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Supplement of

InundatEd-v1.0: a height above nearest drainage (HAND)-based flood risk modeling system using a discrete global grid system

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Supplementary Discussion

Section S1: InundatEd and Damage Computation

As part of the features of the InundatEd web application, and to contextualize the modelled inundation depths, FEMA's Hazus Depth-Damage functions were applied to the simulated flood depths via the R package Hazus (https://www.fema.gov/hazus) (Goteti, 2014). Using the Hazus package, estimated percentage losses can be generated for model output inundation depths at individual locations specified by the user. Furthermore, the Hazus loss percentages are contingent on building-specific properties, offering a built-in variety of building types, descriptions, and situations (e.g., fresh water vs. salt water) to tailor final estimations to a user's personal experience. The use of Hazus within the R Development environment allows for seamless integration with a user interface for inputs such as building type.

Section S2: The Composite Manning's n:

The analysis of composite and compound channel cross-sections entails the calculation of a roughness coefficient, representing the degree of frictional resistance to flow found in a particular area. To this end, multiple formulas have been proposed and compared in the literature with differing assumptions relating the subarea forces, shear stresses, discharge, and velocity of a given channel or channel cross-section. To investigate the impact of changing the Manning's n method on the agreement of our simulated floods with observed floods, we have selected and applied 7 Manning's n methods: the Pavlovskii method, Lotter method, Horton method, Colebatch method, Krishnamurthy and Christensen method, Cox method, and Yen methods.A description and equation for each method is given below, such that:

n_c = Composite Manning's Roughness Coefficient

P = Wetted perimeter

h = Water cross-sectional depth

n = Manning's Roughness Coefficient

i = Subscripts denoting individual subareas of the entire compound channel section

Method	Assumption(s)	Equation
Pavlovskii	The magnitude of subarea resistance forces is equivalent to the magnitude of the channel’s flow resistance force	$n_c = \sqrt{\frac{\sum P_i n_i^2}{P}}$
Lotter	Total subarea discharge is equivalent to total channel discharge	$n_c = \sqrt{\frac{PR^{5/3}}{\sum \frac{P_i R_i^{5/3}}{n_i}}}$
Horton	Average, disparate cross-sectional velocities are equivalent to total average cross-sectional velocity	$n_c = \left(\frac{\sum P_i n_i^{1.5}}{P}\right)^{2/3}$
Colebatch	Average, disparate cross-sectional velocities are equivalent to total average cross-sectional velocity	$n_c = \left(\frac{\sum A_i n_i^{1.5}}{A}\right)^{2/3}$
Krishnamurthy	There is a logarithmic decrease in velocity as depth-from-surface increases	$n_c = e^{\left(\frac{\sum P_i h_i^{1.5} ln n_i}{\sum P_i h_i^{1.5}}\right)}$
Cox	Total, weighted subarea shear velocities are equivalent to the total shear velocity	$n_c = \frac{\sum A_i n_i}{A}$
Yen	Total, weighted subarea shear velocities are equivalent to the total shear velocity.	$n_c = \frac{\sum \left(\frac{P_i n_i}{R_i^{1/6}}\right)}{\frac{P}{R^{1/6}}}$

Supplementary Tables

Table S1: Hurricane Hazel Regulatory Flood vs. 100-year Return Period – Grand River Watershed

Hydrometric Station	**Upstream Area (km^2)**	**Regulatory Flood Discharge (m^3s^{-1})**	**100-Year Return Period Discharge (m^3s^{-1})**
02GA003	2966.4	1140.0	1115.1
02GA010	857.8	328.0	355.2
02GA013	689.3	592.0	751.8
02GA015	477.7	130.0	153.3
02GA016	665.7	168.0	286.6
02GA017	278.3	137.0	177.2
02GA018	452.4	232.0	381.7
02GA022	399.4	235.0	300.7
02GA033	54.5	21.2	30.6
02GB001	4373.0	1100.0	1495.4
02GB006	137.5	50.4	67.7

Table S2: Excluded Observed Flood Extent Polygon Areas

Observed Flood Extent Polygon	**Subcatchment Number**	**Intersection (% subcatchment area)**	**Excluded Observed Flood Extent Polygon Area (km^2)**
FloodExtentPolygon_QC_CentralOttawa_20190503_113004.shp	5156	0.039	0.00992
FloodExtentPolygon_QC_CentralOttawa_20190503_113004.shp	4582	0.127	0.03154
FloodExtentPolygon_QC_CentralOttawa_20190503_113004.shp	12863	4.047	0.06318
FloodExtentPolygon_QC_LowerOttawa_20190429_230713.shp	1755	13.90	2.25351
FloodExtentPolygon_QC_LowerOttawa_20190429_230713.shp	10505	24.055	14.852
FloodExtentPolygon_QC_LowerOttawa_20190507_111329.shp	1755	18.599	3.01422
FloodExtentPolygon_QC_LowerOttawa_20190507_111329.shp	10505	24.100	14.8803
FloodExtentPolygon_QC_LowerOttawa_20190513_225800.shp	12115	14.262	3.18542
FloodExtentPolygon_QC_LowerOttawa_20190513_225800.shp	9504	6.8904	1.6800
FloodExtentPolygon_QC_LowerOttawa_20190513_225800.shp	1755	19.830	3.2136
FloodExtentPolygon_QC_LowerOttawa_20190513_225800.shp	10505	23.722	14.6467

Table S3: Comparison of Manning's n Methods- Grand River Watershed (RP 100) CSI Results

Method	**25th Percentile CSI**	**Median CSI**	**75th Percentile CSI**	**Number of evaluated subcatchments**
Colebatch Method	0.584	0.729	0.825	71
Cox Method	0.589	0.733	0.824	71
Horton Method	0.581	0.726	0.826	71
Krishnamurthy Method	0.596	**0.741**	0.826	71
Lotter Method	0.592	0.733	0.824	71
Pavlovskii Method	0.577	0.726	0.825	71
Yen Method	0.574	0.725	0.825	71
Range	0.022	0.016	0.002	----

Table S4: Comparison of Manning's n Methods - Ottawa River Watershed CSI Results

Return Period	**Method**	**25th Percentile CSI**	**Median CSI**	**75th Percentile CSI**	**Number of evaluated subcatchments**
16.52	**Colebatch Method**	0.546	0.76	0.948	21
	Cox Method	0.546	0.76	0.939	21
	Horton Method	0.546	0.736	0.951	21
	Krishnamurthy Method	0.546	**0.785**	0.939	21
	Lotter Method	0.546	**0.785**	0.939	21
	Pavlovskii Method	0.546	0.706	0.951	21
	Yen Method	0.546	0.707	0.951	21
	Range	0	0.079	0.012	
25.96	**Colebatch Method**	0.561	0.803	0.95	22
	Cox Method	0.561	0.803	0.947	22
	Horton Method	0.561	0.762	0.95	22
	Krishnamurthy Method	0.561	0.803	0.931	22
	Lotter Method	0.561	**0.816**	0.931	22
	Pavlovskii Method	0.561	0.752	0.95	22
	Yen Method	0.561	0.752	0.95	22
	Range	0	0.064	0.019	
26.5	**Colebatch Method**	0.752	0.845	0.965	17

	Cox Method	0.752	0.845	0.965	17
	Horton Method	0.686	0.845	0.965	17
	Krishnamurthy Method	0.754	0.849	0.965	17
	Lotter Method	0.754	**0.867**	0.965	17
	Pavlovskii Method	0.682	0.845	0.965	17
	Yen Method	0.682	0.845	0.965	17
	Range	0.072	0.022	0	
42.69	**Colebatch Method**	0.496	0.581	0.654	7
	Cox Method	0.496	0.581	0.654	7
	Horton Method	0.496	0.581	0.633	7
	Krishnamurthy Method	0.51	0.581	0.654	7
	Lotter Method	0.506	0.581	0.654	7
	Pavlovskii Method	0.496	0.581	0.633	7
	Yen Method	0.496	0.581	0.637	7
	Range	0.014	0	0.021	

Table S5: Additional Binary Classification Results for the Krishnamurthy Method – Medians

	TPR	TNR	PPV	NPV	FNR	FPR	FDR	FOR	PT	ACC	BA	F1	FM	BM	MK
Grand RP 100	0.906	0.99	0.883	0.991	0.094	0.01	0.117	0.009	0.100	0.975	0.914	0.851	0.853	0.828	0.859
Ottawa RP 16.52	0.941	0.996	0.979	0.977	0.059	0.004	0.021	0.023	0.065	0.785	0.941	0.946	0.826	0.886	0.891
Ottawa RP 25.96	0.927	0.998	0.985	0.973	0.073	0.002	0.015	0.027	0.052	0.803	0.948	0.946	0.852	0.895	0.891
Ottawa RP 26.5	0.978	0.992	0.97	0.994	0.022	0.008	0.03	0.006	0.083	0.849	0.958	0.964	0.888	0.921	0.927
Ottawa RP 42.69	0.892	0.976	0.668	0.994	0.108	0.024	0.332	0.006	0.145	0.581	0.97	0.939	0.743	0.755	0.879

TPR = True Negative Rate; TNR = True Positive Rate; PPV = Positive Predictive Value; Negative Predictive Value; FNR = False Negative Rate; FPR = False Positive Rate; False Discovery Rate; FOR = False Omission Rate; PT = Prevalence Threshold; ACC = Accuracy; BA = Balanced Accuracy; FM = Fowlkes–Mallows Index; MK = Markedness

For additional information and equations for these metrics, please see the following:

Brooks, H. et al.(2015). "WWRP/WGNE Joint Working Group on Forecast Verification Research". *Collaboration for Australian Weather and Climate Research*. World Meteorological Organisation.

Chicco & Jurman (2020). The advantages of the Matthews correlation coefficient (MCC) over F1 score and accuracy in binary classification evaluation. *BMC Genomics*. **21** (1): 6-1–6-13. doi:10.1186/s12864-019-6413-7.

Fawcett, T. (2006). An Introduction to ROC Analysis. *Pattern Recognition Letters*. **27** (8): 861–874. doi:10.1016/j.patrec.2005.10.010.

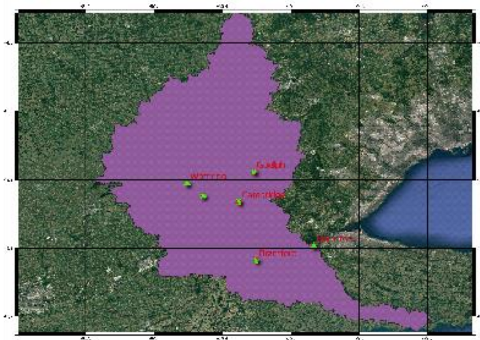
Powers, D. M. W. (2011). Evaluation: From Precision, Recall and F-Measure to ROC, Informedness, Markedness & Correlation. *Journal of Machine Learning Technologies*. **2** (1): 37–63.

Tharwat, A. (2018). Classification assessment methods. *Applied Computing and Informatics*. doi:10.1016/j.aci.2018.08.003.

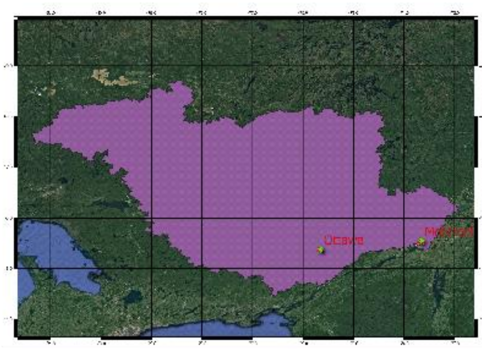
Ting, K. M. (2011). Sammut, Claude; Webb, Geoffrey I. (eds.). *Encyclopedia of machine learning*. Springer. doi:10.1007/978-0-387-30164-8. ISBN 978-0-387-30164-8.

Supplementary Figures

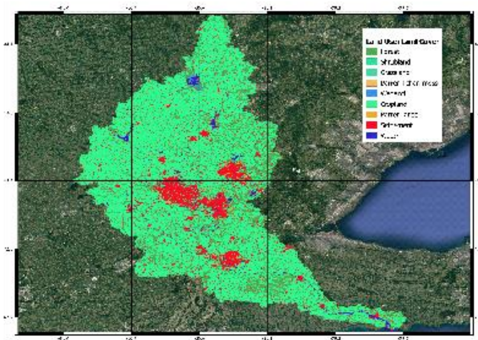
Figure S1: GIS Inputs for the Grand River Watershed and Ottawa River Watershed: study area (a-b), land use/ land cover (c-d), and flow lines (e-f). The maps are created in Qgis with the basemaps provided by © Google Satellite Maps and © Google Street Maps under OpenLayerPlugin.



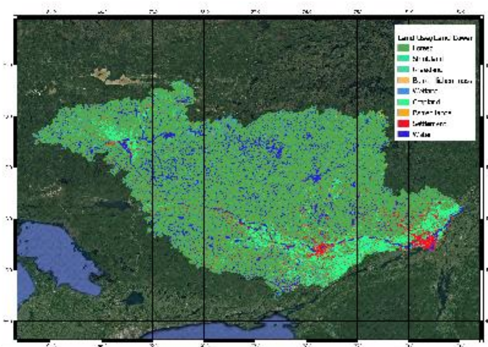
a) Grand River Watershed Study Area



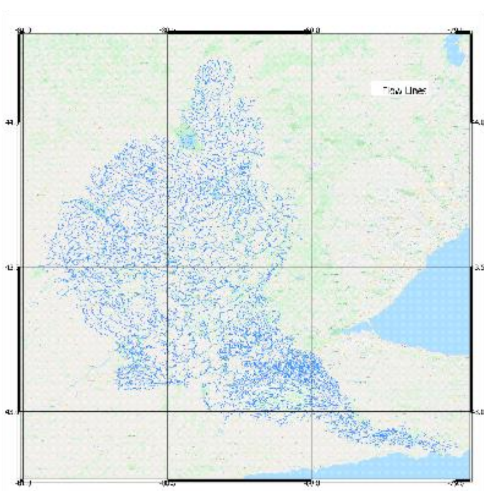
b) Ottawa River Watershed Study Area



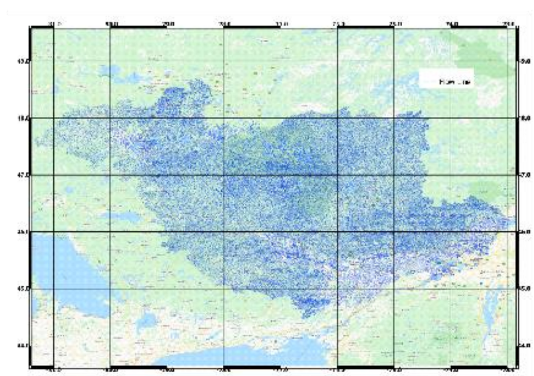
c) Grand River Watershed Land Use/Cover



d) Ottawa River Watershed Land Use/Cover



d) Grand River Watershed Flow Lines



e) Ottawa River Watershed Flow Lines

Figure S2: DGGS conversion flowcharts for raster input data (a), polygon vector input data (b), and network (directional) input data (c). The maps are created in ArcGIS with the basemaps provided by © ESRI.

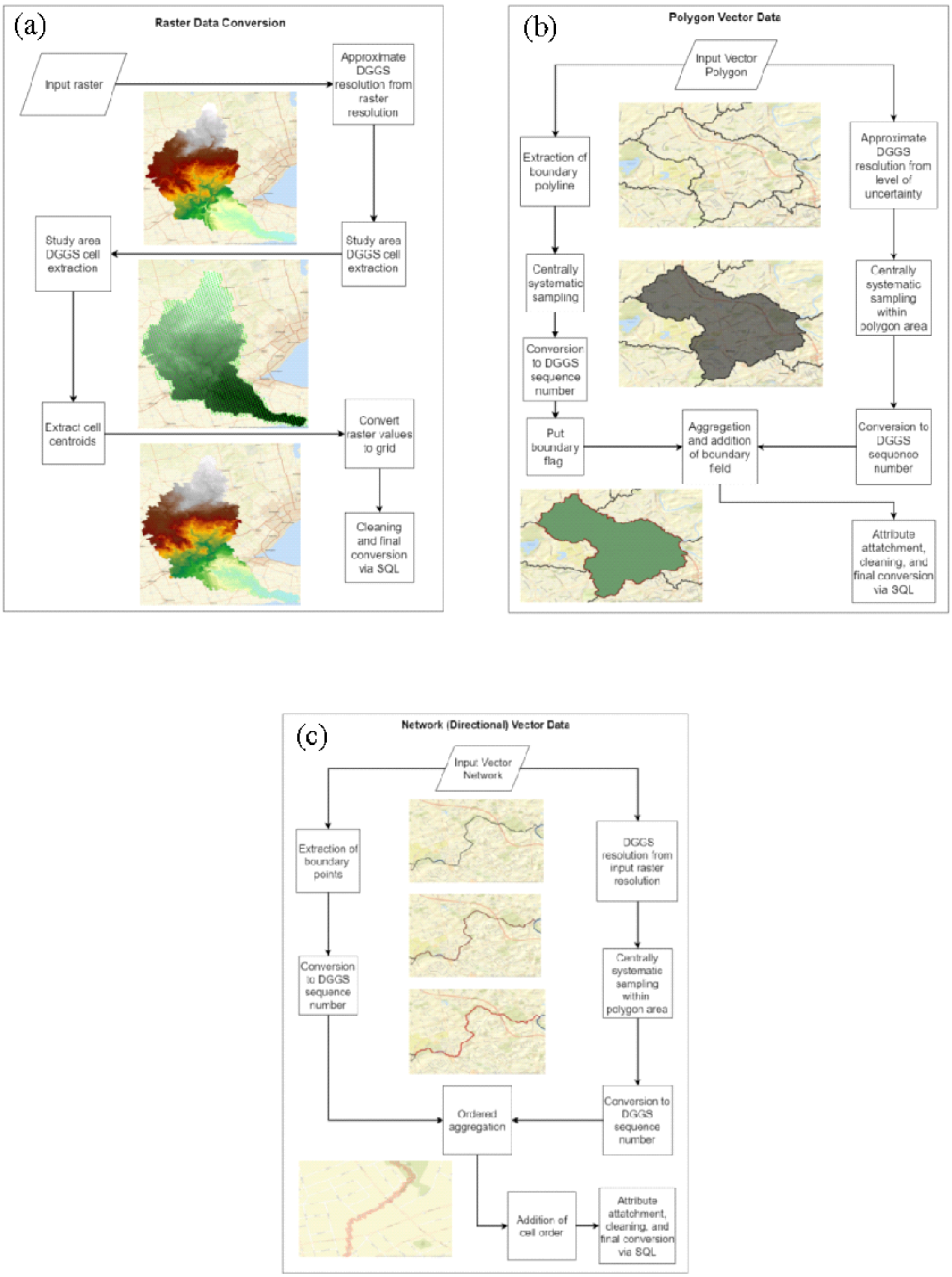
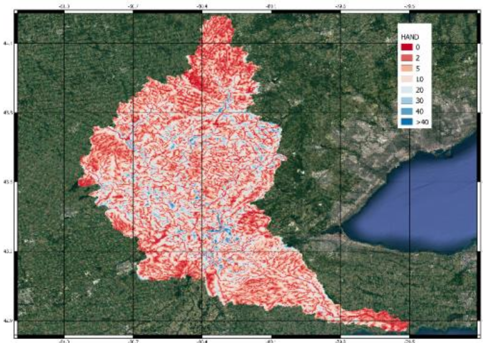
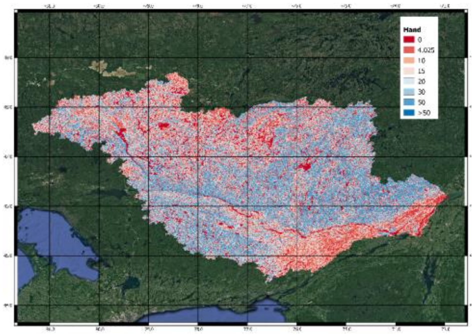


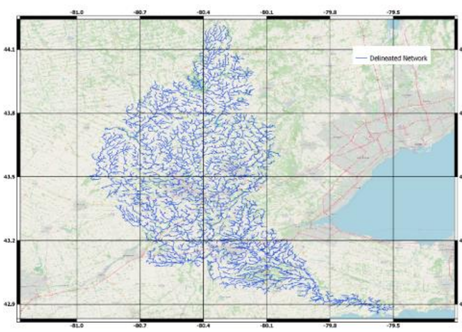
Figure S3. GIS processing outputs for the Grand River Watershed and the Ottawa River Watershed: Height Above Nearest Drainage (a-b), Drainage network (c-d), and Manning's n values (e-f)



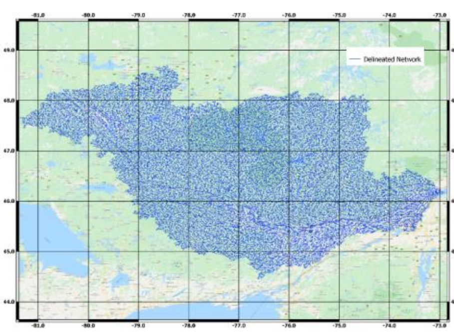
a) Grand River Watershed Height Above Nearest Drainage



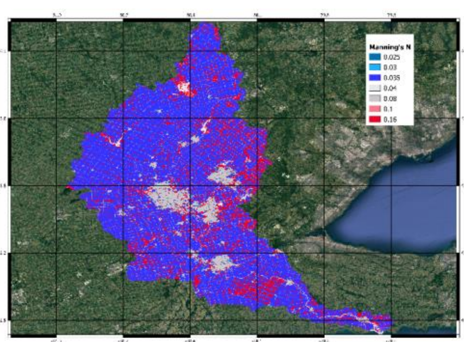
b) Ottawa River Watershed Height Above Nearest Drainage



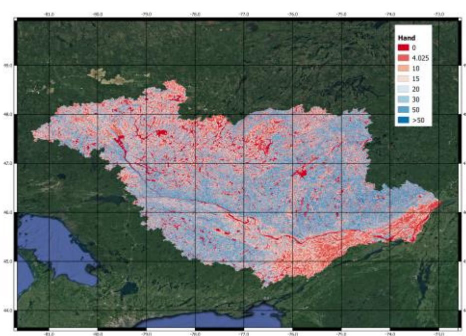
c) Grand River Watershed Drainage Network



d) Ottawa River Watershed Drainage Network



e) Grand River Watershed Manning's n



f) Ottawa River Watershed Manning's n

Figure S4: GEV Distribution Regional Growth Curves – Grand River Watershed and Ottawa River Watershed

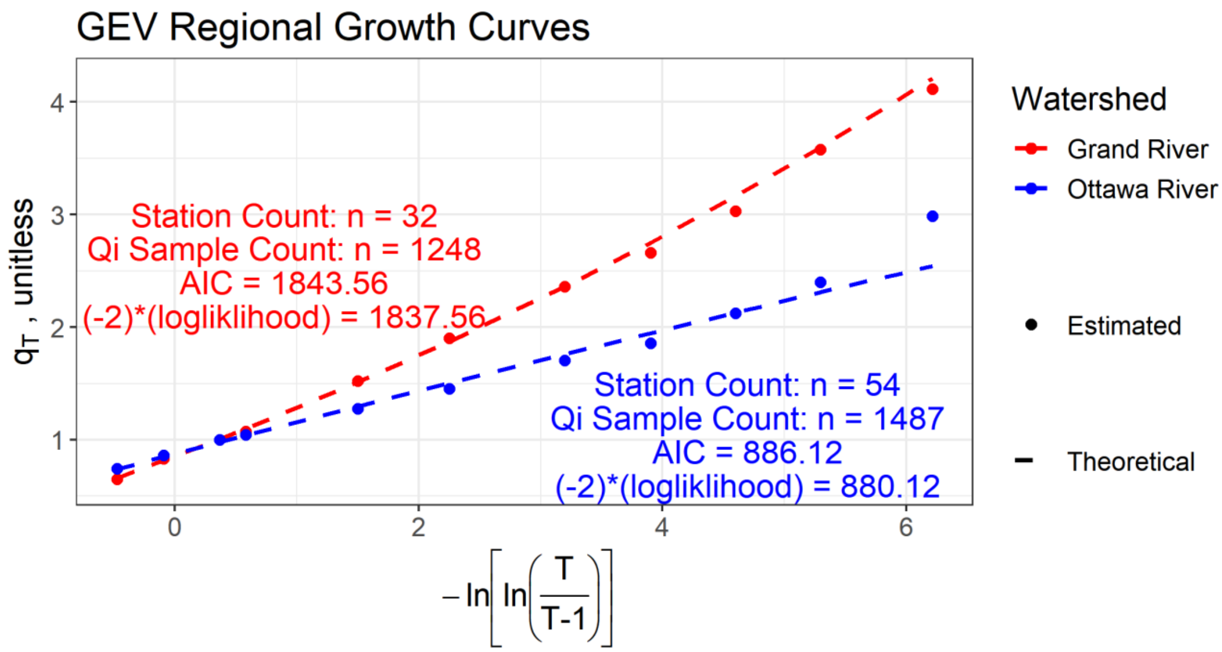


Figure S5: Additional Binary Classification Results – Ottawa River Watershed