Ground Temperature Modelling: Backward and Forward

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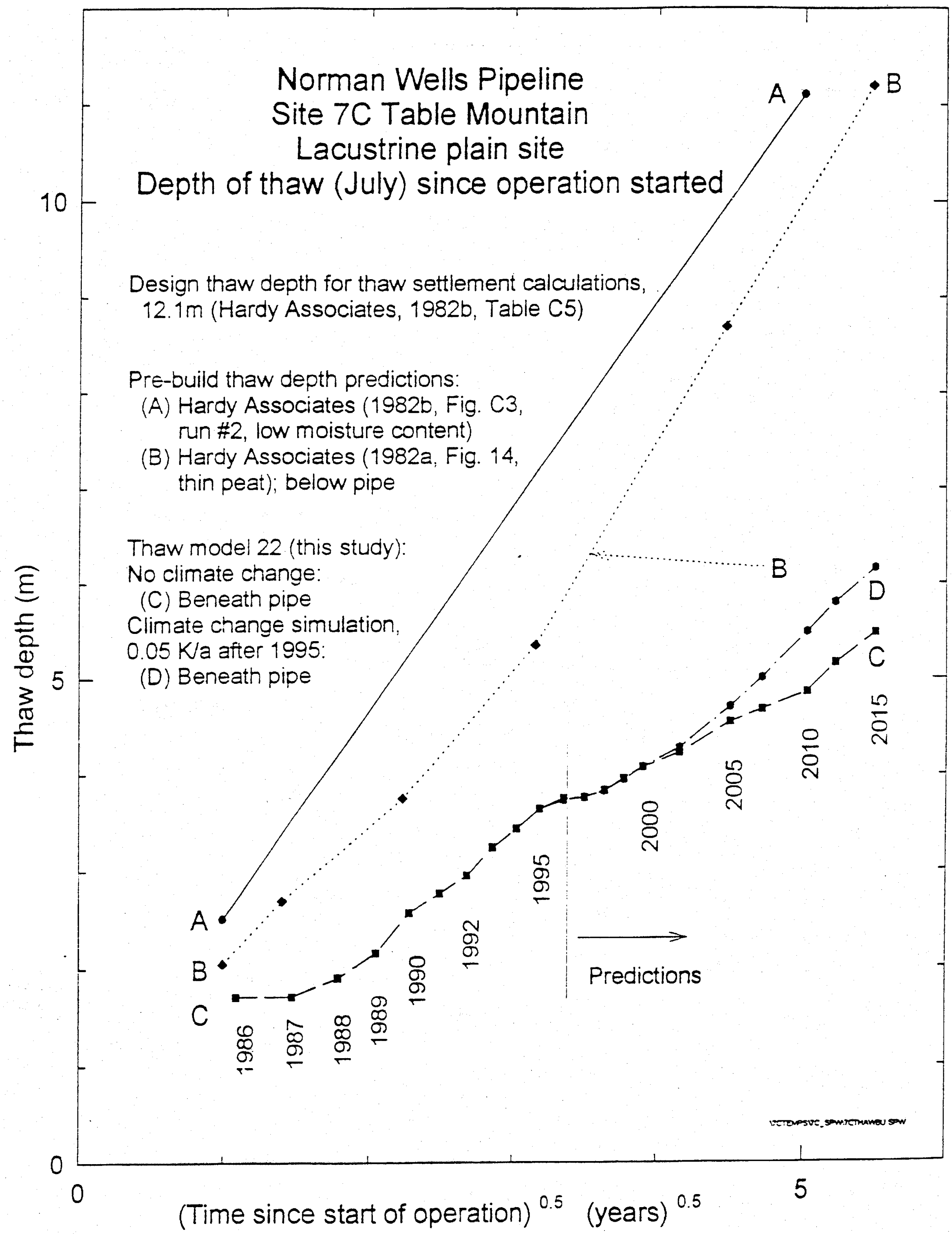
I referred this morning to some seminal work by Lachenbruch and Marshall on reconstruction of past climate and past ground temperature history from deep ground temperature data. In Canada quite a bit of this work has been done. In fact, there is a worldwide community using these well-established techniques of inversion of ground temperature profiles into climate. Unfortunately, opportunities to work with deep holes (several hundred meters depth) to do that type of modelling are rare. We have made an initiative to look at data for more shallow holes (to 50 m or so), to look for the signal of ongoing climate change in the next 10 - 20 years.

What I would like to present today is say something very briefly about modelling because I have a feel for what will follow me. Vlad Romanovsky mentioned the value of modelling when you take a lot of shallow ground temperatures (down to a few meters or tens of meters) in the active layer or shallow permafrost, If you have a temperature time series at manually-read intervals of a few months or half a year or annually, you can often use modelling to interpolate. This can be done by developing an understanding of the processes involved, calibrating using processes inherent in the study area to establish a model that is well calibrated on those processes and borehole temperatures, and validating by reproducing the original time series. Once this is done, one can proceed to investigate the effect of changing scenarios.

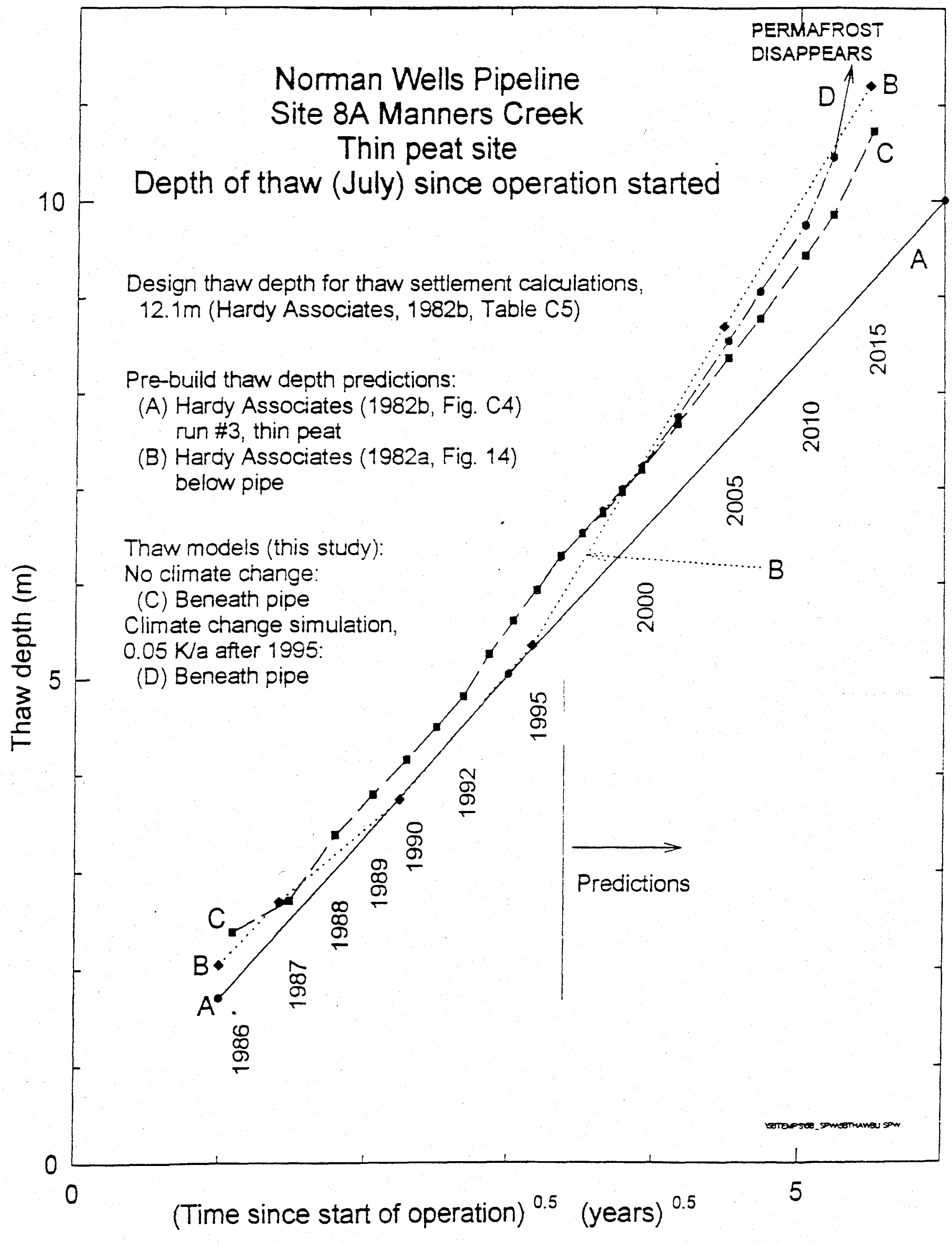
In this talk I will discuss some work that was done several years ago, in which we took the wealth of information for three sites along the Norman Wells pipeline. These consisted of several sites that were heavily instrumented with ground temperature cables, known physical and geotechnical properties (Water content, thermal properties, unfrozen water content, mineralogy and so on). This information was used to build a numerical model, to calibrate it very well against the temperature logs. Validation involved running for ten years to establish that it could faithfully reproduce what was measured. We then moved on to look at several climate change scenarios.



This was really just an introductory or trial run. It was based on measurements near Wrigley, starting shortly after the pipeline was started, until 1995-96. Results were within an acceptable tolerance of the measurements. Once this was done, the model was used to examine some climate change scenarios. The model predicts thaw depth and ground temperatures. Results show early thaw depths of about 1.5 m, increasing after a number of years to about 2-3 meters after 10 years (the limit of actual data) extending to 5-6 meters in the climate change scenarios. Projections are somewhat speculative, since conditions on the right-of-way may change, such as vegetation conditions.

Comparing these results with design and pre-build thaw depths suggests that these scenarios are within the design limits for the pipeline. Design values are not readily comparable to results at a single site, since design values represent general conditions over perhaps hundreds of kilometers, and are intended to be conservative. Results for another area (near Manners Creek) were closer to the design value, and are greater than predicted by pre-build calculations. As before, the data that we had for this modelling was tremendous, whereas the pre-build modelling was based on limited information.

A good model is a reflection of our understanding of the processes and behavior of nature. If you can replicate that then it combines all of your knowledge into one neat package.


Norman Wells Pipeline
Site 8A Manners Creek
Thin peat site
Depth of thaw (July) since operation started
PERMAFROST
DISAPPEARS
Design thaw depth for thaw settlement calculations,
12.1m (Hardy Associates, 1982b, Table C5)
Pre-build thaw depth predictions:
(A) Hardy Associates (1982b, Fig. C4)
run #3, thin peat
(B) Hardy Associates (1982a, Fig. 14)
below pipe
Thaw models (this study):
No climate change:
(C) Beneath pipe
Climate change simulation,
0.05 K/a after 1995:
(D) Beneath pipe
Predictions
A
B
C
D
1986
1987
1988
1989
1990
1992
1995
2000
2005
2010
2015
Thaw depth (m)
0
5
10
(Time since start of operation) 0.5 (years) 0.5