MODELLING URBAN DEVELOPMENT TRENDS AND OUTDOOR RESIDENTIAL WATER DEMAND IN THE OKANAGAN BASIN, BRITISH COLUMBIA

by

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ABSTRACT

The Okanagan Basin, the most arid watershed in Canada per capita, has been undergoing rapid population growth in the past 30 years. The results of this research show the varying residential water demand in the major communities in the Okanagan Basin. The outdoor water use was determined on a lot size basis for 2006 and projections were made to the year 2026 using a projected population increase and three urban development scenarios. The outdoor residential water demand varied from 30% to 60% of the annual domestic water demand depending on lot size. Two extreme urban growth cases: urban sprawl and densification, and an in-between scenario were developed using GIS for four case study communities: Vernon, Kelowna, Penticton and Osoyoos, which represent the diversity in climate and population trends in the Basin. The results showed that currently 47% of the domestic water is used for outdoor watering for the case studies. The business as usual growth scenario (urban sprawl), includes climate change and results in 7.3 Mm$^3$ of additional water needed for outdoor residential water demand, a 55% increase from existing conditions. However, with densification, 5.7 Mm$^3$ of outdoor residential water savings can be made. Additional water savings can be made if the existing outdoor residential water demand is reduced through more aggressive conservation practices such as effective marketing, reduced grassed area through xeriscape and mandatory watering restrictions. Using current growth projection to 2026 it is possible to significantly reduce outdoor residential water demand by more than 50% from existing conditions if densification and aggressive conservation practices are put in place.

The methods and results of this research have been incorporated into the Okanagan Basin Water Supply and Demand Project, which is in the final phases of completion.
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ABBREVIATIONS

ALR – Agricultural Land Reserve
ArcGIS – A program used for GIS presentation and manipulation
CORD – Central Okanagan Regional District
CMA – Census Metropolitan Area
CT – Census Tract
DA – Dissemination Areas
DBFs – Database Files
ET – Evapotranspiration
ET₀ – Reference Evapotranspiration (grass)
GIS – Geographic Information Systems
GVRD – Greater Vancouver Regional District, now Metro Vancouver
IDM – Irrigation Demand Model
Kc – Crop Coefficient
LPCD – Liters per capita per day
MAL – BC Ministry of Agriculture and Lands
MF – Multi-family
NORD – North Okanagan Regional District
OCP – Official Community Plan
RDOS – Regional District of Okanagan-Similkameen
SF – Single Family
1 Introduction

1.1 Significance and Context

The Okanagan Basin is the driest area in Canada per capita and has been experiencing rapid population growth in the past 30 years (Statistics Canada, 2000). This has led to concerns for the water future in the Basin as the water withdrawal licenses in most sub-watersheds are fully allocated. Residential water demand accounts for approximately 20%-25% of the water withdrawals in the area, with the agricultural sector being the largest water user at 70%. A recent study in the area indicates that over half of the residential water use is for outdoor purposes (Neale, 2005). Therefore, quantifying the residential water use in order to assess the effectiveness of conservation is important for municipal planning.

However, domestic water use in British Columbia is not very well studied as only a few municipalities have residential metering. For example, Metro Vancouver, the third largest city in Canada, has no single-family residential metering programs in place. Even when cities or towns do have residential metering in place, indoor and outdoor use is not separated. A recent study indicates that 91% of British Columbians have lawns and/or gardens and nearly 2 out of 3 households water their lawns (BC Stats, 2009a). Indoor domestic use has been typically assumed to be the winter month demand and outdoor water use is calculated by the difference between the summer and winter demand.

There is complexity in predicting the outdoor water demand for future conditions because it is a function of many factors. Climate, landscaping design and human behaviour are the unpredictable factors that affect outdoor residential water demand. Modeling residential water demand allows for scenario building to assess various conditions and possible future water demands.

Climate change is a concern in the Basin and several studies have looked at climatic change impacts in the Okanagan (Cohen et al, 2004 & 2006; Neale, 2005; Neilsen et al, 2001, 2004 &
Irrigation demands vary with precipitation and temperature, and predicting future precipitation pattern is highly problematic and uncertain. Nevertheless, it is generally agreed upon that there will be more precipitation extremes: flooding and droughts. Since temperatures are increasing, it is possible to use the climate data for 2003 (a very dry year) and a good analogue to document what a future climate regime may look like.

Landscape design and residential development is non-controllable within municipalities unless bylaws are put in place. Additionally, the planning departments within each municipality or town have indirect control over the outdoor residential water demand, the amount of lawn and gardens that are maintained on private residences, and what proportion of new developments are single and multi-family.

Irrigation modeling is a common practice in the agricultural industry; however, it is not commonly used to determine outdoor residential water use. The purpose of this thesis is to explore whether irrigation modeling is an effective way to model domestic outdoor water use with a focus on lawn watering. The Irrigation Demand Model (IDM) was developed by the British Columbia Ministry of Agriculture and Lands (MAL) in 2007 for use within the Okanagan Basin and includes all of the inputs that affect irrigation water demand: crop, soil, climate and irrigation type. The IDM was developed for use within the Okanagan Basin Water Supply and Demand project and focused on agricultural water demands (Mr. Ted van der Gulik, pers. comm.). Water demands in the urban sector were not initially included in the model (except for city parks); therefore, a project to assess the residential irrigation demand was required to fill this gap.

An additional concern is the rapidity of growth within urban areas to meet the population influx. The Water Supply and Demand project uses 2006 as a baseline year, and it is not expected that agriculture lands will change much as a result of the constraints inherent in the Agricultural Land Reserve, however the urban expansion is expected to be significant in the Okanagan. Therefore,
to improve upon the model, future scenarios of urban growth are important for water planning and management.

The way that the municipalities in the Okanagan Basin grow can greatly impact the future outdoor residential water demand; therefore, three scenarios were developed for use within the IDM. Two extreme scenarios: urban sprawl and densification, and a third in-between scenario are developed using GIS. The grassed area per lot was determined by digitizing fourteen sample areas in the four major communities in the Okanagan Basin to create a relationship between lot size and the proportion of the grassed area.

Finally, the outdoor residential water demand for the three urban growth scenarios is presented. The current conservation practices to reduce outdoor residential water demand are discussed along with additional recommended approaches.

1.2 Research Questions and Objectives

The research questions for this project were to determine the current amount of water used for outdoor watering of lawn and to develop scenarios for future outdoor water demand depending on population growth rates and urban design criteria. The overarching question is:

- How will population increases and urban development trends impact outdoor residential water use in the Okanagan?

To answer this question, three sub-questions were developed and are as follows:

- What are the extreme cases for urban growth?
- What is the current outdoor residential water use?
- What are potential water conservation practices?

Through answering the above questions, this project was developed in phases to meet the objectives outlined below.
Objectives

- Assess the current landscaping and water use conditions for four case study communities for the year 2006:
  - Choose representative sub-divisions to determine grassed area per lot,
  - Develop a relationship between proportion grassed and lot size,
  - Apply a proportion of grassed area to all existing developed residential lots.

- Develop three urban growth scenarios to the year 2026:
  - Develop an urban sprawl, densification and in-between scenario following the Official Community Plans for each case study community using GIS,
  - Use existing lots with census data to meet the population projections.

- Calibrate the IDM with measured water use:
  - Obtain metering data where available,
  - Assess the difference between the model output to the actual water use,
  - Calibrate the IDM by modifying the adjustable parameters within the model.

- Project future water demands to 2026:
  - Determine the appropriate climate data to represent future conditions,
  - Run the IDM to determine the possible outdoor residential water demand for the four case study communities.

- Explore options for water conservation:
  - Quantify potential water savings through various conservation practices.

The following chapter discusses the background and details on other projects that are related to outdoor residential water demand. Next, the methods to address the above objectives are presented. The results are then introduced and finally the conclusions and recommendations are presented in the final chapter.
2 Background and Literature Review

2.1 The Okanagan Basin, British Columbia

The Okanagan Basin is located in south-central British Columbia, Canada and is a tributary of the Columbia River (Figure 2.1). The Basin is approximately 8,200 km$^2$ in size and is characterized by the long narrow Okanagan Lake at the valley bottom with steeply sloping valley walls. The Basin is semi-arid and ranges from approximately 400 mm annual precipitation in the north to 300 mm in the south (Neilsen et al, 2006).

Figure 2.1 – Location of the Okanagan Basin
The Basin is a fertile agricultural area and has a favorable climate to produce many different fruits and grapes. Additionally, tourism is an important industry with large numbers of visitors in the summer season as well as the ski season. Golf courses and vineyards are a common landscape feature. The Agricultural Land Reserve (ALR) is a zoning designation developed in order to preserve areas suitable for agriculture. Municipalities can gain exclusion from the ALR in some cases if urban expansion and development is constrained; however, this practice may have detrimental impacts on long term food security (Agricultural Land Commission, 2009). Significant urban development has occurred in the past 20 years. The Basin’s temperate climate has led to a population increase from just over 200,000 in 1986 to nearly 350,000 in 2008; see Figure 2.2 (BC Stats, 2009b). The Central Okanagan Regional District is the most populous District with the most rapid growth rate in comparison to other Regional Districts.

Figure 2.2 – Historical Population in the Okanagan Basin (Regional District and Total)
The semi-arid climate and growing population in the Okanagan has led to a concern for the water future. In response, several water-focused projects in the Okanagan have been worked on and are discussed in further detail below.

2.2 Okanagan Basin Water-Related Projects

2.2.1 The Okanagan Basin Supply and Demand Project

The Okanagan Basin Water Board (OBWB) was established in 1969 to help facilitate water resource management with respect to quality and supply. The Okanagan Basin Study was conducted in 1974 as a basin-wide assessment of water supply and demand. It was updated in 1994, but no other studies since then have been basin-wide in scope. In response to increasing demands with population growth in the arid environment, the Okanagan Basin Water Supply and Demand Project commenced in 2005 (OBWB, 2009). In order to complete this project, the OBWB is working in partnership with the BC Ministry of Environment and with significant contributions from the BC Ministry of Agriculture and Lands, the BC Ministry of Community Services, Environment Canada, Agriculture Canada, Fisheries and Oceans Canada, and the Okanagan Nation Alliance.

The purpose of the Water Supply and Demand Project is to develop a water balance for the Basin on a watershed scale. Once complete, the water balance will highlight what watersheds in the basin may be at greatest risk for water scarcity (OBWB, 2009) and what type of conservation methods need to be put in place to assure that sufficient water resources are available in the future for people and the environment. This research presented in this thesis was developed to contribute to the Okanagan Basin Water Supply and Demand Project through assessing the current outdoor residential water demand and projecting demand to the year 2026.

2.2.2 University of British Columbia Projects

Neale’s (2005) thesis entitled *Impacts of Climate Change and Population Growth on Residential Water Demand in the Okanagan Basin, British Columbia* is an in depth, non-spatial, analysis of
potential residential water demand to the year 2069, using 2001 as the baseline year. Scenarios were developed with varying development patterns and population growth rates for three case study communities, Kelowna, Penticton and Oliver. Additionally, climate change impacts were analyzed.

A part of Neale’s work outlines various demand management practices already in practice within the Okanagan Basin. These were reviewed and recommendations were made on how to reduce water demand to the year 2069. The population projections were determined for three growth rates, low, medium and high. Additionally, the housing development was given as either a current preference or a smart growth scenario. The differences were related to the proportion of ground-oriented dwellings to apartment type dwellings.

Neale’s project does include outdoor residential water demand, which was determined by analyzing the relationship between temperature and the occurrence of outdoor water use. The temperature at which outdoor water use occurs is related to the daily maximum temperature. Therefore, in future climate scenarios, the daily maximum for outdoor water use occurs earlier in the year and lasts longer resulting in an increase in water demand with a longer growing season.

Neale’s (2005) conclusions were that the region can expect a doubling of water demand by 2069 if no additional demand management practices or housing density changes occur. Furthermore, climate change increased water demands above what was predicted by population growth alone.

Neale’s work was completed as part of two interdisciplinary studies that were conducted to assess the effects of climate change and local adaptation options in the Okanagan Basin. Dr. Stewart Cohen of UBC and Environment Canada led both studies.

The first project characterized the future climate and hydrology of the area and projected future water demands in both the agricultural and residential sectors with analysis of possible adaptive water management strategies (Cohen et al., 2004 & 2006). The preliminary results of Neale’s (2005) thesis were published in the report entitled Learning with Local Help: Expanding the
Dialogue on Climate Change and Water Management in the Okanagan Basin, British Columbia (Cohen et al., 2006).

The second project focused on the development of a model as a support tool for water managers and examining the policy implications of climate change in the region (Langsdale et al., 2007). Langsdale’s model entitled Okanagan Sustainable Water Resources Model (OSWRM) simulates future conditions by projecting current conditions and overlaying the effects of population growth and climate change on water supply and demand. This comprehensive model combined inputs from climate models, hydrologic models, residential outdoor demand (from Neale (2005)) and crop water demand from Agriculture Canada Model (Langsdale et al., 2007). The model was based on available data prior to the completion of the development of the Irrigation Demand Model Developed by the B.C. Ministry of Agriculture and Lands (MAL).

2.2.3 The Irrigation Demand Model

The Irrigation Demand Model (IDM) was specifically developed to determine water use for all crops grown in the entire basin (Mr. Ted Van der Gulik, pers. comm.). The initial scope was focused on agriculture demand, however as further development of the model took place, additional irrigation demands were included. Golf courses, city parks and other public spaces that use irrigation were incorporated.

The IDM is based on a spatial analysis of landuses within the basin. Cadastral data were used with orthophotographs to determine which crops were grown and what type of irrigation systems were used. Soil data were also collected and ground surveys were completed to confirm crop types and irrigation systems. A climate grid was developed using data from climate stations throughout the Basin. With this data, the model can then be run to calculate the irrigation demand for each parcel of land or “lot” within the Basin. The results are provided in table form with irrigation demand for each crop type and month. The model can also be run for different years based on available climate data from 1997-2006 (Fretwell, 2009).
The IDM was initially for use by the MAL to provide the Okanagan Basin Supply and Demand Project with values for agriculture irrigation demand for different crops. However, to more accurately represent irrigation demand, it was proposed that residential irrigation demand be included as well. A challenge with including this into the model is that residential development is occurring at a more rapid pace within the Basin than agricultural intensification and agricultural changes. Therefore, the residential landuses of 2006 will not be representative of future years when the model is complete. An approach to mitigating this inconsistency is to develop future scenarios of urban development to be run with the same model and project possible future residential irrigation demands.

In order to estimate the crop water requirements, the equations for estimating seasonal crop coefficients ($K_c$) and the ratio of plant water use to the reference evapotranspiration ($ET_o$) were derived for tree fruits, grapes and pasture. The crop water use is calculated by the following equation:

$$ET_c = ET_o \times K_c$$

Where $ET_o$ = calculated grass reference ET (mm); $K_c$ crop coefficient which can be obtained from literature; and $ET_c$ = crop evapotranspiration or crop water use (mm). The crop coefficient is the ratio of crop water use to estimated evapotranspiration. The $K_c$ values depend on canopy size and climate; therefore, they vary through the year due to the growing season length and stages of growth for the crop. For example, in the Okanagan, the crop coefficient for apples, cherries and pears ranges from 0.45 in April to 1.25 in July and August (Farmwest, 2009). In this project, the crop of interest is grass ($K_c = 1.0$) and the crop water requirements are modeled using the basic inputs of climate, soil type and irrigation system (Neilsen et al., 2001 and 2004).

2.3 Urban Growth Patterns

The development of urban centers has a varied impact on the environment. Water demands vary greatly with patterns of urban development. For example, per capita water use varies greatly
from areas of dense urban living, such as downtown cores of cities, to suburban areas on the outskirts of cities. Indoor water use does vary with urban development mainly due to infrastructure and behaviour patterns; however, it is outdoor water use that is the largest variable. This is of particular concern because the outdoor residential water demand occurs during the summer month when temperatures are highest and precipitation is the lowest.

Apartment and multilevel homes typically have minimal outdoor space per habitant; therefore, in these cases, the outdoor water use is negligible in comparison to a large suburban lot with 2 to 3 inhabitants (Neale, 2005; WRA, 2004).

This project attempts to provide urban growth scenarios of extreme development patterns. Below are definitions of these development patterns. This project is not meant to predict how urban growth will occur in the Okanagan Basin, but to give two extreme situations and one somewhere between the two.

2.3.1 Urban Sprawl

Urban sprawl has many definitions, it is a commonly understood term, eventhough most people may not be able to define it, but “know what it is when they see it”. Urban sprawl most often refers to low-density urban and sub-urban development of previously undeveloped areas (Sierra Club, 1998; WRA, 2004). Some definitions reference the magnitude of its impacts such as commute time for daily activities, how much land is consumed by non-residential uses as well as impacts on the landscape (WOA, 2009; WRA, 2004). The Western Resource Advocates (2004) summarize Urban Sprawl as a function of the population growth of an area and how this population spreads across the land.

The WRA outlines a water use and urban sprawl study conducted by the Real Estate Research Corporation (1974) that compared water consumption of residential developments with different densities. The study defined sprawl as “unplanned” development, however different community types were defined using varying proportions of dwelling types. The highest water consumption
by approximately 200-300 million gallons (0.757 Mm$^3$ – 1.14 Mm$^3$) per year were in low-density planned and unplanned communities. The lowest water consumptive community (1.51 Mm$^3$ per year less than low-density) was in high-density planned communities with 10% of the dwellings as single-family clustered and the remaining residences as townhouses and apartments. The study concluded that housing arrangements do not affect water consumption, but density does (RERC, 1974).

In this project, urban sprawl is only related to the expansion of single-family dwellings and not to infrastructure or non-residential buildings.

2.3.2 Densification

Urban density has been stated as a more sustainable way for cities to grow; therefore, in this project it was important to explore an extreme alternative to urban sprawl by developing a densification scenario. Generally, urban densification is the encouragement of higher population density in previously developed areas. In larger cities, densification tends to occur in the city centers as new, larger apartment buildings replace older, smaller dwellings.

In multifamily dwellings, the water demand is much less than that of single-family dwellings, largely due to the minimal to no outdoor water demands. As outdoor water demand is about 50% of residential water use in single family dwellings, multifamily dwellings potentially use half that of lower density residences (Neale, 2005).

2.4 Outdoor Residential Water Use Studies

In general, studies of urban water demand focus on total water use in residential areas and rarely partition the indoor and outdoor water use. Some projects have focused on using climate as an indicator or predictor of water demand and how climate change may influence this demand (Morgan and Smolen, 1976). One recent study in Phoenix, Arizona used simple correlation methods to illustrate that annual water use is controlled mostly by the overall state of drought, fall temperatures and summer precipitation (Balling and Gober, 2007). Other studies have attempted
to isolate the difference between water demand and water use. These studies tend to focus on the influence of pricing on water use and which methods are best at reducing overall water demand (Arbués et al, 2003).

Mayer and DeOreo (1999) conducted a study on the Residential End Uses of Water Study (REUWS) in 12 cities of the United States. It was determined that the net evapotranspiration explained 59% of the spatial variation related to outdoor water use. According to the REUWS works, the most common method to determine outdoor water use is to assume anywhere between one to three months of the winter represent the indoor water use and the difference is the outdoor use. For their study, however, two methods were used to approximate outdoor use, 1) historical billing and 2) logged indoor water use. The lot size and building footprints for each of the sample areas (between 37 and 100 samples area for the 12 cities) were obtained. The average irrigated area was determined by subtracting the paved areas and building footprints from the total lot size. This area was used to determine the required irrigation from using the evapotranspiration (ET) rates. The calculated irrigation rates were compared to the actual logged use and the study illustrated that the homeowners irrigated well below the theoretical demand. By conducting a regression analysis of the average irrigation application rate versus the net ET, it was determined that the homeowners were irrigating to only 55% of the annual ET requirement. However, by looking closer to the individual samples, large variations with outdoor water use are observed, therefore, predicting individual households outdoor water use is challenging as it is related to the behaviour of the individual homeowners. The study included a sample size of 1,188 homes in 12 cities across the US (from Tampa, FL to San Diego, CA to Seattle, WA); therefore the various external variables that affect water use including price were not isolated in this study (Mayer and DeOreo, 1999).

A Californian study entitled “Waste Not Want Not” (Gleick et al., 2003) estimated that in 2000, 1,850 Mm$^3$ were used for outdoor residential use in the state. The study used varying methods to
determine outdoor residential water use that were adapted from the 1994 California Water Plan
Update (CDWR, 1994a and 1994b). These methods included:

a) Assuming outdoor use for different hydrologic regions within the state based on average
indoor use and evapotranspiration values;

b) Using the difference between summer (April-September) and winter (October-March)
uses to approximate outdoor use;

c) Assuming the lowest water use month (January) as the indoor use, and the outdoor use is
the difference between this month and the other months;

d) Using the three lowest month’s average to represent indoor use (December-February).

Included in this study was a calculation for potential water savings through reduction in outdoor
use. This involved determining lot characteristics for a representative large and small lot with a
single family home. The large landscape was 1,850 m² with 36% of the lot irrigated and the
small landscape 512 m² with 59% irrigated. The evapotranspiration (ET) data were obtained to
determine the amount of water required for a coastal (wetter) climate versus an arid climate. The
water savings were determined by applying a lower ET value, which was stated as a reasonable
target for landscape conservation. The proportion of outdoor to total residential water use ranges
from 30% in the coastal areas to 60% in the hotter, inland areas of California (Gleick et al., 2003).
Skeel and Lucas (1998) determined that for single-family homes in Seattle, outdoor water use
made up more than 95% of the observed increase in the peak summer consumption.
Approximately 85% was attributed to landscape irrigation and less than 5% was from a slight
increase in indoor use in the summer.

A study in Aurora, Colorado (Kenney et al, 2008) was conducted to determine factors influencing
residential water demand during the drought period of 2000-2005. Their concluding thoughts
demonstrated that residential water demand is largely a function of price, demand management
programs and weather and climate. They determine that pricing and outdoor water restrictions
policies interact to a greater total water savings than each program operating independently.
Researchers continue to search for best combination of weather factors to explain consumptive habits, with precipitation being the most valuable, but temperature and ET also being useful (Kenney et al, 2008).

In Central Florida, automatic inground irrigation is common for residential homeowners, however high population demands are putting stress on the water resources in the region. A study conducted in 2007 (Haley et al, 2007) assessed the irrigation use for three types of landscapes: typical residential lots, lots with irrigation controlled by historical ET, and lots with reduced turf area along with ET scheduled irrigation systems. It was determined that significant savings (50%) can be made with reduced turf area and ET scheduled irrigation systems.

A summary of the various residential water use studies is provided in Table 2.1, classified by study region. The water demand was sometimes provided for winter use, which is also considered equivalent to indoor use and is provided in the second column where available. The proportion of annual water use that is attributed to outdoor residential water is provided in the fourth column.

<table>
<thead>
<tr>
<th>Municipality or Region</th>
<th>Water Demand (Lpcd)</th>
<th>Outdoor Water Use</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winter/Indoor</td>
<td>Summer</td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>329 (annual average)</td>
<td>50%</td>
<td>Environment Canada, 2007</td>
</tr>
<tr>
<td>British Columbia</td>
<td>426 (annual average)</td>
<td>50%</td>
<td>BC Stats, 2009a</td>
</tr>
<tr>
<td>GVRD (Metro Vancouver)</td>
<td>267</td>
<td>n/a</td>
<td>59% of total</td>
</tr>
<tr>
<td>Durham Region, Ontario</td>
<td>511</td>
<td>703</td>
<td>192 Lpcd</td>
</tr>
<tr>
<td>Denver, Colorado</td>
<td>545 (annual average)</td>
<td>54%</td>
<td>Denver Water, 2009</td>
</tr>
<tr>
<td>California</td>
<td>277 (approx)</td>
<td>n/a</td>
<td>30-60%</td>
</tr>
<tr>
<td>Central Florida</td>
<td>n/a</td>
<td>n/a</td>
<td>64%</td>
</tr>
</tbody>
</table>

What this summary shows is that a very large proportion of urban domestic water use is attributed to summer outdoor irrigation and with increased urbanization and increased climatic variability large savings can be made with innovative conservation practices.
3 Urban Growth Scenario Development

3.1 Research Approach

This study was done using scenarios developed with available data to address the research question: How will population increases and urban development trends impact the outdoor residential water use in the Okanagan? This was accomplished in three case studies of urban development with the following scenarios: a) business as usual (urban sprawl); b) reduced grassed area and growth (densification); and c) in-between (half sprawl and half densification). The in-between scenario was meant to be a possible future, but none of these scenarios should be considered predictive but potential future option that can be compared. The scenarios include how changes in residential landscaping will increase or decrease the outdoor water demand in the Okanagan Basin. The scope of this project allowed for four municipalities to be taken as the case study communities: Kelowna, Penticton, Vernon and Osoyoos.

This project was conducted in collaboration and with support from the BC Ministry of Agriculture and Lands (MAL) to be used in their Irrigation Demand Model.

This project was completed in three phases. This chapter discusses the first task, which was to meet the data needs of the Irrigation Demand Model by assessing the existing grassed area per residential lot. From this data on the existing grassed area, the urban growth scenarios were then developed using the Official Community Plans in ArcGIS.

The following Chapter (Chapter 4) outlines the second phase, which involved comparing the model output to existing metering data from the Kelowna case study. Finally, the scenarios were run to provide a range of possible future outdoor residential water demands with varying climate data and conservation practices discussed in Chapters 5 and 6.

3.2 Case Study Communities

The Okanagan Basin is divided geographically into three regional districts (RD), the North Okanagan Regional District (NORD), Central Okanagan Regional District (CORD) and the
Regional District of Okanagan-Similkameen (RDOS). The 16 municipalities in the Basin are located in the valley bottom, adjacent to the lake or river (see Figure 3.1). In order to remain within the scope of this project, four municipalities were chosen. The largest communities from each RD were chosen: Vernon (NORD), Kelowna (CORD) and Penticton (RDOS); furthermore, Osoyoos in RDOS was included due to its rapid growth and driest climate.

**Figure 3.1 - The Okanagan Basin with the Case Study Communities**

3.2.1 Vernon

The City of Vernon is the largest municipality in the NORD with a 2006 population of 37,716 (46% of the 2006 total NORD population). It had an 8% increase in population over 5 years from
the 2001 population base of 34,957 (BC Stats, 2009b). Vernon is located on the north end of Okanagan Lake and has an average annual precipitation of 410 mm (Environment Canada, 2009).

Four sample areas were chosen from the City of Vernon, see Figure 3.2. The sample areas for each case study community were chosen to provide a variety in lot size through choosing both newer and older residential subdivisions. The quality of orthophoto coverage was also a key factor to choose the sample sites, more details are provided in section 3.5.1 (page 27).

**Figure 3.2 – City of Vernon with Sample Areas**

3.2.2 Kelowna

Kelowna is the largest municipality in the Basin and the third largest city in British Columbia after Metro Vancouver and Victoria. The 2006 population of Kelowna was 111,802 (66% of the total CORD population), which is an 11% increase over 5 years (BC Stats, 2009b). Kelowna is located adjacent to Okanagan Lake and has an annual average precipitation of 381 mm (Environment Canada, 2009). Seven sample areas were chosen from Kelowna, see Figure 3.3.
3.2.3 Penticton

Penticton is the largest municipality in the RDOS, with a population of 33,550 in 2006, an increase of 4% over 5 years from 2001 (BC Stats, 2009b). Penticton is located between the south end of Okanagan Lake and the north end of Skaha Lake. The annual average precipitation is 333 mm (Environment Canada, 2009). Two sample areas were chosen from Penticton, see Figure 3.4.
3.2.4 Osoyoos

Osoyoos is the southern-most community in the Okanagan Basin and borders the United States. The 2006 population was 4,979, which was an increase of 11% from 2001 (BC Stats, 2009b). The town is located on Osoyoos Lake and receives an average annual precipitation of 318 mm (Environment Canada, 2009). Only one sample area was chosen, see Figure 3.5.
3.3 Modeling and Spatial Analysis Background

3.3.1 ArcGIS Program

Geographical Information Systems (GIS) are a method to integrate, analyze, manipulate and project geographically referenced data. GIS allows for data analysis and to display results as an interactive map. The ArcGIS program developed by ESRI was used in this project for quantitative analysis of the Okanagan case study communities. ArcGIS allows for data visualization, integration and management as well as spatial modeling and analysis (ESRI, 2009).

3.3.2 Irrigation Demand Model

The Irrigation Demand Model (IDM) was developed by the British Columbia Ministry of Agriculture and Lands (MAL) in 2007 and is continuously updated. The model runs for this project were completed in March and October, 2009. The model uses spatial data to calculate the irrigation demand for each lot defined as a cadastre. The data needs of the model are the crop type, soil type, climate (temperature and precipitation), and irrigation type. The model calculates the crop water demand using this data and the output is the irrigation demand in $m^3$ and mm.
(used to compare the difference in crop water demands regardless of area irrigated) (Fretwell, 2009).

The model is able to calculate and store data in MS Access and display the information in a GIS system using ArcGIS or ArcInfo. Different scenarios based on crop type, geographic location, irrigation system use and climatic data can be run and stored. A crop coefficient \( K_c \), dependant on the crop type and time in the growing season, is used to adjust crop water use daily, based on the reference \( \text{ET}_o \) (Fretwell, 2009; Neilsen et al., 2004)

The model was initially designed for agriculture irrigation demands for the Okanagan Basin and the cadastral information for the Basin has been amalgamated into a single shapefile entitled “lots”. A climate grid was developed using the climate stations in the Basin. The soil type and irrigation type were determined using soil survey data and ground surveys. Therefore, when the model is run, the irrigation demand is calculated for each polygon that has a crop, soil and irrigation system type combination. A simplistic description of this calculation is:

\[
\text{Crop Type + Soil Type + Climate + Irrigation System} \Rightarrow \text{Crop Water Demand} - \text{Precipitation} \Rightarrow \text{Irrigation Demand.}
\]

The Irrigation Demand Model can be run on three different management settings: good, poor and average, to reflect on the irrigation practices of the property owner. In this study, the average was chosen to minimize additional variables in determining outdoor residential water demand.

Furthermore, the model is a powerful tool as it can be used to test sensitivity for the input data. For example, for each crop type, the irrigation demand for various irrigation systems can be tested to illustrate the efficiency of each.

In this project, assumptions were made with regards for the inputs using the IDM. The crop type was assumed to be grass, which has its own distinction in the IDM database, “Domestic”. The irrigation system in place was assumed to be “Landscape Sprinkler” and the soil type is listed as “Sandy Loam”. These input values are assumed to be the most appropriate for urban residential lots.
3.4 Existing Spatial Data

3.4.1 Orthophotos

Orthophotos are georeferenced aerial images that are used in spatial programs like ArcGIS. The MAL obtained orthophotos in tiff format from the Crown Registry and Geographic Base Branch of the BC Provincial government (GeoBC, 2009). These orthophotos are primarily used to establish the land use in the IDM. Due to copyright, only printed copies of orthophotos were provided by the MAL and were then scanned as jpgs for use in ArcGIS. The scanned photos were georeferenced using the property boundaries. An example of one of the scanned images from a Kelowna sample is shown below (Figure 3.6). The yellow lines are the property boundaries and the lots with blue numbering are the city parks. The orthophotos provided were taken in 2007 and the pixel size is 0.5 meters.

Figure 3.6 – Example of an Orthophoto, Kelowna Sample Area 7

Online orthophotos from each municipality were accessed as well to supplement and improve upon the printed photos. However, these photos were taken at different times than those provided by the MAL and there were some discrepancies noted in stages of residential development. For example, the online airphotos for Vernon were taken in 2004 and there was one residential area
under development in 2004 and completed in 2007. Therefore, the grassed areas were calculated differently depending on which photo was used.

3.4.2 Residential Lots

Each of these scenarios was developed using the original “lots” shapefile provided by the MAL on October 31st, 2008. This shapefile contains all of the cadastral information from the Okanagan Basin and can be sorted geographically by the attribute LOCAL_GOV, which distinguish the lots into municipalities or regional districts. The shapefile can be joined using the MALLOTSLNK attributed to database files (dbfs) also provided by the MAL.

The dbfs of interest for this project include GeneralZones, ZoneCatLookup and Zone Categories, the zoning attributes are shown in Table 3.1. The zoning attributes are listed as residential, rural, commercial, industrial and agriculture. Therefore, this allowed for the residential lots to be selected within the “lots” shapefile. Additionally, the lots of interest were selected using the LOCAL_GOV attribute for Kelowna, Vernon and Penticton. Osoyoos does not have the distinction of city or municipality and was therefore included in the Regional District of Okanagan-Similkameen (RDOS). The lots within Osoyoos were selected using the census shapefile, described below. All lots within the boundaries of the Osoyoos census tracts were selected.

<table>
<thead>
<tr>
<th>R</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>RU</td>
<td>Rural</td>
</tr>
<tr>
<td>A</td>
<td>Agriculture</td>
</tr>
<tr>
<td>I</td>
<td>Industrial</td>
</tr>
<tr>
<td>C</td>
<td>Commercial</td>
</tr>
<tr>
<td>P</td>
<td>Park</td>
</tr>
</tbody>
</table>

Table 3.1 Zoning Attribute Description for the “Lots” Shapefile

New shapefiles for each of the municipalities were created which included the zoning attributes. From these shapefiles, the residential lots were selected and exported as new shapefiles. The purpose was to create shapefiles for each municipality that are representative of the developed
residential lots for the year 2006 as the existing conditions. This process is described in further
detail in Section 3.5.3 below.

3.4.3 Agricultural Land Reserve

The Agricultural Land Reserve (ALR) contains areas in British Columbia that are zoned for
agricultural uses. Additionally, the “ualr” shapefile, provided on November 21st, 2008 by the
MAL, was used as guidance for developing the urban growth scenarios.

The ALR is updated quarterly and the shapefile provided was from the spring of 2006. It was
understood that the ALR boundaries may change due to zoning exemptions and the shapefile
provided was not the most recent version, but was relevant for the 2006 existing conditions
chosen in this project.

3.4.4 Census Data

To develop the urban growth scenarios, the most recent census year, 2006, was used as the
baseline year. Spatial data was obtained from Statistics Canada for each Regional District in the
Okanagan Basin. The census data is divided into Dissemination Areas (DAs), which are small
areas comprised of 400 to 700 people (Statistics Canada, 2009).

The City of Kelowna is a Census Metropolitan Area (CMA) because the population is greater
than 100,000. Therefore, Kelowna is sub-divided into Census Tracts (CTs), which are relatively
stable geographical areas with a population of 2,500 to 8,000 (Statistics Canada, 2009).

The DAs or CTs for each case study community were clipped from the original file which covers
all of British Columbia. The shapefile attributes can be joined to several database files (dbfs).

The dbfs of interest were population and housing information. The 2006 population was given as
a single figure; however the housing and dwelling data were detailed in providing the number of
each type of dwelling within the DA or CT. The dwelling types were grouped in the following
categories:

- Single Detached
• Semi-Detached
• Row House
• Duplex Apartments
• Apartments 5 storeys and up
• Apartments less than 5 storeys
• Other Single Family
• Moveable Dwellings.

3.4.5 Official Community Plans

Official Community Plans (OCPs) are produced by the planning department of cities and towns and outline where and what type of future urban development will take place in the city. For this project, the OCPs were very useful to develop the urban growth scenarios as they were used to locate the new residential lots in the case study areas.

Access to the OCPs for all of the case studies was done online via the city websites. However, for Vernon and Kelowna, shapefiles of the OCPs were provided (City of Kelowna, 2009; City of Vernon, 2009; City of Penticton, 2009; Town of Osoyoos, 2009). The attributes of these shapefiles included planning for future residential lots as well as commercial and industrial areas. In addition, the future residential zoning is designated for different densities. The Kelowna and Vernon residential zoning and OCP descriptions are shown in Tables 3.2 and 3.3.

Table 3.2 Kelowna OCP Attributes

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCH</td>
<td>Multiple Unit Residential (Cluster Housing)</td>
</tr>
<tr>
<td>MLD</td>
<td>Multiple Unit Residential (Low Density)</td>
</tr>
<tr>
<td>MRM</td>
<td>Multiple Unit Residential (Medium Density)</td>
</tr>
<tr>
<td>MHD</td>
<td>Multiple Unit Residential (High Density)</td>
</tr>
<tr>
<td>S2RES</td>
<td>Single/Two Unit Residential</td>
</tr>
<tr>
<td>FUR</td>
<td>Future Urban Reserve</td>
</tr>
</tbody>
</table>


Penticton and Osoyoos did not provide shapefiles of their OCPs, however public access is available on the city or towns website. The areas zoned for development for these two case studies were relatively small, as the population increases are less than what Vernon and Kelowna are projecting and they are geographically smaller communities.

3.5 Existing Grassed Area Analysis

To meet the objective to determine the current landscaping conditions in the Okanagan, orthophotos were used in combination with the census data and lots shapefiles. In order to determine the proportion of grassed area for the existing lots in the case study areas, representative samples were chosen from the four municipalities. The number of samples per municipality was dependent on the size of the city (Table 3.4). Fourteen samples were selected and the area of grass was digitized using orthophotos and the lots shapefile in the ArcGIS program. The total area of grass was then divided by the total area of the lots and divided again by the number of lots. This result gave a proportion of grass per lot for each sample area. The relationship of lot size to grassed area was then used to apply a proportion of grass to the existing developed residential lots for each case study community. The shapefiles representing the existing conditions, 2006, were comprised of only developed residential lots. Any lots that were zoned as residential, but not yet developed were removed as described in more detail in Section 3.5.3.

3.5.1 Sample Area Selection

To assess the existing grassed area representative samples were chosen based on criteria, which includes type of housing and location in the city. Furthermore, census tracts bound the sample areas so the 2006 population statistics are known. The samples were chosen where the housing
had a majority of single-family (SF) lots; however, most samples had a few duplexes or other
two-family dwellings. Additionally, any lots that were not a developed residential lot such as one
zoned as commercial or a city park were removed from the sample areas. These lots were
uncommon in each sample area and only occurred once or twice.

The number of samples per municipality was chosen with relation to the population. Table 3.4, is
the summary of the sample area attributes and the location of these samples can be found in
Figures 3.2 to 3.5 at the beginning of this Chapter. The column on the right of the table shows
the municipality and sample numbers. The 2006 population varies from less than 300 to over
800. The average lot area was calculated by summing the total lot area per sample and dividing
by the number of lots. The samples were chosen so that the majority of the lots were of similar
size so the average lot size is representation of any given lot within the sample area.

The total dwellings per sample area are from the 2006 census. The number of lots differs from
the total dwellings because as mentioned above, there are instances with more than one dwelling
per lot.
Table 3.4 Sample Area Attributes

<table>
<thead>
<tr>
<th>Sample and Location</th>
<th>2006 Population</th>
<th>Number of lots</th>
<th>Average Lot Area (m²)</th>
<th>Total Dwellings</th>
<th>People per Dwelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>KELOWNA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>280</td>
<td>92</td>
<td>1765</td>
<td>95</td>
<td>2.95</td>
</tr>
<tr>
<td>2</td>
<td>418</td>
<td>118</td>
<td>933</td>
<td>155</td>
<td>2.70</td>
</tr>
<tr>
<td>3</td>
<td>517</td>
<td>201</td>
<td>611</td>
<td>265</td>
<td>1.95</td>
</tr>
<tr>
<td>4</td>
<td>526</td>
<td>169</td>
<td>748</td>
<td>220</td>
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</tr>
<tr>
<td>5</td>
<td>392</td>
<td>124</td>
<td>673</td>
<td>130</td>
<td>3.02</td>
</tr>
<tr>
<td>6</td>
<td>875</td>
<td>203</td>
<td>718</td>
<td>300</td>
<td>2.92</td>
</tr>
<tr>
<td>7</td>
<td>435</td>
<td>136</td>
<td>1083</td>
<td>135</td>
<td>3.22</td>
</tr>
<tr>
<td>VERNON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>428</td>
<td>154</td>
<td>559</td>
<td>160</td>
<td>2.68</td>
</tr>
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<td>2</td>
<td>430</td>
<td>132</td>
<td>768</td>
<td>195</td>
<td>2.21</td>
</tr>
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<td>551</td>
<td>119</td>
<td>674</td>
<td>235</td>
<td>2.34</td>
</tr>
<tr>
<td>4</td>
<td>550</td>
<td>247</td>
<td>671</td>
<td>200</td>
<td>2.75</td>
</tr>
<tr>
<td>PENTICTON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>510</td>
<td>159</td>
<td>857</td>
<td>255</td>
<td>2.00</td>
</tr>
<tr>
<td>2</td>
<td>387</td>
<td>118</td>
<td>878</td>
<td>125</td>
<td>3.28</td>
</tr>
<tr>
<td>OSOYOOS</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>391</td>
<td>185</td>
<td>950</td>
<td>185</td>
<td>2.11</td>
</tr>
</tbody>
</table>

The sample locations within each municipality were chosen to provide a representation of different lot sizes and age of development. For example, in Kelowna, the newer residential developments are located on the extremities of the city (south, north and east) while the older sub-divisions are located near the downtown core.

In order to more accurately digitize the grassed proportion of lots, the sample areas were also limited to areas with orthophoto coverage and where the quality of the photos were adequate for digitization of the grassed area.

3.5.2 Orthophoto Interpretation

In order to determine the grassed proportion of the sample lots, the grassed area was hand-digitized in ArcGIS. The sample areas were clipped from the lots shapefile and analyzed one at a time. As described in Section 3.4.1 the orthophotos were provided from the MAL in hardcopy form and were scanned and geo-referenced in ArcGIS. The geo-referencing has some error
associated to it, however the alignment of the lots over the images was accurate enough for the hand-digitizing.

The fourteen samples as described in more detail above were analyzed to determine grassed area by hand digitizing the area that was green on each lot. The driveways, walkways, swimming pools and rooftops of houses, garages and sheds were not included in the new polygons that represented the grassed area. Additionally, areas in the yard that did not look like grass was present, such as under large treed areas were also not included. Where it was possible to determine garden areas, they were included into the grassed area; however, in most cases, the resolution of the orthophotos did not allow for any difference between lawn and garden to be noticed, see Figure 3.7 for an example of the digitized area of grass.

Figure 3.7 – Digitization of Grasied Area, Kelowna Sample Area 3

In addition to the grassed area per lot, there were some areas where it was evident that grass was present and being irrigated outside of the lot boundary. For example, the length of grass between the road and sidewalk was not always within the property or lot boundary, but was included in the total grassed area.

The fourteen samples that were digitized provided a positive relationship between the size of lot and the proportion of grass. The smaller lots had a lower proportion of grass where the larger lots
did indicate a higher proportion of grass. The results from the fourteen samples are shown in Figure 3.8.

**Figure 3.8 – Manual Digitization of the Sample Areas**

The fourteen samples show a linear trend based on lot size versus proportion grassed. The sample with the largest lots was in Kelowna and had the highest proportion grassed. There was a reasonable relationship between lot sizes when all community samples were included, therefore each sample area was assumed to be representative of lot size in all of the municipalities. For example, a lot of 700 m² in Penticton was assumed to have the same proportion of grass as one of the same size in Kelowna. The following Figure indicates this relationship between lot size and proportion grassed for all of the samples.
The largest lot sample area could be assumed as an outlier as the majority of the sample areas are lot sizes between 500 m$^2$ and 1000 m$^2$ in area. This is also shown in the lot distribution for each of the case study communities in Figure 3.10, below. Additionally, it can be noted that a significant number of lots (over 4,000) do fall within the largest lot category (greater than 1500 m$^2$); therefore, the large lot sample should be included in the relationship developed from the fourteen sample areas, shown above.

The samples described above were chosen to represent the grassed area for varying sizes of single-family (SF) lots. Lots with SF homes are by far the most common type of dwelling in the case study communities (Statistics Canada, 2009). However, additional sample lots were analyzed to represent multifamily (MF) lots chosen from three census tracts in Kelowna. The results from this analysis are shown in Table 3.5. The average grassed proportion for the MF lots was 29%, which is comparable to the SF lots. In total, 28 MF lots of varying size were analyzed. It was assumed that a proportion of 29% grassed area for the existing MF lots is an applicable value.
Table 3.5  Multifamily Grassed Area Analysis – Kelowna

<table>
<thead>
<tr>
<th>Number of Lots</th>
<th>Average Lot Size (m²)</th>
<th>Average Grassed Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>5,714</td>
<td>29%</td>
</tr>
</tbody>
</table>

3.5.3 Assign Grassed Area to Existing Developed Residential Lots

The relationship between lot size and proportion grassed was then used to apply to the existing conditions. An additional attribute called pct_grass was added to the existing residential lots shapefile for each municipality. Categories of lot size were then selected and a value for pct_grass was input into the new attribute. The value based on lot size is shown in Figure 3.10. The left y-axis is the percentage of grass that was used for the category of lot size along the x-axis. The bar portions of the graph are the number of lots that fall within each category. Kelowna is the largest municipality, therefore has the most number of lots in each lot size category with the majority falling with the 800-1000 m² size.

Proportionally, Penticton has the highest number of lots that are smaller than 500 m², Vernon and Osoyoos are relatively evenly spread out with number of lots in each category.

An additional attribute was then added to the shapefile called Area_Grass and was calculated by multiplying the Area by the pct_grass attributes. It is this new attribute that the Irrigation Demand Model used as the crop to calculate the irrigation demands.
During lot selection for application of the grassed percentage and subsequent calculation of grassed area, only developed residential lots were included. In several cases, the lots had the zoning attribute misnamed. To ensure all of the residential lots were included, all lots zoned as residential were selected from the original “lots” shapefile provided by the MAL. In Kelowna, it was immediately noted that several of the residential lots had not been selected in this initial step. Therefore, the online orthophotos available from the websites of the municipalities and towns were used for ground confirmation of the residential lots. In the cases where residential lots were missed, the lots were zoned as rural or had a null value for the attribute.

Additionally, there were a few residential lots that were much larger than the largest category size of 1500 m$^2$. These lots were further analyzed using the online orthophotos and were largely MF lots, therefore the assumed proportion grassed of 29% was applied. This was done to minimize error associated with the relationship between lot size and proportion grassed. For example, the larger the lot, the greater proportion of grass; however this is only applicable when the lot
contains a SF home, which remain relatively constant from lot to lot. Multifamily buildings are typically much larger in size and therefore the footprint is a larger proportion of the lot.

3.6 Urban Growth Scenario Development

To develop the urban growth scenarios, the existing residential lots shapefiles were prepared for each municipality separately. The attributes of these shapefiles include the proportion grassed and the area grassed for each lot. The existing residential lots were to represent the baseline year of 2006 from which to build the growth scenarios to 2026. For example, the existing conditions for Kelowna are shown in Figure 3.11, the existing conditions for the three other case studies are provided in the results Chapter 5. The dark purple lots are the existing residential lots, the light purple are the existing industrial and commercial lots, the dark green are the parks and light green areas are the ALR and the blue shaded areas are water bodies. Details on how these existing conditions are described in the preceding section.
In ArcMap, the existing lots shapefile for each municipality were used to build up each scenario as various subdivisions of lots were selected and copied to create the new lots. The Urban Sprawl scenario was built up of entirely SF lots, the Densification scenario was mostly MF lots and the In-Between scenario was where half of the population was housed in SF lots and the other half in MF. In both the Densification and In-Between scenarios, future demand management practices were included by reducing the grassed area per lot.
The urban growth scenarios were developed by following the OCPs from each case study as well as using the ALR boundaries. The new lots were placed in areas where new development is anticipated. The scenarios are not meant to be predictive, but are guided by the Official Community Plans.

The population projections for the year 2026 were used to develop each scenario. The projections for each case study were downscaled from the regional projections taken from the census data. Each urban growth scenario used the same population change as shown in the final column of Table 3.6.

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Population 2006</th>
<th>Population 2026</th>
<th>Additional Population 06-26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kelowna</td>
<td>111,802</td>
<td>157,867</td>
<td>46,065</td>
</tr>
<tr>
<td>Vernon</td>
<td>37,716</td>
<td>49,178</td>
<td>11,462</td>
</tr>
<tr>
<td>Penticton</td>
<td>33,550</td>
<td>37,870</td>
<td>4,320</td>
</tr>
<tr>
<td>Osoyoos</td>
<td>4,979</td>
<td>6,875</td>
<td>1,896</td>
</tr>
</tbody>
</table>

3.6.1 Urban Sprawl Scenario

The first scenario developed was an extreme case of urban sprawl for each case study community. In order to meet the population projection using SF lots for this scenario, the subdivisions of the existing lots were copied and moved to create the new lots. An example of this process is shown in Figure 3.12, a sample from Kelowna.

The images are numbered to indicate the sequence for the placement of new lots. The light purple polygons are the existing developed residential lots for the City of Kelowna; the light grey is areas that are zoned for future residential development from the OCP. The black outlines are the census tract boundaries and the tan area is current commercial and industrial developments.

The first image shows a bolder black line outlining a subdivision of lots. This is a census tract that is primarily SF lots and is appropriate to use as new lots in this scenario. These lots are then selected (the blue lots in the second image), copied and moved to the area for future residential development shown as the red lots in the final image in Figure 3.12.
In order to meet the population projections, lots within a census tract were used. Therefore, the 2006 population was known for the subdivisions. The attributes of the subdivisions used for Kelowna are shown in Table 3.8. The areas selected were of varying lot size as indicated in the third column. The average proportion grassed is shown in the fourth column. The final two columns show the number of each growth sample and the total population that these new subdivision areas will “house”. For example, the K1 sample is a total of 320 lots with 964 people, but was copied 8 times (used 9 times) to represent a total increase in population of 8,676. The projected population for Kelowna 2026 is 46,065 as shown in Table 3.6, therefore the growth samples were copied, moved, and placed to achieve a total population 45,912, which is statistically the same as the projected value.
Table 3.7 Kelowna Subdivisions Used for Urban Sprawl Scenario

<table>
<thead>
<tr>
<th>Growth Sample Number</th>
<th>Population (2006)</th>
<th>Lot Size (m²)</th>
<th>Number of Lots</th>
<th>Average Proportion Grassed</th>
<th>Number Used</th>
<th>Total Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1</td>
<td>964</td>
<td>874</td>
<td>320</td>
<td>45%</td>
<td>9</td>
<td>8,676</td>
</tr>
<tr>
<td>K2</td>
<td>1,627</td>
<td>958</td>
<td>480</td>
<td>45%</td>
<td>10</td>
<td>16,270</td>
</tr>
<tr>
<td>K3</td>
<td>882</td>
<td>746</td>
<td>323</td>
<td>42%</td>
<td>8</td>
<td>7,056</td>
</tr>
<tr>
<td>K4</td>
<td>1,391</td>
<td>1,230</td>
<td>450</td>
<td>53%</td>
<td>10</td>
<td>13,910</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>45,912</strong></td>
</tr>
</tbody>
</table>

When developing the Kelowna Urban Sprawl Scenario, challenges were found in placing the lots in areas that were within the OCP. The ALR was not shown in the example in Figure 3.12, however, in this scenario lots had to be placed in areas within the ALR, see Figure 3.13. The Kelowna Urban Sprawl scenario is shown in Figure 3.13, with the remaining case study scenarios provided in the results Chapter 5. Furthermore, the patterns in which the lots were placed on slopes are unlikely to develop in the same way. In respect of meeting the population projection with entirely SF lots, some areas would be used for new developments where infrastructure extension and slope stability are likely to be the limiting factors to development.
The same approach for selection of the growth scenario lots described above was used for the remaining case study areas.

Developing the Urban Sprawl scenario for Vernon was relatively straightforward as the City of Vernon has a number of undeveloped areas which are zoned for residential in along the north and south lake shore (see Figure 3.2) including areas on the hillsides north of the downtown core.
There are limited areas for new development within central Vernon as it is bounded on the east by the community of Coldstream.

When developing the Urban Sprawl scenario for Penticton, the OCP was accessed online through the city’s website. The City of Penticton is unique in comparison to the other case studies as it is very limited in areas for future residential development. Penticton is bounded by steep slopes on the east; a Native Reserve and municipal boundary on the west as well as lakes on the north and south (see Figure 3.4). As in Kelowna, lots were placed in areas where slope stability and infrastructure are likely to be the limiting factors.

Osoyoos is also constrained in areas where future residential development can occur. The OCP that was accessed online indicates limited areas for development, as it is constrained by the US border and lakes on the north and south (see Figure 3.5).

3.6.2 Densification

The constraints imposed in developing the Densification scenario for each municipality include redevelopment on existing lots with MF lots and the grassed area on the SF lots to be reduced to 30%. The same approach as described for the Urban Sprawl scenario was taken, however, the new lots were chosen from existing lots from Kelowna only. It was assumed that since Kelowna is the most developed and the largest case study in this project it may be a good representation of a possible future for the other communities in the Okanagan Basin. For instance, there are several subdivisions within the City of Kelowna that are primarily MF in comparison to few to no areas of predominant MF dwellings in the other case studies.

Two MF subdivisions were chosen to represent the future developments; the first is within four census tracts in central Kelowna and is mixed MF and SF. The second is also mixed MF and SF, but is within three census tracts and located in east Kelowna. The grassed area of the two subdivision samples were digitized to provide a more accurate representation for the MF lots. However, as mentioned above, the grassed area of the SF lots were reduced to 30% to reflect
some demand management in the future. Below, in Table 3.9 the population and dwelling types of the two MF subdivisions, DenK1 and DenK2 are illustrated.

The differences between the third and fourth columns of Table 3.9 are due to the fact that there is more than one dwelling per lot. This is to be expected for the MF dwellings where 1290 dwellings are located on 55 lots for the first example. However, the difference for the SF lots is due to some of the lots may be duplexes or rowhouses with more than one dwelling per lot.

### Table 3.8 Subdivision Samples Used in the Densification Scenarios

<table>
<thead>
<tr>
<th>MF Subdivision Sample Number</th>
<th>Population (2006)</th>
<th>Number of Lots</th>
<th>Number of Dwellings</th>
<th>Proportion Grassed</th>
</tr>
</thead>
<tbody>
<tr>
<td>DenK1 SF</td>
<td></td>
<td>116</td>
<td>125</td>
<td>30%</td>
</tr>
<tr>
<td>DenK1 MF</td>
<td></td>
<td>55</td>
<td>1290</td>
<td>12%</td>
</tr>
<tr>
<td>DenK1 Total</td>
<td>2,200</td>
<td>171</td>
<td>1,415</td>
<td></td>
</tr>
<tr>
<td>DenK2 SF</td>
<td></td>
<td>60</td>
<td>65</td>
<td>30%</td>
</tr>
<tr>
<td>DenK2 MF</td>
<td></td>
<td>28</td>
<td>1,180</td>
<td>29%</td>
</tr>
<tr>
<td>DenK2 Total</td>
<td>2,135</td>
<td>88</td>
<td>1,245</td>
<td></td>
</tr>
</tbody>
</table>

The MF subdivision samples were used for each of the Densification scenarios, however, the number of sample areas necessary varied depending on the projected population increase for that case study. For example, Vernon required 3 subdivisions of DenK1 and 5 of DenK2 to meet the population projection of 11,462 (3 x 1,415 + 5 x 1,245 = 13,005). The population requirement to reach the 2026 projection was met as close as possible using the subdivision samples, however there were some differences as shown in the Vernon example (projected population of 11,462 versus the 13,005 applied in this scenario). The tables showing the number of subdivision samples for each of the municipalities are found in Appendix.

Redevelopment on existing residential lots was done by using the OCPs from the case studies and focusing on areas where higher density residences are zoned. The larger MF lots were placed on top of the existing lots. The Densification scenario for Kelowna is shown in Figure 3.14 and the other Densification scenarios are presented in Chapter 5.
3.6.3 In-Between

The final scenario developed was the In-Between scenario, which was meant to represent a possible future somewhere between the extreme Urban Sprawl and Densification scenarios. This scenario was the most straightforward to develop and it used the shapefiles from the previous two
scenarios. Again, to meet the projected population values for each of the case studies, different numbers of the Urban Sprawl and Densification subdivisions were used.

The In-Between scenario was developed where half of the projected population is to be housed in MF lots and the remaining in SF lots. There is redevelopment on the existing residential lots and demand management is represented by reducing the grassed area of half of the new SF lots to 30% grassed. The Kelowna In-Between scenario is shown in Figure 3.15 (see Chapter 5 for the other case study communities).
Each scenario described above is meant to be a possible future when combined with the existing residential lots. No modifications to the existing lots has been done except in the cases where redevelopment is represented by new MF lots over the SF lots. Upon completion, shapefiles with the four case study communities for each scenario along with the existing residential lots were provided to the Ministry of Agriculture and Lands for use within the Irrigation Demand Model.
4 Sensitivity Analysis and Calibration

4.1 Research Approach

The Urban Growth scenarios described in the previous chapter are for use within the Irrigation Demand Model (IDM) developed by the BC Ministry of Agriculture and Lands (MAL). This model is described in detail in Chapter 4. The second phase of this project was to conduct a sensitivity analysis and assess calibration options for the IDM to address the research questions and objectives. Actual residential water use data was obtained for four sample areas within the City of Kelowna where metered data were available. The IDM was used to determine the outdoor water demand for the same four sample areas. The model was also tested for sensitivity by reducing the grassed area per lot. The number of grass areas that were not irrigated during the summer was also examined in one test area using a ground survey. The results of the sensitivity analysis along with the ground survey formed the basis for calibration of the IDM with respect to outdoor residential water demand.

4.2 Sample Areas and Metering Data

Metering data could only be obtained from the City of Kelowna Water Purveyor. Therefore, only four of the sample areas as introduced in Chapter 4 for the grassed area analysis had metering data. Metering data was provided for each of the sample areas for the years 2003 and 2006. The 2003 data was included to provide data about residential water demand for a dry year, but was not used in the sensitivity analysis or calibration. The four sample areas are shown in Figure 4.1.
The four sample areas in Kelowna vary in lot size and grassed area. The attributes of each sample area are shown in Table 4.1.

Table 4.1 Sample Areas with Metering – Kelowna

<table>
<thead>
<tr>
<th>Sample Area Number</th>
<th>2006 Population</th>
<th>Number of lots</th>
<th>Average Lot Area (m²)</th>
<th>% grass per lot</th>
<th>Average Winter Month Demand (Nov-Feb)</th>
<th>Average Summer Peak (July/August)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>526</td>
<td>169</td>
<td>748</td>
<td>45%</td>
<td>24</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>517</td>
<td>201</td>
<td>611</td>
<td>33%</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>435</td>
<td>136</td>
<td>1083</td>
<td>47%</td>
<td>19</td>
<td>105</td>
</tr>
<tr>
<td>4</td>
<td>280</td>
<td>92</td>
<td>1765</td>
<td>74%</td>
<td>19</td>
<td>148</td>
</tr>
</tbody>
</table>

The metering data was provided as an excel spreadsheet with water use per lot and month. The monthly use was summarized as the total water demand per month. The 2006 monthly water
metering data for the sample areas are shown in Figure 4.2. The x-axis is the month and the y-axis is the volume of water in meters cubed per lot.

**Figure 4.2 – Water Metering Data for Kelowna Sample Areas (2006)**

The metering data shows the water demand peaked in August for all cases, but Sample 4. The winter months (November to March) show that approximately the same amount of water is used per lot for each sample area. However, the summer months show variability in demand depending on lot size. The largest lots, Sample Area 4, show a peak water demand at 145 m$^3$ per lot where the smallest lots, Sample 2, peaks at 50 m$^3$ per lot.

There is also a positive relationship with the summer water demand and the proportion of grassed area per lot. However, Samples 1 and 3 have similar proportions of grassed area, but Sample 3 has a greater water demand. This is likely due to the larger lot size in Sample 3 as it is located in the southern portion of Kelowna where newer, larger lots are developed.
4.3 Modeling Results

The same four sample areas as described in the previous section were selected from the existing residential lots and the proportion grassed applied was determined in the grassed area analysis. The model results are shown in Figure 4.3 using the 2006 climate data; the x-axis is the month and the y-axis is the water demand in meters cubed per lot.

Figure 4.3 – Model Results for the Kelowna Samples (2006 climate data)

When comparing the model results (Figure 4.3) to the actual water demand (Figure 4.2), there are some general differences. The model results all peak in July and as there is no indoor water use included in the model output, therefore, a comparison is not straightforward. However, it is apparent that the model is over-predicting water use in Sample 4 as the peak water demand is 230 m$^3$ per lot and the actual water demand is 148 m$^3$ per lot. The model results are compared in the series of Figures in the next section (Figures 4.5 – 4.8).
4.4 Indoor Water Use Calculation

Residential water metering does not separate indoor water demand from outdoor demand. A common method to determine the indoor and outdoor water use is to assume that there is no outdoor use in the winter months; therefore the average of the monthly winter water use can be used to represent the indoor water use all year. The difference between the winter and summer months is assumed to be the outdoor water use. Neale (2005) used this approach to determine the difference between indoor and outdoor water use as shown in Figure 4.4. Her metering data is from Penticton for the years 1998 to 2003.

Figure 4.4 – Separating Indoor Water Use from Outdoor – Penticton Example from (Neale, 2005)

The lower line in Figure 4.4 represents the indoor use (winter month average) and the upper line is the summer use. The vertical arrow indicates the difference between the summer and winter water demand, which is assumed to be the outdoor water use.

The metering data for the four sample areas was analyzed to determine the average water demand for the winter months (November to February) per lot. The results for each sample are shown in Table 4.2.
Table 4.2 Average Winter Water Demand for Kelowna Metering Samples (m³ per lot)

<table>
<thead>
<tr>
<th>Lot Size (m²)</th>
<th>Average Winter Monthly Demand (m³)</th>
<th>per Lot</th>
<th>per Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>748</td>
<td>24</td>
<td>7.7</td>
</tr>
<tr>
<td>Sample 2</td>
<td>611</td>
<td>20</td>
<td>7.8</td>
</tr>
<tr>
<td>Sample 3</td>
<td>1083</td>
<td>19</td>
<td>5.8</td>
</tr>
<tr>
<td>Sample 4</td>
<td>1765</td>
<td>19</td>
<td>6.1</td>
</tr>
</tbody>
</table>

The winter demand ranges from 19 m³ per lot to 24 m³ per lot per month. There is no relationship between lot size and winter water demand. The range is most likely due to differences in the number of people per lot, indoor water use habits, and efficiency of appliances as well as the resident’s winter travel patterns.

The average winter demand for each sample area was then applied to the model results to provide a curve to represent total water demand for each sample area. The results for Sample area 1 are shown in Figure 4.5, the lower blue curve is the model results (outdoor use), the upper blue curve is the model curve plus the average winter months use (indoor use) and the red curve is the metering data (indoor and outdoor).
Shifting the model result to include indoor use as shown in Figure 4.5 allows for comparison to be made between the metering data and model results. The above example is for Sample area 1 and the remaining Sample Areas are shown in Figures 4.6 – 4.8.

As mentioned about, the model peaks in July whereas the metered water use data peaks in August. The model results are also a smooth curve where the actual water demand is a gradual increase starting in May and increasing rapidly from June to August. The model is over predicting the water demand in the earlier and mid months of the summer.
Figure 4.6 – Model and Metering Comparison – Sample Area 2

Model Results and Metering Data
Kelowna Sample 2 - 33% Grass

Figure 4.7 – Model and Metering Comparison – Sample Area 3

Model Results and Metering Data
Kelowna Sample 3 - 47% Grass
4.5 Sensitivity Analysis

In order to test the sensitivity of the model to the proportion of grassed area, an analysis was done by reducing the grassed area for each of the lots within the sample areas by 10% and 20%. The model results are shown in Figure 4.9. The blue curve is the model result plus the average winter water use assumed to be the indoor use. The lower two curves are when the grassed area per lot was reduced by 10% and 20%.
Reducing the proportion of grassed area by 20% caused about a 15 m³ per lot reduction in peak month. The model does appear to be a closer match to the metering data when the area grassed per lot is reduced by 20%.

When the water demand for the sample areas is summed to an annual total, the differences between the model and metering data are more easily observed. The lines in Figure 4.10 are the total annual water demand for each of the sample areas in meters cubed. The samples are separated by lot size as shown on the x-axis.
The upper brown line represents the model results where indoor water use was added; the lower red line is the metering data (actual annual water use). The model results show an over prediction for the smaller lots of roughly 100 m$^3$, but over 400 m$^3$ in the largest lots. The middle blue curve is the annual total water demand from the model with a reduced grassed area per lot of 20%. This curve also has the indoor water use included assumed to be the average winter months water use. The reduction in grassed area results in a much closer curve to the actual water use (metering), except for the largest lots.

4.6  Ground Survey
The model is over predicting the irrigation demand when compared to the actual water use, therefore, it is assumed that not all residents are irrigating or only partially irrigating their lawns.

In August, 2009, two employees of the BC Ministry of Agriculture and Lands conducted a visual
ground survey of Sample Area 3 in Kelowna. Three categories of irrigation intensity were developed as shown in Table 4.3.

**Table 4.3 Ground Survey of Sample 3 in Kelowna for Irrigation Practices**

<table>
<thead>
<tr>
<th>Irrigated Land</th>
<th>Description</th>
<th>Number of Lots</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>half; lawn looks quite green, but is not fully irrigated.</td>
<td>23</td>
</tr>
<tr>
<td>N</td>
<td>no; lawn looks dry and is not irrigated.</td>
<td>27</td>
</tr>
<tr>
<td>Y</td>
<td>yes; lawn is fully irrigated</td>
<td>86</td>
</tr>
</tbody>
</table>

It was apparent from the ground survey that not all of the lots are being fully irrigated, but the majority (63%) of the residents are fully irrigating their yards. The results are also provided as a histogram shown in Figure 4.11. The ground survey shows that 20% of the residential lots were not irrigating their yards in August, 2009 and an additional 17% were only partially irrigating.

Due to limited scope and budget, only one ground survey was able to be completed, however the results support the sensitivity analysis above with a 20% reduction in grassed area per lot.

**Figure 4.11 – Ground Survey Results**

It is understood that watering restrictions were in place at the time of the survey, however, the fact that not all properties reflected the same irrigation practices at the time indicates that behaviour and preference is likely the dominant variable. Therefore, a simple proxy to account
for this is that a 20% reduction in grassed area reflects the large-scale behaviour pattern in the area and improves the IDM with results that are closer to actual water use.

4.7 Calibration

As shown in the series of figures (Fig. 4.5 – 4.8) above, the model is over-predicting the water demand when compared to the metering data. This is likely due to human behaviour in yard irrigation practices. The results of the ground survey confirm that the majority of residences are irrigating their yards, but approximately 20% are not. In the sensitivity analysis, the proportion grassed was reduced by 20% and the model curves with indoor water demand included (average monthly winter demand) were closer to the metering data. The four sample areas with metered data and the model results with grassed area reduced by 20% are shown in Figure 4.12.

**Figure 4.12 – Reduced Model Results Compared to Metering Data (all Samples)**

The solid lines in Figure 4.12 are the metering data and the hatched lines are the model results plus the average winter demand (assumed to be the indoor water use). The sample areas are separated by colour, for example, Sample 3 is the green lines. Sample areas 1, 2 and 3 all show
the model results with the reduced proportion of grass are similar to the metering data; however, in Sample area 4, which is the subdivision with the largest lots and the highest proportion of grass, the model is still over-predicting by approximately 50 m$^3$ per lot for the peak month (July). The annual reduction in water demand with a reduced proportion of grass was shown in Figure 4.10. The lines for Samples 1, 2 and 3 support the above statement where the model with a 20% reduced proportion of grassed area is closer to the metering data, however, again the model is still over-predicting for the larger lots in Sample 4.

In summary, it is assumed that reducing the grassed area by 20% is a conservative calibration for the IDM with regards to residential lots. Due to limited metering data, only four sample areas were involved in the calibration and sensitivity analysis; however, the metering data supports the assumption that as lot size increases, the summer and therefore, annual water demand per lot will increase. The model was over-predicting the water demand especially in the large lots; therefore, reduction in grassed area per lot brought the model curve closer to the metering data.
5 Results and Discussion

This chapter presents the results of this research and highlights the key findings. The population projections from 2006 to 2026 and the results of the grassed area analysis are discussed. These provided the basis for the Urban Growth Scenarios to 2026, which are used in the Irrigation Demand Model (IDM). The calibration of the IDM is discussed and the Urban Growth Scenarios are presented along with the water demand associated with each. Sources of error as well as the results and implications are future discussed.

5.1 Population Projections and Baseline Conditions

For the existing conditions, the last census year, 2006, was used. The Irrigation Demand Model (IDM) developed by the BC Ministry of Agriculture and Lands (MAL) uses 2006 as the baseline year as well. The four case study communities chosen are Kelowna, Vernon, Penticton and Osoyoos shown in Figure 3.1.

The 2006 population and population projections to 2026 for the case study communities are shown in Table 5.1, which are downscaled from the regional projections from BC Stats (2009b). The year 2026 was chosen for the future conditions to represent a 20-year span of development.

The final column in Table 5.1 is the additional population to be incorporated into each municipality.

The planning departments of each case study community have population projections based on an annual growth rate. For each case study, except Kelowna, the municipal projections are greater than that of the regional population projections. The municipal projections compared to the downscaled regional projections are shown in Table 5.1.
Table 5.1 Population Projections Municipal and Regional

<table>
<thead>
<tr>
<th>Municipality</th>
<th>2006</th>
<th>2026 Pop.</th>
<th>Additional Pop. (06-26)</th>
<th>Annual Growth Rate</th>
<th>2026 Pop.</th>
<th>Annual Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kelowna</td>
<td>111,802</td>
<td>157,867</td>
<td>46,065</td>
<td>1.74%</td>
<td>154,000</td>
<td>1.52%</td>
</tr>
<tr>
<td>Vernon</td>
<td>37,716</td>
<td>49,178</td>
<td>11,462</td>
<td>1.34%</td>
<td>58,000</td>
<td>2.00%</td>
</tr>
<tr>
<td>Penticton</td>
<td>33,550</td>
<td>37,870</td>
<td>4,320</td>
<td>0.61%</td>
<td>54,000</td>
<td>2.10%</td>
</tr>
<tr>
<td>Osoyoos</td>
<td>4,979</td>
<td>6,875</td>
<td>1,896</td>
<td>1.63%</td>
<td>8,100</td>
<td>2.0%-3.0%</td>
</tr>
</tbody>
</table>

The annual growth rates vary greatly from the downscaled regional projections from the rates used by the municipalities. The rates used by the municipalities are similar to the high growth rates used in Neale’s (2005) thesis except for Kelowna.

5.1.1 Grassed Area Analysis Results

To assess the current landscaping conditions, fourteen subdivision sample areas were chosen in the four case study communities. The grassed proportion of each lot was hand-digitized using orthophotos in the ArcGIS program. The total grassed area of each sample was divided by the total lot area to provide a proportion of grass per average lot size. The results of this analysis are shown in Figure 3.9.

The relationship between the lot size and proportion grassed was used to apply a proportion grassed to each individual lot. The relationship for the grassed area is \( y = 0.0003x + 0.1871 \) with an \( R^2 \) value of 0.6351.

The sample area descriptions are shown in Table 5.2 below. The average lot area was determined by summing the total area covered by the lots and divided by the number of lots within the subdivision. The subdivisions were chosen with respect to similar sized lots within the sample area; therefore, it is assumed the average lot size is a good representation of any lot within the sample area. The range of grassed area per lot is dependent on the lot size as well as factors such as size or presence of driveways/walkways and swimming pools, landscape design, treed areas, size and type of dwelling. The final columns indicate the dwelling type statistical data associated with the sample areas. In the sample areas with a large number of multi-family dwellings (e.g. Vernon Sample 3), the dwellings were not included in the grassed area analysis. This was due to
the fact that the multi-family buildings were located on much larger lots and would skew the analysis results.

Table 5.2 Sample Areas and Statistical Data

<table>
<thead>
<tr>
<th>Sample and Location</th>
<th>2006 Population</th>
<th>Number of lots</th>
<th>Average Lot Area (m²)</th>
<th>% grass per lot</th>
<th>Total Dwellings</th>
<th>Single Family</th>
<th>Duplexes less than 5 storeys</th>
</tr>
</thead>
<tbody>
<tr>
<td>KELOWNA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>280</td>
<td>92</td>
<td>1765</td>
<td>74%</td>
<td>95</td>
<td>95</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>418</td>
<td>118</td>
<td>933</td>
<td>60%</td>
<td>155</td>
<td>105</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>517</td>
<td>201</td>
<td>611</td>
<td>33%</td>
<td>265</td>
<td>150</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>526</td>
<td>169</td>
<td>748</td>
<td>45%</td>
<td>220</td>
<td>160</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>392</td>
<td>124</td>
<td>673</td>
<td>45%</td>
<td>130</td>
<td>105</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>875</td>
<td>203</td>
<td>718</td>
<td>42%</td>
<td>300</td>
<td>130</td>
<td>110</td>
</tr>
<tr>
<td>7</td>
<td>435</td>
<td>136</td>
<td>1083</td>
<td>47%</td>
<td>135</td>
<td>130</td>
<td>5</td>
</tr>
<tr>
<td>VERNON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>428</td>
<td>154</td>
<td>559</td>
<td>40%</td>
<td>160</td>
<td>145</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>430</td>
<td>132</td>
<td>768</td>
<td>34%</td>
<td>195</td>
<td>190</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>551</td>
<td>119</td>
<td>674</td>
<td>38%</td>
<td>235</td>
<td>115</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>550</td>
<td>247</td>
<td>671</td>
<td>36%</td>
<td>200</td>
<td>180</td>
<td>15</td>
</tr>
<tr>
<td>PENTICTON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>510</td>
<td>159</td>
<td>857</td>
<td>43%</td>
<td>255</td>
<td>145</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>387</td>
<td>118</td>
<td>878</td>
<td>46%</td>
<td>125</td>
<td>125</td>
<td>0</td>
</tr>
<tr>
<td>OSOYOOS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>391</td>
<td>185</td>
<td>950</td>
<td>34%</td>
<td>185</td>
<td>175</td>
<td>5</td>
</tr>
</tbody>
</table>

The main sources of error associated with the manual digitization of the grassed area for each of the sample areas are primarily due to the resolution of the orthophotos. The orthophotos were provided in hardcopy and were scanned to jpeg format and georeferenced in ArcGIS. The sample areas were chosen where there was good photo coverage; however the final digital copies were not as clear as the aerial photos that could be accessed online through the municipality’s websites. These were used to improve the resolution, especially in lots with a number of trees.

5.1.2 Automated Imagery Analysis

The Summerland Research Station conducted an alternative method to determine the grassed area per lot in the residential areas of the Okanagan Basin. Automated imagery analysis is done by classifying colours from orthophotos which represent the area of interest, grassed area in this project. The analysis is then run and the grassed area is determined. This method is efficient;
however, errors are associated with the selection of grassed area. In shadowed areas, the grassed area may not be selected. Therefore, in densely built areas, the error is likely to be higher. The automated imagery analysis was compared to the hand-digitization in the fourteen sample areas. The results are shown in Figure 5.1 where the percentage difference is the y-axis and the average lot size for each sample area is the x-axis.

**Figure 5.1 – Comparison Between Automated Imagery Analysis and Hand-Digitization**

The positive percentages indicate where the manual digitization over-estimates the grassed area in comparison to the automated imagery analysis. There are large differences with both over and under estimation from 30% to -30% for the sample areas. The larger lots show a bit less variation with may be attributed to less interference with shadows as the larger lots have more open grassed areas away from buildings and trees.

5.1.3 Water Metering Data and Indoor Water Use

The analysis completed in the previous Chapter with regards to the current water demands in four sample areas in Kelowna showed a relationship to summer water demand and lot size. The metering data is shown in Figure 4.2 where the months are the x-axis and the monthly water
demand per lot is the y-axis. A summary of the attributes of the four sample areas is provided in Table 5.3.

The assumption in this project is that as lot size increases, the area and proportion of grassed area per lot increases, therefore the water demand in the summer months should increase. The metering data shows a clear relationship: as the lot size increases, the summer water demand increases.

**Table 5.3 Metering Sample Areas**

<table>
<thead>
<tr>
<th>Sample</th>
<th>2006 Population</th>
<th>Num of Lots</th>
<th>Grassed Area</th>
<th>Size of lots (m²)</th>
<th>Average Winter Monthly Demand (Nov-Feb)</th>
<th>Summer Peak (Aug/July)</th>
<th>Per Capita Demand (LPCD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>526</td>
<td>169</td>
<td>45%</td>
<td>748</td>
<td>24</td>
<td>85</td>
<td>257</td>
</tr>
<tr>
<td>2</td>
<td>517</td>
<td>201</td>
<td>33%</td>
<td>611</td>
<td>20</td>
<td>50</td>
<td>252</td>
</tr>
<tr>
<td>3</td>
<td>435</td>
<td>136</td>
<td>47%</td>
<td>1083</td>
<td>19</td>
<td>105</td>
<td>189</td>
</tr>
<tr>
<td>4</td>
<td>280</td>
<td>92</td>
<td>60%</td>
<td>1765</td>
<td>19</td>
<td>148</td>
<td>197</td>
</tr>
</tbody>
</table>

The per-capita water demand is also of interest as municipalities use the population projections to determine the projections in water demand, not the increase in lots (Mr. Andrew Boyland, pers. comm.). The metering data for the four sample areas is shown in Figure 5.2. The trends are the same as the per lot metering in Figure 4.2, with similar per capita values for the winter months and the summer peak varying depending on the lot size.
The average winter water use, as shown in columns 6 and 8 of Table 5.3, are assumed to represent the indoor water demand. This approach is useful and common in separating outdoor water use from indoor because traditional meters do not separate indoor from outdoor. The differences in the winter months are not related to lot size, but more so to human behaviour with regards to indoor water use. Detailed indoor water use studies are needed to quantify this variation as they include winter travel plans, hygiene habits and efficiency of appliances.

Additional analysis was done on the metering data which involved assessing more specifically the differences in water demand from the winter months to the peak water use in August. The analysis was done on a lot-by-lot basis with the August demand being divided by the average of the winter months water use (November to February) for each lot. The lots were then sorted based on the increase in water use from the winter months to August. The increase was categorized into three categories, the first where the August water demand was the same and up
to two times that of the winter months, the second was between two and ten times that of the winter and lastly those lots where the August demand was more than ten times that of the winter month average. This is shown as the x-axis on Figure 5.3 and the y-axis is the proportion of lots that fall within each category for each sample area. For example, in Sample area 4, the largest lots, almost 30% of the lots use more than ten times the water in August than in the winter months.

**Figure 5.3 – Increase in August use for the Kelowna Sample Areas**

![August 2006 Metered Water Use](chart)

This analysis was done in an attempt to highlight whether some residences were using significantly more water in the summer and possibly skewing the average water demand for the sample areas. This analysis supports the trend that the larger lots (Sample areas 3 and 4) use much more water in the summer than the smaller lots. Sample areas 3 and 4 indicate that only about 15% of the lots show no or a small increase in summer water use whereas the smaller sample areas show 50% to 60% of the lots in this category.
5.1.4 Model Calibration

As described in the previous Chapter, the Irrigation Demand Model is over-predicting the water demand when compared to the metering data for the same areas. In order to compare the model results with the metering data, the indoor water use was added to the model results. The indoor water use was taken as the average of the winter months as described in the previous section. The results of the model compared to each of the sample areas after the grassed proportion of each lot was reduced by 20% are shown in Figure 4.12.

The reduction in proportion grassed per lot is also supported by the ground survey conducted in the form of a field survey in August 2009, by the Ministry of Agriculture and Lands (MAL). The survey indicated that 20% of the lots in Sample Area 3 are not being irrigated in the month of August. Additionally, there are 17% who are only partially irrigating with the remaining lots (63%) being fully irrigated. Reducing the grassed proportion by 20% per lot is a conservative calibration approach as the model is still over-predicting the water demand on an annual basis shown in Figure 4.10. It is understood that for planning purposes, municipalities and communities require more detailed information in regards to daily water demands, not annual quantities. However, it is the purpose of this project to illustrate the large-scale impacts on water demand for extreme urban development patterns.

The red line is the original model annual water demand for the four Kelowna samples with the indoor water use included. The green line is the actual water use from the metering data. The blue line is the model results with the grassed area per lot reduced by 20%.

The Irrigation Demand Model (IDM) was developed for agricultural purposes, therefore, the assumption is that the crop is irrigated with respect to climate and crop water demands. However, in an urban setting, the irrigation amount and timing is related to water restrictions already in place as well as the resident’s behaviour. For example, the more gradual increase in water demand as shown by the metering data (Figure 4.12) for the months of May and June, are likely due to the fact that very few residents begin irrigating their yards until the summer months. The
increase in water demand in July coincides with the end of the school term in June and it is likely that if no irrigation has taken place until then, the lawns are showing signs of brown. The IDM results show that if the residential grassed areas were being fully irrigated, the water demand would be greater than current practices. The model was developed to assess crops that are produced for commercial purposes such as apples, pasture and grapes; therefore, poor irrigation practices result in measurable economic losses. Irrigation scheduling and efficiency are much better studied in the agricultural sector and good management practices are implemented. This is not often the case for irrigating lawns.

5.2 Urban Growth Scenarios

The urban growth scenarios were developed from the 2006 existing conditions shown in the series of Figures 5.4 to 5.7. The light purple areas are the existing commercial and industrial developments with the dark purple being the existing developed residential lots. The dark green areas are parks and the light green is the Agricultural Land Reserve (ALR). The municipal boundaries are the light grey in the background with water shaded in blue.
The Urban Growth scenarios for the year 2026 were developed using existing lots from each of the municipalities. The selected lots had a known 2006 population and were copied, moved and placed according to the communities’ Official Community Plans (OCP). Three development scenarios were developed for each of the case study communities and are shown in the series of Figures 5.8 to 5.18.

The Urban Sprawl Scenario (Figures 5.8, 5.11, 5.14 and 5.17), was developed with entirely single family dwellings to meet the population projections for the year 2026 as shown in column 4 of Table 6.1. The new lots are shown in red in the figures and were placed where the OCPs have zoned for future residential development and avoidance of the ALR. In the Urban Sprawl Scenario for Kelowna, lots had to be placed on the ALR in order to meet the population projection.

The In-Between Scenarios (Figures 5.9, 5.12, 5.15 and 5.18) were developed with half of the new population being housed in single family lots and the remaining in multifamily lots. Additionally, to represent possible demand management in the future, half of the new single family lots were assigned a reduced proportion of grass. This reduction may represent new landscaping bylaws or stricter watering restrictions in the future.

The Densification Scenarios (Figures 5.10, 5.13, 5.16 and 5.18) were developed with the entirety of the projected population being housed in multifamily dwellings. There were a few single family lots associated with the multifamily as they were selected from more than one census tract. Therefore, the Osoyoos Densification and In-Between scenarios were determined to be the same development since it had the smallest increase in population of the case studies and only one census tract represents the future growth in Osoyoos. Redevelopment of the existing lots was done for this scenario as indicated by the red lots in the city centers. However, previously undeveloped areas were still needed for this scenario. Again, demand management was represented by reducing the grassed proportion per lot for the few single family lots.
Figure 5.11 – Vernon Urban Sprawl Scenario (2026)

Figure 5.12 – Vernon In-Between Scenario (2026)

Figure 5.13 – Vernon Densification Scenario (2026)
Figure 5.14 – Penticton Urban Sprawl Scenario (2026)

Figure 5.15 – Penticton In-Between Scenario (2026)

Figure 5.16 – Penticton Densification Scenario (2026)
5.3 Irrigation Demand Model Results

The Urban Growth Scenarios were developed for use within the Irrigation Demand Model (IDM). The irrigation demand for the existing residential lots (2006) for each case study community was assessed as well as the three growth scenarios. Climate data was also a factor in determining the irrigation demand and as the future climate is uncertain, an extremely dry year was used to represent a possible future.

5.3.1 Climate Data Variation

The Okanagan Basin is a semi-arid region and the driest area in Canada per capita (Statistics Canada, 2009). Historical climate data is included in the IDM for the years 1997 to 2006. Within the span of this ten-year period, the precipitation varied greatly. For example, the precipitation data from the Penticton weather station is shown in Figure 5.19, obtained from the Environment Canada website (Environment Canada, 2009).

Figure 5.19 – Historical Precipitation Data for Penticton
The year 1997 was a wet year whereas 2003 was dry and 2006 was somewhere in between. The climate data that directly impacts the IDM is in the summer months. The annual and summer precipitation values are shown in Table 5.4.

**Table 5.4 Historical Precipitation - Penticton**

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Precipitation (mm)</th>
<th>Summer Precipitation July-Sept (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>418.4</td>
<td>165.8</td>
</tr>
<tr>
<td>2003</td>
<td>280.6</td>
<td>16.5</td>
</tr>
<tr>
<td>2006</td>
<td>470.5</td>
<td>51.9</td>
</tr>
</tbody>
</table>

The annual precipitation comparison show that the difference between 1997 and 2003 was over 100 mm; however the annual total for 2006 was greater than the wet year of 1997. In contrast, when comparing the summer precipitation from July to September for each year, more significant differences are noted, in 2003 only 16 mm of precipitation fell in the summer months whereas in 1997, ten times that amount occurred. The summer of the year 2006 is more representative of an average summer precipitation of 83 mm (1971 to 2000) (Environment Canada, 2009).

The results from the Irrigation Demand Model shows a significant change when different climate years are used. For the existing conditions (2006) the three climate years were run and the results are shown in Table 5.5.

**Table 5.5 Climate Variation on Existing Conditions (2006)**

<table>
<thead>
<tr>
<th>Municipality</th>
<th>2006 Outdoor Water Use (Mm$^3$) Using Varying Historical Climate Data</th>
<th>Difference from a Wet to Dry Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1997 Climate</td>
<td>2003 Climate</td>
</tr>
<tr>
<td>Kelowna</td>
<td>7.06</td>
<td>8.42</td>
</tr>
<tr>
<td>Vernon</td>
<td>2.33</td>
<td>3.05</td>
</tr>
<tr>
<td>Penticton</td>
<td>1.54</td>
<td>2.00</td>
</tr>
<tr>
<td>Osoyoos</td>
<td>0.51</td>
<td>0.60</td>
</tr>
<tr>
<td>Total</td>
<td>11.43</td>
<td>14.06</td>
</tr>
</tbody>
</table>

The difference between a wet and dry year is shown as a proportion from the year 1997 to 2003 for each municipality. The total difference from a wet to dry year is 11.4 Mm$^3$ to 13.4 Mm$^3$, which is 23% increase. This comparison is meant to highlight the difference climate can make in water demand with the assumption that the irrigation demands will be met as according to the
model calculations. No conservation practices are imposed and therefore the results highlight the importance of planning for drought, as climate is unpredictable and highly variable.

Climate change is a concern in the Okanagan Basin; therefore, in development of the IDM, climate change scenarios were included. However, there is no clear convergence of the various climate change scenarios with regards to amount of precipitation (Schreier, 2008; Cohen, 2004). Therefore, the 2003 climate data was chosen to represent a possible future for the year 2026 because the scenarios prepared by the climate change modelers suggest that the precipitation event will be more intense and the dry periods will be drier (Hamlet & Lettenmeier, 1999); as a result it is expected that the climate extreme that occurred in 2003 is likely to occur more frequently in the future.

5.3.2 Urban Growth Scenario Results

The three Urban Growth Scenarios were run for each case study community in the Irrigation Demand Model. The scenarios were run with all three climate years (1997, 2003 and 2006), however the results for the existing conditions used the 2006 climate and the future scenarios used the 2003 climate data as discussed in the previous section.

The indoor water use was included by using the limited metering data from the four Kelowna sample areas (Table 5.3). The indoor water use was determined from the average of the winter average (November to February) in column 8 of Table 5.3 as 222 liters per capita per day (Lpcd). The indoor water use was calculated based on the population statistics.

The annual water demands for the Urban Growth Scenarios are shown in Table 5.6 along with the indoor water demand for each case study community. The differences in the scenarios show that different development patterns have a significant impact on the future water demands. The annual outdoor water savings for a densification scenario versus urban sprawl is over 5 million m$^3$ by the year 2026.
Table 5.6 IDM Urban Growth Scenario Results

<table>
<thead>
<tr>
<th>Municipality</th>
<th>2006 Indoor Water Use (Mm³)</th>
<th>2026 Indoor Water Use (Mm³)</th>
<th>2006 Outdoor Water Use (Mm³)</th>
<th>Urban Growth Scenarios 2026 Outdoor Water Use (using 2003 climate data)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2026 Urban Sprawl (Mm³)</td>
<td>In-Between (Mm³)</td>
<td>Densification (Mm³)</td>
</tr>
<tr>
<td>Kelowna</td>
<td>9.06</td>
<td>12.79</td>
<td>8.09</td>
<td>13.49</td>
</tr>
<tr>
<td>Vernon</td>
<td>3.06</td>
<td>3.98</td>
<td>2.87</td>
<td>4.00</td>
</tr>
<tr>
<td>Penticton</td>
<td>2.72</td>
<td>3.07</td>
<td>1.86</td>
<td>2.38</td>
</tr>
<tr>
<td>Osoyoos</td>
<td>0.40</td>
<td>0.56</td>
<td>0.56</td>
<td>0.81</td>
</tr>
<tr>
<td>Total</td>
<td>15.24</td>
<td>20.40</td>
<td>13.38</td>
<td>20.68</td>
</tr>
</tbody>
</table>

The outdoor water demand is shown in Figure 5.20 compared to the existing conditions.

Kelowna is the greatest water user as it has the largest existing population and is expected to continue to grow at the fastest rate. The smaller communities also show variable water demand depending on the growth scenario.

Figure 5.20 – Model Results for Outdoor Water Demand (2006 & 2026)

As discussed Chapter 1 and 2, a previous study (Neale, 2005) at UBC assessed the current and future water demands in the Okanagan Basin qualitatively. The ratio of outdoor to indoor water demand was in the range of 51% to 54%. The four sample areas with metering data obtained
from Kelowna are shown in Figure 5.21 with the model and metering results. The outdoor water demand to total ranges from about 30% to 60% of the total water demand.

**Figure 5.21 – Proportion of Outdoor Water Use for Kelowna Sample Areas (with 20% reduction in grassed area per lot)**

The areas with metering data are small scale and as the results shown in Table 5.6 include the indoor water use for the existing conditions and the urban growth scenarios. The indoor and outdoor water demand for the total of all case studies is shown in Figure 5.22.
The indoor water demand stays the same for the future growth scenarios whereas the variation of outdoor demand is evident depending on the scenario. The proportion of outdoor to total water demand for the existing conditions is 47% and increases to 50% for the urban sprawl scenario, but reduces to 45% and 42% for the In-Between and Densification scenarios respectively.

In all cases of the urban growth scenarios, no modifications to the existing conditions have occurred except for the In-Between and Densification scenarios where some of the lots were redeveloped for multifamily dwellings. Additionally, the indoor water demand is assumed to remain at 222 Lpcd in all scenarios, which is unlikely to continue as there have been communities that encourage taking indoor water conservation measures such as toilet retrofitting in Penticton and the Get Water Smart program in Kelowna (Klassen, 2009). This indoor amount is comparable to the amount presented by Kerr Wood Leidal (2005) for the Greater Vancouver Regional District (GVRD, now Metro Vancouver) as 267 Lpcd during a study of metered residences. Also presented was a 12-city average indoor water use at 262 Lpcd and Seattle’s
indoor use was 212 Lpcd. The proportion of outdoor water usage was determined to be 59%, on the higher end of proportion in this study (30% to 60%), but still within a similar range. The Canadian average water demand for 2004 was 329 Lpcd (Environment Canada, 2008) and up to 50% of residential use is for outdoor purposes.

5.4 Sources of Error

The population in 2026 for the four case study communities is impossible to predict, however from assessing recent growth and regional projections one possible projection was determined. The error associated as population growth within a community is ultimately related to human behaviour. However, there are limiting factors such as geography as well as municipal boundaries. Penticton is a good example as it is bounded by lakes on the north and south as well as steep slopes on the east and a Native reserve on the west.

The manual digitization was done to determine the grassed area per lot, the resolution of the orthophotos was not optimal because significant resolution was lost by scanning hard copies and georeferencing the data in ArcGIS. On a lot scale, errors would be associated with the boundaries of the grass next to driveways and sidewalks as the tone of colour between the light green of the grassed areas against the grey of the cement was often difficult to distinguish. The comparison done between the automated imagery analysis and the manual digitization of this project, indicated an equal over and under estimation (-30% to 30%) by the automated process.

During calibration of the IDM against the metering data for the four Kelowna sample areas, it became evident that the model was over-predicting the outdoor water demand for residential areas. As discussed, this is likely due to the fact that the IDM was developed for agricultural purposes were economic losses by poor irrigation practices are usually avoided, whereas poor practices in urban areas result only in esthetical damage and not economic losses. The 20% reduction in grassed area per lot was done to partially offset this.
It is understood that modeling the current and future outdoor residential water demands are ultimately an attempt to model human behaviour. These are factors beyond those related to science (soil data, climate, irrigation type) and were not included in the IDM model. These include such personal habit as timing and frequency of irrigation, amount of lawn area irrigated and efficiency of the irrigation system. The ground survey conducted on one sample area supports this assumption as regardless of the watering restrictions in place, 63% of the residents were fully irrigating their yards and approximately 20% of their neighbours were not irrigating in August, 2009.

5.5 Results and Implications

The water demands for the four case study communities are shown in Table 5.6 in Mm$^3$. However, many reports state water demand in liters per capita per day (Lpcd) and are shown in Table 5.7. The indoor water demand was assumed to remain the same for the present and future conditions at 222 Lpcd; however, the outdoor water demand varies depending on the urban development patterns. The average current per capita water demand is calculated from the total water demand divided by the total population. The 2006 total per capita is 417 Lpcd and the future scenarios range from 447 Lpcd for the urban sprawl scenario to 407 Lpcd and 385 Lpcd for the In-Between and Densification scenarios respectively. It is clear that the outdoor water demand varies from case study community with Osoyoos with the highest per capita demand and Penticton with the lowest regardless of growth scenario.

| Table 5.7 Current (2006) and Future (2026) Outdoor Water Demands (LPCD) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 |                 |                 | Urban Sprawl | In-Between | Densification |
| Kelowna         | 111,802         | 157,867         | 198         | 234         | 185            | 158            |
| Vernon          | 37,716          | 49,178          | 208         | 223         | 197            | 183            |
| Penticton       | 33,550          | 37,870          | 152         | 172         | 156            | 147            |
| Osoyoos         | 4,979           | 6,875           | 307         | 322         | 251            | 251            |
| **Total**       | **188,047**     | **251,790**     | **195**     | **225**     | **185**        | **163**        |
The Residential End Uses of Water Study (REUWS) was conducted by assessing several cities in the US, the outdoor water use proportion ranged from 58% in Boulder, Colorado to 72% in Scottsdale, Arizona (Mayer and DeOreo, 1999). The results from this project show that the outdoor water proportion ranges from 47% for 2006 conditions to 50% for the Urban Sprawl scenario in 2026.

The water demand per lot from the REUWS project was similar to that determined in this research. Depending on lot size, the total annual water demand per lot ranges from 338 m$^3$ to 739 m$^3$ for the year 2006. The REUWS study was conducted over a few years (mid 1990s), however the average annual water demand per household ranges from 485 m$^3$ to 881 m$^3$, which is comparable to the aforementioned results (Mayer and DeOreo, 1999).

The annual total water demand for the four case study communities in 2006 was determined to be 28.6 Mm$^3$ and 13.4 Mm$^3$ of that was for outdoor purposes (see Table 5.6). In comparison, the agriculture water demand for the entire Okanagan Basin for 2006 is roughly 140 Mm$^3$ (Mr. Ted Van der Gulik, pers. comm.). This means that these four communities (out of a total of 15 in the Okanagan Basin) consume about 20% as much as all of the agricultural irrigation demands.

Assuming agriculture demands remain the same; the four communities demand could increase to 29% with urban sprawl and no conservation measures in place by 2026. As the urban water demand increases with population, conflicts may arise in the allocation of water resources. Water savings associated with development patterns by 2026 could be as much as 5.7 Mm$^3$ for the four case study communities.

The development patterns that occur in the Okanagan Basin communities in the next 15 to 20 years will have significant impacts on the water demand. This project was conducted with little to no changes on the existing conditions within the case study communities. However, significant water saving can occur if demand management is applied to both current and future residences, both indoor and outdoor use. Reducing the grassed area per lot by encouraging xeriscaping is one method. Additionally, savings can also be obtained through indoor water conservation. This
project was conducted in order to illustrate the water savings that can be achieved through densification versus urban sprawl. Outdoor water use is roughly half of the total water demand, therefore, conservation outdoors is as important and indoor savings. It may, in fact, have a greater impact on water savings as outdoor water use can be minimized to a very low volume; however, there is a minimum indoor water demand for all residences for drinking and hygienic purposes.
6 Conclusions and Recommendations

The results of this study show the varying residential water demand in the major communities in the Okanagan Basin. The outdoor water use was determined on a lot size basis for 2006 and projections were made to the year 2026 using different population growth and urban development scenarios. The outdoor residential water demand varied from 30% to 60% of the annual domestic water demand depending on lot size. The four case study communities in the Okanagan Basin, Vernon, Kelowna, Penticton and Osoyoos, represent the diversity in climate and population trends in the Basin. The year of 2006 was used as existing conditions from which three urban growth scenarios were developed: Urban Sprawl, In-Between and Densification to the year 2026. The conclusions that were drawn with respect to population, residential development patterns, climate variability and use of the Irrigation Demand Model are presented below. Additionally, recommendations for conservation practices and potential future water savings are outlined.

6.1 Population Projections

Projecting the population to the year 2026 from the last census year in 2006 is challenging, as it is difficult to predict. The method used for this study relied on the regional population projections to 2026 developed by BC Stats (2009b) and downscaling the data to the case study communities based on how they have been growing recently (2001-2006). Migration to the region is influenced by many factors, most of which are not within the control of the towns or municipalities such as: economic conditions, housing prices, climate, geography, recreational trends and demographics. Additionally, using a fixed annual growth rate as municipal planning departments have tended towards, leads to a greater population projection than the downscaled regional projections (except for Kelowna). In terms of water management, population projections are necessary to determine future demands so that supplies can be secured as well as planning for infrastructure for water supplies and wastewater collections, treatments and recycling. The population projections for the year 2026 used for the four communities were 158,000 for
Kelowna, 49,000 for Vernon, 38,000 for Penticton and 7,000 for Osoyoos. The annual growth rates were dependant on the regional population projections and how the communities had been growing recently.

6.2 Urban Residential Development Patterns

Unlike population, towns and municipalities have control over how residential development occurs through zoning bylaws. The Agricultural Land Reserve (ALR) is zoning for agricultural purposes only, however, exemption can be granted for urban development which may cause controversy related to food production. Currently, the Official Community Plans (OCPs) for each case study community include zoning areas for future residential development. The Urban Sprawl scenario consumed the greatest area of land, and lots were needed to be placed on marginal land and the ALR in Kelowna. The Densification scenario showed that nearly all of the new residences developed were multifamily and could be accommodated without expanding into the ALR areas. The reason for this was that only a small increase in residential grassed area is needed with densification.

6.3 Modeling and Actual Outdoor Water Use

Modeling residential water demand is a complex challenge. The grassed area per residential lot was determined by digitizing fourteen sample areas in the 4 communities and assessing existing conditions for use within the Irrigation Demand Model (IDM). The results from the IDM were for outdoor water demand based on crop water demand and covered the five month growing season during which irrigation is required and the results showed that the model consistently over-predicted water demand when compared to the metered data for the same sample areas. This is consistent with another study that showed that only 55% of the required water was used for irrigating residential grassed areas (Mayer and DeOreo, 1999). In order to mimic the actual water use, the grassed proportion per residential lot in the current study was reduced by 20% which resulted in the demand being closer to actual use. This was done for the following reasons:
a) errors in measuring lot areas
b) efficiency of different irrigation methods uses, and
c) not all residences irrigated the grassed area on a regular basis.

Most of this is dependent on human behaviour, which is very challenging to model; Balling and Gober (2007) state:

“People’s perception of the landscape’s water needs and their willingness and ability to respond to their perceptions by changing landscaping practices are probably more important than the landscape’s need for water in assessing residential water demand and the variation therein.”

Therefore, the use of the IDM is valuable for approximating the outdoor residential water demand in the Okanagan Basin; however, understanding the perceptions and values of the residents is also an important step to determining residential water demand.

Furthermore, the methods developed in this project for use with the IDM were applied to all of the communities in the Okanagan Basin by the MAL in the summer of 2009. The urban growth scenarios were extended to 2030 and are now incorporated into the Okanagan Water Supply and Demand Project which will form the basis for water management planning in the region (OBWB, 2009).

6.4 Climate Variability

The outdoor water demand is dependant on climate; therefore, climate change is a concern in projecting future residential water demand. Studies show a relationship between daily maximum temperature and residential water use (Neale, 2005; Kenney et al., 2008). In this study, three historical years of climate were used to represent extremes in a wet year (1997), a dry year (2003) and an average year (2006). The difference in demand from using a wet to dry year for the existing conditions is 23% for the four case study communities. Climate change projections show no clear convergence with the amount precipitation; however, it is predicted that more extreme
events will occur, such as floods and more frequent droughts. The year 2003 received only 16.5 mm of precipitation in the summer months (July-September), 100 times less than a wet year, and 10 times less than an average year. Therefore, it is assumed that extreme drought years like 2003 will occur more often in the future and represent a possible climate regime for 2026. Using the 2003 climate on the 2006 conditions in the IDM resulted in a water demand was 23% higher than in a wet year (1997 climate data).

6.5 Current and Future Outdoor Residential Water Demands

The difference between winter and summer water use was determined from metering data available for four sample areas in Kelowna for 2006. The average winter demand was determined to be 222 Lpcd and the peak summer demand (August or July) varied based on lot size from 621 Lpcd for the small lots to 1564 Lpcd for the largest lots.

Three urban growth scenarios were developed for this project: urban sprawl and densification with the third scenario in-between. The outdoor water demand for the existing (2006) conditions was determined to be 13.4 Mm$^3$. New residential developments are tending to be single family lots, therefore if business as usual continues, up to an additional 7.3 Mm$^3$ (55% increase from 2006) will be needed to meet the outdoor residential water demand for the four case study communities in 2026. If indoor water demand is included (assumed to be 222 Lpcd) 5.2 Mm$^3$ of additional water will be required to for indoor use for 2026 (34% increase). Clearly, outdoor water demand is where the greatest water savings can be made, as it will increase to a greater amount than indoor. Additionally, a minimum amount of water is essential for indoor use for drinking and hygienic reasons (laundry, toilets and washing), but there is no minimal outdoor use required if alternative landscaping measures are taken (e.g. drought resistant plants).

6.6 Current and Recommended Conservation Practices

Demand management is already in place in many areas of the Okanagan. The effectiveness of the conservation efforts on outdoor water use is unknown; however, it is important to recognize that
municipalities currently have summer water restrictions in place and other efforts to reduce the outdoor residential water demand. Kelowna, Penticton and Vernon have residential metering in place and reclaimed wastewater is in practice in Vernon, Penticton and Osoyoos. Each city and town encourages and provides information on how to conserve outdoor water through their websites.

The results of this project indicate that average annual outdoor water use in the Okanagan Basin is approximately 47% for the current conditions (2006) and may increase to 50% in 2026 for the urban sprawl scenario; however with densification, the outdoor water proportion would reduce to 42% for the four case study communities. The significance of this savings is more clearly apparent when presented as water quantity savings: 5.7 Mm$^3$, which is equivalent to 20% of the current total residential water demand for the four case studies.

In order to quantify the potential savings with conservation practices in place, the urban sprawl scenario for 2026 (using 2003 climate data) is the worse case scenario against which all potential outdoor water savings measures can be made. The conservation practices are presented in Table 6.1, with the cumulative savings shown in bottom row and the reduction in total water demand for 2026 shown in the second column as each conservation practice is imposed on the urban sprawl scenario. If densification, a 20% reduction in grassed area per lot for all of the residential lots and mandatory watering restrictions are put in place, a potential savings of 14.1 Mm$^3$ can be achieved by the year 2026 for the four case study communities (see Table 6.1). This is actually a reduction in quantity from current (2006) outdoor residential water use by 5.8 Mm$^3$ (43%), which a proportion of outdoor water demand to total of 27% in 2026. Details on how these conservation practices can be implemented are discussed below.
<table>
<thead>
<tr>
<th>Scenario &amp; Conservation Practice</th>
<th>Total Water Demand (Indoor &amp; Outdoor)</th>
<th>Outdoor Water Demand</th>
<th>Additional Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Sprawl 2026</td>
<td>41.1 Mm³</td>
<td>20.7 Mm³</td>
<td></td>
</tr>
<tr>
<td>Densification 2026</td>
<td>35.4 Mm³</td>
<td>15.0 Mm³</td>
<td>5.7 Mm³</td>
</tr>
<tr>
<td>20% reduction in grassed area for all residential lots</td>
<td>31.3 Mm³</td>
<td>10.9 Mm³</td>
<td>5.1 Mm³</td>
</tr>
<tr>
<td>Mandatory watering restrictions (up to 30% savings) (Kenney et al, 2004)</td>
<td>28.0 Mm³</td>
<td>7.6 Mm³</td>
<td>3.3 Mm³</td>
</tr>
<tr>
<td><strong>Final</strong></td>
<td><strong>28.0 Mm³</strong></td>
<td><strong>7.6 Mm³</strong></td>
<td><strong>14.1 Mm³</strong></td>
</tr>
</tbody>
</table>

**Densification**

The densification scenario developed for this project consisted of redeveloping existing lots for higher density and reducing the proportion of grass for the new single family lots to 30% grass per lot. A typical single family lot size in the case study communities is approximately 750 m²; therefore, this lot would have roughly 225 m² of lawn, equivalent to the square footage of a small house (approximately 2,500 ft²). In order for significant densification to occur future residential zoning would be modified through the Official Community Plans for each community.

**Reducing the Grassed Area by 20% per lot**

The water savings achieved by reducing the grassed proportion of all lots by 20% in the densification scenario was determined from the IDM calibration results. Further reducing the grassed area (from 30%) would result in a typical single family area of lawn to 180 m², which is still a significant grassed area. The reduced proportion of grass per lot by 20% can be achieved by encouraging xeriscaping, which is the use of low-water-use plants. According to the Denver Water website, Xeriscape is based on seven principles: planning and designing, limiting turf areas, selecting and zoning plants appropriately, improving soil, using mulch, efficient irrigation and maintenance (Denver Water, 2009). Improving soil for by ensuring that at least 30 cm of topsoil used for landscaping greatly increases the water storage capacity and water availability for the turf (Klassen, 2009).
The reduction of 20% grassed area for all residential lots (including existing lots) would be a challenging program for residents. Many homeowners take pride in their lawns and tearing up a portion of their yard would be a dramatic step. In fact, in the arid countries of the Middle East, it has been recommended that water be diverted (from agriculture) to urban uses including “assuring quality of life with green open spaces” (Shuval, no date); a concept that is counterintuitive where food and water security are of concern.

For new developments, bylaws can be put in place to require landscaping to meet the water conservation standards. For instance, only 20-30% of each lot could be lawns. Furthermore, in planning for new developments, public greenspaces could be developed which would be managed by the municipalities. Therefore, residents can use the parks for leisure activities that involve turf and the irrigation of these areas are controlled by the municipalities.

*Mandatory Watering Restrictions*

In Colorado, an average reduction of 30% water use occurred when mandatory watering restrictions were put in place. The watering restrictions allowed residents to water in the late evening and early morning for only 10 to 15 minutes per zone, twice a week (Kenney et al, 2004). The table above does not include indoor water conservation practices; however, there are water savings to be achieved by continuing to encourage retrofitting existing households with low flow toilets and showerheads as well as water efficient appliances. It should be mandatory that all new developments have low flow fixtures and there be incentives for purchasing water efficient appliances. Steps towards these indoor water conservation practices have been taken in the Okanagan.

Because outdoor residential water use is largely based on human behaviour and perceptions of irrigation requirements for grassed areas, effective marketing of water conservation has potential significant water savings. Denver Water (2009) has been a leader in this area and has reduced water demand by 33% from pre-drought (2002) demands to the spring and summer of 2009 through aggressive marketing entitled *Use Only What You Need* (www.useonlywhatyouneed.org).
It focused on reducing outdoor residential water demands through creative advertising and marketing.

In summary, the recommendations for water conservation practices are the following:

- Impose minimal soil requirements to increase water storage capacity on new developments;
- Plan for densification and multi-family developments;
- Encourage xeriscaping through bylaws and public greenspaces;
- Enforce mandatory watering restrictions to twice a week;
- Continue to encourage retrofitting and indoor water conservation;
- Create effective marketing to encourage outdoor water conservation.
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