Water Resources and Economics 11 (2015) 22–32

Contents lists available at ScienceDirect

Water Resources and Economics

journal homepage: www.elsevier.com/locate/wre

Do water service provision contracts with neighbouring communities reduce drinking water risk on Canadian reserves?

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ARTICLE INFO

Article history:
Received 7 July 2014
Received in revised form
7 May 2015
Accepted 5 August 2015

Keywords:
First Nations
Drinking water quality
Municipal Type Agreements (MTAs)
Standards
Probit

ABSTRACT

In 2011, 39% of drinking water systems on Canadian First Nations' reserves were classified as high risk [31]. In recent years some First Nations have contracted water services from neighbouring communities through "Municipal Type Agreements", or "MTAs". Using a unique data set of 804 First Nations' water systems, we explore both factors that influence participation in MTAs, and the effect of participation on the likelihood that a First Nations' water system will be under a boil water advisory. Our empirical analysis consists of two probit models. The first model describes the likelihood that a First Nation will participate in a MTA. The second estimates the likelihood that a First Nations' water system will be under a boil water advisory. Our primary finding is that participation in a MTA significantly reduces the likelihood that a First Nations' water system will be under a boil water advisory. This is an important consideration when developing incentives or institutions that influence infrastructure collaboration between First Nations and non-First Nation communities.

1. Introduction

The quality of drinking water on Canadian First Nations' reserves[1] is of widespread concern to First Nations and non-First Nations people alike. As of 2011, 39% of drinking water systems on Canadian reserves were classified as "high risk", which implies that they are not adequately equipped to deal with exposure to contamination [31]. Boil water advisories (BWAs) are a common indicator of drinking water quality issues, and saw a 35% increase in prevalence in First Nation communities between 2006 and 2014 [20,46]. A BWA is an announcement issued when "the water in a community's water system is contaminated with faecal pollution indicator organisms (such as *Escherichia coli*) or when water quality is questionable due to operational deficiencies (such as inadequate chlorine residual)" [23], and requires that tap water be brought to a "rolling boil" for a minimum of one minute in order for it to be rendered safe for human consumption [21,23]. BWAs can range from weeks to years in duration, and are only rescinded once the contamination event or operational deficiency has been resolved[2]. Many BWAs on First Nations' reserves are long-term, persisting for twelve months or longer [35,48].

The challenges of providing adequate drinking water services in rural areas are legion, and these challenges – finance, economies of scale, planning capacity, etc. – are not isolated to First Nations' communities. Approximately 15.4% and 14.4% of non-First Nation Canadian drinking water systems are ranked "fair" and "very poor", respectively, for the condition of their pipes, plants, reservoirs, and pumping stations [16]. The estimated replacement cost for these insufficient drinking water systems is $25.9 billion, or $2082 per Canadian household.

In recent years, some First Nations have sought partnerships with neighbouring non-First Nation communities for the provision of drinking water services on their reserves. These partnerships, classified as "Municipal Type Agreements" (hereafter referred to as "MTAs"), take the form of a contract between a First Nation Band[3] and the local government of a neighbouring municipality or township. Aboriginal Affairs and Northern Development Canada (AANDC)[4], the Canadian Federation of Municipalities (FCM)[5], and

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[1] A reserve is a "[t]ract of land, the legal title to which is held by the Crown (i.e. the Canadian Federal government), set apart for the use and benefit of [a First Nation] [B]and" [1].

[2] BWAs issued in response to evidence of bacteriological water quality conditions are rescinded when two consecutive bacteriological tests, collected a minimum of 24 hours apart, produce negative results for the problem contaminant. Precautionary BWAs issued due to evidence of poor operational conditions are rescinded once the treatment, distribution, or operational malfunction has been corrected [20].

[3] A First Nation Band is a body of First Nations people "for whose collective use and benefit lands have been set apart or money is held by the Crown, or [a body of First Nations people] declared to be a Band for the purposes of the Indian Act" [1]. Each First Nation Band is governed by a council, usually consisting of a chief and several councillors, selected through an electoral or customary process.

[4] AANDC encourages MTAs in situations where they are the least cost alternative to other forms of service delivery [24,3].

[5] The FCM promotes MTAs through the "First Nations – Municipal Community Infrastructure Partnership Plan" (CIPP), which provides resources (i.e. toolkits, case studies, agreement templates, workshops, etc.) to First Nations and municipalities interested in forming these contracts [11,15].

http://dx.doi.org/10.1016/j.wre.2015.08.002
2212-4284/

many First Nations leaders support MTAs as one means of reducing water service provision costs and enhancing water quality on reserves. The growing popularity of these voluntary agreements appears to be prima facie evidence of their mutual gains. For example, Nelles and Alcantara [33] survey 93 cooperative arrangements between First Nation and non-First Nation communities and conclude that these types of jurisdictional agreements are on the rise, as "… both First Nations and municipal governments have progressively recognised the mutual benefits of collaboration" (pp. 327).

Servicing agreements between local governments, like MTAs, are a growing means of improving community service provision throughout North America and Europe. These agreements are the subject of an expanding literature in the field of economics (prominent examples include: [19,26,27,29,43,45]). The majority of this literature identifies and evaluates factors that lead to the emergence of these agreements. Social capital between communities, community characteristics, and cost considerations are frequently emphasised [19,26,43,45]. With the exception of Steiner [43], none of the aforementioned literature evaluates the impact of these agreements on the quality of the service provided.

Our research addresses this gap in the literature. Specifically, we assess whether participating in a MTA improves water quality on First Nations' reserves. To our knowledge, ours is the first study to examine the extent to which MTAs actually enhance water quality on First Nations' reserves. Our empirical analysis of 804 First Nations' water systems generates a number of important findings. We find that MTA participation reduces the likelihood of a water system on a First Nations' reserve being under a BWA. We also find that geographic remoteness (measured as the distance from each reserve to its closest proximal population centre[6]) influences the likelihood that a First Nation will participate in a MTA, as well as the population and population density on reserve. One important observation, from a policy perspective, is that there are many First Nations in close proximity to neighbouring population centres that are not currently participating in MTAs.

The remaining sections of this paper are organised as follows. First, a background section briefly outlines institutional differences between First Nation and non-First Nation communities in Canada. In this section we pay particular attention to differences in drinking water quality standards and monitoring. We also outline key characteristics of MTAs, and their role in water service provision on reserves. The following section, Section 3, outlines factors that influence First Nations' decisions to participate in MTAs. Specifically, we identify a number of reserve characteristics that influence the costs of MTA participation and negotiation. In Section 4, the data section, we define and review variables that will be included in the empirical analysis. This is followed by a specification of our empirical approach in Section 5. Section 6 then discusses our primary empirical results, and an additional sensitivity analysis is discussed in Section 7. Lastly, we provide conclusions and a discussion of the key policy implications of our findings in Section 8.

2. Background

The Walkerton Inquiry[7] emphasised the important role of institutions and regulatory oversight in determining individual actions affecting water quality [34]. In this regard, it is important to recognise that First Nations' reserves fall into a jurisdictional gap with respect to drinking water quality standards. In Canada, drinking water safety and regulatory standards are set and enforced at the Provincial level, and do not apply to water services on First Nations' reserves. First Nations are under Federal jurisdiction as specified by the Indian Act [12], and drinking water quality guidelines for water systems on their reserves exist at the Federal level under AANDC. However, to date these guidelines are not enforceable [6,10][8]. And Canada is the only OECD country that does not have enforceable national drinking water quality standards [7]. Hence, a key distinction between Canadian population centres and First Nations' reserves is that water systems in Canadian population centres are held to uniform standards of water quality and safety that apply to all population centres within a Province; these Provincial standards do not apply to water systems on First Nations' reserves, and First Nations' are not subject to enforceable standards by the Federal government.

This jurisdictional gap leads to substantive differences in water quality monitoring between First Nation and non-First Nation communities within a Province. For example, in the Province of Ontario, inspectors from the Provincial Ministry of the Environment (MOE) ensure that water systems in population centres are being properly sampled and monitored on a regular basis [47]. And the MOE mandates a BWA if water quality does not meet Provincial standards. In contrast, Health Canada recommends that a BWA be issued on a First Nations' reserve when water quality does not meet Federal guidelines. However, monitoring responsibilities and the decision to implement a BWA ultimately fall under the jurisdiction of the First Nation Band. First Nations receive funding and assistance from Health Canada[9] to implement their own community standards (based on Federal guidelines), to develop their own community-based water quality monitoring programmes, and to train water quality monitors [20]. In some cases, an external monitor is hired by the First Nation Band, or by Health Canada (with the permission of the Band). This decentralised approach to monitoring and standards on First Nations' reserves has not adequately addressed water quality concerns. In 2006, an expert panel on safe drinking water for First Nation communities argued that "the federal government has never provided enough funding to First Nations to ensure that the quantity and quality of their water systems [is] comparable to that of off-reserve communities" [44].

One potential pathway to improved water quality for a First Nation is to purchase water from a nearby population centre. In some cases, as a result of jurisdictional and financial differences, these population centres may be in a better position to ensure water quality than the First Nation. In a MTA, the First Nation Band receives water that is treated and monitored according to water quality standards set by the Province. MTA stipulations vary, but typically they identify the quantity of treated drinking water to be purchased, the price per unit[10], and state that the First Nation

[6] The Canadian census defines a population centre as an area with a population of at least 1000 and a population density of 400 persons or more per square kilometre, based on the current census population count [39]. Prior to 2011, these areas were referred to as "urban areas".

[7] In 2000, *E. coli* bacterial contamination resulted in the deaths of seven people and the illness of thousands of others in the city of Walkerton Ontario. A subsequent assessment of the situation identified the institutions governing water quality monitoring and reporting as inadequate (for more information see the Walkerton Inquiry website: http://www.waterprotection.ca/cwa/walkerton.htm).

[8] A *Safe Drinking Water for First Nations Act* was passed in 2013, enabling the creation of federal drinking water quality standards for First Nations' communities (this legislation is available from the Justice Laws Website here: http://laws-lois.justice.gc.ca/eng/acts/S-1.04/page-1.html). It has faced significant resistance from First Nations groups that feel that it infringes on their jurisdiction [10], and will hold First Nation Bands to an unachievable standard without providing any additional resources [9]. To date, no Federal standards have been developed or implemented.

[9] Canadian Provinces and Territories are responsible for delivering healthcare to the majority of Canadians, but the Federal government also has key roles and responsibilities in areas that affect health and healthcare, which are the mandate of Health Canada. These include: food safety, health care delivery to First Nations and Inuit peoples, the promotion of innovation in healthcare, and the proliferation of health related information [22].

[10] The template for MTAs published by the FCM recommends pricing based on

assumes all of the costs associated with distributing purchased water to reserve households (including the costs of constructing and maintaining piped infrastructure, or the funding of trucked water distribution). A MTA may service all or only a portion of the reserve population, and the lengths and terms of these agreements vary from case to case[11]. Pricing and consumption volumes are generally renegotiated at the end of a MTA term.

3. Factors influencing the MTA participation decision

The primary goal of this paper is to identify the effect of MTA participation on the likelihood that a First Nations' water system will be under a BWA. In some situations, empirically identifying the effect of MTA participation on the likelihood of a BWA requires consideration of the factors influencing MTA participation in the first place. Imagine a scenario where – for example – the decision to participate in a MTA and the likelihood of a BWA are correlated (our empirical approach, developed in Section 5, allows for this possibility). In the remainder of this section we identify key factors that influence the emergence of a MTA.

Of central importance is the geographic proximity of a First Nations' reserve (or reserves) to a potential MTA partner. In a MTA, both the First Nation and non-First Nation partner make costly investments that are positively correlated with their proximity. For example, the cost of water lines, incurred by both parties, will depend on the distance between them. By similar logic, the costs of supplying water will increase over increasing distances if water is moved using trucks. Diseconomies of scale in water distribution result from variable costs that increase with the construction of additional infrastructure over greater distance; this is due to capital and energy costs that increase as water is transported farther from the treatment source to additional users. Hence, MTAs are less feasible – and in turn, less likely to occur – as the distances between First Nations' reserves and neighbouring population centres increase.

The transaction costs of coordinating a MTA are also likely to be influenced by proximity. First, close proximity will reduce the direct costs of contracting (i.e. meeting costs). Second, and perhaps most important, proximity may be associated with a history of cooperation between the two parties. Steiner [43] argues that social contact between the residents of municipalities is a critical component to successful inter-municipal cooperation and merging.

Reserve population is also expected to influence the likelihood of MTA participation. Economies of scale in drinking water treatment incentivize the construction of large water treatment facilities. Communities with small populations are not in a position to take advantage of these economies of scale; hence, First Nations governing reserves with small populations may be more likely to seek out MTAs. This may parallel the preferences of partnering population centres to provide water services to smaller reserves. Smaller reserve populations enable the supplier to take advantage of economies of scale given current treatment capacity; however, supplying a large reserve population may require new plant capacity, and a much more substantial commitment to maintaining the MTA over time. Therefore, we expect an inverse relationship between reserve population size and the likelihood of a MTA.

Population density influences the costs associated with water provision on a reserve, and the potential net-benefits associated with a MTA. Because there are diseconomies of scale in water distribution, a high service area density reduces the cost of distributing water. Therefore, when reserves are more densely populated, there may be greater financial incentives to enter into a MTA. A more dispersed reserve population may disincentivize a MTA, and encourage a First Nation to instead construction one (or several) small and concentrated on-reserve distribution network(s) [8,25].

Another key consideration, albeit more difficult to measure, is the importance that First Nations place on self-governance and self-determination [5]. In his study of U.S. municipal service provision contracts with external providers, Ferris [17] emphasises the importance to local officials of maintaining control over service provision and the perceived costs associated with losing that control. Ferris argues that the perceived benefits of using an external service provider must be substantial in order for the costs associated with losing autonomy over vital services to be perceived as worthwhile. LeRoux and Carr [27] also postulate that the appeal of potential cost savings through servicing agreements is only as important as the perception that local governments have as to the level of control they will maintain over the service being contracted out. In this regard, and more generally, socio-demographic characteristics of a First Nations' Band population – such as educational attainment and age – may influence the perceived benefits and costs associated with a MTA.

4. Data

Our empirical model is applied to data gathered from five key sources: the *Report on First Nation Water and Wastewater Systems*, *Aboriginal Population Profiles* of the 2006 Canadian Census and the 2011 Canadian National Household Survey (NHS)[12], Environment Canada, and Natural Resources Canada. All data included in our analysis is summarised in Table 1.

The *Report on First Nation Water and Wastewater Systems*, published by the engineering firm Neegan Burnside [31], provides key information on BWAs and water system characteristics on First Nations' reserves. This report is based on a survey of 804 active water systems on 691 reserves (multiple water systems are located on some reserves) in all Canadian Provinces and the Yukon Territory (the Northwest Territories and Nunavut were excluded from the study)[13]. The survey took place between 2009 and 2010. Of the 587 First Nations in Canada, 571 participated in the study (four First Nations chose not to participate, and twelve had no active infrastructure on their reserve(s)). Of the participating First Nations, 11 are serviced solely by individual wells and 560 are serviced by water systems – 143 of which are systems supplied through MTAs. All active water systems on participating First Nations' lands were surveyed[14]. Fig. 1 displays the locations of these water systems, highlighting MTAs. The report identifies both water systems supplied through MTAs and those under BWA, providing the key dependent variables used in the empirical analysis developed in Section 5 [15]. Approximately 19% of the water systems in

(*footnote continued*)
a fee that is equivalent to the rates established under municipal by-law regarding rates and regulations for the municipal partner [11]. The majority of municipalities in Canada price according to average cost [14] so it follows that the majority of First Nations with MTAs likely fall under some type of average cost pricing structure.

[11] Additional services (like fire protection, waste removal, animal control, etc.) may also be included in the MTA.

[12] In 2011, the voluntary NHS replaced the mandatory long-form census to collect information about demographic, social, and economic characteristics of the Canadian population [37].

[13] See https://www.aadnc-aandc.gc.ca/eng/1313770257504/1313770328745#chp1_1 for additional details on the Neegan Burnside sampling.

[14] A water system is broadly defined as consisting of assets funded by Indian Affairs and Northern Development Canada (INAC), serving five or more residents or public facilities [32].

[15] This report provides no information on the duration of BWAs or the dates that they were put into effect, nor does it provide information on the terms of MTAs or the dates that they were entered into by the First Nation; it simply indicates if either a BWA or MTA – or both – were in effect at the time of the survey. Data

Table 1
Summary statistics for variables included in empirical analysis.

Variable	Obs	Mean	Std. dev.	Min	Max
Dependant variables					
MTA participation	792	0.1894	0.3921	0	1
BWA in effect	792	0.2765	0.4476	0	1
Explanatory variables					
Distance from reserve to closest population centre (km)	753	58.513	82.422	0.1443	483.49
Natural log of distance from reserve to closest population centre (km)	753	3.2793	1.3287	−1.9359	6.1810
Reserve area (100s of km)	778	0.5225	1.3047	0.0002	14.139
Reserve population (100s)	754	5.7092	7.3629	0.05	51.71
Reserve population density (100s of persons per km^2)	754	1.0521	2.6926	0.001	33.589
First Nation Band area median income	454	13814.6	5763.6	2931	49714
Percentage of First Nation Band without highschool	407	59.643	15.805	23.256	97.826
Percentage of reserve households on piped water supply	789	88.157	26.885	0	100
Population serviced by water system (100s)	789	5.2731	7.6916	0	78
Age of water system servicing reserve	744	19.227	10.706	1	82
Ten year average temperature range (10s of °C)	696	40.049	9.5021	14.146	54.136
Ten year average annual total precipitation (10s of cms)	695	722.83	434.21	202.68	3297.2
Elevation (metres relative to mean sea level)	752	856.26	948.64	10	5700
Reserve located in Yukon Territory	792	0.0290	0.1680	0	1
Reserve located in British Columbia	792	0.3662	0.4821	0	1
Reserve located in Alberta	792	0.1010	0.3015	0	1
Reserve located in Saskatchewan	792	0.1263	0.3324	0	1
Reserve located in Manitoba	792	0.0896	0.2859	0	1
Reserve located in Quebec	792	0.0480	0.2139	0	1
Reserve located in Atlantic Canada	792	0.0442	0.2057	0	1
Variables included in sensitivity analysis					
High risk ranking	792	0.3813	0.4860	0	1
Fails health guidelines	471	0.6688	0.4711	0	1
Fails aesthetic guidelines	460	0.6000	0.4904	0	1

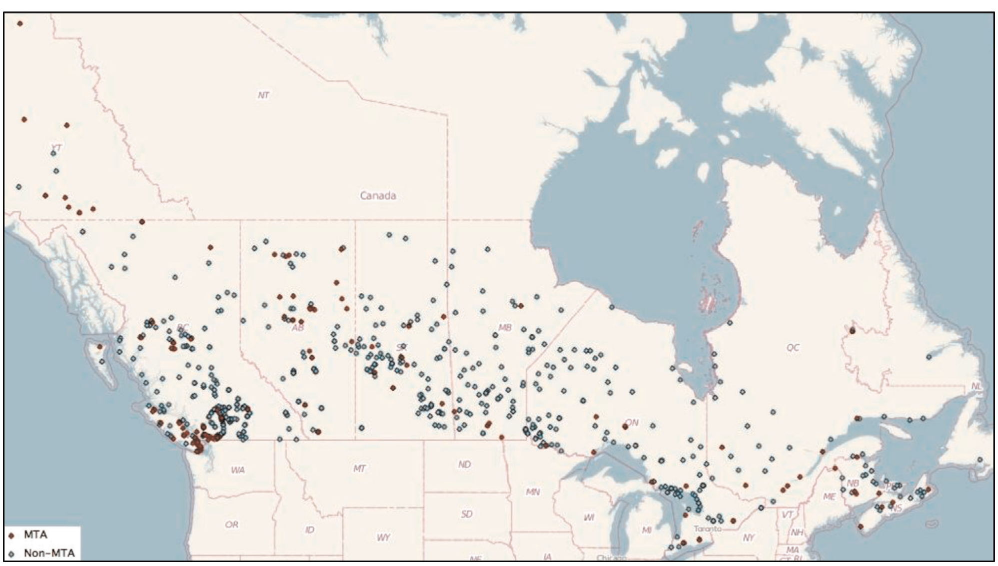

Fig. 1. Locations of water systems in the data set. **Source:** Figure produced by the authors. Water systems were identified in Neegan Burnside [31], and plotted by longitude and latitude coordinates using Cartographica (GIS software).

our data set are supplied through a MTA, and approximately 28% had an existing BWA at the time of the survey. For MTA water systems, the prevalence of BWAs is only 13.5%, while the prevalence of BWAs among non-MTA water systems is 31.4%. Other water system characteristics from the report – age, scale, and type of distribution – are included in the analysis as additional potential factors influencing the likelihood of a BWA.

Data from *Aboriginal Population Profiles* of the 2006 Census and 2011 NHS are used to describe each reserve in the data set by key socioeconomic characteristics [38,40]. The surface area, population and population density of each reserve were taken from the 2006 profiles. A measure of educational attainment – the percentage of the First Nation Band population without a highschool diploma – was calculated using education data from the 2006 profiles, and

(*footnote continued*)
detailing the length and implementation dates for BWAs is available for only a very small subset of the First Nations' reserves in our data set (approximately 13%) through an alternate source, and its inclusion would have severely limited the analysis.

Table 2
By MTA participants and non-participants – summary statistics for key variables with *t*-tests for equality of means.

	MTA participant		MTA non-participant		*t*-test
	Mean	Std. dev.	Mean	Std. dev.	
Reserve characteristics					
Distance from reserve to closest population centre (kms)	32.588	65.593	64.59	84.797	−4.2256***
Natural log of distance from reserve to closest population centre (kms)	2.3607	1.4423	3.4946	1.2044	−9.7409***
Reserve population (100s)	4.3448	5.6919	6.0258	7.6683	−2.4593***
Reserve population density (100s of persons per km^2)	2.8606	4.9492	0.6325	1.5316	9.3830***
Outcome					
Boil water advisory in effect	0.1267	0.3337	0.3115	0.4635	−4.6125***

*** $p < 0.01$.

First Nation Band population data from the AANDC report *Registered Indian Population by Sex and Residence* [4]. The median income of each First Nation Band (a measure for the total Band area) was taken from the 2011 profiles. A measure of remoteness – the distance between each reserve and its closest proximal population centre – was calculated through the use of GIS software and census boundary files [41,42]. The mean of this distance was approximately sixty-five kilometres for the overall sample, but only thirty-three kilometres for the subset of MTA participants (see Table 2 for a comparison of this remoteness measure, as well as other key reserve characteristics, for MTA participants and non-participants). This contrast motivates our hypothesis that First Nations governing more remote reserves will be less likely to participate in MTAs, due to a lack of potential partners and the significant costs associated with expanding water distribution networks across large distances.

Climate data is also included in the analysis to account for the effect of climactic variation on a water system's exposure to risk, and on the costs of water system upkeep. This data was taken from the Environment Canada weather stations in closest proximity to each reserve in the data set, which were paired to reserves using longitude and latitude coordinates [13]. Ten year average temperature range (with temperature range defined as the difference between annual maximum and annual minimum temperatures) is included to account for the effect of extreme temperature variation on water system susceptibility to risk (i.e. through freezing and thawing of pipes, and changes to pipe–soil interactions). Also included is a measure of ten year average total annual precipitation for each reserve, to account for the potential for pollution to enter a water system through infiltration into groundwater sources or water mains. Data from the most recent ten year period[16] available for the closest proximal weather station to each reserve was used, with the decade between 1996 and 2006 set as a cutoff, before which no data was collected. In cases where the closest weather station did not have data that fell within this decade or more recent, data from the next closest weather station was used. For reserves with no proximal weather station (within a 200 km radius) with data that fell within the cutoff range, climate data was omitted.

Elevation data for each water system was included to account for the effect of altitude and topography on water distribution costs, and the costs of MTA participation. This data was gathered from Natural Resources Canada's GeoGratis database [30], and was plotted and paired using GIS software to reserve coordinates for each reserve in the data set.

A number of factors reduce our sample size from the initial count of 804 water systems. Twelve water systems were dropped because they had no form of household distribution[17]. Data limitations for a number of reserve characteristics reduced the sample size further, including: climate data (696 and 695 observations for temperature and precipitation variables, respectfully)[18], geographic remoteness (753 observations)[19], elevation (752 observations)[19], reserve area (778 observations)[20], reserve demographics (i.e. population and population density, both with 754 observations)[20], and Band socioeconomic characteristics (namely, median income (454 observations) and educational attainment (407 observations))[20]. Limitations to water system data reported by Neegan Burnside [31], specifically system age (744 observations) and distribution data (789 observations), further reduced the sample size. Cumulatively, these limitations result in a final sample size of 593 for our model assessing the effect of MTA participation on BWAs, and 306 for our model assessing the MTA participation decision. Both of these models are outlined in detail in the following section.

5. Empirical model

Our empirical approach consists of two probit models. The first model identifies factors influencing the emergence of MTAs. In this model, we are most interested in assessing the effect of reserve characteristics on the likelihood of MTA participation. The second model evaluates the effect of MTA participation on the probability that a water system on a reserve will be under a BWA. Importantly, we control for other factors that may influence a system's susceptibility to drinking water risk.

Our first model is represented as follows:

$$P(MTA = 1|X_M) = \Phi(\alpha_0 + \alpha_1 \ln DISTRP + \alpha_2 ELE + D_r^{\backprime}\beta + S_r^{\backprime}\gamma + TP_r^{\backprime}\delta + PROV_r^{\backprime}\vartheta) \quad (1)$$

where $P(MTA = 1|X_M)$ is the probability that a First Nation is participating in a MTA, and Φ is the standard normal cumulative distribution function[21]. The variable *MTA* is equal to 1 in cases

[16] Ten year averages were used to capture a representative measure of general temperature and precipitation trends in each water system location.

[17] These are very small systems servicing only single buildings, or functioning as bottling plants or self-haul stations.

[18] Due to weather station data limitations discussed.

[19] Due to cases where the reserve on which the water system resides cannot be identified (i.e. cases where a First Nation has multiple reserves, and the water system name does not specify the water system location), or cases where geographic data was not available for the specified reserve.

[20] Reserve area and demographic data from the census is often suppressed for smaller reserves for privacy reasons, or due to non-compliance.

[21] The standard normal cumulative distribution function can be expressed as: $\Phi(z) = \int_{-\infty}^{z} \phi(v)dv$. The function $\phi(v)$ is the standard normal density function, which can be expressed as $\phi(v) = (2\pi)^{-(1/2)}\exp(-(z^2/2))$.

Table 3
Probit results – MTA participation model.

Correctly classified = 87.25%, Pseudo R^2 = 0.4194, Log pseudolikelihood = −85.413, N = 306	**Marginal effect (dF/dx)**	**Robust std. error**	***Z***	***P* > |z|**	***x*-bar**	**95% confidence interval**	
Natural log of distance between reserve and closest population centre (km)	−0.0814	0.0269	−3.06	0.002***	3.3926	−0.1342	−0.0286
Reserve population (100s)	−0.0109	0.0035	−3.04	0.002***	8.5057	−0.0178	−0.0039
Reserve area (100s of km)	0.0333	0.0152	2.14	0.032**	0.7491	0.0036	0.0630
Reserve population density (100s of persons/km^2)	0.0479	0.0147	3.77	0.000***	0.9971	0.0191	0.0768
10 Year average temperature range (10s of °C)	−0.0016	0.0049	−0.32	0.750	42.542	−0.0111	0.0080
10 Year average annual total precipitation (10s of cms)	0.0000	0.0001	0.37	0.711	667.96	−0.0001	0.0001
Reserve elevation (100s of metres relative to mean sea level)	−0.0065	0.0027	−2.38	0.017**	8.8144	−0.0119	−0.0011
First Nation Band area median income (1000s)	0.0134	0.0054	2.35	0.019**	12.782	0.0027	0.0240
Percentage of First Nation population without highschool	−0.0015	0.0017	−0.87	0.384	59.749	−0.0048	0.0019
Reserve located in the Yukon	0.8709	0.0861	3.22	0.001***	0.0098	0.7022	1.0396
Reserve located in British Columbia	0.0879	0.1219	0.84	0.403	0.2190	−0.1509	0.3268
Reserve located in Alberta	0.6247	0.1489	4.34	0.000***	0.1438	0.3328	0.9166
Reserve located in Saskatchewan	0.2270	0.1433	2.05	0.040**	0.2320	−0.0539	0.5078
Reserve located in Manitoba	0.2522	0.2127	1.55	0.120	0.1667	−0.1648	0.6691
Reserve located in Quebec	0.1028	0.1413	0.89	0.372	0.0458	−0.1741	0.3797
Reserve located in Atlantic Canada	−0.0939	0.0292	−1.44	0.150	0.0458	−0.1512	−0.0366
Obs. P	0.1863						
Pred. P	0.0944	(at x-bar)					

Wald $chi^2(16) = 61.82$
Prob $> chi^2 = 0.0000$.
Z and $P > |z|$ correspond to the test of the underlying coefficient being 0.
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

where a reserve water system is supplied through a MTA, and 0 otherwise; and X_M is a vector of explanatory variables included in the analysis. Of key interest is the variable ln*DISTRP*, which is the natural log of the distance between each reserve and its closest proximal population centre. As the distance between a reserve and its closest proximal population centre increases, the likelihood of a MTA emerging is expected to decrease. The variable *ELE* is a measure of elevation (in metres relative to mean sea level) for each reserve in the data set. This variable accounts for the influence of topography on water distribution costs.

D_r' is a vector of the following characteristics for each reserve: surface area (in hundreds of square kilometres), population (in hundreds of people) and population density (in hundreds of people per square kilometre). As discussed in Section 3, we expect reserves with smaller populations and larger population densities to be more likely to pursue MTAs.

S_r' is a vector of the following socioeconomic characteristics of the First Nation Bands responsible for each water system in the data set: Band area median income, and percentage of the Band population without a highschool diploma. The income measure is included to control for the influence of Band income level on the capacity to sustain independent water services, or (conversely) on the incentive to pursue a MTA. The educational attainment variable is included as a measure of human capital.

TP_r' is a vector of climate variables – ten year average annual temperature range and ten year average total annual precipitation – that may influence the costs of water system maintenance and/or increase a water system's exposure to contamination (i.e. freezing and thawing of pipes and excessive rainfall influence a water system's maintenance costs, and susceptibility to pollution infiltration). $PROV_i'$ is a vector of categorical variables indicating the Province that each water system is located within.

The second model evaluates the effect of MTA participation on the probability that a water system on a reserve will be under a BWA, and can be represented as follows:

$$P(BWA = 1|X_B) = \Phi(\mu_0 + \mu_1 MTA + \mu_2 \ln DISTRP + WSC'\tau + D_r'\varphi + TP_c'\omega + PROV_i'\eta) \quad (2)$$

where $P(BWA = 1|X_B)$ represents the probability that a water system is under a BWA. The variable *BWA* is equal to 1 in cases where a BWA is in effect, and zero otherwise; and X_B is a vector of explanatory variables included in the model. The key variable of interest in this model is the variable *MTA*, which is identical to the dependent variable in Eq. (1). We expect that participation in a MTA reduces the likelihood that a reserve is under a BWA.

The distance variable, ln*DISTRP*, is included to account for geographic remoteness. It is important to note that this distance variable is highly correlated with the distance between each reserve and its closest proximal resource or industrial site (a correlation of 0.85). Therefore, proximity to population centres may capture the effect of both remoteness and proximity to potentially polluting resource or industrial activities that may also affect water quality.

WSC' is a vector of water system characteristics that may influence risk susceptibility, including: system age (in years), the population serviced by the water system (in hundreds of persons per day) and the percentage of households serviced by piped water. The vectors D_r', TP_c' and $PROV_i'$ are identical to those in Eq. (1).

A key empirical challenge in identifying whether a MTA reduces the likelihood that a water system on a reserve will be under a BWA, is that an identification problem emerges if the variable *MTA* is correlated with the error term in the BWA model. This identification problem might occur for a number of reasons. Suppose, for example, that reserves that are more likely to experience a BWA are also more likely to enter into a MTA. Monfardini and Radice [28] outline a method to assess this endogeneity concern, using information from a two-model approach like the one developed in this section. The first step is to estimate both models simultaneously using a recursive bivariate probit model. This enables one to examine the correlation between the error terms of the two

Table 4
Probit results – BWA model.

Correctly classified = 73.36%, Pseudo R^2 = 0.0996, Log pseudolikelihood = −311.329, N = 593	Marginal effect (dF/dx)	Robust std. error	Z	P > |z|	x-bar	95% confidence interval	
MTA participation	−0.1079	0.0478	−2.01	0.045**	0.1551	−0.2015	−0.0142
Reserve population (100s)	−0.0118	0.0063	−1.86	0.063*	5.6134	−0.0241	0.0005
Reserve area (100s of km)	0.0106	0.0225	0.47	0.638	0.5080	−0.0334	0.0546
Reserve population density (100s of persons/km^2)	0.0090	0.0064	1.39	0.165	0.9539	−0.0036	0.0216
Population serviced by water system (100s)	−0.0021	0.0047	−0.44	0.656	5.1951	−0.0113	0.0071
Percentage of reserve households supplied by piped water	0.0008	0.0009	0.90	0.368	89.431	−0.0009	0.0026
Age of water system servicing reserve	0.0015	0.0019	0.82	0.411	19.400	−0.0021	0.0052
Natural log of distance between reserve and closest population centre (km)	0.0360	0.0195	1.85	0.065*	3.2626	−0.0023	0.0744
10 Year average temperature range (10s of °C)	−0.0053	0.0049	−1.08	0.280	40.441	−0.0149	0.0043
10 Year average annual total precipitation (10s of cm)	−0.0002	0.0001	−1.92	0.055*	699.23	−0.0004	1.1e−06
Reserve located in the Yukon	−0.2050	0.0610	−1.55	0.122	0.0084	−0.3246	−0.0854
Reserve located in British Columbia	−0.2943	0.0711	−3.47	0.001***	0.3643	−0.4338	−0.1549
Reserve located in Alberta	−0.1246	0.0651	−1.57	0.116	0.0860	−0.2523	0.0030
Reserve located in Saskatchewan	−0.0228	0.0664	−0.34	0.736	0.1602	−0.1528	0.1073
Reserve located in Manitoba	−0.2103	0.0410	−3.33	0.001***	0.1062	−0.2905	−0.1300
Reserve located in Quebec	0.0610	0.1335	0.48	0.631	0.0270	−0.2006	0.3227
Reserve located in Atlantic Canada	−0.1078	0.0699	−1.30	0.194	0.0489	−0.2448	0.0292
Obs. P	0.2698						
Pred. P	0.2419	(at x-bar)					

Wald $chi^2(17) = 62.96$.
Prob > chi^2 = 0.0000.
Z and P > |z| correspond to the test of the underlying coefficient being 0.
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at the 1% level.

models, conditional on the other covariates. Adopting this approach, we use a maximum likelihood estimate of the correlation between the error terms of our two model equations, and conduct a Wald test of this correlation to determine if it is significantly different from zero[22] (the null hypothesis being that the error terms are not correlated). If the error terms are correlated, this indicates that a joint estimation approach is needed. Conversely, a failure to reject the null indicates that the models should be estimated as separate probit models. The joint estimation approach results in inflated standard errors, and a substantial loss in predictive power; therefore, independent estimation of the two models is preferable if significant endogeneity issues can be ruled out.

6. Results

In this section we report the results of our two empirical models: i.e., Eqs. (1) and (2). When jointly estimated using a recursive bivariate probit model, we find a correlation of 0.85 between the error terms of the two model equations. However, this correlation is not statistically significant (with a p-value of 0.24), a result that supports an exogeneity assumption. For this reason, we report marginal effects from independent probit models for each equation[23].

6.1. MTA participation model

Table 3 provides the regression results for the probit model used to examine factors influencing the likelihood that a First Nation will participate in a MTA. Factors expected to influence the costs of MTA participation, discussed in Section 3, were found to be significant with the expected signs. Geographic remoteness has a statistically significant effect on the likelihood that a First Nation will participate in a MTA. A 1% increase in the distance between a reserve and its closest population centre decreases the probability of a MTA emerging by approximately 0.1%[24]. Reserves with smaller populations and larger population densities are also more likely to pursue MTAs. A decrease in reserve population by 100 persons increases the probability of MTA participation by approximately 1%; and an increase in reserve population density by 100 persons per square kilometre increases the probability of MTA participation by approximately 5%.

The size and elevation level of reserves were also found to influence the likelihood that a First Nation will choose to participate in a MTA. An increase in reserve size of 100 square kilometres increases the likelihood of MTA participation by approximately 3%. This may reflect the fact that very small reserve communities are likely serviced primarily by well water, with maybe one (or several) small system(s) (i.e. servicing wells for public buildings or schools) in densely populated pockets, and would not pursue a MTA to service the majority of their population. An increase in reserve elevation of 100 metres above mean sea level decreases the likelihood of MTA participation by approximately 0.6%. This likely reflects the high costs of water distribution across more topographically variable areas and at higher elevations, which may discourage MTA participation.

Band area median income influences the likelihood of MTA participation. An increase in Band area median income of $1000 increases the likelihood of First Nation participation in a MTA by approximately 1.3%. This may indicate that First Nations with wealthier on-reserve populations will be more likely to pursue these types of servicing agreements. This could be because

[22] See Greene [18] for a full discussion of this test.
[23] Our key findings did not vary between the two estimation approaches.
[24] See Woolridge [49], pp. 459, for additional details on the interpretation of marginal effects.

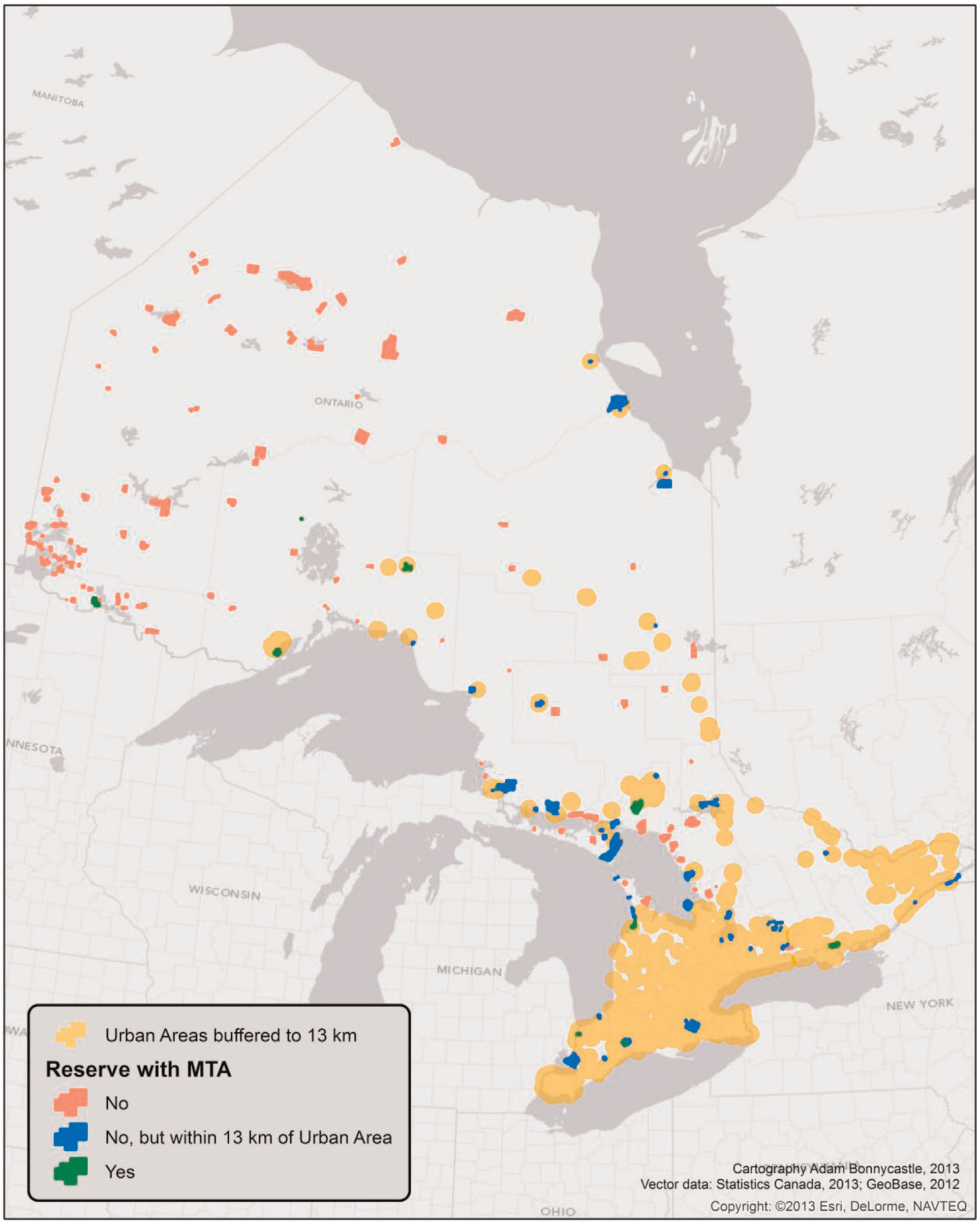

Fig. 2. First Nations' reserves in Ontario (MTA participants and non-participants) and their proximities to population centres.
Source: Author and data references contained in figure.

wealthier First Nations are more likely to be located in more economically developed areas with greater potential for interlocal cooperation; or, it may be because wealthier First Nations have more resources to allocate to pursuing these types of agreements.

The Provincial categorical variables significantly influence the likelihood of MTA participation. First Nations located in the Yukon Territory, Alberta, and Saskatchewan were found to be 87%, 62%, and 22% more likely to participate in MTAs, respectively, compared to First Nations located in Ontario. These Provinces may have institutional characteristics that make the negotiation of MTAs less costly within their jurisdictions, or there may be characteristics unique to First Nations in these Provinces that make MTA participation more likely. For example, trucked water distribution is very common in the Yukon[25]; and because trucked water distribution across large distances is more economically viable than large piped water infrastructure, this may explain the high prevalence of trucked water MTAs in this Territory. In Alberta, reserves and neighbouring communities facing exposure to oil-sands activities may experience higher costs of drinking water treatment, which may encourage MTAs. And Saskatchewan is a Province dominated by prairies and relatively level terrain, which likely reduces the costs of constructing water distribution networks between MTA partners.

6.2. BWA model

Table 4 provides the regression results for the probit model used to assess factors influencing the likelihood that a water

[25] Approximately 78% of water distribution systems in our data set located in the Yukon consist of either primarily trucked, or mixed piped and trucked distribution [31].

Table 5
BWA model sensitivity analysis – alternative water quality measures.

	Base model (correctly classified: 73.36%)		Alternate water quality measures: High risk ranking (correctly classified: 74.70%)		Fails health CGDWQ (correctly classified: 70.31%)		Fails aesthetic CGDWQ (correctly classified: 74.71%)	
	Marginal effect	Robust std. error	Marginal effect	Robust std. error	Marginal effect	Robust std. error	Marginal effect	Robust std. error
MTA participation	−0.1079**	0.0478	−0.4002***	0.0323	−0.1818**	0.0929	−0.3806***	0.0916
Reserve population (100s)	−0.0118*	0.0063	−0.0049	0.0056	−0.0080	0.0071	0.0039	0.0094
Reserve area (100s of km)	0.0106	0.0225	0.0272	0.0250	−0.0017	0.0355	0.0509	0.0394
Reserve Population Density (100s of persons/km^2)	0.0090	0.0064	−0.0058	0.0122	0.0027	0.0153	0.0004	0.0224
Population serviced by water system (100s)	−0.0021	0.0047	−0.0097*	0.0057	0.0110**	0.0055	−0.0124*	0.0067
Percentage of reserve households supplied by piped water	0.0008	0.0009	0.0013	0.0011	0.0002	0.0014	0.0025*	0.0014
Age of water system servicing reserve	0.0015	0.0019	0.0095***	0.0023	0.0030	0.0030	0.0070**	0.0031
Natural log of distance between reserve and closest population centre (km)	0.0360*	0.0195	0.0244	0.0213	0.0466*	0.0266	−0.0214	0.0304
10 Year average temperature range (10s of °C)	−0.0053	0.0049	−0.0048	0.0053	0.0009	0.0066	−0.0016	0.0077
10 Year Average annual total precipitation (10s of cm)	−0.0002	0.0001	−0.0001	0.0001	0.0000	0.0001	−0.0003	0.0002
Reserve located in the Yukon	−0.2050	0.0610	0.1915	0.2289	−0.3389	0.2562	−0.5398**	0.1183
Reserve located in British Columbia	−0.2943***	0.0711	0.0634	0.0990	−0.0368	0.1224	−0.4553***	0.1336
Reserve located in Alberta	−0.1246	0.0651	−0.1350	0.0859	0.0793	0.1080	−0.3764***	0.1204
Reserve located in Saskatchewan	−0.0228	0.0664	−0.1788***	0.0608	−0.1447	0.0935	−0.1223	0.1098
Reserve located in Manitoba	−0.2103***	0.0410	−0.0792	0.0862	−0.4928***	0.1151	0.0654	0.1521
Reserve located in Quebec	0.0610	0.1335	−0.1384	0.1342	−0.5937***	0.0905	−0.3745**	0.1589
Reserve located in Atlantic Canada	−0.1078	0.0699	−0.1931*	0.0801	−0.3243**	0.1366	−0.5817***	0.0736

*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

system on a reserve will be under a BWA. Participation in a MTA was found to have a negative and statistically significant effect on the probability that a water system on a reserve will be under a BWA. First Nations' water systems supplied through MTAs were 11% less likely to be under a BWA than those with independent treatment.

Reserves with smaller populations are also more likely to have a water system under a BWA. Specifically, a 100 person increase in the population of a reserve was found to decrease the likelihood of a BWA by approximately 1%, likely reflecting the relationship between scale economies and water quality outcomes. Reserves that are located in more remote areas are also more likely to have a water system under a BWA, with a 1% increase in the distance to the closest neighbouring population centre increasing the likelihood of a BWA by approximately 3.6%[26].

Surprisingly, water systems located in areas with more precipitation (i.e. higher ten year average total annual precipitation) are less likely to be under a BWA. The marginal effect of this variable was very small: only a 0.02% decrease in the likelihood of a BWA for a 10cm increase in ten year average total annual precipitation. This finding is also sensitive to the inclusion of the Provincial categorical variables[27].

The Provincial categorical variables are also significant. Water systems on reserves located in the Provinces of Manitoba and British Columbia are 21% and 29% less likely to be under a BWA, compared to those located in the Province of Ontario. This may reflect differences in risk exposure and water quality monitoring and reporting in these Provinces that make water systems less vulnerable to BWA. Further research is needed in order to better understand why First Nations' water systems located in different Provinces may face different risks of BWA.

7. Sensitivity analysis

We test the sensitivity of the results of the BWA model to alternative measures of water quality, by using three alternative dependent variables[28]: (1) whether the system was given a high risk ranking[29] (a measure that was available for all water systems in the data set), (2) whether the system was determined to have failed the health guidelines of the Canadian Guidelines for Drinking Water Quality (CGDWQ)[30] (a measure that was available for only 471 water systems), and (3) whether the system was determined to have failed the aesthetic guidelines of the CGDWQ (a measure that was available for 460 water systems). These findings are presented

[26] Anecdotally, we know that the most remote First Nations' reserves in Canada appear to have the most significant water quality concerns [31] and face unique challenges in retaining resources to adequately monitor water quality [36]. Our findings are consistent with this anecdotal evidence.

[27] When Provincial categorical variables are removed from the model, the precipitation variable loses significance; and the ten year average annual temperature range variable becomes significant with a positive marginal effect. All other findings remain consistent.

[28] All of these variables were taken from the Neegan Burnside report [31].

[29] Systems that were assigned a high risk raking by Neegan Burnside surveyors were those with "major deficiencies that may, individually or combined, pose a high risk to the quality of water" [2]. These water systems are often providing safe water to communities, but are considered to be high risk for a number of reasons (i.e. water source, system design, system operation and maintenance, operator training and certification, and record keeping and reporting). More information on system risk assessments is available on the AANDC website, here: https://www.aadnc-aandc.gc.ca/eng/1313687144247/1313687434335.

[30] The Canadian Guidelines for Drinking Water Quality (CGDWQ) have been published by Health Canada since 1968, and are developed by a Federal-Provincial-Territorial Committee on Drinking Water. The full guidelines are available from the Health Canada website, here: http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/guide/index-eng.php.

in Table 5, along with the findings from the base model specification.

Our key finding, that MTA participation improved water quality, remains consistent regardless of the measure of water quality used as the dependent variable in the model. MTA participation reduces the likelihood of a system having a high risk ranking by approximately 40%. MTA participation reduces the likelihood of a system failing the health guidelines and aesthetic guidelines of the CGDWQ by approximately 18% and 38%, respectively.

Findings for other covariates vary depending on the dependent variable used. For example, in contrast to the base model, population size did not significantly influence the likelihood of any of the alterative water quality measures. On the other hand, population serviced by the water system was found to have an influence on the likelihood of all three alternate measures (with an increase in population serviced decreasing the likelihood of a high risk ranking and aesthetic issues, and increasing the likelihood of a health guideline failure). Additionally, the percentage of the serviced population on piped water distribution was found to increase the likelihood of aesthetic issues. Geographic remoteness increases the likelihood of health guideline failure, but does not significantly influence the likelihood of aesthetic guideline failure, or the likelihood of a high system risk ranking. The age of the water system has a positive and significant effect on the likelihood of a high system risk ranking and aesthetic guideline failure. Findings for Provincial categorical variables varied markedly between the different water quality measures used.

8. Conclusion

There is little empirical literature examining the outcomes of service provision contracts, like MTAs, between First Nation Bands and non-First Nation communities. Indeed, to our knowledge, this is the first study to empirically assess these contracts. With respect to water quality and MTAs in Canada, our study identifies a number of key results with implications for policy. Importantly, we find that First Nations participating in a MTA are less likely to experience a boil water advisory (BWA). This finding lends support to the promotion of MTAs as a solution to drinking water provision and water quality challenges on reserves. Currently, AANDC's position on MTAs is that they should be encouraged in situations where they are the least cost alternative to independent service provision. Given our results, AANDC and First Nations leaders may want to consider an expanded role for MTAs.

A major finding of our study is that First Nations governing remote reserves are far less likely to participate in MTAs. Due to the significant costs associated with transporting water across large distances, MTAs are not feasible if reserves are geographically isolated. However, importantly (from a policy perspective) there are many reserves that lie within a feasible distance to a potential MTA partner that do not have an existing MTA. In Ontario alone (which contains only 12 active MTAs) we've identified 25 First Nations with reserves that fall within a feasible distance to a potential MTA partner, but do not have an existing MTA[31] (Fig. 2 shows the locations of these reserves, as well as the locations of all reserves in Ontario with existing MTAs). In many of these cases, prohibitively high transaction costs may be preventing MTAs from emerging. Assessing these transaction costs, and examining ways to economically reduce these costs, is an important area of future research.

The current institutions that constrain First Nations and neighbouring non-First Nation communities from engaging in service transactions are historic and formidable. This paper focuses on examining water provision contracts; however, the potential gains for contracting a variety of services between Canadian First Nations and non-First Nation communities warrant continued research. These relationships can go in either direction: i.e. in some situations there may be gains to First Nations from providing services to a neighbouring non-First Nation community. Importantly, the need to seek out opportunities for cooperation between First Nations and non-First Nations extends to business and entrepreneurial-based actions as well. Continued research on institutions like MTAs that promote exchange will remain an important area for future enquiry.

Acknowledgements

Funding for this project was provided by the Social Sciences and Humanities Research Council of Canada (SSHRC) through the Joseph-Armand Bombardier Canada Graduate Scholarship, and by the RBC Blue Water Project (Grant No. 052304).

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