No Quick Fixes to Gas Well Problem

Case Study of Big Creek Valley, Ontario

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Cam Baker

June 1st, 2022

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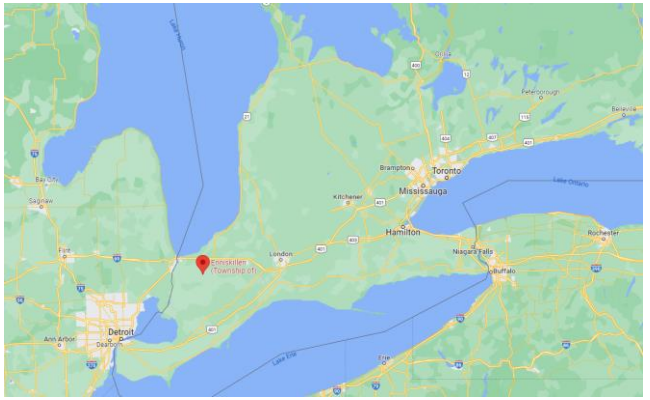
History of Conventional Oil and Gas in Ontario



1850 - Oil reserves in Enniskillen Township, Lambton County documented by Geological Survey of Canada.

1861 – More than 400 wells

This oil field in Lambton County, Ontario, was the site of Canada's first oil boom.
Source: Glenbow Archives, NA-302-9

Reference: http://history.alberta.ca/energyheritage/oil/early-industrialization-and-exploration-1776-1920/oil-in-canada-exploitation-and-entrepreneurs/oil-springs-and-petrolia-ontario.aspx

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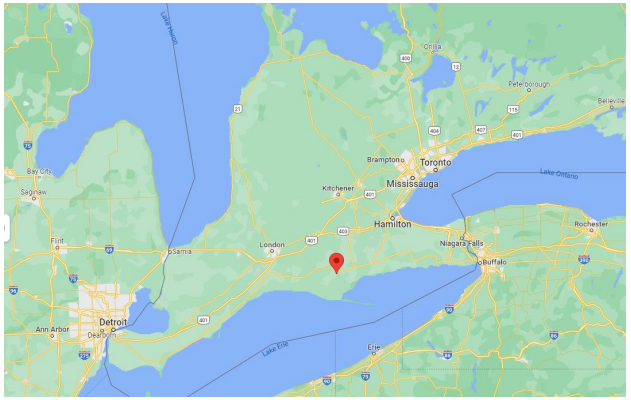
History of Conventional Oil and Gas in Ontario



1870 – Silurian wells reported to be drilled in Norfolk County

1906 – Lot 3 Concession III, Woodhouse Township (Port Dover; Norfolk County),
Well No 3.
Grimbsy Fm. 150,000 cfd – First commercial well

Reference: http://history.alberta.ca/energyheritage/oil/early-industrialization-and-exploration-1776-1920/oil-in-canada-exploitation-and-entrepreneurs/oil-springs-and-petrolia-ontario.aspx

History of Conventional Oil and Gas in Ontario

1906-1913

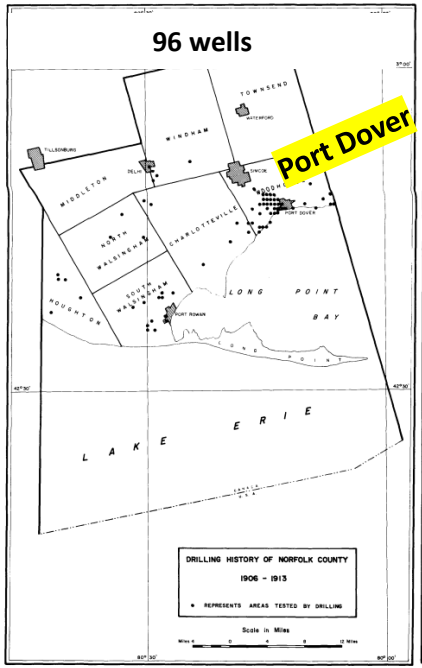


Figure 1-1: Drilling History of Norfolk County, 1906-1913.

1906-1945

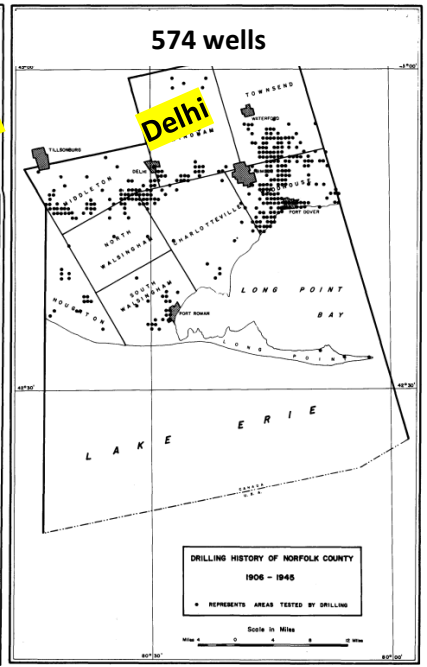


Figure 1-4: Drilling History of Norfolk County, 1906-1945.

1906-1970

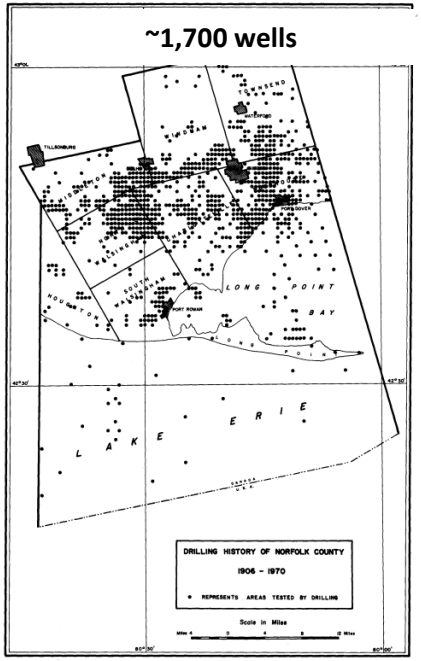
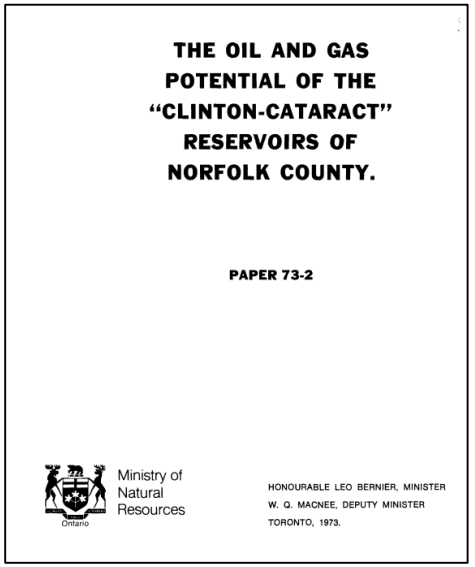


Figure 1-7: Drilling History of Norfolk County, 1906-1970.



THE OIL AND GAS POTENTIAL OF THE "CLINTON-CATARACT" RESERVOIRS OF NORFOLK COUNTY.

PAPER 73-2

Ministry of Natural Resources

HONOURABLE LEO BERNIER, MINISTER
W. Q. MACNEE, DEPUTY MINISTER
TORONTO, 1973.

Reference: Norfolk Co.: "Clinton-Cataract" reservoirs (gov.on.ca)

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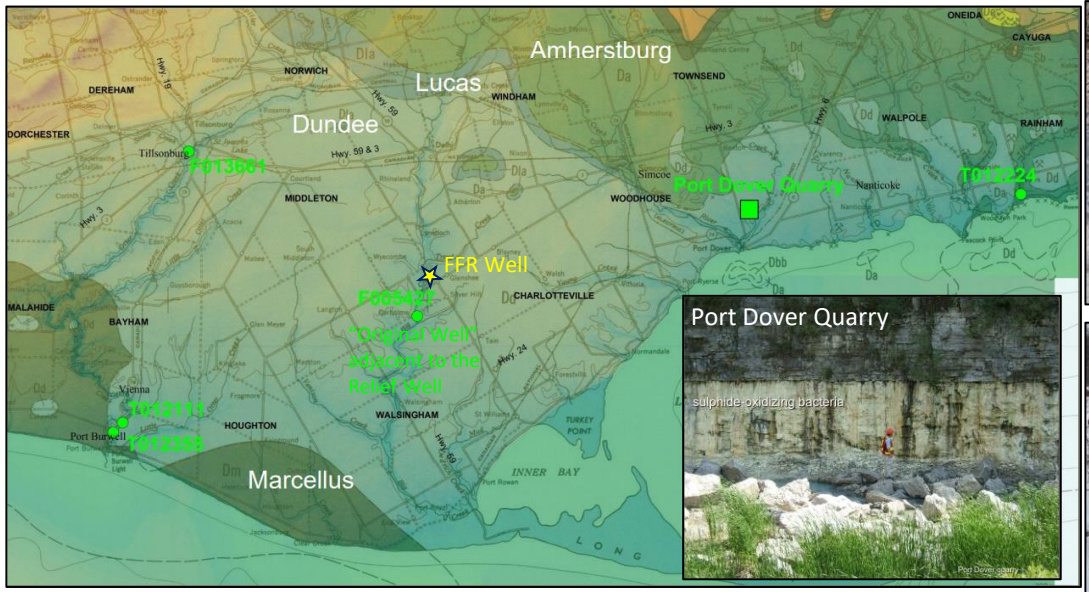
History of Conventional Oil and Gas in Ontario

- Well abandonment standards have evolved over time:
  - ***1910s to mid-1960s :*** lead and/or wood plugs over bridges
  - ***mid- to late-1960s :*** cement plugs over bridges to base of surface casing
  - ***late-1960s to 2000 :*** thicker cement plugs (20 to 40 m)
    - Wells cemented to above bedrock surface
  - ***2000s :*** Thick intervals of cement commonly extending to within ~1.5 m bgs
    - Whole well commonly filled with cement
    - Sulfate-resistant cement mandated in 1990s

Flowing Sulfur Water – A Regional Problem

Flowing Sulfur Water in Big Creek, Big Otter Creek, and Hemlock Creek Valleys



Map and photos taken from Carter et al (2014)

Wells in Big Otter Creek

Before Plugging – Flowing Holes

During Plugging

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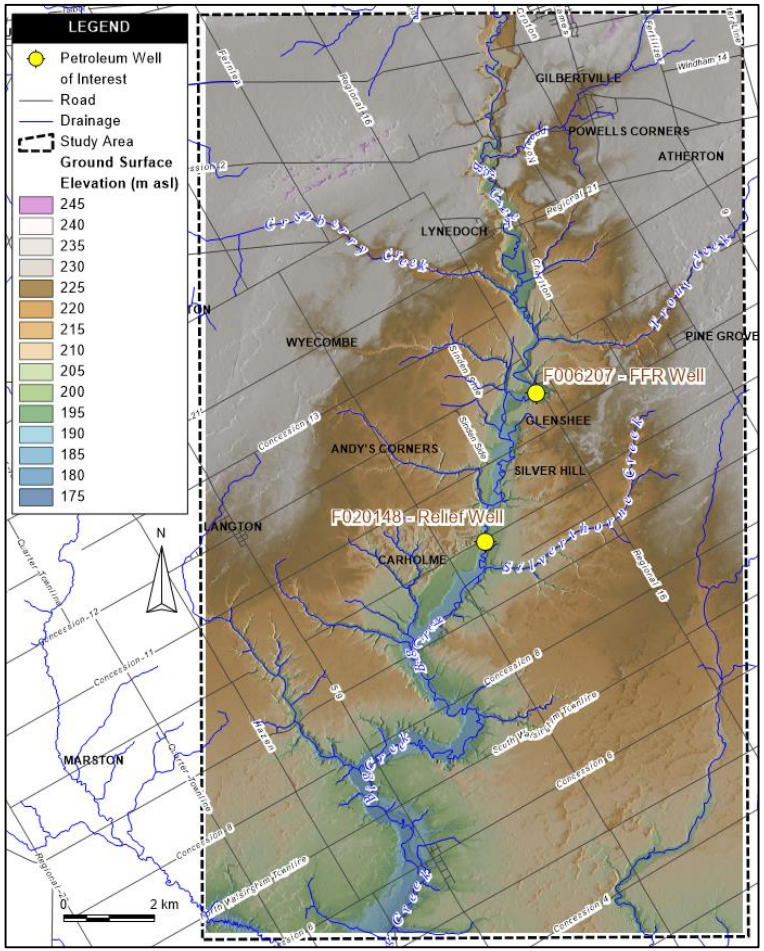
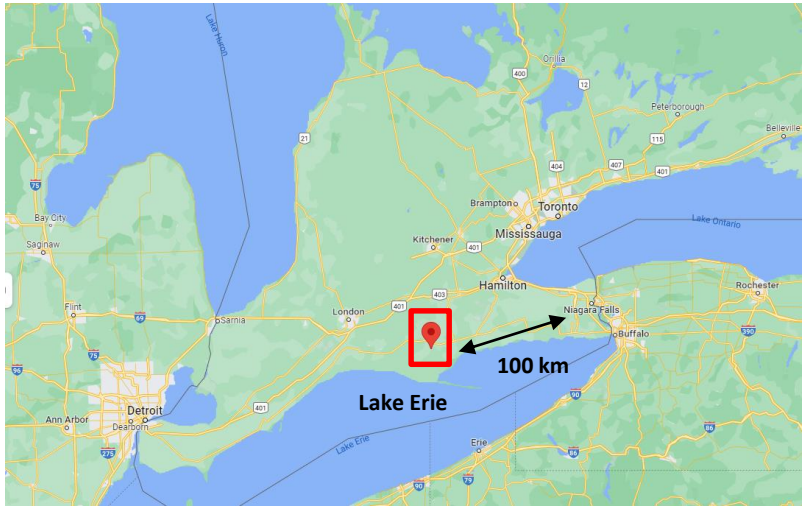
Case Study – Big Creek Valley





* FFR – Forestry Farm Road

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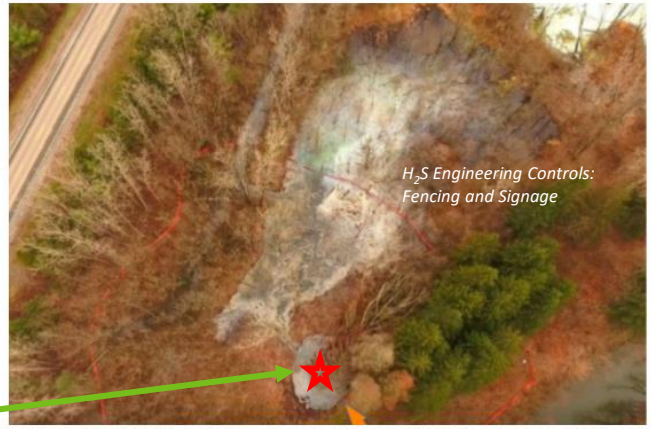
Location – FFR Well



The area of dead foliage surrounding the leaking oil well on Forestry Farm Road has grown over the years. Effluent is flowing into a creek that feeds into Lake Erie. Photo by the Municipality of Norfolk County

Norfolk County Mayor Kristal Chopp describes a leaking well in the area as the municipality's "own Chernobyl" and wants the province to fix it. Photo by Nick Iwanyshyn/National Observer

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Well Information – FFR Well (F006207)

OGSR well card:

CASING AND TUBING RECORD - (3)			
Casing O.D. (mm)	Weight (kg/m)	Setting Depth (m)	How Set
273.05	62.50	28.70	
218.95	35.72	33.20	
139.95	20.83	315.20	

Plugged date: 1956

- Stone bridge at 334.7-330.7 m below ground surface.
- Pine plug #1 at 330.2 m - stone.
- Lead plug #2 at 329.2 m.
- Pine plug #3 315.2 m - stone and cement.
- Stone bridge 48.8-47.2 m.
- Pine plug #4 at 47.2 m - stone.
- Pine plug #5 at 44.2 m - stone.
- Lead plug #6 at 41.8 m - stone.
- Pine plug #7 at 35.0 m - stone.
- Lead Plug #8 at 35.5 m - stone.
- Filled to surface with stone, clay and cuttings.

Gas Well Issues in Big Creek Valley

- Decades long history of flowing wells in the Big Creek valley (reported sulphur spring in 1973 MNR report)
- Current flowing well on Norfolk County property (F006207)
- Norfolk County undertook to:
  - Understand the geological and hydrogeological conditions resulting in flowing sulfur-rich water at gas wells in valley, specifically around the well F006207
  - Support future remedial actions by:
    - assess the impacts of previous well plugging initiatives
    - define of the potential area that may be affected by flowing gas wells
    - provide a framework for assessment of remedial action(s)

Norfolk County's support in enabling this presentation is gratefully acknowledged

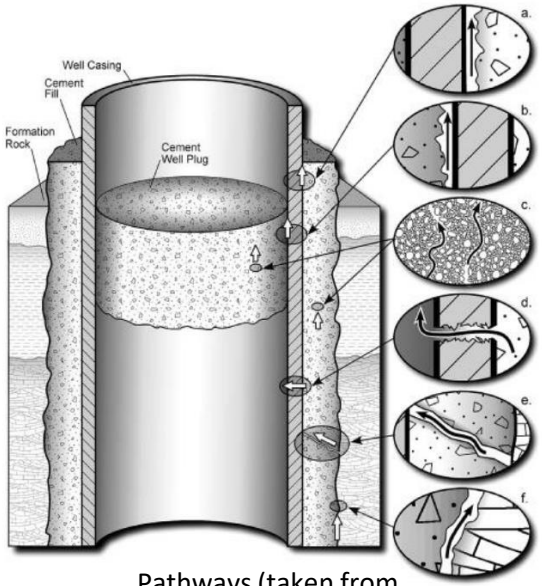
Why are there Flowing Wells?

1. Natural artesian conditions
water level in Dundee Formation is above ground surface

2. Corroded well casings and failed plugs = pathway from confined sulfur water aquifer to ground surface

Photos taken from Carter et al (2014)

Examples of sulfur water induced casing corrosion (taken from Carter 2011)



Pathways (taken from Celia et al 2004)

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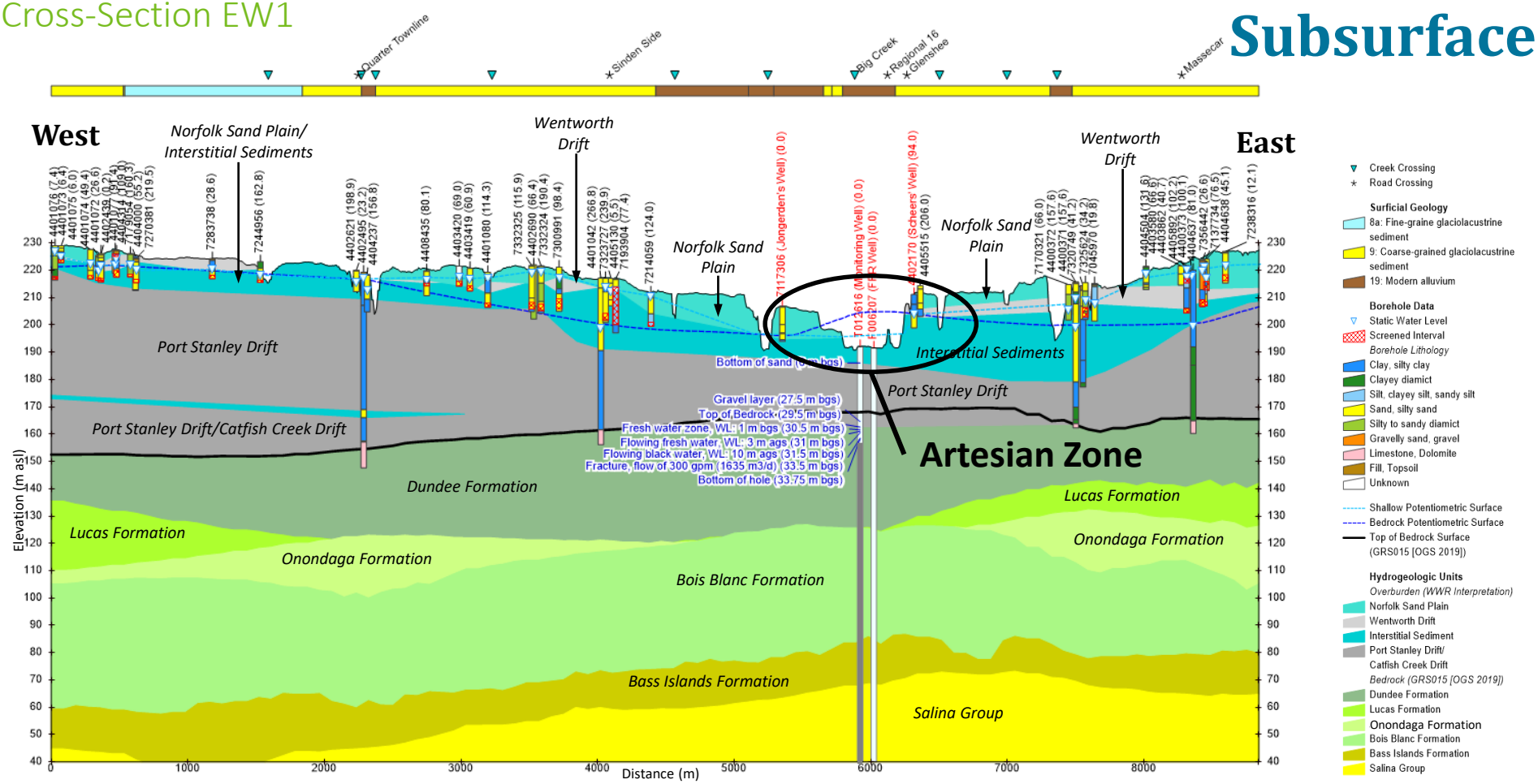
Cross-Section EW1

Subsurface



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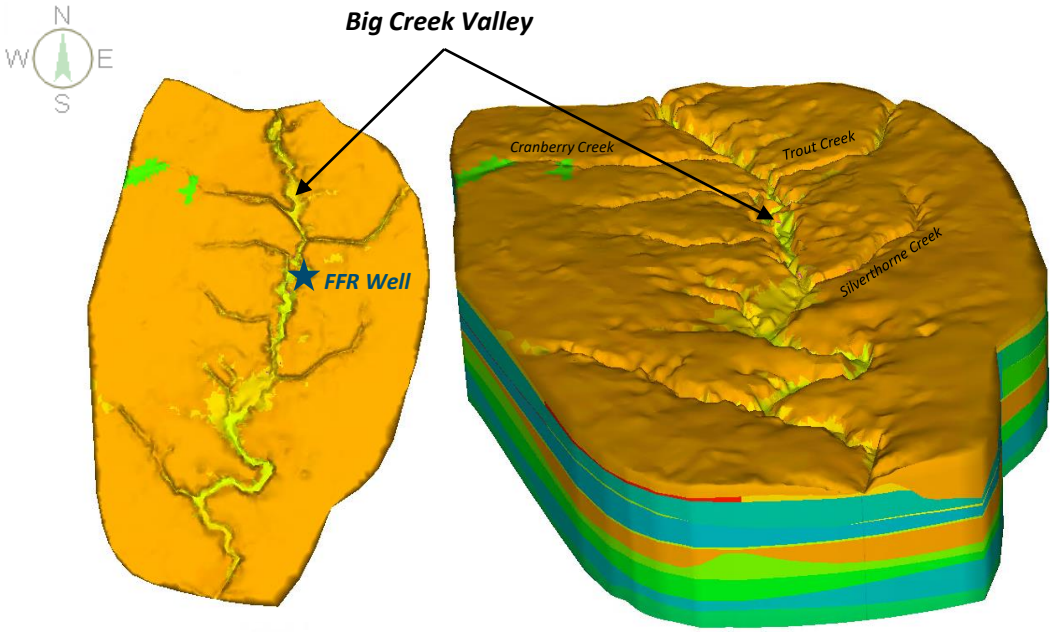
3D Numerical Model of Groundwater Flow

- Width (EW): 12.5 km
- Length (NS): 19.4 km
- Area: 186 km^2
- Considerations:
  - Area of observed flowing wells
  - Regional flow system for overburden and bedrock
  - Surface and groundwater divides
  - Inflow from Northeast, outflow to the South
- 278 Existing Oil and Gas wells in study area



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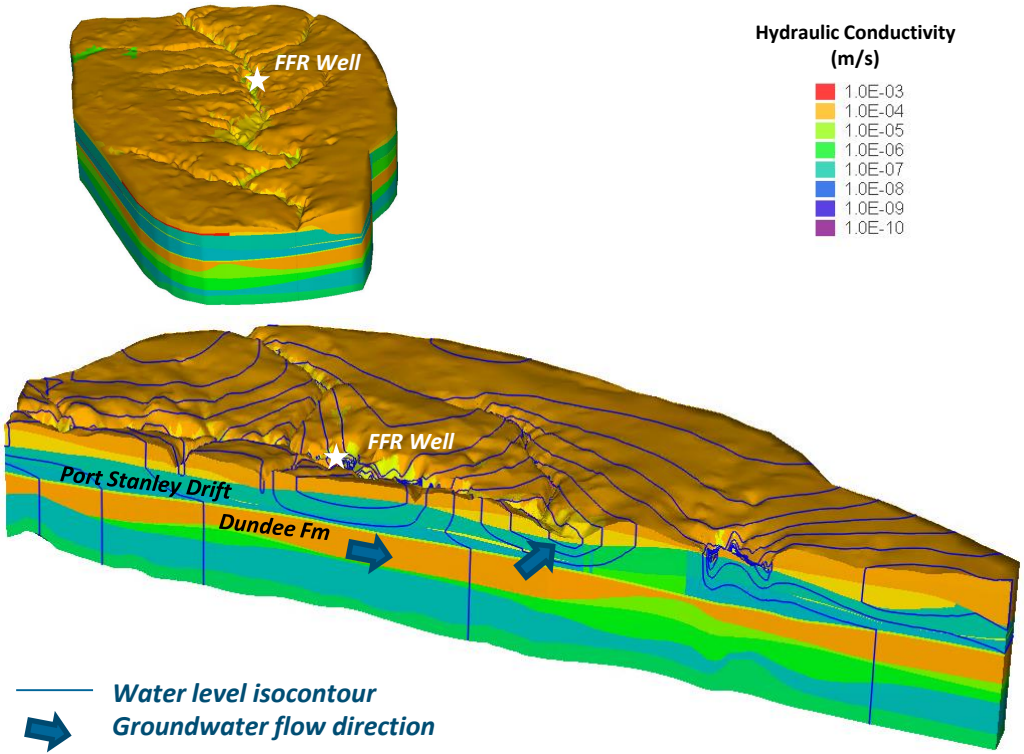
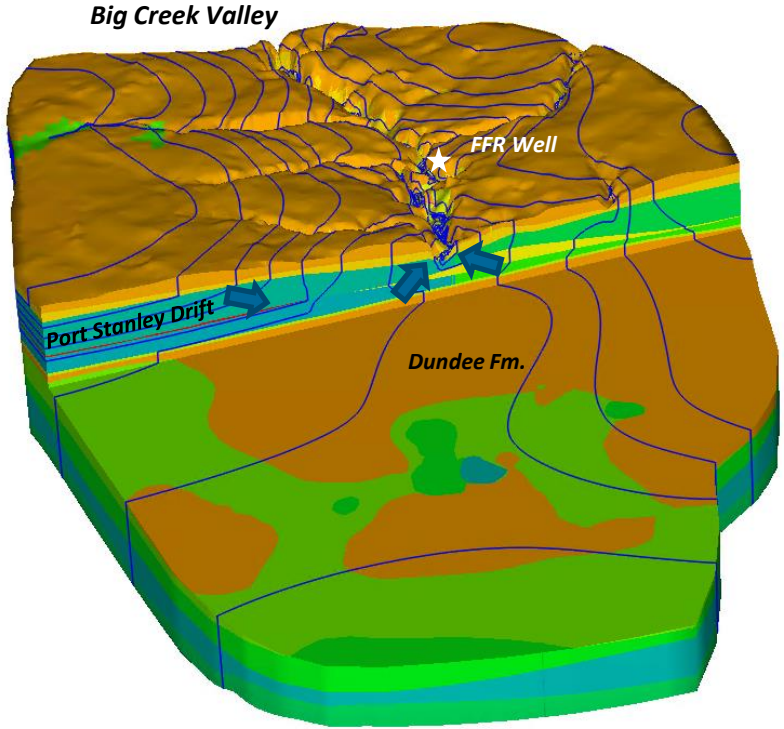
3D Numerical Model of Groundwater Flow



Hydraulic Conductivity (m/s)

- 1.0E-03
- 1.0E-04
- 1.0E-05
- 1.0E-06
- 1.0E-07
- 1.0E-08
- 1.0E-09
- 1.0E-10



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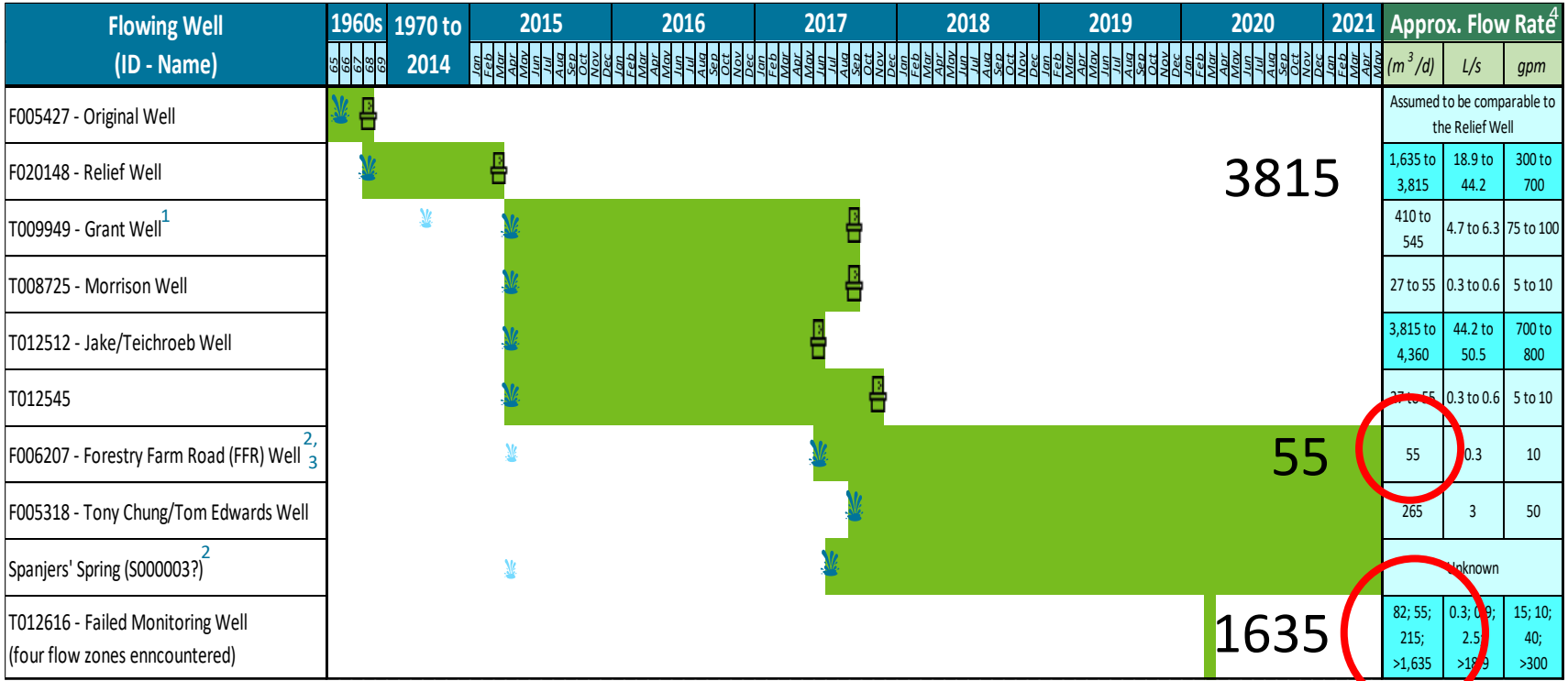
Recent Timeline of Events in Big Creek Valley

Flowing Plugging



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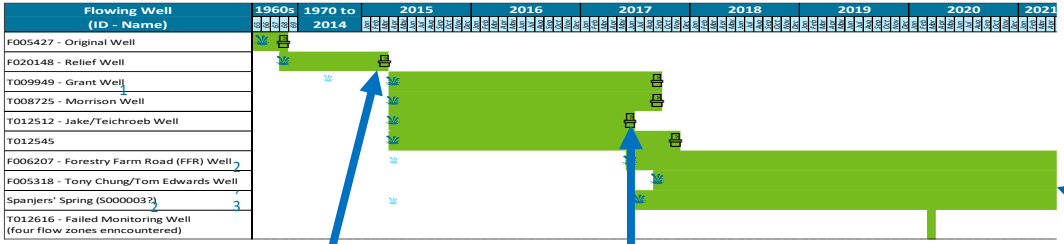
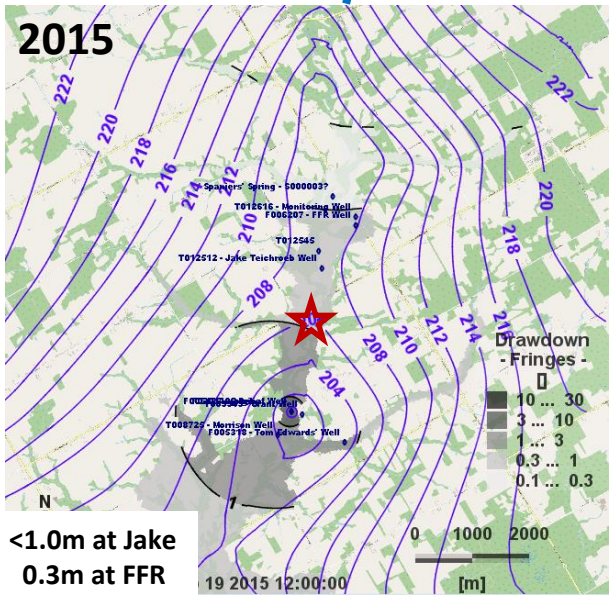
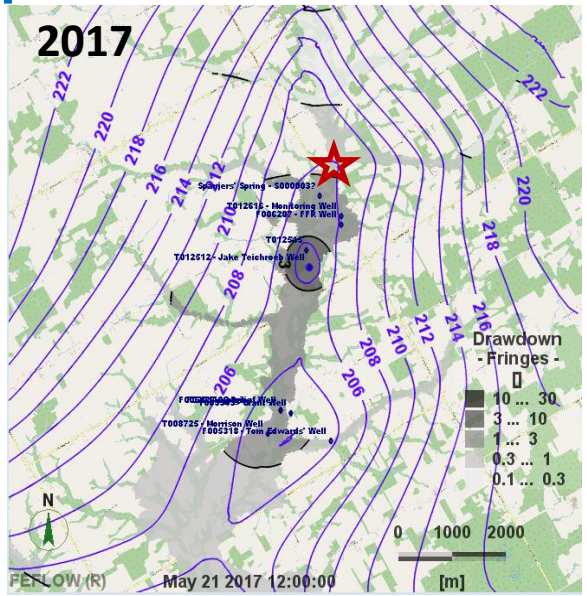
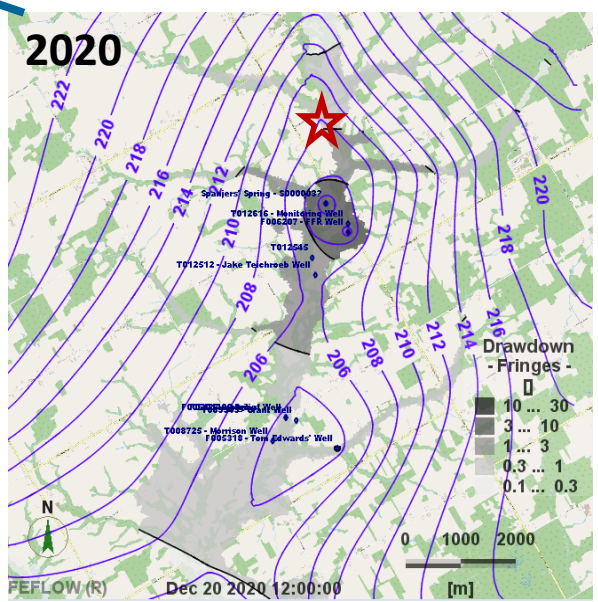
Simulated – Timeline of Events



Elevation of Potentiometric Surface







<1.0m at Jake
0.3m at FFR

Ranking Future Flowing Well Potential

TABLE D Well Status in Big Creek Valley

Well Status	Within the Artesian Zone (Big Creek Valley)	Within 500 m of the Artesian Zone	Total Number of Wells
Abandoned	76	133	209
Active	14	18	32
Suspended	7	6	13
Unknown	10	14	24
TOTAL	**107**	**171**	**278**

- **Abandoned:** wells for which a plugging record is on file at the OGSR Library
- **Active:** wells currently in production
- **Suspended:** wells recently in production that are not currently producing oil or gas
- **Unknown:** wells for which it cannot be determined if plugging was or was not completed (i.e., there is no record of plugging)

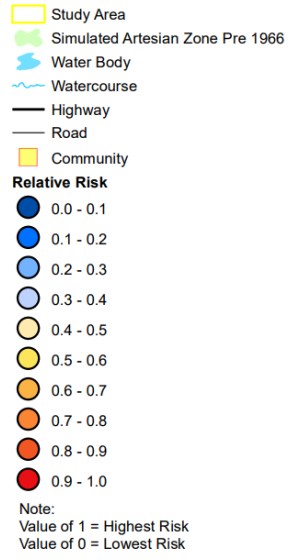
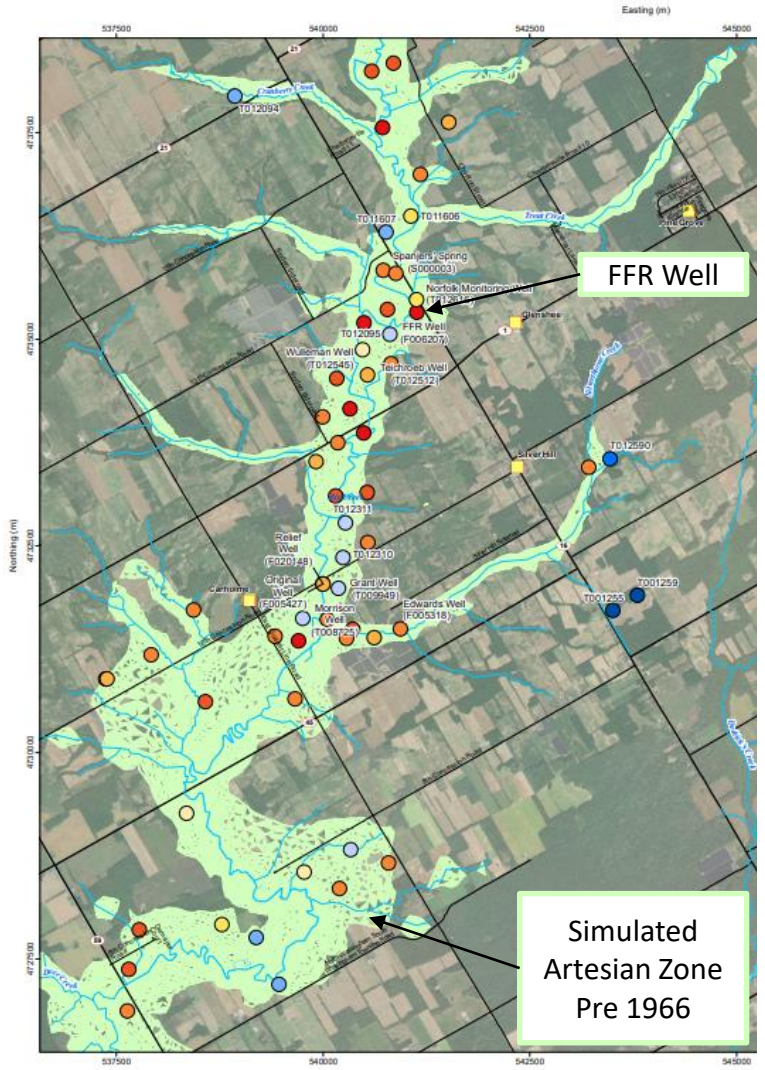


TABLE F Compromise Approach Criteria Weighting

Criteria	Weight	Lower Limit	Upper Limit	Unit
Dundee Fm. Water Level Above Ground Surface	1	-11	20	m
Plugging Event Date	1	Pre-1965	2019	year

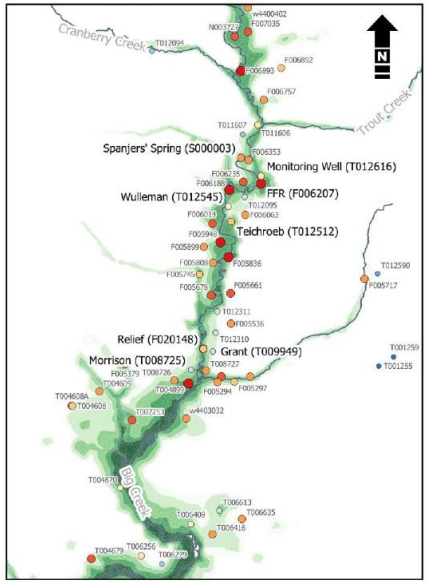


Assessment of Remedial Options

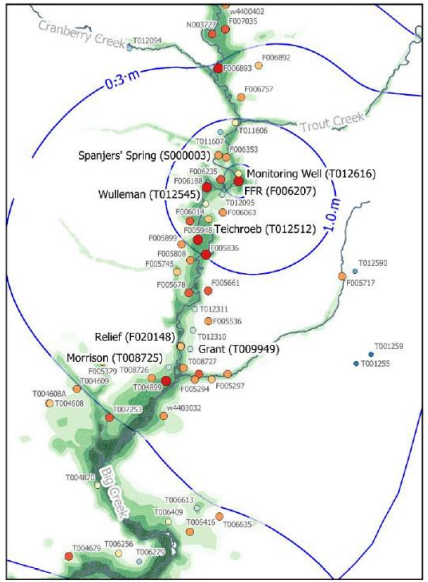
Name	Pros	Cons
Option #1 Plugging the Forestry Farm Road (FFR) Well	- Eliminates environmental concerns at FFR location - Meets requirements of *Oil, Gas and Salt Resources Act*	- Other current flowing wells not addressed - Will likely cause a pressure increase and/or increase in flowing rates at other currently flowing wells
Option #2 FFR flow to surface capture and treatment	- Improves local air quality - Current volume is estimated to be 55 m^3/day, marginal compared to option #3 and #4	- No warranty that the flowing rate will remain at this rate in the future - Requires construction of water treatment facility - System may need upgrading if flow volume increases due to deterioration of plugs or casing - Recurring/ongoing cost for future generations
Option #3 Relief FFR C&T: Relief well near FFR capture and treatment	- Potential sub-regional solution to flowing wells	- Need to drill new well - Time and costs associated with an EA, design and construction - Recurring/ongoing cost for future generations - Regulators may still require other wells to be plugged
Option #4 Relief Original C&T: Relief well near original well capture and treatment	- Potential sub-regional solution to flowing wells	- Need to re-enter relief well or drill new well - Time and costs associated with an EA, design and construction - Recurring/ongoing cost for future generations - Regulators may still require other wells to be plugged

Remedial Options: Spatial Influence

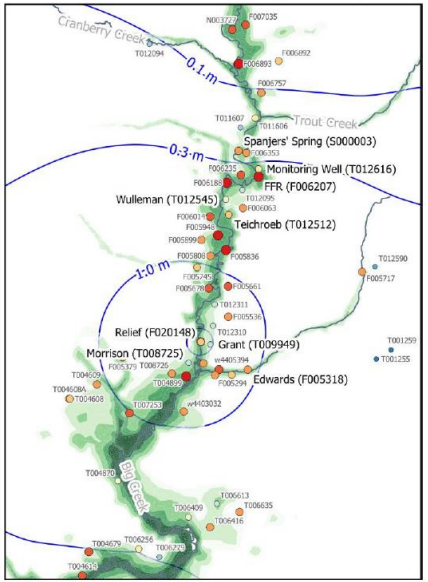
Option 1 & 2:
Plugging FFR or Capture & Treat

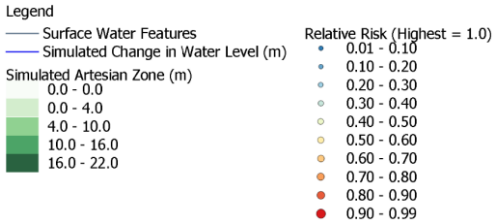


Option 3:
Relief Well Near FFR (F006207)



Option 4:
Relief Well Near Original (F005427)





- Predicted 0.3m increase in water levels within 10m radius of FFR well

- Assumed flowing rate of **55 m³/day***

- Options 3 and 4: have the **most impacts regionally**

- Between **10 and 14 wells** within the 1 m change in water levels radius (1.7 km)

- Predicted well capacity in the order of **3,800 m³/day**.

Note: **Norfolk County monitoring well encountered flowing rate up to **1,635 m³/day***

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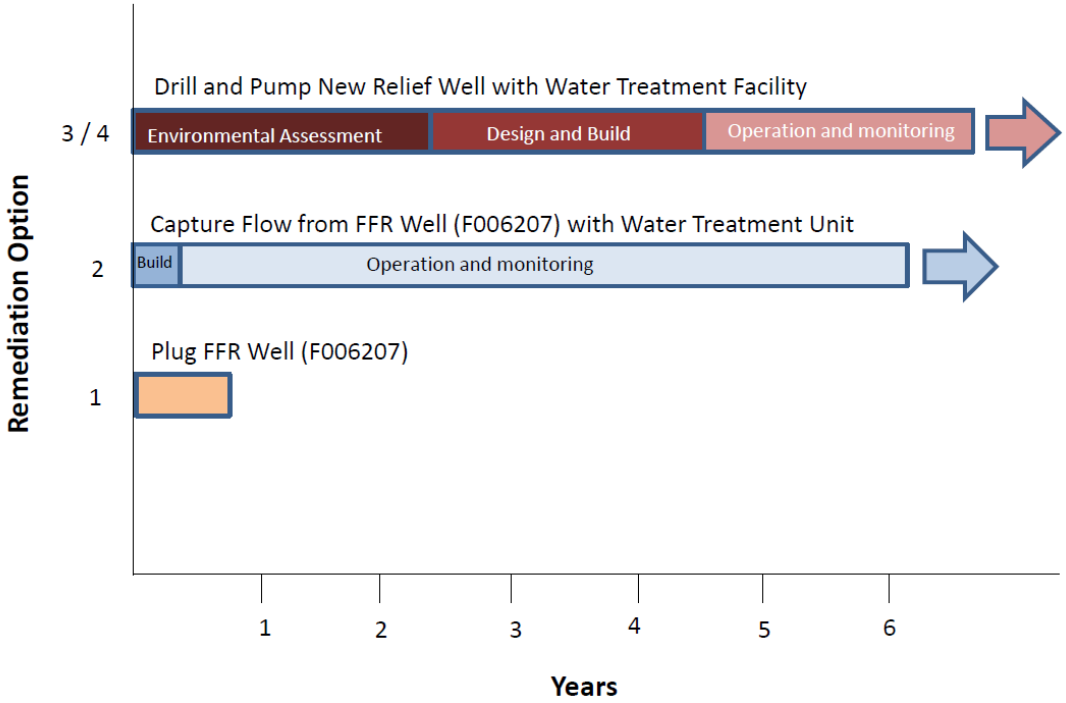
Remedial Options: Time and Cost



	Cost	
	Capital	Ongoing
3 / 4	$$$$$	$$$$$
2	$	$$$$
1	$$	N/A

*Capital cost and ongoing cost **multi-millions** of dollars.*
Formal cost estimate was not part of this scope of work.

*Capital cost: less than **$500,000***
***Ongoing cost** until a different remedial option is implemented.*

*Capital cost: **$500,000 to $750,000***
***No ongoing cost** once plugged.*

Summary

- Flowing gas wells likely to be an ongoing concern in the Big Creek valley
- Wells most at risk those that are:
  - unplugged
  - plugged pre-1965
- Dundee/Contact aquifer must be considered as a regional scale feature
- Isolation of CH_4/H_2S sources to freshwater aquifers is interpreted the best long-term solution
- Abandonment of a flowing well results in transfer of pressure in aquifer, which may result in additional flowing wells or appearance of “springs”
- Solutions to flowing wells have different environmental and financial consequences

Edwards Well
Current flow rate ~265 m^3/day

Acknowledgement

- Cam Baker
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- Laura Weaver
- Norfolk County team
- Norfolk County residents

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