery while staff are off-site.

12) *Review the data:* Data should be reviewed prior to leaving the site to ensure it is sufficient.

13) *Post step drawdown test:* If a constant rate pumping test is planned after the step test, ensure the water level is fully recovered before starting (greater than 95% recovery is desired). This will typically require twice the step test duration (i.e., be prepared to allow for 10 hours of recovery following a 5-hour step-drawdown test). Typically, the well that was subject to a step-drawdown test is left to recover overnight before initiating a constant rate pumping test.

7. References

1. Kruseman, G.P., and de Ridder, N.A. 1994. Analysis and Evaluation of Pumping Test Data, Analysis and Evaluation of Pumping Test Data, Second Edition. Publication 47, International Institute for Land Reclamation and Improvement, 377 p.
2. Hantusch, Hydraulics of wells. In: V.T. Chow (editor). Advance in Hydroscience, Vol. I, Academic Press, New York and London. Pp. 281-432.
3. Bierschenk, W.H. 1963. Determining Well Efficiency by Multiple Step-drawdown Tests. Intern. Assoc. Sci. Hydrol. Publ. 64, pp. 493-507.

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Approval