

# Canadian Achievements in Hydrogeology

## 1970s - Early 2000s

### Contaminant Hydrogeology (1975-1987)

1975: **Cherry, Gillham** and **Pickens** demonstrated why contaminant hydrogeology differs from water-supply hydrogeology.<sup>1</sup>

1974-1979: **Cherry** led the establishment of a groundwater field research facility at the **CFB Borden landfill** to facilitate long-term, interdisciplinary field research of contaminant hydrogeology. Yielded the Stanford Borden experiments, investigating the fate and transport of dissolved chlorinated hydrocarbons.

1976: **Gélinas** worked on problems of resource and contaminant hydrogeology throughout Québec, where he was regarded as the Father of Québec Hydrogeology. He was the first to suggest the naming of the **Robert N. Farvolden Award**, an award he received himself in 2009.

1981: **Tang, Frind** and **Sudicky** conducted groundbreaking research on contaminant transport in fractured rock.<sup>2</sup>

1985: **Cherry** received both the **Meinzer Award** for a group of (seven) papers published in the *Journal of Hydrology*<sup>3</sup> in 1983 on the Borden case history, and the **Horton Award** for contributions of the understanding of the physical and chemical aspects of groundwater contamination.

1987: The **University Consortium Solvents-in-Groundwater Research Program** was initiated in response to the urgent need for focussed research on **dense non-aqueous phase liquids (DNAPLs)** in groundwater and its treatment options.<sup>4</sup>

### Groundwater Geochemistry (1970-1981)

1972: Cherry developed the concept of order-of-encounter to explain the evolution of the major-ion chemistry of groundwater quality in Prairie groundwaters.<sup>5</sup> The general concepts were presented by Cherry at the **24th International Geological Congress in Montreal**, which brought the international hydrogeological community to Canada for many field trips.

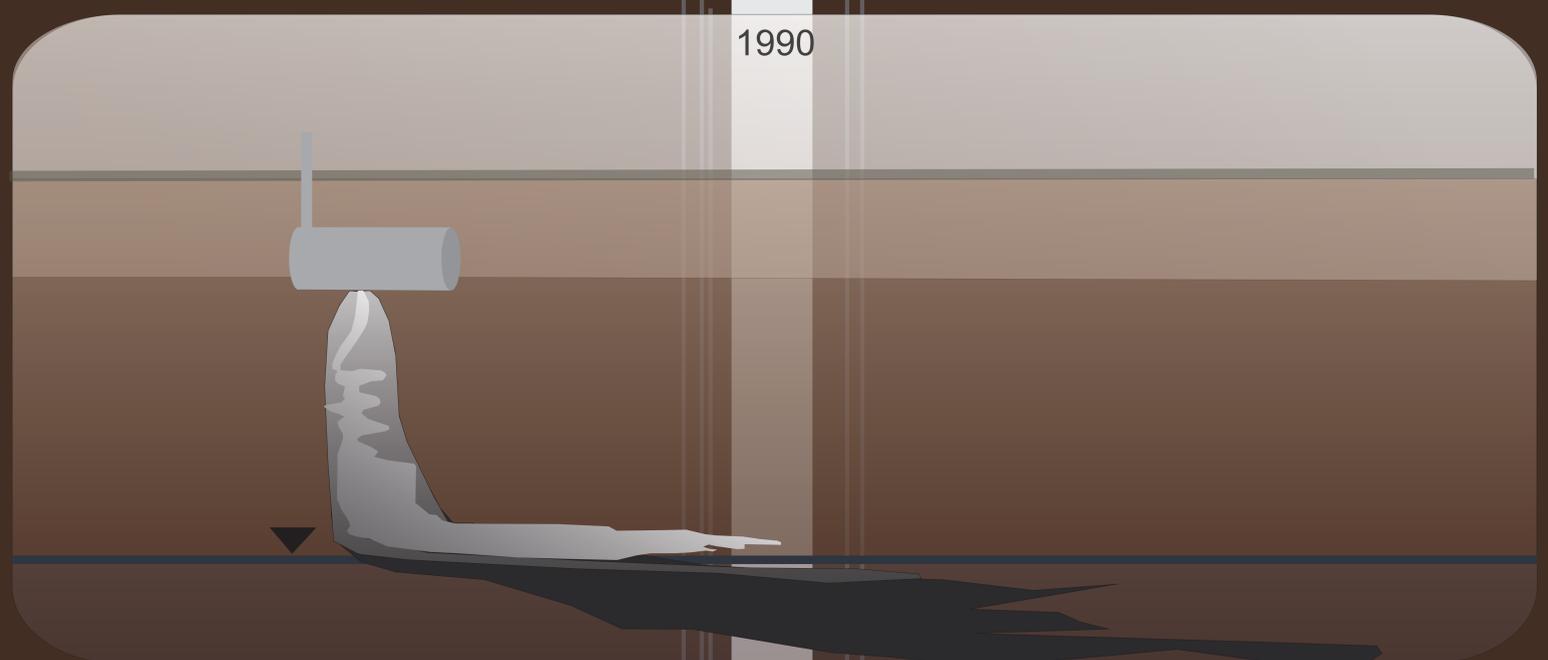
1979: Researchers at **Chalk River Nuclear Laboratories**<sup>6</sup> identified the redox-evolution sequences in groundwater flow systems based on the thermodynamic models of Stumm. They indicated the likelihood of the microbial catalysis of the redox sequences and laid a foundation for monitored natural attenuation as a remedial option.

### Environmental Isotopes (1970s-1990s)

1971: **Fritz** built up an internationally recognized laboratory and graduate program in **environmental isotope** research and introduced **isotope geochemistry** into hydrogeology.

1981: The geochemistry of methane in groundwater was studied by **Barker** and **Fritz** showing that methane could be fingerprinted isotopically as to its origin.<sup>7</sup> This laid the geochemical foundation for understanding fugitive-gas migration during the fracking boom of the 21st century and questions raised about leaking oil and gas wells.

1997: **Clark** and **Fritz** published *Environmental Isotopes in Hydrogeology*.<sup>8</sup>



### Stochastic Hydrogeology (1975-1986)

1975: **Freeze** published the first paper conceptualizing stochastic analysis of groundwater flow in heterogeneous media.<sup>9</sup>

1986: **Sudicky** published findings from the Borden experiment, demonstrating small-scale, random patterns of heterogeneity control longitudinal dispersion in groundwater.<sup>10,11</sup>

### Technological Advancements (1970 - 1989)

1970s: **Westbay Systems**' introduced multilevel groundwater level monitoring technology, providing three-dimensional hydrogeologic data.

1989: **Waterloo Hydrogeologic Inc.** released FLOWPATH, the first graphical modelling software package in the industry.

### Publications (1970s to 2014)

1979: **Freeze** and **Cherry** publish *Groundwater*.<sup>12</sup>

2009: The Council of Canadian Academies published *The Sustainable Management of Groundwater in Canada*.<sup>13</sup>

2014: The Geological Survey of Canada (GSC) published *Canada's Groundwater Resources*<sup>14</sup>, a major compilation of the current knowledge of the groundwater resources in Canada since the previous synthesis in 1967.

### Nuclear Waste Disposal (2005-2011)

The **Nuclear Waste Management Organization** undertook field characterization of a potential deep geological repository at the Bruce Nuclear Site in southwest Ontario. Record low hydraulic conductivities ( $10^{-14}$  m/s) were measured. Isotope geochemistry suggested pore fluids are >60 million years old. Diffusion dominates radionuclide migration.

### Crossing Disciplines (1967- Present)

1967: **Lennox** and **Carlson** used surficial techniques such as seismic refraction to establish the field of hydrogeophysics.<sup>15</sup>

1969: **Freeze** and **Harlan** publish a "blue-print" for numerical modeling of watersheds with coupled groundwater and surface water.<sup>16</sup>

1971: **Patton** and **Deere** first considered groundwater flow systems around open pit mines.<sup>17</sup>

1972: **SRC** worked with USGS to demonstrate downhole geophysics.<sup>18</sup>

1972: **van Everdingen** investigated thermal and mineral springs of the southern Rocky Mountains.<sup>19</sup>

1973: **van Everdingen** made significant contributions on groundwater flow in permafrost.<sup>20</sup>

1977: **Hodge** and **Freeze** conducted the first simulations that demonstrated slope stability and landslide geomorphology as a groundwater problem.<sup>21</sup>

1981: **van der Kamp** investigated saltwater intrusion in a layered coastal aquifer on Prince Edward Island.<sup>22</sup>

1983: **van der Kamp** and **Gale** publish theory of earth tide and barometric effects in porous formations with compressible grains.<sup>23</sup>

1986: **Hendry, Cherry** and **Wallick** study the origin and distribution of sulphate in the Prairies.<sup>24</sup>

1991: **van der Kamp** and **Maathuis** show that snow accumulation at the ground surface and changes of total soil moisture cause changes of mechanical stress which show up as fluctuations of groundwater levels in deep observation wells.<sup>25</sup>

1998: **van der Kamp** and **Hayashi** investigated the groundwater recharge function of small wetlands in the semi-arid northern prairies.<sup>26</sup>

2003: **Chapuis** and **Aubertin** conducted laboratory permeability testing to predict saturated hydraulic conductivity.<sup>27</sup>