San Antonio Water System

SAN ANTONIO WATER SYSTEM
Mitchell Lake – Constructed Wetlands Below the Dam
Preliminary Feasibility Study

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1 Executive Summary

This study evaluates the feasibility of implementing constructed wetlands below the dam for the purpose of improving the quality of water discharged from Mitchell Lake. Specifically this study includes the following:

- Addresses the suitability of the available land below the dam for a constructed wetland system,
- Provides an opinion regarding whether the constructed wetlands can be operated by gravity flow,
- Provides an opinion with respect to the quality of the wetland discharge and whether it will comply with the permit limits, and
- Explores how management of stormwater inflows to the lake will affect the performance of the constructed wetlands.

San Antonio Water System (SAWS) provided an initial location for the constructed wetlands to be located below the dam. The initial site included three distinct parcels, all located east of Pleasanton Road. A desktop screening of this land was performed to assess suitability based on Texas Commission on Environmental Quality (TCEQ) requirements and generally accepted wetland design practices. Eight screening criterion were used in the analysis to identify and exclude any unusable or unsuitable land, resulting in a final area of approximately 129 acres available for wetland development. Of that area, approximately 112 acres would be “wetted” area used for water treatment. Actual site surveys, including a geotechnical subsurface investigation, should be conducted to confirm the suitability of the land identified in the study.

The elevation of the land identified for wetland development is at least 3 feet lower than the normal lake operating level proposed in the 2015 Merrick and Company study (elevation 517.5 feet). As such, it appears that the wetland could be gravity fed from the lake.

If treatment wetlands are added downstream of the lake, it would constitute the addition of a treatment unit to the facility and trigger a major amendment to the Mitchell Lake Texas Pollution Discharge Elimination System (TPDES) permit. When a permit is amended, TCEQ updates the water quality model for the receiving streams to determine if revisions to permitted effluent limits are appropriate. In addition, in this case the Mitchell Lake permit would be amended from an intermittent discharge to a continuous discharge. These changes can be expected to result in revised effluent quality limits. In order to identify the possible effluent limits that the constructed wetland would need to meet, the stream water quality model for the Medina River was obtained from TCEQ and an analysis was performed using discharge rates of 4 and 15 million gallons per day (MGD) from the constructed wetlands. Based on this modeling, the limit for five-day biochemical oxygen demand (BOD_5) would be reduced from 30 mg/L to either 10 mg/L or 15 mg/L; dissolved oxygen (DO) would be increased from 4 mg/L to 5 mg/L; and ammonia would be added with a limit of either 3 mg/L or 4 mg/L. The current permit limit of 90 mg/L for total suspended solids (TSS) is the technology-based limit for a pond system. The case should be made that the lake and constructed wetlands are a pond system and that the 90 mg/L limit should be retained. If the Mitchell Lake permit is amended, it is likely that TCEQ will reassess the effluent limits for the Leon Creek Water Recycling Center (LCWRC) and Dos Rios Water Recycling Center (DRWRC).

Water quality data for Mitchell Lake is limited. Most of the reports characterizing water quality in the lake were developed in the mid to late-1990s and these reports included a limited number of samples. More recent data was provided by SAWS. However, these data were limited to when the lake was discharging and only including BOD_5, TSS, DO, and pH. The most recent nitrogen data reviewed was from the older reports (Simpson Group 1996, 1997).

Wetland outflow quality was estimated using various modeling techniques. To meet a potential BOD_5 limit of 10 mg/L to 15 mg/L, flow through the wetland would need to be limited to approximately 4 to 7 million gallons per day (MGD). The outlet concentration for TSS was estimated to be approximately 27 mg/L. Wetland outflow ammonia was estimated to range from 0.8 to 5.3 mg/L, with higher flow rates achieving slightly lower concentrations for ammonia. However, due to the limited number of studies on wetlands treating eutrophic water substantially similar to Mitchell Lake, there is a degree of uncertainty in the estimated concentration for ammonia. Furthermore, the modeling results for BOD_5 suggest that 4 to 7 MGD would be appropriate, but those performed for ammonia suggest higher flow rates may be acceptable. A pilot study would be necessary to identify the appropriate flow rate needed to achieve the best discharge quality and identify whether the constructed wetland system could meet the potential effluent limits.

A preliminary water balance model was developed to explore how management of stormwater inflows to the lake could affect performance of the constructed wetland. The model assumed a continuous inflow ranging between 4 and 7 MGD to the wetlands and used storage within the lake itself for management of runoff. During calibration of the model, the modeled discharges did not correlate well with the discharges reported by SAWS. A more detailed examination of reported discharges and management of stormwater within the lake should be done in conjunction with identifying the optimal flow rate through the constructed wetlands to achieve water quality improvement.

The evaluations conducted for this study indicates a significant potential that constructed wetlands can be used to improve the quality of discharges from Mitchell Lake. However, this study has been conducted using only currently available information. There are areas of significant uncertainty regarding the potential performance of the constructed wetlands. The following studies are recommended to reduce these uncertainties prior to making a decision whether to construct a full-scale constructed wetland system:

- Conduct a study utilizing a pilot scale wetland system. This study would provide data to better determine whether the proposed wetland system could meet the current and/or future effluent limits. Additional quality data should be obtained from the lake. The pilot study should be operated for a period of at least one year after the vegetative cover has fully matured in order to capture seasonal changes and collect enough data for meaningful analysis.
- Conduct a detailed water balance study. This study would be performed to identify the ability of the lake to moderate storm flows to the wetland system through temporary storage of runoff above the 517.5 normal operating level proposed in the Merrick study. The results of this study would help refine the range of flow rates expected through the wetland and subsequently provide better estimates of outflow quality. A detailed water balance study could also provide information helpful in identifying potential issues related to calculating lake discharge rates.
- Update the TCEQ receiving stream models to determine the potential impact of a continuous discharge from Mitchell Lake on the permit limits for LCWRC and DRWRC.

2 Introduction

Mitchell Lake is a permitted wastewater treatment unit owned by SAWS and operated under TCEQ TPDES Permit No. WQ0010137004. The lake is an on-channel impoundment and discharges at times in response to rainfall runoff within its watershed. When discharges occur, SAWS is required to monitor and report flow, as well as water quality sampling results for pH, BOD_5, DO and TSS in accordance with the TPDES permit. Due to the eutrophic nature of the lake and its correspondingly high phytoplankton biomass, the facility has periodically exceeded the permit limits for pH, BOD_5, DO and TSS. SAWS has commissioned several studies that have explored various concepts to improve water quality of the lake, while maintaining or enhancing the wildlife habitat at the facility. Several concepts have been proposed using constructed wetlands, including wetlands located below the dam. The purpose of this study is to evaluate the feasibility of implementing constructed wetlands below the dam for water quality improvement. Specifically, this study will include the following:

a. Address the suitability of the available land below the dam for a treatment wetland system;
b. Provide an opinion regarding whether the constructed wetlands can be operated by gravity flow;
c. Provide an opinion with respect to the quality of the wetland discharge and whether it will comply with the permit limits; and
d. Explore how management of stormwater inflows to the lake will affect the performance of the constructed wetlands.

3 Reports and Documentation Reviewed

As background for this study SAWS provided reports other documentation that previously addressed various aspects of Mitchell Lake. A list of the reports and documentation provided by SAWS is included in the Appendix

4 Suitability of the Setting

For the purpose of this study, it is assumed that the proposed constructed wetland would be a free water surface (FWS) wetland. FWS wetlands mimic natural wetlands in that the water surface remains above the top of the soil media at all times and the wetland includes areas of open water and a diversity of floating, submerged, and emergent plants. In contrast, subsurface flow (SSF) wetlands are those wetlands utilizing a coarse, granular plant rooting media where the water profile remains below the top of the media. SSF wetlands are prone to clogging (and eventually failing) when high TSS water is introduced to the system. For this reason, the use of a FWS wetland is the most appropriate application to accommodate the high algal loads received from Mitchell Lake. All of the previous studies contemplated using FWS wetlands.

Because Mitchell Lake is a permitted treatment facility, the addition of a constructed treatment wetland downstream of the dam would need to meet the design criteria established in 30 TAC 217, Subchapter H (Natural Treatment Units). This evaluation considers the TCEQ design requirements.

FWS constructed wetlands can be categorized as a land-intensive treatment technology. In other words, greater treatment capacity can generally be achieved through a larger footprint. Because of this, the availability of suitable land is usually one of the limiting constraints in developing constructed wetland projects. SAWS provided an initial location for the constructed wetlands to be located below the dam. The proposed site includes three distinct parcels (Identified as "W", "C", and "E") all located east of Pleasanton Road. The location of the parcels is shown in Figure 1. A desktop screening of this land was performed to assess suitability based on TCEQ requirements and generally accepted wetland design practices. Land deemed unsuitable was then excluded and the remaining land was considered available for development of the constructed wetland below the dam. Any small orphan parcels remaining were also excluded.

Screening criterion used for determining suitability included the following:

- Topography
- Types of soils
- Presence of floodplain
- Presence of natural wetlands
- Presence of groundwater/springs
- Presence of wells (water, oil/gas)
- Physical obstructions
- Requirements for property line set-backs

Each of these criteria is examined in greater detail below and an estimate of the total area available for the constructed wetland is provided.

FIGURE 1 – Land Initially Considered for Constructed Wetlands Located Below the Dam

4A. Topography

It is desirable to locate a FWS wetland on land that is flat to gently sloping. In doing so, earthwork costs can be minimized. The land identified by SAWS was evaluated for slope using LIDAR contours obtained from the San Antonio River Authority (SARA)[1]. This land is relatively flat with slopes ranging from less than 1 percent to approximately 2 percent, which makes it suitable for constructed wetland development.

4B. Soils

For constructed wetland treatment units, TCEQ requires a liner with a hydraulic conductivity (permeability) less than 1×10^{-7} centimeters per second (cm/sec) and a minimum compacted thickness of 2.0 feet for water depths less than or equal to 8 feet [§217.203 (d)]. Alternatively, §217.203(e)(2) establishes conditions pursuant to which in-situ soils can be used for the liner. The requirements for using in-situ soils include completely excavating and re-compacting the top 2 feet of in-situ soils (defined as “amended in-situ soils”) or compacting the top six inches only (defined as “unamended in-situ soils”). Use of unamended in-situ soils for a liner is highly desirable if the natural soils have sufficient clay, so that the required hydraulic conductivity and thickness can be achieved; otherwise suitable clay would need to be imported from offsite to construct the liner. This would significantly increase the cost of the project.

The Natural Resources Conservation Service (NRCS) Soil Survey map[2] (Figure 2) indicates soils located within the footprint of the land proposed for the constructed wetlands are Sunev clay loam (mapped as VcA and VcB). The typical profile of Sunev is clay loam from 0 to 32 inches and loam from 32 to 62 inches. Depth to groundwater is greater than 80 inches. The hydrologic soil group is B (moderately low runoff potential). Clay loam has the potential of meeting the permeability requirements when properly moistened and compacted. However, this would need to be confirmed through testing of actual soil samples taken at the site.

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[1] https://www.sara-tx.org/public-services/geographic-information-systems/lidar-aerial-imagery/

[2] http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

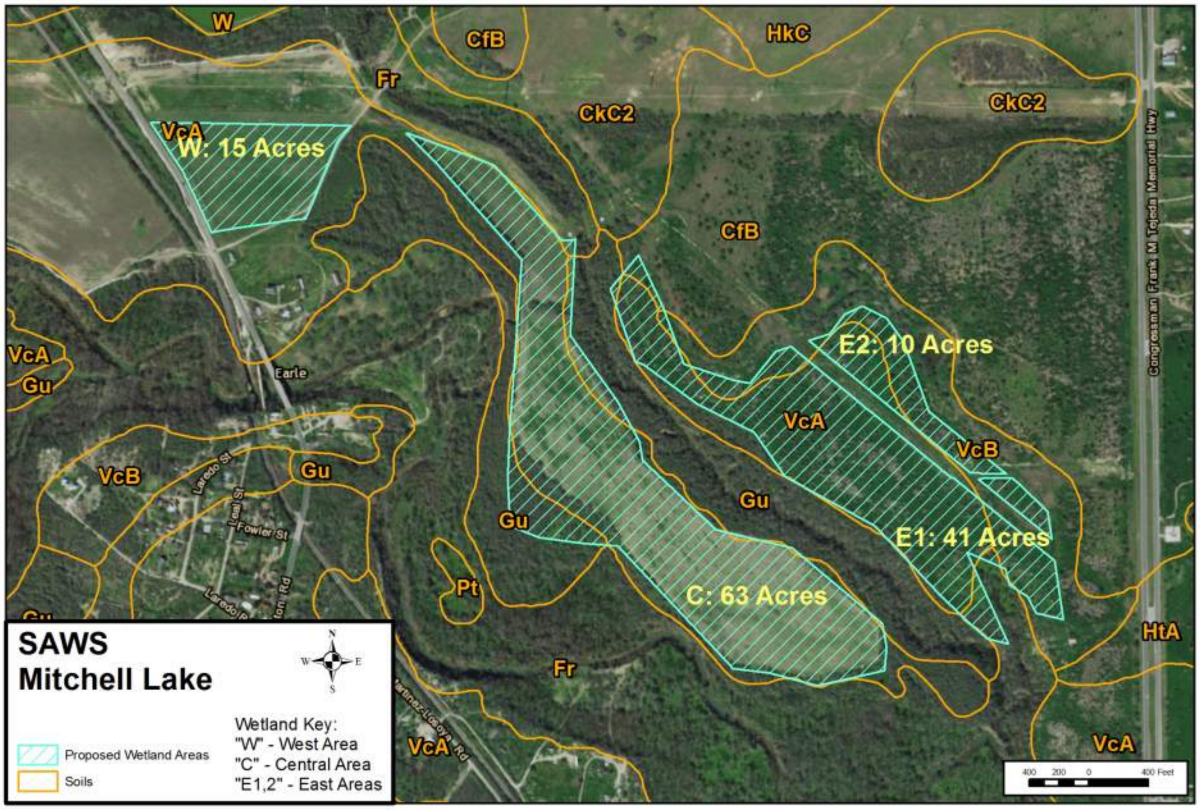

FIGURE 2 - NRCS Soil Survey Map for the Proposed Wetlands Area

Geotechnical data provided by SAWS were also reviewed to evaluate the suitability of the soils in the area of interest. A 1989 subsurface investigation conducted for a dam stability analysis by Bryant-McClelland Consultants indicated that soils immediately downstream of the dam were lean clay (CL) to at least 20 feet (Boring 11+30B). A Raba-Kistner study (1992) conducted to investigate deepening of the lake included four borings along Pleasanton Road that were located immediately west of wetland tract "W". Three of the Raba-Kistner borings (B-6, B-7, and B-8) indicated one to two feet of clay overlying several feet of very silty clay. The fourth boring (B-9) showed silty clay from the surface to a depth of 10 feet. Another geotechnical study provided by SAWS (Raba-Kistner 2010) indicated clay along Pleasanton Road in the general area of the wetland. However, none of the documents provided by SAWS included geotechnical data from within the main areas proposed for the wetlands. Geotechnical borings would need to be located within the wetland footprint to confirm whether the in-situ soils will meet TCEQ liner requirements.

4C. Floodplain

TCEQ prohibits wastewater treatment units from being located within the 100-year floodplain [§309.13(a)]. A flood hazard map developed by the Federal Emergency Management Agency (FEMA) was used to determine if any of the land proposed for wetlands development below the dam fell within the 1% Annual Chance Flood Hazard Zone (i.e., the 100-year floodplain). Figure 3 is the FEMA Flood

Insurance Rate Map[3] used for this evaluation, which shows that the 100-year floodplains for Cottonmouth Creek and the Medina River do not encroach onto the proposed wetlands location.

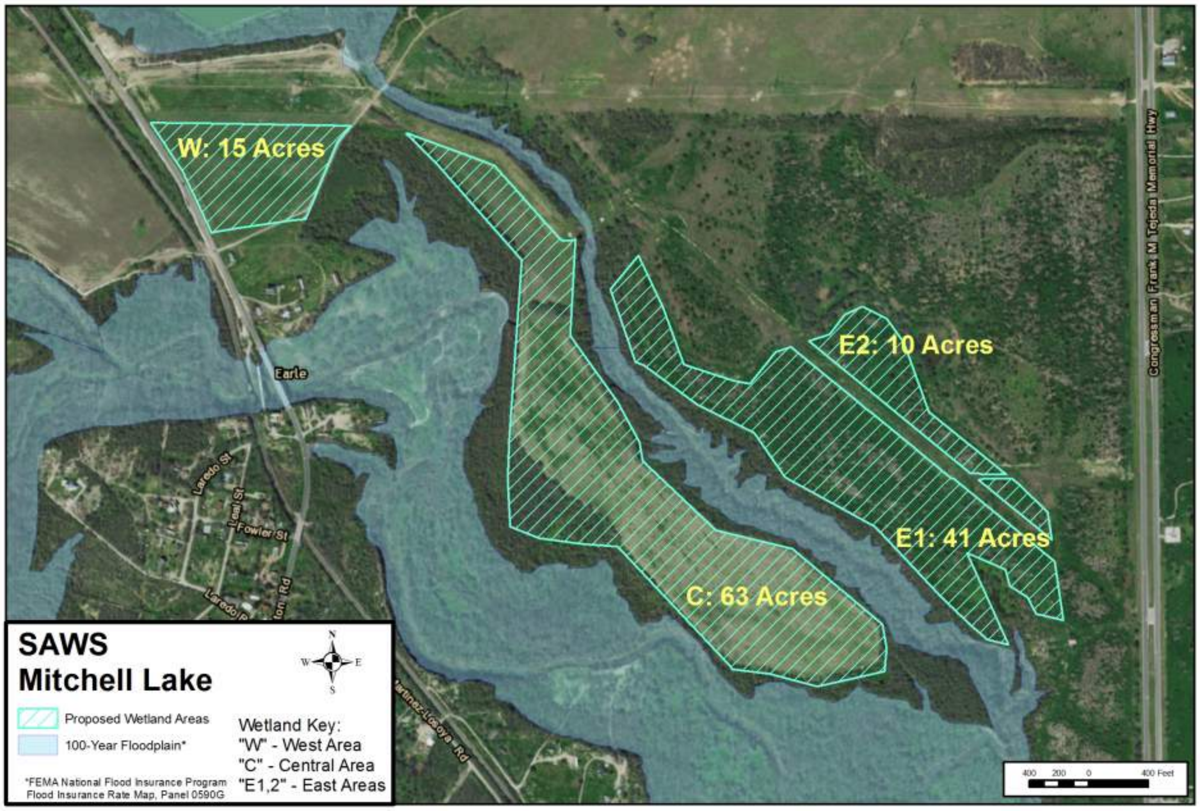

FIGURE 3 – 100-Year Floodplain Map

4D. Natural Wetlands

TCEQ prohibits the use of natural wetlands for wastewater treatment [§217.209(b)]. Furthermore, Section 404 of the Clean Water Act regulates impacts related to dredge or fill activities within jurisdictional waters of the United States, including natural wetlands. A desktop survey of the area proposed for constructed wetlands development was performed by reviewing the National Wetlands Inventory map from the U. S. Fish and Wildlife Service (USFWS), Ecological Services Division[4]. The desktop survey indicated that no jurisdictional wetlands appear to be located within the area of interest, except for a very small overlap into a lacustrine area (freshwater pond) in the south-most part of wetland tract E1. A site survey would need to be conducted to confirm the actual boundary of any jurisdictional wetlands in this area so that they could be avoided. See Figure 4 for the National Wetlands Inventory Map superimposed on the proposed constructed wetlands site.

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[3] FEMA FIRM map panel 48029C0590G (effective 9/29/2010)

[4] https://www.fws.gov/wetlands/

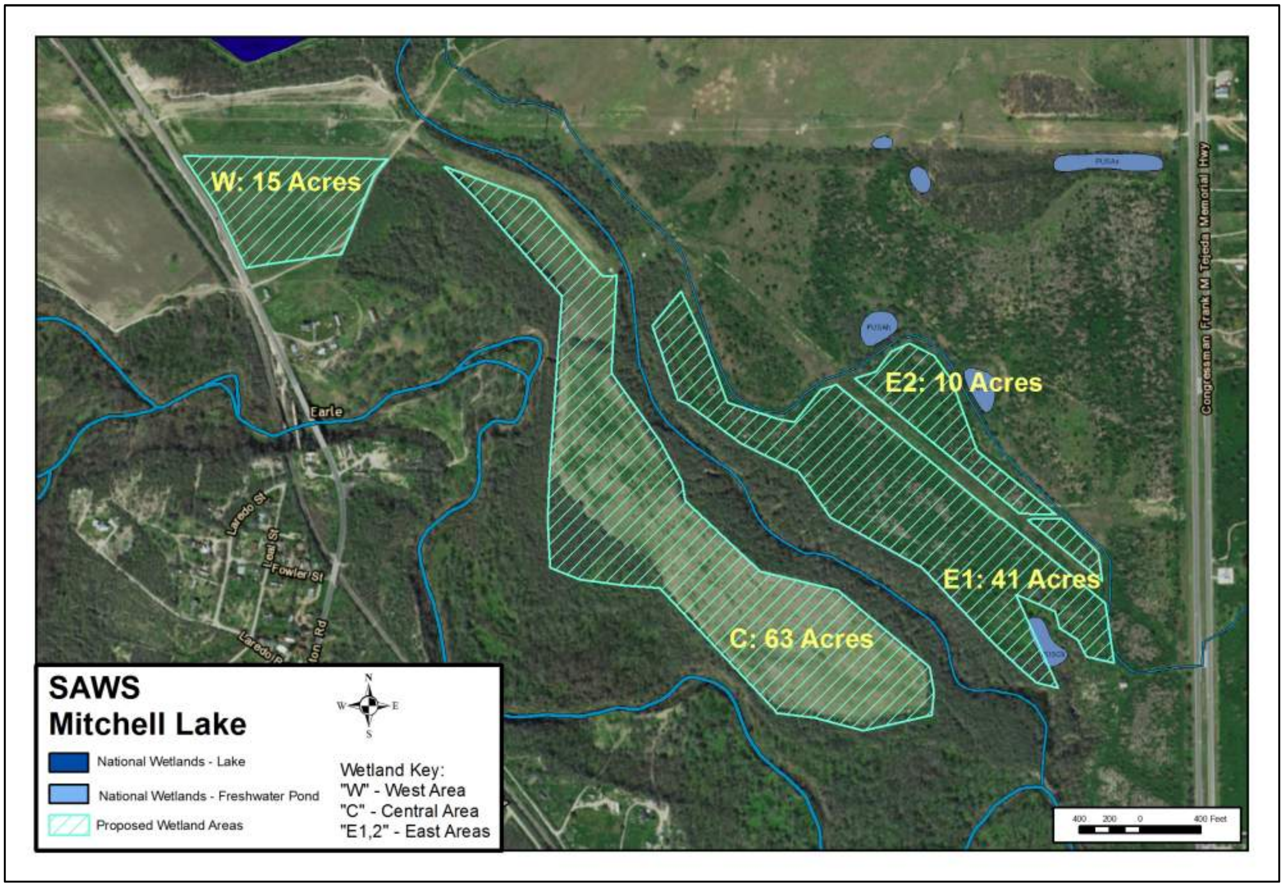

FIGURE 4 – National Wetlands Inventory Map (USFWS)

4E. Groundwater/Springs

Geotechnical data reviewed did not indicate perched shallow groundwater or natural springs in or near the land proposed for the wetlands. However, a geotechnical investigation specific to the area proposed for the wetlands would need to be conducted to confirm the presence or absence of perched groundwater or springs

TCEQ prohibits treatment units from being located within the recharge zones of major or minor aquifers as defined by the Texas Water Development Board (TWDB), unless the treatment units are lined [§309.13(a)]. Since the constructed wetlands would need to be lined in order to meet §217.203 (d) or (e), this requirement would be satisfied.

4F. Wells

Based on data from the Texas Railroad Commission[5], it appears that one dry hole exists within the footprint of wetland tract E1 (see Figure 5). If properly abandoned, the dry hole should pose no threat to groundwater. Should development of the wetland proceed, this area should be inspected to confirm that

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[5] http://wwwgisp.rrc.texas.gov/GISViewer2/

no open holes exist. If one is found, it should be corrected in accordance with Texas Railroad Commission procedures. Lining of the wetland would provide further protection of groundwater.

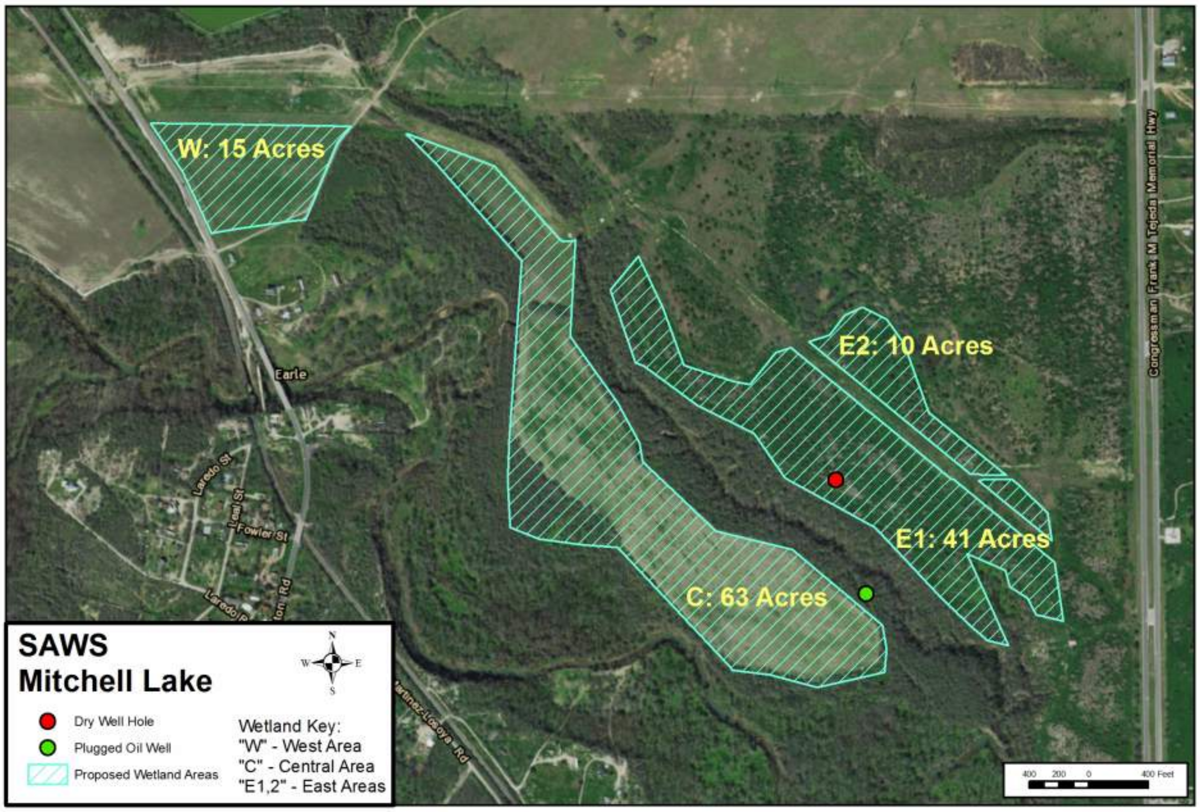

FIGURE 5 – Oil & Gas Well Locations

TCEQ prohibits wastewater treatment units from being located within 500 feet of a public water supply well or 250 feet from a private well [§309.13(c)]. The TWDB groundwater well database[6] indicates that there are no public or private wells within 500 feet of the area proposed for the constructed wetlands. This finding should be confirmed with on-site reconnaissance.

4G. Property Line Set-Backs

TCEQ requires a 150-foot buffer zone between treatment units without zones of anaerobic activity and the nearest property line [(§309.13(e)(1)]. Much of the area proposed for the constructed wetland is located beyond 150 feet from the nearest property line. However, wetland tract W adjoins property owned by Mariano and Charlotte Perez to its south. The Perez property has occupied structures. It may be possible to obtain a buffer zone waiver from the owners or receive a variance from TCEQ to reduce the width of the buffer zone, due to the low strength wastewater received from the lake. However, for the

[6] http://www2.twdb.texas.gov/apps/WaterDataInteractive/GroundwaterDataViewer/?map=gwdb

purpose of this study, a set-back of 150 feet from the Perez property was used to determine the net area available for the wetlands. This set-back is shown on Figure 6.

4H. Physical Obstructions

The presence of above or below ground obstructions were investigated using desktop methods from public sources. The obstructions that were found included the following: powerline south of the dam; water and sewer pipelines located north of wetland tracts W and C and through wetland tract E; and a gas pipeline easement (width unknown). The locations of these obstructions are shown on Figure 6.

4I. Net Area Available

After adjustments are made for physical obstructions and property line set-backs, approximately 129 acres of suitable area remain for wetland development. Of that area, 85 to 90 percent will be “wetted”, which is the area used for treatment. The remaining 10 to 15 percent will be occupied by embankments, roads, and other non-treatment components. Using 87% of the total area, approximately 112 acres should be available for treatment. The net area available for wetlands development is shown in Figure 6.

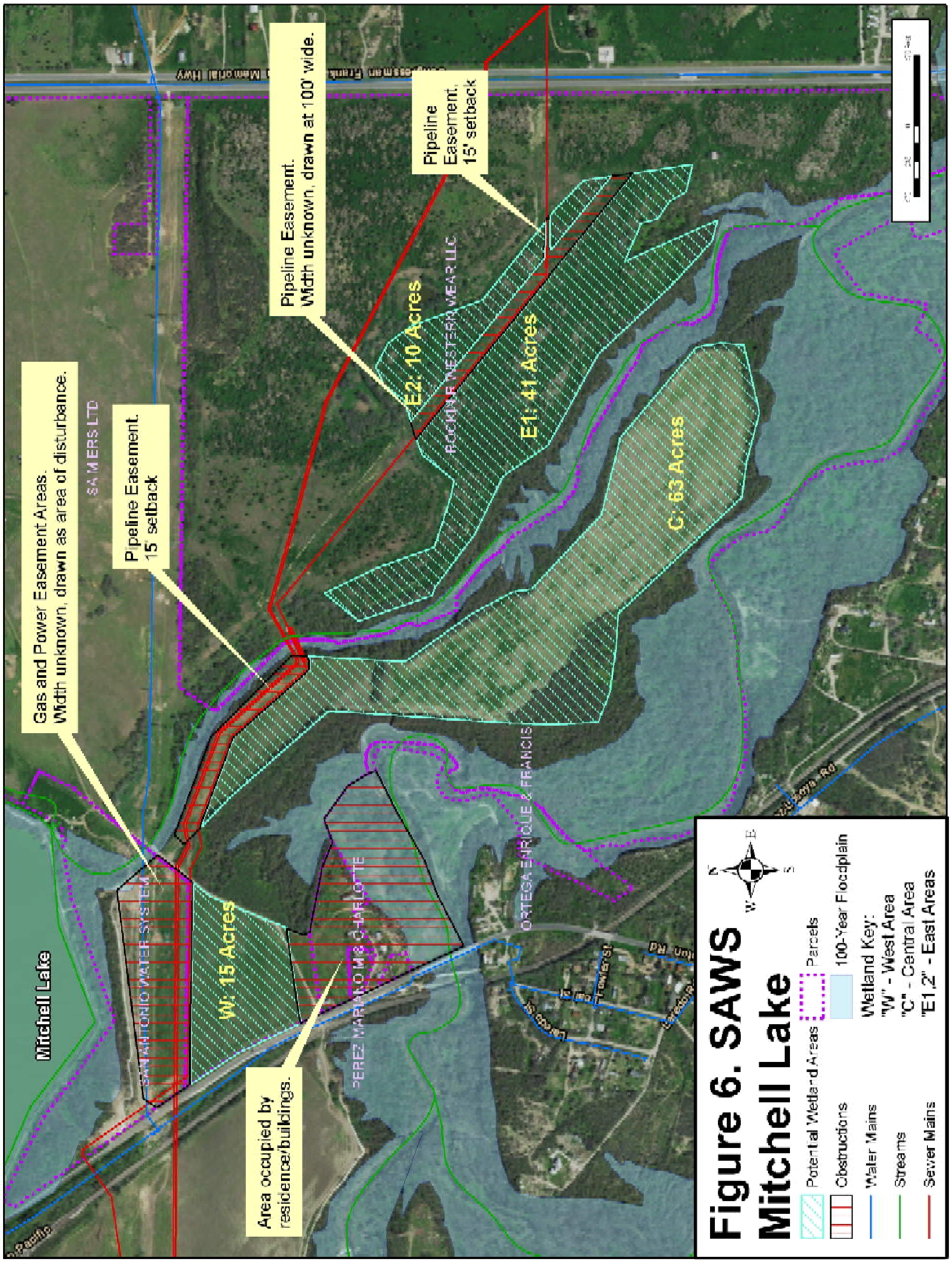
Figure 6. SAWS
Mitchell Lake
Potential Wetland Areas
Obstructions
Water Mains
Streams
Sewer Mains
Parcels
100-Year Floodplain
Wetland Key:
"W" - West Area
"C" - Central Area
"E1,2" - East Areas
Mitchell Lake
W: 15 Acres
C: 63 Acres
E1: 41 Acres
E2: 10 Acres
Gas and Power Easement Areas.
Width unknown, drawn as area of disturbance.
Pipeline Easement.
15' setback
Pipeline Easement.
Width unknown, drawn at 100' wide.
Pipeline
Easement.
15' setback
Area occupied by
residence/buildings.
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5 Discharge Quality Requirements

If constructed wetlands are added downstream of the lake, this will constitute the addition of a treatment unit to the facility and trigger a major amendment to the TPDES permit. When a permit is amended, typically TCEQ updates the water quality model for the receiving streams to determine if revisions to receiving streams are appropriate. The receiving streams in this case are Cottonmouth Creek and the Medina River. In addition, the permit would be amended from an intermittent discharge to a continuous discharge. These changes can be expected to result in revised permitted effluent quality limits. The existing permit limits are shown in Table 1 for reference.

Table 1. Existing Effluent Limits for Mitchell Lake

Parameter [a]	**Existing Permit** [b]
Flow	monitor
BOD_5, mg/L	30
TSS, mg/L	90
Ammonia, mg/L	N/A
DO, mg/L	> 4
pH, SU	6 - 9

a. Partial list of permit effluent parameters.
b. Daily average.

In order to identify the possible effluent limits that the constructed wetland would need to meet, the stream water quality model for the Medina River was obtained from TCEQ and an analysis was performed using various discharge rates from the proposed constructed wetlands. The existing Medina River model was used as provided and not revised to update the model or to provide more site-specific values. Flow rates of 4 and 15 million gallons per day (MGD) were used to bracket an assumed lower and upper bound for flow through the wetlands. Modeling efforts resulted in two potential sets of effluent quality limits that could be applied: 10 mg/L BOD_5, 4 mg/L ammonia, 5 mg/L DO; or 15 mg/L BOD_5, 3 mg/L ammonia, and 5 mg/L DO. It may be desirable to refine the model once the wetland flow rate is better defined, especially if the effluent limits will be difficult to achieve.

6 Ability of Wetlands to Meet Water Quality Requirements

This section presents a summary of historic water quality data for Mitchell Lake and a discussion of modeled outflow water quality from a wetland downstream of the dam.

6A. Mitchell Lake Water Quality

Water quality data for the lake is limited. Reports by the Simpson Group (1996, 1997) provide water quality data from several locations within the lake and polders. While representing several locations, these data are very limited in that this represents only one point in time. The quality of the lake would be expected to vary substantially based on seasonality, the amount of rainfall runoff entering the lake, the volume of water from LCWRC, and other factors. Furthermore, the data represent the condition of the lake 20 years ago. However, it is the most comprehensive data set currently available.

When the lake discharges, SAWS analyzes samples of the discharge for BOD_5, TSS, DO, and pH in accordance with the requirements of the TPDES permit. Water quality data for these constituents have been provided by SAWS for the period of May 2013 through July 2016. Table 2 is a summary of water quality data provided in the report by the Simpson Group (1997) and water quality data provided by SAWS. The values from the Simpson Group are the average of the samples taken at all locations in the lake. SAWS values are the average of the data provided. SAWS samples were taken during discharge events only.

Table 2. Mitchell Lake Water Quality

Parameter	Value	
	Simpson Data [a]	SAWS [b]
BOD_5, mg/L	40	25.5 (n=217)
TSS, mg/L	138	114.1 (n=218)
Volatile Suspended Solids, mg/L	108	N/A
Total Phosphate, mg/L P	1.1	N/A
Total Nitrogen, mg/L N	15.5	N/A
Total Kjeldahl Nitrogen, mg/L N	15.4	N/A
Organic Nitrogen, mg/L N	15.4	N/A
Ammonia, mg/L N	< 0.1	N/A
Nitrate, mg/L N	0.05	N/A
Total Dissolved Solids, mg/L	1,450	N/A
DO, mg/L	0 – 20	7.8 (n=219)
pH, SU	9.4	8.7 (n=219)

a. From The Simpson Group, 1997

b. SAWS, 5/2013 – 7/2016.

Another report from The Simpson Group (May 1996) provided analytical results for the concentrations of the various nitrogen species in filtered and unfiltered samples. Notably, virtually all nitrogen in the water is in the form of organic nitrogen. Of the organic nitrogen, approximately 60% is in particulate form and 40% dissolved. This breakdown of nitrogen is representative of algal-dominated, eutrophic lake water. The nitrogen data are summarized in Table 3.

Table 3. Mitchell Lake Nitrogen Data [a]

Species	Concentration	Percent of Total N
Total Nitrogen, mg/L	15.0	100%
Organic Nitrogen, mg/L	~ 14.95	~99%
Particulate Organic Nitrogen, mg/L	9.0	~60%
Dissolved Organic Nitrogen, mg/L	6.0	~40%
Nitrate, mg/L as N	0.05	<1%
Ammonia, mg/L as N	< 0.1	<1%

a. Mitchell Lake Intake Structure and Booster Station Project: Technical Report No. 2 Water Quality Data Collection, Simpson Group, May 1996

6B. Quality of Wetland Discharge

This section presents modeled wetland outflow water quality based on the historic Mitchell Lake water quality data. Potential modeled outflow concentrations are presented for BOD_5, TSS, and ammonia. Outflow pH and DO concentrations are also discussed.

Because wetlands are "open" systems, they are heavily influenced by environmental factors. The models used to estimate outflow water quality provide a central treatment tendency with respect to outflow concentrations, but they do not sufficiently capture the anticipated variability away from the central tendency caused by random environmental factors. The results presented below include adjustments intended to account for some of the expected variability.

Furthermore, special challenges were encountered in estimating outflow ammonia concentrations. The kinetic models typically used to estimate the transformation and removal of nitrogen from wetland systems were based on large data sets where water quality included a significantly different distribution of N species. Studies on wetland systems treating water dominated by organic N are very limited. As such, universally accepted reaction rate constants specific to these systems are not available.

i. BOD_5

The quality of the wetland discharge for BOD_5 was estimated using the relaxed Tanks-In-Series (TIS) concentration model (Kadlec and Wallace, 2009):

$$\left(\frac{C_O - C^*}{C_i - C^*}\right) = \frac{1}{\left(1 + {k}/{Pq}\right)^P} \qquad \text{Equation 1.}$$

Where:

C_o = outflow BOD_5 concentration, mg/L
C_i = inflow BOD_5 concentration, mg/L
C^* = irreducible background BOD_5 concentration = 2 mg/L
k = first-order areal rate constant for 50^{th} percentile of FWS wetlands = 33 m/yr
P = apparent number of TIS = 3
q = hydraulic loading rate, m/yr

The values for C*, k, and P are standard values taken from Kadlec and Wallace (2009). The term C_o represents the outflow concentration from the wetland. It should be noted that this represents the long term central tendency or average outlet concentration. However, as noted above, there is an inherent variability in the quality of effluent discharged from natural treatment systems due to random physical and environmental events. For example, when outlet data from a constructed treatment wetland is plotted, it will typically have a "scatter" pattern around a general trend line, representing the mean of the data. The trend line may also display some degree of sinusoidal behavior through the course of a calendar year, reflecting seasonal effects. Based on the probability distribution of effluent concentrations, it is possible to determine a multiplier (C_o/C_{median}) associated with a given percentile of the effluent distribution. These multipliers are often used when evaluating probable compliance with an effluent limit. Accordingly, this approach is being used in the analysis of the constructed wetlands for Mitchell Lake. The target effluent concentration is calculated using a "trend multiplier" that would cover 90% of all the excursions expected above the median effluent concentration. For example, the 90% excursion frequency trend multiplier for effluent BOD_5 in FWS wetlands is 1.56[7]. This means that in one month out of ten, one could expect a BOD_5 concentration that is 1.56 times higher than the long-term mean value. To comply with a BOD_5 limit

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[7] Kadlec, R. and Wallace, S. Treatment Wetlands, CRC Press 2009. Table 8.6.

of 30 mg/L, one would use a target outflow concentration of 19.2 mg/L (30/1.56) and solve for the design hydraulic loading rate, q. Table 4 shows the existing and potential permit limits for BOD_5, the target outflow concentration and the flow rate calculated to meet the target outflow concentration, based on an inflow BOD_5 of 26 mg/L and using a treatment area of 112 acres.

Table 4. Maximum Flow Rates through the Wetland to Meet Various Permit Limits for BOD_5

BOD_5 Permit Limit, mg/L	Trend Multiplier Applied	Design Outflow Target, mg/L	Maximum Flow Rate, MGD
30	1.56	19.2	20
15	1.56	9.6	7
10	1.56	6.4	4

ii. TSS

FWS constructed wetlands are generally effective in filtering TSS. However, due to natural cycling within the system, FWS wetlands will always have some level of background TSS being discharged. Because of the presence of TSS background concentrations, percent removal is an inadequate measure for many treatment wetlands. Some TSS removal efficiencies may actually be negative where pretreatment includes removal of TSS prior to the wetland. Kadlec and Wallace (2009) recommend using an input-output regression relationship for TSS as shown in Equation 2.

$$C^* = C_o = 1.5 + 0.22C_i \qquad \text{Equation 2.}$$

Where:
C^* = Irreducible background concentration for TSS, mg/L
C_o = Outlet concentration for TSS, mg/L
C_i = inlet concentration for TSS, mg/L

Using an inflow concentration of 114 mg/L for TSS, the resulting outflow concentration is estimated to be 27 mg/L. As with the BOD_5 calculation, this represents the long-term mean. To account for inherent variability, a trend multiplier is applied. The 90^{th} percentile trend multiplier for TSS is 2.21, so the wetland should reliably meet a permit limit of 60 mg/L for TSS (27 x 2.21). It should be noted that TCEQ does not use a model to determine permitted effluent quality limits for TSS. The current limit of 90 mg/L is the technology-based limit for a pond system. The case should be made to TCEQ that the lake and constructed wetlands are a pond system and the 90 mg/L limit should be retained.

It is further noted that certain measures can be taken in design that can help reduce TSS and improve reliability in meeting this parameter. This includes having minimal open water areas near the outflow (to reduce algal production) and maintaining very shallow (6 to 12 inches) water within the marsh areas.

iii. Ammonia

The transformation within and removal of nitrogen from constructed wetland systems can occur via various processes including nitrification-denitrification, mineralization, sedimentation, resuspension, diffusion, sorption, assimilation, and volatilization. There is a large body of work that has studied N removal dynamics within wetland systems treating various water sources. However, very few studies have been performed on wetland systems whose primary purpose is treating eutrophic lake water.

As previously shown in Table 3, virtually all N in the eutrophic water from Mitchell Lake is in the form of organic N, with 60% present as particulate organic N (PON) due to photoplanktonic algae. FWS wetlands with adequate hydraulic residence time (approximately 5 to 7 days) and good emergent vegetation coverage will generally capture and filter incoming algae, but as the algae dies, settles, and undergoes decomposition, dissolved organic N will be released into the water column and will then be subject to ammonification and eventual transformation to ammonia. Ammonia formed within the system can then be removed via some of the pathways mentioned above, but the rates at which the ammonia is produced from algae break-down and removed from the system are unique to each of the few wetland systems that exist for the purpose of polishing eutrophic lake water. For example, a 9 hectare (22.2 acres) pilot system in Spain had removal rates of 52% and 64% for TN and ammonia, respectively[8]. In contrast, the Lake Apopka Marsh Flow-way in Florida, a 276 hectare (682 acres) FWS wetland with 4 cells, had a removal rate of 24% for TN, but released ammonia (negative removal) at a rate of 21 g N/m^2-yr[9]. There are several reasons for the broad difference in ammonia removal rates between these two systems, but this illustrates the uniqueness of various systems.

Of the studies reviewed, the Marsh Flow-way system at Lake Apopka appears to provide the most useful information. Although the concentration of TN in Lake Apopka is about one-third that of Mitchell Lake (4 mg/L and 15 mg/L TN, respectively), the speciation of nitrogen is very similar in that 60% of TN is in the form of PON, with very little ammonia or nitrate in the water entering the wetlands. Furthermore, the climate of the Florida system is more similar to central Texas than the other wetland systems that have been found in the literature that treat eutrophic lake waters (China[10], Spain, and Norway[11]). For these reasons, the Lake Apopka Marsh Flow-way system is used to estimate potential ammonia outflow concentrations for the proposed Mitchell Lake constructed wetlands.

For this evaluation, it has been assumed that the mass removal rates for PON, TN and NH_4-N occurring in the Mitchell Lake constructed wetlands will be similar to those observed at the Lake Apopka Marsh Floodway and that the hydraulic loading rates would be managed in a similar fashion. Lake Apopka data used in the analysis were as follows: a PON areal mass removal rate of approximately 60 g/m2-yr, a percent PON concentration removal of approximately 80%, and a PON rate constant of 85 m/yr. After estimating PON reductions in the Mitchell Lake water, the ammonia release rate from Apopka was applied to estimate outflow concentrations for ammonia. After calculating the outflow concentrations, a factor of 1.5 was applied to the higher value in the range to account for expected excursions.

Two flow rates were used in the modeling for ammonia, 4 and 15 MGD, which correspond to the discharges used in the stream quality modeling. The results of the modeling suggest that ammonia concentrations ranging from 2.0 mg/L to 5.3 mg/L could be achieved with a flow rate of 4 MGD. Modeling

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[8] Martin, M. et al. The use of Free Water Constructed Wetland to Treat the Eutrophicated Waters of Lake L'Albufera de Valencia (Spain). Ecological Engineering 50 (2013) 52-61.

[9] Dunne, Ed J., et al Nitrogen Dynamics of a Large Scale Constructed Wetland Used to Remove Excess Nitrogen from Eutrophic Lake Water. Ecological Engineering 61 (2013) 224-234.

[10] Wang, G.., A Mosaic Community of Macrophytes for the Ecological Remediation of Eutrophic Shallow Lakes. Ecological Engineering 35 (2009) 582-590.

[11] Braskerud, B.C. Factors Affecting Nitrogen Retention in Small Constructed Wetlands Treating Agricultural non-Point Source Pollution. Ecological Engineering 18 (2002) 351-370.

further suggests that ammonia concentrations of 0.8 mg/L to 4.5 mg/L could be achieved with a flow rate of 15 MGD. The lower ammonia concentration at the higher flow rate is presumably the result of a shorter hydraulic residence time within the system, providing less time for settling of particulate organic N (algae) and conversion to ammonia.

It is emphasized that there is a degree of uncertainty in these results, due to the lack of wetland systems treating water substantially similar to that found in Mitchell Lake. Furthermore, the modeling results for BOD_5 suggest that 4 to 7 MGD would be appropriate, but those performed for ammonia suggest higher flow rates may be acceptable. A pilot study would be necessary to identify the appropriate flow rate necessary to achieve the best discharge quality and identify whether the constructed wetland system could meet the potential effluent limits.

iv. pH and DO

Constructed wetland systems tend to normalize pH from upstream sources. It is anticipated that the proposed wetland could meet the pH requirements of an amended permit, which would be 6 to 9 SU.

Outflow DO concentrations in constructed wetland systems can vary widely from less than 1 mg/L to more than 9 mg/L. For systems with low DO, a cascade at the outflow can typically provide the increase in DO needed to meet a potential permit limit of 5 mg/L. Again, conducting a pilot study would be helpful in identifying expected outflow DO concentrations.

7 Other Considerations

This section presents additional considerations related to implementation of constructed wetlands below the dam.

7A. Impact on Other Permits

If the Mitchell Lake TPDES permit is amended and revised effluent volumes and quality are proposed, it is likely that TCEQ will reassess the appropriate effluent limits for the DRWRC. Depending on the volume of the permitted discharge from the Mitchell Lake constructed wetlands, there could be a significant increase in the background load of BOD_5 and NH_3-N at the point of the DRWRC discharge, which could result in more restrictive permit limits. Also, re-evaluation of Mitchell Lake, in general, could result in a re-evaluation of the permit limits for the LCWRC during the next permit renewal cycle. However, the LCWRC permit might be the subject of a re-evaluation in any case. It is recommended that, after a discharge volume is identified for the constructed wetlands, the model for the DRWRC discharge be obtained; a lake model be developed for Mitchell Lake; and potential impacts on permitted effluent quality limits for LCWRC and DRWRC be determined.

7B. Gravity Flow to the Wetlands

Merrick and Company (2015) developed conceptual dam cross sections and spillway configurations that could be employed to reduce discharges from the lake for storms whose frequency of occurrence greater than once in 100-years. The basis for the concept spillway capacities and dam geometry included a starting water surface elevation of 517.5 feet when considering the 100-year storm detention. It is assumed that this elevation would be the normal operating level for the lake and that the elevation would be maintained through pumping of supplemental water from the LCWRC or by discharges from the lake following storm events. Therefore, the water level within the lake should never fall below 517.5 feet. LIDAR data from SARA indicate elevations on the land proposed for the constructed wetlands range from approximately 514 feet to 509 feet. Based on this information, it appears that gravity flow to the wetlands is feasible.

7C. Managing Storm Flows

The proposed project envisions a lake-wetland system that would operate at a relatively constant flow through the coordinated management of inflows from stormwater runoff and discharges from the LCWRC. During dry weather, flow from the LCWRC would be pumped to the lake to insure lake levels are maintained at 517.5, keeping sediments submerged and reducing the potential for odors to be released from exposed and drying sediments. Some outflow from the lake through the wetlands would occur during the dry-weather scenario in order to maintain the wetland vegetation. Stormwater runoff would be stored temporarily within the lake above the 517.5 elevation and discharged through the wetland over time. The maximum allowable discharge rate through the wetland would be based on the lesser of the hydraulic capacity or treatment capacity of the wetland. For permitted treatment wetlands, treatment capacity is typically the limiting factor. Increased hydraulic loading rates from storms can be accommodated by appropriately-sized flow conduits and temporary storage within the wetland itself. However, as described above, while there is uncertainty in accurately modeling the treatment performance of a FWS wetland treating water dominated by planktonic algae, it appears the maximum flow rate through the wetland may need to be limited to between 4 to 7 MGD to achieve permit compliance.

A preliminary water balance model was developed to explore how management of stormwater inflows to the lake could affect performance of the constructed wetland. The model assumed a continuous inflow ranging between 4 and 7 MGD to the wetlands and used storage within the lake itself for management of runoff. Historical daily precipitation and evaporation data were utilized along with data from the LCWRC to account for water added to the system. Storage within the lake was estimated using the stage-storage relationships described in the Merrick Study (2015). Daily time-steps were used in the model. During calibration of the model, the modeled discharges did not correlate well with the discharges reported by SAWS. A more detailed examination of reported discharges and management of stormwater within the lake should be done in conjunction with identifying the optimal flow rate through the constructed wetlands to achieve water quality improvement.

7D. Variability of Discharge Quality

As described above, there is an inherent variability in the quality of the water discharged from FWS constructed wetlands used for treatment. Seasonal variations, wildlife impacts, and other factors can influence the treatment performance and outflow quality. Routing large storm flows through the wetland will also affect treatment performance. The random variations occurring in natural systems coupled with the uncertainty of kinetic modeling for algal dominated water may be problematic for consistently meeting TPDES permit limits. As previously noted, a pilot study is needed to better characterize performance and variability.

7E. Continuous Effluent Monitoring

If the facility is permitted as a continuous discharge greater than 1 MGD, TCEQ will require continuous flow measurement and frequent collection of samples to determine effluent quality. Electrical power and instrumentation would be required at the wetland outfall for flow and quality monitoring. Furthermore, the available land parcels for the constructed wetlands are not contiguous, resulting in three separate wetland areas. It may be possible to pipe outflows from two of the areas to the third to avoid multiple outfalls, but this would need to be confirmed through further study.

7F. Federal Aviation Administration Coordination

In Advisory Circular No. 150/5200-33B, the Federal Aviation Administration (FAA) provides guidance on certain land uses that have the potential to attract hazardous wildlife on or near public-use airports. The FAA considers “artificial marshes” to be bird attractants and recommends the construction of any new wetlands to be at least 5,000 feet from the nearest air operations area for airports serving piston-powered aircraft. The nearest airport to the proposed wetland site is Horizon Airport, located just west of Mitchell Lake. The distance from the south end of the runway to the closest wetland area is approximately 4,900 feet. The FAA would require a review of the plans for the proposed wetland.

8 Summary and Recommendations

The findings related to the primary objectives of this feasibility study are summarized as follows:

- Approximately 129 acres of land below the dam appears to be suitable for development of a FWS constructed wetland system. A geotechnical subsurface investigation would need to be conducted to confirm whether the in-situ soils would meet the TCEQ liner criteria and the presence or absence of shallow groundwater.

- The land proposed for constructed wetland development is lower than the 517.5 operating level proposed for the lake in the 2015 Merrick study. This would allow for gravity flow from the lake to the wetlands.

- Adding constructed wetlands below the dam would trigger a major amendment to the TPDES permit for Mitchell Lake. In doing so, the stream quality modeling associated with amending the permit will result in more restrictive limits on Mitchell Lake and could potentially impact the permits for the LCWRC and the DRWRC.

- Initial stream modeling efforts indicate an amended permit would decrease the effluent limits for BOD_5 from 30 to either 15 or 10 mg/L. It is also likely that an ammonia limit of 3 or 4 mg/L would also be imposed. Ammonia would be a new regulated constituent. Meeting potential permit limits for TSS, pH and DO should be manageable.

- Preliminary kinetic modeling of the wetland indicates a maximum flow rate of 4 to 7 MGD through the wetland would be needed to meet a BOD_5 limit of 10 to 15 mg/L. Estimated average outflow concentration for TSS is approximately 27 mg/L. Kinetic modeling for degradation of PON and subsequent transformation to ammonia within a Mitchell Lake wetland is not well established due to the limited number of studies conducted on wetland systems treating eutrophic lake water. Studies conducted on the Lake Apopka Flow-way wetland system in Florida appear to provide the most useful information in estimating outlet ammonia concentrations for a constructed wetland system at Mitchell Lake. Applying removal rates similar to those achieved at Lake Apopka results in an estimated range of ammonia concentrations from 0.8 to 5.3 mg/L for flows between 4 and 15 MGD.

- The ability to pass storm flows through the wetland will be limited by the system's treatment capacity and its ability to satisfy permit limits during higher flow events. Hydraulic conveyance is likely not the limiting factor. Storage of storm surges within the lake itself would help mitigate high flows through the wetland, but would extend the duration of flows from the system. A detailed site-specific water balance is needed to determine whether flow rates can be maintained at 4 MGD to 7 MGD during periods of extended rainfall or very large rainfall events.

The evaluations conducted for this study indicates a significant potential that constructed wetlands can be used to improve the quality of discharges from Mitchell Lake. However, this study has been conducted using only currently available information. There are areas of significant uncertainty regarding the potential performance of the constructed wetlands. The following studies are recommended to reduce these uncertainties prior to making a decision whether to construct a full-scale constructed wetland system:

- Conduct a study utilizing a pilot scale wetland system. This study would provide data to better determine whether the proposed wetland system could meet the current and/or future effluent limits. The pilot study would entail constructing multiple wetland cells and operating different sections of the system at different hydraulic and mass loading rates. Additional water quality data would be needed from Mitchell Lake. The pilot study should be operated for a period of at least one year after the vegetative cover has matured in order to capture seasonal changes and collect enough data for meaningful analysis.

- Conduct a detailed water balance study. This study would be performed to identify the ability of the lake to moderate storm flows to the wetland system through temporary storage of runoff above the 517.5 normal operating level proposed in the Merrick study. The results of this study would help refine the range of flow rates expected through the wetland and subsequently provide better estimates of outflow quality.

- Update the TCEQ receiving stream models to determine the potential impact of a continuous discharge from Mitchell Lake on the permit limits for LCWRC and DRWRC.

9 Appendix

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- SAWS Interoffice Memorandum from Steve Clouse to Diane Westfall. Subject: Analytical Testing at Mitchell Lake Wetlands. October 3, 1994.
- SAWS Memorandum from L. D. Westfall to Mitchell Lake Data Users. Subject: Complete Report. December 9, 1994.
- SAWS letter from Steven Clouse to Judy Edelbrock (US EPA Region 6) Re: AO Docket No. CWA-06-2016-1770. September 15, 2016.
- Technical Report No. 2 Water Quality Data Collection; Mitchell Lake Intake Structure and Booster Station Project (Draft). Simpson Group. May 1996.

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- Texas Commission on Environmental Quality Agreed Order Docket No. 2011-2034-MWD-E. May 31, 2012.
- Texas Commission on Environmental Quality Texas Pollution Discharge Elimination Permit No. WQ0010137003; Leon Creek Water Recycling Center. Issued October 7, 2015.
- Texas Commission on Environmental Quality Texas Pollution Discharge Elimination Permit No. WQ0010137004; Mitchell Lake Site Wastewater Treatment Facility. Issued October 7, 2015.
- United States Environmental Protection Agency Administrative Order Docket No. CWA-06-2016-1770 NPDES Permit No. TX0065641. August 12, 2016.
- Wastewater Treatment Annual Report City of San Antonio, 1970.
- Excel spreadsheet – daily volumes of LCWRC water pumped to Mitchell Lake and Golf Course.