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TECHNICAL MEMORANDUM

Wastewater Effluent Disposal Water Quantity Benefit Calculation

TO: Suwannee River Water Management District

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FROM: Wetland Solutions, Inc.

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Introduction

The Suwannee River Water Management District (SRWMD) is pursuing a wide variety of projects to improve both water quality and water quantity in springs within the District. Many of these projects have focused on easily identified and targeted point sources including wastewater treatment facilities (WWTFs). Some of these projects have included conversions of disposal from sprayfields to groundwater recharge wetlands. Groundwater recharge wetlands have been demonstrated to provide significantly improved removal of nitrogen, and specifically nitrate, one of the chemical constituents implicated in springs degradation. At other locations, utilities relying on rapid infiltration basins (RIBs) have been considered for conversion to groundwater recharge wetlands. While conversions between disposal methods have been both modeled and monitored with regard to water quality, the implications for water quantity and aquifer recharge have not been similarly evaluated.

This study provides a framework for evaluating the water quantity benefit associated with conversion between disposal types. This evaluation specifically focuses on the North Central Florida Region in the SRWMD, although the methods discussed are applicable in other areas of the state, contingent on adjustment for regional variations. This study is broken into two primary sections with the first section focusing specifically on effluent disposal methods, regulatory considerations, and typical application rates; and the second section focused on an estimation of the water balance, the quantity of water recharged, and calculating the water quantity benefit.

Effluent Disposal Alternatives

A variety of effluent disposal methods are available to WWTFs in Florida. These include discharge to: sprayfields, RIBs, groundwater recharge wetlands, reclaimed systems (typically for irrigation or industrial uses), surface waters, or injection wells. Generally, within the SRWMD the most frequently used disposal methods have been sprayfields, RIBs, and groundwater recharge wetlands. While referred to as “disposal”, these systems provide valuable recharge to the Floridan Aquifer and enhance spring flows in the poorly confined springs region.

Disposal systems are permitted within the Florida Administrative Code (FAC) in Chapter 62-610. Within these rules, application rates, a depth of water per time, are identified for slow-rate (e.g. sprayfields) and rapid-rate land application (e.g. RIBs). Less clear rules exist for groundwater recharge wetlands, which typically fall between these application rates with rates higher than sprayfields, but lower than RIBs. This section briefly summarizes the rules of FAC 62-610 with regard to disposal and also requirements in FAC 62-600 relative to WWTF expansion.

Slow-Rate Land Application (FAC 62-610: Part II)

Sprayfields are generally permitted as slow-rate land application systems with restricted public access. Under this rule, the initial design loading rate is typically two inches per week although it can be lower if onsite conditions dictate lower hydraulic capacity. With an engineering report FDEP can also approve a rate higher than two inches per week for sprayfields.

Rapid-Rate Land Application (FAC 62-610: Part IV)

RIBs are permitted as rapid-rate land application systems. This rule allows for an initial design loading rate of three inches per day as an annual average, although this can be lower if site conditions dictate. An engineering report can be used to justify higher rates up to nine inches per day if specific conditions are met. Permitting for RIBs also includes loading and resting cycles which allow for percolation rates to be restored through drying and oxidation of accumulated surface solids. The rule recommends operation for a period of 1-7 days followed by a resting period of 5-14 days, with 7 days loading and 14 days resting being a typical schedule. For the average annual loading rates described, 3-9 inches per day, this equates to an actual daily loading rate of 9-27 inches per day.

Planning for Wastewater Facilities Expansion (FAC 62-600: Part IV)

To accommodate projected flows, WWTFs must begin planning for expansion before they will reach their permitted capacities. This exercise requires that when the facility has a 3-month average daily flow that exceeds 50% of the capacity of the facility, reuse system, or disposal system, the facility will prepare and submit a capacity analysis report within 180 days.

Based on the findings of the capacity analysis report, if the permitted capacity is not found to be exceeded for a period greater than 10 years then an updated capacity analysis report will be provided every five years. If the capacity will be exceeded within the next 10 years then annual capacity analysis reports will be provided.

The need for a plant expansion is based on the capacity analysis report and the following schedules:

- Capacity exceeded ≤5 years, planning and preliminary design initiated
- Capacity exceeded ≤4 years, plans and specifications being prepared
- Capacity exceeded ≤3 years, submit a complete permit application within 30 days

Effective Application Rates

The combination of typical application rates and WWTF expansion requirements yields a more accurate picture of the effective application rates for the described disposal methods. Operationally, having substantially more capacity in the disposal mechanisms than is needed at current flows can be managed in a variety of ways. This can include loading all areas equally with reduced flows, loading only a portion of the areas with the permitted flow, or a hybrid of the two.

The specific operational approach becomes important in the context of evapotranspiration (ET) and recharge because more heavily loading a smaller area will result in a proportionally smaller loss to ET and greater net recharge. As an example, if the ET loss of applied water on a 10-acre sprayfield is 30,000 gallons per day (gpd), the ET loss on a 5-acre sprayfield loaded with the same volume of water (assuming no runoff) would be closer to 15,000 gpd. A further complication in some landscapes can be that the infiltrative capacity of the soils within the disposal site may be substantially higher than the permitted application rate. As an example, this could result in a 2-acre RIB basin that when loaded with a permitted 3 inches per day never sees more than 0.25 acres of wetted area. These complications are discussed further in the proposed methodology later in this memorandum.

Disposal System Water Balance

Water Balance

To evaluate the change in recharge amongst various disposal alternatives it is first necessary to outline a generalized water budget for wastewater disposal. A simple water budget diagram is shown in Figure 1. Components of the water budget are discussed in more detail in subsequent sections.

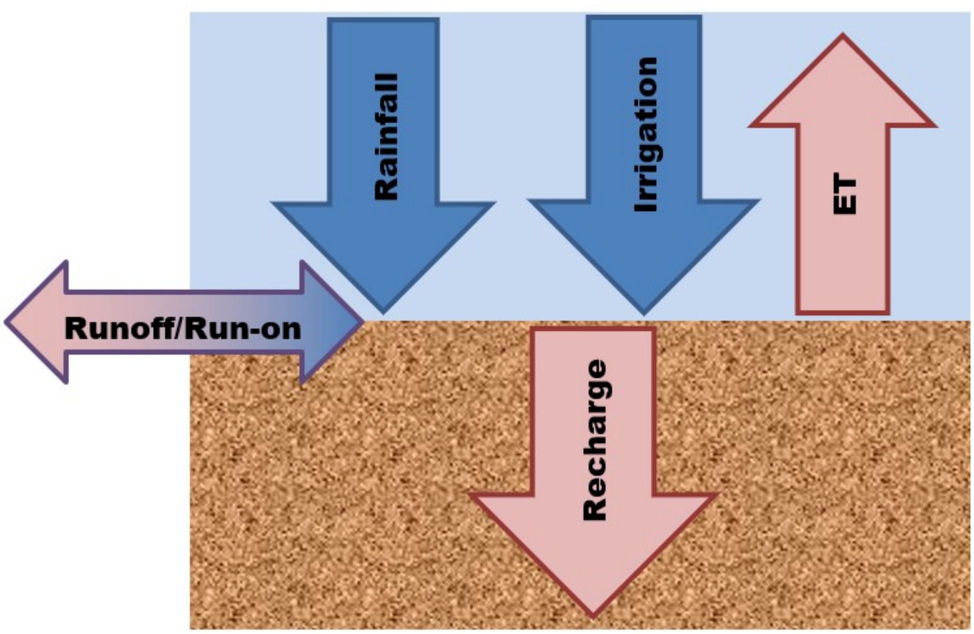

Figure 1. Generalized Water Budget

Water Gains

Based on the generalized water budget the water inflows include direct rainfall, run-on, and irrigation. Rainfall is readily available for all areas of the state from the University of Florida – Florida Automated Weather Network (FAWN). Run-on (and runoff) should generally be inapplicable for wastewater sites as disposal is permitted to avoid runoff and would be located outside of drainages that could contribute water during weather events. Therefore, this potential inflow is considered negligible. Finally, irrigation depth can be calculated from data collected and reported by the WWTF based on the following equation:

$$I = \frac{V}{A} \times 36.82$$

where:

I = Irrigation depth (in/d)

V = Volume delivered to disposal area (MGD)

A = Area that receives irrigation on that day (ac)

Water Losses

The water losses in the generalized water budget include evapotranspiration (ET), runoff, and recharge. ET is the combination of evaporation, the phase change from liquid to gas, and transpiration, the release of water vapor from plants. ET, like rainfall, is available from the FAWN for all areas of the state. As discussed for run-on, runoff should be generally inapplicable for properly permitted and functioning disposal systems.

By considering the generalized water budget, the recharge is observed to be the water that infiltrates below the plant root zone and that reaches an underlying aquifer. For the purposes of this analysis, this is the parameter of primary interest and is the only parameter for which there is not a direct measurement. Based on the previous discussion of permitting for disposal areas, determining the area over which water is actually applied is critical. This is especially the case for systems that are permitted for lower application rates (e.g. sprayfields).

As an example, if a WWTF has 100 acres of sprayfields with a permitted disposal rate of 2 inches per week (0.78 MGD), but is only operating at half of its permitted flow (0.39 MGD) while irrigating the entire sprayfield, the resulting application rate is 1 inch per week. The average annual ET rate at the Alachua FAWN station is 0.12 inches per day, or 0.84 inches per week, and significantly higher during the summer. In a week without rain, nearly all the applied water could be lost to ET. This computation necessitates a daily soil water balance for a precise calculation. However, as an alternative there have been studies of the relationship between ET, rainfall, and the daily soil water balance for different locations with results reported at the annual scale.

Net Irrigation Requirement

In general, rainfall exceeds ET on an annual basis in Florida. However, at a finer temporal scale, rainfall is highly variable with dry periods having reduced ET and no recharge in absence of supplemental water supply. By supplying water during these dry periods, or on a continuous basis, ET can be maximized during the annual cycle. Application beyond the point at which ET is maximized can result in runoff and additional recharge, or in the absence of runoff, just increased recharge.

In the irrigation context, the term *Net Irrigation Requirement* (NIR) is used to describe the difference between the potential ET (the point at which ET is maximized for grass or another plant type) and the effective rainfall (rainfall that supplies the potential ET). In a study by Romero & Dukes (2013), NIR was calculated for turfgrasses at ten locations in Florida and one location in Alabama for a data record of 30 years (1980-2009). This study found that NIR varied between 16.6 inches in Mobile and 41.9 inches in Key West. Values in North Central Florida in Tallahassee, Gainesville, and Jacksonville were seen to vary to a much lesser extent between 19.7, 19.8, and 20.3 inches, respectively. These were average values and would be expected to be higher during drier years and lower during wet years. However, for estimating average water quantity benefits for a project the average NIR can be applied.

Simplified Recharge

The NIR gives a simple metric that can be used to estimate recharge for a given location and a chosen disposal mechanism. The average annual recharge can be estimated as follows:

$$R = I - (NIR/365)$$

where:

R = Recharge (in/d)

I = Irrigation applied (in/d)

NIR = Net Irrigation Requirement (in/yr)

Depending on the application, the percent of the applied water that is recharged may be of more interest. This recharge percentage can then be multiplied by the total volume of water applied in the annual cycle to estimate the volume of water recharged. The recharge can be converted to a percentage as follows:

$$R_{\%} = 1 - \left(\frac{NIR}{I \times 365}\right)$$

where:

$R_{\%}$ = Percent recharge

Limitations

There are some cases where this approach may not provide high-quality estimates. These include systems with seasonal, or otherwise highly variable flows when seasonality and flows could result in more or less recharge. A second case where this method could be inaccurate is in systems that have very low flows and hence load their disposal systems at rates that are less than would be required to completely satisfy potential ET. In this case, this simplification may underestimate recharge, although a system loaded this lightly is unlikely to provide significant recharge in any case.

Disposal Examples

Below are examples for several types of disposal. For each of the presented examples, it was assumed that the system was operated at half of the permitted flow rate over the entire permitted area. Each system was considered to be similar to the Gainesville area with a NIR of 19.8 inches per year. In each example, water was also assumed to be evenly distributed over the permitted area.

Sprayfields

For a sprayfield permitted at two inches per week and operated at half the permitted flow, a total of 52 inches per year of irrigation is applied over an annual cycle. At the Gainesville NIR of 19.8 inches per year, the loss to ET is approximately 38% of the applied water, with recharge of the remaining 62% of the water.

RIBs

For a RIB system permitted at three inches per day and operated at half the permitted rate, a total of 547.5 inches are applied over an annual cycle. With the Gainesville NIR of 19.8 inches per year the loss to ET is approximately 3.6% of the applied water, with the remaining 96.4% recharging groundwater.

Wetlands

Groundwater recharge wetlands operate in a fundamentally different way than either sprayfields or RIBs. This is because wetlands are continuously flooded to achieve conditions favorable to biological treatment and nutrient removal. For this example, a recharge wetland that infiltrates one inch per day was considered. This would equate to 365 inches per year of application. At a NIR of 19.8 inches per year, the loss to ET would be approximately 5.4%, with 94.6% recharging groundwater.

Application Rate Relationship

The application/recharge relationship can also be evaluated across a broader range of application rates. For this evaluation, the values of interest are the application rate in inches per year and the NIR. This calculation was made for five of the cities presented by Romero & Dukes (2013) that spanned the range of values. This analysis shows that application rates beyond about one inch per day result in about 90% or more of the applied water being recharged, and in North Florida closer to 95% is recharged (Figure 2). The relationship between application rate and recharge shows the tradeoff of ensuring adequate disposal capacity from a permitting standpoint and rotating disposal to maintain equipment, while maximizing beneficial recharge. This problem is particularly significant in WWTFs that are operating at the lower end of their permitted flows.

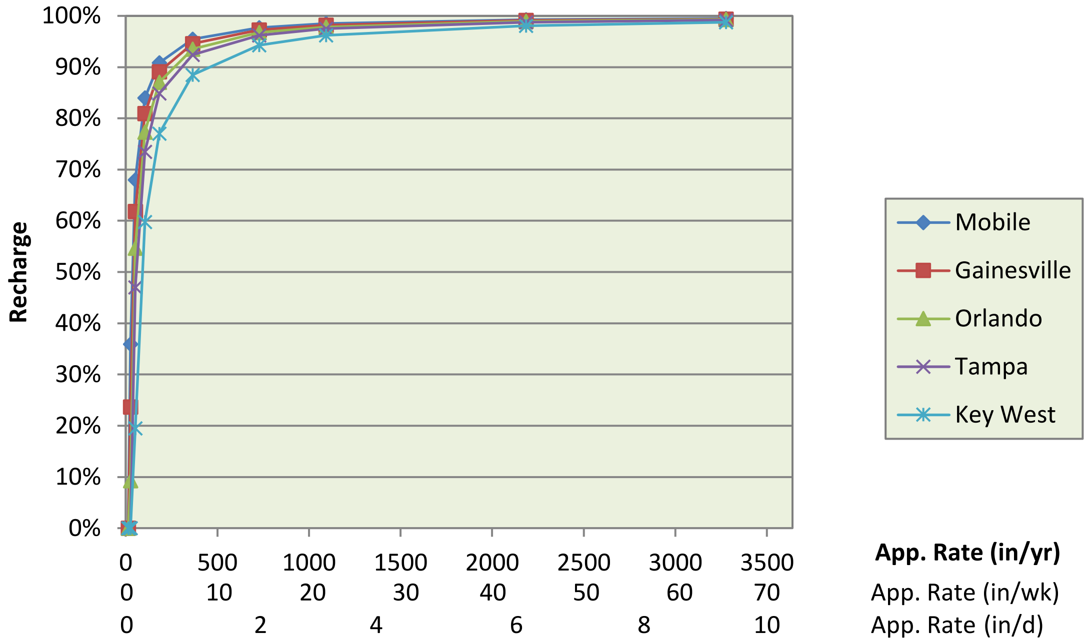

Figure 2. Net Recharge as a Function of Application Rate and Location

Water Quantity Benefit Calculation

To evaluate the water quantity benefit associated with a change in disposal methods, the recharge can be estimated for both the current and proposed disposal methods. The difference in these estimates represents the water quantity benefit or deficit that can be assigned to a project. This evaluation shows the balance that exists between the potentially competing goals of water quality and water quantity. Specifically, in the groundwater recharge wetland context this could mean that conversion of a RIB to a groundwater recharge wetland may result in less recharge, but improved water quality. Similarly, a larger wetland may provide better treatment, but result in reduced recharge. By calculating these differences, a more informed decision can be made.

The methods described in this memorandum only apply to disposal areas and do not include any ET losses that occur in lined features that do not infiltrate. These losses can be estimated by increasing the footprint of the disposal to represent the total area of wetted features. This technique will likely have some inaccuracies associated with different rates of ET between open water and various vegetative communities but can provide an approximate estimate.

Given the permit requirements for various forms of disposal it is generally evident that a facility discharging to a sprayfield offers the most potential for gains in recharge with a disposal conversion because of the lower application rates and higher ET losses. As an example, the High Springs WWTF is permitted for 0.24 MGD with disposal on a 32.5-acre sprayfield. This facility has been operating above 50% at about 0.16 MGD and has a planned WWTF expansion underway. Conversion from a sprayfield to a groundwater recharge wetland at this facility would be evaluated by applying the NIR value for Gainesville and assuming water is applied across the sprayfield zones. This would result in an estimated recharge percentage of 70% for the existing sprayfield at existing flows. Conversion to wetlands at this facility involves the installation of approximately 7 acres of lined wetland cells to reduce nutrients and 4 acres of recharge wetland cells. A portion of this modified disposal is providing nutrient removal and is essentially an extension of the treatment plant but will increase ET losses for the facility by having additional continuously wet vegetated area. Considering the entire area in wetland as part of the disposal and based on the NIR for Gainesville the recharge percentage is calculated to be 90% for the treatment wetland and groundwater recharge wetland. This equates to an increase in recharge at the current flow rate of about 20%, 0.032 MGD, or 32,000 gallons per day.

Here, it is worth mentioning that there may be alternatives that can be used to improve the quantity of water recharged without a complete change in disposal mechanisms. This can be accomplished by reducing the footprint used for disposal. For instance, a WWTF operating at half of their permitted flow could consider only discharging to half of their disposal area on a continuous basis, rather than rotating across all the disposal areas. Similarly, an alternative loading and resting cycle could be considered for RIBs to further reduce losses to ET. These operational modifications could require discussion with regulatory agencies prior to implementation.

Summary and Conclusions

This technical memorandum describes an alternative method to evaluate the water quantity benefit associated with a change in disposal mechanisms for WWTFs. This study largely focuses on conversions between sprayfields, RIBs, and groundwater recharge wetlands, but is also applicable to other disposal methods with adjustments. Based on the examples provided and typical permitted application rates, recharge is typically in the range of 50-98% of applied water. This provides a broad range for potential increases in recharge efficiency by converting operations and disposal methods.

The method described in this study relies on an annual average estimate of the supplemental water needed to maximize ET for a specific crop (turfgrass in this study). For the area of interest in this study, this value typically averages about 20 inches per year of supplemental water to maximize ET during an annual cycle. This approach offers a reasonable estimate for water quantity benefit calculation at an annual scale and as a planning-level tool for estimating project benefits and cost-effectiveness.

This methodology could be further refined by applying a daily soil water balance based on site-specific characteristics including plants and soils, although this approach is much more complex to implement across a variety of projects and locations. This method also does not consider intra-annual variability in weather conditions that would provide a picture of annual variations in the water quantity benefit.

References

Romero, C. C., & Dukes, M. D. (2013). Net irrigation requirements for Florida turfgrasses. *Irrigation Science*, *31*(5), 1213–1224. https://doi.org/10.1007/s00271-013-0400-6