# Water Balance and Hydraulic Analysis: Maximizing the Beneficial Use of Reclaimed Water Through Seasonal Changes and Growth

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The City of Orlando (city) is experiencing significant growth and expansion of its existing reclaimed water system. In the face of rapid change, the city wanted to proactively consider water management strategies for reclaimed water supplies and the demand for urban irrigation, along with hydraulic improvements to its growing system through 2045.

The Eastern Regional Reclaimed Water Distribution System (ERRWDS) is comprised of 185 mi of reclaimed water pipe, with an average daily flow of approximately 14 mil gal per day (mgd), peak-hour demand of approximately 32 mgd during the dry season, and maximum day demand of approximately 19 mgd. This complex system is supplied by the city's Conserv I and Iron Bridge Regional Water Reclamation Facilities (WRFs), as well as the Orange County Utilities (OCU) Eastern Water Reclamation Facility (EWRF).

The OCU and the city have an agreement that reserves an average annual daily capacity of 4 mgd in the ERRWDS for OCU. The system is also equipped with an inline booster pump station (IBPS), owned and operated by the city, which assists in transferring water from the north, where most of the reclaimed water supply is generated, to the south, where most of the reclaimed water is demanded. The

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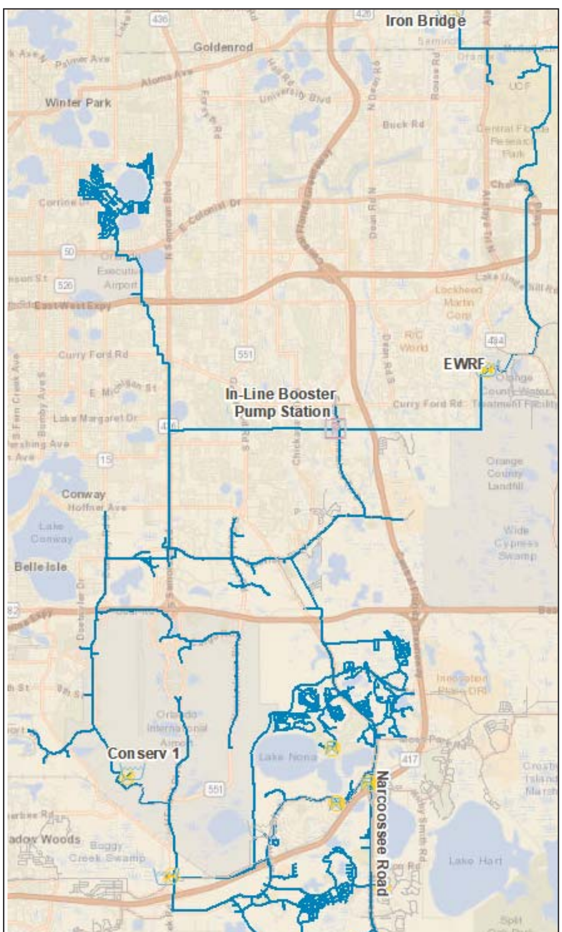


Figure 1. Eastern Regional Reclaimed Water Distribution System

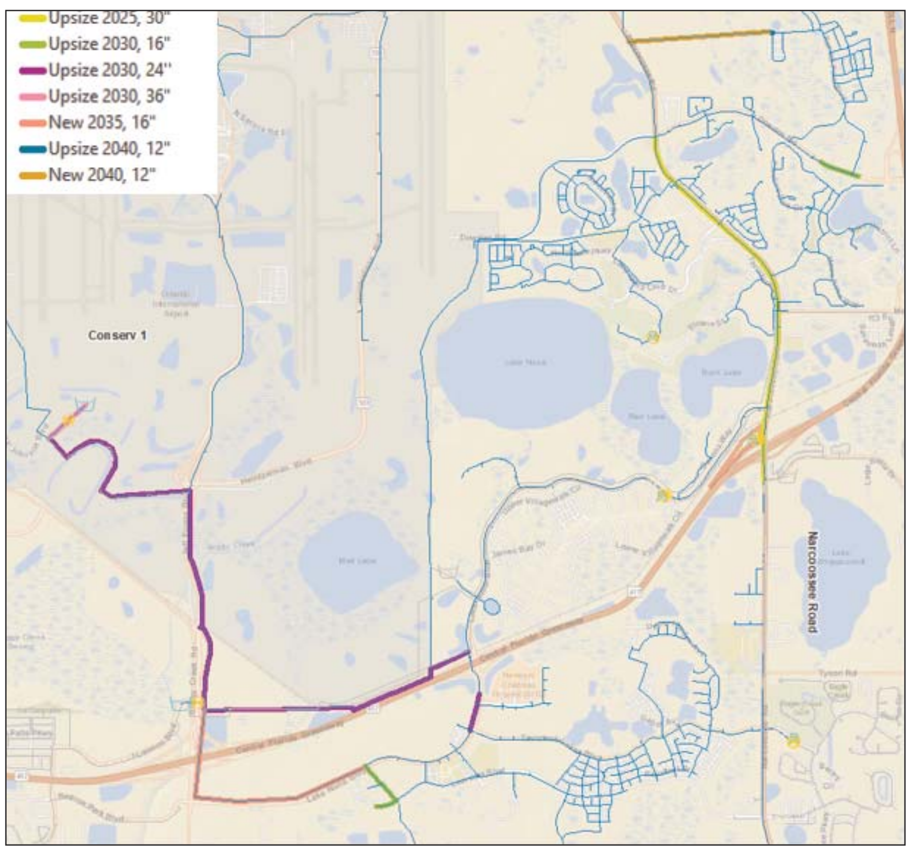


Figure 2. Future Infrastructure Improvements

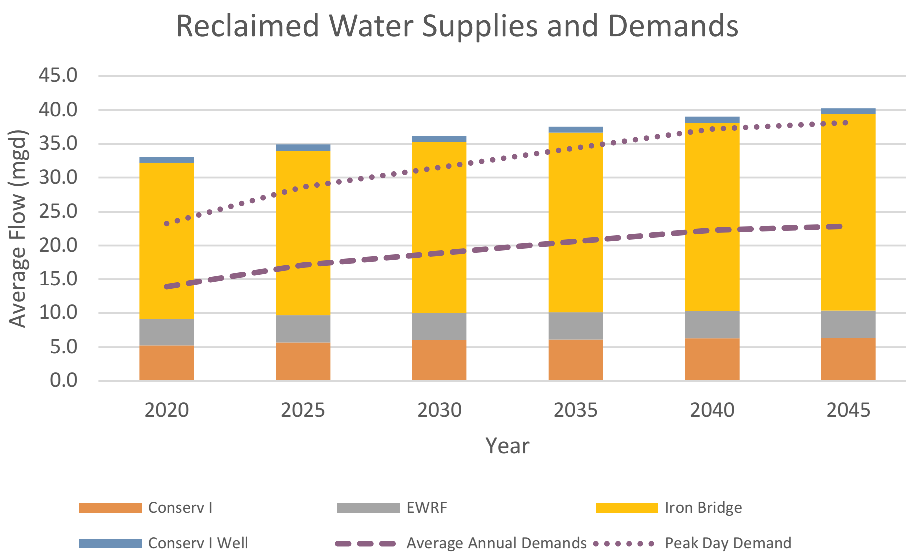


Figure 3. Projected Reclaimed Water Supplies and Demands for the Eastern Regional Reclaimed Water Distribution System (2020 through 2045)

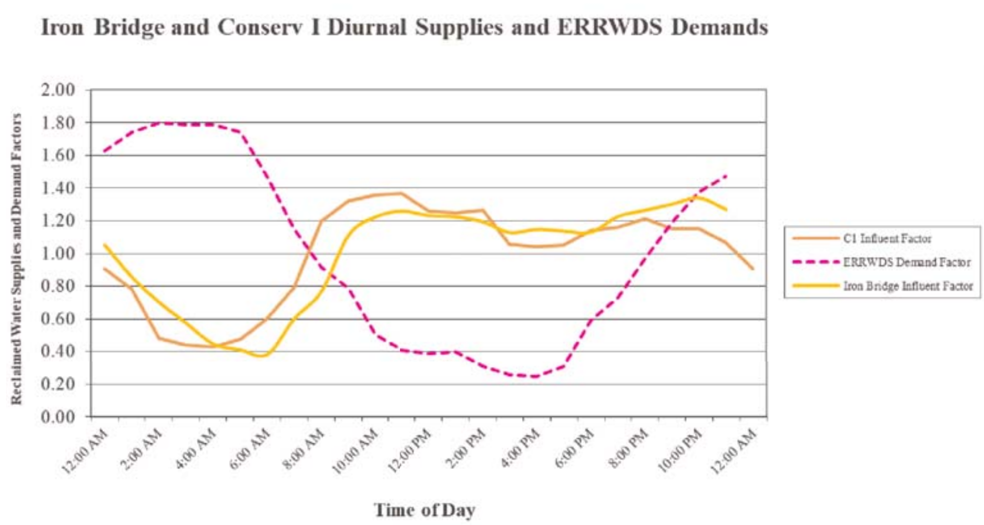


Figure 4. Eastern Regional Reclaimed Water Distribution System Diurnal Supply and Demand Patterns

system serves directly connected customers, such as residential and commercial irrigation, pressure-dependent customers that include an interconnection to OCU, and time-restricted service to onsite storage ponds for irrigation of golf courses.

During the dry season, when demand for reclaimed water is high, the hydraulic restrictions of the system become more apparent, as customers are not provided reclaimed water at adequate pressure for irrigation. Concerns for supply and management are also raised during the dry season, when the generation, storage, and delivery of reclaimed water to customers can be difficult to balance.

The purpose of this project was to determine necessary hydraulic, storage, and management improvements for the system to effectively meet seasonally high demands and provide a minimum pressure of 50 pounds per sq in. (psi) to all connections in the system throughout a 24-hour model simulation.

## Hydraulic Improvements

The city's hydraulic model was calibrated and updated to include future growth scenarios that were used to identify and locate beneficial improvements for the system throughout the planning period. Model calibration was based on collected field pressure data, WRF supervisory control and data acquisition (SCADA) data, and master meter monthly flow readings, which Carollo analyzed to determine a high-demand week with the most data available for calibration. The selected week was May 7 through May 13, 2018.

Field pressure and SCADA data were averaged on an hourly basis across the calibration period to provide a standard for a typical seasonal high-demand day. The same diurnal pattern and seasonal peaking factor used for calibration was used in the future scenarios. Future growth demands were estimated based on several major planned developments, traffic analysis zone growth, and the conversion of current potable fed jumper systems to reclaimed water. Most of the anticipated growth is in the corridor surrounding Narcoosee Road in the southern portion of the ERRWDS. The system is shown in Figure 1.

Estimated ERRWDS supplies and demands were projected through 2045 and improvements were considered at five-year planning intervals to provide the appropriate storage and hydraulic capacity to serve the rapidly growing system during the dry season. Because the city is experiencing growth and expansion, efforts have been made to combine needed hydraulic improvements with currently planned construction and development projects. Based on the hydraulic analysis, several key near-term improvements were recommended, some of which are already in the planning stages.

The primary recommendation was the upsizing of the city-owned 16-in. reclaimed water main along Narcoosee Road to 30 in. This section of 16-in. reclaimed water main acts as a hydraulic bottleneck to the primary transmission main that supplies the system from the north with water from Iron Bridge and OCU's Eastern WRF. This upsizing project will be completed in conjunction with the Narcoosee Road widening project planned for completion in 2020. The next major improvement recommended from this analysis is a remote storage and repump facility (RSRPF) to be constructed and operated by the city along Narcoossee Road. It's anticipated that the RSRPF will be needed by 2025.

Further recommendations were made to upsize other bottleneck sections of reclaimed water main in the system and to verify the fea-

*Continued on page 42*

*Continued from page 41*

sibility of filling and utilizing future diurnal storage facilities located at the Conserv I and Iron Bridge WRFs. The recommended improvements are shown in Figure 2. All necessary hydraulic improvements were planned to be completed by 2040; however, the hydraulic model did not consider if adequate supply would truly be available for irrigation in the future.

## System Supply and Demand

In order to determine if there will be adequate supply (and how to manage it), an analysis of the current and projected supplies, demands, and diurnal storage was completed. Diurnal storage, also referred to as operational storage, is the volume of storage required to equalize the anticipated differences in reclaimed water supplies and the demands for irrigation over a 24-hour period. These equalization volumes are greatest where the demand for water is the same as the available supply of water. Because of this, the analysis of the diurnal storage required focused on projected peak-season demands for water that typically occur every year in May.

Figure 3 illustrates the projected reclaimed water supplies and demands for the ERRWDS, from the 2020 through 2045 planning horizon. Reclaimed water supplies include, in order of their priority of use:

- *Conserv I WRF* - The Conserv I supply is placed at the base of the supplies in Figure 3, indicating that water from this source should be used to the greatest extent possible. This priority is given to Conserv I supplies for two reasons. First, the supply at Conserv I is generated locally and requires the least amount of pumping to get to the largest ERRWDS customers. Second, it's recognized that the capacity to manage excess reclaimed water at Conserv I is limited. Any water above what is required for ERRWDS can be sent to one of two effluent disposal sites, depending on their available capacity: the local rapid infiltration basin (RIB) system or the easterly wetlands. The logistics required to accomplish the transfer of Conserv I water to the wetlands have yet to be established, but maximizing the Conserv I water used by the ERRWDS customers will minimize the need to discharge excess reclaimed water to the wetlands.
- *EWRF* - Flows from EWRF are assumed to be a constant 4 mgd throughout the planning period. This flow is based on the existing agreement between the city and OCU.

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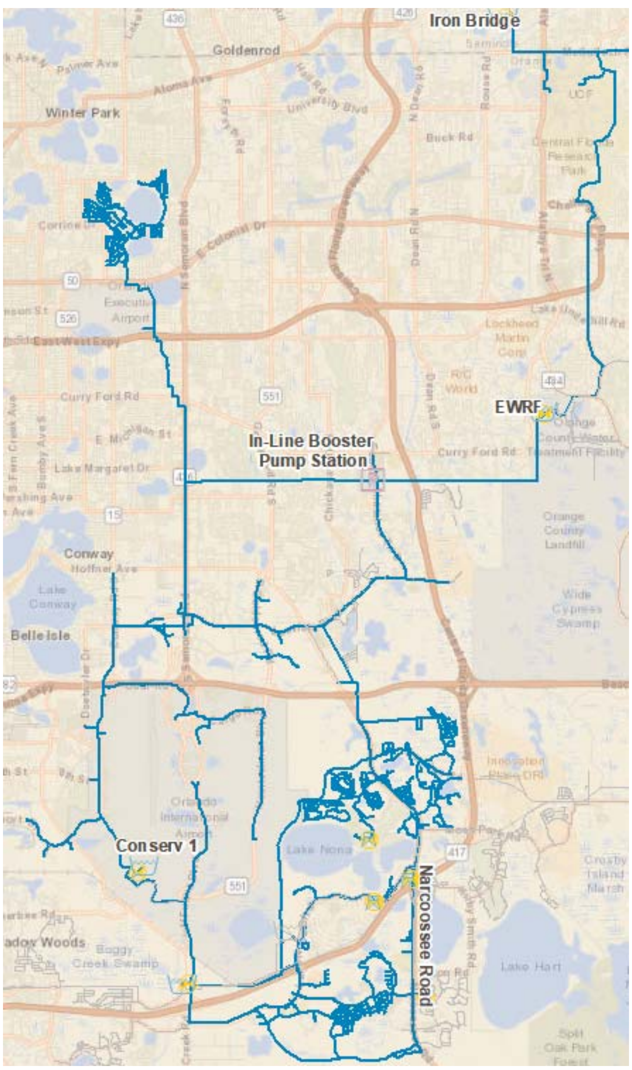


Figure 5. Available Eastern Regional Reclaimed Water Distribution System Diurnal Storage after 2025

Table 1.Storage as a Function of Beneficial Reuse

| Percent of Daily Flow Committed to Beneficial Reuse | Required Storage (Percent of Daily Supply) |
|---|---|
| 0% | 0% |
| 20% | 0% |
| 30% | 0% |
| 40% | 3% |
| 60% | 10% |
| 80% | 21% |
| 100% | 34% |

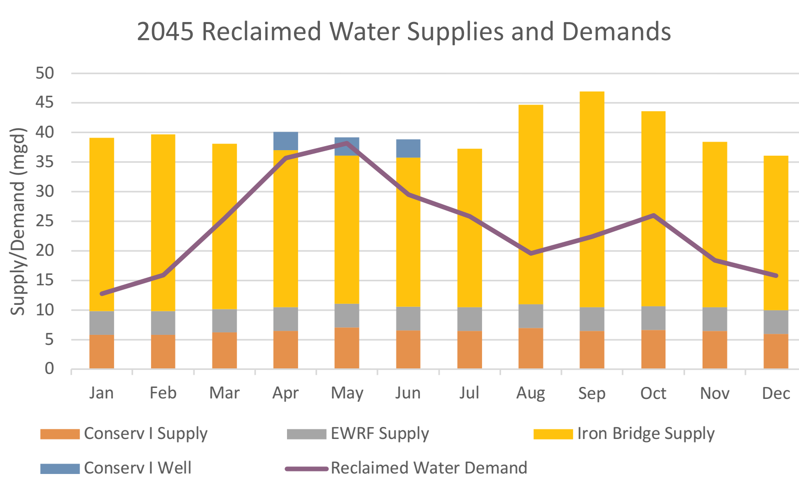


Figure 6. Expected Seasonal Available Eastern Regional Reclaimed Water Distribution System Water Supplies and Demands in 2045

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- *Iron Bridge WRF* - As shown in Figure 3, reclaimed water from Iron Bridge will be required to make up the difference between ERRWDS demands and local supplies. This was always part of the operating concept of the ERRWDS; however, the transfer requirements have been reduced by recent decisions to keep Conserv I in operation and expand its capacity to 10 mgd. This decision is beneficial from a hydraulic standpoint because it retains the reclaimed water supply closer to the center of reclaimed water demands.
- *The Conserv I Supplemental Groundwater Well* - Permitted at an annual average use of 0.88 mgd and maximum month use of 9.21 mgd, this water supply is placed on the top of the supply stack in Figure 3, indicating that it will be the last supply accessed in the event that the reclaimed water supplies from Conserv I, EWRF, and Iron Bridge are not able to meet demands.

As shown in Figure 3, the average annual demands for reclaimed water are always less than the total available supply of water; however, operational storage is designed based on peak-season demands, not the annual average. Figure 3 also shows an estimate of the maximum day demand for irrigation water from 2035 through 2045, which was the basis for sizing operational storage. Again, the maximum day demands do not exceed the total available supply, but they represent a significantly greater fraction of the total water supplies available to meet the ERRWDS demands.

The relative shape of the diurnal supply curve and diurnal demand for that supply are the primary factors driving storage volume: the greater the gaps between the demands for water at any given hour and the supply in that hour, the greater the volumes required to equalize these differences. Figure 4 illustrates the diurnal flow patterns for Iron Bridge and Conserv I, which represent the majority of the reclaimed water supplies available for reuse. These patterns are based on historical SCADA data for the ERRWDS system. Both influent WRF supply curves are similar, showing the least amount of flow in the early morning hours between 3 a.m. and 6 a.m., and the highest flows between 8 a.m. and midnight. The demand for reclaimed water is almost the opposite of hourly supplies, with high demands starting in the early evening and peaking between 2 a.m. and 5 a.m., generally corresponding to the hours of lowest supplies.

## Water Balance

The fraction of the diurnal water supply committed to beneficial use is also an important consideration when sizing operational storage. Using the reclaimed water supply and demand curves shown in Figure 4, an Excel-based water balance model was developed to evaluate the volume of equalization storage required as a function of the percent of total daily supplies committed to beneficial reuse. Table 1 summarizes these calculations indicating that no storage would be required if the demand for reclaimed water was less than or equal to approximately 30 percent of the daily supply. The equalization volumes increase from zero to a volume of approximately 34 percent of the total supply when demands equal 100 percent of the available supply. A volume of 40 percent storage at a commitment of 100 percent of the available supplies was used for the purposes of setting diurnal storage for the ERRWDS at this stage of planning. This volume can be adjusted over the course of the next 20 years as operational experience is gained.

Although it's not specifically a concern for equalization, the location of operational storage does impact diurnal transfer and peak pumping requirements. For the purposes of considering total equalization volumes required in 2045, consideration is given to the total volume of operational storage currently available, and where this storage is located. Figure 5 shows the ERRWDS from Iron Bridge in the north to the southernmost extent of the service area at the county line. Storage tanks are included according to known potential locations.

The storage tanks at Iron Bridge and Conserv I are existing. The 3 mil gal (MG) of remote storage and repumping on Narcoossee Road, which were recommended based on the hydraulic model analysis, has been included in this evaluation, as it's scheduled to be online by 2025. It's noted that the diurnal storage provided by OCU is not included in the

Table 2. Projected Eastern Regional Reclaimed Water Distribution System Maximum Month Water Supplies and Demands (mgd)

| Year | Conserv I | Conserv I Well | EWRF | Iron Bridge | Total RW Supplies | ERRWDS Demands | Percent Demand |
|---|---|---|---|---|---|---|---|
| 2025 | 6.27 | 3.10 | 4.00 | 20.99 | 34.36 | 28.66 | 83% |
| 2035 | 6.71 | 3.10 | 4.00 | 22.98 | 36.79 | 34.42 | 94% |
| 2045 | 7.04 | 3.10 | 4.00 | 25.05 | 39.19 | 38.20 | 97% |

Table 3. Total and Additional Diurnal Storage Required for Eastern Regional Reclaimed Water Distribution System

| Year | Total RW Supplies/Demands (mgd) | Minimum Required Storage (MG) | Iron Bridge GST (MG) | Remote GST (MG) | Additional Storage Required (MG) |
|---|---|---|---|---|---|
| 2025 | 34.36 | 14 | 4 | 3 | 7 |
| 2035 | 36.79 | 15 | 4 | 3 | 8 |
| 2045 | 39.19 | 16 | 4 | 3 | 9 |

analysis of future ERRWDS storage needs. This omission was intentional and provides an additional level of conservatism in calculating future storage needs for the city.

## Diurnal Storage Volumes Required

Seasonal variations in reclaimed water supply and demand are crucial to determining storage requirements. The hot and dry months of the spring tend to require significantly more water for irrigation, whereas, during the wet summer months, irrigation decreases and the need for disposal of excess treated effluent wastewater increases. Figure 6 illustrates the seasonal variations in water supplies from all sources (including the Conserv I well) and the expected demands for water in 2045. This figure clearly shows that the demand for irrigation is essentially equal to the total water available in May.

Monthly variations in reclaimed water supplies are based on historical variations observed at these facilities. For the purposes of this analysis it was assumed that water coming from EWRF is a constant 4 mgd throughout the year, equal to the average annual county demands on the ERRWDS per the existing reuse agreement. The capacity of the Conserv I well was also included as a potential source of water in the months of April, May, and June. The availability of groundwater was assumed to be approximately 3 mgd, one third of the maximum month permitted flow of 9.21 mgd.

Table 2 provides the projected water supplies and demands for the month of May for 2025, 2035, and 2045. From Table 2, the fraction of available water required to meet maximum month demands ranges from 83 to 97 percent. For the purposes of the water balance analysis, it was assumed that the maximum month demand was equal to the available water supply, requiring an operational storage volume of 40 percent of the available supplies.

Table 3 provides the total diurnal storage volumes required, assuming 100 percent use of the available supply in 2025, 2035, and 2045.

From Table 3, total operational storage required in 2045 will be 16 MG. This volume is reduced by the existing 4 MG of storage located at Iron Bridge and the planned 3 MG of remote storage on Narcoossee Road to be online by 2025. The 2.5 MG of storage at Conserv I is not included as available for operational storage in 2045. This volume was not included primarily because its geometry is not compatible with that of a traditional ground storage tank (GST). It's noted that the existing Conserv I tank is still a valuable asset and will likely find a use in the planned expansion of this facility.

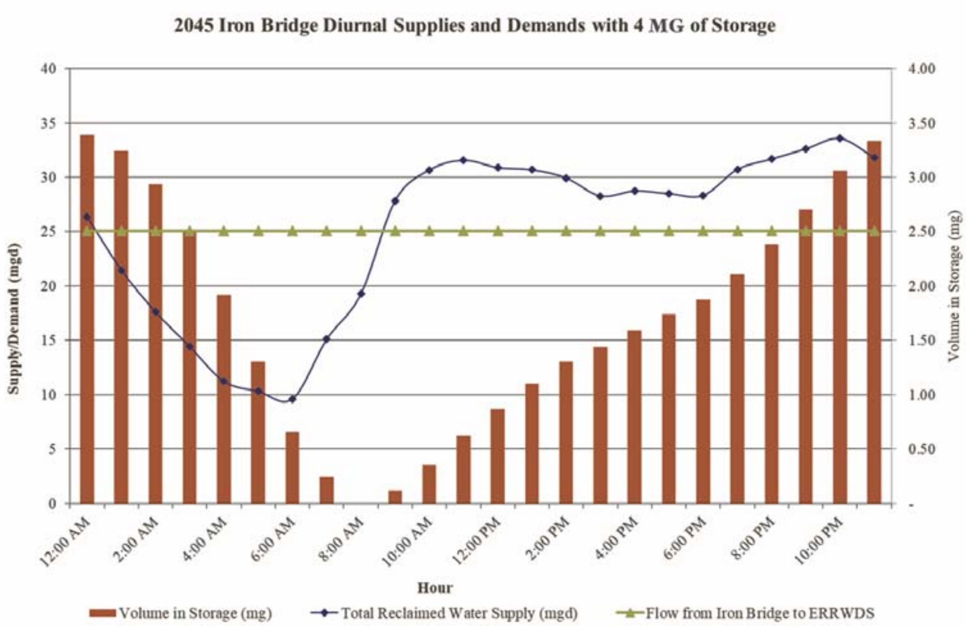


Figure 7. 2045 Diurnal Water Balance for Iron Bridge

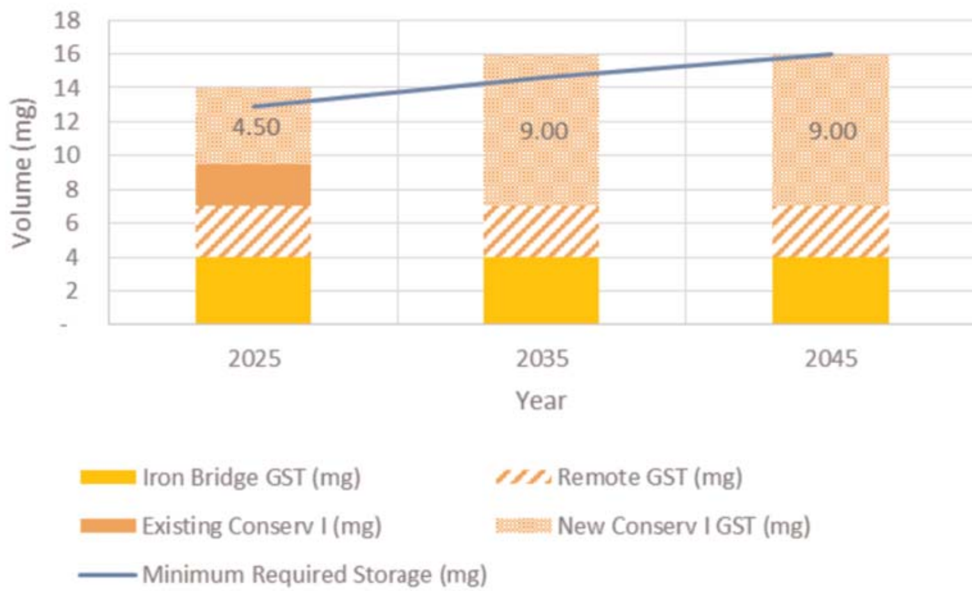


Figure 8. Proposed Timing of Increased Storage at Conserv I

## Operations of Existing and Planned Diurnal Storage Facilities in 2045

Before considering the optimal location(s) for future diurnal storage facilities, an assessment of the operations of the Iron Bridge and RSRPF was in order. The RSRPF was specifically sized and located to address ERRWDS demands from 2025 through 2045 based on current demands and anticipated growth in the service area. As such, this facility has been integrated into the ERRWDS current planning efforts and has been included in this analysis at a potential location.

The 4-MG tank at Iron Bridge was part of the original ERRWDS planning efforts done at a time when it was assumed that

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Conserv I would be taken offline and all wastewater flows would be sent to Iron Bridge. Plans for Conserv I have changed and the city now anticipates an expansion to this plant instead of a shutdown. Regardless of this change of plans, projected flows to Conserv I will remain significantly less than the demand for reclaimed water through 2045, as implied by Figures 3 and 6; therefore, reclaimed water from Iron Bridge will be required to make up the deficit between supply at Conserv I and demand for reclaimed water by ERRWDS customers. From a hydraulic standpoint, it's desirable to send water from Iron Bridge to the ERRWDS service area at a constant rate. This strategy minimizes the need for additional pumping and transmission capacity at Iron Bridge and the existing inline booster pump station.

Figure 7 provides the results of the diurnal water balance model for Iron Bridge given a 2045 maximum day flow of approximately 25 mgd and an available reclaimed water equalization volume of 4 MG. The objective of this analysis was to determine if the diurnal supply of reclaimed water (shown by the blue line) can be completely equalized to an average output of 25 mgd (shown by the green line) using the existing 4-MG storage tank. As shown in Figure 7, the volume in diurnal storage (red bars) varies from 0 MG at approximately 8 a.m. to a maximum of approximately 3.4 MG at midnight. Based on these results, the pumping, storage, and transmission capacities at Iron Bridge and at the inline booster are sufficient to supply a steady flow of reclaimed water to the ERRWDS service area.

## Locating Additional Storage for 2045 Demands

As described in the previous section, the existing pumping, storage, and transmission capacities, from Iron Bridge through the inline booster into the ERRWDS service area, were adequately sized to provide a constant flow of approximately 25 mgd. Given this condition, there was no need or benefit to increasing diurnal storage capacity at Iron Bridge. The two remaining locations for consideration of diurnal storage capacity were Conserv I and the location of the future RSRPF (to be constructed and operational by 2025). Additional storage capacity could be added to the RSRPF site; however, there were several potential disadvantages to this location—primarily, additional property would need to be acquired. There would also be a need for increased repump capacity at the RSRPF site and the associated increased electrical service requirements at the remote location.

In the near term, added storage at a remote location would also require additional pumping from Conserv I in off-peak hours to fill the tanks. In contrast, the Conserv I site has adequate space available, assuming that the city and the Greater Orlando Aviation Authority (GOAA), which owns the surrounding property, can come to an agreement. Locating diurnal storage here would allow for inclusion of additional pumping capacity, following, or along with, the WRF expansion project. It was assumed that additional electrical service would also be provided during or following the WRF expansion project, which would require less effort compared to expanding electrical service at a remote location; therefore, it's recommended that the 9 MG of diurnal storage needed by 2045 be constructed at Conserv I.

## Timing of Expanding Eastern Regional Reclaimed Water Distribution System Diurnal Storage Capacity

Based on the hydraulic modeling efforts, it was determined that the city will have significant latitude in setting discharge pressures at Conserv I, Iron Bridge, IBPS, and the future RSRPF. Because these pumping stations are all hydraulically connected to one another, the operational settings at one location affect the flows at all the other locations. This relationship also extends to when and how much diurnal storage is required. Figure 8 provides the minimum diurnal storage volumes required for 2025, 2035, and 2045. This figure also indicates the existing and expected storage capacities available for these years. The following assumptions were made for the indicated years:

**2025**

- The remote storage/repumping facility will be operational by 2025.
- The existing 2.5-MG Conserv I storage basin will still be in operation and available for diurnal equalization
- A new 4.5-MG storage tank will have been constructed at Conserv I and will be in operation by 2025. This schedule is slightly in advance of when it would be required.

**2035**

- The existing 2.5-MG Conserv I storage basin will no longer serve as operational storage.
- A second 4.5-MG GST will be constructed at the Conserv I facility. As shown in Figure 8, this second GST will be operational slightly in advance of when it's needed, but will provide sufficient capacity to equalize supplies and demands through 2045. The recommendation to build the second Conserv I tank by 2035 is predicated on the 2030 completion of the recommended transmission system improvements in the vicinity of Conserv I. These improvements will be necessary to convey additional water from Iron Bridge into storage located at Conserv I.

The hydraulic model was used to verify the ability to fill tanks during off-peak hours at both Conserv I and the RSRPF. Iron Bridge would be required (along with IBPS) to fill tanks at Conserv I to the required degree, in addition to reclaimed water generation at the Conserv I WRF. The transfer of an additional 2 mgd of flow from the Iron Bridge service area to Conserv I was recommended to increase the future supply at Conserv I when expansion of the reclaimed storage occurs. Both Conserv I and Iron Bridge may be used to fill the RSRPF during off-peak demand hours.

## Planning for the Future

The city has faced seasonal challenges of supplying irrigation at adequate pressures to all its customers. In anticipation of significant growth and expansion to a hydraulically limited system, the city decided to plan through 2045 for necessary hydraulic improvements to the infrastructure and water management strategies of the ERRWDS. Not only will these improvements serve ERRWDS during the peak irrigation season, but the storage facilities may be used during the wet season as auxiliary effluent storage to slow down the influx to disposal locations.

Management of the proposed future facilities will require a delicate, yet adaptable, operational approach to address the needs of the system seasonally, but the city is planning to be equipped to meet a high level of service for its customers, no matter the season.