FLOWING ARTESIAN WELLS

EXPERIENCES WITH CONTROL AND CLOSURE IN BRITISH COLUMBIA

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BC Groundwater Consulting Services Ltd.

OUTLINE

- WHAT'S ALL THE FUSS ABOUT ? *…no worries right ?*
- KNOW YOUR REGULATIONS *…and the potential consequences !*
- ARTESIAN CONDITIONS: THEORY VS. PRACTICE
- WHAT ARE THE OBJECTIVES OF CONTROL AND CLOSURE ?
- GROUTING WITH CEMENT
- DIRECT CLOSURE OR DE-PRESSURIZATION FIRST ?
- CONTROL AND CLOSURE OF EXISTING FLOWING WELLS
- DIVERSION *…short and long-term*
- CONCLUSIONS

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PRESENTERS

Richard Cronin
Qualified Well Driller
(B.C. Canada)

- Well drilling contractor in Ontario and British Columbia (35 Years).
- Flowing well control and grouting service in British Columbia, Alberta and Manitoba (20 Years).
- Colorado School of Mines grouting training (2005).
- Currently working as a superintendent with BC Groundwater Consulting Services on a variety of groundwater control projects.
- Experience with control and closure of open boreholes, cased wells, springs, flowing excavations (and other unmentionable things).

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PRESENTERS

Thierry Carriou
Professional Engineer
(B.C. Canada)

- Training in Geology, Hydrogeology and Mining Engineering in British Columbia and Montana Tech.
- Experience as a consultant, crew foreman, engineer and superintendent (25 years).
- Director of BC Groundwater Consulting Services Ltd. (15 Years).
- Work experience has focused exclusively on groundwater supply, well design / drilling, dewatering, depressurization, infiltration, injection, flowing well control, grouting and groundwater studies.

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ACKNOWLEDGEMENTS

Successful artesian well control and closure requires a team approach. We thank all contractors and clients who have provided opportunity, collaboration and learning…

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BACKGROUND

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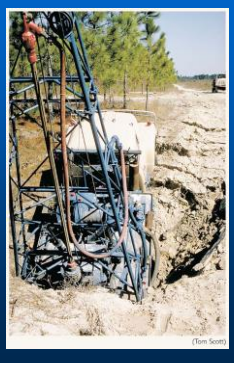
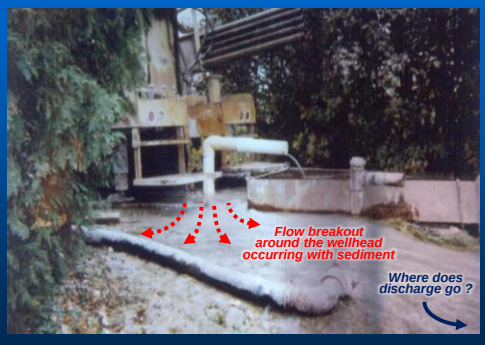
WHAT'S ALL THE FUSS ABOUT ?
NO WORRIES RIGHT ?



- *Safety first !*
- Protect your employees and yourself.
- There is always a risk of subsidence occurring when drilling water wells.
- The potential for subsidence increases when artesian conditions are encountered.
- Artesian wells that experience breakout around the wellhead are at particularly high risk of subsidence.
- Artesian conditions at shallow depth (less than 50 feet) should be considered a hazardous condition.
- *Don't kid yourself…the risk is real !*

WHAT'S ALL THE FUSS ABOUT ?
NO WORRIES RIGHT ?



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WHAT'S ALL THE FUSS ABOUT ?
NO WORRIES RIGHT ?

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WHAT'S ALL THE FUSS ABOUT ?
NO WORRIES RIGHT ?

A properly constructed well will be an asset and not a liability.

- Consider ourselves fortunate if drilling in a *known* artesian area.
- In these areas the general public, clients and regulators generally understand there is a cost to properly drilling, control and complete.
- Areas with unknown artesian conditions or "rogue" high-pressures are the worst-case scenario for the contractor, consultant and owner.

OUR ADVICE

- *Do your homework.*
- *Don't cut corners.*
- *Uncontrolled flow can lead to bankruptcy.*

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KNOW THE REGULATIONS IN YOUR AREA

- New "Water Sustainability Act" and "Ground Water Protection Regulation" enacted in February 2016
- Defines artesian control as follows:
  1. The artesian flow is clear of sediment.
  2. The artesian flow is entirely conveyed through the production casing to the wellhead.
  3. The artesian flow may be mechanically stopped for an indefinite period of time in a manner which prevents leakage on to the surface of the ground.
  4. The artesian flow does not pose a threat to property, public safety or the environment.

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KNOW THE REGULATIONS IN YOUR AREA
AND THE POTENTIAL CONSEQUENCES !

- The new act and regulation define violations as an offence with the following consequences:
  - Flow not ongoing… fine less than $ 200,000 and / or imprisonment less than 6 months.
  - Flow ongoing… fine less than $ 200,000 per day and / or imprisonment less than 6 months.
  - Potential statutory (regulation) and civil implications are severe whether in the USA or Canada.

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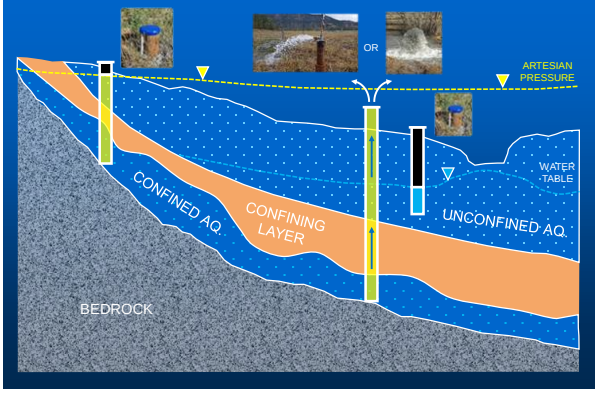
ARTESIAN CONDITIONS … IN THEORY



ARTESIAN CONDITIONS … IN PRACTICE

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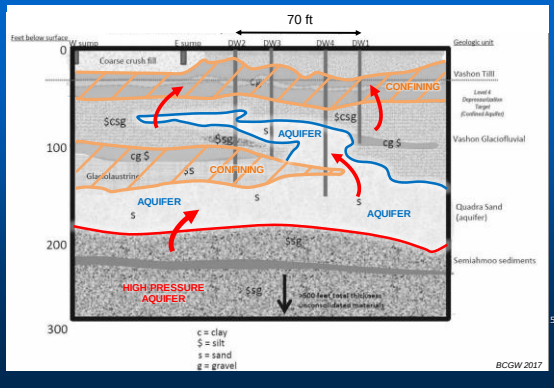
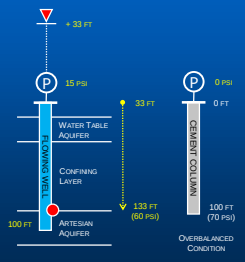


ARTESIAN CONDITIONS (DHHP)

DOWN-HOLE HYDRAULIC PRESSURE



- Understanding the basics is important.
- This is the *first step* to maintaining control ("overbalance") during drilling and achieving a successful closure.
- General approach is to achieve a column weight *exceeding DHHP* whether using mud (drilling) or cement (closure).
- It is very difficult to confirm that overbalance is maintained if pressures are unknown or occur at shallow depth.
- Artesian conditions at shallow depths may require "mechanical" control (casing and flanged connections) rather than reliance on column weight.

APPROACH, OBJECTIVES AND EXAMPLES OF CONTROL AND CLOSURE

WHAT ARE THE OBJECTIVES ?

- Focus of our work is on situations considered to be "out-of-control".
  1. Bypass of discharge and sediment around the wellhead.
  2. Discharge with sediment produced from the casings and / or bore.
  3. Shallow wells / bores and excavations with pressures and flows too high or risky to attempt direct grouting.
- Important to identify, understand, assess and report what the specific objectives are. Is there more than one ? Very likely !

EXAMPLES
- → Flow → Pressure
- → Piping → Voids → Breakout
- → Subsidence → Comingling
- → Off-Site Discharge & Impacts

APPROACH

- Every situation is unique.
- Expect the unexpected.
- Seek external assistance and advice (contractor, professional and legal).
- Team up with a *qualified experienced* hydrogeologist or engineer with a proven track record … and insurance.
- Consider specialty contractor services.

OUR ADVICE

- If engaging a professional, ensure they accept the role of preparing instructions *in consultation with the driller.*
- Also, assign them the role of ensuring that all work is carried out in accordance with the regulations in your area.

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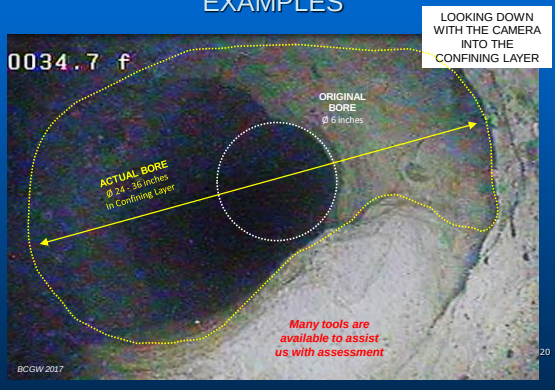
EXAMPLES



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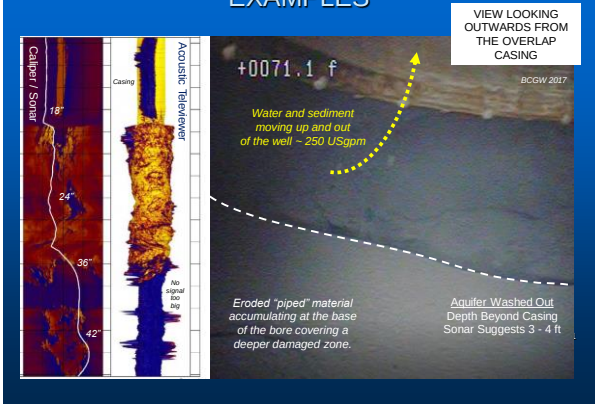
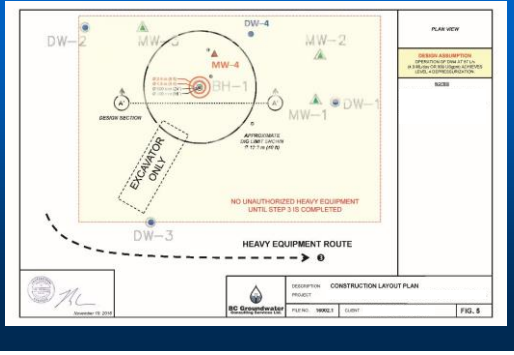
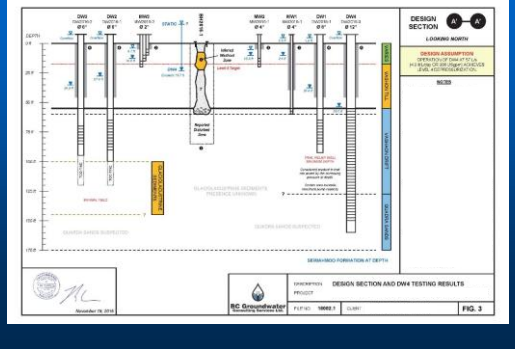
EXAMPLES



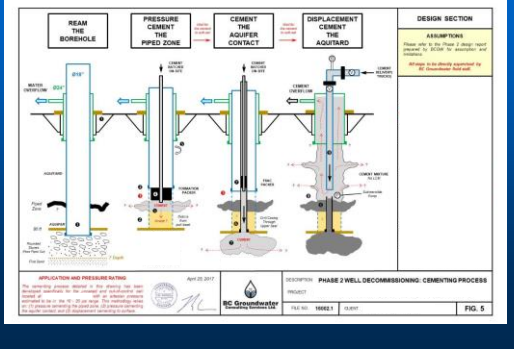
EXAMPLE OF INPUT FROM A PROFESSIONAL
Layout, Access And Restrictions



EXAMPLE OF INPUT FROM A PROFESSIONAL
Conditions Prior To Closure Attempt



EXAMPLE OF INPUT FROM A PROFESSIONAL
Formal Step-By-Step Instructions



GROUTING WITH CEMENT
COMMON PITFALLS AND RECOMMENDATIONS

- In our experience, contractors and professionals alike often overlook the following:
  - Dilution of the cement column from flowing conditions leading to reduced DHHP control.
  - Additional grout volume required due to voids and washouts (caused by drilling and free-flowing conditions).
  - Impaired bonding of cement to casings and borehole walls due to active flow and sediment piping from the well.

OUR ADVICE

- *Grout with visual return to surface.*
- *Measure the overflow density.*
- *Grouting "blind" is not recommended.*
- *Caution when pressure grouting.*

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GROUTING WITH CEMENT
COMMON PITFALLS AND RECOMMENDATIONS

- *Plan your work.* Have all equipment ready, in working order and materials on-site prior to starting. Panic leads to hasty and poor decisions.
- Do not place native cuttings, stones, gravel or debris down the well to "gain control". It is not an adequate solution and complicates the issue.
- Do not use redi-mix concrete. It will segregate and can bridge.
- Bentonite (on its own) is not a reliable method of pressure control. It is prone to piping and channeling under pressure. Often not enough swelling to stop the flow if breakthrough occurs.

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GROUTING WITH CEMENT
COMMON PITFALLS AND RECOMMENDATIONS

OUR ADVICE

- *Consider use of redi-mix trucks to deliver neat cement.*
- *Additives can be added on-site via the hopper.*
- *The need for volume increases with uncertainty.*
- *You may only get one chance to kill the well.*

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DIRECT CLOSURE

- Introducing cement grout directly into the well under a flowing condition (many techniques).
- Generally a reliable approach for cased wells with an intact wellhead.
- In our opinion, particularly suited to deep wells under low pressure (say 5 psig).
- Cement introduced at depth via a tremmie pipe assists with building an intact cement column to surface.
- Dilution and channeling are major concerns. Cementing to refusal may not be possible or desired.
- Exercise caution if wellhead not previously cemented or discharge currently bypassing around the well.

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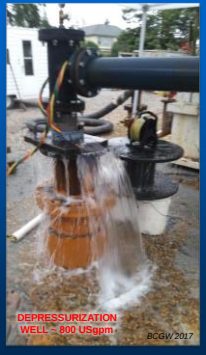
DEPRESSURIZATION



- Drilling a production well nearby the flowing well prior to attempting closure.
- In our experience, a very reliable first step *prior* to attempting cement grouting of wells under moderate to high pressure.
- Particularly important when the problem well is experiencing bypass around the wellhead (or the wellhead is not reliable or intact).
- *In our opinion, this is a necessity prior to attempting cement grouting under piping (sediment producing) conditions.*
- Can complicate cement grouting of the problem well (depends on geology and formation damage).

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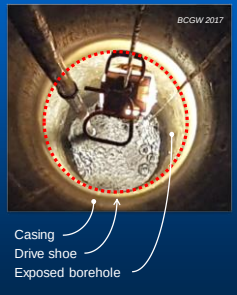
DEPRESSURIZATION



- Provides opportunities not possible with conventional (direct) cementing:
- Can conduct testing to determine if piping is extensive (pumping or dye injection).
- *Can stop bypass around the wellhead and sediment production prior to cementing (reduces potential for channeling).*
- Can provide opportunity for direct closure in a depressurized condition (safety).
- *Can directly observe cement breakthrough during grouting process.*
- Can maintain a depressurized condition after cementing and gradually increase artesian pressures (monitoring).
- *Can conduct post-cementing tests.*

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CONTROL AND CLOSURE OF EXISTING WELLS

- Existing flowing wells are often in a free-discharge condition.
- Opening or closing the valve (or flange) on an existing artesian well has resulted in loss-of-control many times. Beware of being the last one to touch it. *Have the landowner open and close it.*
- Exercise caution when conducting inspections. Undetected piping and subsidence can pose a hazard around the well to a considerable distance.
- Our advice is as follows:
  - *Conduct all investigations with professional and legal support.*
  - *Consider drilling a depressurization well, conducting a pumping test and attempt control by pumping prior to directly investigating it.*

OUR ADVICE

CONTROL AND CLOSURE OF EXISTING WELLS

- Existing flowing wells pose their own "special" challenges:
- The more time a flowing well flows uncontrolled the more likely the confining layer has partially healed around the casing. *This can be positive and negative.*
- The structural integrity of the annular seal of an older flowing well is often uncertain and fragile.
- Well access and land ownership may now be an issue. *Investigate and confirm land tenure prior to visiting and mobilizing.*
- Area around the well may now be saturated. Improvements are frequently required for safe access and work around the wellhead.

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DIVERSION (SHORT AND LONG-TERM)

- Some "out-of-control" wells or artesian conditions are hazardous.
- *Control of such wells can be very difficult even when depressurization is used.*
- The cost of attempting depressurization in productive aquifers can be extremely high.
- Depressurization activities in populated areas and near public infrastructure or homes present additional challenges and risks.
- In some cases long-term diversion may be required prior to addressing the problem.
- *In our opinion, diversion is <u>never</u> a permanent solution even if accepted by regulation. Who is responsible when it goes out of control the next time ?*

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DIVERSION (SHORT AND LONG-TERM)

- Discharge planning is an important component of diversion.
- Design of the discharge wellhead and pipeline must consider operational redundancy, freezing and regular cleanout.
- Be aware that not all artesian wells can free-discharge without producing sediment.
- Compromise may be required between back-pressure at the wellhead (which can cause bypass) and the rate of piping.
- Our advice is as follows:
  - *Retain a professional to assist with design of the wellhead and pipeline.*
  - *Consider legal support.*

OUR ADVICE

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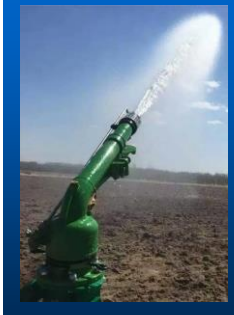
CONCLUSIONS



- Artesian conditions are a regular natural occurrence. Consider each situation unique.
- Employ best practices and reliable advice.
- Drill that surface casing a little bit deeper and use a larger annular space if it makes sense.
- *Don't cut any corners. The cost of dealing with a problematic or out-of-control artesian well will eclipse any potential cost savings.*
- Be careful of blindly following other people's advice …they will likely not be around if the plan doesn't pan out.
- *Have confidence in your approach and remain steadfast. Rely on your intuition!*

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