ENGINEERS & GEOSCIENTISTS BRITISH COLUMBIA

PRACTICE ADVISORY

FLOWING ARTESIAN WELLS AND EXCAVATIONS

Version 1.1, Published May 2, 2022

This practice advisory has been issued to inform registrants and licensees of Engineers and Geoscientists BC (engineering/geoscience professionals) about their responsibilities for anticipating and managing flowing artesian conditions during well design and construction. This practice advisory also includes recently updated reporting requirements and roles for professionals, under the *Water Sustainability Act* and *Groundwater Protection Regulation*.

It is important to stop or control artesian flow, as uncontrolled flowing artesian wells can cause a multitude of issues during well construction. Examples include, but are not limited to, subsurface erosion and void creation, which can damage nearby structures; flooding and sediment run-off, which can harm aquatic habitats; and mixing of contaminated or poor-quality groundwater with clean groundwater, which can pose health risks.

By pre-screening the geology and hydrogeology of a project site, flowing artesian conditions can often be predicted, minimizing the chance that uncontrolled flowing artesian conditions will be encountered unexpectedly during borehole drilling or while excavating in soil or rock. By predicting the potential for flowing artesian conditions, and by understanding how wells should be constructed to manage flowing artesian conditions both while drilling and when the well is completed, it is possible to avoid many of the problems associated with flowing artesian conditions.

Engineering/geoscience professionals must analyze and mitigate risks associated with flowing artesian conditions on a per-project basis, and throughout the screening, planning, design, implementation, and completion stages. In particular, the engineering/geoscience professional should consider the amount of data available and the probable accuracy of the predictions developed during the screening and planning stages. In cases where there is little data available for a specific location and depth, it may be appropriate for the engineering/geoscience professional to make conservative assumptions and, accordingly, produce a more conservative design than for a location where ample subsurface data and flowing artesian conditions are known to exist.

BACKGROUND

In 2016, the enactment of the *Water Sustainability Act* and updated *Groundwater Protection Regulation* brought about new roles and responsibilities for professionals, including:

- new reporting requirements for flowing artesian wells; and
- new roles for professionals with respect to flowing artesian wells.

Uncontrolled or poorly constructed flowing artesian wells may result in the chronic loss of valuable groundwater resources. In addition, flowing artesian wells have the potential to cause significant damage to property and risks to life and the environment. During excavations, the same, if not more, risks from flowing artesian conditions can arise, because near-surface confining formations are often much less resistant to pressure than deeper formations. Furthermore, excavations can be more difficult to repair if a breach occurs. Recent high-profile cases relating to the closure of flowing artesian wells in British Columbia (BC)—such as those in Coldstream, Beechwood, Vernon, and Westwold—have refocused the groundwater community's attention on the hazards and costs of capping uncontrolled flowing artesian wells.

Flowing artesian wells are not a new or unknown phenomenon in BC. Flowing artesian conditions were encountered in Fort St. James in the late 1930s, and wells that controlled flow were, with few exceptions, generally successfully drilled. The original uncontrolled flowing artesian well in Coldstream was drilled in 1965 and made the news when it blew out; it was not successfully plugged until 2015.

CHARACTERISTICS AND EFFECTS OF FLOWING ARTESIAN CONDITIONS

HOW FLOWING ARTESIAN CONDITIONS DEVELOP

Flowing artesian conditions can result from geological and topographic controls (Figure 1) or from topographic controls alone. When the aquifer is penetrated by a well or an excavation, the water level will attempt to rise to the piezometric surface.[1] Flowing artesian conditions exist where the piezometric surface is above ground level. The severity of the flowing artesian condition will primarily be a function of the height of the piezometric surface above ground level and the hydraulic conductivity of the material encountered.

While the focus of this practice advisory is on flowing artesian conditions in confined aquifers, it should be noted that, under some circumstances, these conditions may also be encountered in unconfined aquifers. This occurs, for example, when fresh groundwater pushes over a saltwater wedge or other constriction in the flow path. In both cases, it should be noted that flowing artesian conditions may also occur in excavations.

[1] The "piezometric surface" is an imaginary surface that defines the level to which water in a confined aquifer will rise to in a borehole screened within the aquifer.

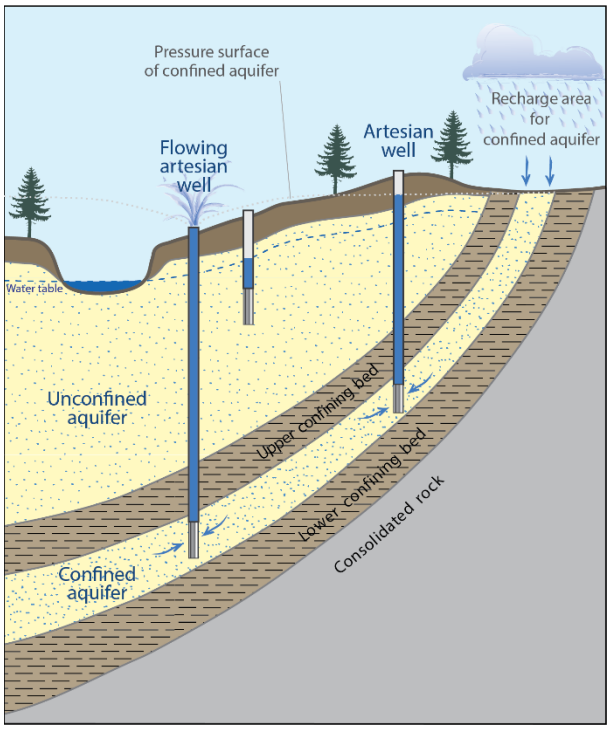

Figure 1: Geological and topographical controls affecting artesian and flowing artesian wells

Adapted from: Ministry of Environment and Climate Change Strategy (2022).

CONTROLLED VERSUS UNCONTROLLED FLOWING ARTESIAN CONDITIONS

CONTROLLED FLOW

The definition of a flowing artesian well that is under control during construction is provided in the *Water Sustainability Act*, under Part 3, Division 3, section 52 (1):

"52 (1) For the purposes of this section and section 53, artesian flow of a well is under control when

a) the artesian flow
   i. is clear of sediment,
   ii. is entirely conveyed through the well's production casing to the wellhead, if the well has a production casing,
   iii. may be mechanically stopped for an indefinite period in a manner that prevents leakage onto the surface of the ground or into another aquifer penetrated by the well, and
   iv. does not pose a threat to property, public safety or the environment

b) if the artesian flow cannot be controlled in accordance with paragraph (a), the well is decommissioned
   i. in accordance with the regulations,

ii. by a person authorized under section 49 *[restrictions on constructing or decommissioning wells]*, and

iii. in a manner that allows no artesian flow at the surface of the ground or leakage into another aquifer penetrated by the well."

For the purposes of this practice advisory, artesian flow is considered to be controlled when a casing has been properly cemented[2] into the ground, and the combination of the annular seal and the strength of the formation are able to withstand the design artesian pressures. The design artesian pressures include those that occur when the well is shut in, and any additional pressures resulting from seasonal factors, reduced drawdown after a nearby well is shut off, or pressure transience when the flow is shut off. When properly designed to meet these requirements, the artesian flow can be completely stopped without risk of the well becoming an uncontrolled flowing well.

UNCONTROLLED FLOW

Uncontrolled artesian flow is often the result of improper well design and/or drilling and construction methods. Problems encountered during drilling may result in the inability to complete the well, which itself may result in uncontrolled flowing artesian conditions.

Uncontrolled artesian flow can also be released into an excavation that has penetrated through a confining layer overlying a flowing artesian aquifer, when the integrity of the overlying strata has not been, or cannot be, restored.

EFFECTS OF UNCONTROLLED FLOWING ARTESIAN CONDITIONS

It is important to stop or control artesian flow, because uncontrolled flowing artesian wells can cause a multitude of issues. Some examples of issues include, but are not limited to the following:

- Failure of the annular surface seal or casing, shallow formations, or loss of well control during drilling that may cause subsurface erosion and void creation or eruption of groundwater containing silt, sand, gravel, or clay at the ground surface. These effects can damage nearby structures through flooding, erosion, and/or subsidence.
- Sediment-laden runoff that may harm aquatic habitats.
- Breakouts that may cause groundwater in one aquifer to mix with that in another. This can be especially problematic if one aquifer has poor water quality. It should be noted that mixing of groundwater between aquifers is specifically identified as an issue in the *Groundwater Protection Regulation*.

In both controlled and uncontrolled conditions, allowing groundwater to flow:

- may result in damage to or failure of the well casing;
- may lower the pressure in the aquifer, affecting the yield of neighbouring wells and springs; and
- will waste groundwater.

[2] "Cement" indicates grout that may be cementitious or bentonitic, depending on the application and the expected pressures.

These risks must be analyzed and mitigated on a per-project basis by an engineering/geoscience professional throughout the screening, planning, design, implementation, and completion stages.

Uncontrolled groundwater flow into an excavation may have many of the same results, including erosion, subsidence, ground instability, flooding, and harm to aquatic habitats by sediment-laden runoff.

STANDARD OF PRACTICE

ROLES AND RESPONSIBILITIES OF PROFESSIONALS

The *Water Sustainability Act*, Part 3, Division 3, section 48(1) defines a “professional” as follows:

> "professional" means
>
> (a) a professional engineer, or a professional geoscientist, who is registered or licensed under the *Engineers and Geoscientists Act*, or
>
> (b) a holder of a limited license under the *Engineers and Geoscientists Act* acting within the scope of the limited license,”

It is the responsibility of engineering/geoscience professionals serving in the capacity of “professional” as defined in the *Water Sustainability Act*, to determine whether they are qualified by education, training, and experience to undertake and accept responsibility for carrying out the engineering or geoscience services required for a project.

The *Water Sustainability Act* clearly outlines that the engineering/geoscience professional, the well driller, and the well and/or land owner have a shared responsibility to stop or bring flowing artesian conditions under control. Generally, the engineering/geoscience professional and/or the well driller are responsible during construction and the owner is responsible post-construction.

Before accepting any engagement, it is recommended that the engineering/geoscience professional makes the well owner/client aware that there is a legislated obligation to decommission flowing artesian wells. It is recommended that the financial responsibility to stop or control flowing artesian conditions is clearly outlined in the contract in the event that these conditions are encountered.

KEY CONSIDERATIONS FOR WELL DESIGN AND CONSTRUCTION

Before any design or drilling is undertaken, the engineering/geoscience professional should conduct a screening evaluation to assess the likelihood of encountering flowing artesian conditions. The result of the screening will determine the level of well design and contingency measures required to safely undertake drilling.

Although confined aquifer pore pressures generally increase with depth, and there is the potential for higher shut-in pressures at greater depths, due to the inherent weakness of shallow formations, shallow flowing artesian conditions may be just as problematic as those encountered at depth.

Consequently, the screening, planning, and design for shallow potentially flowing artesian conditions should be as comprehensive as for deep wells.

SCREENING

The screening for flowing artesian conditions should, at a minimum, include the following:

- Evaluation of available geological and topographic mapping and aerial photography.
- Review of wells logs available online through the Province of BC Groundwater Wells and Aquifers (GWELLS) application (Province of BC 2020a).
  - Note that not all flowing artesian wells are identified as such in GWELLS; however, a lack of logs identifying flowing artesian conditions does not necessarily indicate that flowing artesian conditions will not be encountered.
- Review of available Well Drilling Advisories for Flowing Artesian Conditions (Province of BC 2020b).
  - Note that the lack of a Well Drilling Advisory for an area does not necessarily indicate that flowing artesian conditions will not be encountered.
- Development of a conceptual hydrogeological model for the project site that considers:
  - available data;
  - formations likely to be encountered;
  - probable recharge area and pathway;
  - potential for constrictors of the groundwater flow path;
  - potential for penetrating aquitards; and
  - potential for penetrating productive aquifers below the confining layers.

Regardless of whether or not the *Groundwater Protection Regulation* requires a well construction report, the engineering/geoscience professional should keep a detailed record of the screening that was conducted, referencing all assumptions, sources of data, and justification for interpretations. In addition:

- where appropriate, the screening assessment should record a range of potential aquifer transmissivities and shut-in pressures for properly completed flowing artesian wells;
- the conclusion of the screening report should clearly state the types of formations and conditions that might be encountered, as well as the likelihood of encountering flowing artesian conditions; and
- where applicable, the report conclusions should specify measures to mitigate the potential flowing artesian conditions.

This screening report may or may not be issued to the client or to the Comptroller of Water Rights, but should be retained by the engineering/geoscience professional according to requirements in the *Quality Management Guidelines – Retention of Project Documentation* (Engineers and Geoscientists BC 2018).

PLANNING AND DESIGN

During design, the engineering/geoscience professional should consider the amount of data available and the probable accuracy of the predictions developed during the screening and planning stages.

Engineering/geoscience professionals should exercise extreme caution in situations such as, but not limited to, the following:

- Wells that will be drilled in any areas or at a depth where there is little or no information available.
- Wells that will be drilled in valley fill sediments that are topographically confined by mountains or adjacent areas of higher elevation.
- Wells that will be located where a significant thickness and depth of low hydraulic conductivity material will be drilled before a productive aquifer is encountered.
- Wells where the recharge area of the aquifer is unknown.

Under any of these or other high-risk situations, it may be appropriate for the engineering/geoscience professional to make conservative assumptions and, accordingly, produce a more conservative design than for a location where ample subsurface data and flowing artesian conditions are known to exist.

Taking a conservative approach to design might include proactively incorporating measures that mitigate flowing artesian conditions, as outlined in the screening report, into the well design, or specifying that the casing be cemented into the ground as drilling proceeds. Drilling a small-diameter exploratory well is a common practice to provide options for reducing exploratory costs. Regardless of the diameter of the well, or the exploratory or permanent nature of the well, it must be screened, designed, and constructed to the standard of practice as outlined in this practice advisory.

Based on estimates of shut-in pressure, the engineering/geoscience professional determines the probable depths at which casings will be cemented in place, and identifies the best drilling method to construct the well and maintain well control. The ideal method for cementing casing is one that results in homogeneous placement of cement concentrically around the casing, and adequately bonds to both the casing and the formation.

As discussed above, it is recommended that engineering/geoscience professionals make conservative estimates when there is a lack of data available for a specific location and depth. In these circumstances, there still exists a risk that the actual shut-in pressure encountered will exceed the tested fracture pressure at the shoe of the casing, causing failure of the casing. Note that it is unacceptable practice to forgo installing or cementing the casing, risking that it might fail despite conservative estimates; it is widely accepted that if flowing artesian conditions are encountered, a casing cemented in place with a known pressure capacity provides significantly more options for well control than an open hole or a casing that has not been cemented in place.

During well design, the engineering/geoscience professional should consider eventualities related to both controlled and uncontrolled flowing artesian wells. Accordingly, the engineering/geoscience professional should:

- develop a water management plan that addresses both controlled discharge of non-turbid groundwater, and uncontrolled discharge potentially contaminated with fines, cement, or drilling fluid;
- where weighted drilling fluid will be used, consider loss of drilling fluid as a result of using either drilling fluid that is too-high density for the formations encountered, resulting in loss to the

formation, or too-low density to hold back the flowing artesian pressure, resulting in the drilling fluid being evacuated to surface; and

- consider preventative measures for stopping or controlling artesian flow while drilling, such as using either a flow diverter or a blow-out preventer.

IMPLEMENTATION AND COMPLETION

It is the responsibility of the engineering/geoscience professional to follow the design recommendations through implementation and completion, and to verify that the setup of contingency measures for water, sediment, and flow control, and for the drilling itself, are executed appropriately.

Conducting a field review during drilling allows the engineering/geoscience professional to notice early warning signs of an artesian flowing condition and provide timely recommendations, so measures to mitigate the situation may be taken before it becomes untenable and potentially dangerous.

TESTING

Whenever a casing is cemented in place, the engineering/geoscience professional should be present to evaluate the capability of the formation ahead of the casing shoe, as well as the integrity of the casing, cement, and formation bond created by the annular seal to withstand pressure. The result of this evaluation will dictate how far drilling can safely proceed before another casing should be cemented in place.

REPORTING REQUIREMENTS FOR WELL CONSTRUCTION AND DECOMMISSIONING

WELL CONSTRUCTION REPORT

Under the *Water Sustainability Act*, an engineering/geoscience professional may be responsible for submitting a well construction report to the Comptroller of Water Rights.

Although the submission of well construction reports to the Comptroller of Water Rights is not required for certain classes of wells (such as monitoring wells or temporary dewatering wells), if artesian conditions are encountered, then a well construction report must be submitted.

This report will be added to GWELLS. The information that must be included in the well construction report is outlined in Schedule 3 of the *Groundwater Protection Regulation*.

WELL DECOMMISSIONING REPORT

In addition, the *Groundwater Protection Regulation* requires that the person responsible (well driller or engineering/geoscience professional) for decommissioning a flowing artesian well must complete and submit a well decommissioning report to the Comptroller of Water Rights, even if the well was not previously reported to the Province of BC.

The information that must be included in the well decommissioning report is outlined in Schedule 4 of the *Groundwater Protection Regulation*.

ARTESIAN FLOW MANAGEMENT REPORTS

If an engineering/geoscience professional determines that, due to exceptional circumstances, it is not practicable to bring artesian flow under control in accordance with the *Water Sustainability Act* and other regulations, and if the artesian flow can be managed in another manner without posing a threat to property, public safety, or the environment, then the engineering/geoscience professional can propose, in a report to the decision maker (the Comptroller of Water Rights or the water manager), that artesian flow be managed in another manner. For more information, refer to *Guidance on Implementation of s. 52(6) WSA – Managing Artesian Flow in Exceptional Circumstances* (Province of BC 2020c).

The report from an engineering/geoscience professional, known as an artesian flow management report under the *Water Sustainability Act*, Part 3, Division 3, section 52 (6), should contain the information from Schedule 1 of the *Groundwater Protection Regulation*, to ensure that the decision maker has adequate information to make an informed decision on the artesian flow. The engineering/geoscience professional should also note that section 67(2) of the *Groundwater Protection Regulation* requires that the report be submitted as soon as practicable after the assessment of the artesian flow conditions.

MORE INFORMATION

For more information, contact the Province of BC Regional Groundwater staff for the project area:

- Regional groundwater contact numbers and addresses are available at: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/groundwater-wells-aquifers/groundwater-wells/regional-groundwater-contacts.

REFERENCES

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VERSION HISTORY

VERSION NUMBER	PUBLISHED DATE	DESCRIPTION OF CHANGES
1.1	May 2, 2022	Corrected and replaced Figure 1.
1.0	June 22, 2020	Initial version.