Water

Windsor Utilities Commission

Windsor Water System Master Plan Update FINAL REPORT

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description
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Table of Contents

List of Figures

List of Tables

List of Appendices

1. Introduction

The Windsor Utilities Commission (WUC) water distribution system consists of approximately 1,000 km of watermain. AECOM originally developed the WUC's base water model with the latest update completed as part of the Water Master Plan in 2009. The WUC retained AECOM to complete an update to the 2009 Water Master Plan, with a growth forecast to 2049, including completion of an all-pipe model. The key objectives of the Water System Master Plan Update (WSMPU) are to:

- Revise the 2009 servicing plan forecast with updated growth and demand projections;
- Update and confirm water system servicing strategies under the ultimate design year (2049) conditions, based on growth and non-growth perspectives to ensure that the full cost of water servicing is established; and
- Review and update the recommended infrastructure requirements including, timing, capital cost and cost sharing.

Growth information for the City of Windsor was obtained from the WUC. The Windsor water system also currently serves areas to the south (LaSalle), and to the east (Tecumseh). Growth in these areas and future connections for new or additional services was also updated based on available information from the WUC, Tecumseh and LaSalle.

1.1 Project Requirements

The WUC Water System Master Plan for the provision of water services through to the year 2049 was completed by AECOM in 2009. All work was completed in conformance with Ministry of Environment (MOE) regulatory requirements. The WUC retained AECOM to complete the 2014 Water System Master Plan Update, with the project scope as defined below:

- Review the status of the committed capital projects for the water system and update the hydraulic model accordingly;
- Update the hydraulic model with the latest WUC projected population information;
- Perform a hydraulic analysis to confirm serviceability under Average Day, Maximum Day and Peak Hour conditions for the following design years:
  - 2014
  - 2019
  - 2024
  - 2029
  - 2039
  - 2049
- Perform hydraulic analysis to review/confirm construction scheduling for recommended capital projects as per the 2009 Master Plan in order to provide adequate water supply, whilst adhering to current WUC design standards;
- Update the cost estimates for recommended capital projects for each design year identified above;
- Prepare a letter report summarizing the results.

In addition to the background information outlined above, AECOM utilized the following detailed information as a basis for this Master Plan Update.

- Growth related and renewed/replacement capital works required for the WUC water system.
- Growth projections and water demands from the original report with any modifications to the original plan being documented.

- Storage requirements to meet existing user and emergency needs, reconfirm future storage requirements to service new growth, and confirm pumping needs to service the annexed area to the south, LaSalle and the Town of Tecumseh.
- Pumping optimization at the A.J. Brian and George Avenue High Lift Pumping Stations to provide appropriate servicing pressures to the east and south.
- Proposed cross City transmission mains from the north to the south, or from the west to the east recommended as part of the 2009 Water System Master Plan (later referred as WSMP), that have not been implemented.
- Sizing and needs for the above watermains are to be optimized via additional modeling, in addition to confirming overall operations driven by the Hanna Street elevated water tank.

The 2009 Water System Master Plan selected Servicing Strategy No.2: Pumping & Storage at WTP (High Population Projection) to meet operational needs and future servicing objectives. The primary objective of the WSMPU is to review the recommended servicing strategy from the 2009 Water System Master Plan and update it based on the 2013 growth projections provided.

2. Existing Water System and Regulatory Requirements

Completion of the 2009 Water System Master Plan included review of several background documents for the Windsor, LaSalle and Tecumseh water systems. Regulatory requirements were also confirmed and related storage implications determined based on discussions with the WUC and MOE design guidelines. These conditions and requirements were carried forward to complete the 2014 WSMPU.

2.1 Windsor Water Supply and Distribution Systems

WUC owns and operates an integrated water supply system to provide treated water to the City of Windsor, the Town of LaSalle and the Town of Tecumseh. Two raw water intakes in the Detroit River supply raw water to the Albert H. Weeks and the Old water treatment plants for treatment. Treated water is distributed through approximately 1000 km of watermain ranging in size from 150 to 1800 mm in diameter (6 to 72 inches) to end users via two high lift pumping stations; the A.J. Brian Pumping Station and the George Avenue Pumping Station.

Distribution system storage and pumping facilities maintain service levels to the extremities of the system. The J.F. Cook Reservoir and Pumping Station located on Howard Avenue, an existing elevated water tank located on Hanna Street and an existing elevated water tower in the Town of Tecumseh provide this additional pumping and storage capacity. High lift pump operation at the A.J. Brian and George Avenue pumping stations is controlled based on distribution system pressure. The Hanna Street elevated tank has a relatively small operating capacity of 5.7 million litres (1.25 million gallons).

Reservoir D, located on the water treatment plant campus, has a capacity of 68.1 ML and provides treated water storage upstream of the high lift pumping stations. The J.F. Cook Reservoir and Pumping Station has a storage capacity of 45.4 ML (10 million gallons) and is equipped with booster pumps. The booster pumps are mainly used to supply the water system during peak demands. The pressure and flow at the reservoir and within the rest of the system is generally governed by the Hanna Street elevated tank, and high lift pump operation. Water levels in all distribution system storage tanks (J.F. Cook Reservoir, Hanna Street elevated tank, and Tecumseh elevated tank) are monitored hourly at the WTP. In addition, a system of 15 pressure monitoring stations, recorded hourly, is used to monitor system pressures, and act as a decision basis for pump operations.

The entire water supply system is operated as a single pressure zone. Flows to LaSalle and Tecumseh are sold wholesale based on flow monitoring at boundary flow meters. The following summarizes the overall capacities of the WUC water facilities:

Water Treatment Facilities

➢ Albert H. Weeks Water Treatment Plant	268 MLD	
➢ Old Water Treatment Plant	81 MLD	
	349 MLD	*Total Treatment Capacity*

Treated Water Storage Facilities

➢ Reservoir D (Albert H. Weeks WTP)	68.1 ML	
➢ J.F. Cook Reservoir	44.5 ML	
➢ Hanna Street Elevated Tank	5.7 ML	
➢ Tecumseh Elevated Tank	4.5 ML	
	121.5 ML	*Total Storage Capacity*

Treated Water Pumping Facilities

	Firm Capacity[2]	*Total Capacity*[3]
➢ A.J. Brian High Lift Pumping Station[1]	3,307 L/s	3,764 L/s
➢ George Avenue High Lift Pumping Station	2,104 L/s	3,156 L/s
➢ J.F. Cook Booster Pumping Station[1]	654 L/s	1,214 L/s
	6,065 L/s	8,134 L/s

(1) Based on 2012 capacity test

(2) Capacity with largest pump out of service

(3) Capacity with all pumps in service

2.2 Regulatory Requirements

Provincial regulations have been put in place since the Walkerton tragedy to:

- Protect and enforce drinking water standards (Regulation 459 and the new Safe Drinking Water Act);
- Ensure proper planning and financial recovery for water/wastewater infrastructure (Bill 175 Sustainable Water and Sewage System Act and Public Sector Accounting Board (PSAB) requirements; and
- Promote a renewed emphasis on watershed protection (Nutrient Removal Protection Measures Act, etc.). As a result, all of the water systems in Ontario have been intensely reviewed, with upgrades implemented in most instances to meet these new requirements.

As such, the WUC's water distribution and supply systems, along with other systems, has been undergoing upgrades that impact day-to-day water provision and emergency supply requirements that carry forward for new capacity applications.

The WUC relies on its water infrastructure to deliver high quality service to its ratepayers (new and existing). The tragic events of Walkerton underscored the importance of adequate investment in water systems; however, such investments must be done in a fiscally responsible manner. Recent legislation is moving utilities toward prioritized planning and full cost recovery for their water systems. The effective management and planning of water infrastructure requires a well-considered and planned approach that is focused on providing the appropriate level of service to the customer, while ensuring system reliability and long term sustainability. Necessary funding from growth and non-growth related sources must therefore be co-ordinated to meet this need fairly, and in a responsible manner, to ensure no one party or group pays more than its fair share.

To quantify and justify infrastructure expenditures, utilities must carefully consider the condition and performance of their water infrastructure based on regulatory requirements and realistic service levels. Master Planning and hydraulic modeling remain invaluable tools in the identification of water infrastructure needs from a performance perspective, and has gained greater relevance in the larger context of Development Charges and more recent regulatory requirements.

2.3 Storage Implications

As part of this master planning update, the WUC treated water storage capacity was revisited to confirm the need for additional storage capacity. As outlined in Section 2.1, the WUC currently relies on storage provided by Reservoir D at the WTP and distribution storage provided at the J.F Cook Reservoir and Pumping Station, the Hanna Street elevated storage tank and the Tecumseh elevated storage tank. To determine the level of risk associated with the existing WUC water system storage capacity, storage requirements were calculated for the 2013 water system demands based on the following design criteria:

- MOE design guidelines;
- 10 States Standards;
- several 'self-imposed' municipal standards: and
- One average day demand (ADD).

For the purposes of this evaluation, and consistent with MOE design guidelines, the total rated storage capacity was considered to ensure that sufficient storage capacity is available under situations where treatment capacity may not be available (i.e. raw water concerns). Table 2.1 below, summarizes the results of the storage requirements comparisons.

Table 2.1: Storage Requirements Comparison for Various Design Criteria

Standand[1]	***Additional Storage Requirements (2013)***
MOE Guidelines	(43.8)
City of Toronto Design Standards	49.1
Region of Peel Design Standards	(43.1)
10 States Standards with MOE Fire Flow	34.2
10 States Standards with 2 Industrial Fire	30.9
10 States Standards with 1 Industrial Fire and 1 Residential Fire	28.8
One Average Day Demand	25.5
In-Plant Use Storage Projection Included in Totals Above	*9.6*

[1] All standards include plant use storage requirements, as identified in the Banwell EA Report (Stantec, 2007).

As identified by Table 2.1, the existing WUC water storage facilities have sufficient capacity (43.8 ML excess capacity) when using the MOE design guidelines as the design criteria, but is approximately 25.5 ML less than one average day of water use for the entire water system in 2013. Design criteria are typically developed based on a municipality's risk tolerance and available redundancy and/or flexibility in the system. An emerging practice among municipalities is to provide sufficient storage for approximately one average day of demand for the entire system.

3. Design Criteria/Future Demand Determination

Before future growth related works could be updated, design criteria were reviewed and established. Future population and Institutional/Commercial/Industrial (ICI), growth information was also provided. This information needed to be re-confirmed to determine water system demands for the WUC water system over a 40 year growth period to 2049.

The design criteria utilized for the WUC water distribution system was provided by the WUC and based on 2013 actual demands. The design criteria established the parameters utilized to develop projected demands, evaluate hydraulic system performance, determine necessary infrastructure upgrades, identify operational strategies and determine a scheduling and implementation plan.

3.1 Future Growth Information

Future water system demands were determined using the above service level/design criteria information, and the population and land use projection information provided by the WUC for the City of Windsor, and made available from the last water system master plans completed for LaSalle and Tecumseh, respectively.

This WSMPU made use of the existing population and future growth information supplied by the WUC in order to assess growth areas and allocate future water demands to the system. The following base population (2013) was agreed to as a basis for this master plan study.

Year	Windsor	LaSalle	Tecumseh	Total
2013	210,891	29,096	24,820	**264,807**

The future growth information for the ‘High’, ‘Low’ and ‘Reference’ population projections are shown by Figure 3.1. The high, low and reference population projections for the City of Windsor were obtained from the Official Plan (Windsor) August 28, 2013. The Town of LaSalle and Town of Tecumseh population projections were obtained from Development Charges Background Report July 28, 2009 and October 14, 2009 respectively.

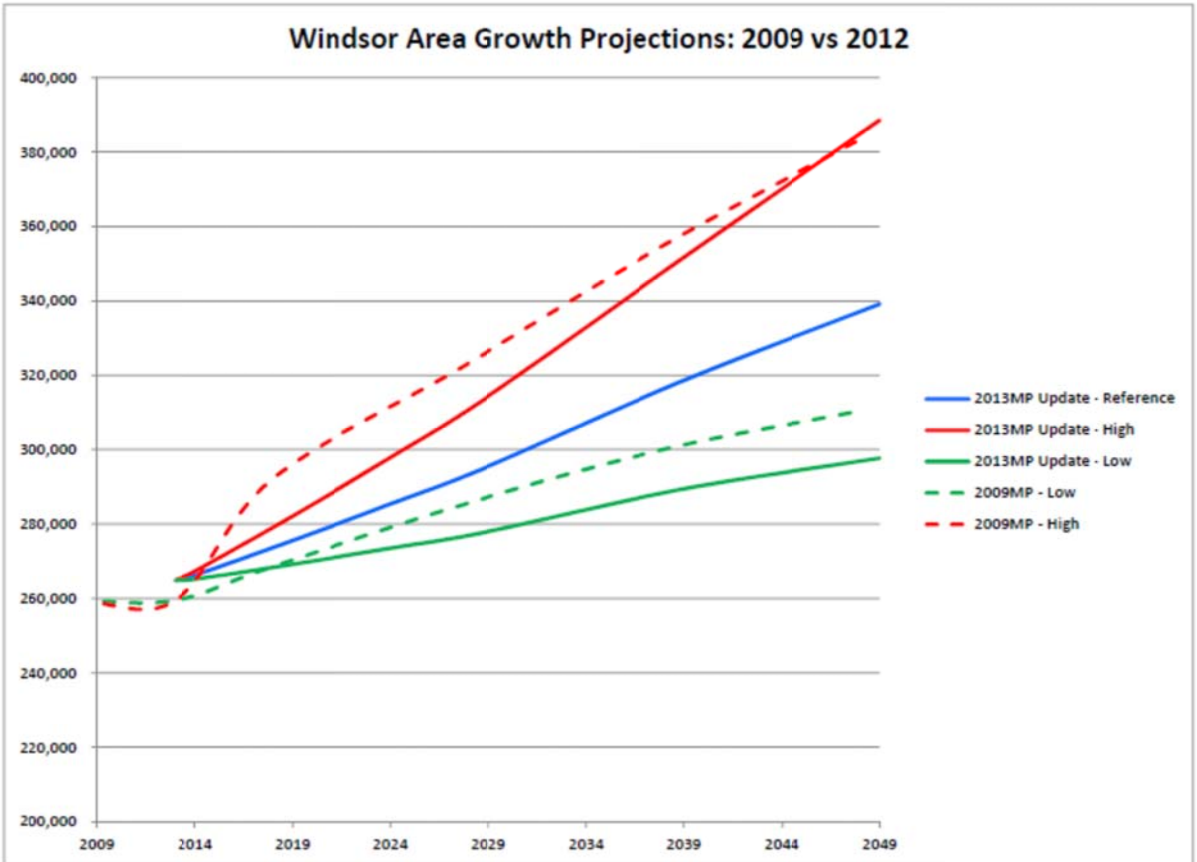

Figure 3-1: Windsor Area Growth Projections

The ultimate population projection for the low growth scenario is approximately 75% of the high growth scenario. To facilitate the hydraulic system evaluations under a conservative approach, the 'Reference' growth scenario was used as a basis of this master plan study update to ensure appropriate water transmission main sizing is provided. Storage and pumping needs were driven by the 'High' growth projection and were compared to the low and reference growth outputs for sensitivity purposes from a capacity need perspective and to determine timing flexibility.

3.2 Water System Demand Determination

The water demand criteria were established by assigning the total water demand established in the 2009 Water System Master Plan to a residential equivalent, then dividing the demand by the 2012 residential and industrial usage percentages; 47% residential, and 53% industrial. Table 3.1 summarizes the water demand criteria for the 2014 WSMPU.

Table 3.1: Water Demand Criteria

Category	***Water Demand Criteria***
Existing Residential and Industrial Water Use	555 Lpcd (Litres per capita per day)
Future Residential and Industrial Water Use	600 Lpcd (Litres per capita per day)
Existing Residential Water Use	322 Lpcd (Litres per capita per day)
Existing Industrial Water Use	233 Lpcd (Litres per capita per day)
Future Residential Water Use	348 Lpcd (Litres per capita per day)
Future Industrial Water Use	252 Lpcd (Litres per capita per day)

The maximum day and peak hour factors used for the WSMPU are 1.47 and 2.28 respectively, as provided by the WUC. These factors are reduced from the 2009 criteria of 1.7 for maximum day and 2.4 for peak hour. Figure 3.2 illustrates the reduction in maximum day demand when the factor of 1.47 is applied to the revised growth projections.

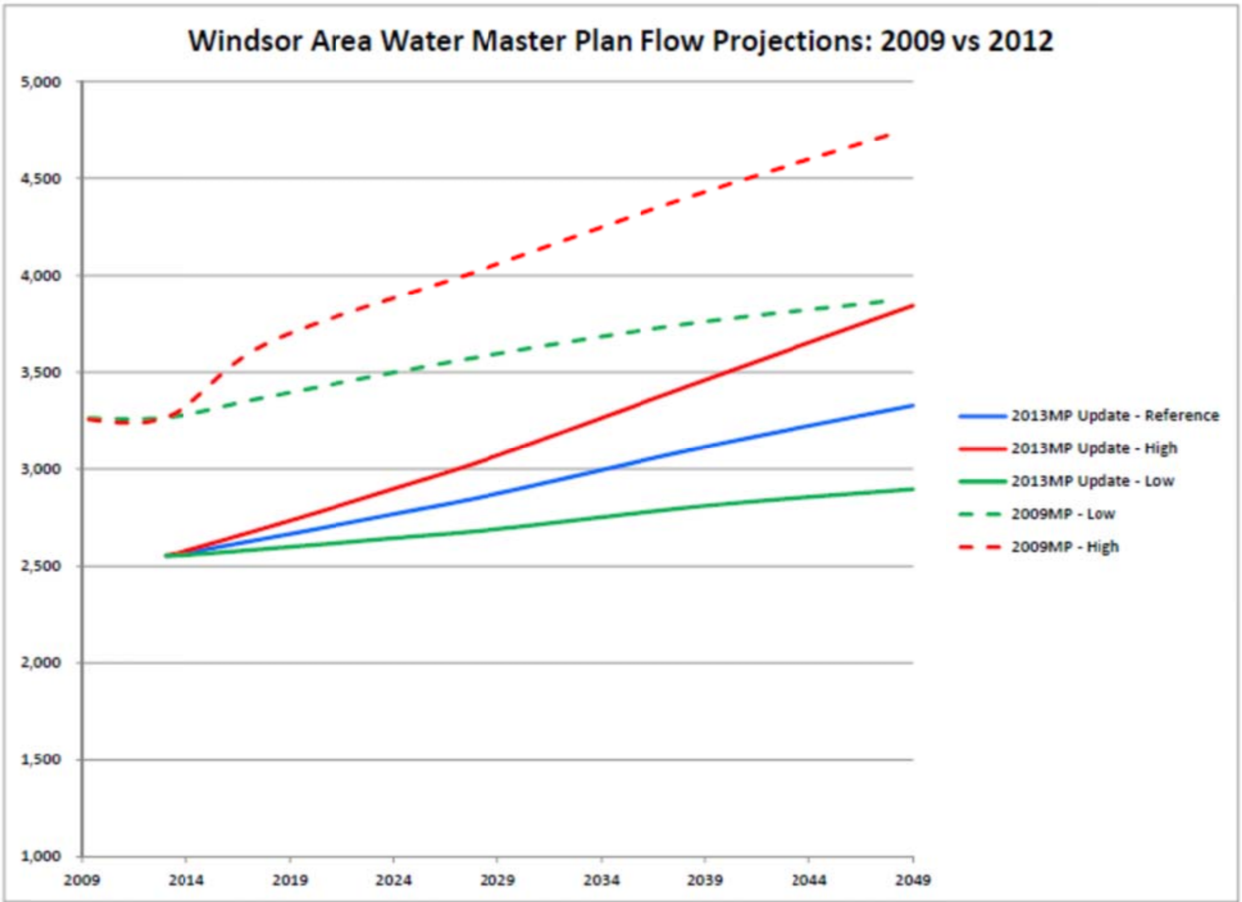

Figure 3 2: Windsor Area Flow Projections

Figures 3.3, 3.4 and 3.5, below, summarize the projected water demands for the City of Windsor, Town of LaSalle and Town of Tecumseh under the ‘Reference’, ‘Low’ and ‘High’ population projections, respectively. Tabled representations of these figures are provided in Appendix A.

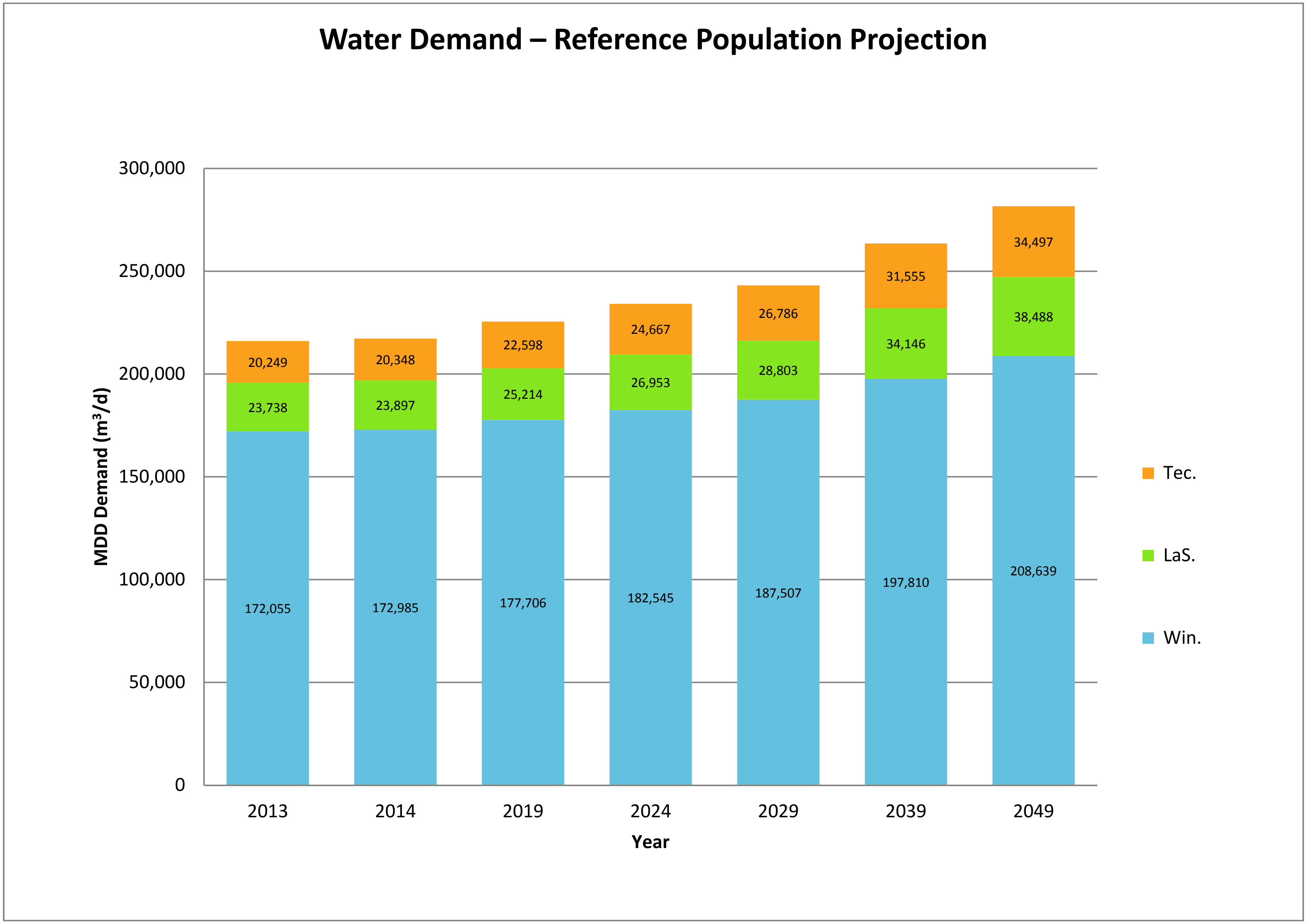

Figure 3.3: Water Demand Projections – Reference Population Projection

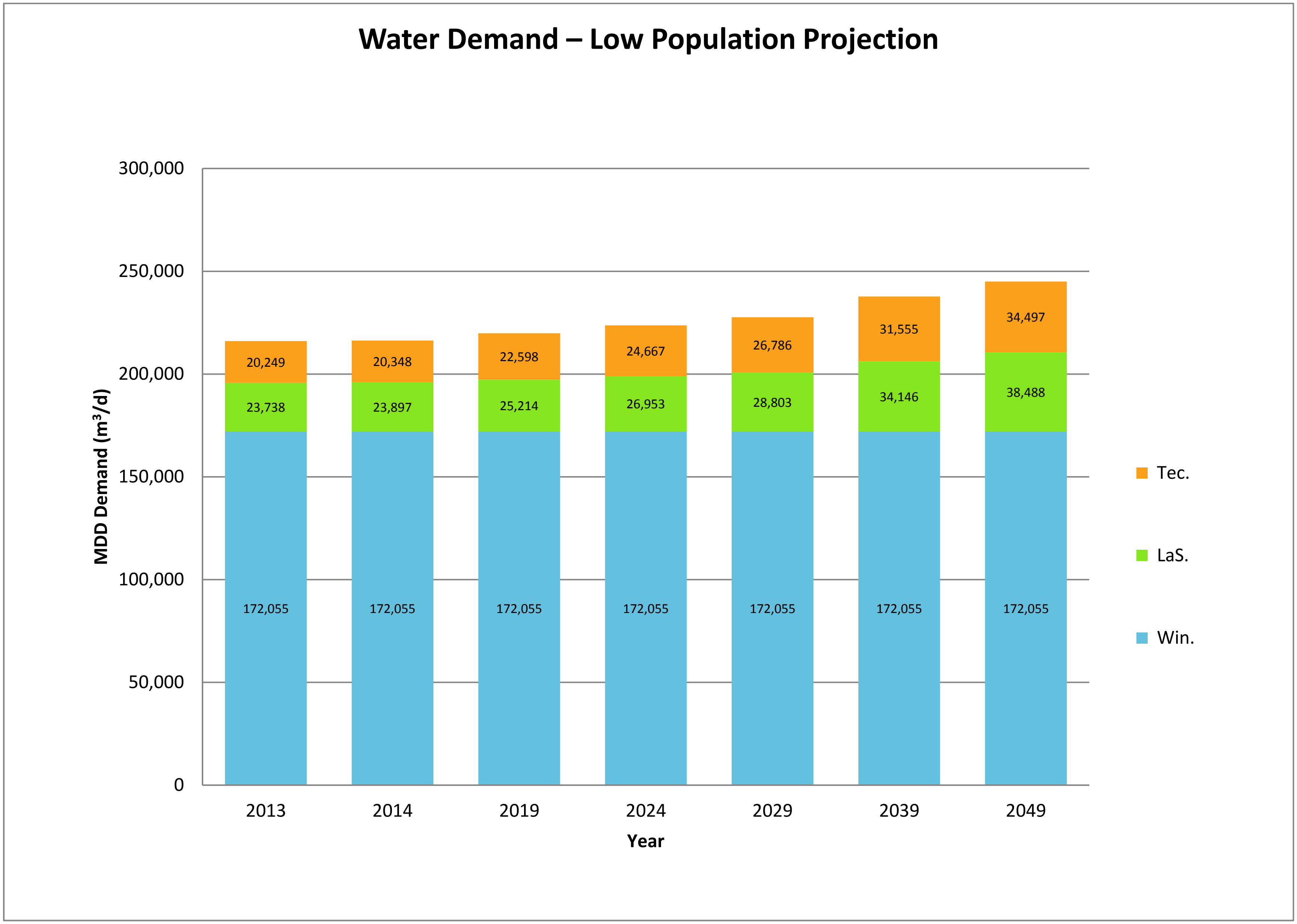

Figure 3.4: Water Demand Projections – Low Population Projection

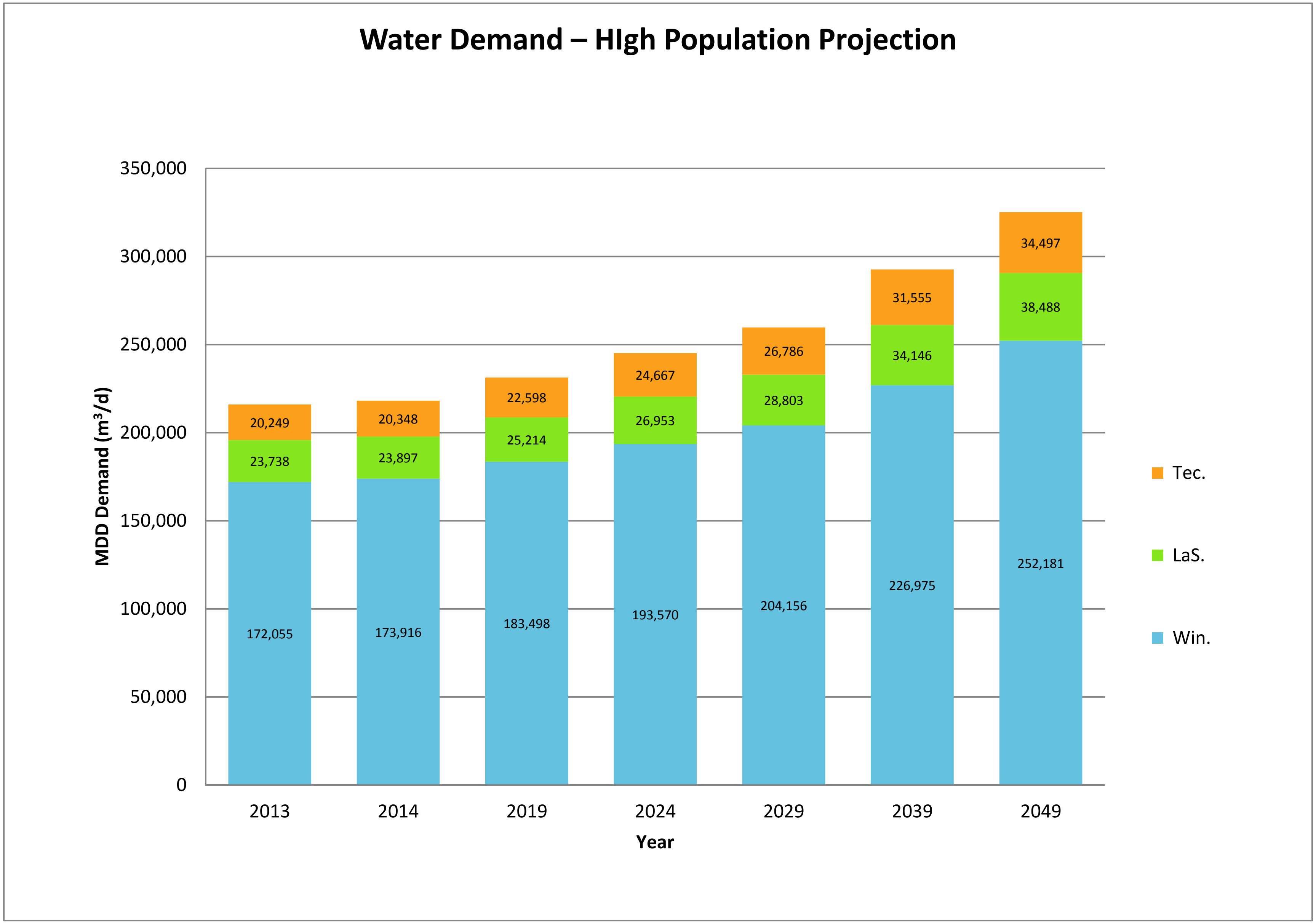

Figure 3.5: Water Demand Projections – High Population Projection

3.3 Future Treated Water Storage Requirements

Building upon the Table 2.1, Storage Requirements Comparison, treated water storage requirements for the WUC water system were determined to 2049 for several different design criteria as shown in Table 3.2. Storage calculations were based on the water demand projections identified in Figure 3.5, (High Population Projection).

Table 3.2: Future Treated Water Storage Requirements

Standard[1]	***Additional Storage Requirements (2013)***	***Additional Storage Requirements (2049)***
MOE Guidelines	(43.8)	(9.7)
City of Toronto Design Standards	49.1	130.8
Region of Peel Design Standards	(43.1)	(6.2)
10 States Standards with MOE Fire Flow	34.2	110.6
10 States Standards with 2 Industrial Fire	30.9	106.9
10 States Standards with 1 Industrial Fire and 1 Residential Fire	28.8	104.3
One Average Day Demand	25.5	99.7
In-Plant Use Storage Projection Included in Totals Above	*9.6*	13.2

[1] All standards include plant use storage requirements, as identified in the Banwell EA Report (Stantec, 2007).

As identified in Table 3.2 above, the existing WUC water system treated water storage capacity is marginally insufficient to accommodate future growth to 2049.

A new reservoir was identified in the 2009 WSMP to meet the 40 year storage requirements. The reservoir was proposed to be constructed prior to the system need in order to accommodate the storage deficit created during rehabilitation of Reservoir D. Although updated storage calculations show the need for a new reservoir beyond the 35 year forecast, Reservoir D must still be taken offline for rehabilitation in the very near future.

Figure 3.6, below, illustrates treated water storage requirements for the WUC service area projected to 2049 for the various design guidelines. One plot in Figure 3.6 (light pink) depicts the total storage projection with consideration for the addition of a 35 ML reservoir prior to the rehabilitation of Reservoir D.

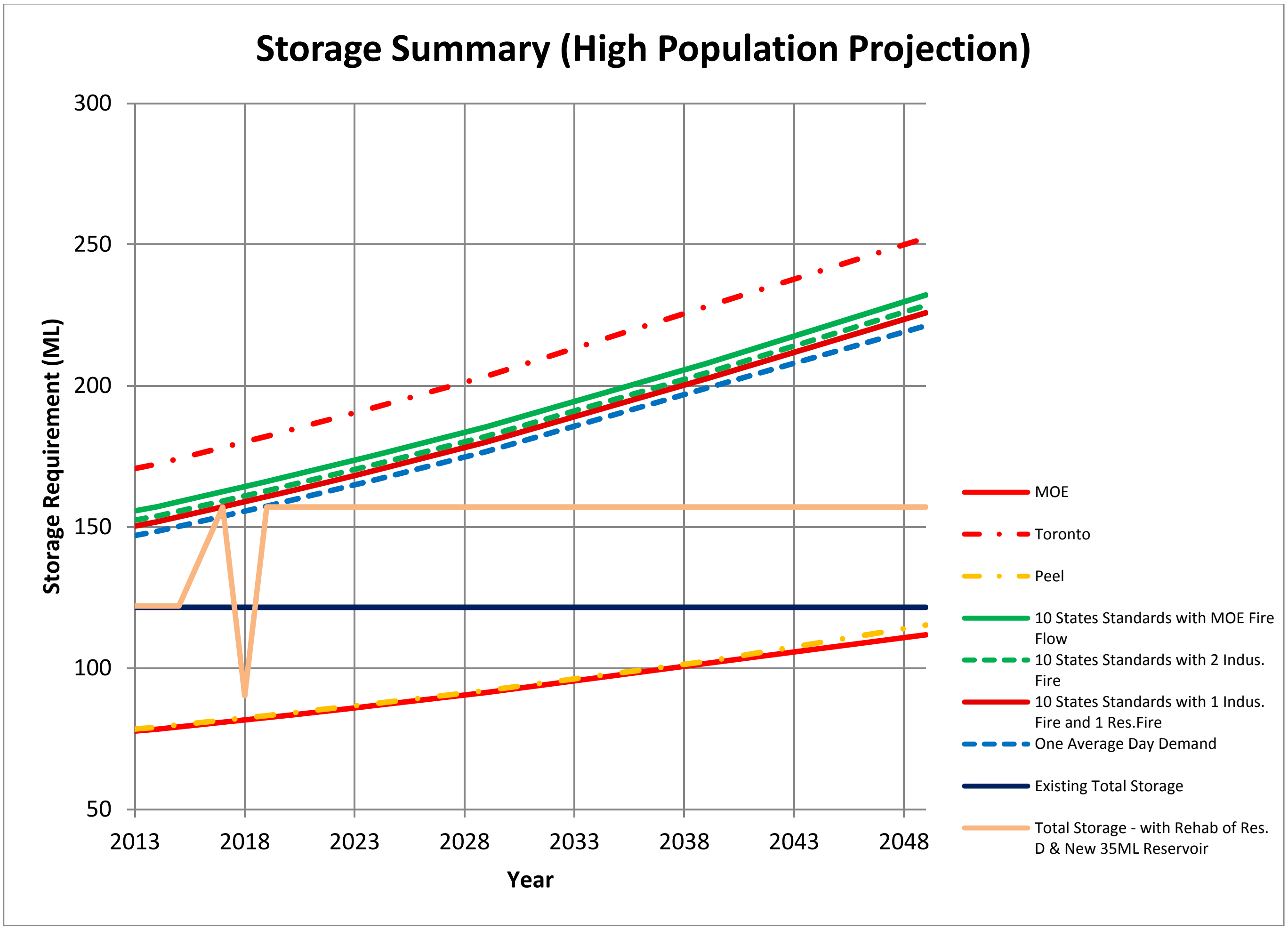

Figure 3.6: Storage Summary

4. City Water System Modeling

To determine future water system needs, the WUC's InfoWater Model was utilized. The all pipe (Windsor system only) InfoWater model validation was completed in 2011. This model was revised with the new growth projections for the WSMPU.

4.1 Model Review

The WUC's historic water system model was developed in WaterCAD version 7.0. This model was a skeletonized version including transmission mains greater than 300 mm in diameter, with some local watermains less than 300 mm. Based on the recommendations of the 2009 Master Plan, this model was migrated to InfoWater and now includes detailed local networks.

The WUC's existing InfoWater hydraulic model developed in 2011 was used for water system modelling purposes. For the 2014 WSMPU, new pipes were added, abandoned pipes removed from the active network and year of installation, material type and C-Factors for all pipes were updated.

4.2 Demand Analysis

For this study, the modelling demand inputs were adjusted to reflect the current population and design criteria determined. Water demands for future growth areas were assigned to the model based on the allocation information provided projected population and water consumption design criteria. The difference in water demands for growth areas and the overall increase in system water demand was assumed to be future intensification growth for the existing City (in-fill). The demand was uniformly assigned to the modelling junctions representing existing conditions as a result, with the exception of specific development areas previously identified in the model which only include future demands.

To accurately simulate hydraulics within the water system and improve the evaluation of hydraulic impacts of future demands or water infrastructure needs, distinct consumption characteristic curves (diurnal patterns), for each land use type were assigned to the hydraulic model. Although these diurnal patterns were theoretical consumption behaviours in a water system, the accuracy of these individual patterns was proven to be representative for the purposes of this study by comparing the observed composite patterns that were determined in the calibration process, and the calculated composite patterns that resulted from the future modelling scenarios.

4.3 Future Growth Scenarios/Modeling

The hydraulic model was utilized to assess system performance under the ‘High’, ‘Reference’ and ‘Low’ future growth scenarios for each design year and identify all necessary improvement works while maximizing the utilization of existing infrastructure. The design years assessed included 2013 (existing), 2014, 2019, 2024, 2029, 2039 and 2049. The hydraulic model was set up for the following conditions under these design years for the ‘High’, ‘Reference’ and ‘Low’ future growth scenarios.

- Maximum Day Demand Conditions (Extended Period Simulation)
- Maximum Day Demand Conditions plus Fire Flow

The hydraulic analysis included the following evaluation of each scenario operation:

- Each simulation was assessed to ensure maximum and minimum pressure criteria were maintained;
- Existing and proposed mains were assessed to ensure maximum headloss gradient and velocities were within design criteria;
- Storage balancing and filling was assessed to ensure adequate operation;
- Pump operation was assessed to ensure pumps operated within a reasonable range of flow and Total Dynamic Head (TDH).

Based on the model results, new mains were added to either upsize (or twin) existing watermains, to provide looping, to add or upgrade facilities, or to service new growth areas. Water system upgrades with Tecumseh and LaSalle were included according to their respective approved Master Plans. System analysis was completed for each of the above scenarios as follows.

- An analysis was initially completed for the year 2049 water demands. Required works were then identified to satisfy design constraints, and for input to the model; and
- Assessed works were then staged for the period up to 2039 by assessing the scenarios in the order identified above and defining the timing of each required work item.

The evaluation of alternate operation strategies (e.g. pump operation) was also completed as part of the modelling analysis to determine the most efficient and cost-effective operating strategy to maintain sustainability of the WUC water system. The first principle in evaluating the best operating strategy was to maximize the use of existing infrastructure. The following operational strategy options were evaluated as part of the master plan study.

- Relocation of existing Hanna elevated tank.
- Evaluation of alternate storage replenishing schedules.
- Implementation of dedicated feedermain to Cook Pump Station (CCFM)
- Reservoir D Storage Requirements

5. System Assessment/Evaluation

The WSMPU objective is to meet the system deficiencies and optimization measures put forward in the 2009 recommended servicing strategy.

5.1 Existing Condition/Deficiencies

While the topography of the WUC water system service area (City of Windsor, Town of LaSalle, and Town of Tecumseh) permits the water distribution system to be operated as a single pressure zone, there is an upward elevation gradient from the WTP to the outer limits of the serviced area south of the City. This gradient, combined with the source of treated water supply being located approximately 17 km from the farthest part of the service boundary, requires that the collective headlosses in the distribution network be minimized while protecting water quality, in order to maintain sufficient pressure to all end users. Table 5.1 summarizes the existing and potential challenges in operating the existing water system and the mitigation measures recommended to overcome these challenges.

Table 5.1: Existing Distribution System Operating Challenges and Mitigation Measures

Operational Challenge	*Short Term Mitigation Measure*	*Disadvantage of the Mitigation Measure*	*Long Term Solution*
➢ Replenishing Cook Reservoir – the system pressure for the areas near Cook Reservoir would significantly reduce.	➢ Avoid filling Cook Reservoir during day time; only filling the reservoir from midnight to 4:00am to minimize the low pressure impact to the water consumers.	➢ Pumping from Cook Pumping Station is limited in order to maintain balanced reservoir levels ➢ Cook Reservoir & Pumping Station is not fully utilized.	➢ Increase pumping from A.J. Brian / George pumping station when filling Cook Reservoir ➢ Increase transmission main capacity by implementing additional watermains from A.J. Brian/George pumping station to Cook Reservoir
➢ Potential overflow of Hanna Tower – could occur when pumping is increased at A.J. Brian and George pumping station for increasing the system pressure at the southern part of the system.	➢ Throttle the inlet/outlet valve to control in/out flow	➢ Energy inefficient ➢ Reduce the function for moderating the system pressure	➢ Relocate Hanna Tower
➢ Replenishing Tecumseh Tower – When water demand increased in the Town of Tecumseh, the collective headloss of the existing feedermain could increase the difficulty in maintaining the balance of the tank level	➢ Increase pumping from A.J. Brian / George pumping station and throttle the inlet valve to prevent overflowing at Hanna Tower	➢ Energy inefficient ➢ Potential over-pressuring the areas near A.J. Brian / George pumping station	➢ Increase transmission main capacity by implementing additional watermains from A.J. Brian/George pumping station to Tecumseh Tower

The long term solution is identified in the capital investment plan. The Cook Reservoir transmission main capacity is an immediate need. WUC has retained AECOM to complete the Class EA to increase the capacity from A.J. Brian/George pumping station to the Cook Reservoir.

The Hanna tower relocation is required in 2049 for the 'High' population projection only. The Tecumseh Tower transmission main is recommended in segments starting with the section from AJ Brian PS to Franklin St. as an immediate need and the remaining length by 2049.

5.2 Optimization

In general, the following approach, established in the 2009 WSMP, was used as a basis of the evaluation to accurately identify improvement requirements and optimize the necessary capital investments.

- Improve operational flexibility – Operational control for all storage facilities was rationalized to improve the utilization of facilities. Controls for filling and draining the storage facilities must avoid causing any negative impacts to the system;
- Maintain basic serviceability – The hydraulic system assessment must comply with the WUC water system design criteria while satisfying the projected demands for each design year;
- Minimize risk and maximize supply sustainability – Fire flow analysis results must comply with the WUC water system design criteria;
- Maximize use of existing infrastructure – The future water supply scheme is similar to those currently applied to maximize the use of the existing infrastructure. Pumping from A.J. Brian / George pumping station was maximized in order to force the water supply to the system and improvement works were identified when the increase in pumping could no longer improve pressures in the system;
- Constructability – each storage location option was evaluated based on its constructability as well as hydraulic considerations. Watermain upgrades were identified based on the availability of road allowances and service interruption to residents during construction; and
- We embraced the concept of an integrated water system (the WUC water system). The hydraulic assessments were conducted based on one integrated water system for the City of Windsor, the Town of LaSalle and the Town of Tecumseh. Municipal boundaries were considered as part of the hydraulic assessments for identifying future infrastructure requirements.

5.2.1 Preliminary Cost Estimates

Preliminary cost estimates for each of the recommended capital projects were prepared based on recently tendered projects of similar nature and capacity across Ontario, and for the City of Windsor. Facility infrastructure estimates were based on recent tendered information and industry standards and are in 2013 dollars. Unit watermain installation costs were developed on a pipe size basis inclusive of watermain material, and installation costs; typical watermain components (valves, connections to existing watermains, hydrants, new water service connections, but not the services themselves, etc.); trench backfill, topsoil, sod; and road restoration costs on the basis of removing or replacing half a roadway and one side of curb & gutter and sidewalk. For the purposes of this study, watermain unit replacement costs were based on 2013 dollars and include engineering fees at 10% and contingency allowances at 15% for unforeseen or missing items. Table 5.2, below summarizes the unit costs used for estimating watermain infrastructure works for comparative purposes.

Table 5.2: Unit Costs for Watermain Replacements

Diameter	***Unit Cost***
400	$1,371
450	$1,411
500	$1,471
600	$1,666
750	$2,026
900	$2,176
1050	$2,476
1200	$2,806
1350	$3,136
1600	$3,536

Notes:

(1) Includes: Watermain, new valves, connection to existing, hydrants, new water services, trench, backfill, topsoil/sod, road restoration (1/2 road, curb and gutter. s/w on one side), Engineering Fees (10%) and Contingency Allowances (15%)

(2) 2013 Dollars

(3) 400-450mm dia. based on PVC pipe material, greater than 450mm dia. based on CPP pipe material

6. Future Work Requirements

The following sections further detail the infrastructure works required for existing deficiency rectification and to accommodate future growth to 2049.

6.1 Pipe Related Works

The pipe related waterworks required to service population and employment growth to 2049 were determined based on the water system demands and modeling outputs outlined herein. Although future system requirements were the focus of this work, any existing water system works required to service growth, or failing to meet the criteria summarized in Section 3, were also identified.

Table 6.1 identifies the infrastructure requirements as the serviced population and water system demand grow to 2049. It includes:

- Watermain location (Component ID, street and from/to), and applicable details (diameter [mm]; length [m]), for each watermain;
- Project implementation requirements in 5 year increments;
- Estimated cost information (incl. pipe, construction, road restoration, engineering, contingency).

Table 6.1: Recommended Servicing Strategy Infrastructure Works to 2049

Year	*Project*	*Replacement/Upgrade Details*	*Servicing*	*Size*	*Units*	*Length (m)*	Cost
2016	*PS2a*	*Cook Pump Upgrade*	*W/T/L*	*1*	*pump*		$ 600,000
2016	*S1*	*New Reservoir*	*W/T/L*	*35*	*ML*		$ 30,000,000
2017	*S2*	*Refurbishment of Reservoir D*	*W/T/L*				$ 3,500,000
2018	*WM1a*	*AJ Brian WTP to Cook PS Feedermain**	*W/T/L*	*1200*	*mm*	*8818*	$ 24,743,000
2019	*WM2a*	*George Ave. from AJ Brian to Franklin St.*	*W/T*	*1200*	*mm*	*404*	$ 1,134,000
2029	*WM5*	*County Rd 42 Sub Trunk*	*W/T*	*600*	*mm*	*1719*	$ 2,864,000
	WM5	*County Rd 42 Sub Trunk*	*W/T*	*900*	*mm*	*3005*	$ 6,539,000
2029	*S3*	*Old Treatment Plant Refurbishment*	*W/T/L*	*81*	*MLD*		$ 60,000,000
2032	*WM1b*	*Cook PS to system**	*W/T/L*	*900*	*mm*	*2810*	$ 6,115,000
2039	*WM2b*	*Franklin St. from Central Ave. to Francois Rd.*	*W/T*	*750*	*mm*	*817*	$ 1,655,000
2049	*WM2c*	*George Ave. from Francois Rd. to Tecumseh Rd. E and Forest Glade Dr.*	*W/T*	*750*	*mm*	*1483*	$ 3,005,000
2049	*WM2c*	*George Ave. from Francois Rd. to Tecumseh Rd. E and Forest Glade Dr.*	*W/T*	*900*	*mm*	*3978*	$ 8,656,000
2049 (high)	*S4*	*Oldcastle Elevated Tank (Hanna Relocation)*	*W/T*	*5.7*	*ML*		$ 6,500,000
						Total	**$155,311,000**

* - subject to actual growth.

The required works are shown by Figure 6.1.

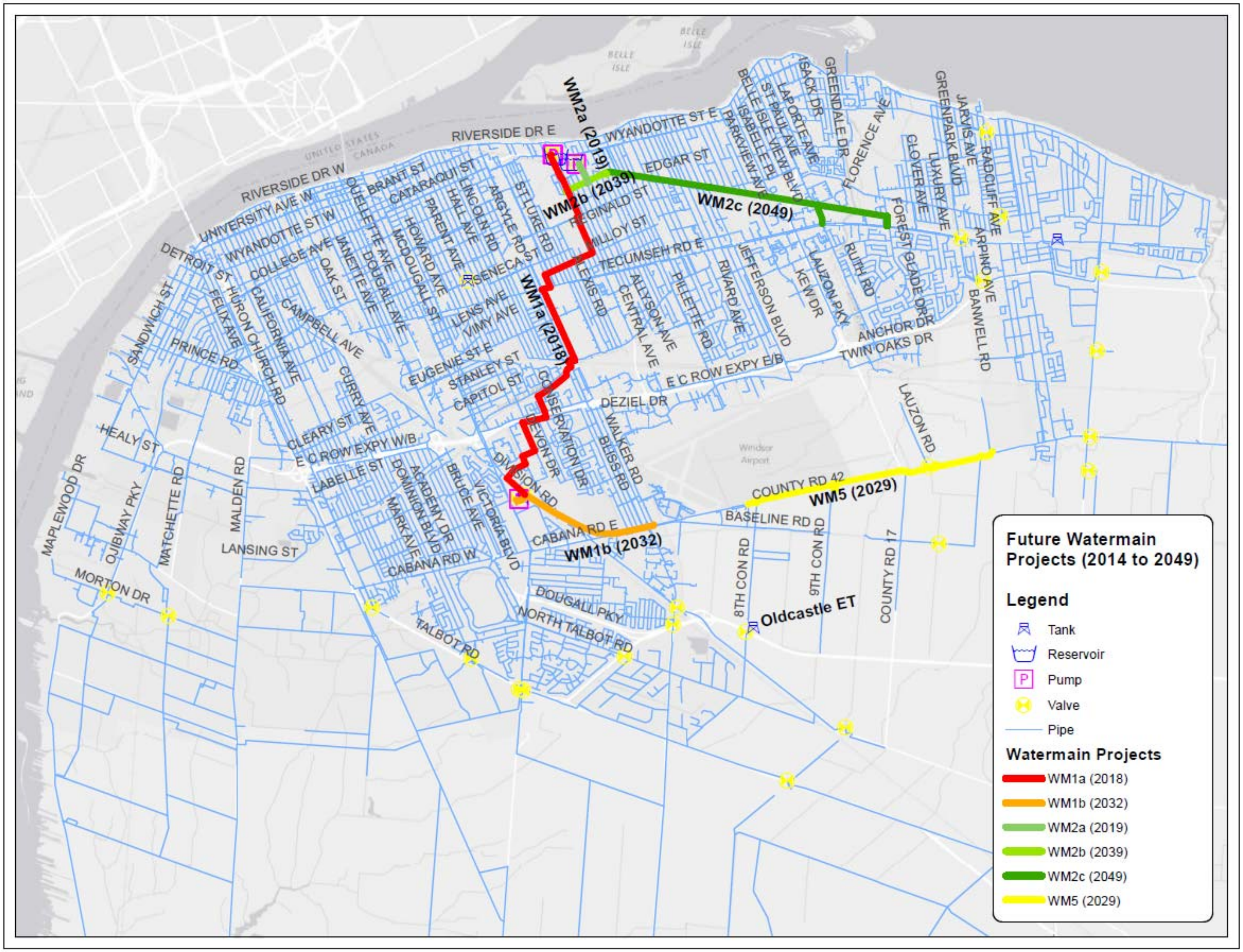

Figure 6.1: Infrastructure Works to 2049

6.1.1 Existing System Reinforcements

The preferred servicing strategy is based on the premise of storing and pumping water from the central A.J. Brian and George Street Pumping Station facilities to the south and east. Initially, WUC's primary feed identified as Watermain No. 1 requires immediate upsizing (Class EA underway), to provide supply to the Cook Pumping Station and Reservoir to address pressure problems in southwest Windsor, and service the Town of LaSalle in the future. Watermain No. 1 also provides a main feed to the southeast portion of Windsor, and the southern portions of Tecumseh. Watermain upsizing to 1200 and 1350 mm diameter respectively is required (or twinning in conjunction with the existing transmission watermain subject to condition and remaining life span), to provide the equivalent capacity of the 1200 and 1350 mm diameter pipe sizes called for.

The 2009 WSMP routing was shown along Walker Road from the heavily built-up area east of the City's core to County Road 42. The Schedule B, Class EA evaluates the potential routes and the preliminary recommended preferred route is shown for this WSMPU. This routing is to be confirmed with the completion of the Class EA.

6.1.2 Southeast Windsor

To provide servicing to southeast Windsor and the southern portions of Tecumseh, upsizing of Watermain No. 5 on County Road 42 to 900 mm in diameter, (or twinning to provide the equivalent capability subject to existing pipe condition and remaining life span), is required. Routing has been tentatively positioned along County Road 42 within the road right-of-way which for the most part should be fairly open for implementation.

6.1.3 Tecumseh

Watermain Nos. 1, 2 and 5 are identified to provide servicing to Tecumseh. No further watermain expansions are required to meet future growth needs and satisfy the terms of the Service Agreement between the City of Windsor and the Town of Tecumseh.

6.1.4 Southwest Windsor

Servicing for southwest Windsor can be provided by the existing water distribution system based on future growth needs for infill/intensification purposes. Although some minor works may be identified through area or site-specific applications via model outputs, no major water transmission main or storage works are required as per the work completed as part of this Master Plan.

6.1.5 LaSalle

To provide water servicing to LaSalle to meet future growth needs, Watermain No. 1 is required within the City of Windsor to provide servicing to the Windsor/LaSalle boundary. This will involve watermain upsizing or twinning to provide the equivalent 900 mm diameter capacity subject to existing watermain condition and lifespan. Routing would be southward along Provincial Road from the J.F. Cook Reservoir and Pumping Station to Walker Road.

6.2 Facility Related Works

In addition to the watermain related works outlined, facility related works are also required for the WUC water system for servicing to 2049. Table 6.1, as presented for the watermain works, also identifies the facility related works required for the WUC water system to 2049. Identified is the facility by name; approximate implementation year as per our work and modelling outputs; new/expansion capacity information; and estimated costs.

6.2.1 Albert H. Weeks WTP and Old WTP

The existing Albert H. Weeks WTP and the Old WTP have a total combined capacity of 349 MLD; of which 268 MLD is provided by the Albert H. Weeks WTP and 81 MLD is provided by the Old WTP. Comparing the population growth and demand projections, as provided in Section 3, to the existing total capacity of the treatment plants, they have sufficient capacity to accommodate growth and demand projections to 2049.

A condition assessment of the Albert H. Weeks and Old WTPs conducted as part of the 2007 Water Rate Study identified significant upgrade requirements for the Old WTP including, by not limited to; filter upgrades, an alternate intake to address suction head concerns, roof repairs and pump replacements. The total estimated capital works required for the Old WTP was over $60 M within the next twenty years, which has been identified within the recommended infrastructure works herein. Given the condition of the Old WTP, further consideration should be given to upgrading the entire plant, or reconstructing the entire plant, to provide the additional capacity requirements. Potential reconstruction or replacement of the Old WTP requires further study to ensure that all options are considered, including consideration of a regional solution, for a strategic long term servicing solution. As identified in Table 6.1, the capital cost of the treatment plant refurbishment has been identified in 2029.

The need and provision for additional treatment capacity is growth driven.

6.2.2 Reservoir D/Additional Treated Water Storage

For reliability, security, maintenance and rehabilitation purposes, the WUC is currently considering options for splitting Reservoir D into two separate operating cells. While the separation of Reservoir D will significantly increase operational flexibility and facilitate staged reservoir rehabilitation, the reservoir will need to be removed from service to permit the construction of a separation wall. During the time Reservoir D is out of service, there will be a storage deficit that will need to be accommodated through plant optimization, water restrictions and the construction of additional storage prior to construction. Table 6.2 confirms the storage deficit that would be realized upon removal of Reservoir D from the WUC water system.

Table 6.2: Storage Deficit Evaluation

Storage Evaluation		***2013***
Existing Conditions (2013)		
MOE Equalization Storage Requirement (ML):		54.0
MOE Fire Storage Requirement (ML):	+	8.2
MOE Emergency Storage Requirement (ML):	+	15.6
Plant Operating Storage Requirement (ML):	+	9.6
Existing Available Storage (ML):	-	121.5
Storage Deficit (ML):	=	(34.1)
Remove Reservoir D for Maintenance (2013)		
MOE Equalization Storage Requirement (ML):		54.0
MOE Fire Storage Requirement (ML):	+	8.2
MOE Emergency Storage Requirement (ML):	+	15.6
Plant Operating Storage Requirement (ML):	+	9.6
Existing Available Storage (ML):	-	54.7
Storage Deficit (ML):	=	32.7

The 2009 recommended servicing strategy identified the construction of a 45 ML reservoir adjacent to the WTP site. The primary purpose of increasing the reservoir to 45 ML was to reduce the storage deficit during rehabilitation of Reservoir D and provide sufficient storage for future demands. The WSMPU illustrates that significant additional storage is not required following rehabilitation of Reservoir D and; therefore, the new reservoir could be reduced to 35 ML.

The construction of a new reservoir will require systematic scheduling and construction of yard piping and connections to both the existing systems and George Avenue PS. The new reservoir will need to be operated at a similar hydraulic grade line to Reservoir D in order to permit turnover of water through the reservoir.

6.2.3 A.J. Brian and George Street High Lift Pumping Stations

The A.J. Brian and George Street High Lift Pumping Stations currently supply all of the treated water to the distribution system. The A.J. Brian PS primarily services areas to the west, including the J.F. Cook Reservoir and Hanna Street Water Tower, and the George Street PS primarily services areas to the east, including the Town of Tecumseh.

System modelling under the growth and demand projections identified herein concluded that these pumping stations currently have sufficient capacity to accommodate the pumping requirements needed to 2049.

6.2.4 J.F. Cook Reservoir and Pumping Station

The J.F. Cook Reservoir and Pumping Station currently provides peak and emergency demand servicing to the south and southwest boundaries of the WUC service area and to LaSalle. While additional linear infrastructure is required to ensure sufficient supply and pressure to these outer limits of the service area and LaSalle in the future, as discussed in Section 6.2, an additional pump, or pump replacement/upgrade of the J.F. Cook Pumping Station is required to accommodate demands to 2049.

6.2.5 Hanna Street Elevated Tank

The Hanna Street Elevated Tank is currently used for control of the high lift pumping at the WTP. As discussed in Section 5.1, the operating range of the Hanna Street tank is relatively limited due to its proximity to the plant. While system modelling indicates that the existing operating strategy is sufficient to meet the reference population projections up to 2049, the operating range will continue to decrease as the requirement pumping rates of the A.J. Brian and George Avenue pumping stations increase in the future. This will not only further complicate system operation which could result in overflowing of the tower, but the water quality in the tower could be compromised as regular cycling of the water will not be accomplished. Hanna Street relocation is identified in the ‘High’ population projection in 2049.

Although not identified as an infrastructure requirement to 2049, the WUC should consider decommissioning and/or relocation of the Hanna Street Elevated Tank as operating requirements and/or water quality concerns deem necessary.

6.2.6 Oldcastle Elevated Tank

The Oldcastle Water Elevated Tank was proposed in the 2009 Master Plan to ensure sufficient pressure and fire storage for areas in southeast Windsor. Updated modelling completed for this work suggests that the proposed linear infrastructure will provide sufficient pressure and demand to these areas to 2049 without the need for the Oldcastle Tower. However, from a system operation perspective, elevated storage near the outer boundaries of a water system promotes system cycling which enhances distribution system water quality. While the Oldcastle Tower is not necessary to ensure system demands and pressure, further consideration should be given to its implementation as a means to decommission the Hanna Street elevated tank.

To relocate the Hanna Elevated Tank, the elevation of a new elevated tank must be below 190m in order to maintain the height of the tank at the most cost effective construable height of 35m and provide an identical top Water Level to the existing Tecumseh Elevated Tank (225m). Based on the elevation of the modeling junctions, the most suitable location for a new Elevated Tank would be around the existing Oldcastle Hamlet area.

6.3 Prioritization

Table 6.3 identifies anticipated timing for each of the infrastructure requirements identified as part of the preferred servicing strategy. Prioritization was forecasted based on the results of separate modelling for 5 and 10 year demand projections as described in Section 3. Prioritization was determined based on the year for which additional capacity was first required through the numerous model runs. The infrastructure was then sized to provide sufficient capacity to 2049.

Table 6.3: Infrastructure Prioritization to 2049

ID	Descriptions	2016	2017	2018	2019	2029	2032	2039	2049	2049-High
PS2a	*Cook Pump Upgrade*	$600,000								
S1	*New Reservoir*	$30,000,000								
S2	*Refurbishment of Reservoir D*		$3,500,000							
WM1a	*AJ Brian WTP to Cook PS Feedermain**			$24,743,000						
WM2a	*George Ave. from AJ Brian to Franklin St.*				$1,134,000					
WM5	*County Rd 42 Sub Trunk*					$2,684,000				
WM5	*County Rd 42 Sub Trunk*					$6,539,000				
S3	*Old Treatment Plant Refurbishment*					$60,000,000				
WM1b	*Cook PS to system**						$6,115,000			
WM2b	*Franklin St. from Central Ave. to Francois Rd.*							$1,655,000		
WM2c	*George Ave. from Francois Rd. to Tecumseh Rd. E and Forest Glade Dr.*								$3,005,000	
WM2c	*George Ave. from Francois Rd. to Tecumseh Rd. E and Forest Glade Dr.*								$8,656,000	
S4	*Oldcastle Elevated Tank*									$6,500,000
						$155,311,000				

* - subject to growth

7. Conclusions and Recommendations

The following key conclusions and related recommendations have been made as a result of the work completed for the Water System Master Plan Update.

- The works shown by Table 6.2 be considered for implementation in the timeframes identified. The budget amounts identified in 2013 dollars should be inflated accordingly on an annual basis.
- Although the current storage capacity of the Windsor Water System is within MOE guidelines, this only represents less than one average day of storage. Following the required upgrades of Reservoir D, the addition of a new 35 ML reservoir will provide just less approximately one average day of storage based on High demand projections.
- An opportunity to combine the current function of the Hanna Water elevated tank and part of a future Oldcastle elevated tank in Tecumseh be looked at to see if one facility could service the needs of both in the future.
- Construction of a new 35 ML reservoir to facilitate rehabilitation of Reservoir D and provide additional storage given that the system has less than one average day demand.
- Fire storage requirements for Tecumseh be incorporated as part of the above storage requirements with cost sharing confirmed for this component as per the current Water Servicing agreements in place.
- The WUC consider a full system-wide model implementation for all watermains and facilities comprising the water system including adding the LaSalle and Tecumseh water systems, and any further afield, as part of a regional water model for the area. If to function on an operational level, extensive calibration and field programs would have to be implemented complete with inventory updating and WUC operation training and staffing to maintain. This was completed in part through completion of the all-pipe model as part of the WSMPU. Calibration for the purposes of an operational level model could be considered in the future.

Appendix A:
Tables for Reference, Low and High Demand Projections

Water Demand Projections – Reference Population Projection

Year	Win.	LaS.	Tec.	Total	Win.	LaS.	Tec.	Total	Win.	LaS.	Tec.	Total
	ADD[1] (m^3/d) - Residential				ADD[1] (m^3/d) - ICI[2]				ADD[1] (m^3/d) - Total			
2013	55,011	7,590	6,474	**69,075**	62,034	8,559	7,301	**77,893**	117,045	16,148	13,775	**146,968**
2014	55,308	7,640	6,506	**69,454**	62,369	8,616	7,336	**78,321**	117,677	16,256	13,842	**147,775**
2019	56,817	8,061	7,225	**72,104**	64,071	9,091	8,148	**81,309**	120,888	17,152	15,373	**153,413**
2024	58,365	8,618	7,887	**74,869**	65,816	9,718	8,894	**84,427**	124,180	18,335	16,781	**159,296**
2029	59,951	9,209	8,564	**77,725**	67,605	10,385	9,658	**87,647**	127,556	19,594	18,222	**165,372**
2039	63,245	10,917	10,089	**84,252**	71,319	12,311	11,377	**95,007**	134,565	23,228	21,466	**179,259**
2049	66,708	12,306	11,030	**90,043**	75,224	13,876	12,438	**101,538**	141,931	26,182	23,468	**191,581**
Year	**MDD[1] (m^3/d) – Residential**				**MDD[1] (m^3/d) - ICI[2]**				**MDD[1] (m^3/d) – Total**			
2013	80,866	11,157	9,517	**101,540**	91,189	12,581	10,732	**114,502**	172,055	23,738	20,249	**216,042**
2014	81,303	11,231	9,564	**102,098**	91,682	12,665	10,785	**115,132**	172,985	23,897	20,348	**217,230**
2019	83,522	11,850	10,621	**105,993**	94,184	13,363	11,977	**119,524**	177,706	25,214	22,598	**225,518**
2024	85,796	12,668	11,594	**110,058**	96,749	14,285	13,074	**124,108**	182,545	26,953	24,667	**234,165**
2029	88,128	13,538	12,589	**114,255**	99,379	15,266	14,197	**128,842**	187,507	28,803	26,786	**243,096**
2039	92,971	16,048	14,831	**123,850**	104,839	18,097	16,724	**139,660**	197,810	34,146	31,555	**263,511**
2049	98,060	18,089	16,214	**132,363**	110,579	20,398	18,284	**149,261**	208,639	38,488	34,497	**281,624**
Year	**Peak[4] (m^3/d) – Residential**				**Peak (m^3/d) - ICI[2]**				**Peak (m^3/d) – Total**			
2013	125,425	17,305	14,761	**157,491**	141,437	19,514	16,646	**177,596**	266,861	36,818	31,407	**335,087**
2014	126,103	17,420	14,833	**158,356**	142,201	19,644	16,727	**178,572**	268,303	37,064	31,560	**336,928**
2019	129,544	18,380	16,474	**164,397**	146,081	20,727	18,577	**185,384**	275,625	39,107	35,050	**349,782**
2024	133,072	19,648	17,982	**170,702**	150,059	22,156	20,278	**192,493**	283,131	41,804	38,260	**363,195**
2029	136,689	20,997	19,526	**177,212**	154,139	23,677	22,019	**199,835**	290,827	44,674	41,546	**377,047**
2039	144,199	24,891	23,003	**192,094**	162,608	28,069	25,939	**216,616**	306,807	52,960	48,942	**408,710**
2049	152,094	28,057	25,148	**205,298**	171,510	31,638	28,358	**231,506**	323,603	59,695	53,506	**436,804**

Water Demand Projections – Low Population Projection

Year	Win.	LaS.	Tec.	Total	Win.	LaS.	Tec.	Total	Win.	LaS.	Tec.	Total
	ADD[1] (m^3/d) - Residential				ADD[1] (m^3/d) - ICI[2]				ADD[1] (m^3/d) - Total			
2013	55,011	7,590	6,474	**69,075**	62,034	8,558	7,301	**77,893**	117,045	16,148	13,775	**146,968**
2014	55,011	7,640	6,506	**69,157**	62,034	8,616	7,336	**77,986**	117,045	16,256	13,842	**147,143**
2019	55,011	8,061	7,225	**70,297**	62,034	9,091	8,148	**79,272**	117,045	17,152	15,373	**149,569**
2024	55,011	8,617	7,887	**71,515**	62,034	9,718	8,894	**80,645**	117,045	18,335	16,781	**152,160**
2029	55,011	9,209	8,564	**72,784**	62,034	10,385	9,658	**82,076**	117,045	19,594	18,222	**154,860**
2039	55,011	10,917	10,089	**76,017**	62,034	12,311	11,377	**85,722**	117,045	23,228	21,466	**161,739**
2049	55,011	12,306	11,030	**78,346**	62,034	13,876	12,438	**88,348**	117,045	26,182	23,468	**166,694**
Year	MDD[1] (m^3/d) – Residential				MDD[1] (m^3/d) - ICI[2]				MDD[1] (m^3/d) – Total			
2013	80,866	11,157	9,517	**101,540**	91,189	12,581	10,732	**114,503**	172,055	23,738	20,249	**216,043**
2014	80,866	11,232	9,564	**101,661**	91,189	12,665	10,784	**114,639**	172,055	23,897	20,348	**216,300**
2019	80,866	11,851	10,621	**103,337**	91,189	13,363	11,977	**116,530**	172,055	25,214	22,598	**219,867**
2024	80,866	12,668	11,593	**105,128**	91,189	14,285	13,074	**118,548**	172,055	26,953	24,667	**223,676**
2029	80,866	13,537	12,589	**106,993**	91,189	15,266	14,197	**120,652**	172,055	28,803	26,786	**227,645**
2039	80,866	16,049	14,831	**111,745**	91,189	18,097	16,724	**126,011**	172,055	34,146	31,555	**237,756**
2049	80,866	18,089	16,214	**115,169**	91,189	20,399	18,283	**129,871**	172,055	38,488	34,497	**245,040**
Year	Peak[4] (m^3/d) – Residential				Peak (m^3/d) - ICI[2]				Peak (m^3/d) – Total			
2013	125,425	17,304	14,761	**157,491**	141,436	19,514	16,646	**177,596**	266,861	36,818	31,407	**335,087**
2014	125,425	17,420	14,833	**157,678**	141,436	19,644	16,727	**177,808**	266,861	37,064	31,560	**335,486**
2019	125,425	18,380	16,474	**160,278**	141,436	20,727	18,577	**180,740**	266,861	39,107	35,050	**341,018**
2024	125,425	19,648	17,982	**163,055**	141,436	22,156	20,278	**183,870**	266,861	41,804	38,260	**346,925**
2029	125,425	20,997	19,527	**165,948**	141,436	23,677	22,019	**187,133**	266,861	44,674	41,546	**353,081**
2039	125,425	24,891	23,003	**173,319**	141,436	28,069	25,939	**195,445**	266,861	52,960	48,942	**368,764**
2049	125,425	28,057	25,148	**178,630**	141,436	31,638	28,358	**201,433**	266,861	59,695	53,506	**380,063**

Water Demand Projections – High Population Projection

Year	Win.	LaS.	Tec.	Total	Win.	LaS.	Tec.	Total	Win.	LaS.	Tec.	Total
	ADD[1] (m^3/d) - Residential				**ADD[1] (m^3/d) - ICI[2]**				**ADD[1] (m^3/d) - Total**			
2013	55,011	7,590	6,474	**69,075**	62,034	8,558	7,301	**77,893**	117,045	16,148	13,775	**146,968**
2014	55,606	7,640	6,506	**69,752**	62,704	8,616	7,336	**78,656**	118,310	16,256	13,842	**148,408**
2019	58,670	8,061	7,225	**73,956**	66,159	9,091	8,148	**83,398**	124,829	17,152	15,373	**157,354**
2024	61,890	8,617	7,887	**78,394**	69,790	9,718	8,894	**88,402**	131,680	18,335	16,781	**166,796**
2029	65,275	9,209	8,564	**83,048**	73,607	10,385	9,658	**93,649**	138,882	19,594	18,222	**176,697**
2039	72,570	10,917	10,089	**93,577**	81,835	12,311	11,377	**105,522**	154,405	23,228	21,466	**199,099**
2049	80,629	12,306	11,030	**103,964**	90,923	13,876	12,438	**117,237**	171,552	26,182	23,468	**221,201**
Year	**MDD[1] (m^3/d) – Residential**				**ADD[1] (m^3/d) - ICI[2]**				**MDD[1] (m^3/d) – Total**			
2013	80,866	11,157	9,517	**101,540**	91,189	12,581	10,732	**114,503**	172,055	23,738	20,249	**216,043**
2014	81,741	11,232	9,564	**102,535**	92,175	12,665	10,784	**115,625**	173,916	23,897	20,348	**218,160**
2019	86,244	11,851	10,621	**108,716**	97,254	13,363	11,977	**122,594**	183,498	25,214	22,598	**231,310**
2024	90,978	12,668	11,593	**115,239**	102,592	14,285	13,074	**129,951**	193,570	26,953	24,667	**245,190**
2029	95,953	13,537	12,589	**122,080**	108,203	15,266	14,197	**137,665**	204,156	28,803	26,786	**259,745**
2039	106,678	16,049	14,831	**137,557**	120,297	18,097	16,724	**155,118**	226,975	34,146	31,555	**292,675**
2049	118,525	18,089	16,214	**152,828**	133,656	20,399	18,283	**172,338**	252,181	38,488	34,497	**325,166**
Year	**Peak[4] (m^3/d) – Residential**				**Peak (m^3/d) - ICI[2]**				**Peak (m^3/d) – Total**			
2013	125,425	17,304	14,761	**157,491**	141,436	19,514	16,646	**177,596**	266,861	36,818	31,407	**335,087**
2014	126,781	17,420	14,833	**159,034**	142,966	19,644	16,727	**179,337**	269,747	37,064	31,560	**338,371**
2019	133,767	18,380	16,474	**168,620**	150,843	20,727	18,577	**190,147**	284,610	39,107	35,050	**358,767**
2024	141,109	19,648	17,982	**178,739**	159,122	22,156	20,278	**201,556**	300,231	41,804	38,260	**380,295**
2029	148,826	20,997	19,527	**189,349**	167,825	23,677	22,019	**213,521**	316,650	44,674	41,546	**402,870**
2039	165,460	24,891	23,003	**213,354**	186,583	28,069	25,939	**240,591**	352,043	52,960	48,942	**453,945**
2049	183,834	28,057	25,148	**237,039**	207,303	31,638	28,358	**267,299**	391,137	59,695	53,506	**504,338**