# Carlsbad Trickle Feed System

## Assessment of Capacity Available to Accommodate New Severance Connections


**INFRASTRUCTURE POLICY GROUP**

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**TABLE OF CONTENTS**



## Appendices

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**FINAL DRAFT**

# 1 Introduction and Background

Carlsbad Springs is a sparsely developed rural area that is supplied with drinking water from the City's central distribution system via a network of small diameter pipes that is commonly referred to as a "trickle feed system". A central supply system was needed to address widespread well-water quality and quantity problems in the area. The trickle feed system was implemented as a demonstration project, and is the only such system in the City. It was 70% funded by the province through the Municipal Assistance Program.

The system was designed to provide sufficient water for indoor use only. Supply to each customer is controlled to a fixed rate. Water is stored in privately-owned tanks within each building that is connected to the system. This allows brief periods of higher consumption rates than that which is available to replenish the indoor storage. No allowances were made for outdoor water uses (e.g., lawn and garden watering, car washing, etc.) and no allowance was made for the supply of water for fire-fighting purposes.

The original design anticipated a total of 775 individual connections to the trickle feed system. This number accounted for existing dwellings and a minor allowance for vacant lots and severances. The majority of the connections supply water to single family homes. However, the capacity of the system allowed for a small number of high water users (a school, a hotel, a seniors complex, a small apartment building, a golf course, and a recovery centre). As a result, the system was designed to accommodate a total of 829 "equivalent units", each limited to a tank re-supply rate of 2.7 $m^3$/day. No provisions were made for any growth beyond the 829 equivalent units.

The system is supplied by a single watermain feed. As such, the entire service area would be at risk of supply interruption in the event of a failure along this feed. Boil water advisories have been issued in the past to property owners in the area as a result of such failures. Tank disinfection is recommended by the City before private plumbing systems are returned to service, once a boil water advisory is lifted.

The trickle-feed network was designed based on a peak demand condition where all of the private tanks are in refill mode concurrently. The City has monitored system demand over time and it is apparent that this condition has not occurred. Conversely, it has been found that there are frequent periods of low demand that result in excess water age in the system. In order to maintain adequate water quality, the City flushes the system continuously at several locations.

Given that demand is lower than anticipated by the original design, it would be possible to accommodate additional connections to the system. Currently, there is demand for further severances along the system, each requiring a connection. City Council has directed staff to evaluate the capacity of the existing trickle feed system to accommodate severances.

The purpose of this memorandum is to present the following:

- assessment of severance potential for properties which front the existing system;
- assessment of the ability of the trickle-feed system to accommodate the additional connections that would be associated with these severances;
- improvements to the system needed to address existing issues and mitigate risks associated with increasing the number of customers that would be connected to the system; and
- preliminary assessment of the potential to extend the system to new areas.

# 2 Severance Potential

All of the properties which front the system were evaluated to identify severance potential based on the criteria established by Official Plan Amendment #150. A total of 56 parcels larger than 10.8 ha where identified. All of these parcels are larger than 11.6 ha, and therefore each parcel has a potential for 2 new residential lots. Thus, there is a potential for 112 new lots that would be serviced by the trickle feed system.

# 3 Capacity to Accommodate Severances

## 3.1 System Capacity

The capacity of the trickle system to accommodate additional demands depends on the following key factors:

- pipe characteristics
- network configuration
- spatial distribution of demands

Pipe capacity is determined by pipe diameter and roughness. The City's watermain design guidelines provide roughness coefficients ("C" factors) as a function of diameter. However, testing of pipes in the network that were carried out in 1999 and 2000 suggest significantly higher C factors. These higher values are explained by the use of high density polyethylene (HPDE) pipe throughout the network, and the low density of service connections (relative to typical urban systems) which tend to increase turbulence in the pipes. However, the C factor testing was limited. Furthermore, some deterioration of the condition of the internal surface of the pipe can be expected over time. The above considerations are reflected in the C factors used in the current analysis, as noted in **Table 1**.

**Table 1 Pipe "C" Factors**

| Pipe Diameter | Guidelines | 1999-2000 Testing Program | Current Study |
|---|---|---|---|
| 75 | N/A | 118-122 | 110 |
| 100 | N/A | 125-127 | 110 |
| 150 | 100 | N/A | 115 |
| 200 | 110 | 144 | 120 |

Capacities across the system also vary considerably due to local network sizing and configuration. A dense network with many interconnections typical of the urban area will provide much greater capacity than a

low-density network such as Carlsbad Springs. In particular, the system contains dead-end watermains which provide relatively little capacity since the supply of water can only come from one direction. There are 13 dead-ends in the Carlsbad system, ranging up to 2.5 km in length.

Demands located near the head of the system can be accommodated more easily because local pipe diameters are larger, and the pressure loss in the pipe network upstream of the demand is much less than demand that is located near the downstream periphery of the system.

## 3.2 Existing Capacity Utilization

A recent analysis of water consumption patterns in the area has been prepared to support the assessment of existing capacity utilization. This analysis is presented in **Appendix A**.

Capacity utilization has been assessed periodically over the life of the system and has been expressed in terms of peak concurrent use, as summarized in **Table 2**. Based on the 2013 peak concurrent use estimate, the maximum supply rate to the existing 593 connections would sum to 683 $m^3$/day.

**Table 2 Existing System Capacity Utilization**

| Year | 1999 | 2000 | 2002 | 2003 | 2013 |
|---|---|---|---|---|---|
| **Estimated Peak Concurrent Use** | 43% | 39% | 40% | 45% | 43% |

The potential reliability of concurrent use estimates have improved substantially as a result of the recent implementation of Advanced Metering Infrastructure (AMI) which established a remote meter reading system which polls all water meters in the City's distribution system at 1-hour intervals. However, there are several uncertainties in peak concurrent use estimates that are not addressed by the available AMI data:

- The period of record is short. As described in Appendix A, there is seasonal variability in the rate at which water is consumed, which suggests some weather-dependent outdoor water use. Peak rates of this type of water use can only be determined with accuracy based on ten years of data or more, depending on the observed variability.
- The meters located within the trickle feed system are only capable of providing readings at 1 $m^3$ increment. Therefore, a change in the meter reading may only occur once every several days under typical low demand periods. Under high demand conditions, most meters record consumption in the range of 1 to 2 $m^3$ per day.
- The AMI does not account for water losses in the system. There is a "master" meter that records water use for the entire trickle feed system, however, this information cannot be used directly to estimate concurrent use because it includes these losses. Almost all of the water "loss" is a result of system flushing.

## 3.3 System Flushing

In order to maintain adequate water quality in the trickle feed system, constant flushing is required at 9 locations. This effectively increases the peak demand on the system. The need for constant flushing was not anticipated when the system was designed. Thus, 100% peak concurrent use - assuming that all of the 829 equivalent units that the City is committed to servicing are connected - would result in failure of the system, even if a reduction in flushing is possible based on typical demand conditions. Thus, the original

design premise of 100% peak concurrent use is no longer valid in terms of assessing the available capacity of the system.

Flushing rates were estimated based on the difference between the master meter records, and the water meter records for each individual connection. Based on the supply and use variances, the calculations indicate a range of 0.32 L/s to 0.47 L/s per flushing point, or an average of about 0.4 L/s each. This corresponds to a total flushing rate of 311 $m^3$/day, or about 30% of the peak supply rate at the head of the system.

Flushing requirements are driven by typical, rather than peak, demand conditions. Based on the 2013 demand analysis presented in Appendix A, average concurrent use is only about 16%. This equates to a typical total customer demand of about 256 $m^3$/day. Thus, flushing accounts for roughly 55% of typical daily system demand.

With the addition of more connections beyond the 593 that are currently in operation, the demand in the system will increase, and the flushing requirements can be expected to fall. However, the degree to which flushing needs drop in relation to the number of new connections is difficult to estimate due to differences in the spatial distribution of demands. The City's 9 flushing points are located near the periphery of the network where water movement in the local pipes is limited (most are at dead-ends). New connections located near the head of the system will have little, if any, impact on flushing requirements.

## 3.4 System Reliability

The City's water system design guidelines require "looped" watermains where the local network supplies demand equivalent to 50 single family homes or more. Existing areas of this scale that are supplied by a single watermain feed are identified as Vulnerable Service Areas (VSAs). The City has a risk mitigation program in place, typically involving construction of secondary watermain feeds to effectively eliminate priority VSAs. With an existing commitment to supply the equivalent of 829 single family units, the Carlsbad trickle feed system is a VSA that constitutes a unique risk management challenge for the City given the large expanse of this sparsely populated area.

If there were to be an increase in the number of connections to the system, the Carlsbad Springs VSA would increase in priority, in terms of risk mitigation. However, the VSA is very unique in several ways:

- It serves a general rural area characterized by very low densities of development (less than 15% of the services are within the Village of Carlsbad Springs).
- The system was planned as a unique solution to water quality and quantity issues associated with private wells in the area.
- The system as constructed provides a lower level of service relative to the urban area and dense village development elsewhere in the City.
- Each customer supplied by the system maintains some storage of water at all times which would be available in the event of a supply interruption.

Given the original intent of the water supply solution, the low density of development, the long distance that an adequate secondary feed would need to cover, and competing rate budget priorities, it is not clear that the cost of a secondary feed is justified. However, provision of a secondary feed could be given further consideration in the context of future updates to the City's Long Range Financial Plan, and water rate review.

## 3.5 Design Criteria

A range of operating conditions must be considered to ensure that the system will perform adequately over the long term. This requires the development of key design demand sets. Two design criteria must be addressed by these demand sets, as summarized in **Table 3**.

**Table 3 Design Criteria**

| Design Criterion | Demand Set | Indicator |
|---|---|---|
| Peak Demand Capacity | Peak Hour on Maximum Day | Minimum System Pressures |
| Flushing Requirements | Average Day | Water Age |

While back-up capacity is not currently a system design criterion, it is considered here for information purposes, and to support any future consideration of a secondary feed.

The peak hour on maximum day demand set reflects the peak concurrent use expected under existing and future normal operating conditions. Under failure conditions, the City's established level of service objective for the central system is to meet the basic demands that are expected on a typical winter day. Thus, adequate back-up capacity (as provided by a secondary feed) would normally be required to meet the peak hour of demand on an average day. The performance indicator for both of these conditions is system pressure. The associated design criteria are satisfied provided that pressures exceed the required threshold at every point in the distribution system. The pressure threshold (20 psi) for the trickle feed system is lower than the rest of the central distribution system because water is re-pumped from the tank in each building that the trickle feed system serves.

While the City's water system design guidelines provide an indication of maximum water age in the distribution system, it is difficult to accurately simulate water age, and there are other factors that contribute to water quality conditions. Thus, for the purposes of this analysis, the focus is on the relative change in water age under existing and future conditions. It is recognized that provision of a secondary feed could result in a small increase in water age, and hence an increase in flushing requirements. However, this effect would be mitigated by increased demands resulting from new connections. This assumption is tested by an analysis presented in a subsequent section of this report.

## 3.6 Design Demands

The calculated system demands under various existing and future scenarios are summarized in **Table 4**. Three different future conditions scenarios are considered:

- Future "A": Current number of committed connections
- Future "B": Future "A" plus total potential residential severances for properties fronting existing system
- Future "C": Future "B" plus potential connections along a possible secondary feed route

A number of assumptions where involved in the demand calculations:

- It is assumed that the average day concurrent use will not change under future conditions. This assumption was made to avoid under-estimating potential future water age relative to existing conditions.
- It is assumed that the peak concurrent use under future conditions will be 65%. This provides a factor of safety of 1.5, which is consistent with recommendations from past studies of the system. While this

factor may prove to be more conservative than necessary (based on the accumulation of further AMI data over time) it could allow for a reduction in tank size required for future installations. The potential benefits of tank size reduction include: reduced space and maintenance requirements, and reduced water age.

- The peak hour concurrent use on an average day (26% as per AMI data) will also increase by a safety factor of 1.5 (i.e. 39%).
- It is assumed that the flushing rates will not change.[1]

**Table 4: Design Demands**

| | | Existing | Future A | Future B | Future C | Design Driver |
|---|---|---|---|---|---|---|
| **Number of Connections** | | **593** | **829** | **941** | **982** | |
| Average Day Demand | m3/day/connection | 0.43 | 0.43 | 0.43 | 0.43 | Water Age |
| | m3/day (no flushing) | 256 | 358 | 407 | 425 | |
| | m3/day (with flushing) | 567 | 669 | 718 | 736 | |
| | concurrent use | 16% | 16% | 16% | 16% | |
| Maximum Day Demand | m3/day/connection | 0.52 | 0.80 | 0.80 | 0.80 | - |
| | m3/day (no flushing) | 310 | 661 | 750 | 783 | |
| | m3/day (with flushing) | 621 | 972 | 1,061 | 1,094 | |
| | concurrent use | 19% | 30% | 30% | 30% | |
| Peak Hour on Average Day | m3/day/connection | 0.70 | 1.06 | 1.06 | 1.06 | Back-up Capacity |
| | m3/day (no flushing) | 413 | 879 | 998 | 1,042 | |
| | m3/day (with flushing) | 724 | 1,190 | 1,309 | 1,353 | |
| | concurrent use | 26% | 39% | 39% | 39% | |
| Peak Hour on Maximum Day | m3/day/connection | 1.15 | 1.76 | 1.76 | 1.76 | Peak Capacity |
| | m3/day (no flushing) | 683 | 1,455 | 1,651 | 1,725 | |
| | m3/day (with flushing) | 994 | 1,766 | 1,962 | 2,036 | |
| | concurrent use | 43% | 65% | 65% | 65% | |

## 3.7 System Model

In order to predict the performance of the system under future conditions, a hydraulic model was developed based on the City's system-wide model. Every watermain in the system is included, and demands are allocated to system "nodes" based on the spatial distribution of the existing service connections. The boundary conditions at the head of the system consider the planned reconfiguration of the existing pressure zones which serve the South Urban Community. This reconfiguration will result in a small reduction in the existing pressure at the head of the system. The model is able to predict operating pressures and water age at every location in the system. There are a number of uncertainties in these predictions related to pipe condition and the movement of water in response to constantly changing demands across the system.

[1] From a practical perspective, opportunities to eliminate flushing at certain locations would be considered as part of any future refinements in the analysis, rather than adjusting rates downward. This is due to the lack of potentially costly monitoring and control facilities for the existing flushing points. Elimination of flushing should only consider increases in average, rather than peak demands, and only those demands that are downstream of the flushing location.

### 3.8 Peak Capacity

Model simulation results for peak capacity for the "Future C" scenario (as defined in Table 3) indicate a minimum pressure of **23 psi** at the boundary road dead-end south of Russell Road, the critical location in the network. This exceeds the minimum 20 psi threshold. The results do not consider the capacity benefit that would be provided by a secondary feed to the system.

### 3.9 Water Age

Existing average water age, based on average day demands, are expected to range from **72 to 92 hours** at the dead-ends of existing watermains. Under the "Future C" scenario, the range would be expected to change to **58 to 77 hours**, ignoring the potential impact of a proposed secondary feed. As expected, the increase in demand along the existing network tends to reduce water age. With dual feed operation, there would be a negligible increase in average water age at the dead ends under both existing and future conditions.[2] Thus, there would be no need to increase flushing rates if the secondary feed project considered in this report were to be implemented. However, water age and potential impacts on flushing needs should be evaluated as part of any future evaluation of secondary feed alternatives, because the alternatives (and impacts) could vary significantly.

### 3.10 Back-Up Capacity

Model simulation results for back-up capacity for the "Future C" scenario (as defined in Table 3) indicate a minimum pressure of **22 psi** at the boundary road dead-end south of Russell Road. This exceeds the minimum 20 psi threshold. These results are based on a 152mm secondary feed from an existing watermain on Bank Street to the existing trickle feed main at Ramsayville and Eighth Line. If the City confirms the need for a secondary feed in the future, other options would be evaluated as part of a more detailed follow-up study. Based on the assumptions outlined in this report, the suggested 152mm pipe would provide very little excess capacity to accommodate any proposed extensions of the system.

## 4 System Connection Levy

Property owners that request new connections under the existing commitment must currently pay a fee of approximately $3,700 to cover their contribution to the cost of the original system. It should be noted that this fee excludes costs associated with the connection itself, and internal plumbing requirements, which are also the responsibility of the property owner. The City will have been reimbursed for its contribution to the project when and if all property owners who are currently eligible, apply and pay for their connection to the system. (The majority of existing connections were put into service by 1997. Since then, the number of connections has increased at a fairly steady rate of about 14 per year. At this rate, all of the committed connections will be in service, and the City will be reimbursed in full, by 2029.)

A report will be brought to Finance and Economic Development Committee (FEDCO) in Q2, 2015 which will address the issue of charges to be imposed on properties for future connections where there has been a local improvement or similar project which has already been paid for by local property owners. It is recommended that the question of what charge to impose on future connections to the Carlsbad system be deferred so that it can be considered in the context of that report.

[2] under existing conditions, it would take less than 3 hours to consume the volume of water contained in the secondary feed considered for the purposes of the report.

# 5 Feasibility of System Extension

Based on the assumptions described in this report, there would be some residual capacity available for extension of the system, but the feasibility of extension depends strongly on the location of the extension. Off-site upgrades, such as new watermain connections to eliminate dead-ends may also be required to provide sufficient capacity.

For extensions involving non-residential land uses, concurrent use rates that are higher than those applied for the purposes of the current study should be considered for peak capacity assessment.

The feasibility of specific extension proposals would also need to consider the impact of the project on water age. As per the City's design guidelines, dead end extensions would not normally be permitted. Generally, the cost of creating looped extensions would be high due to the long distances between available rights-of-way. Furthermore, large loops with limited demand may in fact exacerbate a potential water age issue that would be created by a simple dead-end extension. Thus, extensions should only be considered where:

- the demand is within a short distance of the existing network; and
- the extension would not create a new dead-end (or "P-loop"); or
- the extension would be compensated for by an off-site watermain project that eliminates an existing dead-end in the system.

The technical feasibility of extension can only be determined on a case-by-case basis where it is supported by an engineering study to the satisfaction of City staff. Approval of any extension should consider the increased risk due to the resulting increase in size of the Carlsbad VSA.

If future extensions of the system are found to be technically feasible and are ultimately approved by the City, a charge should be imposed to contribute to the cost of the original system and/or any upgrades to the system. (The basis for this charge will be addressed in the aforementioned report to FEDCO.) If off-site upgrades are required specifically to support an extension, the full cost of these upgrades should be borne by the developer.

# 6 Conclusions and Recommendations

1. The existing trickle feed system has sufficient capacity to accommodate the potential 112 severance opportunities that exist along the existing network.
2. There would be some excess capacity available to accommodate extension of the existing system, but the technical feasibility of extension depends strongly on the location of the proposed extension. Off-site upgrades may also be required to address system and local level issues. Residual capacity for system extensions can only be evaluated on a case-by-case basis. The increased risks resulting from growth of the Carlsbad VSA should be considered as part of any extension approval process.
3. Whereas the design of the original system did not allow for outdoor water use, and whereas the recent analysis of AMI data indicates a seasonal pattern to water use, analysis should be carried out periodically as further data is collected to ensure that the concurrent water use assumptions outlined in this report remain valid. If subsequent analysis suggests that concurrent use assumptions are being exceeded, then a By-Law prohibiting outdoor water use may need to be considered.

4. Further to the previous recommendation, the information that is provided to property owners upon connection to the system should be reviewed to ensure that there adequate emphasis on:
    - the appropriate water uses that the system has been designed to support.
    - the level of service provided by the system, including a higher likelihood of service interruptions relative to urban areas of the City.
5. It is recommended that the levy to impose on any new connections to the system – beyond what is already committed – be established as part of a separate report which will be brought to FEDCO in Q2, 2015. The report will address similar situations City-wide, where charges for future connections to an existing system which has been paid for (in whole or in part) by local property owners through a local improvement or similar project, would be appropriate.
6. Given the original intent of the water supply solution, the low density of development, the long distance that an adequate secondary feed would need to cover, and the many competing rate budget priorities, it is not clear that the cost of a secondary feed is justified. However, provision of a secondary feed could be given further consideration in the context of future updates to the City's Long Range Financial Plan, and water rate review.

# Appendix A

## Carlsbad Springs
## Water Supply Characteristics