

Resource Management and Risk Assessment of Water Use by the Swine Industry in Manitoba, Canada

By

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Abstract

The volume of water utilized by the swine industry in the province of Manitoba has long been a contentious issue due to the potential impacts on the biophysical environmental and society well-being. A quantitative analysis framework was used to examine the concerns of water use and the provincial water use licensing regime as expressed by the Clean Environment Commission (2007) report on the sustainability of provincial swine industry. Data were obtained from a governmental archival source. The research findings revealed that concerns expressed in the Report were unfounded or disproportionate to the actual problem. The study outcome provides clearer understanding on the water volume utilized by the provincial swine industry and the appropriateness of the provincial licensing regime that administrates *The Water Rights Act*. Future policy recommendations include peer-reviewing needs of the CEC report and incorporation of water conservation techniques for future Manitoba Environmental Farm Plan and *Growing Forward* program.

Keywords. Swine, Manitoba, Clean Environment Commission, Water, Licensing

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List of Abbreviations

CEC – Clean Environment Commission

Dam³ – Cubic decametre (1 dam³ = 1 million litres or 1,000 dam³ = 1 billion litres)

GW – Groundwater

RoM – Rest of Manitoba

SW – Surface water

VC – Vertical coordination / vertically coordinated

WRA – *(The) Water Rights Act*

WULS – Water Use Licensing Section

WUR – Water use record(s)

Note:

All ‘license’, ‘licenses’, ‘licensee’, ‘licensees’, ‘licensing’, and ‘licensed’ refers to the context of the Water Use Licensing Section under *The Water Rights Act* of Manitoba.

1.0 Introduction

1.1 Historic and research context

Agriculture is the largest export commodity sector in Manitoba with a total gross farm receipt of \$6.8 billion in 2016, an increase of \$3.3 billion since 2001 (Statistics Canada, 2001; 2017). Furthermore, the provincial swine industry contributes approximately 20% (\$1.1 billion) to the provincial gross receipt with a total cumulative investment of \$6 billion in land, facilities and livestock (Honey, 2015a). From 2001 to 2015, the swine population in Manitoba increased from 2.4 million to 3.1 million head (Statistics Canada, 2006; Government of Manitoba, N.D.a). In contrast, the number of cattle in Manitoba in the same period declined from 1.4 million to fewer than 636,000 head, with an annual farm receipt of \$0.7 billion in 2015 (Honey, 2015b; Statistics Canada, 2017).

The swine industry has had its roots in Manitoba since 1881. Up until the 1980s, the dominant method for swine farming was an all-in-all-out production for which the swine are reared from birth to be market-ready on one farm. This production is associated with small and medium sized mixed-livestock farming with the number of swine in the hundreds (Novek, 2003). However, since the 1980s, the acceleration towards intensive livestock farming shifted the dominant business model towards the modern mono-cultural three-site farming method from the traditional all-in-all-out production (Clean Environment Commission, 2007a). Under the three-site model, the swine are raised in one stage of production (sow, feeder or nursery) on one farm before being transferred to a different location for the next stage (Clean Environment Commission, 2007a). The modern model is colloquially known as ‘mega barns’ that can house up to tens of thousands of swine per barn. The beginning of the rapid growth towards intensive livestock farming was primarily triggered when the Crow’s Nest Pass Agreement was repealed

by the Canadian federal government, leading to the collapse of grain prices across the prairie provinces. In response, the provincial government intervened through legislative measures to foster the growth of the swine industry to consume the flooded grain on the market, and to stabilize its price (Clean Environment Commission, 2007a). These changes gave rise to the modern swine industry in Manitoba.

During the onset of intensive livestock farming, the number of swine farms in Manitoba decreased from 3,150 in 1990 to fewer than 800 in 2014, while the swine population increased from 1.3 million head in 1990 to nearly 3.1 million head in 2015 (Clean Environment Commission, 2007a; Honey, 2015a). The result of the rapid growth in the swine population since the 1990s led to a series of social and environmental concerns that is amplified by the high density of intensive livestock operations in the southeastern Manitoba (where half of the swine operations with a valid Water Rights License reside) and the subsequent collective pressure on natural resources (Government of Manitoba, 2015). The origin of these concerns is derived from the perceived volume of water utilized by the swine industry and the subsequent generation of manure and odour (Clean Environment Commission, 2007a). Social and environmental concerns, regarding water usage in the swine industry, ranges from information gaps on the impact of the industry on water sources, the scale of excessive water waste, the sustainability of the local aquifers and surface water (SW) bodies, and the lack of (or presence of very little) regulatory oversight by the provincial Water Use Licensing Section (WULS) (Irwin, 2007). Additionally, environmental concerns relating to excessive water usage is two-fold. First, the perceived threat of unsustainable practices of diverting large volumes of water from local sources. Second, excess water waste equates to more manure generation, which can deteriorate surrounding air, soil and water quality/availability. The secondary effects of excess manure

disposal on the biophysical environment include deteriorating habitat suitability for native flora and fauna, social dis cohesion due to odours, and the condemnation of water sources for human consumption due to manure contamination and bacterial blooms (Clean Environment Commission, 2007a).

The rapid swine population growth in Manitoba during the 1990s, along with information gaps and the growing public concerns of the rapidly expanding swine industry, caused the provincial government to implement a provincial-wide moratorium on new swine barns and the expansion of existing swine barns in 2007 (Novek, 2007). Simultaneously, under section 6(5) of *The Environment Act*, the Minister of Conservation mandated the Clean Environment Commission (CEC) to launch an inquiry with the objective to examine the whether the swine industry in Manitoba is environmentally sustainable in its current state and ongoing practices.

The CEC is an extension of *The Environment Act* that allows public and stakeholders participation in the decision-making process regarding the proposed project and the potential effects on the biophysical environment. The responsibilities of the CEC are: 1) “the commission may provide advice and/or recommendations to the Minister of Sustainable Development with respect to the environmental issues and concerns examined”, 2) the “commission may engage in public hearings, investigations or as mediator to assist in environmental management”. These responsibilities are highlighted under the mandated mission of the CEC (2017).

A year later in December 2007, after holding several hearings with the public, the CEC released their report on the "Environmental Sustainability and Hog Production in Manitoba". The summary of the Report stated that “yes, but...” with the caveat that unless “significant resources are dedicated” to address the information gaps and concerns, it would be difficult to ascertain for long term sustainability (Clean Environment Commission, 2007a: v). The valued ecosystem

components analyzed in the final CEC Report includes water (quality/quantity), air quality, flora and fauna. Additional components covered in the final report were stakeholder (public) input, as well as the historic context of regulations that pertains to the Manitoba swine industry.

The CEC Report deals with water quantity – specifically the water usage by swine operators and the provincial licensing regime that manage provincial water resources under *The Water Rights Act* (WRA) (in Chapter 9.2). The CEC Report concluded that the long-term water use sustainability practices by the provincial swine industry is questionable and alluded to the perceived ineffectiveness of the provincial licensing regime. At the time of the CEC Report, Small (2001) was the only study that comprehensively examined the water management practices in the Manitoba swine industry. Small (2001) suggested that on average 50% of the water volume utilized within a functioning barn is wasteful. However, their sample size was too small to make inferences. The few studies conducted on water management in Manitoba swine barns had been attributed to the perceived bountiful and nominal cost of water in Manitoba (Nyachoti et al., 2007). In addition, Froese (2003: 1) highlights the general sentiment over the lack of sufficient water use data as “this lack of information hampers efforts to focus and prioritize water conservation practices”, which in turn clouds the argument over the sustainability of water resource management in the Manitoba swine industry. This quote still resonates with ongoing studies over a decade later.

Any conclusions for long-term sustainability would need to address the lack of available data on water usage and the reported inefficiency of the provincial licensing regime (Clean Environment Commission, 2007a). When the missing information is made available, it can be used to maximize the efficiency of water usage and assist in policy making by non-governmental

organizations, business industries and governmental organizations. Particularly the issues of land management policies, environmental consideration, economic feasibility and societal concerns.

1.2 Research purpose, questions and objectives

The purpose of the present study is to investigate, through the application of quantitative analyses, the concerns presented in the Manitoba CEC Report titled ‘Environmental Sustainability and Hog Production in Manitoba’ on water usage within the swine industry and assess the effectiveness of the provincial licensing regime (Table 1.1). This thesis will address the following questions. First, are the concerns expressed by the CEC on water usage within the Manitoba swine industry valid? The present study will attempt to provide an accurate estimate of the volume of water used by the provincial swine industry by collecting water use records (WURs) through archival searches in the government database. Second, are the concerns expressed by the commission still valid today after ten years since the report was released in 2007? This present study will review the provisions of the WRA as it relates to concerns expressed by the CEC. Some of the concerns expressed by the Report that will be address by this thesis are listed in Table 1.1 below:

Table 1.1: Summary of Clean Environment Commission concerns.
(Clean Environment Commission, 2007a: 114-117)

CEC Concerns
“Manitoba Water Stewardship [has a] policy of not recording the reported meter readings or aggregate these readings to ensure that operators are not exceeding their licensed amount”
“The lack of recording the reported meter readings...makes it difficult to get a firm grasp on the amount of water the hog-production sector consumes”
“[Since] Manitoba Water Stewardship does not have data on water use, it is difficult to determine if the resource is being managed to maximize its sustainability”
“...the Commission believes that stronger data are required before a more confident assertion can be made about the sector’s sustainability”
“...the Commission believes that the Manitoba government needs to further develop its water-use monitoring in order to ensure long-term sustainability of the resource”

The layout of this thesis will consist of the methodology described in Chapter 2. The 3rd Chapter will address the first objective by establishing the literature review (3.2), and how the present study differs from the comparable studies in Manitoba that used the holistic approach (3.2.1). The next step will involve using the collected data in order to calculate the annual volume of water used by the provincial swine industry (3.3). Therefore, laying the foundation for comparing the calculated volumes in the present research to the findings presented in the CEC Report (3.4), and to other sources of proposed volumes for different class of swine (3.5). The data will then be examined to account for the fluctuations that appears in the water use trends for each class of swine development (3.6-2), and to disaggregate the total water use trend to consider the factors involved according to the sources of water diversions (licensed allocations), regional differences (licensees behavior), and business models (water volume) (3.7-3). The sections in Chapter 3 will establish the groundwork for assessing the sustainability of water usage in the Manitoba swine industry.

Chapter 4 of this thesis will review the history of the WRA since its inception in the 1800s (4.3) followed by an examination of the procedures involved in issuing a license in the context of a swine operation (4.4). The next part will assess the elements of the licensing provisions administered by the WULS (4.4.1-3). The findings in Chapter 4 will be used in conjunction with findings uncovered in Chapter 3 to assess the CEC findings on the provincial licensing regime (4.5).

Chapter 5 will discuss the findings from Chapter 3 and Chapter 4 (5.1), followed by a discussion on the limitations and challenges faced by this thesis (5.2). The conclusions will then be addressed (5.3) and policy recommendations will lastly follow (5.4).

2.0 Methodology

2.1 Data collection

A total of 173 swine operations with a valid Manitoba license as of December 24, 2015, were selected for the present research – representing over one million swine or one-third of the 2015 swine population in Manitoba. This representation is a subset, of the total swine population in the province, sorted out using the following criteria. All licenses in the subset are class one under *The Environmental Act* (for which the reservoir capacity of the swine operation, if any, is under 50 cubic decametre or dam³). Relevant information and raw data associated with these licenses were obtained, with permission, through archival search from the WULS under the Drainage and Water Rights Licensing Branch within the Department of Sustainable Development of the Government of Manitoba (see Image 2.1).

Information and data gathered from each of the 173 license files include assessment reports, licenses, and WURs. Additional information gathered, if available, includes the following: licensee/public complaints and concerns, consulting reports, images of water sources and meters, written and electronic correspondences that pertain to water usages and licensing policies (identified as Government of Manitoba, 2015, 2016, 2017 and 2018). References from primary literatures, as well as the CEC Report on “Hog Production Industry Review”, were utilized to supplement the findings in the present study.



Image 2.1: The filing cabinet in the Water Use Licensing Section for which raw data and information were obtained. This image shows one-quarter of the total project files (including municipal, irrigation, industrial, domestic and ‘others’).

(Source: Department of Sustainable Development, Cielen, 2018)

There were 173 licenses selected from a total of 1,265 project files from the provincial software database on December 24, 2015. The total number of project files includes the expired applications and licenses, active licenses, and active applications that had yet to be licensed. It should be noted that expired licenses were excluded from the present study because their inclusion would hamper accurate construction of water use temporal trends. Out of the total number of valid licenses, 323 were issued for agricultural-livestock purposes on each license. Out of 323 agricultural licenses, 256 were explicitly identified as agriculturally-swine related in each license assessment report.

Attempts were made to reduce data interferences and limit third party influences when attempting to determine an accurate volume of water being utilized by individual sow, feeder and nursery operations (as representative of Manitoba swine industry) using two exclusion criteria. The decision to exclude the selected licensed swine operations was considered essential to obtain

reliable and accurate data. License information that pertains to each criterion were obtained from the license assessment reports and the correspondences of each license.

The first criterion excludes swine operations that use water for more than one type of swine development type on the same production site (e.g. sow and nursery barns on the same site) and using water for additional purposes that are unrelated to the functioning of the swine barn. A total of 60 licenses, from the subset of 256 licenses, fell under the first criterion and were excluded from this research. This exclusion was justified because the water meters can only account for the total water volume diverted from aquifers and SW bodies, and the recorded volume could not be disaggregated into water use pathways on a production site. Examples of using water for non-swine related purposes includes domestic use (home-function), gardening, raising additional livestock (e.g. caprine, bovine).

For the second exclusion criteria, since the water meters only account for the total water volume diverted from SW and GW bodies, swine operations that had their water needs supplemented via municipal connection will not be reflected in the meter readings and will distort the end results. Thus, a further 13 licenses were identified to have supplement their water needs with municipal pipeline connections and were excluded from this thesis. Of the remaining 183 licenses, an additional 10 were excluded for non-compliance with the condition of their license in that no WURs had been submitted and thus had nothing to provide for this thesis. In compliance with *The Manitoba Freedom of Information and Protection of Privacy Act*, the personal information of the license holders has been removed from this thesis and is substituted via non-identifying numerical values in the Appendices.

2.2 Disaggregation of the swine-operating water-user study population

The following is the composition of the 173 licenses chosen for the present study. By operation type, sow makes up 32% (55) of the total licenses, with the equivalent for feeder at 54% (94) and nursery at 14% (24). Attempts were made to add additional class, farrow-to-finish, which is traditionally associated with the all-in-all-out production to contrast against the three-site production. Unfortunately, the population size of licensed farrow-to-finish operations would have been too small to make population-related inferences, and thus it was excluded from the present research. The word “sow” in the present study will refer to exclusively as a farrow-to-nursery operation. The latter operation refers to gestating swine and the newborns that stays with their mother until they reach 12 lbs. Nursery refers to young swine from 12 lbs up to 57 lbs, and in some cases, up to 75 lbs. Feeders (also known as finisher and grower) refer to swine from at least 57 lbs to market ready. Regionally, 53% (92) of the licenses in the present study are located in Eastern Manitoba, with the remaining 47% (81) in other locations in Manitoba – called Rest of Manitoba (RoM) in this thesis. The RoM includes the following regions: Central, Interlake, Southwest, Midwestern, Parkland and Northern Manitoba. It should be noted that there are no swine operations with a license in Northern Manitoba as of 2015. Together, the licenses in the present study cover 40% (41) of 102 municipalities in Manitoba (as of January 1, 2015 under *The Municipal Amalgamations Act*). Organizing by sources of water diversion, 86% (148) of the licenses rely on GW sources with the remaining 14% (25) on SW sources (rivers, dugouts, creeks, tributaries). Lastly with respect to business models (under the three-site model), 84% (146) are classified as vertically coordinated (VC) with the remaining 16% (27) as independent businesses (no partnership with third-party corporate entities). Consideration was made to add “colony” as a business model due to their prominence on Manitoba prairies (Clean Environment

Commission, 2007). However, no colonies with a license passed the exclusion criteria for the present study and were thus excluded.

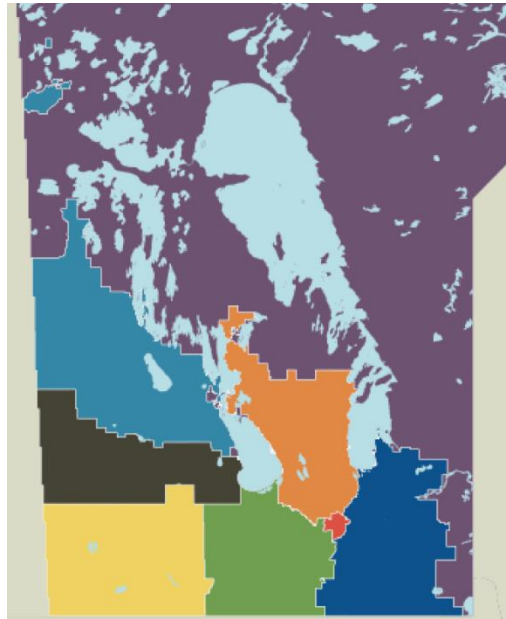


Figure 2.1: A map showing the lower half of Manitoba, Canada. The colours highlight the following regions: Southeastern (dark blue), Interlake (orange), Central (green), Western (yellow), Midwestern (brown), Parkland (light blue), Northern Manitoba (purple), and Winnipeg (red). (Source: Association of Manitoba Municipalities, 2015)

2.3 Establishing the temporal period for this study

Due to the anticipated variations in the annual reporting water volume, the present study set the temporal limit at 16 years - from 2000 to 2015. This timeline enables placing the time of the CEC Report release near the center (2007), which is helpful with before-and-after comparison with the thesis findings. Furthermore, the number of valid licenses fitting the parameters for this thesis becomes increasingly scarce in the pre-2000s period. The self-imposed deadline for collecting WURs for the year 2015, from each of the 173 licenses, was until December 29, 2016. The delay was justified in that it takes time and resources for licensees to collect, organize and submit outstanding WURs to the WULS (Government of Manitoba, 2017).

2.4 Calculating Water Use Records

It is estimated that at least half the WURs submitted by the licensees were incomplete due to varying degrees (days, weeks or months of unaccounted water use). Therefore, the present study used the mean imputations of historic data to account for missing data when statistically appropriate. This was performed by using the reported meter readings or volumes as a bridge over the unreported period for which water use is considered unaccounted. Since the annual reporting rate of barns being devoid of swine is 0.37% - the imputation method was used on the presumption that Manitoba swine barns are always at (or near) full capacity. This presumption is held by several corporate environmental specialists and several members of the licensing staff (Government of Manitoba, 2017). For this same reason, the years for which the WURs had not been reported, nor had there been any reasonable indications of the barn being devoid of swine (e.g. marking of zeroes on the WURs or written slash across the report forms), and furthermore, it was presumed that licensees had been using water but neglected (forgotten or ignored) to report their annual usage. Unfortunately, using this presumption had led to several dozen volume reporting outliers (out of nearly 1,900 volumes of reporting water use) which are too low of levels to maintain the population of swine for which the license was issued. However, the impact of these volumes on the findings of this thesis appear to be negligible. In all 173 licenses, the WURs are provided in either (or both) volume or meter readings – the latter was used to calculate the total annual consumption wherever possible. Thus, the preference of using meter readings over the total volume recording reduces human error associated with manual calculations.

Calculating the annual reporting rates of licensees submitting WURs to the WULS did not include the statistical imputation for the years that WURs had not been reported. The

calculation of compliance rates (WURs against their licensed allocation) used the statistical imputations to substitute the years for which no WURs have been reported – when appropriate. The average annual percentage of using the mean imputation to account for the absence of WURs is 18.93% (or 14.74% if the year 2000 and 2001 were excluded). Furthermore, the method of imputation was essential to uncover a more complete picture of the total volume of water used by the licensees. Throughout this thesis, the term “average” in the context of water use will refer to the statistical mean, unless otherwise stated.

3.0 Estimation of volume of water use by the swine industry, Manitoba

3.1 Introduction

There is uncertainty regarding the water volume utilized by the swine industry within the province of Manitoba and the available data on water usage which undermines the “confident assertion that can be made about the sustainability” practice in the context of water management (Clean Environment Commission, 2007a: 117). In this Chapter, an estimate of the volume of water utilized by the swine industry in Manitoba is attempted. This Chapter begins with discussions of methodologies and the results between the present study and the historical study sponsored by the CEC. These discussions will lay the foundation for examining and discussing the 16 years trends (2000 – 2015) of water use behaviour in the context of swine class development (sow, feeder, nursery), sources of water uptake (GW and SW), geography (eastern Manitoba, RoM), and business models (independent and VC).

3.2 A review of the literature

There are two approaches to analyzing the water requirement for swine: atomistic and holistic. Nearly all studies that analyzed the elements of water resource management in the swine industry of the province of Manitoba do so by specific water function (livestock drinking, sanitation or cooling) or management practices (technologies, attitudes, etc.). For example, approximately 80% of the total water usage within the swine barn is dedicated for livestock drinking, therefore most studies focus on drinking as the function of manure production (Froese, 2003). The disconnected nature of this atomistic approach risks either under or overestimating the findings of the studies as it may neglect to account for the nature of multiple interacting variables that impact water usages. These variables include the type of technologies adopted,

management practices, water quality, swine health/behavior, and diet composition. For example, water waste from cooling and sanitation purposes (the remaining 20% of the total water usage within the barn) will end up in the manure lagoon (Froese, 2003; Government of Manitoba, 2016). This potentially underestimates the quantity of manure requiring disposal by one-fifth. The advantage of using the atomistic approach allows for a small sample size to delve into a topic large-scale analysis, however, doing so often neglects the overall picture (e.g. the drinking patterns of swine due to varying concentration of specific solute without considering the impact of that solute on the water pipes within the barn).

The opposite of the atomistic view is the holistic approach. The latter generally requires a large sample size to allow researchers to create a generalized account for all water use pathways within an operational swine barn. While the holistic approach is manageable for large sample sizes, it comes at the expenses of uncovering in-depth details of each water function and how it behaves under different circumstances. The appropriateness of each approach will depend on the research focus.

3.2.1 A comparison with the Small Study (2001)

The present study differs from historical studies that examined the water management in the provincial swine industry but were constrained by the limited availability of water use data (Small, 2001; Froese, 2003; Nyachoti and Kiarie, N.D.; Alvarado and Predicala, 2013). As of 2017, Small (2001) was the only study that holistically analyzed the water consumption in several swine barns in Manitoba. Small (2001) was also sponsored by the CEC - in conjunction with third-party data. It consisted of nine farrow-to-finish production sites for a total of 12,775 swine spanning up to 615 days (1.68 years). However, of the nine projects evaluated only five

metered their water usages and submitted readings to the author (Small, 2001). In contrast, the 173 licenses (roughly equivalent to “production sites”) reviewed in this study covers over one million swine (sows, feeders and nurseries), and spans up to 5,840 days (16 years, between 2000 to 2015) – along with water readings submitted by each licensee. While the basis of the Small study (2001) is field experimentations representing 0.43% of the total Manitoba swine population, the present research accessed data through government documentations that covers one-third of the total provincial swine population.

One of several objectives under Small (2001) was “to apportion total water usage and waste production into components according to stage of production and function” (p.7). In contrast, the present study examined the total water usage and the usage in different stages of swine production (operation type) – excluding the partition of total water usage into specific functions. This exclusion was justified for two reasons. First, water records submitted by the licensees are obtained from meter(s) or timer(s) that are attached to the well(s) or pump(s) at the source of the water diversion, prior to the partitioning into various water use functions when entering the barns. For this reason, all references to sow, feeder and nursery usage will refer to the water demand of the entire swine barn. For example, sow water usage refers to the total water usage within a sow barn. Second, the holistic analysis of water usage allows for larger population size (173 licenses or production sites versus nine production sites) which is necessary to reduce the large numbers of confounding variables in different swine barns across Manitoba. Clarence Froese from DGH Engineering Ltd. echoed a similar statement over the insufficient population sizes seen in related studies which as a result, may lead to an unreliable conclusion (Froese, 2003).

Table 3.1: Comparison of the daily water volume (average, from Table 3.2): the present study versus the Small (2001) study.

	Present Study (litre/day)	Small (2001) (litre/day)	Difference (%) (litre/day)
Sow	19.83	26.35	6.52 (25%)
Feeder	8.00	11.70	3.70 (32%)
Nursery	4.20	3.80	0.40 (9.5%)

From Table 3.1, the average daily volume calculated in the present study is 15.83% lower than that of Small (2001). The differences may be contributed by the former having a substantially larger population size that minimizes the influence of significant outliers (such as uncommon barn practices). For example, one feeder barn in Small (2001) represented nearly half of the sampled population used the “auxiliary water nipple in each pen” that uses up to “40% more water” than more water efficient technologies (likely due to spillage) that closely matches the discrepancy of 34% under feeder in Table 3.1 (Froese and Yacintiuk, 1990: 11). The utilization of the auxiliary nipple drinker by the sole barn may have acted as a significant outlier in other feeder barns sampled (Small, 2001). The low difference in the nursery daily water usage between the present study and Small (2001), relative to the greater differences in the sow and feeder usage in Table 3.1, may be accounted for by the infrequent practice of using water for cooling purposes (temperature control) that reduces the daily variation in water usage in nursery barns (Matlock et al., N.D.). Furthermore, it was recorded from several VC businesses in several license files that the emerging business trend is to “keep the pigs [nurseries] longer and subsequently heavier” by as much as 10% of the traditional weight - matching the percentage differences shown in Table 3.1 (Government of Manitoba, 2017). With respect to sows, little information was provided by Small (2001) that arrived at the 26.35 litre/day, which is 134% of this thesis findings at 19.83 litre/day. Small (2001) reported that the sampled sow barns had

drinking water delivered via feed troughs and water nipple, but this is typical for sow barns across the Canadian prairies (Alvarado and Predicala, 2013).

3.3 Results – Estimates of Manitoba swine industry annual water usage

The average daily volume in Table 3.1 is derived from a 16 years period shown in Table 3.2. The total population size of swine in the present research is 1,005,663 head from 173 licenses (out of a total of 3,041,600 in Manitoba 2015, according to the Manitoba Department of Agriculture) (see Table 3.4). As stated earlier, the large population size is essential to validate conclusions on water consumption due to the large numbers of interacting variables that will influence the water usage among the sows, feeders and nurseries (Froese, 2003). Such interacting variables include water quality, livestock behaviour, diet composition, environmental factors, equipment design and placement, the physiological (behaviour) status of swine, etc. (Nyachoti, N.D.). Furthermore, no significant outliers were identified (using an online graphpad calculator software) among the volumes calculated in Table 3.2 for each year, under each class of swine. The lack of significant outliers may be attributed to a low level of diversity in water management practices in swine barns across the Canadian prairies. A 2013 survey examined 22 swine barns in the Canadian prairies, and additionally, the adoption of various types of water management practices (Alvarado and Predicala, 2013). The survey found that the adoption rates for different water management practices varies from as high as 97% (e.g. nipple drinker), to as low as 10% (e.g. drinking bowls, drippers for cooling), and split down the middle (e.g. spray/mist for cooling, hot/warm water for cleaning) (Alvarado and Predicala, 2013).

Table 3.2: Summary of the averaged daily usage spanning 16 years (2000 – 2015) from 173 licenses for sow, feeder and nursery operations.

(Source: Appendix 5 and Appendix 8)

Sow	Subset #	Dam ³	Avg. litre/day	Avg. imp/day		Feeder	Subset #	Dam ³	Avg. litre/day	Avg. imp/day
2000	47,140	332.83	19.34	4.26		2000	153,700	421.07	7.51	1.65
2001	68,790	453.40	18.06	3.97		2001	286,100	843.06	8.07	1.78
2002	73,070	531.89	19.94	4.39		2002	356,134	1,046.81	8.05	1.77
2003	79,070	579.05	20.06	4.41		2003	374,534	1,152.17	8.43	1.85
2004	84,570	637.84	20.66	4.55		2004	394,669	1,173.28	8.14	1.79
2005	90,570	677.12	20.48	4.51		2005	423,969	1,226.31	7.92	1.74
2006	104,830	771.05	20.15	4.43		2006	456,839	1,362.78	8.17	1.80
2007	119,830	912.34	20.86	4.59		2007	529,239	1,553.06	8.04	1.77
2008	127,980	943.59	20.20	4.44		2008	537,239	1,524.00	7.77	1.71
2009	131,100	913.50	19.09	4.20		2009	532,439	1,476.59	7.60	1.67
2010	131,100	899.99	18.81	4.14		2010	550,587	1,562.19	7.77	1.71
2011	128,400	904.35	19.30	4.24		2011	550,887	1,614.22	8.03	1.77
2012	127,050	918.47	19.81	4.36		2012	555,847	1,703.23	8.40	1.85
2013	132,950	978.29	20.16	4.43		2013	556,247	1,627.49	8.02	1.76
2014	134,450	1,014.11	20.66	4.55		2014	563,197	1,623.34	7.90	1.74
2015	136,300	976.17	19.62	4.32		2015	571,083	1,690.50	8.11	1.78
		Average	19.83	4.36				Average	8.00	1.76
		Range	± 1.10	± 0.25				Range	± 0.33	± 0.07
Nursery	Subset #	Dam³	Avg. litre/day	Avg. imp/day	Note: 1 dam³ = 1,000,000 litres Average is the statistical mean Range is the interquartile range The subset # represent the population of swine that the license was based on, unless otherwise stated by the licensee					
2000	83,000	155.55	5.13	1.13						
2001	103,000	169.34	4.50	0.99						
2002	175,800	236.07	3.68	0.81						
2003	175,800	273.74	4.27	0.94						
2004	175,800	267.58	4.17	0.92						
2005	185,800	293.24	4.32	0.95						
2006	245,800	337.95	3.77	0.83						
2007	248,300	331.19	3.65	0.80						
2008	248,300	324.09	3.58	0.79						
2009	245,200	354.93	3.97	0.87						
2010	235,200	342.94	3.99	0.88						
2011	237,200	378.58	4.37	0.96						
2012	252,200	412.70	4.48	0.99						
2013	262,200	457.68	4.78	1.05						
2014	298,280	463.84	4.26	0.94						
2015	298,280	470.64	4.32	0.95						
		Average	4.20	0.92						
		Range	± 0.63	± 0.14						

3.4 A comparison with the Clean Environment Commission estimates and methodology

The CEC used Small (2001) and data from Statistics Canada in an attempt to quantify the volume of water consumed by the Manitoba swine industry. As a result, the CEC estimated that 11,278.50 dam³ of water was utilized by the Manitoba swine industry in 2006. The CEC noted that the estimate usage was “higher than the total amount that Manitoba Water Stewardship states is allocated [9,554 dam³] for agricultural purposes” in 2006 (Clean Environment Commission, 2007a: 116) (see Table 3.3). However, the 9,554 dam³ figure is the total allocation volume for all agricultural operations with a license (including non-swine livestock), which does not represent the entire Manitoba livestock industry. Therefore, the comparison of 11,278.50 dam³ with the allocation of 9,554 dam³ is impractical.

Table 3.3: Comparison of the Clean Environment Commission estimate versus the present study (Based on litres/day from Table 3.2).

Year 2006	Allocation (dam³)	CEC (dam³)	Present Study (dam³)	Variation (dam³)
Usage (dam³)	9,554	11,278.50	8,143.27	3,135.23

Using the licenses collected for this research, to measure the proportion of usage versus allocation in 2006, approximately 2,471.78 dam³ of water were diverted against an allocation volume of 2,885.80 dam³ (see Appendixes 6 and 7). This meant that licensees in 2006 were collectively below the allocation threshold by over 14%. The 2,885.80 dam³ is significantly lower than 9,554 dam³ for two reasons. First, this research narrows the definition of swine operations through the exclusion criteria to reduce data interferences (see methodology). Second, the allocation volume excluded all none-swine livestock. Using the total population of swine in 2006, the present study estimates, using the volumes from Table 3.2, that the total 2006 water consumption in the swine industry was 8,143.27 dam³, which is below the CEC estimate by

almost 28% or 3,135.23 dam³ (see Table 3.3). The CEC estimated that in 2006 there were 372,700 sows followed by 1,110,800 nurseries and 1,436,500 feeders for a total of 2,920,000 swine in Manitoba.

The quantitative differences between the CEC Report and the present study is likely primarily due to the population sizes. The information for which the CEC Report relied upon when estimating the total provincial water usage was likely too small to draw valid conclusions. Clarence Froese from Manitoba Livestock Manure Management Inc. summarizes the general sentiments among swine researchers, even 15 years later, over the lack of reliable water use data in stating that “this serves to invalidate existing figures and leads to unnecessary speculation about actual total water use, particularly for publicly scrutinized large operations. As well, this lack of information hampers efforts to focus and prioritize water conservation practices” (Froese, 2003: 1).

Using the recorded number of swine in Manitoba, and the production type, a five years trend can be established (see Table 3.4) using the average volume calculated for the present study in Table 3.2 (Government of Manitoba, N.D.a). Since 2012, the total volume of water utilized increased annually on average by 2.07% (176.66 dam³), while the total number of swine per year increased annually on average by 2.13% (63,750 swine) (see Table 3.4). The similar proportional increase in both water consumption and population size suggest (one of) two scenarios. First, the “increase” in water consumption due to the emerging business practices of raising heavier swine (nursery, feeder) with greater number of offspring (per sow) is negligible to the total annual water consumption. Second, these emerging business practices may not be widely adopted by barn managers in the Manitoba swine industry.

Table 3.4: Total water consumption and the total swine population in Manitoba, 2012 to 2016. Non-bracket is population size, bracket is water consumption. The volume is in cubic decametres. (Source: Government of Manitoba, N.D.a and Table 3.1 under ‘Present Study’)

# & (Volume)	2016	2015	2014	2013	2012
Sow	326,900 (2,366.09)	321,200 (2,324.83)	319,100 (2,309.63)	314,600 (2,277.06)	313,300 (2,267.65)
Feeder	1,574,900 (4,598.71)	1,575,500 (4,600.46)	1,547,800 (4,519.58)	1,405,900 (4,105.23)	1,403,200 (4,097.34)
Nursery	1,179,900 (1,808.79)	1,144,900 (1,755.13)	1,074,800 (1,647.67)	1,136,200 (1,741.80)	1,110,200 (1,701.94)
Total	3,081,700 (8,773.58)	3,041,600 (8,680.42)	2,941,700 (8,476.87)	2,856,700 (8,124.08)	2,826,700 (8,066.93)

Unfortunately, no breakdown in the swine population sizes by production type was available prior to 2012 from the Government of Manitoba website, therefore it can be difficult to draw conclusions based on a five years period. Historically, the largest population of swine in Manitoba was recorded at 3.01 million head in 2007 (Honey, 2015). It declined to 2.68 million in 2009 before rising to 2.84 million head in 2012 (Honey, 2015). Logically, the rise and the decline in the population size will also influence the total volume of water utilized. The 8,773.58 dam³ of water utilized in 2016 was 630.31 dam³ greater than the presumed largest usage of 8,143.27 dam³ in 2006 when the Manitoba swine population was previously the largest. It should be noted that the 2006 total swine population size was not reached again until the year 2015 – making it likely that the total water usage in the provincial swine industry hovered around the 8,000 dam³ mark in 2010 and 2011 (Honey, 2015). Overall, the average water usage from 2012 to 2016 (Table 3.4) is approximately 8,400 dam³.

Considering the 173 licenses that represent over 1 million swine, one can say with 99% certainty that the calculated results are within the margin of less than ± 1.0 of what they would have been if the entire Manitoba swine population had been surveyed. Therefore, the present

study can reasonably surmise the daily volume of water calculated for the sow, feeder and nursery barns is a fair representation for swine barns in Manitoba. However, the calculated daily usage in the present study may not be proper for other regions (e.g. Michigan, North Carolina) for which the regional climate, environmental regulations and business attitudes may differ from that in Manitoba.

3.5 A comparison with other suggested daily volumes for different class of swine

Through the archival search in the license project files, there were two sources of rates uncovered that represented an earlier attempt to quantify the daily volume of water required per class of swine. However, these rates were not attached to any scientific study, but were previously calculated as a result of collective collaboration with selected Manitoba stakeholders (see Table 3.5). These two independent rates were calculated by the DGH Engineering and a collaborative group of stakeholders that provided a water use reference chart to the WULS. The former was time stamped from 1998 while the WULS reference chart were dated from 2002. Since the former was already four years older, the WULS numbers was likely considered to be more accurate and therefore preferred over the version presented by DGH Engineering. Despite originating from at least 20 years ago, the water use estimates from DGH Engineering in Table 3.5 is higher than the results of the present study by 7.13 litres/day (total cumulative difference). In contrast, the WULS and Small (2001) are above the estimate of the present study by respectively 5.40 litres/day and 9.82 litres/day. The close match of daily values compared to the present research results suggests only minor or negligible changes in water management practices over the 20 years span, despite the changing business practices of raising heavier nurseries, feeders and more offspring per sow. The calculation methodology concerning both the

DGH Engineering and the WULS reference chart is unknown. However, the documented volumes obtained from the WULS stated nine stakeholders that were consulted consisting of: two universities, one engineering company, one construction company, with VC businesses make up the remaining five.

Table 3.5: Comparison of daily water consumption values from several Manitoba sources.

Manitoba Literature Guideline	Sow (litres/day)	Feeder (litres/day)	Nursery (litres/day)
WULS (gov.)	25.57	8.50	3.36
Present Study	19.83	8.00	4.20
DGH Engineering 1998	25.53	9.36	4.27
Small 2001 (MB)	26.35	11.70	3.80

Several patterns emerged when comparing the daily volume for different class of swine in Table 3.5. First, the average nursery usage (from the WULS, Small (2001) and DGH Engineering) closely matches the result of the present study by 9.29% (0.39 litres/day). The equivalency for the feeder and sow from Table 3.5 were respectfully 18.81% (1.85 litres/day) and 23.19% (5.99 litres/day). The lower variation for nursery as compared to the higher variation for sow and feeder may be justified for two possible reasons. First, as stated earlier the practice of using water for cooling purposes is not normally utilized in nursery barns since piglets can tolerate up to 32.2 degree Celsius (Matlock et al., N.D.). The use of water for cooling purposes in the sow and feeder barns contributes to approximately 13% of the total water usage within the barn (Froese, 2003 without domestic usage), therefore the omission of cooling for nursery barns will limit the temporal trend fluctuations in water usage. Second, the growing cycle for nursery is generally four weeks before reaching the feeder stage while the growing cycle for feeders take

16 weeks before market ready (Government of Manitoba, 2016). Therefore, a greater variation in body weight in longer periods of raising livestock than that of shorter periods can therefore be expected, and a more consistent volume of water consumed daily per nursery than that of either feeder or sow can also be expected.

3.6 Results - Fluctuations in water use trend for sow, feeder and nursery barns

Despite the near lack of diversity in water management strategies in swine barns across the Canadian prairie, the occurrence of annual fluctuations in water use in Figure 3.1 suggests that third-party factor(s) were influencing the fluctuations across the Manitoba swine industry. However, the identity of these third-party factor(s) would logically be required to be both widespread across the province, and whose impact is significant enough on hundreds of swine barns to alter the long-term water use trends. Potential third-party factors identified in Manitoba includes air temperatures and occurrences of swine disease outbreaks. It is generally agreed upon by studies across North America that an increase in the temperature of the barn will lead to a higher water consumption among swine due to the biological mechanism of the livestock to control their internal body temperature via perspiration (Nyachoti, N.D.; Nyachoti and Kiarie, N.D.; Almond, 1995).

It should also be noted that an increase in water consumption will result in a greater quantity of slurry manure generated, which will prompt further water use within the barn for sanitation purpose. In addition, higher indoor temperatures will prompt swine operators to increase the frequency of sprinklers (cooling mechanism) which will result in higher-than-normal water usage (Matlock et al., N.D.). Due to the wide variation in the temperatures associated with the Manitoba climate (since 2000, average annual max. T° 33.69°C, average

annual min. T° -36.54°C , average annual T° 2.86°C), air temperature outside of the barn will likely play a key role in influencing the water use trend in Figure 3.1 (Environment and Climate Change Canada, 2017).

Disease (e.g. PEDv, circovirus, H1N1) among livestock is another potential factor that has the capability to influence several water use functions within a swine barn – and thus contributes to the annual fluctuation in water volumes for two reasons. First, the symptoms of swine-related diseases are akin to the consumption of poor quality water, in that it will induce a laxative effect in swine that will result in vomiting and diarrhea – prompting the livestock to consume a greater quantity of water to compensate for the water loss (Mroz et al., 1995). Second, swine operators associated with (or perceived) infected barns will increase the frequency of using water to sanitize the quarantined barn to restrict or eliminate the spread of the debilitating disease. According to Statistics Canada (2011), the year from 2006 to 2011 in Manitoba livestock industry was marked by series of outbreaks involving bovine spongiform encephalopathy (cattle), avian influenza (poultry) and H1N1/circovirus (swine). While not all the Manitoban swine barns were infected during that period, swine operators were likely using their contingency plans (increase sanitation effort) as a precautionary measure to protect their financial and livelihood investments (Government of Manitoba, 2017).

3.6.1 Climate: air temperature

In Figure 3.1, the average annual air temperature in Manitoba from 2000 to 2015 fluctuated between 1.4°C (2008, 2013 and 2014) to 4.5°C (2006 and 2012) (Environment and Climate Change Canada, 2017). During the selected 16 years period, the average water volume for sow, feeder and nursery annually fluctuated by, respectively, 4 dam³ (range 14.47-18.44 dam³), 1.90 dam³ (range 16.41-18.31 dam³) and 7.18 dam³ (range 13.63-20.81 dam³). Any relationship between air temperature and water usage, is most strongly manifested among the feeder group for which the annual conformity (positive correlation) occurs in 12 of the 15 years (80% of the time). The year 2000 was excluded because it is unknown whether the 2000 water usage was higher or lower than 1999. For nursery, this occurred in eight of the 15 years (53%), while for sow this occurred in five of the 15 years (33%). The higher conformity for nursery than sow, over 15 years, in Figure 3.1 is unexpected. Since nurseries have a higher temperature tolerance than sows or feeders, a lower correlation for nursery compared to sow is anticipated.

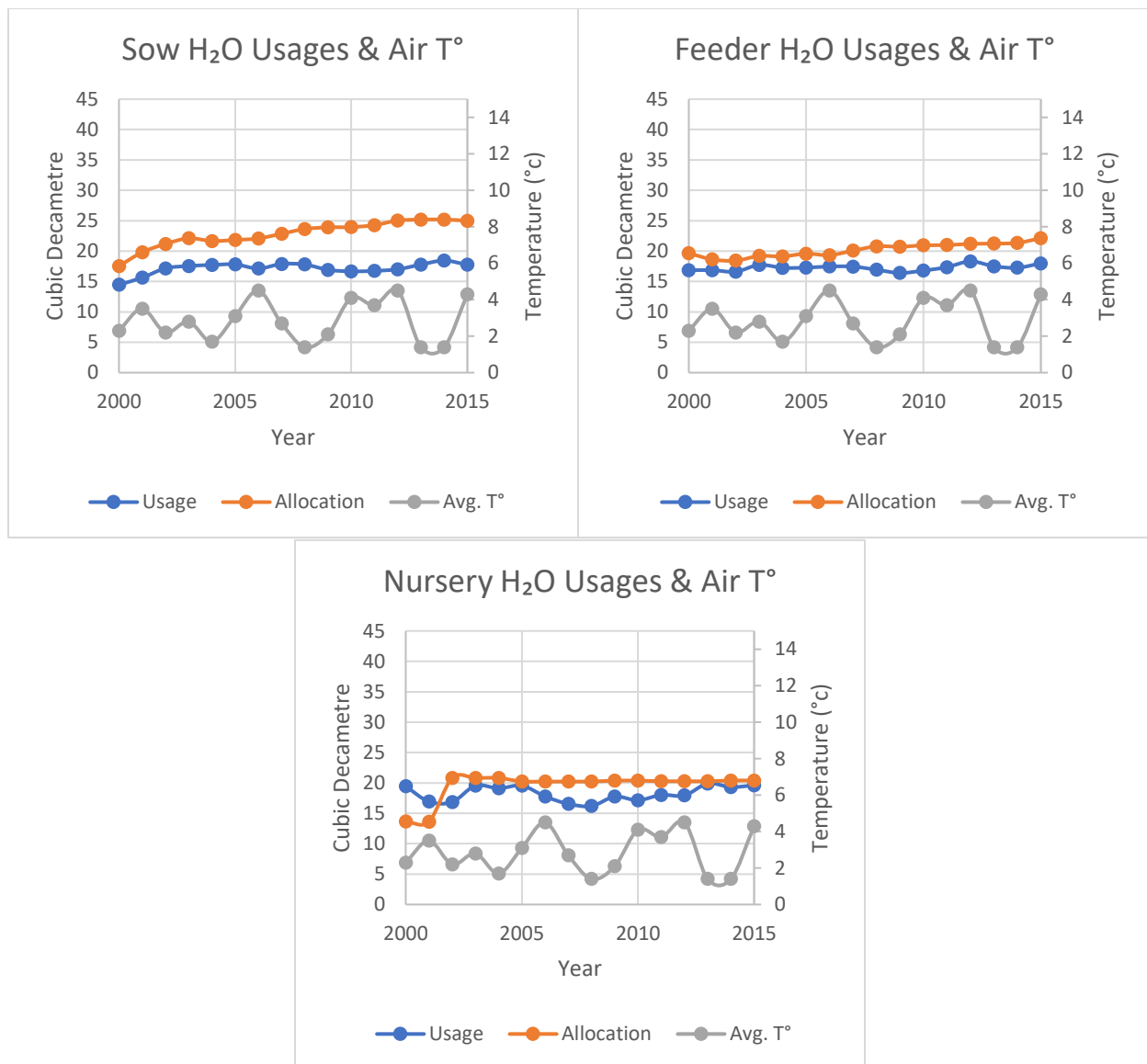


Figure 3.1: The average annual water usage among the 173 licenses.
(Source: Appendix 5 and Environment and Climate Change Canada, 2017)

The nursery water use trend in Figure 3.1 defied the correlation patterns observed in the sow and feeder trend from 2009 to 2014 in that water usages decreased. Instead, the water use trend for nursery increased continuously from 2009 to 2013. The possibility of regional droughts playing a role in the annual fluctuations in Figure 3.1, due to the prairie climate of the southern half of Manitoba, was briefly examined during interpretation of collected data for this thesis with assistance from the federal website that hosted a tool called the “Canadian Drought Monitor”.

This tool kept drought-related records across Canada since the year 2002. For example, the “monitor” indicates that the most severe drought since 2002 in the southern half of Manitoba occurred in 2006 and this was not reflected in Figure 3.1 whose highest annual water usages occurs during the years of low or complete lack of drought. In fact, the sharpest increase in water usages for the three class of swine occurred during late 2000s that, according to the “monitor”, was marked by periods of low or no droughts. Since 86% of the licenses (148) in the present study relied on GW sources, which is less susceptible to the impacts of drought than SW sources, it is likely that seasonal drought plays a negligible role in influencing the overall water use fluctuations. It should be noted that a brief analysis of all SW licenses against the air temperatures reveals a positive correlation of only six years of 15 years (40%). This is likely attributed to the size of farm reservoir(s) that generally holds twice their annual requirement of water. Overall, this suggests that the outdoor air temperatures played a widespread and significant role in affecting sufficient numbers of the swine operations in the present study to influence the annual fluctuations observed in Figure 3.1. The impact on the trend fluctuations due to drought conditions in southern Manitoba, at glance, appears to be negligible.

3.6.2 Disease outbreak

Statistics Canada identified the period from 2006 to 2011 to be marked with series of livestock disease outbreaks affecting poultry (avian influenza), bovine (bovine spongiform encephalopathy) and swine (circovirus, swine influenza such as H1N1). However, it was not until 2009 that the first swine barn in Manitoba had been tested positive for the H1N1 epidemic before it subsequent spread to other barns in the province (Pasma and Joseph, 2010).

Unfortunately, any interpretations involving swine disease outbreaks as a factor in the present study was confined to the timeline of the epidemic in Manitoba and supplementary studies. Even then, extensive online research yields little information on the annual number of confirmed cases relating to viral outbreak among swine livestock in Manitoba since the year 2000. In addition, licensees are not required to report to the WULS whenever their barn becomes quarantined due to a viral outbreak. Therefore, the present study is unable to cross check the graph of annual water usage and the number of infected cases to uncover potential relationships. If a viral outbreak were to impact the water use fluctuations in Figure 3.1, one can expect to observe an increased in water use from 2006 to 2011 before falling back down to pre-2006 levels. An H1N1 epidemic occurred in Manitoba from 2009 to 2010 – which is correlated with an uptick in nursery water usage in the same period in Figure 3.1 (Embree, 2010).

In contrast, the water use trends for sow and feeder dipped. Coincidentally, nursery as opposed to sow and feeder, are the most vulnerable to the impact of swine diseases due to the viral laxative effect that can cause severe diarrhea and death. Thus, any potential impact of the viral outbreak, on water usage, should be most prominently represented in the nursery group. It should be noted that this thesis cannot substantiate a connection between H1N1 outbreak and the impact on water use trend, but only has speculated through supplementary materials. The lack of more pronounced observable changes in the water use trends in Figure 3.1, as a result of viral outbreak lasting from 2006 to 2011, at most can be explained by a lack in sufficient number of infected swine barns among the 173 licenses in the present study.

The lack of sufficient sampling of licensees with infected swine barns is probably due to several reasons. First, the spatial isolations between swine barns in Manitoba generally limit the spread of viral movement – thereby leading to the infection of fewer barns during the outbreak

period. In this thesis, any reporting water usages from infected barns could be offset by the volume of non-infected barns. Second, 84% of the 173 licenses (146) is under the VC business framework for which the swine operators received coordinated assistance from environmental specialists (employed by the corporate partnership) that are partially tasked to prevent or minimize the viral spread/damage in a prompt manner (Government of Manitoba, 2017). Independent businesses, without employing environmental specialists, are likely suffer the most compared to VC, in terms of livestock mortality.

Of the two major variables examined, the air temperature (significant and widespread) is one of the key factors identified that influence in the fluctuation of annual water use in Manitoba swine industry, and to a lesser extent – livestock disease outbreak is the other significant factor (but not as widespread across the province). Overall, it can be inferred that the required volume of water for different class of swine will vary annually due to factors beyond administrative control. Furthermore, predicting higher-than-normal seasonal temperatures or impending livestock epidemic can be used as a tool to anticipate the volume of water that will need to be utilized for any given period under consideration.

3.7 Results – Overall trends

In Figure 3.2, the average water uses for all the three classes over the 16 years period (2000 – 2015) had not fluctuate significantly from the annual estimate of 17.34 dam³ per license (between 16 dam³ and 18 dam³). In exception to nursery, the water use volume trend had been roughly consistent since the year 2000 – growing at an annual average rate of 7.31% based on the previous year. This resonates with a 2013 survey by Alvarado and Predicala (2013) that could be interpret as limited diversity in water management practices in swine barns across the

Canadian prairies. In contrast, the licensed allocation volume increases on average 8.06% based on the previous year. Examining the factors influencing both the water usage and allocation trend in Figure 3.2 can be done by using three control groups and by observing how those trends behave between groups (i.e. trend shape) relative to Figure 3.2.

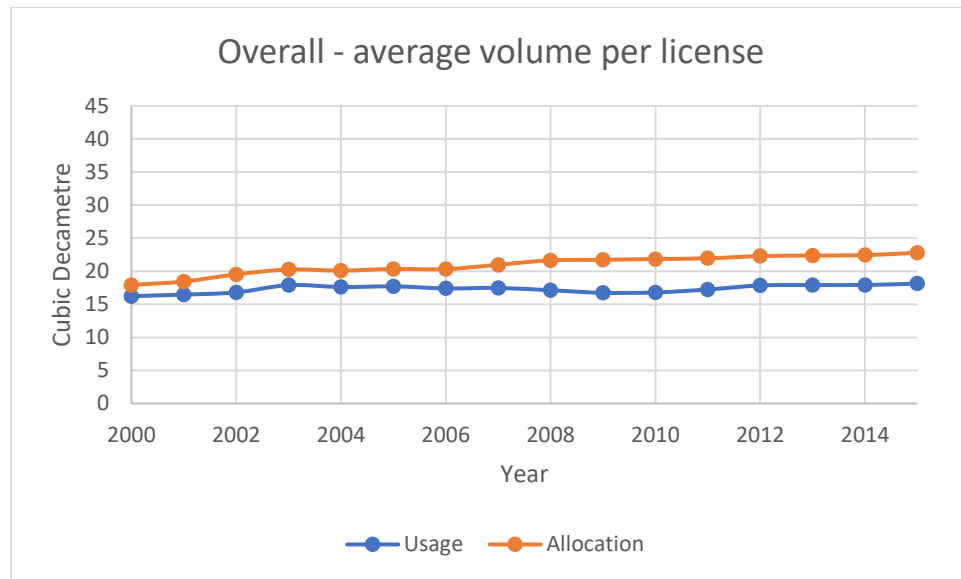


Figure 3.2: The average volume of water used by 173 license holders, 2000 to 2015. (Source: Appendix 1)

The first control group that will be discussed is based on the source of water being diverted for the operation of the swine barn – through SW or GW. Both sources of diversion differ in the licensing procedures for which the WULS allocate water from, availability of water (seasonal versus non-seasonal) and the mechanical differences of diverting water via the use of a well or surface pump.

The second control group to be covered is based on geography, approximately half of the 173 licenses are in eastern Manitoba for which the swine moratorium persisted beyond the year 2015. The remaining half are situated in the RoM for which the moratorium was unevenly applied for one year from 2007 to 2008. This control group will examine the potential

differences in the behaviour of swine operators, between regions, and will regard water management as the result of the moratorium. The moratorium prevents expanding swine barns that limits the number of swine reared – which in turns limits the profit margin per swine sold.

The last control group pertains to the two business models under the three-site model, independent and VC, which differs in water management practices which will play a major role in influencing the extent of water use. The independent model precedes the VC model and the latter came to prominence after the abolition of the “single-desk selling system” (hog marketing board) in the late 1990s that absorbed dozens of independent businesses under few companies (Clean Environment Commission, 2007a: 20-21). Since both of these business models operated under different frameworks, there can expect to be differences in the volume of water utilized and the licensed allocation of water.

3.7.1 Relationship between sources of water uptake and recorded water volume

More licenses in the present study divert from the GW (148) than SW (25) sources for three reasons. First is the issue of reliability, these swine barns operate 365 days, and SW sources are at risk of freezing for at least three of the 12 months. Second is the issue of downtime, as piping water from reservoir risks the chances of clogging the filters with mud and debris that jeopardize the flow of water into these swine barns (Government of Manitoba, 2017). Third is the issue of safety, SW has the “highest risk” of bacterial and chemical contamination due to the contributions of run-off from agricultural and urban setting - and the “concentrating effect of evaporation” on shallow water body (Nyachoti and Kiarie, N.D.: 218). Where GW is unavailable or restricted, pumping SW is sometimes mixed with municipal water to dilute the contaminant.

(Nyachoti and Kiarie, N.D.). However, the cost of municipal water is one of the primary reasons why GW is preferred over municipal connection (Government of Manitoba, 2016).

The licensed allocations are established by the WULS by which water is only allocated if it can be proven that such diversion will not be a detriment to water sources or to other stakeholders. This will be expanded upon in Chapter 4. In Figure 3.2, since 2006, it appears the licensing regime had been increasingly allocating more water than necessary for swine operations. Prior to 2006, nearly all licenses in the present study relied on GW sources for which their allocation is based on the daily water requirement of the barn. Since 2006, more licenses were issued for swine operations that are dependent on SW bodies whose allocation, based on the size of the reservoir(s), is twice their annual requirement. It should be noted that these reservoirs carry unspecified volumes of water over to the following year. For that reason, SW licensees rarely exceed their annual allocation limit (if 2000 and 2001 in Figure 3.3 is excluded due to insufficient number of licenses). Therefore, the water use trend for GW sources in Figure 3.3 can be viewed as a proper representation of annual water usage versus allocation over the temporal period. In turns, the close conformity between water use and the allocation threshold demonstrates that excessive water is not being allocated by the province. Therefore, the licensing staff likely comprehend the water volume required by Manitoba swine operators.

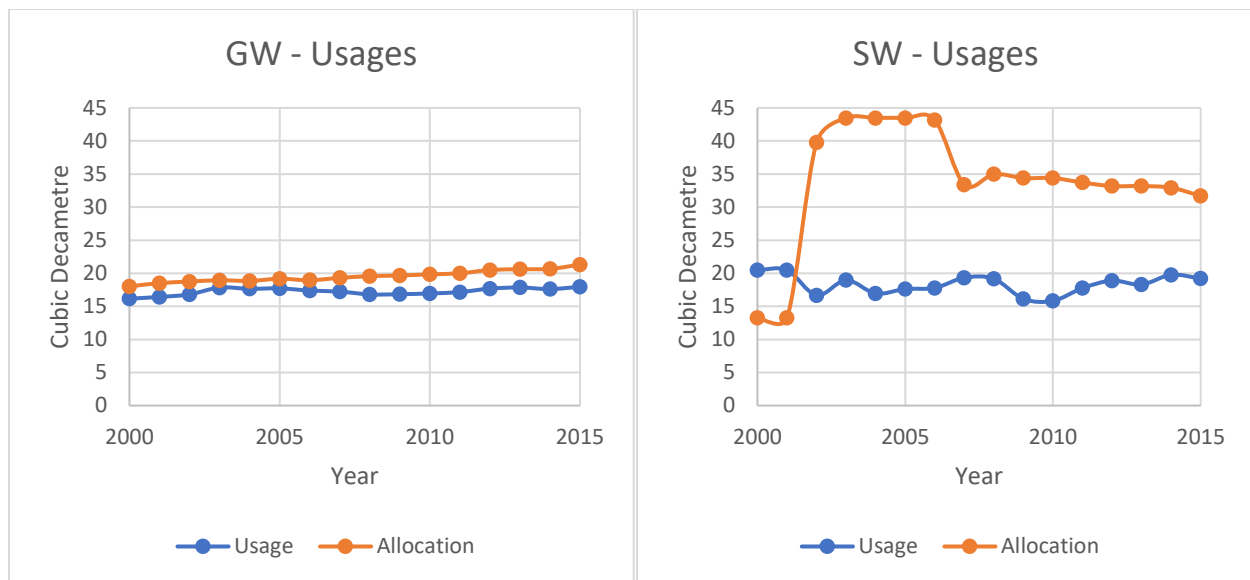


Figure 3.3: Summary of average water usage by surface water and groundwater license holders. (Source: Appendix 2)

In addition to storing at least two years of water in reservoir(s) as insurance against seasonal droughts, most SW licensees in the present study are confined to diverting water from the designated creeks, rivers, or dugouts during the spring flow period from March 31st to May 30th (Government of Manitoba, 2016). These restrictions are in place to protect the ecological function of natural water bodies because the SW recharge rate is often reduced (or ceased) during the summer and fall periods (Government of Manitoba, 2016). When examining the water usage for GW in Figure 3.3 – the trend observed is relatively static, adding credence that GW are less affected by drought or air temperature than SW, in which the latter experienced larger degree of fluctuations that coincides with rising and declining annual air temperature as seen in Figure 3.1.

Of the 25 SW licenses, ten are identified as sow (18% of total SW licenses in the present study) and feeder operations (11%) with the remaining five belonging to nursery operations (21%) (see Figure 3.1). Water usage by SW licensees are on average 49.80% or 18.78 dam³ below their annual licensed threshold. The equivalent for GW licensees averaged at 11.59% or

2.29 dam³ below the annual allocated threshold annually. In fact, the volume of water allocated for sow operations is averaged almost 25% above the actual reporting water usage. For feeder and nursery, that number is respectively close to 14.5% and over 5% (see Figure 3.1). Since most SW licenses are sow-based, this class of development have the largest gap between the reported usage and allocation threshold over a 16 years period. Thus, nursery licensees with the fewest percentage of SW license, better reflect the allocation of water versus actual reported water usage according to class of swine (see Figure 3.1). Overall, the source of water plays a key role for which water is allocated.

3.7.2 Relationship between geography and recorded water volume

In eastern Manitoba and in the RoM, there are respectively 5,613 and 5,457 swine per license in the present study. This explains the consistency in the average volume of water use per year, between the two regions, that differs on average by 4.45% on an annual basis (see Figure 3.4). The allocation trend tells a different story. All but one of the 25 SW licenses are in the RoM which account for the average 5 dam³ difference on an annual basis between the usage and the allocation threshold in Figure 3.4. The single SW licenses reside in eastern Manitoba and the differences in the trend between usage and allocation do not differ by more than 2 dam³ on average annually. Therefore, the region with the most SW licenses will experience the greatest discrepancy between reporting usage and the licensed allocation. Both regions faced declining and rising water usage between 2008 and 2014 that coincides with the air temperature trend in Figure 3.1. The reason for the observed fluctuation patterns cannot be substantiated based on the gathered data for the present research. This may be due to the climate differences between the RoM (prairie classified) and eastern Manitoba (mixed prairie-forests) (Manitoba Archaeological

Society, 1999). Air temperatures in the prairies provinces tend to have higher (summer) and lower (winter) extreme ends than in forested areas. This may account for the greater fluctuated trend for water usage in the RoM than that of eastern Manitoba in Figure 3.4.

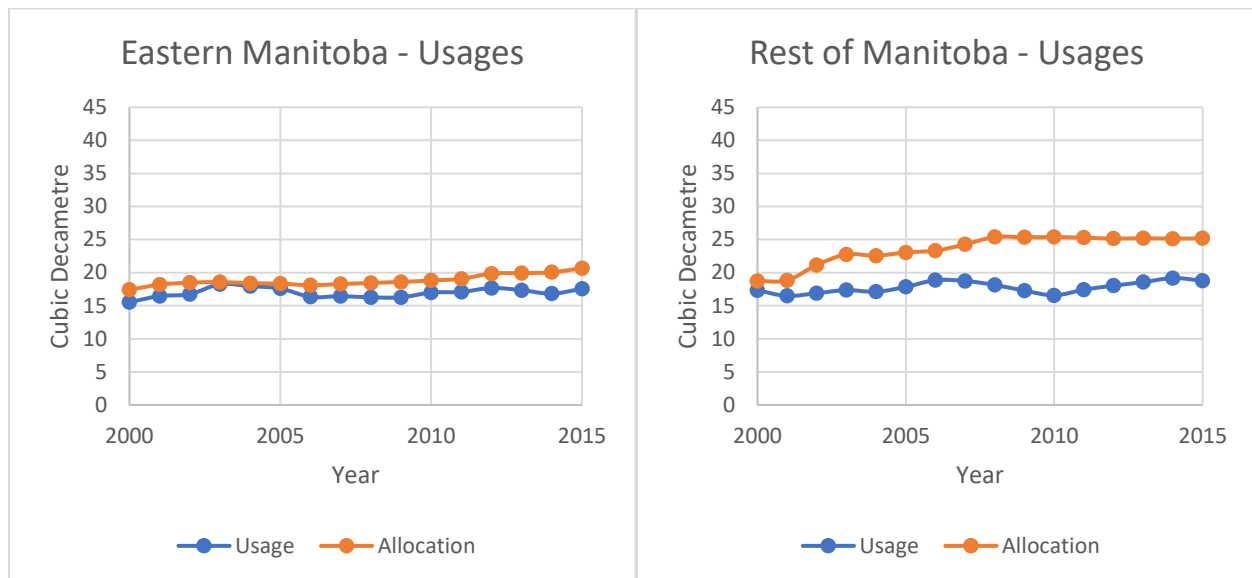


Figure 3.4: Summary of average water usage by licensees in the eastern and in the rest of Manitoba. (Source: Appendix 3)

The awareness of licensees regarding water management practices and the benefit of resource conservation can be assessed (albeit limitedly) with the collected data by establishing the temporal baseline of before the existence of provincial swine moratorium. Rearing a larger number of swine through barn expansion is considered critical to remain profitable by those in the industry, particularly due to the past decade of low profit margin per swine sold. However, the moratorium prevented the expansion of these swine operations from 2007 to 2008 in most regions of the RoM, and it remained in effect for the eastern region until the end of 2017.

Whereas the moratorium persisted in the eastern region and the limited profit margin per swine sold, this should logically be viewed as an incentive for swine operators to reduce operational cost in part by reducing the excess waste of natural resources. Handling, moving and storing

excess water/waste can double the operational expenses associated with water into the hundreds of thousands of dollars annually (Muhlbauer et al., 2010). The differences in the allocation and the water use trends between the two regions can be accounted for by the number of SW licenses and the average number of swine reared. Thus, there was not an observable change in trendline, in either regions, prior to and when the moratorium was implemented (Figure 3.4).

Any significant changes in water management behaviour, due to the moratorium, would have led to an observed decrease in average water use in eastern Manitoba - from the pre-2007 level in Figure 3.4. There is little difference in the volume of water utilized per license between the two regions over 16 years. Most swine barns in Manitoba were built during the 1990s with a life expectancy of up to 30 years and were accompanied with years of low profit margin per-swine sold, there is probably little incentives among swine operators to invest in barn renovations/repairs (Prairie Hog Country, 2014). The outcome of this hypothesis would see low diversity in water management practices adopted in swine barns across Manitoba, leading to little changes in annual volume of water usage per license for the last 16 years or less. Speculatively, it may not be financially feasible (nor easily recoupable) to invest in upgrading the infrastructure of the barn that is at least halfway through the lifecycle. Any link between the moratorium and the effectiveness of implementing water conservation practices is thus speculative and requires validation from future research.

3.7.3 Relationship between business models and recorded water volume

Both business models are characteristic of the three-site method for swine farming that emerged during the 1980s (in contrast to all-in-all-out that are associated with mixed farming). However, the corporate structure of these models differs significantly, and the rise of each model occurred during different decades. The independent model is characterized by the operational facilities, the land, and livestock being owned by the proprietor whom is also responsible for the day-to-day activities while keeping track of the local and regional environmental regulations (Novek, 2003). Since independent businesses do not form corporate partnerships, they are financially limited in the number of swine that can be reared (averaged 4,556 swine per license) as opposed to being limited by the carrying capacity and infrastructure of the barn. During the 1990s, the VC business model made their debut, during the changing market conditions, which includes the abolition of the single-selling desk system by the provincial government (Clean Environment Commission, 2007a).

VC businesses refer to a company that is tied to, or dependent on, third-party corporate partnership. Examples of the two largest corporate partnership in Manitoba include Maple Leaf Foods Inc. and Hylife Ltd. Novek (2003) articulated that in this model “corporations contract with barn operators to supply goods and services, including swine, feed, antibiotics, veterinary services and the climate-controlled structures for the swine. The farmer provides the barn, labour and the land on which the liquid manure waste must be spread” (Novek, 2003: 9). In some cases, the corporate partnership owns the land and the barns while renting it out to swine operators. The purpose of the VC model is two-fold. First, to control the movement of swine between barns to minimize the spread of viral infections. Second, to capitalize on “cheap land, cheap feed, and a low population density in rural Manitoba” (Clean Environment Commission, 2007a: 20) which

in turn lowers operational expenses by spreading out the cost across barns, allowing operators to raise a larger number of swine per barn (averaged 5,724 swine per license) (Government of Manitoba, 2017). Thus, the result is increased biosecurity and a maximized profit margin per swine sold (Clean Environment Commission, 2007a).

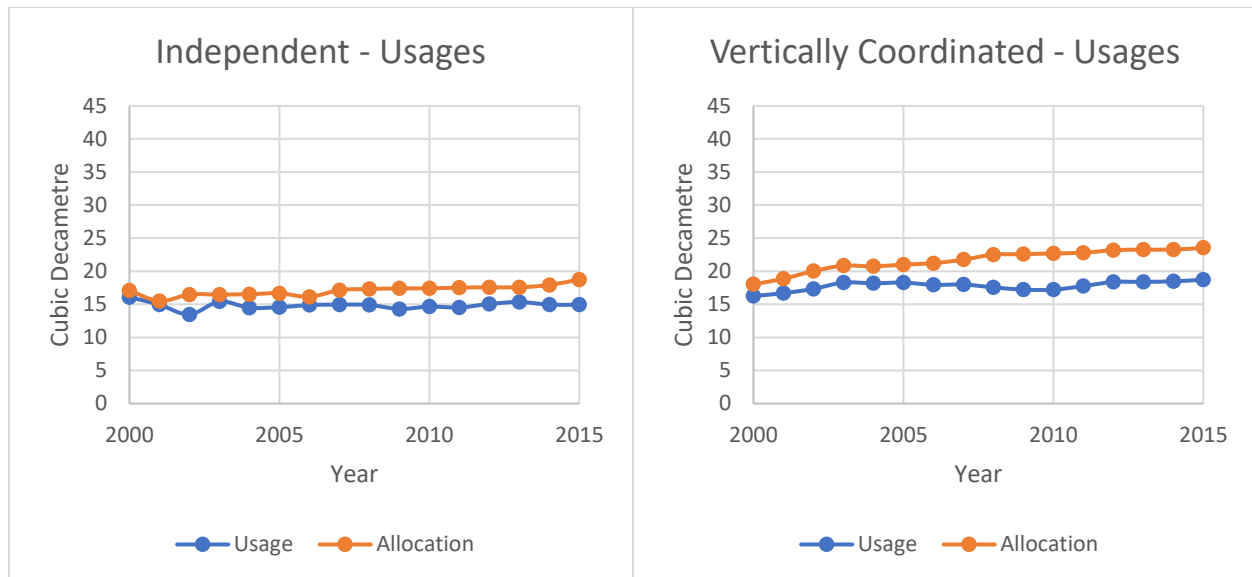


Figure 3.5: Summary of average water usage by independent and vertically coordinated license holders. (Source: Appendix 4)

An average difference of 1,168 swine per license between the two business models translate to an annual difference between 1.52 dam³ (nursery, low range from Table 3.2) to 8.92 dam³ (sow, high range from Table 3.2) of water utilized between license holders of different business models. This accounts for the VC operators using 16.44% more water per license than independent operators on an annual basis in Figure 3.5 (averaged 14.85 dam³ per independent license holder and 17.79 dam³ per VC license holder, a difference of 3 dam³). In addition, approximately 23 of the 25 SW licenses falls under the VC business model, which accounts for the higher allocation threshold than the independent business trend in Figure 3.5.

3.8 Summary

The swine population sizes differ between the study sponsored by the CEC and the present research by almost 79 times. As a result, the 2006 water use estimate for the Manitoba swine industry differ by almost 28%. The CEC pegged it at nearly 11,300 dam³ of water while the present study calculated it slightly above 8,100 dam³. From 2012 to 2016, the annual differences narrowed to 24% (CEC estimate at 11,070 dam³ versus the present study at 8,400 dam³).

Through the disaggregation of WURs into control groups, several characteristics can be ascertained. The fluctuations in water usage are influenced by class of swine development (air temperature, drought, disease outbreak). The volume of annual water usages was influenced by business models – the average VC licenses rear 1,200 more swine than independent licenses – resulting in higher water usage. The perception of excess water volume being licensed by the WULS is contributed to SW users being allocated twice their annual requirement – based on the size of their reservoir as insurance against seasonal drought. Geographically, the RoM (prairie) is more susceptible to water use fluctuations than in the eastern region (woodlands). Despite the varying temporal length of the moratorium between regions, no major changes were observed in water use volumes or patterns. Overall, the majority of the license holders in this thesis are associated with feeder operation in eastern Manitoba relying on GW sources under the VC business model. Licensees operating nursery barns are the least frequent.

4.0 *The Water Rights Act*, licensing provisions and concerns of the Clean Environment Commission

4.1 Introduction

Several policy concerns expressed by the CEC Report cast doubt whether water is being managed responsibly and sustainably by the provincial licensing regime. Specifically, as it pertains to monitoring the compliance of license holders to the conditions of their license(s). In Chapter 4, the findings between the CEC Report and the present study on the provincial licensing regime are compared and analyzed. This Chapter begins with a historic overview of the WRA since the 1930s, and the review of licensing provisions in the context of a swine operation. Some examples of the licensing provisions include the licensing steps, allocation of water for licensing, and submitting WURs as per the licensing conditions. These discussions lay the foundation for the next part of this Chapter that involves addressing the validity of each concern expressed by the CEC Report with findings uncovered in the present study.

4.2 Clean Environment Commission findings review

The final CEC Report on the water consumption in Manitoba swine industry was centered on two concerns as it pertains to the provincial licensing regime. First, the Department of Manitoba Conservation “does not record or aggregate” the submitted readings by the licensees “to ensure that operators are not exceeding their licensed amount” (Clean Environment Commission, 2007a: 114). Second, since these readings are “not recorded” by Manitoba Conservation, in addition to “the large number of operators that are not licensed, makes it difficult to get a firm grasp on the amount of water the hog production sector consumes”. Therefore, “it is difficult to determine if the resource is being managed to maximize its

sustainability” (Clean Environment Commission, 2007: 115). Addressing or validating these concerns will involve examining the context of these concerns, particularly the history of the WRA and the licensing provisions involved in issuing a license in the context of a swine operation. These are followed by addressing the CEC concerns by incorporating several findings from Chapter 3 and Chapter 4.

4.3 History of *The Water Rights Act*

From the time the province of Manitoba was established in 1870, until the 1930, the sole authority for the provincial-wide management of natural resources (water, mining, fisheries, forestry, etc.) fell under the federal jurisdiction in Ottawa (Manitoba Law Reform Commission, 2015). In the 1930s, the federal government transferred this authority, under *The Natural Resources Transfer Agreement*, to the Government of Manitoba. This transfer triggered a plethora of provincial resource management acts that includes (but not limited to): *The Forest Act*, *The Mines Act*, *The Water Rights Act*, and *The Water Power Act* (Manitoba Law Reform Commission, 2015). At the time of inception, the focus of these Acts was geared towards increasing the provincial coffers and to limit the scope of resource extraction (Manitoba Law Reform Commission, 2015). As of 2017, these Acts are still in effect and it makes up for the larger shares of Manitoba regulatory framework for the management of natural resources.

The provincial jurisdiction and the regulatory authority for the diversion of water from natural sources are governed under the WRA which states that “no one may divert or use water, or construct, establish, operate, or maintain the structures for these purposes without a Water Rights License”, except for domestic use (at a rate no greater than 25,000 litres per day) (Government of Manitoba, 1987). Presently, the purpose of the WRA is to ensure that the water

resource is allocated in a sustainable way that benefits most stakeholders. Originally, the WRA was only applied to surface water bodies that cover over 94,000 km² area, or 14.51% of the total 648,000 km² in Manitoba (Statistics Canada, 2005). Diverting water from aquifers was not addressed in the original WRA until an amendment was made in 1972 to include references to GW uses (Government of Manitoba, 2000). The last major amendment to the WRA occurred in 1987, which introduces the provincial framework for licensing requirement as well as fees and enforcement measures (Government of Manitoba, 2000). It should be noted that the WRA does not address the issue of water quality. The regulatory authority for water for quality rests with the Environmental Approvals Branch.

The WRA itself is described as being “more permissive than prescriptive” and a considerable amount of discretion is provided to the Minister of Sustainable Development to administer the WRA (Government of Manitoba, 1999: 57). For example, there is series of sections and subsections under the WRA that is largely based on what the minister “may” do - based on the principle of “What is in the best interests of the residents of Manitoba” (Government of Manitoba, 1999: 57). This principle allows decision-makers to adapt to the temporal changes in public values regarding the society, environment and the economic aspects on water diversion and usage (Government of Manitoba, 1999). The tools to administrate the WRA may be created by the Lieutenant Governor in Council under *The Water Rights Regulations*.

4.4 Water use licensing provisions

For a license to be issued, it must be reasonably demonstrated that the proposed project will not likely have unforeseeable adverse effects on the biophysical environment and it will not conflict with the WRA. Figure 4.1 outlines the licensing procedure in the province of Manitoba. A preliminary investigation involves analyzing three components, although it may include additional components depending on the nature of the project application and its location (Government of Manitoba, 2018):

- a works description, of the proposed project using the water as prescribed on the application;
- the water requirements, for the proposed project and the justification from the proponent for the requested volume (during renewal of a license, the provided WURs is considered);
- a resource evaluation, this generally examines the type of water sources (see Image 4.1) and subterranean geologic or terrestrial surficial characteristics, allocation/water budget availability (if previously established), known stakeholders upstream/downstream or well users immediately surrounding the location of the proposed well

If the application passes a preliminary investigation by the licensing technologist, a preliminary works permit (GW exploration permit or SW development authorization) lasting for one year will be issued to the applicant (Government of Manitoba, 2018). Accompanying the permit is the requirement for a registered hydrogeologist (Engineers Geoscientists Manitoba) to administrate the necessary testing and to document the results in a consultant report (see Image 4.1). The report is then delivered to the WULS - once the development permit expired. Examples of the results coming from well testing includes (transmissivity, specific capacity, and



Image 4.1: Images of surface water pumps and groundwater wells belonging to different swine operators with a valid license. Top: SW diversion with the use of pumps. Bottom: GW diversion by using wells. (Source: Department of Sustainable Development, Government of Manitoba, 2017)

A comprehensive license investigation involved analyzing the consultant report to assess the viability of the application by examining whether the biophysical environment and stakeholders would be adversely impacted by the proposed project if it were to proceed. With respect to the comprehensive investigation (with emphasis on GW, SW will be covered in 4.4.3) covering the biophysical environment, the following questions are considered by the licensing staff (Government of Manitoba, 2018):

- “have well(s) or pump(s) of sufficient capacity been developed to provide the required water?”;

- “what is the calculated interference drawdown at nearby domestic or licensable wells in the same aquifer?”;
- “what is the location of the nearest provincial monitoring well in the same aquifer?”;
- “which aquifer is the nearest provincial monitoring well completed in?”;
- “what is the historic fluctuation in water levels at the nearest provincial monitoring well(s)?”;
- “are in-stream flow needs a consideration?”;
- “are nearby domestic and/or water rights projects expected to have sufficient available drawdown to accommodate the calculated interference drawdown?”

The other half of the comprehensive license investigation account for the consideration of the stakeholders (generally within several miles radius of the proposed well or pump) surrounding the proposed project, and additional regulatory considerations (access, permits, approvals) that may be required for the project to proceed. Several questions are considered, however further questions may be included depending on the scope of the project (Government of Manitoba, 2018):

- “does the proposed use/change conflict with other existing water rights?”;
- “does the use/change conflict with protectable interests in existing domestic wells or pumps?”;
- “is the project as proposed in the public interest?”;
- “is there unappropriated water at the proposed source?”;
- “is there a credible threat of serious or irreversible ecological damage?”;

- “is there reasonable expectation that the applicant plans to construct the works and apply the water to the intended beneficial use with reasonable diligence?”

Consideration of both the biophysical environment and social regulatory aspects from the consultant report form the basis of a licensing decision, which if granted, is supplemented by proposed terms and conditions of the license. However, during an application assessment, the application may be put on hold if an insufficient volume of water is available (e.g. as in most sub-basins of the Assiniboine Delta Aquifer in Western Manitoba) or if the delay is attributed to the lack of information (on part of the proponent) for the licensing assessment to proceed (Government of Manitoba, 2018). The length of time for which an application is processed by the licensing staff depends on the application being either a first-time or a renewal of a pre-existing license (see Table 4.1).

Table 4.1: Average wait time (year) for first-time and renewal applications to be processed. There is less resource expenditure for processing renewal application as most information are already gathered from the original application process. Processing first-time applications require greater resource expenditure to obtain information that have not been establish. This includes all category of water usage.

(Source: Department of Sustainable Development, Government of Manitoba, 2017)

New App.	2012	2013	2014	2015		Renew App.	2012	2013	2014	2015
Avg. time	5.31	3.13	3.48	3.53		Avg. time	2.13	1.67	2.30	2.28
Avg. total	3.86					Avg. total	2.09			

Processing renewal applications is responsible for nearly half the time for first-time applications (2.09 years versus 3.86 years) because most of the biophysical environment and the social regulation aspects are covered under the first-time application process (see Table 4.1). However, renewing a license requires the licensing staff to account for factors subject to modification over time such as new public comments, submitted WURs, changes to the licensed project since the last assessment process (e.g. corporate practices, technologically). First-time

applications, however, require greater expenditure of resources in order to acquire the information for assessing the two aspects. Thus, the applicants will also contribute to the wait time.

There are some exceptions to the rule that a project whose diversion of water exceed the rate of 25,000 litres per day must apply for a license. First, projects using water for municipal and industrial purposes technically have no minimum licensing threshold. Second, projects that use more than 25,000 litres per day, from either the municipal pipeline or the community water distribution system, do not require a license.

It should be noted that while a license legally prescribed the allocated volume of water that a licensee can divert from SW or GW sources, these allocations may be rescinded or altered under extraordinary circumstances (Government of Manitoba, 2017). For example, a severe drought spanning several years which caused water levels to deplete to unsafe levels may prompt the Minister of Sustainable Development to temporary rescind the right to use water (or lower the allocation volumes) within a given area, from a lower priority use in favour of a higher priority use (Government of Manitoba, 2017). The following priority of water usage is ranked from high to low: domestic, municipal, agricultural, industrial, irrigation and other purposes (e.g. geothermal, recreation). This power vested in the Minister of Sustainable Development was not observed nor mentioned in any of the 173 license files, which is defined as agricultural under the WRA. Agricultural purpose is defined as water used “-for the production of primary agricultural products, but does not include the use of water for irrigation purposes”, primary agriculture in this sense refer exclusively to livestock operations. In contrast, irrigation purpose is strictly defined under the WRA as using water “for the artificial application to soil to supply moisture essential for plant growth.”

4.4.1 Assessing the workload in the Water Use Licensing Section

The consultation report titled “Water Use and Allocation” released in 1999 was particularly critical of the limited staffing capacity, which contributed to a growing backlog of unprocessed assignments that includes first time and renewal applications, and expired licenses. While not explicitly mentioned in the CEC Report – there were several instances of such criticisms of varying degrees (from stakeholders) found among several of the 173 licenses files. According to the 1999 consultation report, there was a backlog of 783 Water Rights applications and 836 expired licenses for a total 1,619 unprocessed assignments in 1998 (this includes all category of water usage). Additionally, it is likely that the 1,619 number is underestimated, as it did not consider the number of submitted renewal applications at that time. By 2004, the total number began to decrease to approximately 1,200 and to around 400 by the year 2015 (see Figure 4.2). Unfortunately, the limitation of the WULS software database made it impossible to gather such data earlier than 2004. This made it difficult to ascertain when and how the backlog began, whether it had been continually increasing since, and when the backlog started to decline. However, the WULS software database provides several insights that contributed to the continual decline (see Figure 4.2).

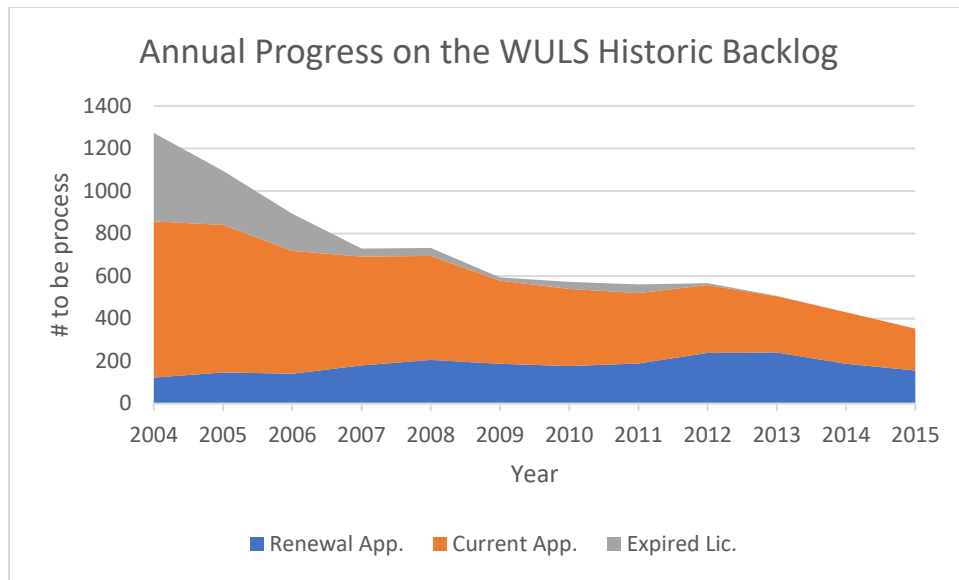


Figure 4.2: An overview of the cumulative workload for the Water Use Licensing Section for each subsequent year, the workload is not exclusive to swine operations. The expired license status refers to licenses that have yet to be processed by the licensing staff for renewal or closure. Current application status refers to applications for projects that have never been issued a license. Renewal application status refers to applications for license renewal.

(Source: Department of Sustainable Development, Government of Manitoba, 2017)

In 1996, the WULS deployed their first custom built database for the purpose of tracking and prioritizing the workload of (but not limited to): applications, storing WURs, licensing timelines, and projects status (McCombe, 2017). Prior to 1996, the tracking of applications and projects were documented in notebooks written in pencil. However, it took several years with numerous updates for the database software to fully mature. The decline in the number of “current application” in 2005 coincided with an update to the software to be accessible for all the licensing staff stationed across Manitoba. Another noticeable decline in the number of “current application” in 2008 coincided with another software update to allow the licensing staff to escape the “read-only” privilege to edit and modify project accounts and to create licenses (McCombe, 2017). Thus, the workload was lessened by being spread across multiple licensing technologists. Considering the timeline of the software development and the backlog in Figure 4.2, it is

therefore probable to suggest that the 1998 total number of unprocessed assignments was part of a downward trend from a presumed historic high of 1,619 assignments prior to 1996.

The ability to enhance the efficiency of collaboration between the licensing staff (increased access to the database), as well as shifting the licensing procedure towards a decentralized system (edit privilege for multiple licensing technologists), contributed significantly to the continual decline in the historic backlog. It should be noted that there were fewer licensing staff employed in 2015 than in the 2000s. Thus, the method of tracking and prioritizing the workload was more of a factor in dealing with the backlog of unprocessed assignments than the number of licensing staff as claimed by the 1999 consultation report. The combination of using software to track and prioritize (e.g. expired licenses) – both impacted each other towards decreasing the backlog. Using any one of the two methods alone would have probably diminished the extent of the annual decline.

4.4.2 Examining how the Water Use Licensing Section allocate water for swine operations

The licensing staff are given a degree of discretion when determining the appropriate volume of water to be allocated for each license. This is partially due to insufficient studies on water consumption in the Manitoba swine industry to which the licensing staff can refer. The discretion allows the licensing staff to take a variety of factors into consideration that could impact the annual barns water usage. These factors include but not limited to: specific business practices tied to the project relative to the general status quo (technologies, management practices); WURs that had been submitted over the course of the license; factors that would limit the water use capacity of the barn (e.g. water treatment plant, reservoir size, maximum diversion rate); the status of the infrastructure of the barn (e.g. normal versus quarantined versus

renovation versus hibernation); any connections to municipal pipelines; the water use reference chart of the licensing staff (see Table 3.5), (Government of Manitoba, 2017). The licensing staff are required to use these considerations to justify the allocated volume before issuing a license.

For the first-time applications, the licensing technologist will often refer to their water use reference chart to determine whether the requested volume of water is reasonable. If it is not, and the requested volume deviates substantially, the licensing technologist will contact the applicant to discuss the reasons for justifying the requested volume on the application. For example, applicants whose requested water volume is deemed significantly below what is expected to support a given swine population, may be practicing the use of whey or had extra water supplemented via connections to municipal pipeline. Application requests for significantly larger water volumes than expected may be associated with inefficient water management practices, historic viral outbreaks, pipe/reservoir leakages (Government of Manitoba, 2017). These discussions will occur with the proponent, during the license renewal process, if the licensing technologist deems that the aggregation of past water records shows a substantial deviation from their current licensed allocation.

With respect to the licenses undergoing renewal, the licensing technologist will aggregate and examine the WURs provide by the licensee to determine whether the allocation for the renewal license should be increased, decreased or remain unchanged. In the examination of 173 licenses spanning over 16 years (2000 – 2015) – 13 renewal licenses had their allocation volume reduced on average by 9.66 dam³. This normally occurred when swine operations had not expanded as originally planned by the applicant during the original assessment phase ten years prior.

Generally, the decision on the amount of water to allocate is based on two common scenarios. If the aggregation of water records had been shown to be consistently above the current allocation, but not substantially, the licensing staff will likely choose the historic high as the new allocation volume, providing there is sufficient water available to accommodate the requested increase (Government of Manitoba, 2017). This was observed in 87 licenses over the 16 years period whose increase in the allocation (for renewal licenses) averaged 5.57 dam³. Whereas the allocation limit will likely remain unchanged if the aggregation of water records remains consistency below the current license allocation. This was observed in 15 licenses over the 16 years span. The remaining 58 were first time licenses not yet up for renewal.

As stated earlier, the licensing staff are given the discretion to determine the appropriate volumes to be allocated, but the justifications must be stated in the final assessment report. For example, in one case an applicant applied for a license renewal and only provided a few years of vague water records that revealed inconsistent volumes of water being utilized. Upon further investigation by the licensing technologist during the license renewal process, it was determined that the applicant utilized a water treatment plant (Government of Manitoba, 2017). Since the volume of water utilized by those barns could not exceed the output capacity of the treatment plant, the licensing technologist decided that the renewed allocation volume will reflect the capacity of the treatment plant.

Determining the availability of water to be allocated differs between SW and GW sources, due to the visibility of the water source. The availability of GW for allocation is determined by the consulting reports generated by a registered hydrogeologist (Engineers Geoscientists Manitoba) (Government of Manitoba, 2017). How water is allocated for SW licenses depends on whether the water source is based on either spring flow or firm flow. Of the

two, spring flow (diversion of water permitted only from March 1st to May 31st) is the most common temporal period for which licensees are confined to the diversion of water. Spring flow is associated with creeks, small rivers, streams, and tributaries that are prevalent throughout southern Manitoba and are fed by the annual spring flooding. The water bodies associated with spring flow are often reduced or discontinued during the summer and autumn months that greatly restrict the availability of water for human usage. Firm flow, on the other hand, are less prevalent than spring flow, and they are associated with larger rivers (e.g. the Red River, the Assiniboine River) and other large water bodies for which the flow of water continues unabated throughout the summer and autumn months.

Determining the availability of water for allocation for projects that rely on firm flow sources will be assessed by the analysis of stream flow data to determine the instantaneous flow and the annual water demand of all nearby license holders, riparian needs, domestic needs (using less than 25,000 litres of water daily), and instream flow needs. Whereas the water budget for firm flows is fully allocated or unavailable in the area surrounding the project of the applicant, spring flow will be considered as an alternative source to divert water for human use (Government of Manitoba, 2017). The availability of water for swine barns that rely on spring flows to supplement their operation would be based on acceptable risk levels of annual supply shortfalls. The risk level is one-half of 80% of the spring runoff water budget as determined by the Surface Water Management Section within the Department of Sustainable Development (Government of Manitoba, 2017). All projects relying on spring flow will be required to construct storage works to hold sufficient volumes of water, once the spring runoff wanes. This will allow a carry over to the next spring runoff in the following year. Such storage works generally hold at least two years worth of water in order to mitigate against seasonal droughts.

It should be noted that if a project had been diverting GW or SW, for years prior to submitting an application for a license, an applicant may be exempted under specific circumstances from submitting a hydrologic consultant report. For example, a user diverts at least 25,000 litres of water per day in a relatively isolated area for which no other stakeholders are identified within several miles radius of the well or pump of the project (i.e. barn). It could be presumed that if no negative decline in the water table/level was observed for the length for which the applicant had been diverting water, it would be unlikely that adverse third-party effect (based on the diversion rate) will occur under the normal circumstances (Government of Manitoba, 2017). Thus, the licensed allocation may be based on the maximum pumping rate of the machinery or based on the size of the reservoir(s).

It is estimated that among the 173 licenses, approximately half do not have additional wells or pumps within a mile radius belonging to other property owners. This supports the notion that the distances between large swine barns can be seen as a business advantage for minimizing the spread/dispersal of biosecurity risks. Such isolation of farmsteads is not unusual in Manitoba as more than 60% of the population live in communities (Manitoba Bureau of Statistics, 2016).

4.4.3 Reporting water use

All licenses have the following clauses with respect to keeping WURs. First, “The LICENSEE shall keep records of [daily, weekly or monthly] and annual water use and shall provide a copy of such records to Manitoba Sustainable Development not later than February 1st of the following year” (Government of Manitoba, 2017). Second, “A flow [meter or timer] must be installed, positioned to accurately measure instantaneous pumping rate and accumulative

withdrawals from the water source” (Government of Manitoba, 2017). At what periodic interval is water usage to be recorded at depends on the water use category.

For example, irrigator licensees are often required to record their water usage daily, due to the sporadic occurrences of large water diversion occurring several days per month (Government of Manitoba, 2017). License holders, whose diversion of water occurs daily at a relatively fixed rate, will likely be requested by the WULS to record their water usage at a monthly interval. Examples of recording at a monthly interval generally fall under the municipal and geothermal licensees. Agricultural users, where the diversion of water occurs more frequently than irrigators but less frequent than municipal users, can be expected to record their water usage at a weekly interval. The purpose of recording at a given interval, in addition to the total annual volume, serves two purposes. First, the licensing staff or the licensees can adjust the total usage on their recording sheet for when the water meter rolls back to zero, as it is often the case for meters reading in gallons. Second, if a farm experienced a spike in the total volume of water being utilized, the licensing staff or the licensee can examine the weekly readings and use it to investigate the cause further.

Only a small fraction of the 173 licensees, mainly independent businesses, do not report their water usage at a regular annual interval. Whether the lack of recording at an interval is due to forgetfulness, motivational, or accessibility issues (e.g. clarity of the meter screen, enclosed space) on part of the licensees is unclear. While there are no financial penalties involved for licensees either not submitting their WURs or not recording their readings at a regular interval, it may contribute to a delay during the license renewal process for an investigation by the licensing staff. There are cases where the reported readings submitted to the WULS will be unclear. The licensing technologist may therefore request a photograph of the water meter with a time stamp

in order to estimate the total quantity of water diverted within a given period and to investigate for potential human errors (commonly associated with the replacement of the meter decimal point by the recorder (see Image 4.2) (Government of Manitoba, 2017).



Image 4.2: Images of several water meters belonging to different swine operators with a valid license. (Source: Department of Sustainable Development, Government of Manitoba, 2017)

There are two types of water measuring devices available to all licensees to record their water consumption – a meter and a timer. The latter is commonly associated with irrigators and other licensees whose measuring devices are continually exposed directly to the elements of the climate in Manitoba. Metering devices on the other hand, are most commonly used when situated indoors and is insulated against the climate in Manitoba (see Image 4.2). Among the 173 licenses, virtually all of them used a meter and are situated inside the barns or pumphouse. It should be noted that the accuracy precision is higher for a meter than a timer device. The latter records the volume of water being diverted, while the former records the length of time it takes to be diverted. Thus, the result of a timer is combined with the maximum flow rate of the equipment that diverts the water to obtain the total water volume. It will invariably lead to overestimating the consumptive volume.

Table 4.2: Percentage of licensees that submitted water use records to the Water Use Licensing Section from 2009 to 2015 (includes all category of water usage).

(Source: Department of Sustainable Development, Government of Manitoba, 2017)

Year	2009	2010	2011	2012	2013	2014	2015
WURs submission	41%	42%	50%	72%	72%	68%	62%

From the year 2009 to 2011 as shown in Table 4.2, an average of 44.33% of the total number of licensees were submitting their WURs, without reminders, to the WULS. A university student was hired part-time with the task to send out reminders to all licensees to submit outstanding WURs. As a result, the average submission rate rose to 70.67% (+26.34%) by 2014 (see Table 4.2). Due to unforeseen circumstances, only half the reminders were sent out for the year 2015 – lowering the response rate by almost 9% to 62%. These percentages tell us that approximately half of those licensees not submitting their WURs is likely the result of neglected responsibility. The remaining half of licensees not responding to reminders may not been recording their volume usage and thus had no data to provide to the WULS. It should be noted that the number of cumulative valid licenses increases approximately by 50 annually since the year 2004. The annual continuous increase in valid licenses points to the potential requirement of additional resources for the licensing staff to ensure that licensees are reporting their water usage in a timely manner and that all other conditions of their license are being adhered (Government of Manitoba, 2017).

4.5 Assessing the findings from the Clean Environment Commission report on water quantity and the provincial licensing regime

“...while all holder of water rights license is required to report their water consumption on an annual basis, the province does not record or aggregate these readings to ensure that operators are not exceeding their licensed amount” (Clean Environment Commission, 2007a: 114).

Archival research through government documents found that in the late 1990s, it was made mandatory for all license holders to report their water usage annually to the WULS. Prior to that, some licensees were requested by the WULS to keep and submit WURs regularly – largely due to the circumstances of the project (e.g. area prone to seasonal drought, information gaps on local water supply) (Government of Manitoba, 2017). Furthermore, the water records uncovered during the archival search were dated as far back as the 1970s and were mostly municipal-related. The earliest WURs uncovered that belongs to a swine operation was found to be dated from the mid 1990s. All WURs are stored in the respective project file of the license and on the WULS database (Government of Manitoba, 2017).

To address the above CEC observation, there are two functions to note. First is the reporting rate, which is percentage of the licensees that submit their WURs on an annual basis. Second, is the compliance rate, which is the annual percentage of the submitted WURs whose reporting volume is below their assigned licensed allocation. In Figure 4.3, the reporting rate among the 173 licenses increased from 85.19% (2002) to 88.44% (2015) with an overall average reporting rate of 81.07% since the year 2000. The compliance rate, on the other hand, rose from

60.55% (2002) to a record high of 76.16% (2015) – and the average rate is 62.99% since the year 2000. This suggests that any relationship between the reporting and compliance rates is mutually exclusive. In other words, even if the licensees do not report their usage – they are more likely to be under their licensed threshold than to be over it. It should be noted that having an annual reporting or compliance rates of 100% for 173 licenses is unrealistic, which reflects the inability of the reporting rate to rise above the 90% mark over the 16 years period in Figure 4.3.

With respect to the compliance trend in Figure 4.3, the upward trajectory since 2006 coincided with the release of the CEC report in 2007. While it is probable that the outcome of the CEC Report had influenced the licensing staff to address the low compliance with licensees, there is insufficient data in this research to confirm a link between the two. Furthermore, there were no evidence of the CEC Report being mentioned in any of the 173 license files.

Interestingly, and unclearly if related, the post-2006 period was marked by a sharp increase in the number of licenses issued for both VC from 117 (2006) to 133 (2007) and SW from 8 (2006) to 19 (2007). It is therefore likely that there were multiple factors responsible for the rise in the compliance trend after 2006.

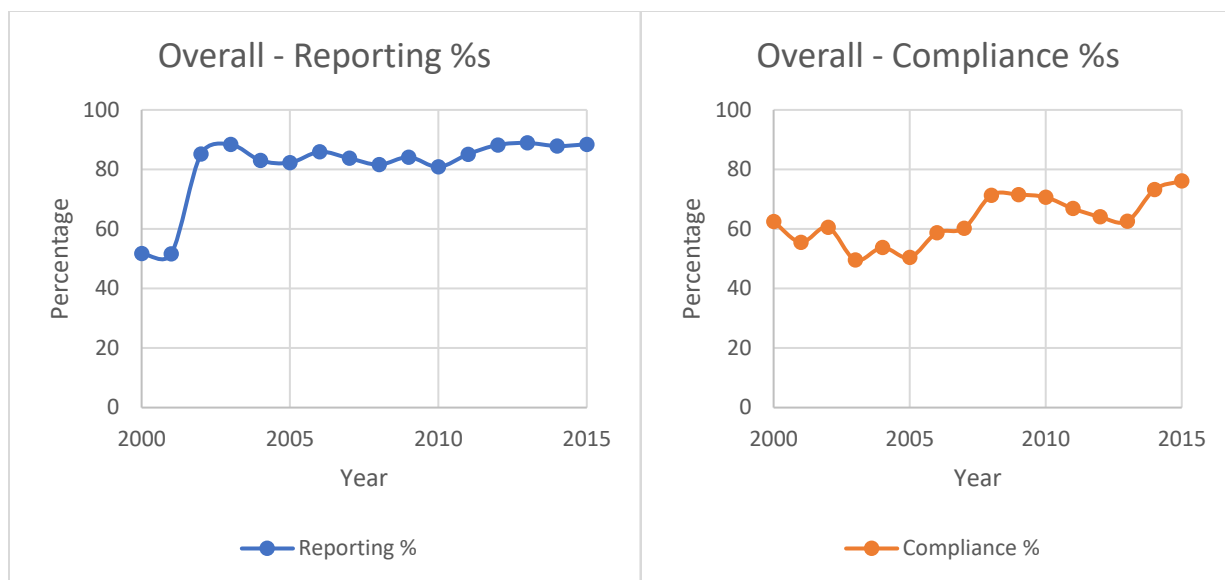


Figure 4.3: The reporting and compliance trends for water use records relative to the 173 licenses over the 16 years period (2000 – 2015).

(Source: Appendix 1, Appendix 6, and Appendix 7)

Table 4.3: Summary of the reporting and compliance rate for the 173 licenses.

(Source: Appendix 6 and Appendix 7)

Submitted Readings	% of Reporting	Complied with the allocation threshold		Average reported volume relative to allocation
Yes	81%	Yes	63%	-8.47 dam ³
		No	37%	+4.63 dam ³
No	19%			

According to the data presented in Table 4.3, the average volume of the agricultural-swine compliance rate is 8.47 dam³ under the allocation threshold from the year 2000 to 2015. Similarly, the non-compliance volume (for which water usage surpass the allocation limit) is averaged 4.63 dam³ in the same period. This tells us that majority of the swine operators with a license are likely to be below the licensing threshold than those above the threshold. This may contribute to the fact that the CEC estimate, of the total provincial swine consumption in 2006, was 128% of the estimates provided by the present study in Table 3.3. It is therefore likely that swine operators are using less water than previously thought under the CEC 2007 Report.

An examination of licensees exceeding their allocation limits (37% of reporting usage) found that these situations are generally associated with barn-related mechanical issues (e.g. broken meters, undetected leaks in the water pipes/reservoirs), natural events (e.g. drought) or livestock population growth due to barn(s) expansion (Government of Manitoba, 2017). With regards to mechanical issues, a news article from Prairie Hog Country notes that presently most of the swine barns in Manitoba were built during the 1990s and have a life expectancy of 30 years. These aging infrastructures may contribute to mechanical issues that result in leaks in water pipelines and reservoirs. During the analysis of submitted WURs, it was noted that swine operators tend to report leakages on their report forms if it was deemed to have noticeably impacted their overall annual water usage.

However, some of these leakages may not be readily visible due to some pipelines within the swine barns being located behind walls, below floors, or in inaccessible spaces. To put it into context, a water pipe in the barn “leaking at 90 drips per minute will waste 29 litres a day” (Nyachoti and Kiarie, N.D: 225). While the wastage may seem paltry compared to the overall water use in a swine barn, multiple leakages can contribute to a significant volume of waste over time along with a higher-than-normal operating cost. With respect to natural events, several swine operators claimed that during seasonal droughts, they are forced to utilize more water for sanitation purposes (dislodging fecal matter becomes more difficult in dry air) (Government of Manitoba, 2017). Lastly is the issue of unreported barn expansion as one of several causes of licensees exceeding their licensed allocation. Most swine operators with a license do not report to the WULS of impending or completed swine barn expansions. It would often come to the attention of the licensing staff (generally during the license renewal process) when aggregating

WURs shows abnormally high level of water consumption for the original number of swine that the license allocation was based upon.

During the CEC inquiry in 2006, some participants expressed concerns regarding the truthfulness of the water usage being reported by swine operators themselves. According to several members licensing staff that was consulted for the present study, they do not recall coming across any situation for which the submitted WURs were intentionally altered to appear below the allocated license threshold. In fact, one licensing technologist stated that “some water use reports have incorrectly recorded meter readings indicating a lack of comprehension of the actual volume being used” and that businesses have “little or no incentives” to undermine the provincial licensing regime (Thibert, 2018). Of the 173 license files, the first quote mentioned was often linked to independent businesses, while the second quote was primarily referred to VC businesses.

Of nearly 1,900 WURs examined in this thesis, approximately 84% were from VC businesses such as (but not limited to) Maple Leaf Foods Inc. and Hylife Ltd. WURs submitted by such businesses are often completed in their own computerized format, which provide additional information of each swine barn (e.g. current livestock population, any mechanical malfunctions, status of the barns such as normal/infection/renovating/hibernation) (Government of Manitoba, 2017). The average reporting rate for VC businesses had been relatively high and stable from the year 2002 (88%) to 2015 (93%), and the reasons may be two-fold. First as stated earlier, VC businesses have an average of 1,168 more swine per license (up to 8.92 dam³ more water use) than independent businesses. Therefore, the former will have higher operational expenses associated with the collecting, storing and disposal of manure. To put it into perspective, it costs swine operators \$0.07 Canadian per litre of water waste (manure) to be

disposed. Handling excess quantity beyond the infrastructure limitation of the barn (e.g. manure lagoon) can increase the cost to \$0.16 per litre (Muhlbauer et al., 2010).

The important difference between the business models involves the employment of environmental specialists, afforded by VC licensees, dedicated to ensuring that their clients and themselves are adhering to the relevant environmental regulations and to control operational expenses associated with the use of natural resources and their disposal into the biophysical environment (Government of Manitoba, 2017). The attention of VC environmental specialists to these details is manifested in their own standardized water use form to record the water usage of their clients, often in greater details than that of the standard governmental water use form. Second, the reputations and the corporate brands of VC businesses are subject to greater public scrutiny than that of independent businesses, which is due to their presence on the regional, national and/or international scale. Therefore, VC businesses will likely face greater pressure to demonstrate adherence to relevant environmental regulations to protect both their corporate brands and reputations for new and repeating clients. In contrast, the outreach of independent businesses is likely confined to the local scale and thus faced lesser pressure to demonstrate similar adherence. Since the VC business model (compared to their independent counterpart) generally use less water relative to the larger swine population in the barns, despite using overall more volume of water annually than the independent businesses - it could be reasonable to surmise that VC businesses are closely scrutinizing the water consumption of their clients in a reasonable manner.

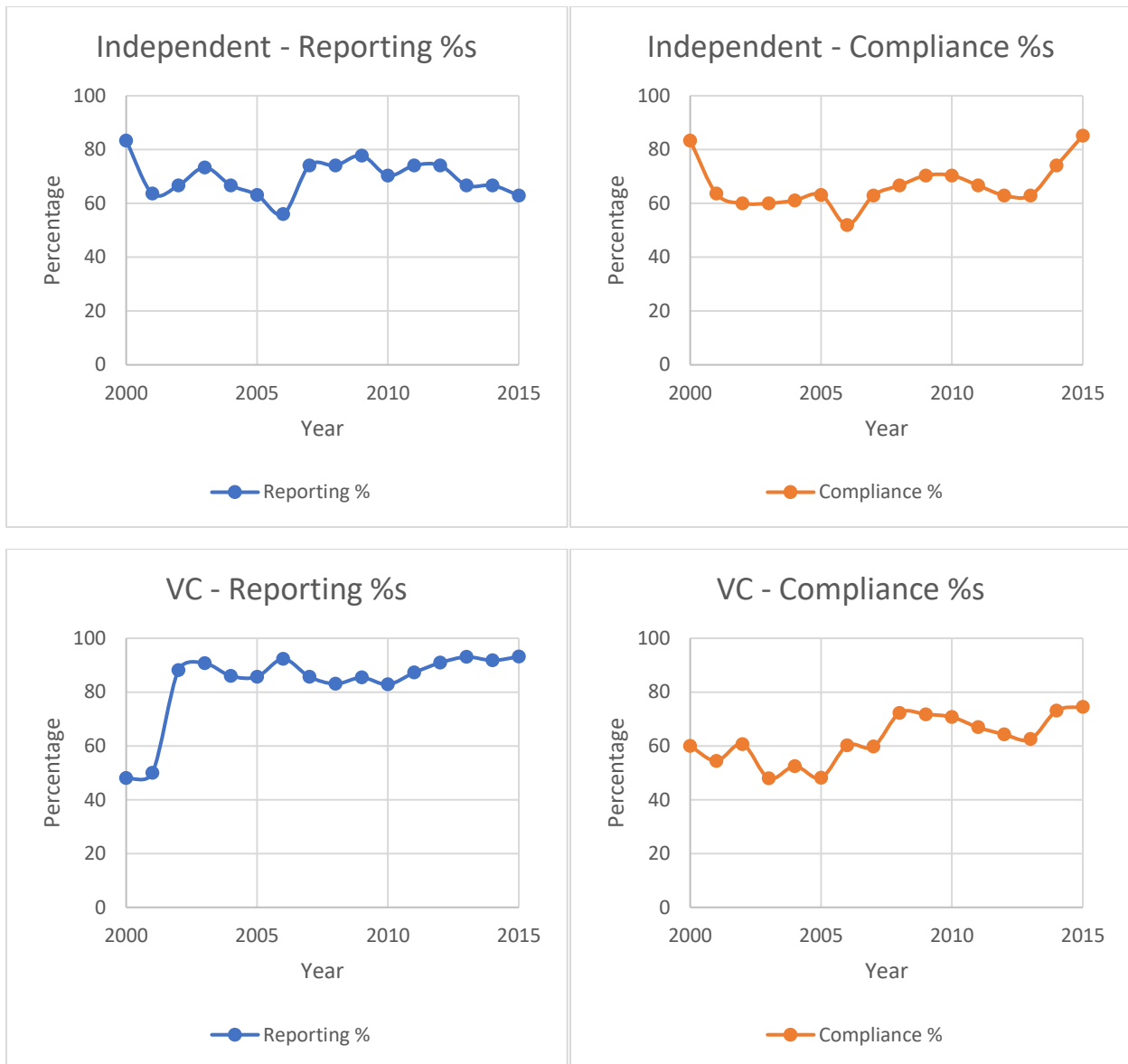


Figure 4.4: The reporting and compliance trends according to business models, relative to the 173 licenses over the 16 years period (2000 – 2015).
(Source: Appendix 4, Appendix 6, and Appendix 7)

Table 4.4: Summary of two business models and their respective reporting and compliance rates/volumes among the 173 licenses.

(Source: Appendix 7 and Appendix 9)

Company Models	Category	Reporting	Complied by reporting businesses with the allocation threshold		Average reported volume relative to allocation
VC Businesses	Yes	83%	Yes	63%	-9.10 dam³
			No	37%	+4.79 dam³
	No	17%			
Ind. Businesses	Yes	70%	Yes	67%	-5.20 dam³
			No	33%	+3.73 dam³
	No	30%			

The reporting WURs from independent businesses is largely in the format provided by the WULS. These businesses have a reporting rate of almost 70% since the year 2000. However, this reporting rate had been on a downward trend from the year 2009 (78%) to 2015 (63%) (see Figure 4.4). There are several scenarios that may account for this decline. First, is the lack of awareness among some licensees to keep and submit their WURs annually as shown in Table 4.2. An estimate of more than half the WURs submitted by independent businesses was examined and found to be incomplete (missed readings, measurement units) or incoherent (e.g. smudged writing or misplacement of decimal places). This lends credence to the earlier statement by a licensing technologist regarding the awareness and understanding of the regulatory responsibility among licensees.

Lastly is the issue of available resources for licensees to comply with the environmental regulations. Unlike the VC business model that maximized profits while minimizing expenses, independent businesses likely do not have the available resources to employ an environmental specialist to keep track of, and adhere to, the environmental regulatory responsibilities. A general

theme shared among large number of independent swine operators that participated in the CEC inquiry via written submissions was that the perceived excess red tape had made it difficult to keep up the pace of regulatory responsibility. None of the 27 independent businesses from a total of 173 licenses were found to employed environmental specialist(s). The recording and the submission of WURs are completed by the owners themselves that are typically tasked with other regulatory responsibilities.

Despite raising larger number of swine, VC licensees were likely to be almost twice below their annual licensed allocation than that of independent licensees. The independent business models are likely to have a greater proportion of licensees reporting below the annual licensing threshold. An attempt was made to test statistical significance using Pearson's Chi-square Test, with Yates' continuity correction, to compare reporting rate between VC businesses and independent businesses. The calculated Pearson Chi-Squared statistic is 4.005 with 1 degree of freedom, corresponding to a p – value =0.04537. Therefore, there is clear evidence to reject the null hypothesis and it can be inferred that the proportion of reporting by the VC businesses significantly differ (higher) from the proportion of independent business reporting. Of the reporting volumes that exceeded their licensing allocation, both business types were nearly identical. The reason for VC businesses scoring a lower compliance rate (63%) than independent businesses (67%), despite employing environmental specialists, remains unclear. Speculatively, it may have to do with both the physical limitation of the swine barn and its age. Maximizing the output of swine in an aging barn could put undue stress on the infrastructure that could lead to increased water loss (e.g. water leaks). It should be noted that this does not necessarily imply that independent businesses have a higher volume of water use efficiency, because the differences in the reporting volume against the licensed allocation, is narrower (8.93 dam³) for independent

license holders than those following the VC model (13.89 dam³). In terms compliance of licensed allocation of water among those who reported, no significant difference between VC businesses and independent businesses is found. T calculated Pearson Chi-Squared statistic is 0.1978 with 1 degree of freedom, corresponding to a p – value =0.6565. Therefore, the null hypothesis cannot be rejected, and an inference can be made that although the compliance rate is higher and different among the independent businesses than the VC businesses, such differences are not statistically significant with regard to compliance with allocated threshold.

“Manitoba Water Stewardship’s policy of not recording the reported meter readings, coupled with the large number of operators that are not licensed, makes it difficult to get a firm grasp on the amount of water the hog-production sector consumes” ”- and if the resources is being managed to maximize its sustainability” (Clean Environment Commission, 2007a: 115).

While a “large number of [swine] operators” may not be licensed due to using less than 25,000 litres of water per day (or rely on the municipal water pipelines), only the larger swine operations using over 25,000 litres of water per day will be the focus of the WULS. An estimate number of swine operations in Manitoba can be calculated backwards using the total volume of water utilized in 2015 which is 8,680.42 dam³ (Table 3.4). The total volume of water utilized by 173 licenses, plus the 83 licenses (average 17.34 dam³ annually based on the average volume of 173 licenses) that were excluded from this thesis (see Methodology) is 4,576.53 dam³. From 8,680.42 dam³ of water, this provided a difference of 4,103.89 dam³.

If the assumption is followed that all large swine operations in Manitoba had been licensed ($4,103.89 \text{ dam}^3$ divided by 9.124 dam^3 that is slightly below the licensing threshold), we can estimate that there were a total 706 swine operations in Manitoba. This 2015 estimate number of 706 swine operations is higher than the estimate of Honey (2016), that there were 611 barns with swine. The estimate number of 706 swine operations in Manitoba can be broken down to approximately 450 (63.74%) swine operations that do not require a license. Overall, swine operations with a license make up to 36% (36.26%) of the total number of Manitoba swine operations, yet they utilize up to 53% (52.72%) of the total water used by the entire provincial swine industry.

It should be noted that the number of swine operations in Manitoba varies depending on the source of the numbers. For example, the Manitoba Pork Council “reports on producers who meet specific marketing requirements”, Manitoba Conservation derives their understanding based on “operators that have been required to either file manure management plans or seek permits or manure-storage facilities” (Clean Environment Commission, 2007a: 146). It is pointed out that Statistics Canada defines it simply as “the number of farms with pigs” (Honey, 2015a: 3).

4.6 Summary

The WRA provides the framework for the province to ensure that water resource is allocated in a sustainable way that benefits most stakeholders while maintaining the ecosystem functions. This involved extrapolating data from submitted WURs that plays an integral role in the licensing steps and other licensing provisions. Close to 77% of the license holders had been reporting their WURs prior to the CEC Report in 2007. Since 2008, that percentage rose to

almost 86%. Therefore, the CEC findings on the WULS policy of not recording, keeping or aggregating the reported readings submitted by the licensees are largely unsubstantiated.

Over the span of 16 years, over 80% of the license holders in the present study had submitted their meter readings annually to the WULS. Of which almost 65% complied with their licensed threshold, whose reported volume averaged almost 4 dam³ (3.84 dam³) below their licensed allocation. Approximately half of 20% that did not submit reporting usage annually is likely due to forgetfulness with the other half had nothing to submit.

The rates and volumes of reporting and compliance varied considerably between business models. While the VC license holders had the highest reporting rate (83% versus 70%), it was the independent licensees that scored the highest compliance rate (67% versus 63%). The reason for the reversal is unclear, especially when the annual average reporting volume for VC and independent license holders are respectively 3.85 dam³ and 2.25 dam³ below their threshold. Overall, the findings revealed that licensees of both business models largely complied with their licensed allocation.

5.0 Discussion and Conclusion

5.1 Discussions

The rapid growth of the Manitoba swine industry throughout the 1990s and 2000s were beset by controversies pertaining to the impact of the industry on societal and environmental well-being. These controversies were mainly centered around the increasing output of swine manure and their eventual disposal into the environment. Such controversies that are linked to manure production includes primary (manure production), secondary (obnoxious odours) and tertiary effects (resources contamination and pathogen dispersals). Despite the contentious issues of the manure impact on the biophysical environment, there are few studies that examine the system of water management in the Manitoba swine industry – despite that the former is directly tied to the latter. The seemingly lack of motivation to undertake such studies, despite being one of the largest industries in Manitoba, is contributed by the operational difficulties of obtaining water use data and the perceived inexpensiveness and bountifulness of water.

The 2007 CEC Report on “Environmental Sustainability and Hog Production in Manitoba” highlighted the lack of sufficient studies which made it difficult to determine an accurate volume of water consumed by the swine industry. The CEC attempted to address the information gap by sponsoring a study that had such a small sample size of swine, that it raises the question of whether it properly represented the hundreds of swine barns across the province and the differences in barn practices and management styles.

The CEC estimated that 11,278.50 dam³ of water were utilized by the Manitoba swine industry in 2006. This thesis put that number at 8,143.27 dam³ - a difference of almost 28%. This translated up to 3,135.23 dam³ of manure that was never generated. Applying the estimates provided by the present study and the CEC, over the span of five years from 2012 to 2016, it

provides an average annual water use of 8,400 dam³ and 11,070 dam³ – a difference of 24%. In fact, the estimated daily water volume for sow, feeder and nursery between this thesis and the study sponsored by the CEC differ as much as 32%. The discrepancy among the estimates can be attributed to the population size of 12,775 swine (CEC sponsored study) versus 1,005,663 swine (the present study). The larger the population size, the lower the susceptibility of the latter to the influence of significant outliers (e.g. unusual barn practices, management styles).

Working from an estimate of 8,680.42 dam³ of water utilized in 2015 against the total swine population, with the presumption that all production sites using more than 25,000 litres of water per day were licensed, the present study suggests that there were 706 swine operations in Manitoba as of 2015. The 706 number is comparable to another study (Honey, 2016). Of those 706 swine operations, close to 36% (36.26%) are licensed that accounts for 53% (52.72%) of the total volume of water utilized by the entire provincial swine population.

Several participants during the CEC inquiry and licensees expressed concerns regarding the sustainability of local aquifers and SW sources - due to the perceived quantity of water being diverted for the swine operations. To put it into perspective with two industrial companies, one paper mill in Northern Manitoba uses on average 12,900 dam³ of water annually (Government of Manitoba, 2018). A fertilizer company in Western Manitoba uses an average 4,000 dam³ of water annually. Using urban examples, the City of Portage la Prairie and the City of Brandon uses on average, respectfully 6,500 dam³ and 8,000 dam³ of water annually (Government of Manitoba, 2018). One important caveat to keep in mind when comparing the water usages between settlements (towns, cities, colonies) and primary industries is the concentration of these licensed water diversions. The 8,400 dam³ number would come from hundreds of groundwater wells and surface water pumps located across the southern half of Manitoba. Thus, the overall

collective pressure from swine operations on local aquifers and surface waterways is minimized. Contrast to the rural/urban settlements and industries, in which each often owns several wells/pumps within an area that likely put a greater collective pinpoint pressure on water sources than that of the provincial swine industry.

If the submission of WURs can be viewed as a function of communication from the licensees to the licensing staff – then 81% of licensees in the present study keep in touch with the WULS on an annual basis. Of that, 63% complied with their licensed allocations. In contrast, the average annual reporting rate for all category of water usages is slightly over 58%. While the total number of licenses in the present study may be heavily skewed to the VC framework, that accounts for the relatively high reporting rate, it reveals that Manitoba swine operators using the largest quantity of water were far more likely to follow the VC model than the independent model.

5.2 Research limitations and challenges

Three limitations identified in this thesis had therefore narrowed the interpretation of the thesis results. They were: i) trade-off in data gathering, ii) the raw data associated with the submitted WURs, and iii) the accuracy of the latter. With respect to the first limitation, quantifying the volume of water utilized by the Manitoba swine industry involved working with the current licenses as of December 24, 2015 and it was required to “work backwards” to determine how water use trends behaved over time. This resulted in overlooking the historic circumstances of agricultural-swine licenses that had expired without renewal or had been revoked by the Minister of Sustainable Development. Therefore, those circumstances had not been explored nor covered in this thesis. Had the present research covered those circumstances, it

may have uncovered a more comprehensive picture of the licensing procedures and the causes/events that led to those licenses to become void without renewal. Thus, the discussion of the licensing procedures (as well as the reporting/compliance rates) pertains to the active licenses, and not the expired equivalent.

The second limitation pertains to the raw data associated with the submitted WURs. Despite gaining access to nearly 1,900 WURs from 173 licenses, the data provided by those records are limited to interpretations. For example, these data are obtained from water meters that records the cumulative volume of water prior to entering the barn for various water functions. Thus, the total water usage cannot be disaggregated into swine drinking, sanitation and cooling purposes – a categorization that the CEC sponsored study had followed. However, the impact of this limitation may be offset by a 2013 survey from Alvarado and Predicala (2013) that suggested a limited variation in water management technologies that was adopted for different water functions in swine barns across the Canadian prairies. Therefore, the daily water volume calculated in the present study cannot be viewed as the biological requirement of the swine. It can only be viewed holistically as the anticipated volume of water that is utilized within a Manitoba swine barn (according class development). As a result, this may create difficulty in comparing the results of this thesis to other literatures.

The third limitation is the accuracy of the submitted WURs - which depends entirely upon the licensees understanding when they record the meter readings on their report forms (meter measurement units, clarity of handwriting, regular periodic recording of meter readings, obligation to submit report to the WULS, etc.). Therefore, any uncertain, missing, or erroneous information on these report forms will contribute to the challenge of enhancing the accuracy of the WURs through recalculations. For example, any incomplete data for WURs covered under

this thesis is corrected, where possible and appropriate, using the mean imputation of historic volumes – which was justified in Chapter 2. The mean imputation did not correct all incomplete WURs as this led to several dozen volumes that are unrealistically low - if the presumption is held that the licensed barns are always at full capacity. The WURs that was unable to be corrected were not discarded to maintain the integrity of the data set. Fortunately, the impact of those several dozen volumes was insignificant compared to the total number of obtained WURs (1,900).

Overall, the challenges stemming from these limitations were manageable and largely mediated through consultations with the WULS, supplementary studies, and data interpretative trade-offs. As an example of the latter, while the present study cannot partition water usage into barn functions, it does account for all water usage that enters the barn. Another example of interpretative trade-off is the exclusion of analyzing the circumstances of expired licenses in order to construct an accurate trend of water consumption in swine barns that spans 16 years (2000 – 2015).

5.3 Conclusions

The foundation of this thesis is based on two questions that pertained to the 2007 CEC Report on “Environmental Sustainability and Hog Production in Manitoba”. First, are the concerns expressed by the CEC on water usage within the Manitoba swine industry valid? Second, are the concerns expressed by the commission still valid today after ten years since the report was released in 2007? The concerns arise from the following issues stated in the report: 1) “any attempt to estimate water usage by Manitoba hog operations is a daunting task given the lack of sufficient information”; 2) “Manitoba Water Stewardship’s policies...makes it difficult to

get a firm grasp on the amount of water the hog-production sector consumes” (Clean Environment Commission, 2007a: 115). This thesis sought to evaluate the findings and concerns uncovered in the CEC Report on water usage by assessing the available data on water use and the effectiveness of the regulatory authority responsible for managing provincial water resources.

The first objective of this thesis was to determine an accurate volume of water used by the swine industry by collecting WURs that are maintained by the WULS within the Drainage and Water Rights Licensing Branch. The present research concluded that licensed swine operators largely complied with their annual licensed allocation of water spanning 16 years (2000 – 2015) and the estimated total for the 2006 water consumption was almost 30% below the CEC estimate. This means that swine operators were using substantially less water than previously thought by the CEC. Furthermore, the earliest evidence of WURs from swine operators in the WULS depository dated back to the mid 1990s and since then became more numerous available.

The second objective of this thesis was to review the licensing regime and the allocation policies as it relates to concerns expressed by the CEC. The present research concluded that the policy concerns expressed by the CEC (in Chapter 9.2) is largely unfounded. For example, WURs is an essential component of the licensing provisions and plays an important role in the licensing process that includes establishing allocation threshold for licenses, reviewing project licenses for renewal, and ensuring the compliance of license holders to the legal conditions of their license. Thus, the CEC had not reviewed their findings on water use with the licensing staff for accuracy prior to the publication of the 2007 report.

In conclusion, whether the water resource is being managed sustainably by swine operators, as part of the concern listed in the CEC Report, is difficult to answer in part because

the term “sustainability” is largely an abstract concept that can be difficult to apply in real-world context. While there are multiple definitions for “sustainability”, the general idea is that the rate of diverting natural resources should not exceed the natural rate of recovery/replenishment. For practical purpose, if we compare the reported water usages and the licensed allocations over the past 16 years (2000 – 2015), we can surmise that the provincial licensing regime had been reasonably managing the water resource for the Manitoba swine industry, and the latter had been diverting water at a sustainable rate. The present researcher expects that the findings uncovered in this thesis will bring a degree of clarity to several information gaps that sometimes lead to acrimonious debate on the future of the Manitoba swine industry and their impact on local and regional water supply.

5.4 Policy Recommendations

The implication of the present study, other than addressing the concerns in the CEC Report, is to lay out the foundation for further studies, as well as assisting local and regional authorities, as it relates to water (supply) management in the Manitoba swine industry. However, addressing any concerns requires accurate information for which a proper assessment can be made. Prior to the publication of CEC Reports, any references to government-sourced information should be reviewed by their respective government institutions to ensure the accuracy of information. This is necessary, especially when the inquiry topic is known to be environmentally and socially controversial among members of the public. According to one government official associated with the WULS at the time of the CEC inquiry in 2007, the CEC did not offer the draft to be reviewed by the WULS. Had it been reviewed by government

officials prior to the publication, it would likely had forced the CEC to re-examine their analysis on water use.

There are several studies suggesting that monitoring water usage could be used as “a diagnostic tool for efficient barn management” (McKerracher, 2007: 89). For example, the regular recording of consumption numbers can alert the operator to problems such as poor ventilation, feed issues, equipment leaks/malfunction, or the health/stress concerns of swine (McKerracher, 2007; Brumm, 2006). In other words, monitoring water usage can be equivalent to observing a canary in the coal mine, a tool to protect financial investment while minimizing unnecessary loss of natural resources and operational expenses. Whether Manitoba swine operators are using their recorded readings for these purposes, other than to meet the regulatory requirement under the WRA, remains dubious. The examination of submitted WURs in the present study suggests moderate level of awareness among licensees to record and submit meter readings to the WULS, but a low level of awareness to utilize the information to improve the operational efficiency of their barns.

The inclusion of water conservation technologies (i.e. water metering) for future Manitoba Environmental Farm Plan and the *Growing Forward 2* program is further recommended. The former allows farmers and livestock operators “to identify agri-environmental assets and risks on their operations and develop an action plan to reduce the identified risks” (Government of Manitoba, N.D.b: 1). Afterwards, the action plan can be used under *Growing Forward 2* to apply for government subsidies to assist in carrying out the action plan. The inclusion of water conservation technologies in these two programs could help raise awareness among swine operators, particularly independent license holders, to identify water

saving measures to reduce operational expenses – in addition to managing the high cost of technological upgrades.

Appendices

App. 1: Summary of total annual water usage, allocation, and per license. Volume unit are in cubic decametre.

(Source: Department of Sustainable Development, Government of Manitoba, 2016)

Year	Usage	Allocation		Year	Usage/Lic.	Allo./Lic.		% Response	# Licensee
2000	909.45	1004.14		2000	16.24	17.93		51.79	56
2001	1465.80	1642.14		2001	16.47	18.45		51.69	89
2002	1814.77	2109.15		2002	16.80	19.53		85.19	108
2003	2004.96	2268.84		2003	17.90	20.26		88.39	112
2004	2078.70	2371.73		2004	17.62	20.10		83.05	118
2005	2196.67	2523.10		2005	17.72	20.35		82.26	124
2006	2471.78	2885.80		2006	17.41	20.32		85.92	142
2007	2796.59	3357.01		2007	17.48	20.98		83.75	160
2008	2791.68	3528.12		2008	17.13	21.64		81.60	163
2009	2745.02	3563.77		2009	16.74	21.73		84.15	164
2010	2805.12	3648.22		2010	16.80	21.85		80.84	167
2011	2897.15	3688.58		2011	17.24	21.96		85.12	168
2012	3034.40	3789.07		2012	17.85	22.29		88.24	170
2013	3063.46	3825.67		2013	17.91	22.37		88.89	171
2014	3101.29	3882.01		2014	17.93	22.44		87.86	173
2015	3137.31	3944.01		2015	18.13	22.80		88.44	173

App. 2: Summary of water source annual water usage, allocation, and per license. Volume unit are in cubic decametre. Blue = GW, orange = SW.

(Source: Department of Sustainable Development, Government of Manitoba, 2016)

Year	Usage	Allocation	Year	Usage/Lic.	Allo./Lic.	% Response	# Licensee
2000	888.97	990.88	2000	16.16	18.02	52.73	55
2001	1445.32	1628.88	2001	16.42	18.51	52.27	88
2002	1748.06	1950.08	2002	16.81	18.75	85.58	104
2003	1891.21	2007.97	2003	17.84	18.94	90.57	106
2004	1977.00	2110.86	2004	17.65	18.85	84.82	112
2005	2090.92	2262.23	2005	17.72	19.17	83.90	118
2006	2329.50	2540.33	2006	17.38	18.96	87.31	134
2007	2429.39	2722.23	2007	17.23	19.31	90.07	141
2008	2369.96	2758.56	2008	16.81	19.56	88.65	141
2009	2373.82	2772.66	2009	16.84	19.66	87.94	141
2010	2441.07	2857.11	2010	16.95	19.84	85.42	144
2011	2470.87	2879.47	2011	17.16	20.00	88.19	144
2012	2581.16	2992.63	2012	17.68	20.50	89.04	146
2013	2624.23	3029.23	2013	17.85	20.61	89.12	147
2014	2607.11	3058.67	2014	17.62	20.67	88.51	148
2015	2656.71	3151.67	2015	17.95	21.30	89.19	148

Year	Usage	Allocation	Year	Usage/Lic.	Allo./Lic.	% Response	# Licensee
2000	20.48	13.26	2000	20.48	13.26	0.00	1
2001	20.48	13.26	2001	20.48	13.26	0.00	1
2002	66.71	159.07	2002	16.68	39.77	75.00	4
2003	113.75	260.87	2003	18.96	43.48	50.00	6
2004	101.70	260.87	2004	16.95	43.48	50.00	6
2005	105.75	260.87	2005	17.63	43.48	50.00	6
2006	142.28	345.47	2006	17.79	43.18	62.50	8
2007	367.20	634.78	2007	19.33	33.41	36.84	19
2008	421.72	769.56	2008	19.17	34.98	36.36	22
2009	371.20	791.11	2009	16.14	34.40	60.87	23
2010	364.05	791.11	2010	15.83	34.40	52.17	23
2011	426.28	809.11	2011	17.76	33.71	66.67	24
2012	453.24	796.44	2012	18.89	33.19	83.33	24
2013	439.23	796.44	2013	18.30	33.19	87.50	24
2014	494.18	823.34	2014	19.77	32.93	84.00	25
2015	480.60	792.34	2015	19.22	31.69	84.00	25

App. 3: Summary of regional annual water usage, allocation, and per license. Volume unit are in cubic decametre. Blue = eastern, orange = RoM.

(Source: Department of Sustainable Development, Government of Manitoba, 2016)

Year	Adjusted	Allocation	Year	Usage/Lic.	Allo./Lic.	% Response	# Licensee
2000	528.15	591.84	2000	15.53	17.41	47.06	34
2001	888.84	982.84	2001	16.46	18.20	37.04	54
2002	1104.92	1219.84	2002	16.74	18.48	87.88	66
2003	1223.70	1244.73	2003	18.26	18.58	95.52	67
2004	1257.14	1288.80	2004	17.96	18.41	87.14	70
2005	1250.61	1301.21	2005	17.61	18.33	85.92	71
2006	1339.86	1485.37	2006	16.34	18.11	87.80	82
2007	1446.85	1609.15	2007	16.44	18.29	88.64	88
2008	1431.29	1623.25	2008	16.26	18.45	88.64	88
2009	1431.84	1636.85	2009	16.27	18.60	86.36	88
2010	1528.82	1693.55	2010	16.99	18.82	84.44	90
2011	1538.10	1715.91	2011	17.09	19.07	85.56	90
2012	1627.02	1827.82	2012	17.69	19.87	85.87	92
2013	1596.56	1833.62	2013	17.35	19.93	86.96	92
2014	1547.96	1845.92	2014	16.83	20.06	85.87	92
2015	1615.40	1902.06	2015	17.56	20.67	85.87	92

Year	Adjusted	Allocation	Year	Usage/Lic.	Allo./Lic.	% Response	# Licensee
2000	381.30	412.30	2000	17.33	18.74	59.09	22
2001	576.96	659.30	2001	16.48	18.84	74.29	35
2002	709.85	889.31	2002	16.90	21.17	80.95	42
2003	781.26	1024.11	2003	17.36	22.76	77.78	45
2004	821.56	1082.93	2004	17.12	22.56	77.08	48
2005	946.06	1221.89	2005	17.85	23.05	77.36	53
2006	1131.92	1400.43	2006	18.87	23.34	83.33	60
2007	1349.74	1747.86	2007	18.75	24.28	77.78	72
2008	1360.39	1904.87	2008	18.14	25.40	73.33	75
2009	1313.18	1926.92	2009	17.28	25.35	81.58	76
2010	1276.30	1954.67	2010	16.58	25.39	76.62	77
2011	1359.05	1972.67	2011	17.42	25.29	84.62	78
2012	1407.38	1961.25	2012	18.04	25.14	91.03	78
2013	1466.90	1992.05	2013	18.57	25.22	91.14	79
2014	1553.33	2036.09	2014	19.18	25.14	90.12	81
2015	1521.91	2041.95	2015	18.79	25.21	91.36	81

App. 4: Summary of business models annual water usage, allocation, and per license. Volume unit are in cubic decametre. Blue = Independent businesses, orange = VC businesses.

(Source: Department of Sustainable Development, Government of Manitoba, 2016)

Year	Usage	Allocation	Year	Usage/Lic.	Allo./Lic.	% Response	# Licensee
2000	96.50	102.47	2000	16.08	17.08	83.33	6
2001	164.42	170.47	2001	14.95	15.50	63.64	11
2002	202.12	247.17	2002	13.47	16.48	66.67	15
2003	231.29	247.17	2003	15.42	16.48	73.33	15
2004	260.78	297.55	2004	14.49	16.53	66.67	18
2005	276.75	316.85	2005	14.57	16.68	63.16	19
2006	372.19	403.35	2006	14.89	16.13	56.00	25
2007	403.81	463.08	2007	14.96	17.15	74.07	27
2008	402.49	467.28	2008	14.91	17.31	74.07	27
2009	386.22	470.19	2009	14.30	17.41	77.78	27
2010	395.69	470.19	2010	14.66	17.41	70.37	27
2011	392.20	473.25	2011	14.53	17.53	74.07	27
2012	406.52	474.50	2012	15.06	17.57	74.07	27
2013	414.52	474.50	2013	15.35	17.57	66.67	27
2014	403.70	484.11	2014	14.95	17.93	66.67	27
2015	403.63	506.30	2015	14.95	18.75	62.96	27

Year	Usage	Allocation	Year	Usage/Lic.	Allo./Lic.	% Response	# Licensee
2000	812.95	901.67	2000	16.26	18.03	48.00	50
2001	1301.38	1471.67	2001	16.68	18.87	50.00	78
2002	1612.65	1861.98	2002	17.34	20.02	88.17	93
2003	1773.67	2021.67	2003	18.29	20.84	90.72	97
2004	1817.92	2074.18	2004	18.18	20.74	86.00	100
2005	1919.92	2206.25	2005	18.28	21.01	85.71	105
2006	2099.59	2482.45	2006	17.95	21.22	92.31	117
2007	2392.78	2893.93	2007	17.99	21.76	85.71	133
2008	2389.19	3060.84	2008	17.57	22.51	83.09	136
2009	2358.80	3093.58	2009	17.22	22.58	85.40	137
2010	2409.43	3178.03	2010	17.21	22.70	82.86	140
2011	2504.95	3215.33	2011	17.77	22.80	87.23	141
2012	2627.88	3314.57	2012	18.38	23.18	90.91	143
2013	2648.94	3351.17	2013	18.40	23.27	93.06	144
2014	2697.59	3397.90	2014	18.48	23.27	91.78	146
2015	2733.68	3437.71	2015	18.72	23.55	93.15	146

App. 5: Summary of operation type annual water usage, allocation, and per license. Volume unit are in cubic decametre. Blue = sow (farrow-to-nursery), green = nursery, red = feeder.

(Source: Department of Sustainable Development, Government of Manitoba, 2016)

Year	Usage	Allocation	Year	Usage/Lic.	Allo/Lic.	% Response	# Licensee
2000	332.83	403.44	2000	14.47	17.54	65.22	23
2001	453.40	574.24	2001	15.63	19.80	51.72	29
2002	531.89	656.54	2002	17.16	21.18	90.32	31
2003	579.05	729.43	2003	17.55	22.10	96.97	33
2004	637.84	779.84	2004	17.72	21.66	94.44	36
2005	677.12	829.60	2005	17.82	21.83	94.74	38
2006	771.05	993.50	2006	17.13	22.08	91.11	45
2007	912.34	1165.61	2007	17.89	22.86	92.16	51
2008	943.59	1252.81	2008	17.80	23.64	90.57	53
2009	913.50	1291.35	2009	16.92	23.91	90.74	54
2010	899.99	1293.11	2010	16.67	23.95	87.04	54
2011	904.35	1310.37	2011	16.75	24.27	94.44	54
2012	918.47	1351.76	2012	17.01	25.03	94.44	54
2013	978.29	1384.86	2013	17.79	25.18	90.91	55
2014	1014.11	1385.56	2014	18.44	25.19	90.91	55
2015	976.17	1374.72	2015	17.75	24.99	92.73	55

Year	Usage	Allocation	Year	Usage/Lic.	Allo/Lic.	% Response	# Licensee
2000	155.55	109.26	2000	19.44	13.66	25.00	8
2001	169.34	136.26	2001	16.93	13.63	40.00	10
2002	236.07	291.37	2002	16.86	20.81	85.71	14
2003	273.74	291.37	2003	19.55	20.81	85.71	14
2004	267.58	291.37	2004	19.11	20.81	71.43	14
2005	293.24	303.64	2005	19.55	20.24	66.67	15
2006	337.95	384.28	2006	17.79	20.23	84.21	19
2007	331.19	404.68	2007	16.56	20.23	80.00	20
2008	324.09	404.68	2008	16.20	20.23	75.00	20
2009	354.93	407.59	2009	17.75	20.38	80.00	20
2010	342.94	407.59	2010	17.15	20.38	85.00	20
2011	378.58	426.09	2011	18.03	20.29	85.71	21
2012	412.70	466.36	2012	17.94	20.28	86.96	23
2013	457.68	466.36	2013	19.90	20.28	86.96	23
2014	463.84	489.56	2014	19.33	20.40	87.50	24
2015	470.64	489.56	2015	19.61	20.40	91.67	24

Continue to the next page

Year	Usage	Allocation	Year	Usage/Lic.	Allo/Lic.	% Response	# Licensee
2000	421.07	491.44	2000	16.84	19.66	48.00	25
2001	843.06	931.64	2001	16.86	18.63	54.00	50
2002	1046.81	1161.24	2002	16.62	18.43	82.54	63
2003	1152.17	1248.04	2003	17.73	19.20	84.62	65
2004	1173.28	1300.52	2004	17.25	19.13	79.41	68
2005	1226.31	1389.86	2005	17.27	19.58	78.87	71
2006	1362.78	1508.02	2006	17.47	19.33	83.33	78
2007	1553.06	1786.72	2007	17.45	20.08	79.78	89
2008	1524.00	1870.63	2008	16.93	20.78	77.78	90
2009	1476.59	1864.83	2009	16.41	20.72	81.11	90
2010	1562.19	1947.52	2010	16.80	20.94	76.34	93
2011	1614.22	1952.12	2011	17.36	20.99	79.57	93
2012	1703.23	1970.95	2012	18.31	21.19	84.95	93
2013	1627.49	1974.45	2013	17.50	21.23	88.17	93
2014	1623.34	2006.89	2014	17.27	21.35	86.17	94
2015	1690.50	2079.73	2015	17.98	22.12	85.11	94

App. 6: Maximum allocation per license over 16 years period (2000 – 2015). Volume unit are in cubic decametre.

(Source: Department of Sustainable Development, Government of Manitoba, 2016)

Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
001	-	-	-	-	24.67	24.67	24.67	22.80	22.80	22.80	22.80	22.80	22.80	22.80	22.80	22.80
002	-	-	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90
003	-	-	-	-	-	-	-	-	-	-	17.75	17.75	17.75	17.75	17.75	17.75
004	-	-	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	17.00
005	-	-	-	-	-	-	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60
006	-	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	27.00
007	-	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	24.00
008	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	35.00	35.00	35.00	35.00	35.00	35.00
009	-	-	-	-	-	-	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60
010	-	-	-	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	34.00
011	-	-	-	-	-	-	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50
012	-	-	-	-	-	-	-	15.30	15.30	15.30	15.30	15.30	15.30	15.30	15.30	15.30
013	-	-	-	-	-	-	-	27.38	27.38	27.38	27.38	27.38	27.38	27.38	27.38	27.38
014	-	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	33.00	33.00
015	18.50	18.50	18.50	18.50	18.50	18.50	18.50	18.50	18.50	18.50	20.50	20.50	20.50	20.50	20.50	20.50
016	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
017	-	-	-	-	-	-	-	-	-	-	-	18.00	18.00	18.00	18.00	18.00
018	-	17.70	17.70	17.70	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	28.00	28.00
019	-	-	-	-	-	-	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
020	39.80	39.80	39.80	39.80	39.80	39.80	39.80	34.20	34.20	34.20	34.20	34.20	34.20	34.20	34.20	34.20
021	-	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	13.65	13.65	13.65	13.65
022	-	23.20	23.20	23.20	23.20	30.09	30.09	30.09	30.09	30.09	30.09	30.09	30.09	30.09	33.00	33.00
023	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	35.84	35.84	35.84	35.84	35.84	35.84
024	-	-	-	-	-	32.26	32.26	32.26	32.26	32.26	32.26	32.26	32.26	32.26	32.26	32.26
025	-	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	34.00	34.00
026	-	-	-	-	-	-	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40
027	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67	24.67
028	-	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	12.00
029	-	-	-	-	-	-	-	33.20	33.20	33.20	33.20	33.20	33.20	33.20	33.20	33.20
030	-	-	51.81	51.81	51.81	51.81	51.81	51.81	51.81	51.81	51.81	51.81	51.81	51.81	51.81	51.81
031	-	-	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	14.30
032	-	-	-	-	-	-	-	49.58	49.58	49.58	49.58	49.58	49.58	49.58	49.58	49.58
033	-	-	-	-	-	17.92	17.92	17.92	17.92	17.92	17.92	17.92	17.92	17.92	17.92	17.92
034	-	-	-	-	-	-	15.70	15.70	15.70	15.70	15.70	15.70	15.70	15.70	15.70	15.70
035	-	-	-	-	-	-	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40	21.40
036	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	20.50	20.50
037	-	-	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	20.00
038	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	12.94	16.00	16.00	16.00	16.00	16.00
039	-	-	-	-	-	-	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60
040	-	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90
041	-	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90
042	-	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	15.50
043	-	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	13.00
044	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	14.60	14.60	14.60	14.60
045	-	-	-	-	-	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41
046	-	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	13.70	13.70
047	-	-	-	-	-	-	-	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
048	18.20	18.20	18.20	18.20	18.20	18.20	18.20	18.20	18.20	18.20	18.20	18.20	18.20	18.20	29.50	29.50
049	-	11.90	11.90	11.90	17.85	17.85	17.85	17.85	17.85	17.85	17.85	17.85	17.85	17.85	17.85	25.00
050	-	24.80	24.80	24.80	24.80	24.80	24.80	24.80	24.80	24.80	24.80	24.80	44.50	44.50	44.50	44.50
051	-	-	19.80	19.80	19.80	19.80	19.80	19.80	19.80	19.80	19.80	19.80	19.80	19.80	25.00	25.00
052	-	-	-	-	-	-	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50
053	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	14.26	14.26	14.26	14.26
054	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	17.68	17.68	17.68
055	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	16.60	16.60	16.60	16.60
056	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	17.64	17.64	17.64	17.64
057	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	12.55	12.55	12.55	12.55
058	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	12.55	12.55	12.55	12.55
059	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	12.55	12.55	12.55	12.55
060	-	49.20	49.20	49.20	49.20	49.20	49.20	49.20	49.20	49.20	49.20	49.20	68.45	68.45	68.45	68.45
061	-	-	28.80	28.80	28.80	28.80	28.80	28.80	28.80	28.80	28.80	28.80	28.80	28.80	14.00	14.00
062	12.40	12.40	12.40	12.40	12.40	12.40	26.90	26.90	26.90	26.90	26.90	26.90	26.90	26.90	26.90	26.90
063	-	-	-	-	-	-	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40
064	12.40	12.40	12.40	12.40	12.40	12.40	26.90	26.90	26.90	26.90	26.90	26.90	26.90	26.90	26.90	26.90
065	12.60	12.60	12.60	12.60	12.60	12.60	12.60	12.60	12.60	12.60	12.60	12.60	12.60	12.60	12.60	16.00
066	-	-	-	-	-	-	-	33.20	33.20	33.20	33.20	33.20	33.20	33.20	33.20	33.20
067	-	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	15.00	15.00
068	-	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	19.00	19.00
069	28.20	28.20	28.20	28.20	28.20	28.20	28.20	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
070	9.90	9.90	9.90	9.90	9.90	9.90	9.90	9.90	9.90	9.90	9.90	11.00	11.00	11.00	11.00	11.00
071	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.80	10.80	10.80	10.80	10.80
072	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	15.00	15.00	15.00	15.00	15.00
073	9.90	9.90	9.90	9.90	9.90	9.90	9.90	9.90	9.90	9.90	9.90	13.70	13.70	13.70	13.70	13.70
074	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	34.20	34.20	34.20	34.20	34.20
075	-	-	-	53.80	53.80	53.80	53.80	53.80	53.80	53.80	53.80	53.80	53.80	53.80	40.00	40.00

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Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
076	-	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	45.00
077	-	-	-	-	-	-	-	33.80	33.80	33.80	33.80	33.80	33.80	33.80	33.80	33.80
078	-	-	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	16.00
079	-	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	15.50
080	-	-	-	-	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30
081	-	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10
082	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	38.50	38.50	38.50	38.50	38.50	38.50	38.50
083	-	-	69.00	69.00	69.00	69.00	69.00	69.00	69.00	69.00	69.00	69.00	69.00	69.00	69.00	56.00
084	-	-	-	-	-	24.88	24.88	24.88	24.88	24.88	24.88	24.88	24.88	24.88	24.88	24.88
085	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40.70
086	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	21.83	21.83	21.83	21.83	21.83	21.83	21.83	21.83
087	18.70	18.70	18.70	18.70	18.70	18.70	18.70	25.59	25.59	25.59	25.59	25.59	25.59	25.59	25.59	25.59
088	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	22.80	22.80	22.80	22.80	22.80	22.80	22.80	22.80
089	-	-	-	-	18.41	18.41	18.41	18.41	18.41	18.41	18.41	18.41	18.41	18.41	18.41	18.41
090	12.50	12.50	12.50	12.50	12.50	12.50	21.10	21.10	21.10	21.10	21.10	21.10	21.10	21.10	21.10	21.10
091	16.00	16.00	16.00	16.00	16.00	16.00	16.00	29.20	29.20	29.20	29.20	29.20	29.20	29.20	29.20	29.20
092	16.80	16.80	16.80	16.80	16.80	16.80	16.80	21.80	21.80	21.80	21.80	21.80	21.80	21.80	21.80	21.80
093	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	12.50	12.50	12.50	12.50	12.50	12.50	12.50
094	-	-	-	-	-	-	-	-	-	-	17.00	17.00	17.00	17.00	17.00	17.00
095	-	-	-	-	-	-	-	-	-	-	31.90	31.90	31.90	31.90	31.90	31.90
096	-	-	-	-	-	-	-	9.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
097	-	-	-	-	-	-	-	22.80	22.80	22.80	22.80	22.80	22.80	22.80	22.80	22.80
098	-	-	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	55.20	55.20
099	-	-	19.90	19.90	19.90	19.90	19.90	19.90	19.90	19.90	19.90	19.90	19.90	19.90	19.90	23.00
100	-	-	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	9.10	13.00
101	-	-	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10
102	-	-	-	-	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	17.10
103	-	27.70	27.70	27.70	27.70	27.70	27.70	27.70	27.70	27.70	27.70	27.70	27.70	27.70	22.50	22.50
104	-	27.30	27.30	27.30	27.30	27.30	27.30	27.30	27.30	27.30	27.30	27.30	27.30	27.30	28.00	28.00
105	-	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	15.40	15.40
106	-	12.90	12.90	12.90	12.90	12.90	12.90	12.90	12.90	12.90	12.90	12.90	12.90	12.90	15.30	15.30
107	-	-	-	-	-	12.27	12.27	12.27	12.27	12.27	12.27	12.27	12.27	12.27	12.27	12.27
108	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	11.30
109	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30
110	-	-	-	-	-	24.88	24.88	24.88	24.88	24.88	24.88	24.88	24.88	24.88	24.88	24.88
111	-	-	-	-	-	-	42.30	42.30	42.30	42.30	42.30	42.30	42.30	42.30	42.30	42.30
112	-	-	-	-	-	-	42.30	42.30	42.30	42.30	42.30	42.30	42.30	42.30	42.30	42.30
113	-	-	-	-	-	-	-	-	34.20	34.20	34.20	34.20	34.20	34.20	34.20	34.20
114	-	-	-	-	-	-	-	-	-	23.44	23.44	23.44	23.44	23.44	23.44	23.44
115	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30.80	30.80
116	-	-	12.90	12.90	12.90	12.90	12.90	12.90	12.90	12.90	12.90	12.90	13.51	13.51	13.51	13.51
117	-	-	-	-	-	-	11.06	11.06	11.06	11.06	11.06	11.06	11.06	11.06	11.06	11.06
118	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	30.00	30.00	30.00	30.00	30.00	30.00	30.00
119	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	12.00	12.00	12.00	12.00	12.00	12.00	12.00
120	-	-	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	20.00
121	-	-	-	-	-	-	-	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40
122	-	-	-	-	-	-	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60
123	-	-	-	24.89	24.89	24.89	24.89	24.89	24.89	24.89	24.89	24.89	24.89	24.89	24.89	24.89
124	-	-	-	-	-	-	-	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70
125	45.50	49.80	49.80	49.80	49.80	49.80	49.80	49.80	49.80	49.80	49.80	49.80	49.80	49.80	49.80	49.80
126	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	24.00
127	16.40	16.40	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00
128	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	29.20	29.20	29.20	29.20	29.20	29.20	29.20	29.20
129	10.20	10.20	10.20	10.20	10.20	10.20	10.20	10.20	10.20	15.00	15.00	15.00	15.00	15.00	15.00	15.00
130	-	-	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	30.00
131	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40
132	-	-	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	12.33	12.33	12.33	12.33
133	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	14.26	14.26	14.26	14.26	14.26	14.26
134	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	34.13	34.13	34.13	34.13
135	-	-	-	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	30.00
136	-	-	-	-	-	-	-	13.66	13.66	13.66	13.66	13.66	13.66	13.66	13.66	13.66
137	25.90	25.90	25.90	25.90	25.90	25.90	25.90	25.90	25.90	25.90	25.90	25.90	33.12	33.12	33.12	33.12
138	-	-	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	27.30
139	-	-	-	-	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41
140	-	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90
141	-	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	17.00
142	-	-	-	-	-	-	12.30	12.30	12.30	12.30	12.30	12.30	12.30	12.30	12.30	12.30
143	-	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	18.00	18.00
144	13.26	13.26	13.26	13.26	13.26	13.26	13.26	13.26	13.26	11.37	11.37	11.37	11.37	11.37	11.37	11.37
145	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60	34.10	34.10	34.10
146	-	-	-	-	-	-	-	27.30	27.30	27.30	27.30	27.30	27.30	27.30	27.30	27.30
147	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	14.56	14.56	14.56	14.56
148	-	-	-	-	-	-	13.70	13.70	13.70	13.70	13.70	13.70	13.70	13.70	13.70	13.70
149	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	18.25	18.25	18.25	18.25
150	-	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10

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Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
151	-	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	14.90	17.20	17.20	17.20
152	-	-	-	-	-	-	13.44	13.44	13.44	13.44	13.44	13.44	13.44	13.44	13.44	13.44
153	-	-	-	-	-	-	-	-	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
154	-	-	-	-	-	-	13.70	13.70	13.70	13.70	13.70	13.70	13.70	13.70	13.70	13.70
155	-	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	19.00
156	-	-	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30
157	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60
158	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	14.26	14.26	14.26	14.26
159	-	-	-	-	-	-	-	14.60	14.60	14.60	14.60	14.60	14.60	14.60	14.60	14.60
160	-	-	-	-	-	-	-	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40
161	-	48.30	48.30	48.30	48.30	48.30	48.30	48.30	48.30	48.30	48.30	48.30	48.30	48.30	48.30	48.30
162	-	-	-	-	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	12.41	14.00
163	11.30	11.30	11.30	11.30	11.30	11.30	12.80	12.80	12.80	12.80	12.80	12.80	12.80	12.80	12.80	12.80
164	-	-	-	-	-	-	-	41.85	41.85	41.85	41.85	41.85	41.85	41.85	41.85	41.85
165	-	-	-	-	-	-	-	14.60	14.60	14.60	14.60	14.60	14.60	14.60	14.60	14.60
166	-	-	-	-	-	-	-	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00
167	-	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90	11.90
168	-	-	-	-	-	-	-	-	-	-	-	-	11.50	11.50	11.50	11.50
169	-	-	-	-	-	-	-	-	-	-	-	-	11.50	11.50	11.50	11.50
170	-	12.40	12.40	12.40	12.40	32.26	32.26	32.26	32.26	32.26	32.26	32.26	32.26	32.26	32.26	32.26
171	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	16.60	22.00
172	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	22.00
173	-	-	-	-	-	-	-	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60	13.60

App. 7: Water usage per license over 16 years period (2000 – 2015). Volume unit are in cubic decametre.
Green value = reported water usage, orange = data substitution.

(Source: Department of Sustainable Development, Government of Manitoba, 2016)

Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
001					14.74	14.74	14.74	15.91	16.43	17.73	13.64	13.66	13.83	14.00	13.40	14.09
002			17.30	17.30	17.30	17.30	17.30	17.30	17.30	15.62	15.52	17.38	17.11	17.59	16.64	21.24
003											17.14	17.57	19.77	18.57	14.30	18.00
004			8.62	11.16	8.59	9.93	11.25	12.05	11.41	11.24	11.66	11.35	18.79	14.02	15.46	13.90
005							9.88	10.66	9.83	10.12	10.12	10.12	10.12	10.12	10.12	10.12
006		20.45	21.28	12.89	16.53	17.99	21.69	23.49	20.25	13.39	16.76	21.07	26.84	24.10	25.16	24.81
007		9.10	13.23	12.85	15.89	6.26	16.99	12.55	8.59	14.22	13.62	15.88	16.03	15.46	14.93	15.11
008	4.70	25.85	24.76	22.69	16.13	16.13	16.13	16.13	16.13	16.13	26.88	31.30	25.29	29.37	31.30	31.65
009							8.53	8.99	8.06	8.53	8.53	8.53	8.53	8.53	8.53	8.53
010				6.08	21.82	11.92	29.33	22.32	31.77	29.57	27.41	29.39	29.34	25.83	4.49	30.25
011							14.92	12.88	14.37	15.67	15.57	15.50	15.50	14.92	14.92	14.92
012								16.79	16.79	14.30	9.87	10.68	26.38	18.65	18.14	19.51
013								29.97	24.94	24.94	24.94	24.94	25.13	25.06	24.35	24.13
014		31.00	29.66	27.69	32.76	30.30	30.30	31.94	31.25	30.09	30.98	30.98	29.35	26.94	30.25	30.25
015	21.58	21.58	16.35	21.03	17.44	19.21	19.08	34.50	10.63	25.27	24.22	22.52	22.52	20.47	23.17	25.76
016	21.27	19.98	17.91	17.91	17.91	17.91	18.81	19.67	21.72	24.02	26.82	24.85	22.82	24.31	25.32	25.46
017												16.60	17.55	18.74	16.41	18.34
018		19.56	20.12	20.34	11.05	22.66	21.78	21.35	19.15	14.55	10.60	28.00	25.60	27.36	20.85	22.17
019							11.01	12.19	14.20	15.16	15.31	15.02	14.65	15.83	8.54	3.14
020	29.87	6.67	47.31	46.54	47.12	33.29	21.38	29.12	28.16	28.67	28.69	30.74	33.70	26.61	27.15	26.09
021		9.60	10.90	11.37	12.31	12.07	12.91	12.80	12.00	12.79	9.85	14.28	12.96	13.90	13.95	12.48
022		22.20	14.44	26.91	16.34	27.22	31.57	25.32	24.00	23.19	23.19	7.78	12.85	27.28	28.48	22.20
023	18.68	32.10	30.54	30.14	30.70	25.35	23.33	26.83	26.58	24.55	26.38	25.99	25.82	25.21	30.86	24.48
024						16.49	16.49	20.96	16.49	23.97	12.55	12.06	12.29	17.08	15.90	17.13
025		24.79	24.79	28.60	24.91	25.95	26.43	26.92	24.41	28.79	19.82	22.60	28.00	24.81	19.06	21.93
026							30.08	28.05	22.72	22.93	23.03	23.79	25.37	25.65	27.11	25.92
027	22.15	26.43	15.69	15.69	15.69	15.69	15.69	15.69	15.69	15.69	15.69	15.69	15.69	7.41	6.76	15.69
028		9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86
029								29.81	29.81	30.83	31.60	34.22	30.23	30.31	26.28	25.21
030			16.61	25.07	15.79	15.79	15.79	15.79	15.79	15.79	12.57	13.58	12.24	13.99	15.79	16.43
031			9.19	11.03	12.06	13.18	13.18	14.99	14.99	14.99	14.73	12.10	12.10	12.10	12.10	12.11
032									18.20	18.20	18.20	18.20	18.20	18.20	18.20	18.20
033						18.37	20.64	23.33	23.33	23.33	23.33	23.33	23.33	23.33	23.33	23.33
034							13.35	14.00	13.00	13.00	13.00	14.83	15.81	13.86	13.86	13.86
035							16.99	18.98	20.70	20.70	20.70	21.20	23.94	23.40	23.67	22.22
036	9.44	8.65	11.48	10.46	14.76	1.75	2.06	2.36	2.21	2.20	8.02	10.53	14.91	18.56	16.77	16.95
037			9.72	3.95	3.42	3.37	3.58	9.80	11.23	12.85	13.06	13.01	13.28	13.50	12.66	12.65
038	10.51	10.18	10.61	11.43	10.19	9.33	9.58	9.91	9.61	9.95	9.95	9.56	6.79	9.82	9.82	9.82
039							4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.91	4.33
040		15.92	12.78	12.25	11.34	11.14	12.36	17.57	18.81	12.17	20.08	16.89	25.52	25.52	10.58	15.92
041		10.22	10.22	10.22	10.22	10.22	10.22	10.21	10.22	10.22	10.22	10.22	10.22	10.22	10.22	10.22
042		11.55	12.14	12.01	12.42	15.22	14.34	13.84	12.91	12.91	12.91	12.91	12.91	12.91	12.91	11.76
043		11.71	11.98	15.03	13.59	10.65	12.28	10.73	10.53	10.98	11.38	12.72	12.16	10.09	10.62	11.16
044	13.82	13.82	12.74	15.33	16.26	15.75	11.55	11.74	11.35	12.79	12.91	14.59	15.09	14.10	15.31	13.93
045						11.80	11.80	11.80	11.80	12.73	10.57	12.96	11.96	9.80	11.80	11.80
046		9.17	14.04	10.62	16.24	14.30	17.02	17.28	12.23	10.92	12.62	12.30	12.52	12.17	12.45	12.27
047								20.65	20.48	20.83	20.83	20.83	20.83	21.37	20.83	20.83
048	18.21	21.94	12.19	12.65	17.98	16.17	17.26	19.11	18.97	18.43	18.43	18.43	21.64	25.22	18.21	16.54
049		5.89	19.93	20.42	31.48	21.85	31.33	27.26	13.66	14.40	20.60	29.48	22.04	22.61	9.29	18.70
050		22.99	32.17	32.00	32.90	32.93	32.93	36.04	38.69	41.11	44.36	42.33	38.80	38.19	45.84	46.86
051			20.88	21.57	24.39	24.39	21.69	26.33	25.22	20.80	21.96	22.24	22.56	22.98	23.70	20.15
052							9.58	13.62	15.29	4.04	4.04	4.04	5.70	14.35	15.59	9.58
053	12.45	12.45	10.27	13.97	12.94	14.13	10.60	11.39	10.95	11.86	11.21	11.56	12.33	15.05	13.84	14.17
054	12.71	12.71	9.32	14.06	13.29	13.33	11.25	11.23	12.02	12.99	12.84	13.13	13.60	14.05	13.52	13.32
055	17.25	17.25	16.47	18.92	15.59	16.91	14.07	14.65	15.76	14.47	16.61	16.47	21.99	18.69	20.41	20.50
056	16.52	16.52	16.34	19.65	14.59	17.92	14.43	14.86	13.36	13.33	13.29	17.69	19.50	20.78	15.44	20.12
057	2.12	9.04	10.42	11.63	10.64	11.14	10.49	9.70	8.94	9.04	9.04	8.34	9.00	9.01	8.01	8.05
058	3.13	7.65	10.03	8.89	7.36	8.52	6.61	7.08	5.96	8.37	9.14	8.48	8.10	7.65	7.51	7.92
059	2.61	7.62	6.57	8.26	8.53	9.23	7.66	7.39	6.73	7.74	8.38	8.36	9.22	7.74	7.73	8.13
060		42.26	24.77	33.08	30.83	30.08	41.22	41.24	41.10	43.32	46.68	46.46	46.77	47.30	59.39	59.39
061			0.56	7.30	7.91	9.23	8.08	9.25	10.55	5.95	7.75	6.95	7.93	10.75	13.03	12.34
062	33.16	33.16	26.04	22.72	33.16	33.16	30.21	31.77	32.51	35.13	35.88	28.97	43.33	38.05	24.83	48.44
063							14.95	18.19	16.37	18.00	19.43	20.88	24.09	23.10	23.77	24.50
064	35.33	35.33	24.92	31.23	32.02	37.07	39.84	30.32	31.02	32.37	34.71	42.29	43.66	41.05	33.37	40.79
065	6.10	13.76	7.32	12.41	17.21	17.16	15.52	15.85	15.87	13.98	13.51	14.55	13.80	14.18	13.90	15.10
066								14.32	13.34	14.12	14.98	14.28	14.96	13.51	11.78	12.51
067		12.80	12.10	15.72	16.11	16.90	12.74	11.01	12.01	11.43	11.30	11.56	13.26	12.18	11.07	11.75
068		15.45	15.47	22.53	13.38	17.49	14.77	13.79	10.94	10.19	25.53	15.72	16.68	14.32	12.65	12.88
069	32.43	42.87	33.71	42.87	45.49	47.16	39.39	39.87	42.67	42.95	45.64	44.91	41.66	51.37	48.41	44.46
070	5.70	9.39	9.78	10.08	12.38	11.36	9.74	9.92	7.87	8.47	9.24	9.10	8.87	9.06	9.35	9.91
071	7.88	7.88	8.30	8.60	7.75	8.62	8.54	6.53	6.42	5.83	4.79	4.54	12.48	9.50	8.42	10.05
072	14.70	14.70	14.50	17.05	14.90	15.44	14.30	12.46	12.55	13.03	14.11	13.93	18.58	13.00	15.18	16.73
073	3.51	11.29	11.71	12.20	11.71	12.25	11.13	10.73	7.71	10.78	10.69	10.79	14.17	14.59	12.60	14.78
074	8.46	21.00	16.34	21.31	21.09	22.62	19.67	20.52	21.50	21.30	22.34	23.73	24.07	23.11	24.40	24.52
075				13.48	13.48	13.48	13.48	13.48	13.48	11.30	3.01	7.02	18.51	22.41	18.63	13.48

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Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
076		38.06	38.06	38.06	38.06	38.06	38.06	38.06	38.06	38.06	38.06	38.06	38.06	25.11	45.31	43.76
077								17.79	17.79	17.79	17.79	17.79	18.34	17.59	16.93	18.30
078			11.06	15.35	14.44	12.47	11.75	13.21	12.61	11.30	13.50	14.19	14.94	14.98	15.56	14.97
079		14.21	11.25	16.17	15.05	15.90	14.09	13.22	13.16	13.84	14.53	15.45	14.92	14.16	13.97	13.17
080					10.37	10.37	10.37	5.56	7.35	4.71	13.61	13.61	13.61	11.32	11.76	11.76
081		9.33	21.20	25.62	22.27	44.04	41.90	18.88	12.26	13.14	11.90	12.75	12.88	12.11	11.44	13.49
082	17.21	17.21	17.21	2.93	14.12	6.89	6.56	5.66	20.47	23.47	22.29	22.27	24.04	24.12	24.47	26.44
083			19.28	19.94	19.26	19.76	22.92	23.98	22.27	20.04	19.34	22.17	22.06	23.21	20.19	29.11
084						25.10	25.87	23.77	23.28	23.28	21.38	22.33	21.51	28.47	16.27	12.59
085															23.32	20.57
086	19.23	19.23	19.23	19.23	19.23	19.23	23.73	19.35	20.60	19.02	17.05	17.05	18.02	20.36	20.14	16.97
087	28.35	21.95	28.35	18.16	28.35	28.35	44.53	39.26	36.58	10.14	26.03	26.03	27.24	29.68	33.35	27.25
088	18.16	18.70	20.49	15.42	19.67	20.49	16.27	19.24	18.49	18.38	20.49	20.49	19.51	20.72	19.91	21.31
089					13.98	13.98	13.66	18.37	6.07	4.04	13.98	18.88	16.80	18.74	15.59	13.70
090	15.67	15.67	3.12	0.96	0.38	0.11	23.53	20.10	20.69	20.69	20.69	20.69	22.97	22.97	24.15	18.33
091	27.15	27.15	30.08	27.63	25.48	26.91	25.72	27.24	24.75	24.75	24.75	24.75	26.54	29.88	32.61	28.98
092	21.27	21.27	20.67	19.81	22.60	22.60	19.65	26.94	21.27	13.52	21.27	21.27	22.52	25.44	20.65	19.61
093	9.07	10.40	10.25	11.21	10.18	13.82	11.27	10.38	9.68	10.46	10.46	10.46	11.72	9.62	11.23	11.74
094											11.30	10.84	7.89	4.45	6.96	13.79
095											10.31	8.35	9.67	10.43	8.64	9.11
096								20.87	20.87	10.75	20.87	20.87	18.30	14.76	32.78	27.75
097								24.53	16.41	9.33	11.27	28.47	33.06	37.07	37.31	23.32
098			23.66	27.47	27.41	27.41	37.05	33.28	50.67	45.80	51.60	77.19	69.82	82.51	80.45	75.04
099			24.39	23.46	25.94	25.94	22.12	24.77	12.17	19.69	12.17	12.17	23.98	18.14	8.51	19.06
100			36.88	18.45	19.09	19.09	19.09	15.73	10.32	4.68	4.68	6.70	7.04	12.29	0.00	15.20
101			7.62	7.39	6.86	6.86	4.93	6.91	5.61	5.76	3.74	4.65	6.47	9.54	7.99	11.72
102					11.39	11.21	10.90	11.98	13.63	13.63	15.03	12.39	0.00	0.00	36.96	14.59
103															13.12	13.29
104		12.98	23.96	27.56	25.84	20.56	17.22	20.57	21.15	23.90	23.90	31.90	26.90	27.52	26.96	27.58
105		0.96	26.02	27.31	28.34	33.22	32.21	29.70	0.01	18.76	16.26	10.93	12.37	15.42	15.19	14.71
106		7.34	10.31	10.41	12.73	12.98	12.35	10.55	11.35	11.69	12.55	12.27	13.30	13.35	15.99	13.20
107						10.28	11.89	12.10	12.47	23.93	0.00	0.00	0.00	18.28	23.17	13.86
108	11.19	11.75	8.98	7.38	7.27	9.00	9.61	8.85	9.76	11.58	12.57	9.82	6.95	6.63	8.07	7.04
109	13.60	13.52	14.02	13.71	13.65	12.09	12.60	13.34	13.77	13.36	14.29	13.50	13.58	14.80	15.13	12.58
110						15.45	24.74	23.95	23.84	22.91	21.36	22.33	21.51	28.47	16.27	12.59
111							18.30	20.48	20.48	20.48	20.48	20.48	20.48	18.56	18.48	19.05
112							15.02	19.30	19.30	19.30	19.30	19.30	19.30	16.37	17.41	18.94
113								28.21							28.21	28.21
114										2.98	2.88	3.28	3.96	3.40	3.43	3.92
115														10.85	10.07	12.44
116			14.28	14.28	14.28	14.28	14.28	14.28	14.28	14.28	14.28	14.28	14.28	14.28	14.28	14.28
117							12.38	12.38	12.38	12.38	12.38	12.38	12.38	12.38	11.89	12.87
118	29.42	27.08	26.35	23.98	26.40	25.15	25.38	26.84	26.17	25.32	23.35	24.12	19.95	15.37	22.02	19.06
119	12.03	9.07	8.39	6.69	8.22	8.25	8.77	9.90	10.51	12.06	11.11	9.75	8.65	5.88	8.91	7.00
120			7.77	9.20	14.60	14.60	16.19	14.60	13.16	13.85	15.04	17.91	19.60	17.33	15.17	15.38
121								2.50	2.50	2.50	2.50	2.50	3.09	2.71	2.01	2.18
122							14.61	17.09	14.89	14.89	12.85	20.60	25.94	16.41	19.99	22.59
123				3.73	21.08	26.19	23.17	21.34	22.20	24.61	27.00	26.64	23.86	23.38	14.92	16.35
124								12.81	12.06	14.34	16.02	19.73	16.00	14.28	14.85	14.60
125	40.53	31.52	43.43	48.33	42.88	40.27	46.27	45.96	45.96	45.96	43.44	23.79	23.79	32.49	43.99	49.80
126	16.99	11.65	22.31	22.26	20.54	19.19	21.03	24.00	24.00	16.99	16.99	16.99	16.99	8.33	9.73	3.82
127	10.65	6.95	15.13	21.57	13.69	10.15	33.26	25.57	24.73	21.31	23.20	24.17	29.06	24.72	25.05	27.82
128	23.36	24.28	26.65	27.42	25.86	25.86	25.45	30.66	30.81	25.70	27.42	29.01	31.70	28.71	28.89	27.01
129	9.35	10.17	10.97	14.76	14.08	16.60	15.00	11.94	13.31	13.56	14.44	15.83	19.65	21.27	20.00	18.56
130			2.98	15.11	22.62	18.68	23.26	23.86	22.98	24.33	24.46	28.76	28.19	27.80	27.40	27.59
131	25.96	26.00	27.21	25.98	24.09	24.73	24.11	23.15	22.81	22.50	23.44	24.43	25.39	23.77	27.84	27.73
132			10.34	12.19	11.07	12.21	9.47	11.10	8.84	9.45	10.23	10.26	11.30	15.37	12.44	11.07
133	9.52	9.95	10.97	10.58	10.48	9.52	9.72	9.72	9.06	8.69	9.26	10.53	10.48	9.34	7.31	7.12
134	18.61	33.05	32.41	28.72	25.90	27.27	25.86	30.34	29.72	26.65	26.65	30.49	36.62	35.69	40.94	38.96
135				22.59	21.62	24.03	26.82	22.09	22.76	21.58	15.52	23.20	23.47	23.66	22.73	23.58
136								11.07	15.32	13.33	15.37	23.20	23.10	10.68	10.91	15.37
137	15.58	20.25	21.11	25.54	23.45	19.29	20.13	22.72	20.18	19.71	15.73	15.73	22.08	16.54	18.19	12.48
138			20.51	29.57	27.28	29.16	23.53	21.04	20.24	22.52	22.78	23.79	24.66	24.52	24.07	23.10
139					5.43	5.43	5.43	5.43	5.43	5.43	5.43	5.43	5.43	5.43	3.72	7.14
140		10.31	10.31	10.31	10.31	10.31	10.31	10.31	10.31	10.31	10.31	10.31	10.31	10.31	10.31	10.31
141		14.65	13.71	13.34	14.02	14.24	14.75	15.01	15.01	15.01	15.01	15.01	15.01	15.01	15.01	15.01
142							5.49	6.32	7.45	7.34	9.06	4.60	6.71	6.71	6.71	6.71
143		8.42	8.96	14.99	8.39	20.55	16.49	13.87	15.83	16.24	16.39	15.52	15.76	17.81	17.24	18.41
144	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48
145	29.67	20.95	30.27	30.92	32.70	33.11	25.45	16.59	29.28	13.79	35.14	35.71	37.67	34.95	34.88	33.69
146								25.59	25.59	25.59	25.59	26.14	24.79	24.45	24.82	27.74
147	6.18	15.28	11.65	25.52	26.08	26.60	12.85	12.53	11.69	13.37	17.69	12.55	14.83	13.64	12.19	11.90
148							9.83	9.24	9.12	8.83	8.70	9.65	7.22	7.22	6.39	4.31
149	9.29	8.38	10.72	8.47	13.07	13.07	13.07	13.07	13.21	15.11	1.35	1.35	1.35	3.54	11.36	12.28
150		19.54	19.70	20.15	18.22	22.06	15.72	13.24	12.61	12.41	0.43	8.89	14.93	17.75	12.56	14.23

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Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
151		3.94	14.64	16.87	15.78	28.53	30.19	13.77	13.19	14.26	13.41	14.29	17.43	11.51	16.93	16.59
152							12.15	13.77	15.41	20.85	25.70	21.78	9.61	15.65	25.73	21.34
153									17.90	17.90	17.90	18.56	18.66	18.14	18.51	15.61
154							9.36	10.36	10.55	12.73	12.73	12.73	12.73	13.25	11.31	14.19
155		12.30	12.30	11.60	11.06	9.06	11.89	14.01	12.19	17.74	19.36	14.31	18.76	8.37	7.04	4.51
156			10.31	6.55	9.46	11.06	13.29	10.88	8.86	9.94	9.14	10.84	11.58	10.66	11.45	10.31
157	12.27	12.27	12.27	41.83	12.27	1.52	7.59	3.97	12.27	13.75	10.89	5.32	8.05	13.89	14.04	14.09
158	12.93	12.93	7.84	15.01	14.95	15.23	11.81	11.81	11.48	12.06	12.47	14.28	13.35	14.48	13.49	12.76
159								13.52	7.24	7.22	8.20	8.20	8.20	6.25	8.20	6.77
160								31.77	31.77	31.77	31.77	31.77	31.77	31.77	31.70	31.84
161		14.70	14.86	14.86	14.86	14.86	14.86	14.86	14.86	14.86	14.86	14.86	14.86	14.86	14.86	14.86
162					11.06	11.06	11.06	11.06	11.06	11.04	11.96	11.96	11.96	11.96	11.96	13.55
163	4.89	4.99	5.41	5.24	4.45	5.35	8.11	7.23	6.87	6.34	7.25	6.77	7.53	10.24	8.78	10.05
164								27.15	24.70	24.70	24.70	24.70	24.70	24.70	24.70	22.25
165								10.04	12.25	13.58	16.35	12.95	13.43	15.22	3.10	2.10
166								23.75	23.75	23.75	23.75	23.75	23.75	23.75	23.75	23.75
167		7.77	15.78	14.52	14.10	15.83	17.13	15.42	20.85	16.93	16.93	16.93	16.93	8.19	4.74	14.43
168													0.77	4.55	5.83	9.89
169													3.12	15.45	12.48	12.69
170		10.52	10.59	11.28	11.79	12.69	1.64	0.96	27.93	33.79	17.83	13.64	27.14	9.37	20.81	34.69
171	20.21	17.91	15.78	18.40	19.37	18.47	18.82	18.35	18.59	18.87	8.65	0.00	0.00	17.40	17.40	15.36
172	16.34	16.42	17.91	19.44	20.26	19.88	17.09	19.13	20.96	19.99	8.96	0.00	0.00	17.89	17.89	18.33
173								10.66	12.71	11.64	12.15	9.14	8.98	12.37	9.51	8.78

App. 8: Maximum number of swine housed per license over 16 years period (2000 – 2015).
(Source: Department of Sustainable Development, Government of Manitoba, 2016)

Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
001					2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500
002			4,800	4,800			4,800	4,800	4,800	4,800			4,800	4,800	4,800	4,800
003											5,200	5,200	5,200	5,200	5,200	5,200
004			4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,200
005							4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
006		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,300
007		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
008	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	10,000	10,000	10,000	10,000	10,000	10,000
009							4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
010				10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400
011							6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
012								4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,200
013								3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
014		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
015	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,300	6,300	6,300	6,300	6,300
016	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400
017												2,000	2,000	2,000	2,000	2,000
018		5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200
019							10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
020	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
021		4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
022		7,200	7,200	7,200	7,200	9,700	9,700	9,700	9,700	9,700	9,700	9,700	9,700	9,700	9,700	9,700
023	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,500	10,500	10,500	10,500	10,500	10,500
024						10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400
025		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,600	8,600
026							3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
027	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100	6,100
028		4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
029							3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
030			20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
031			4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,200
032								8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
033						6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
034							4,600	4,600	4,600	4,600	4,600	4,600	4,600	4,600	4,600	4,600
035							6,270	6,270	6,270	6,270	6,270	6,270	6,270	6,270	6,270	6,270
036	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
037			4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	6,000
038	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,750	1,750	1,750	1,750	1,750
039							1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
040		1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
041		4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
042		4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,200
043		4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
044	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,150	4,150	4,150	4,150
045						4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
046		2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	4,000	4,000
047							8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
048	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,300	6,300
049		4,000	4,000	4,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,470
050		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	12,600	12,600	12,600	12,600
051			6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400
052							1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
053	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250
054	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550
055	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	9,200	9,200	9,200	9,200
056	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	9,200	9,200	9,200	9,200
057	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
058	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
059	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,100	1,100	1,100	1,100
060		6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
061			5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600
062	10,000	10,000	10,000	10,000	10,000	10,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
063							10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
064	10,000	10,000	10,000	10,000	10,000	10,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
065	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,200
066							10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400
067		4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,400	4,400
068		4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
069	5,700	5,700	5,700	5,700	5,700	5,700	5,700	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
070	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
071	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
072	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
073	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
074	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
075				8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000

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Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
151		1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
152							10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
153									3,250	3,250	3,250	3,250	3,250	3,250	3,250	3,250
154							4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
155		1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,250
156			1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280
157	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
158	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,100	4,100	4,100
159								1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
160								8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
161		5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300
162					4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
163	1,440	1,440	1,440	1,440	1,440	1,440	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400
164								10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
165								1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
166								3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
167		4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
168													7,500	7,500	7,500	7,500
169													7,500	7,500	7,500	7,500
170		4,000	4,000	4,000	4,000	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400
171	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	0	0	1,600	1,600	2,400
172	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	0	0	1,600	1,600	2,400
173								4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000

App. 9: Summary characteristics of 173 licenses in terms of control groups.
 (Source: Department of Sustainable Development, Government of Manitoba, 2016)

Code	Source	Region	Model	Type
001	GW	RoM	Ind.	Sow
002	GW	RoM	Ind.	Feeder
003	GW	RoM	Vert.	Feeder
004	GW	East	Vert.	Feeder
005	GW	East	Ind.	Feeder
006	GW	East	Vert.	Feeder
007	GW	East	Vert.	Feeder
008	GW	RoM	Vert.	Feeder
009	GW	East	Ind.	Feeder
010	GW	RoM	Vert.	Feeder
011	GW	East	Ind.	Feeder
012	SW	RoM	Vert.	Feeder
013	GW	East	Vert.	Sow
014	GW	East	Vert.	Feeder
015	GW	East	Vert.	Feeder
016	GW	RoM	Vert.	Feeder
017	SW	RoM	Vert.	Nursery
018	GW	RoM	Vert.	Feeder
019	GW	East	Vert.	Nursery
020	GW	East	Vert.	Sow
021	GW	RoM	Ind.	Feeder
022	GW	RoM	Ind.	Feeder
023	GW	East	Vert.	Feeder
024	GW	RoM	Vert.	Feeder
025	GW	East	Vert.	Feeder
026	GW	RoM	Vert.	Sow
027	GW	RoM	Ind.	Feeder
028	GW	East	Vert.	Feeder
029	SW	RoM	Vert.	Sow
030	SW	RoM	Vert.	Nursery
031	GW	East	Ind.	Feeder
032	SW	RoM	Vert.	Feeder
033	GW	RoM	Vert.	Feeder
034	GW	East	Ind.	Feeder
035	GW	RoM	Vert.	Feeder
036	GW	RoM	Vert.	Feeder
037	GW	RoM	Ind.	Feeder
038	GW	East	Ind.	Sow
039	GW	East	Ind.	Sow
040	GW	East	Vert.	Sow

Continue to the next page

Code	Source	Region	Model	Type
041	GW	RoM	Vert.	Feeder
042	GW	RoM	Vert.	Feeder
043	GW	East	Vert.	Feeder
044	GW	East	Vert.	Feeder
045	GW	East	Ind.	Feeder
046	GW	RoM	Ind.	Feeder
047	SW	East	Vert.	Feeder
048	GW	RoM	Vert.	Feeder
049	GW	East	Vert.	Feeder
050	GW	East	Vert.	Feeder
051	GW	East	Vert.	Feeder
052	GW	RoM	Ind.	Sow
053	GW	East	Vert.	Sow
054	GW	East	Vert.	Sow
055	GW	East	Vert.	Nursery
056	GW	East	Vert.	Nursery
057	GW	East	Vert.	Sow
058	GW	East	Vert.	Sow
059	GW	East	Vert.	Sow
060	GW	East	Vert.	Sow
061	GW	East	Vert.	Nursery
062	GW	East	Vert.	Nursery
063	GW	East	Vert.	Nursery
064	GW	East	Vert.	Nursery
065	GW	East	Vert.	Feeder
066	GW	RoM	Vert.	Feeder
067	GW	East	Vert.	Feeder
068	GW	East	Vert.	Feeder
069	GW	East	Vert.	Sow
070	GW	East	Vert.	Sow
071	GW	East	Vert.	Nursery
072	GW	East	Vert.	Feeder
073	GW	East	Vert.	Sow
074	GW	East	Vert.	Sow
075	SW	RoM	Vert.	Feeder
076	GW	RoM	Vert.	Feeder
077	SW	RoM	Vert.	Feeder
078	GW	East	Vert.	Feeder
079	GW	East	Vert.	Feeder
080	GW	East	Ind.	Sow

Continue to the next page

Code	Source	Region	Model	Type
081	GW	RoM	Vert.	Feeder
082	GW	East	Vert.	Sow
083	SW	RoM	Vert.	Sow
084	GW	RoM	Vert.	Sow
085	SW	RoM	Vert.	Nursery
086	GW	RoM	Vert.	Feeder
087	GW	RoM	Vert.	Feeder
088	GW	RoM	Vert.	Sow
089	GW	RoM	Vert.	Feeder
090	GW	RoM	Vert.	Feeder
091	GW	RoM	Vert.	Sow
092	GW	RoM	Vert.	Feeder
093	GW	RoM	Vert.	Sow
094	GW	East	Vert.	Feeder
095	GW	East	Vert.	Feeder
096	SW	RoM	Vert.	Feeder
097	SW	RoM	Vert.	Sow
098	GW	East	Vert.	Nursery
099	GW	RoM	Vert.	Feeder
100	GW	East	Vert.	Feeder
101	GW	East	Vert.	Feeder
102	GW	RoM	Vert.	Sow
103	GW	RoM	Vert.	Feeder
104	GW	RoM	Vert.	Sow
105	GW	RoM	Vert.	Nursery
106	GW	East	Vert.	Nursery
107	GW	RoM	Vert.	Nursery
108	GW	RoM	Vert.	Feeder
109	GW	RoM	Vert.	Sow
110	GW	RoM	Vert.	Sow
111	SW	RoM	Vert.	Sow
112	SW	RoM	Vert.	Sow
113	SW	RoM	Vert.	Sow
114	SW	RoM	Vert.	Sow
115	GW	RoM	Vert.	Sow
116	GW	East	Vert.	Nursery
117	GW	East	Vert.	Feeder
118	GW	RoM	Vert.	Feeder
119	GW	RoM	Vert.	Feeder
120	GW	East	Vert.	Feeder

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Code	Source	Region	Model	Type
121	SW	RoM	Vert.	Nursery
122	GW	RoM	Vert.	Sow
123	GW	East	Vert.	Sow
124	GW	RoM	Vert.	Feeder
125	GW	East	Vert.	Sow
126	GW	East	Vert.	Feeder
127	GW	RoM	Ind.	Feeder
128	GW	RoM	Ind.	Sow
129	GW	RoM	Ind.	Nursery
130	GW	RoM	Ind.	Feeder
131	GW	East	Vert.	Feeder
132	SW	RoM	Vert.	Feeder
133	GW	East	Vert.	Sow
134	GW	East	Vert.	Feeder
135	SW	RoM	Vert.	Sow
136	SW	RoM	Vert.	Feeder
137	GW	East	Vert.	Nursery
138	GW	East	Vert.	Feeder
139	GW	East	Vert.	Feeder
140	GW	East	Ind.	Feeder
141	GW	East	Ind.	Feeder
142	GW	East	Vert.	Nursery
143	GW	RoM	Vert.	Feeder
144	SW	RoM	Ind.	Nursery
145	GW	East	Vert.	Feeder
146	SW	RoM	Vert.	Feeder
147	GW	East	Vert.	Feeder
148	GW	East	Vert.	Sow
149	GW	East	Vert.	Sow
150	GW	RoM	Vert.	Feeder
151	GW	East	Vert.	Sow
152	GW	RoM	Vert.	Nursery
153	SW	RoM	Vert.	Sow
154	GW	East	Vert.	Feeder
155	GW	East	Vert.	Sow
156	GW	East	Vert.	Sow
157	GW	East	Vert.	Feeder
158	GW	East	Vert.	Feeder
159	GW	East	Vert.	Sow
160	GW	East	Vert.	Feeder

Continue to the next page

Code	Source	Region	Model	Type
161	GW	East	Vert.	Sow
162	GW	East	Ind.	Feeder
163	GW	East	Vert.	Sow
164	SW	RoM	Vert.	Feeder
165	GW	East	Ind.	Sow
166	SW	RoM	Ind.	Sow
167	GW	East	Vert.	Feeder
168	GW	East	Vert.	Nursery
169	GW	East	Vert.	Nursery
170	GW	RoM	Vert.	Feeder
171	GW	RoM	Vert.	Sow
172	GW	RoM	Vert.	Sow
173	GW	East	Vert.	Feeder

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