CGU HS Committee on River Ice Processes and the Environment
12th Workshop on the Hydraulics of Ice Covered Rivers
Edmonton, AB, June 19-20, 2003

Tests of River Ice Jam Models – Phase 2

R. W. Carson
KGS Group
3rd Floor – 865 Waverley Street
Winnipeg, Manitoba
R3P 5P4
Rcarson@kgsgroup.com

D. Healy
University of Alberta
Edmonton, Alberta
Dhealy@ualberta.ca

S. Beltaos
Environment Canada
Burlington, Ontario
Sbeltaos@cciw.ca

J. Groeneveld
Acres Manitoba Ltd.
500 Portage Avenue
Winnipeg, Manitoba
Jgroeneveld@acres.com

The Committee on River Ice Processes and the Environment formed a sub-committee to test and compare computer models of ice jam processes. The sub-committee planned to do the tests in three phases:

The first two cases have been carried out. Results of Case #1 were reported in the 11th Workshop on River Ice, in Ottawa in 2001.

The second case is reported herein. The river that was adopted for this test was the Thames River. Specifically, an ice jam that occurred near Chatham, Ontario in 1986 has been addressed. Observed maximum water surface profile and measured ice thicknesses were supplied for the test, along with an estimated steady state flow of 290 m^3/s that was believed to have occurred at the time of the peak water levels within the jam.

The comparison of results is presented in this paper. The intent is that discussion at the Ice Workshop will identify key questions about the models and their results, which could be the subject of a subsequent paper to further compare the models.

1.0 INTRODUCTION

The Committee on River Ice Processes and the Environment (under the auspices of the Canadian Geophysical Union) has initiated a series of tests of prominent computer models of river ice jams. The tests were planned to be comprised initially of hypothetical situations, followed by real case histories. This paper summarises the results of the second test using observed data from an ice jam on the Thames River (1986).

2.0 MODEL OVERVIEWS

i. DYNARICE

DYNARICE was developed under the direction of Dr. H.T.Shen and L. Liu of Clarkson University. It is a two dimensional, unsteady flow and ice dynamic model. Description of the modelling algorithms and strategy can be seen in U.S. Army Corps of Engineers Report TR-00-10. ***Unfortunately, although DYNARICE was applied in the first test case, it was not included in the case described in this paper. We hope that it will be applied in future tests.***

ii. ICEJAM

The ICEJAM model (Flato and Gerard (1986)) was developed to calculate the thickness and water surface profiles for a cohesion-less, wide channel ice jam with a floating toe. For a floating toe configuration, the "seepage" through the interstitial spaces in the ice cover is neglected. The theory behind the development of the jam stability equation in ICEJAM closely follows those theories presented by Pariset, Hausser, and Gagnon (1966) and Uzuner and Kennedy (1976).

iii. ICEPRO

KGS Group developed ICEPRO. It is a one-dimensional steady state model that is compatible with HEC-RAS data input. The ice mechanics follow the algorithms and approach that was planned for the RIVICE project (TALAS Report (1993)).

iv. ICESIM

ICESIM was developed by Acres International as a tool to be used for analysing means to manage river ice conditions during the construction of hydroelectric generating stations on the Nelson River. It is a one-dimensional, steady state model, although it has a sister program (ICEDYN) that can simulate ice accumulation under unsteady flow conditions.

v. RIVJAM

RIVJAM was developed by Dr. S. Beltaos and is a steady state model applicable primarily to breakup ice jams whose profiles are governed by internal resistance to hydraulic loads exerted on the ice cover.

3.0 TEST DESCRIPTION

The Thames River is located in south-western Ontario and flows primarily southwards through Chatham to empty into Lake St. Claire at the town of Lighthouse Cove. Winter jams occur frequently in this river, as periods of above freezing temperatures and rain are not uncommon during the coldest months of the year (Beltaos and Moody, 1986). This case study represents a jam which formed as a result of a period of warm weather combined with rain which raised the water level in the river, causing the ice to break up and move downstream (Beltaos and Moody, 1986).

Downstream Toe of the Ice Jam on the Thames River

200 m Upstream from Toe of Jam

This winter ice jam on the Thames River in Ontario, as documented by Beltaos and Moody (1986), formed as a result of the release of an upstream ice jam during the evening of January 22, 1986. High water marks were photographed during the morning of January 23, and surveyed after cold weather had returned and conditions had stabilised. With the resumption of cold weather, a solid ice layer formed over the ice jam making it safe to collect thickness measurements. Based on the consistency between ice thickness measurements taken within the same section of the jam on February 4 and February 25, 1986, it was assumed that the jam thickness did not change over the period during which the measurements were taken (January 23 to February 26, 1986).

Using the Water Survey of Canada gauge record at Thamesville (WSC Gauge 02GE003), and estimating the time of travel between the gauge and the jam site to be 12 hours, Beltaos (1988) estimated the discharge to be 290 m^3/s.

The observed water surface profile, the measured ice thicknesses, and the estimated ice jam profile (laterally averaged top and bottom of the ice cover) are shown in Figure 1.

The modellers were requested to select parameters for their numerical models that would best represent the site conditions provided.

4.0 TEST RESULTS

The results of each test were provided to the Sub-Committee in a pre-designed spreadsheet that facilitates consistent comparison. The results are summarised graphically in series of figures:

- Figure 2 – computed profile for ICEJAM simulations
- Figure 3 – computed profile for ICEPRO simulations
- Figure 4 – computed profile for ICESIM simulations
- Figure 5 – computed profile for RIVJAM simulations
- Figure 6 – Superimposed lines showing computed water levels for all four models, compared to the measured water levels.
- Figure 7 – Superimposed lines showing deviations of computed ice thicknesses for all four models, compared to the measured thicknesses.
- Figure 8 – Graph of Manning n-values used by each model for the best fit of both the ice thicknesses and the water surface profile. Note that only composite n-values that represent the combination of the riverbed, and the ice under-surface, are used by ICEJAM and RIVJAM. The other two use the Torok-Saboneev equation to combine the ice and riverbed n-values into a composite value.

The model parameters for each model that were used by each modeller in making the best fit shown in Figures 2 to 7 are summarized in Table 1.

TABLE 1

Summary of Key Parameters Adopted to Simulate Thames River Ice Jam

PARAMETER	VALUES ADOPTED			
	ICEJAM	ICESIM	ICEPRO	RIVJAM
Specific gravity of ice	0.92	0.92	0.92	0.92
Porosity of ice	n.a.	n.a.	n.a.	0.4
Ice Strength parameter, μ	1.0	1.2	1.2	1.2
Leading edge Critical Froude Number	n.a.	0.12	0.10	n.a.
Manning's n-value for riverbed	n.a.	0.027	0.027	n.a.
Manning's n-value for ice	n.a.	Varies from 0.04 to 0.10	Varies from 0.035 to 0.08	n.a.
Composite n-value	0.07	Varies from 0.034 to 0.069	Varies from 0.031 to 0.057	Varies from 0.033 to 0.085
Steady Discharge	290 m^3/s	290 m^3/s	290 m^3/s	290 m^3/s
Water Level at toe of Ice Jam	177.35 m	177.35 m	177.35 m	177.35 m

n.a – not applicable

Table 1 refers to variations in Manning's n-values. Further explanation of this for each model follows:

ICEJAM – The version applied to this simulation maintains a constant user-specified composite Manning's n-value over the length of the ice jam. There is no separation of n-value for the riverbed and the ice under-surface. The selected composite n-value is based on the user's estimate of the appropriate value.

ICESIM - This model allows the user to specify separate values of n-value for the riverbed and for the ice under-surface. The composite Manning's n-value is computed by the program using the Torok-Saboneev equation. The Manning's n-value for the riverbed is selected by the user based on calibrations to best represent observed open water conditions, if possible. In this test case, the riverbed Manning's n-value of 0.027 was used because it was estimated in other work by Dr. Beltaos, and reported to the test sub-committee. The Manning's n-values of the ice under-surface were varied in proportion to the ice jam thickness (0.10 being at the thickest portion of the ice jam, and 0.04 being at the thinnest, upstream segment), to best represent the ice jam profile.

ICEPRO - Uses methodology similar to ICESIM, but the selected Manning's n-values for the ice cover were lower than that for ICESIM, varying from 0.08 at the thickest part of the ice jam, to 0.035 at the thinnest, upstream segment.

RIVJAM – RIVJAM does not use a separate Manning's n-value for riverbed and ice under-surface. Rather, it uses a semi-empirical equation that relates the composite friction factor (which can be translated into a Manning's n-value) to the thickness of the ice jam and depth of flow under the ice jam.

5.0 COMPARISON OF MODEL METHODOLOGIES

The intent of this paper was to publish the basic results of the tests. Comparisons of fundamental methodologies can be found in the previous paper published in the Proceedings of the 11th Workshop on River Ice (Carson et al, 2001). Further comparisons of the methodologies and their influence on the results are planned for a future paper. Input from CRIPE members and attendees at the 12th Workshop on River Ice is solicited to assist in identifying the issues that justify the greatest focus in such a paper.

6.0 REFERENCES

Beltaos, S., and Moody, W.J., 1986, "Measurements on the Configuration of a Breakup Jam", National Water Research Institute

Beltaos, S., 1988, " Configuration and Properties of a Breakup Jam", Canadian Journal of Civil Engineering

Carson, R.W., Beltaos, S., Shen, H.T., Groeneveld, J., Healy, D., Hicks, F., Andres, D., 2001, "Tests of River Ice Jam Models", 11th Workshop on River Ice, Ottawa

Flato and Gerard, 1986, “ICEJAM Model”

Kennedy, J.F., and Uzuner, M.S., 1976, “Theoretical Model of River Ice Jams”, ASCE Journal of Hydraulic, Vol. 102 (HY9)

Liu, L., H.T. Shen, 2000, “Numerical Simulation of River Ice Control with Booms”, USACE Cold Regions Report TR-00-10

Pariset, E., R. Hausser, A. Gagnon, 1966, “Formation of Ice Covers and Ice Jams in Rivers”, ASCE Journal of Hydraulics, Volume 92 No. HY6

TALAS Joint Venture, 1993, “Report on RIVICE Development”

Figure 1 - Observed Water and Ice Profiles
Thames River Ice Jam, 1986

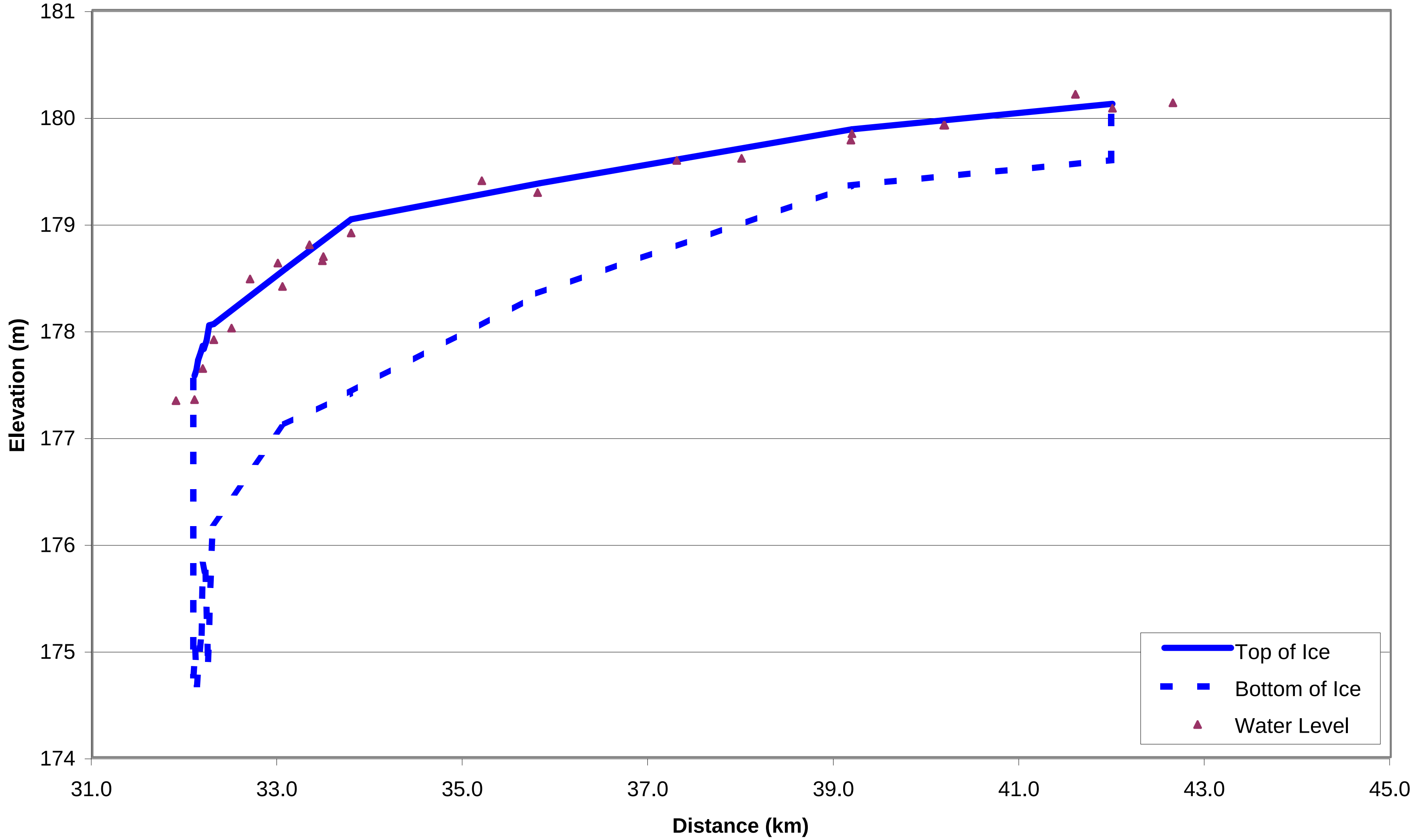


Figure 2 - Computed Water and Ice Profiles for ICEJAM Model
Thames River Ice Jam, 1986

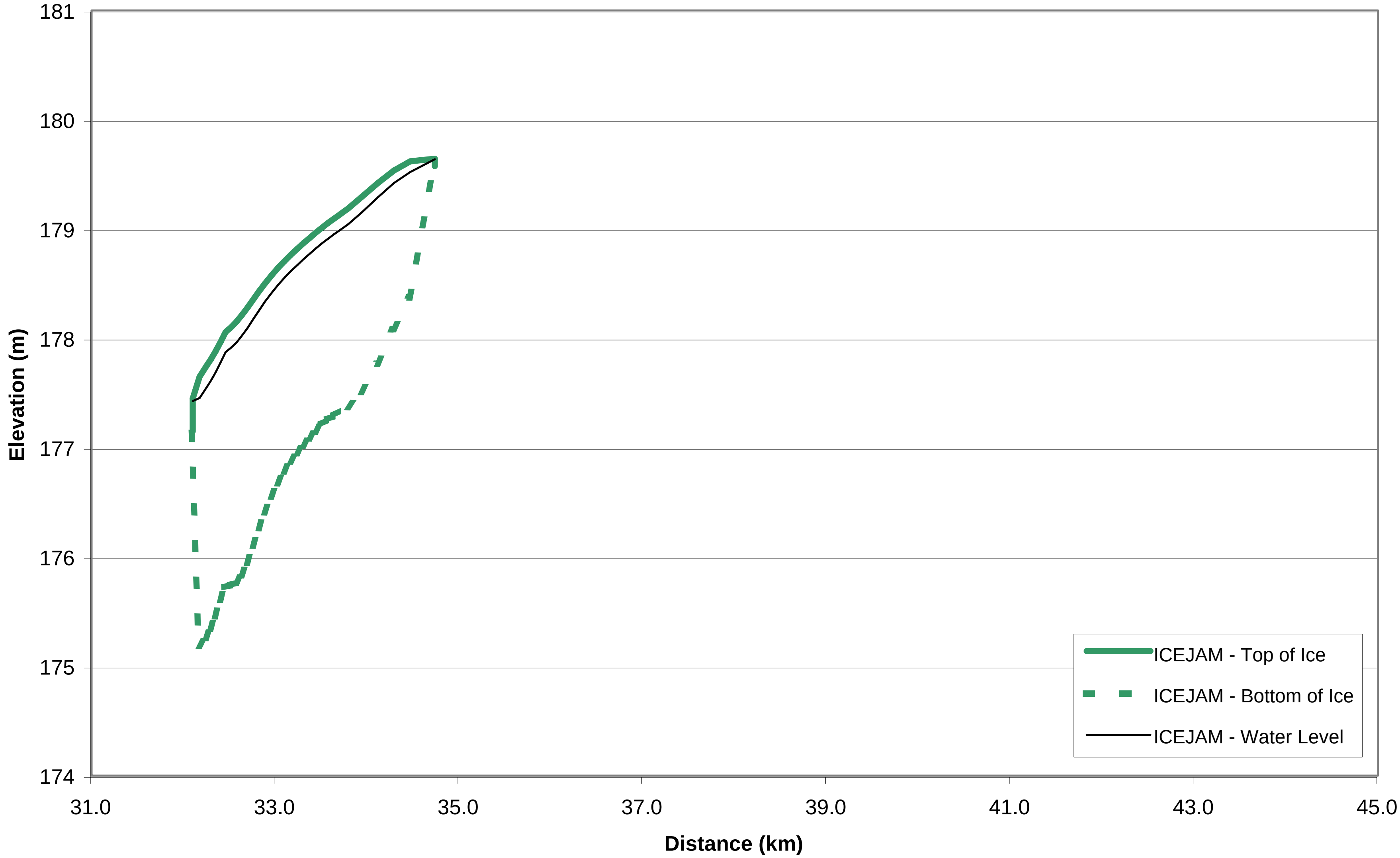


Figure 3 - Computed Water and Ice Profiles for ICEPRO Model
Thames River Ice Jam, 1986

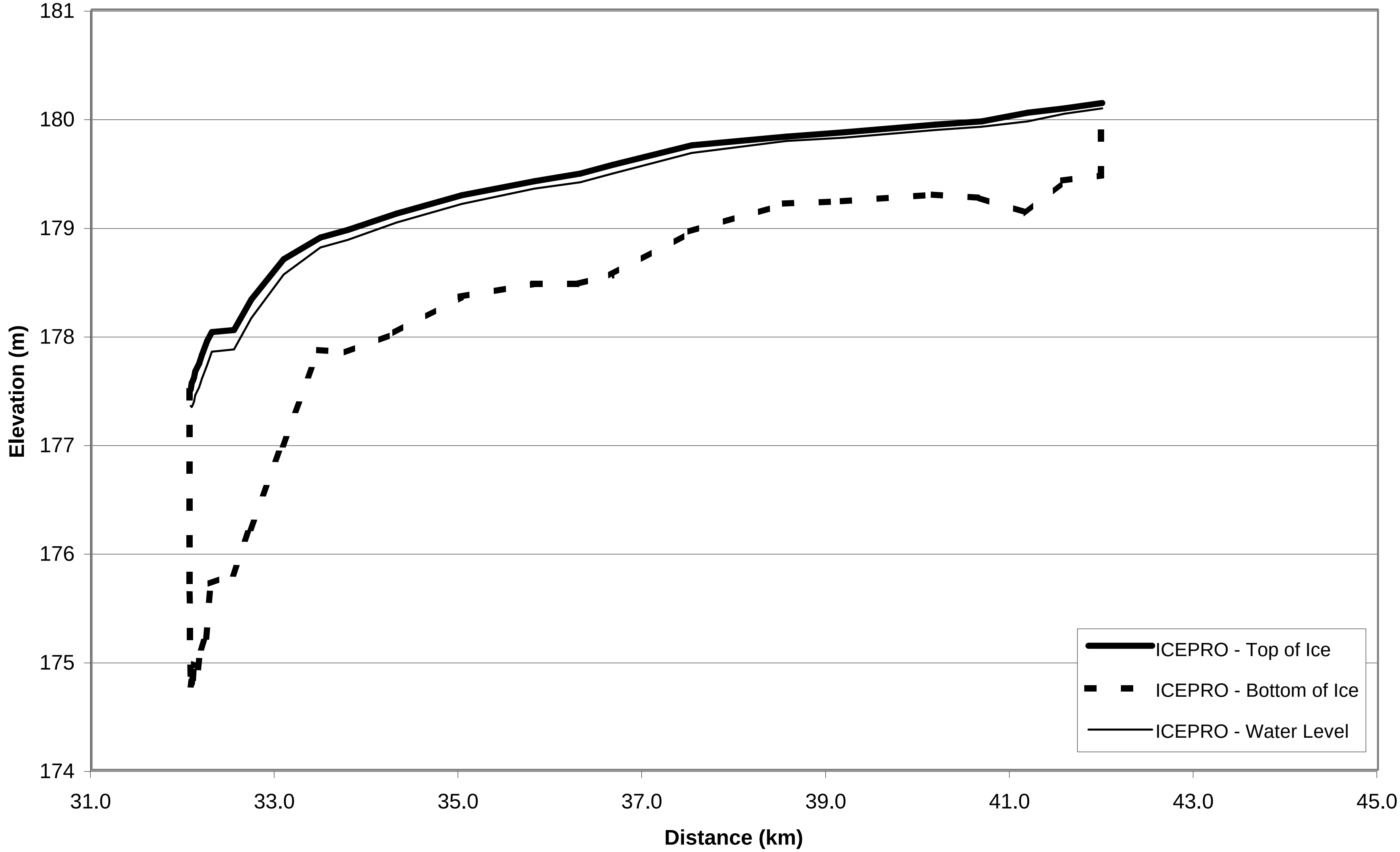


Figure 4 - Computed Water and Ice Profiles for ICESIM Model
Thames River Ice Jam, 1986

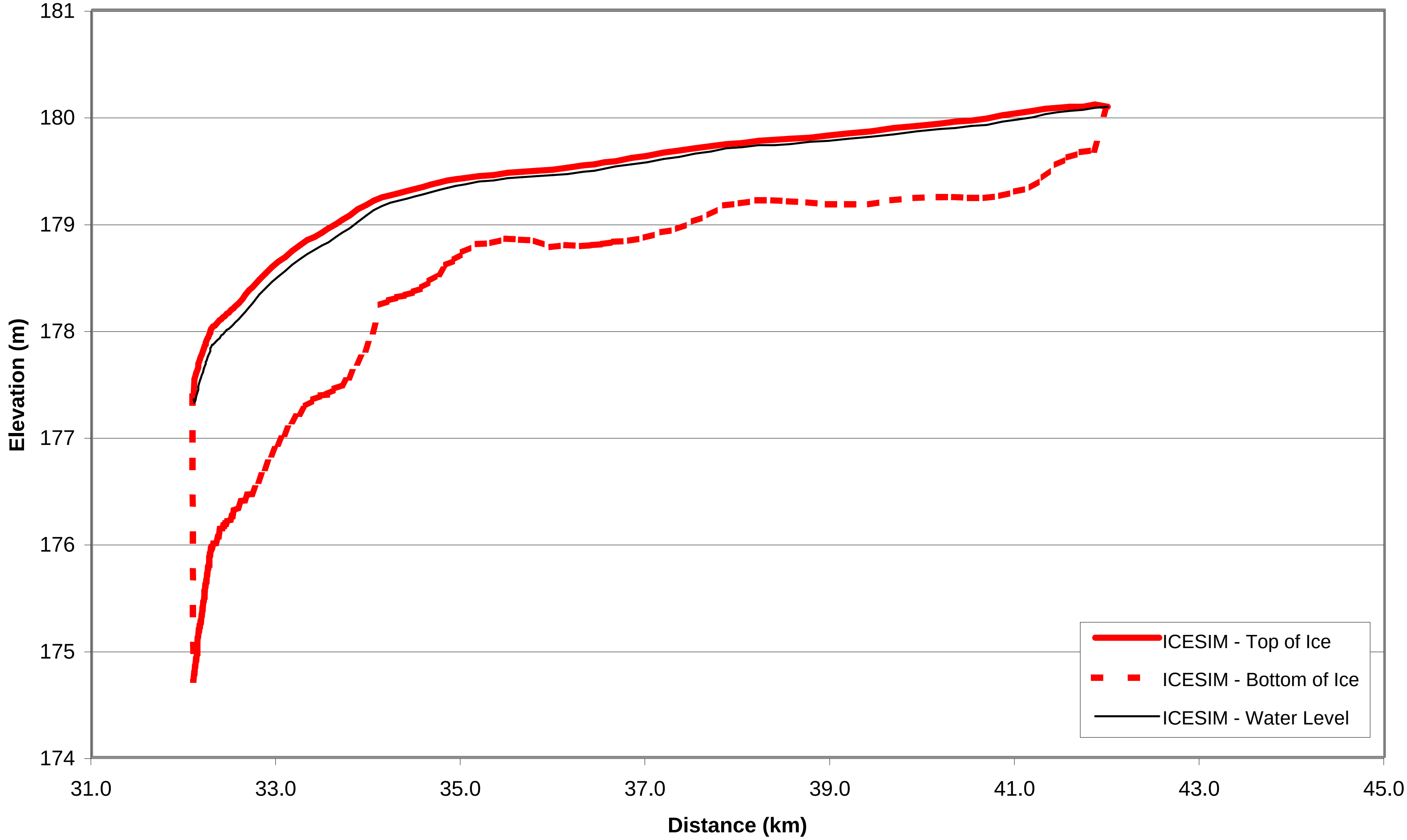


Figure 5 - Computed Water and Ice Profiles for RIVJAM Model
Thames River Ice Jam, 1986

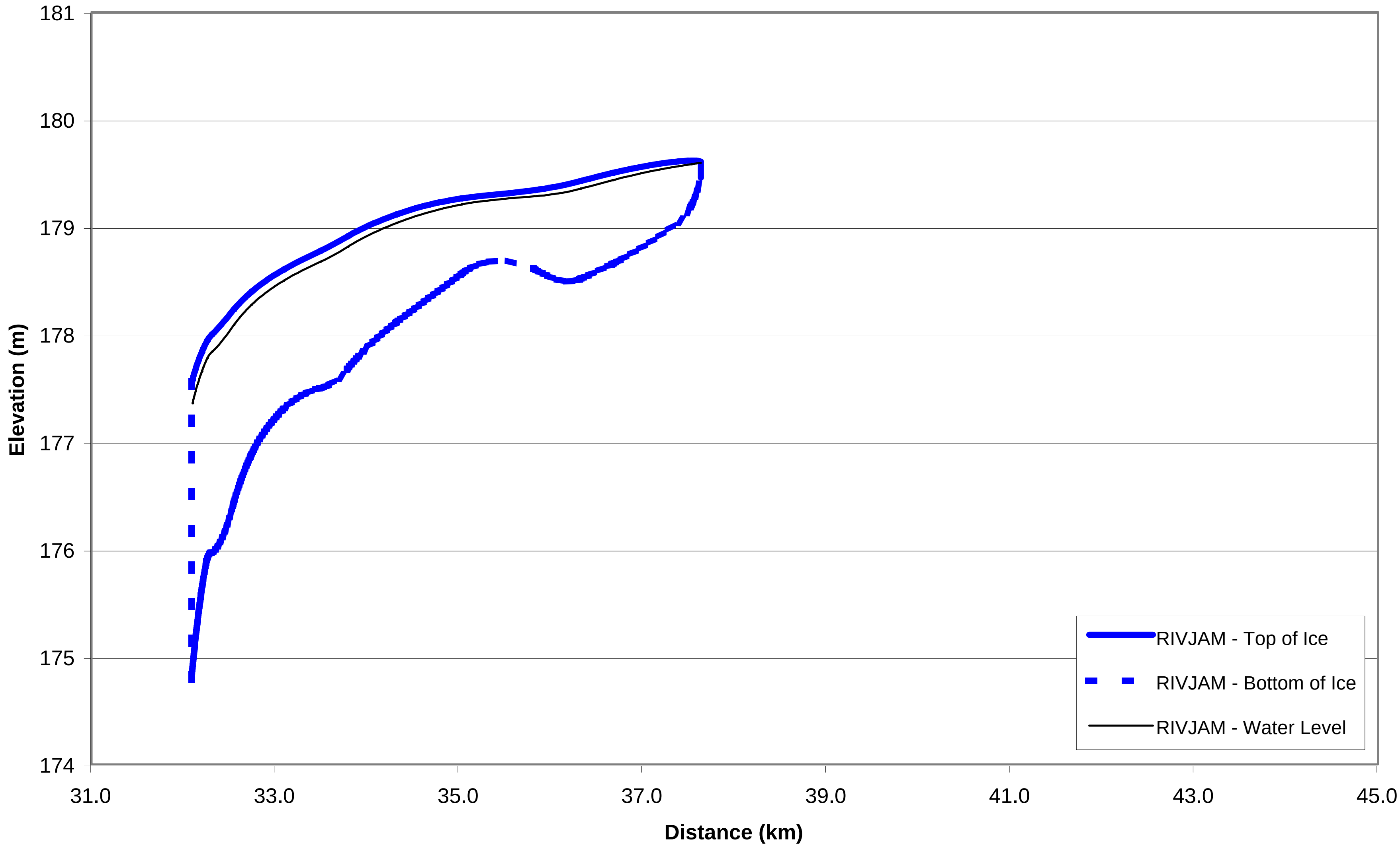


Figure 6 - Computed Water Levels for Each Model
Compared to Measured Water Levels

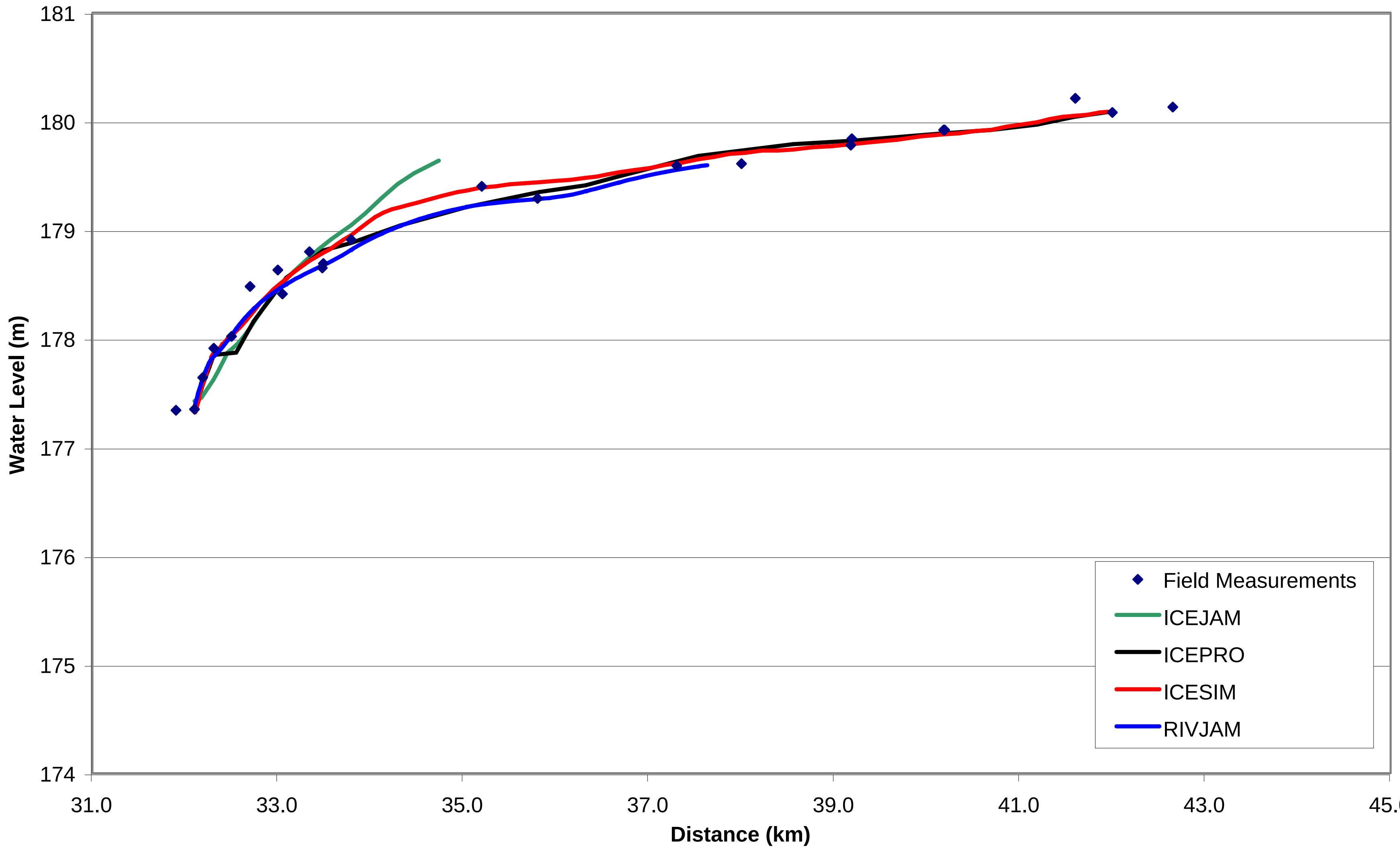
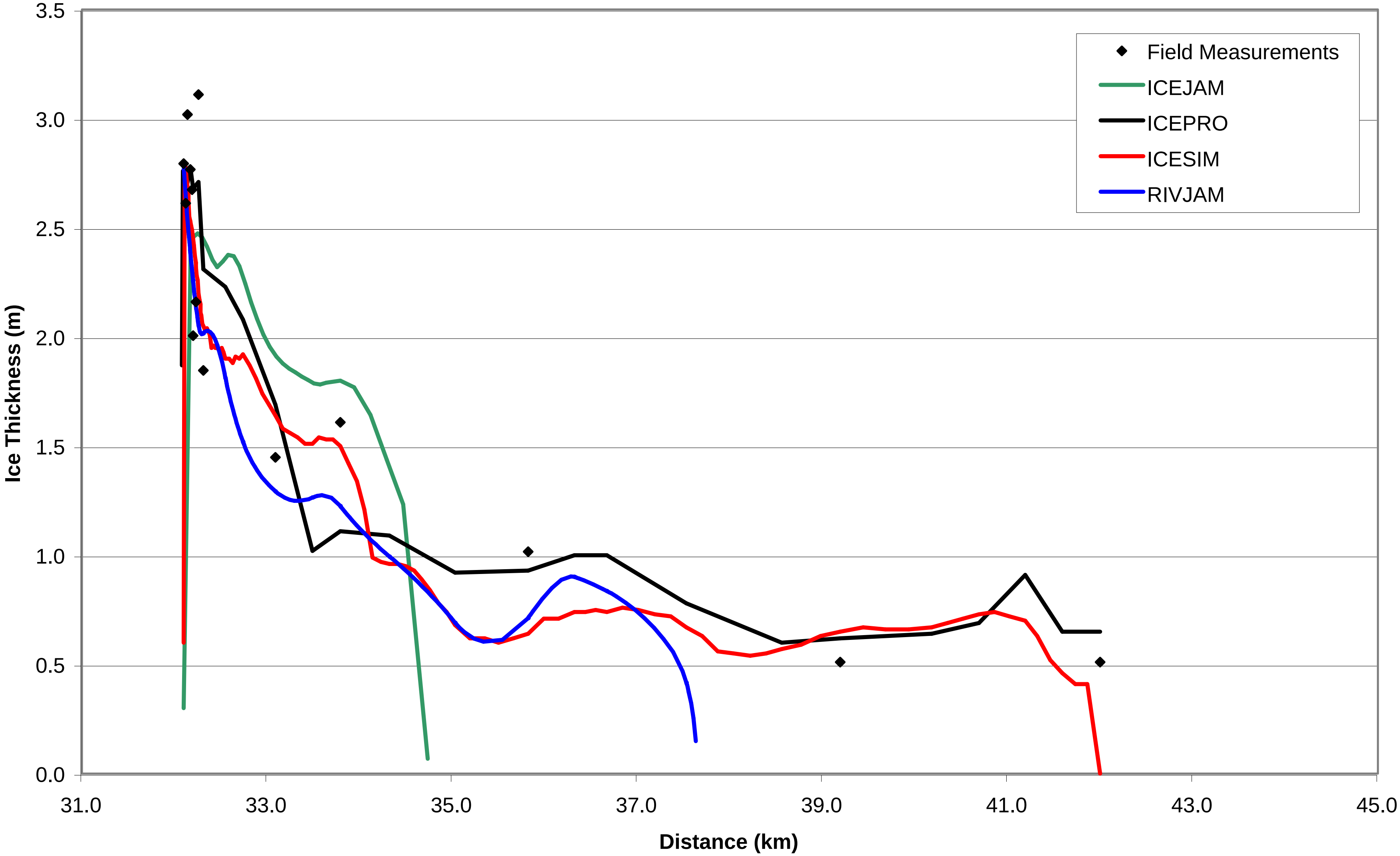


Figure 7 - Computed Ice Thickness for Each Model Compared to Field Measurements



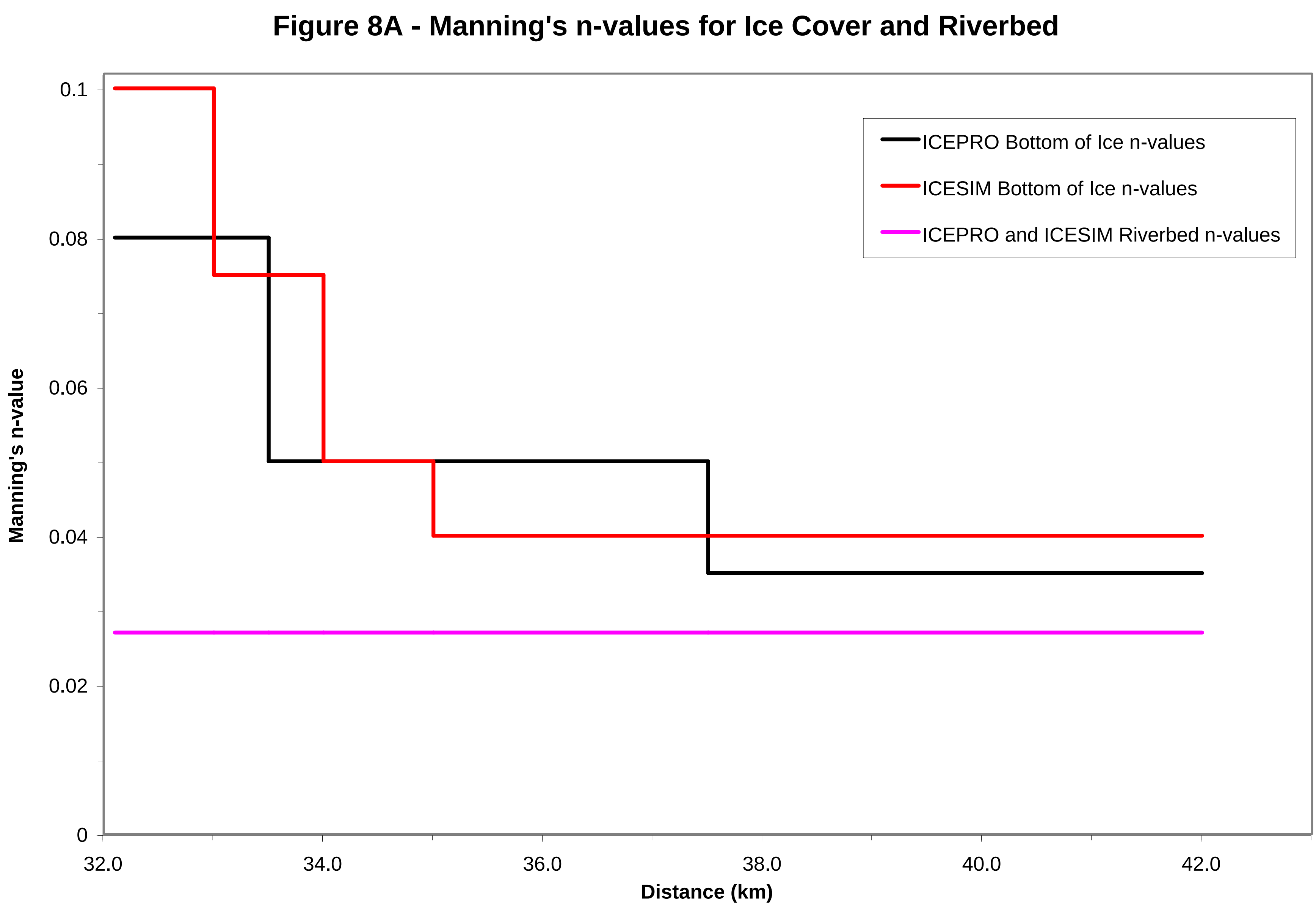


Figure 8A - Manning's n-values for Ice Cover and Riverbed
Manning's n-value
0.1
0.08
0.06
0.04
0.02
0
32.0
34.0
36.0
38.0
40.0
42.0
Distance (km)
ICEPRO Bottom of Ice n-values
ICESIM Bottom of Ice n-values
ICEPRO and ICESIM Riverbed n-values

Figure 8B - Composite Manning's n-values