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CUSTOMER CONCEPT DOCUMENT
FOR UPGRADING THE
WASTEWATER TREATMENT PLANT

Beale Air Force Base

FINAL

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ACRONYMS AND ABBREVIATIONS

ACC	Air Combat Command
AFB	Air Force Base
AxRS	anoxic return sludge
BEHP	bis(2-ethylhexyl)phthalate
BOD	biochemical oxygen demand
CCB	chlorine contact basin
CCD	Customer Concept Document
Cl	chlorination
DBCM	dibromochloromethane
DBP	disinfection byproduct
dN	denitrifying or denitrification
DSE	disinfected secondary effluent
ft	feet
gpm	gallons per minute
HRT	hydraulic retention time
HQ	Headquarters
H_2SO_3	sulfurous acid
HWK	headworks
LBD	land-based discharge
M	million
mgd	million gallons per day
mg/L	milligrams per liter
mgy	million gallons per year
mL	milliliter
MLSS	mixed liquor suspended solids
MPN	Most Probable Number
msl	mean sea level
N	nitrogen
N_2	nitrogen gas
NaOCl	sodium hypochlorite
ND	not detected
NH_4-N	ammonia nitrogen as N
NO_3-N	nitrate nitrogen as N
NPDES	National Pollutant Discharge Elimination System

ACRONYMS AND ABBREVIATIONS (Continued)

NTU	nephelometric turbidity unit
O_2	oxygen
OCF	oxidation, coagulation and flocculation
PAB	post aeration basin
PC	primary clarifier
PE	primary effluent
Pri	primary
P/S	pump station
RSS	return secondary sludge
SC	secondary clarifier
SCB	solids contact basin
SCE	secondary clarifier effluent
SE	secondary effluent
Sec	secondary
SO_2	sulfur dioxide
SRT	solids retention time
SWW	screened wastewater
TDS	total dissolved solids
TF	trickling filter
TFR	trickling filter recirculation
TFU	trickling filter underflow
TF/SC	trickling filter solids contact
THM	trihalomethane
TPH	total petroleum hydrocarbons
TSS	total suspended solids
URS	URS Group, Inc.
UV	ultraviolet
VSS	volatile suspended solids
W	watts
WDR	waste discharge requirement
wss	waste secondary solid
WTP	water treatment plant
WWTP	wastewater treatment plant
°C	degrees Celsius
µg/L	micrograms per liter

1.0 SUMMARY – CUSTOMER CONCEPT DOCUMENT

The following is a summary of the information presented in the Customer Concept Document (CCD):

- **SECTION 2 – INTRODUCTION**

  The existing in Beale Air Force Base (AFB) Wastewater Treatment Plant (WWTP) is an aged facility that requires upgrading in order to bring wastewater discharges into full compliance with existing and anticipated future water quality regulatory permits. The wastewater treatment plant currently is regulated under permit to discharge to Hutchinson Creek, a golf course and to a 40-acre irrigation field. In the future, the Base has plans to develop a recycled water program that will allow reclaimed effluent to be used to irrigate additional landscaped or recreational areas where human access is not restricted.

  The scope of this study was to develop a cost-effective method of modifying, repairing or replacing the existing WWTP to comply with current and future permits. An initial cost target for upgrading the infrastructure was $1.5 million was established. A secondary cost target of $3.0 million was established if human health or safety issues could be shown to exist.

- **SECTION 3 – EXISTING SYSTEM AND COMPLIANCE STRATEGY**

  The existing wastewater treatment plant is a conventional rock trickling filter facility as illustrated on the flow diagram on Figure 1-1. Figure 1-2 provides photographs relevant to the main treatment units at the existing plant. Treated secondary effluent from the existing WWTP is disposed of primarily through land-based discharge (LBD). During occasional high flow events, discharge to nearby Hutchinson Creek has been required for short periods of time.

  Wastewater discharge effluent limitations depend upon discharge location (i.e., whether the discharge is to the creek or to land). To achieve certain effluent limitations that will become effective on 1 April 2009 for discharges to Hutchinson Creek, tertiary and/or advanced treatment technology will be required. The effluent limitations that will, perhaps, present the greatest compliance challenge are nitrate nitrogen (NO_3-N), turbidity, disinfection byproducts, and total copper. For discharges to land, effluent limitations are generally less restrictive. However the existing total dissolved solids (TDS) discharge limit may be difficult, if not impossible to achieve because of high background levels of TDS in the groundwater. In addition, nutrients (such as nitrogen) must be controlled so there is no adverse impact to the underlying groundwater. Finally, the Base's desire to develop a recycled water system will require that tertiary treatment be installed and that improvements and/or reliability be increased.

  After considering a number of alternatives (see Appendix A) it was concluded that the best method for upgrading the Beale AFB WWTP would be to discontinue (at least for the time being) discharges to Hutchinson Creek. Additional irrigation lands will be identified in order to increase capacity for land-based discharges and to reduce or eliminate potential impacts to groundwater.

- **SECTION 4 – CONCEPTUAL DESIGN**

  The best method for upgrading the Beale Air Force Base wastewater treatment plant is to remove nitrate by modifying the existing trickling filter system to a "trickling filter solids contact" (TF/SC). The solids contact system will include an anoxic reactor designed to remove nitrate. Ultraviolet (UV) disinfection will be added to enhance disinfection and reduce TDS. In the final development of the best method for upgrade, the following changes were made to lower cost and maximize the use of existing equipment/units:

  1. Modify the existing grit channels to a solids contact system that will accomplish partial denitrification (dN).
  2. Install UV vessels in the existing treatment units rather than construct a new equipment vault. Either the existing trickling filter recirculation pump station wet well or the existing chlorine contact basin will house the new UV equipment (exact location to be determined during final design).

  A simplified schematic flow diagram for the Best Upgrade (the completed upgrade described in Section 4.0) is given on Figure 1-3. Figure 1-3 includes the basic project and Bid Options 1 and 2, as described below:

Basic WWTP Upgrade

The following are components of the Base WWTP Upgrade:

1. Recirculation Pump Station – Construction of a new trickling filter recirculation pump station with new recirculation flow pattern.
2. Anoxic Return Secondary Sludge – Modify existing grit channels to accomplish partial denitrification.
3. Return Secondary Sludge Pump Station – A new pump station to transfer settled sludge from the secondary clarifier to the solids contact basin.
4. Methanol Feed System – Installation of a chemical feed storage tank and feed system to supply a carbon source for the denitrification process.
5. Disinfection Facility – A new UV system will be installed to achieve a 2.2 Most Probable Number (MPN) coliform limit. Flows in excess of 2.0 million gallons per day (mgd) will be bypassed to the chlorine contact basin for disinfection. In the future, the existing chlorine contact basin will also be used (after UV disinfection) to further treat reclaimed water prior to a recycled water ("purple pipe") system.

Bid Option 1 – Tertiary Treatment Upgrade

The following are components of the Bid Option 1 (tertiary treatment) Upgrade:

1. Solids Contact Basin – Construct a new contact basin for additional denitirification, enhanced bioflocculation (turbidity reduction) and re-aeration.
2. Effluent Filter Pump Station – A lift station will be installed to transfer either secondary or chemical clarifier effluent to the effluent filters.

3. Effluent Filters – Two 2-disk cloth media filters will be installed to remove particulate solids.

Bid Option 2 – Advanced Treatment Upgrade
The following are components of the Bid Option 2 (advanced treatment) Upgrade:

1. Chemical clarifier – A new 60-foot diameter clarifier with energy dissipating inlet and rapid sludge withdrawal may serve as (1) a secondary clarifier, (2) a chemical clarifier (following the existing secondary clarifier), or (3) as a redundant (standby) secondary clarifier.

2. Chemical Feed System – Construct a chemical feed and storage system for use in effluent polishing.

• SECTION 5 – PROJECT DEMONSTRATION AND EXECUTION
A literature review and consideration of case histories of the trickling filter solids contact (TF/SC) process shows that modifications similar to those considered at the Beale AFB WWTP have been successfully used to upgrade aged trickling filter facilities. However, denitrifying using an anoxic reactor in the return secondary sludge line is an innovative approach that required an independent analysis by a leading expert in nutrient removal. Findings from the independent process review showed that the proposed improvements should produce the desired results. Key factors to success will be in maintaining an adequate solids retention time and in using a carbon source to drive the denitrification process (see Appendix B).

• SECTION 6 – DESIGN AND MANUFACTURER INFORMATION:
Design drawings providing design criteria, layout, piping plans and location of principal structures are provided as Figures at the end of this report. An outline of specifications for components likely to be utilized in the upgrade is provided in Appendix D. Appendix E provides information for the selected equipment that has been supplied by manufacturers.

2.0 INTRODUCTION

2.1 Purpose

The purpose of this study was to investigate and provide solutions to existing and potential future regulatory compliance problems at the Beale AFB WWTP. After identifying issues at the facility, alternatives for correcting the problems were to be developed. A single best process for upgrading the Beale AFB WWTP was to be developed.

The study goal was to provide a concept for upgrading the Beale AFB WWTP in a logical and cost-effective manner.

2.2 Background

Treatment units at the existing Beale WWTP were designed in the early 1940s when redundancy, reliability, and discharge standards varied greatly from modern practices. General issues at the wastewater plant include the following:

- Aged Treatment Units – While the concrete structures appear reasonably sound, a number of pumps and mechanical parts will need to be replaced because of their age.
- Under-Loaded Treatment Units – Being under-loaded may, in some cases, result in improved treatment performance. However, when units become extremely under-loaded, operational problems and poor performance can occur. For example, the light organic loading on the trickling filter allows these units to fully nitrify, resulting in the ability to meet present-day ammonia discharge limits even though the trickling filters were not originally designed for this purpose. Under-loading on the primary clarifier limits the level of biological treatment and solids settling. Under-loading at the post-aeration pond increases the long hydraulic retention time, contributing to algae growth and poor control on effluent suspended solids and chlorine residual.
- Reliability and Redundancy – Reliability requirements for certain types of reuse include standby units. An evaluation will be required to determine whether adequate reliability/ standby exists.

Issues that need to be addressed at the Beale WWTP are also largely dependent upon the disposal option being considered. Following are issues that vary depending on effluent disposal choices:

- Hutchinson Creek: New discharge limits to Hutchinson Creek will become effective on April 2009. Final limits will be more stringent for biochemical oxygen demand (BOD) and total suspended solids (TSS), and an additional limit for turbidity will be imposed. New limits will also be in effect for certain metals and other compounds. Disinfection requirements for surface water discharge dictate that the total coliform bacteria count must not exceed 2.2 MPN per 100 milliliter (mL). Finally, the 2009 permit will require that wastewater be treated by an oxidation/coagulation and filtration or equivalent treatment technology.

  The existing WWTP is lightly loaded, so the future ammonia limit is presently being achieved. However, process changes would need to occur to increase denitrification and thereby reduce nitrate/nitrite limits. Effluent filtration would be required to meet future BOD/TSS standards.

- Irrigation of Restricted-Access Lands – Waste Discharge Requirements (WDRs) for land-based discharges generally have fewer and/or less restrictive effluent limitations than effluent limitations identified in the NPDES permit for discharges to Hutchinson Creek. The WDRs state "The use of irrigation water must comply with the reclamation requirements of Title 22, Division 4, CCR (Section 60301 et seq.) (WDRs Section D.2.). Title 22 criteria for irrigation of restricted-access lands require sufficient disinfection to limit total coliform bacteria to 23 MPN per 100 mL.

  WDRs further state, "Discharge of reclaimed water shall be at agronomic rates consistent with good agricultural practices." for the irrigation field (WDRs Section D.7). Groundwater, therefore, cannot be adversely impacted by irrigation practices. The 2007 Engineering and Operation Plan (Earth Tech, 2007) points out that "a potential permit violation exists for over irrigation of the nitrate laden, treated wastewater above agronomic rates." Therefore consideration must be given to: denitrification, increasing the irrigation field size, changing crop/management practices or other actions.

- Unrestricted Irrigation – Achievement of Title 22 criteria for unrestricted access uses will likely be required for future irrigation applications of recycled water to landscaped areas and the O'Malley Ball Field. These criteria require the effluent to be "disinfected tertiary recycled water" equivalent to requirements for discharge to Hutchinson Creek. In addition, either a coagulation system must be added or the filtered effluent turbidity must not exceed 2 nephelometric turbidity units (NTUs) (existing wastewater effluent generally exceeds 10 NTUs); and the total coliform bacteria count must not exceed 2.2 MPN per 100 mL.

2.3 Scope of Work

The Scope of Work for this portion of the Wastewater Discharge Compliance Evaluation includes the following:

The contractor shall propose, test and develop a CCD for cost-effective, fully compliant WWTP modification/repair/replacement. Primary cost target for new treatment process infrastructure (such as tertiary treatment filtration, etc.) design-build is less than $1.5 million; secondary cost target is less than $3 million, if imminent threat to human health and safety can be shown. Contractor's conceptual design and cost estimate should clearly delineate new infrastructure from their repair or modification of existing infrastructure.

Modification or repair of existing infrastructure (pumps, bar screens, grit chambers, etc.) will be funded separately and does not fall under the cost cap. Modification/repair/ replacement can be any single, or multiple components of treatment processes, wastewater discharge or storage.

The contractor shall demonstrate efficacy of any proposed treatment process through bench-scale tests. *(A combination of site visits and bench-scale testing may be used to demonstrate performance and assess operability issues.)* The contractor shall provide a full documentation of such tests and submit with a Recommendation Report prior to development of the Conceptual Design.

The contractor shall provide a conceptual level design for approval modification/ repair/ replacement. Conceptual design will be to approximate 30% level and include general specifications for all components, as well as footprint, layout and utility requirements. The contractor shall submit a draft conceptual design document for government review. Upon acceptance of review comment edits and/or additions by the government, the contractor shall submit final conceptual design documents.

The following submittal satisfies the Scope of Work for this portion of the project.

3.0 EXISTING SYSTEM AND COMPLIANCE STRATEGY

3.1 Existing System

3.1.1 Background

The existing Beale AFB WWTP (shown on Figure 3-1) is an under-loaded, conventional rock, trickling filter plant, which treats very dilute (low-strength) wastewater of primarily domestic origin. Because of light organic loading, the facility already achieves future ammonia (ammonia as nitrogen [NH_4-N]) limitations for discharge to Hutchinson Creek (Table 3-1). Effluent ammonia concentration generally averages from 0.2 to 0.3 milligrams per liter (mg/L) as NH_4-N, while future discharge limits are estimated at 1.5 mg/L or greater (depending upon water pH and temperature).

Pollutant discharge limitations vary depending on whether the discharge is to Hutchinson Creek, spray irrigation fields, or the golf course. In the future, recycled water (water qualifying for reuse application with limited restriction for public contact) may be developed. Table 3-1 presents a simplified comparison of existing plant effluent (average and maximum) concentrations compared to key pollutants that appear to be limiting under future permit conditions.

3.1.2 Layout of Facilities

The existing Beale AFB WWTP lies on a relatively flat site as shown on Figure 3-2. A prominent site feature is the control building, which is located just west of and between the primary and secondary clarifiers. The existing chlorine contact basin and trickling filter recirculation pump station adjoin the control building.

Although two trickling filters exist (North and South) only the North unit is presently in service. Underflow from the trickling filter is recirculated at the diversion box located west of the North trickling filter. The post-aeration basin is located at the southern portion of the treatment site while sludge or drying beds are located to the west.

Piping is very congested around the existing control building and chlorine contact basin. Open areas are located south of the primary anaerobic digester, primary clarifier, and south trickling filter. There is also a sizable open area between the clarifiers and the trickling filters.

A hydraulic profile for the existing WWTP providing critical water surface elevations and top of wall for key structures is provided on Figure 3-3. It is interesting to note that from the bottom of the air vents in the trickling filter (elevation 98.52 feet mean sea level [msl]) to the water surface level in the secondary clarifier (elevation 95.00 feet msl) there is only difference of 3.52 feet. The difference in elevation from the secondary clarifier water surface to high water level in the post aeration pond (elevation 91.00 feet msl) is 4.00 feet.

When considering upgrading the existing Beale AFB WWTP, these relatively minor differences in elevation between existing treatment units will necessitate careful consideration of hydraulics.

3.1.3 Water and Material Balance

3.1.3.1 Water Balance

The yearly inflow (million gallons per year [mgy]) of domestic wastewater and air-stripper effluent should roughly equal the amount of yearly outflow (note: meter inaccuracies and leakage often amount to 10% or more of true values). As shown on Figure 3-4, the balancing of water flow for 2006 starts with an average domestic wastewater flow (including both domestic sewage and commercial/ industrial waste) of 0.7 mgd (or 253 mgy). Another important water input was the air-stripper effluent (also known as Site 13 Effluent), which averaged 0.35 mgd (129 mgy). The total combined wastewater flow from the WWTP averaged 1.05 mgd (382 mgy). The 382 mgy combined inflow closely matches the measured 367 mgy outflow and is within the 10% accuracy strived for in a water balance.

A water balance prepared by Earth Tech estimates that the annual treated wastewater to be disposed of (after evaporation/percolation from storage ponds) would average 354 mgy. It was proposed in the March 2007 draft *Engineering and Operation Plan* to dispose of 57 mgy on a 40-acre irrigation site (containing 23 acres of wetted area) and 297 mgy on a 120-acre golf course (containing 120 acres of wetted area), as summarized in Table 3-2. The proposed application rate for irrigation is a total of 10.2 feet per year, which includes 91.42 inches per year (7.6 feet) of final treated wastewater and 31.23 inches (2.6 feet) of rainfall. With the current land application area (no expansion of irrigation site), the applied water would be disposed of through evapotranspiration from total crop uptake estimated at 4.4 feet per year (205 mgy) and an estimated 5.8 feet (273 mgy) of water would percolate into the ground (Earth Tech, 2007).

3.1.3.2 Material Balance

The Beale AFB WWTP was originally designed to accommodate loading from the population equivalent of 15,000 persons, with an average dry weather design flow of 1.5 mgd at a peak design flow of 5.0 mgd. The existing rock trickling filter (fixed film reactor) plant has a conventional primary (Pri) and secondary (Sec) clarifier, as shown on Figure 3-1. Disinfection is accomplished through chlorination in a chlorine contact basin. The final WWTP feature is a concrete-lined, post-aeration basin where air-stripper effluent and treated/chlorinated effluent commingle prior to transfer to one of several available disposal options. Dechlorination is achieved by adding a liquid sulfurous acid solution to the post-aeration basin.

Several options are available for the discharge of treated effluent. The discharge of treated effluent to Hutchinson Creek is authorized under an NPDES Permit, but present plans are to maintain the Creek as a secondary or standby disposal method because of stringent effluent limitations. Alternatively, treated effluent can be discharged to one of two irrigation sites: the golf course via the A Street pond, or an irrigation field via Pond 4. Golf course irrigation is currently considered a “restricted access” use of recycled water. Effluent discharged to the 40-acre irrigation field, on the other hand, is regulated pursuant to Title 22 “unrestricted access” of recycled water. Title 22 criteria for irrigation uses of recycled water to “restricted access” areas are less stringent than criteria for unrestricted access areas where direct public contact is allowed. Potential future irrigation options (described in the draft Engineering and Operation Plan [Earth Tech, 2007]) include irrigating unrestricted access areas, including landscape areas within the Base and the O’Malley Ball Field, located at C Street and Doolittle Street in the Cantonment Area.

Solids handling at the WWTP include the return of waste secondary solids (wss) produced in the trickling filter process to the headworks (HWK). Primary/secondary solids are transferred from the primary clarifier to a primary anaerobic digester. Digested solids flow from the primary digester to a secondary digester and then finally are discharged to sludge drying beds.

The existing WWTP is being loaded at approximately 50% of its design hydraulic loading and less than 25% of its original design organic BOD load. The solids handling portion of the WWTP is likely loaded at less than 25% of its original design solids handling criteria because of solids destruction in an under-loaded liquid treatment scheme. Figure 3-5 presents a simplified schematic of key monthly average liquid/solids flows and loading that occurred in 2006 at the Beale AFB WWTP.

3.1.4 Past Performance

A comparison of measured effluent quality to those proposed at future permitted discharge locations is given in Table 3-1. Perhaps the most critical parameter that requires additional removal is nitrate nitrogen (NO_3-N). Discharge to Hutchinson Creek is limited to 10 mg/L NO_3-N. Although disposal of effluent by land application (irrigation/golf/recycled water) has no specific nitrate limitation, the application rate for nitrogen is limited to crop uptake and/or to be controlled so that no adverse impact to groundwater occurs. Since the hydraulic loading to land-based discharge exceeds the need for crop uptake, nitrogen loading should be maintained under the limit for drinking water (10 µg/L NO_3-N).

Denitrification (dN or the removal of NO_3) to less than 7 mg/L NO_3-N (approximately 50% NO_3-N removal) is desirable for discharge to Hutchison Creek or for land based discharge. A goal of 7 mg/L NO_3-N has been chosen by URS for upgrade of the Beale AFB WWTP because of the 10 mg/L NO_3-N limit to Hutchinson Creek and the EPA drinking water criteria where the presence of organic and ammonia nitrogen must be allowed for (in addition to NO_3-N). A goal of 7 mg/L NO_3-N is also reasonable, since reductions greater than 50% require significantly greater pumping and/or chemical addition.

Additional key pollutants to control are associated with a number of disinfection or chlorine related issues. The existing disinfection processes includes the on-site generation of sodium hypochlorite from a salt solution. Contact time is provided by a chlorine contact basin (CCB) with three channels. Chlorine dosage averages 11 mg/L and may be as high as 24 mg/L. Limited data on the treated effluent indicates that the presence of free chlorine (rather than chloramines) is resulting in the production of undesirable disinfection byproducts (DBPs). Principal among the undesirable DBPs are trihalomethanes (THMs). Future discharge limitations for THMs to Hutchinson Creek will include 0.41 micrograms per liter (µg/L) for dibromochloromethane (DBCM) and 0.56 µg/L for bromodichloromethane (BDCM).

Dechlorination is accomplished by generating a sulfur dioxide (SO_2) solution (sulfurous acid [H_2SO_3]) on site and adding the sulfurous acid solution to the edge of the post aeration basin (PAB). The dechlorination system is relatively new; the first SO_2 generator installed at the Base experienced problems with sulfur fumes and concerns over operator safety. At the time of writing this report, a new SO_2 generator has been installed and testing is underway.

Although SO_2 mixing in the PAB is poor, the combination of SO_2 as a reducing agent, algae production, sunlight degradation, and hydraulic retention time (HRT) result in measured chlorine residuals in the PAB effluent of less than 0.1 mg/L (0.1 mg/L is the present reporting limit). Chlorine residual discharge limitations to Hutchinson Creek are 0.01 mg/L (as a four-day average). Lower detection/reporting limits are needed to evaluate compliance with the residual chlorine effluent limitation.

Minimum levels of treatment are required depending upon the disposal option. Discharge to the spray irrigation field or to the golf course requires disinfected secondary (DS) effluent. Future discharge to Hutchinson Creek or the production of recycled water will require a minimum of oxidation, coagulation, and filtration (OCF) or equivalent treatment prior to discharge.

A TDS limit of 350 mg/L (30-day average) has been established for land application options. Regulatory negotiation is required to address TDS because the average background TDS concentration is greater than 300 mg/L. In several of the wastewater treatment steps TDS is added, so the naturally high background TDS makes compliance impossible with standard technology.

Turbidity requirements of 2.0 NTU for discharge to Hutchinson Creek or for the production of recycled water will not be achievable without additional treatment. The ability to predict achievable turbidity values is difficult without full-scale facilities in place. The use of solids contact or tertiary treatment technology will undoubtedly reduce turbidity. However, it is not possible at present to predict whether an effluent of 2 NTU can be achieved without chemical addition.

Finally, an average effluent concentration of 10 mg/L or less of TSS and BOD is required for future discharge to Hutchinson Creek. Conventional tertiary treatment (which includes effluent filtration) should be able to easily achieve the required effluent TSS/BOD limit.

3.1.5 URS WWTP Sampling

Table 3-3 provides laboratory information on key pollutants sampled in May and June 2007 that may affect the Beale AFB WWTP upgrade. The following are observations and comments on the preliminary laboratory results.

TSS: Testing at the CCB indicated that effluent TSS was below the future permit limit of 10 mg/L. In fact, future effluent TSS concentration is expected to be below the permit limit most of the time. However, effluent filtration is required to consistently achieve both the effluent TSS limit and to assure good removal of metals and other particulates that could otherwise cause compliance problems.

NH_4-N: Testing confirmed that the Beale AFB WWTP has a fully nitrified effluent (ammonia has been converted to nitrate). Since the plant is already nitrifying, no further action is required to comply with future ammonia standards.

NO_3-N: Testing showed high NO_3-N concentrations at both the chlorine contact basin and post-aeration basin. Interestingly, there appears to be a significant amount of denitrification occurring in Pond 4. Recent sampling results do not change URS' current thinking as to the appropriate treatment technology for the WWTP upgrade. However, obtaining information on NO_3-N concentration is important in predicting usage of a carbon source (such as methanol, used for denitrification) and for sizing biological reactors/recycle flows.

IMPORTANT:
Present TDS limits for land based disposal are unachievable without extreme measures.

<u>TDS</u>: TDS sampling results confirm that background levels are near or even above permitted limits. Recent testing reaffirms the need to discuss/negotiate TDS limits with environmental professionals having regulatory oversight of the Beale AFB WWTP, if discharge to Hutchinson Creek continues.

<u>Copper</u>: Copper concentrations appear to be high relative to future permit limits. However, additional adsorption of copper will likely occur with treatment plant improvements. These improvements, along with steps to add corrosion inhibitors at the water treatment plant (WTP), are expected to reduce copper to acceptable levels.

<u>BEHP or phthalate</u>: Bis(2-ethylhexyl)phthalate (BEHP) detection levels at laboratories used historically was slightly above the future discharge limit, not allowing a determination of compliance. Future tertiary treatment (filtration, chemical addition, or solids contact) should provide added removal of BEHP from the wastewater treatment plant effluent. Testing facilities capable of detecting levels down to the future discharge standards will be sought.

<u>THMs</u>: DBCM and BDCM both exceeded future permit limits. The recent sampling confirms that DBPs need to be addressed in the current upgrade of the Beale AFB WWTP.

3.2 Consideration of Alternatives

Appendix A presents a Technical Memorandum providing the history of alternative evaluations for upgrading the Beale AFB WWTP.

3.3 Compliance Strategy

If project cost and complexity could be minimized, the Air Force preferred to have the ability to discharge to Hutchinson Creek or develop recycled water options in the future. On the other hand, eliminating the NPDES discharge or not developing recycled water options were considered. Increasing the irrigation field size, or direct use/discharge of Site 13 water were all part of compliance strategies that have been considered.

The following compliance strategies have been selected:

<u>Discharge to Hutchinson Creek</u>: Plans are to discontinue discharge to Hutchinson Creek and eliminate the NPDES permit. This will eliminate concerns over achieving stringent permit limits on THMs, BEHH, and copper.

<u>Direct Use/Discharge of Site 13 Water</u>: Flow from Site 13 consists of reclaimed groundwater and averages 0.35 mgd. Site 13 water can be applied to landscaped areas and in close proximity to human contact with no restrictions or concerns about public health or safety. Therefore plans are to separate Site 13 water from reclaimed domestic water and land apply Site 13 water separately. This will reduce the hydraulic loading to the LBD system and reduce the use of potable drinking water for landscape irrigation.

<u>Land-Based Discharge</u>: An additional 60 acres will be added to the LBD system and improvements are planned to the existing 40 acres to increase the wetted area. In addition, the irrigation system will be fenced and/or public access restricted so that a request to reclassify these sites can be made. Reclassification should allow disinfection requirements to be relaxed to 23 total coliform bacteria (versus the existing 2.2 MPN limit) and consideration of relaxing or eliminating the total petroleum hydrocarbon (TPH) limit.

As indicated in Table 3-4, the combination of additional irrigation area and elimination of Site 13 water will result in a 70% reduction in percolation (1.8 feet versus 5.8 feet).

Installation of UV Disinfection Equipment: Testing in 2007 at the Beale AFB WWTP indicates that TDS of the drinking water is near or above 300 mg/L. With background levels of TDS being near the limit for LBD, extreme treatment measures such as reverse osmosis may be necessary to lower the effluent TDS to meet existing limits. The current strategy is to minimize increases in TDS at the treatment plant by using UV for normal disinfection purposes (chlorination will still be available for high flow conditions or for producing recycled water).

Trickling Filter Solids Contact: Trickling Filter Solids Contact (TF/SC) will be utilized to reduce turbidity and achieve partial denitrification. A new solids contact basin will be constructed that will consist of an anoxic zone for denitrification and an oxic zone for bioflocculation/turbidity reduction.

Anoxic Return Sludge: One TF/SC operating process mode at other locations has been to use sludge reaeration (operating an aerobic reactor in the return secondary sludge line). Sludge reaeration has often been utilized to augment or even been the sole source of maintaining an aerobic suspended growth bacterial population. However, since the main issue at the Beale AFB WWTP is denitrification, it is desirable to achieve anoxic (rather than oxic or aerobic) conditions. Therefore, at the Beale AFB, an anoxic return sludge (AxRS) reactor will be used to achieve partial denitrification.

Replacement of the Existing Trickling Filter Pump Station: To operate TF/SC in either the conventional or AxRS mode, it is necessary to maintain a growth of suspended growth bacteria and settle these produced bacteria in the secondary clarifier. With TF/SC, reuse of the secondary clarifier effluent to supply recirculation to the trickling pump station must be eliminated. Recirculation of secondary clarifier effluent will cause excessive solids loading on the clarifier and would result in solids carryover in the secondary effluent. To eliminate this, the existing trickling filter pump station will be replaced.

The new pump station will have recirculation features that will be suitable for the TF/SC process. Recirculation features of the new pump station will include flow control/measurement for recirculation of trickling filter effluent to the primary clarifier. By adding the control/ measurement feature, operators will be able to control the amount of denitrification that occurs in the primary clarifier. Direct recirculation to the trickling filter pumps will be supplied from the trickling filter underflow rather than (as currently practiced) from the secondary clarifier.

Effluent Filtration: Filters will be added so that effluent quality can be improved and requirements for recycled water can be met.

Chemical Clarifier: The existing secondary clarifier does not have a standby or redundant unit, except by taking the existing primary clarifier out of service. Plans are to add an additional secondary clarifier that can be used either for effluent polishing as a chemical clarifier or used to increase reliability by serving as a standby clarifier.

4.0 CONCEPTUAL DESIGN

4.1 Overall Project Concept

After selection of the apparent best method for upgrading the Beale AFB WWTP, further refinements were developed. As a means of lowering cost and maximizing the use of existing equipment/units the following changes were made:

1. Modify the existing grit channels to accomplish denitrification.
2. Install UV vessels in the existing trickling filter recirculation pump station wet well.

The current concept for upgrading the Beale AFB WWTP is illustrated on the flow schematic Figure 4-1. A site plan and hydraulic profile for the Beale AFB WWTP Upgrade project are shown on Figure 4-2 and Figure 4-3, respectively.

4.2 Project Description – Beale AFB WWTP Upgrade

Table 4-1 provides a description of the design criteria and unit sizing/loading. Unit descriptions have been arranged as they occur within the flow pattern (influent to effluent) and also whether the units are existing or constructed in the basic upgrade, Bid Option 1 (tertiary treatment), or Bid Option 2 (advanced treatment).

4.2.1 Basic WWTP Project

The Basic WWTP Upgrade addresses LBD needs. This will include constructing a new trickling filter recirculation pump station (TFR P/S) to transfer primary effluent along with recirculated trickling filter underflow to the rock trickling filter. No changes are planned to the rock trickling filter. However, a recirculation valve will be added to allow trickling filter underflow to be used as makeup water to the constant-speed TF recirculation pumps. An additional control valve will be added to allow trickling filter underflow to also recirculate to the primary clarifier. The majority of the trickling filter underflow will flow by gravity to the secondary clarifier.

A return secondary sludge pump station (RSS P/S) will be added to allow the recirculation of biologically produced solids from the bottom of the secondary clarifier to the existing grit channels. A three-way valve will be used to control the wasting of secondary sludge back to the HWK.

Partial denitrification (annual reduction of nitrate to less than 7 mg/L) will be accomplished by converting the existing grit channels to anoxic (anoxic means non-aerated, low oxygen) return sludge (AxRS) channels. A methanol feed system will be constructed to provide a carbon source at the grit channels for the denitrification process. Primary effluent can also be pumped from the tricking filter recirculation pump station to the grit channels as another source of carbon for denitrification. Denitrified anoxic RSS from the grit channels will flow to the existing trickling filter diversion box and be combined with underflow from the trickling filter. Re-aeration will occur by combining the RSS with aerated tricking filter underflow and by installing diffused air in the diversion box.

From the diversion box, flow will transfer by gravity to the existing secondary clarifier. Treated effluent from the secondary clarifier will flow to the existing trickling filter recirculation pump station (or the existing CCB, to be determined in the final design), which will be converted to a vault for housing new ultraviolet radiation equipment.

New UV radiation vessels will work in series with the existing chlorination system to provide disinfection under a number of flow and discharge scenarios. For example, during normal flow and discharge to land based discharge only UV disinfection will be used. During high-flow events to land-based discharge, both UV and chlorination will be used to meet disinfection standards. In the future, when recycled water is desired the existing chlorination system in series with the new UV equipment will provide redundancy and meet stringent disinfection standards. Finally, the UV radiation system will provide a discharge suitable for Hutchinson Creek by eliminating or minimizing disinfection byproducts. The UV disinfection system is also a key element to the basic upgrade because it will allow a reduction in total dissolved solids to occur which presently is a limiting factor for irrigation.

4.2.1.1 Trickling Filter Recirculation Pump Station

The existing Beale AFB WWTP (Figure 3-1) has a trickling filter recirculation pump station (TFR P/S) where three vertical turbine pumps transfer water to the trickling filters. The TF pumps are rated for 5.7, 8.6, and 7.2 mgd flow capacity (total capacity = 21.5 mgd). Recirculation is accomplished by two means: by recirculating effluent from the secondary clarifier (secondary clarifier effluent [SCE]) to the TFR P/S or by recirculating trickling filter underflow (TFU) from the distribution box to the inlet pipe to the primary clarifier. Neither of these recirculation flows is measured. The operations staff estimate that about two thirds of the recirculated flow comes from SCE and the remaining one third from recirculating TFU to the primary clarifier.

In the present upgrade, it is important that all recirculation come from the TFU. Recirculation of the secondary clarifier effluent would result in unnecessary shortening of hydraulic retention time in solids contact and increase the solids loading rate to the secondary clarifier. High solids loading could limit the capacity of the secondary clarifier.

A new TFR P/S will be constructed incorporating a distribution box that will allow TFU to automatically provide makeup water to three new vertical turbine pumps. Pump capacity will be reduced to save energy while still providing the necessary recirculation. Each new pump will have a 2,100 gpm (3.0 mgd) capacity. During low-flow conditions, level controls in the primary effluent wet-well will automatically open a recirculation valve to allow the transfer of TFU into the wet-well. During high-flow conditions, level controls in the primary effluent wet-well will automatically close the recirculation valve so that TFU in excess of that required for the recirculation pumps is automatically transferred by gravity to the solids contact basin.

4.2.1.2 Return Secondary Sludge Pump Station

Waste biological solids from the secondary clarifier at the existing Beale AFB WWTP are currently transferred to a manhole adjacent to the clarifier and then conveyed by gravity to the influent sewer upstream of the HWK. There is currently no means of recirculating or concentrating biological solids prior to wasting.

A new return secondary sludge pump station (RSS P/S) will be constructed adjacent to the secondary clarifier. Two, 695 gpm submersible pumps with a variable frequency drives will be used to return solids to the AxRS Channels (existing grit channels). It is anticipated that the RSS concentration will be in excess of 1% solids and will provide from three to six days of retention time.

4.2.1.3 Anoxic Return Sludge Channels

The existing grit channels will be converted to return sludge (AxRS) channels that will be used for denitrifying the RSS. A submersible pump will be used to recirculate flow within each channel to assure that solids do not settle. A weir at the end of the AxRS channel will maintain approximately 3 feet of water in each channel so that a reservoir can be maintained where denitrifying organisms can utilize NO_3-N as an oxygen source, thereby releasing nitrogen gas harmlessly to the atmosphere.

4.2.1.4 Methanol Feed System

Primary effluent at the existing Beale AFB WWTP is low strength and contains insufficient carbon to reduce the projected amount of nitrate nitrogen to nitrogen gas. Unless sufficient carbon is present, denitrification will not occur within the hydraulic retention time provided in the AxRS channels.

To supply carbon and control the denitrification process, a methanol feed system will be provided. A 3,000-gallon polypropylene methanol storage tank will be provided to supply an anticipated methanol demand of 20 to 40 gallons per day. Two variable-flow motor-driven chemical feed pumps will be used to deliver the methanol to the SCB. These diaphragm metering pumps will each have a feed capacity of 0.5 to 5.0 gph. The methanol tank and feed system will be an outdoor installation with full containment. A carport-type roof will be installed to protect pumping equipment and provide shelter for electrical and control equipment.

4.2.1.5 Disinfection System

The existing disinfection system at Beale AFB WWTP consists of adding sodium hypochlorite (NaOCl) to overflow from the secondary clarifier. Disinfection takes place at the chlorine contact basin located adjacent to the Control Building. Dechlorination is presently accomplished by adding a sulfurous acid solution after the chlorination process. The sulfurous acid solution (H_2SO_3) is added at two locations at the edge of the aeration pond. Both dechlorination and pH adjustment are accomplished by adding sulfurous acid.

Problems with the existing disinfection system include the increase in TDS with the addition of chemicals for both chlorination and dechlorination. In addition, the use of a sulfurous acid solution will lower effluent pH, which will likely require the addition of caustic once the effluent sample point is relocated upstream of the existing post-aeration basin. Finally, a combination of high chlorine dosing and residual organics in the treated effluent presently result in the generation of disinfection byproducts that must be eliminated to comply with the new discharge requirements to Hutchinson Creek.

UV Disinfection System: A pressure inline UV system will be installed to disinfect treated secondary effluent up to flows of 2.0 mgd. Flows in excess of 2.0 mgd will be bypassed to the chlorine contact basin for disinfection. The existing chlorine contact basin will also be used (after UV disinfection) to further treat reclaimed water prior to reuse in a recycled water (“purple pipe”) system.

The medium-pressure UV lamps can emit from 2,650 to 3,750 watts (W), depending upon flow and transmittance. The UV system will consist of two in-line UV reactors operating in series. Each reactor will consist of 316 stainless and eight medium-pressure UV lamps. Each medium-pressure UV lamp is equivalent to approximately 15 conventional low-pressure UV lamps.

Other UV system features will include automatic mechanical and chemical wiper systems for cleaning the lamp's quartz sleeves. The system will be designed as a low-head unit that will have less than 10 inches of head drop at a peak flow of 2 mgd.

Electrical power requirements for the UV equipment will be approximately equivalent to an average of 50 hp when treating to a 23 MPN fecal coliform count. When treating wastewater to a 2.2 MPN fecal coliform count, power requirements will increase to approximately an average of 70 hp. Electrical power demand and lamp intensity will be regulated automatically depending upon effluent goals and water quality.

The UV equipment will be housed in the existing trickling filter pump station (or existing CCB, to be determined during final design), adjacent to the chlorine contact basin. A carport-like structure will protect the UV equipment from the elements.

Chlorination/Dechlorination: The existing chlorination/dechlorination system will remain in operation for periods of high flow or to produce recycle water. However, rather than treating effluent from the secondary clarifier, chlorination will be applied to effluent that has already been disinfected through the UV system. Chlorine demand should be greatly reduced with pretreatment by UV radiation. During normal flow conditions to LBD, it should be unnecessary to chlorinate.

Dechlorination currently involves generating a sulfur dioxide (SO_2) solution (H_2SO_3 or sulfurous acid) on site and adding the sulfurous acid solution to the edge of the post-aeration basin (PAB). Dechlorination will only be required for discharge to Hutchinson Creek. During periods of discharge to Hutchinson Creek, the sulfurous acid solution will be added at the end of the existing chlorine contact basin after the outlet weir. The sample location will be located at a distribution box downstream of the chlorine contact basin (after dechlorination) and before treated effluent reaches the PAB.

4.2.2 Bid Option 1 – Tertiary Treatment

Bid Option 1 provides tertiary treatment necessary to allow effluent to be discharged to a recycled water system or to Hutchinson Creek. It will include construction of a solids contact basin that will provide additional denitrification and be used to reduce turbidity in the trickling filter effluent. A new effluent filter pump station will transfer disinfected secondary effluent to final effluent filters. The effluent filters will consist of two 2-disk filters each (four disks total). The disk filters will polish chlorinated/dechlorinated secondary effluent to standards required for discharge to a recycle water system.

Disposal of treated effluent through reuse at parks, playgrounds, residential landscaping or irrigation to the O'Malley Ball Field will trigger California State Health and Safety Laws related to recycled water, commonly referred to as Title 22 (also known as "the purple pipe book") and Title 17 regulations. Title 22 regulations for application of this type will require that effluent be oxidized, coagulated, clarified, filtered and disinfected similar to treatment steps required for discharge to Hutchinson Creek.

4.2.2.1 Solids Contact Basin

Partial denitrification (~ 50% NO_3-N removal) will have already been accomplished in the AxRS channels constructed during the basic upgrade. However, nitrate removal efficiency is likely to vary, depending upon temperature conditions and other variables. The solids contact basin will provide increased removal in nitrate and also assure better performance during maximum month conditions. Effluent for the existing TF is also high in turbidity because of dispersed fixed film (rock media) growth and relatively short retention times.

To increase nitrate removal and reduce turbidity, a relatively small aeration basin, referred to as a "solids contact basin" (SCB), will be constructed. The SCB will consist of two non-aerated zones followed by two aerated (re-aeration cell) zones. The first two SCB zones will create an anoxic (minimum free oxygen, or stated differently, low-dissolved O_2) environment to further remove NO_3-N from the RSS. The RSS will be mixed with the trickling filter underflow in the third zone and aerated. Biological solid concentrations in the SCB will be as high as 2,000 mg/L mixed liquor suspended solids (MLSS), in order to form a biological floc capable of reducing turbidity. Aeration in the third and fourth zones establish aerobic conditions and will prevent rising solids (from nitrogen gas rising due to nitrogen gas [N_2] release) in the secondary clarifier.

4.2.2.2 Effluent Filter Pump Station

Whether effluent is from the secondary or from the chemical clarifier, effluent filtration will be required for discharge to Hutchinson Creek or for reuse of recycled water. All of the effluent filters considered as part of this concept design required from 3 to 5 feet of head in their operation. Therefore, the addition of an effluent filter pump station is planned in Option 1.

Because LBD is the primary means of disposing of treated effluent, it is not necessary to design for the 5.0 mgd plant capacity. Instead, the effluent filtration will be designed for a peak of 1.0 mgd with the largest pump out of service.

4.2.2.3 Effluent Filtration

Effluent filtration will be via disk filters with cloth medium, which will be used infrequently, only during discharge to Hutchinson Creek, or when recycled water is demanded. Two filter units will be installed with a total filtration surface area of 215 $feet^2$. Each filter will have an electronic drive and automatic backwash system. Automatic backwash will be triggered when head loss through the filters increases to a predetermined set point.

4.2.3 Bid Option 2 – Advanced Treatment

Bid Option 2 provides an advanced level of treatment that is treatment beyond conventional tertiary facilities. Advanced treatment will include adding a 60-foot diameter chemical clarifier and chemical treatment system. With advanced treatment, water from either the chemical clarifier or from the secondary clarifier will flow by gravity to the UV disinfection system. From the UV disinfection system, UV treated effluent will flow into the existing chlorine contact basin where additional disinfection may occur. Disinfected effluent may then either be pumped to the effluent filters (installed as part of the Tertiary Plant Upgrade) or transferred to the existing PAB.

Advanced treatment may be necessary because of redundancy requirements for the secondary clarifier, to meet turbidity limits, or may be required to meet the stringent limits to Hutchinson Creek. Discharge of treated effluent to Hutchinson Creek will require that "wastewater be oxidized, coagulated and filtered, or *that* equivalent treatment be provided" (Order No. R5-2004-0045, NPDES No. CA110299). In addition, discharge to Hutchinson Creek will add a wide range of pollutants to the WWTP discharge requirements (see Table 3-1) that are more restrictive than those required for LBD.

4.2.3.1 Chemical Treatment

A number of approaches have been considered that would meet the intent of Title 22 requirements to provide the coagulation of finely divided suspended matter and to coagulate particulate material by adding floc-forming chemicals. Arrangements for chemical precipitation could be as simple as providing the ability to add chemicals at the secondary clarifier influent (co-precipitation) and/or inject the chemicals into the line that transfers secondary effluent to the tertiary filters. However, it may be necessary to allow additional time for chemical reactions to occur (requiring a flocculation tank). If extensive chemical addition is needed or high solid removal rates are required, then post-precipitation may advantageous. Post-precipitation involves adding chemicals to the secondary effluent, followed by removing the chemical floc in either an inclined plate separator or in a chemical clarifier.

Post-precipitation involves installing chemical addition facilities and a 60-foot diameter chemical clarifier (chem-clarifier). The chem-clarifier unit will provide both the ability to produce an effluent of the highest quality and also serve as a redundant secondary clarifier should the existing secondary clarifier become inoperable.

4.2.3.2 Recycled Water System

A Beale AFB goal is to develop a recycle water system for providing reclaimed treated wastewater for a wide variety of uses. The recycle water system will allow reuse in addition to LBD options (such as restricted irrigation or golf course application) planned for in the Basic Plant Upgrade. The development of a recycled water system falls under the standards of the California Department of Health Services and allows a broader use of reclaimed water within the Beale AFB and surrounding areas. The main use for recycled water is typically for the irrigation of crops, landscape areas, golf courses, athletic fields, commercial use, industrial parks and cemeteries. Other uses may also include reclaimed water for industry, wildlife habitat enhancement, residential landscaping or for use in water features.

5.0 PROJECT DEMONSTRATION AND EXECUTION

5.1 Project Demonstration

5.1.1 Case Histories and Site Visits

One method of demonstrating the reliability of process changes at the Beale Air Force Base is to look at case histories or to conduct site visits. The use of a trickling filter solids contact (TF/SC) process to improve effluent quality from trickling filters with rock media has been well-known since the mid-1980s. Literature references providing case histories and/or the benefits of TF/SC are provided in Appendix B. Specific application to trickling filters with rock media at military establishments has been referred to by Richard Scholze in an August 1988 paper entitled *"The Trickling Filter/Solids Contact Process: application to Army Wastewater Plants.*" It is estimated that there may be nearly 100 facilities using the TF/SC process. Some example case histories, which contain some of the features being considered at the upgrade of the Beale AFB WWTP, are presented in Table 5-1.

Although none of the case histories cited on Table 5-1 models exactly what is proposed at the Beale AFB WWTP, they provide examples of how variations of TF/SC can be used to modernize an aged rock-trickling filter. To establish greater confidence in using a modification on conventional TF/SC to accomplish denitrification and improved effluent quality, an independent process review along with bench scale testing were conducted. These efforts are described in the following report sections.

5.1.2 Process Review

Because the planned upgrade for the Beale Air Force Base WWTP uses unusual process modifications, an independent process review by a leading expert and nutrient removal was sought. A letter report by Dr. David Stensel of the University of Washington (along with support calculations) is provided in Appendix B. Dr. Stensel evaluated the conversion of the existing grit channels to anoxic reactors (that is, he evaluated the "Basic" Plant Upgrade). The Basic Project is arranged to accomplish denitrification with minimal sized suspended growth reactors. Since the planned improvements after the Basic Project (Bid Option 1 or Tertiary Treatment) will greatly increase the suspended growth reactor sizes, there was no need for further evaluation if the Basic Project proved adequate.

The following are key findings/comments from Dr. Stensel's evaluation:

- The idea of nitrate removal in the recycle is very innovative with merit and it should work well under specified loadings.
- If sufficient methanol is added and there is sufficient time in an anoxic tank, all of the nitrate can be removed.
- The main issue is the need to have sufficient solids retention time (SRT) in the anoxic tank to maintain an effective methylotrophic population. He recommends a minimum SRT of five, four, and three days, respectively, at 13, 16 and 20 degrees Celsius (°C).

- Methanol is used by a special group of bacteria (the methylotrophs) capable of using single carbon compounds. To develop a sufficient population to maximize denitrification, it may take two to three weeks from startup. Another alternative to methanol (which is more expensive) is to use acetate as a carbon source. Acetate may be readily assimilated by a wide variety of bacteria and can be maintained at a lower SRT then required by the methylotrophs.

Dr. Stensel's use of rational equations that define biological kinetics indicated that nearly half of the produced nitrate can be removed by converting the existing grit channel to an anoxic reactor. An empirical approach using field experience was used by URS to confirm that adequate anoxic SRT for denitrification would be available. As presented in Table 4-1, the anoxic SRT available in the Basic Project is six days (compared to Dr. Stensel's recommended minimum or three to five days). The available anoxic SRT after Bid Option 1 (Tertiary Treatment) is completed is calculated at nearly 10 days (compared to Dr. Stensel's recommended minimum or three to five days). Simply stated, there should be adequate SRT available for denitrification even for the basic project, and certainly more than adequate SRT will be available after construction of the solids contact basin (half of this basin will be anoxic) planned with Bid Option 1.

5.1.3 Bench-Scale Testing

On October 4, 2007, bench-scale filtration tests were conducted on secondary effluent. The purpose of these tests was to determine whether filtration would result in a measurable reduction in pollutant level. The secondary effluent was also subject to 20 minutes of solids contact using return secondary sludge take from an activated sludge plant. Results from the bench-scale tests are presented in Table 5-2.

The following are observations from the bench field test:

- Total suspended solids: unfiltered secondary effluent was less than 4 mg/L at the time of the bench tests. Although no quantitative TSS tests were taken on filtered effluent, the filter-reclaimed water would be less than 4 mg/L.
- Turbidity: Filtration alone resulted in no measurable change in turbidity. Although the quantitative tests showed that solids contact had a higher turbidity than either filtered or unfiltered secondary effluent, this may have resulted because of deterioration during storage or shipping. In retrospect, turbidity tests should have been performed on-site to prevent degradation. Visual observations at the time of the tests indicated that the solids contact effluent was clearer than effluent without solids contact.
- Metals (copper and silver): Concentrations of metals in the treated effluent were not detected (ND) so no measurable changes from filtration were observed.
- Total petroleum hydrocarbons (TPH): There appeared to be little change in TPH due to filtration or solid contact. The TPH concentration at the time of testing was high and may not represent typical values.

Tests were also conducted at the following locations for TDS:

1. Primary Clarifier Effluent = 420 mg/L
2. Chlorine Contact Basin Effluent = 650 mg/L

3. Post Aeration Pond = 490 mg/L

4. Pond # 4 = 420 mg/L

The TDS values indicate that the 350 mg/L permit may be impossible to achieve on a monthly or daily basis. Concerns over TDS concentrations further strengthen the need to select processes that reduce salt addition at the WWTP.

5.2 Project Execution

The Beale AFB WWTP upgrade will be accomplished by implementing the Basic Project, followed by Bid Options 1 and 2 as funding allows. Of greatest importance is the understanding of the Basic Project. To provide the added detail, Figures 4-4 and Figure 4-5 provide comparable flow schematics for (1) the existing WWTP and (2) the Basic Upgraded WWTP, respectively. The use of similar color coding on main pipes on Figures 4-4 and 4-5, may help to clarify the following:

- Screened wastewater (SWW) will be diverted from the headbox at the grit channels to the primary clarifier (PC).

- A relatively small flow of primary effluent (PE) can be transferred to the grit channels to serve as a carbon source for denitrification; however, the majority of PE will be pumped to the trickling filters (TF).

- Trickling filter underflow (TFU) will be either transferred to the trickling filter recirculation pump station (TFR P/S) or to the primary clarifier.

- A new return secondary sludge (RSS) pump station (P/S) will be used to return settled biological solids to the grit channels (AxRS channels), where methanol will be added.

- Denitrified (dN) return secondary solids will flow by gravity to the existing trickling filter diversion box for re-aeration after being combined with the trickling filter underflow.

- Secondary effluent (SE) will flow by gravity to the new UV disinfection vessels. The UV disinfection vessels will be located in the existing chlorine contact basin or, if allowed, in the existing TF recirculation P/S.

- Disinfected secondary effluent (DSE) will normally not require chlorination. However, UV treated effluent may be chlorinated as it passes through the existing chlorine contact basin.

The layout of units and major piping for the Basic Project is shown on Figure 4-6. To provide an easy grasp of line locations, the same color-coding has been used on Figure 4-6 as is used on Figure 4-5.

6.0 DESIGN AND MANUFACTURER INFORMATION

Design drawings providing design criteria, layout, piping plans and location of principal structures are provided as Figures at the end of this report. An outline of specifications for components likely to be utilized in the upgrade is provided in Appendix D. Appendix E provides information for the selected equipment that has been supplied by manufacturers.

TABLES

Table 3-1. Simplified Comparison of Existing to Future Effluent Limitations

Constituent	Units	Effluent Concentration Avg – Max	2004 NPDES-WDRs Hutchinson Creek and Golf Course	2009 NPDES-WDRs Hutchinson Creek and Golf Course	LBD-WDRs Pond 4 and 40-acre Irrigation Field	Compliance Time Period
BOD	mg/L	6–16	30	10	30	Monthly average
TSS	mg/L	12–17	30	10		Monthly average
NH_3-N	mg/L	0.2–0.4	1.5	1.5		Monthly average, assuming 72°F and pH 8.0
NO_3-N	mg/L	11–13	10	10		6-month average Monthly average
NO_2-N	mg/L		1	1		6-month average Monthly average
Turbidity	NTU	6–13		2.0		Daily average
TDS	mg/L	369–480			350	30-day average
Total Copper	μg/L	10–12	40	5.8		Daily average
				14	20	Monthly average
						Daily maximum (NPDES-WDRs assumes hardness of 100 mg/L)
BEHP	μg/L	2.2–3.7		1.8		Monthly average
			53	5.4		Daily maximum
TPH	μg/L	140–320	5	5	<50	Monthly Average
Total Coliform	MPN/100 mL	2 -8		2.2 (creek) 23 (golf course)		7-day median
			23	23 (creek)	2.2 (Pond 4)	Monthly median 30-day average
					23 (Pond 4)	Instantaneous maximum
			230			Daily maximum
Cl Residual	mg/L	0.01	0.01	0.01		4-day average
			0.02	0.02		1-hour average

Table 3-1. (Continued)

Constituent	Units	Effluent Concentration Avg – Max	2004 NPDES-WDRs Hutchinson Creek and Golf Course	2009 NPDES-WDRs Hutchinson Creek and Golf Course	LBD-WDRs Pond 4 and 40-acre Irrigation Field	Compliance Time Period
THMs						
DBCM	µg/L	1.0		0.41		Monthly average
			1.1	0.8		Daily maximum
BDCM	µg/L	2.1		0.56		Monthly average
			4.1	1.6		Daily maximum
Minimum Treatment		DS	DS	OCF	OCF	

BDCM = bromodichloromethane
BEHP = bis(2-ethylhexyl)phthalate
BOD = biochemical oxygen demand
Cl = chlorine
Cu = copper
DBCM = dibromochloromethane
DS = disinfected secondary
L = liter
LBD = land-based discharge
MBAS = methylene-blue active substances
mg/L = milligrams per liter
mL = milliliter
MPN = most probable number
NH_3-N = ammonia as nitrogen
NO_2-N = nitrite as nitrogen
NO_3-N = nitrate as nitrogen
NPDES = National Pollutant Discharge Elimination System
NTU = nephelometric turbidity unit
OCF = oxidation, coagulation, and filtration
RL = reporting limit
TDS = total dissolved solids
THM = trihalomethane
TPH = total petroleum hydrocarbons
TSS = total suspended solids
WDR = waste discharge requirement
µg/L = micrograms per liter

Table 3-2. Existing Annual Irrigation Practice

Item	Units	Value
Golf	Acres	
Nominal		120
Wetted		120
Irrigation	Acres	
Nominal		40
Wetted		23
Total Wetted Area	Acres	143
Irrigated Water	mgy	354
Precipitation	feet	2.6
Evapotranspiration	feet	4.4
Percolation	feet	5.8

Table 3-3. Preliminary Comparison – Future Limits to June 2007 Testing

			Wastewater			Treated Effluent			
Item	Units	Future Limit	Plant Influent	Primary Clarifier Effluent	SC	CCB	PAB	Pond 4	Site 13 Effluent
TSS	mg/L	10				4			<2.5
NH_4-N	mg/L	1.5				0.237			0.125
NO_3-N	mg/L	10	<0.006			12.7	7.5	0.9	5.9
Turbidity	NTU	2.0	16	9.6	3.1	4.6	16	6.2	0.85
TDS	mg/L	350 (LBD)		306	296	498			300
Copper	µg/L	7.5	20			10	<0.05	8	0.9
BEHP (phthalate)	µg/L	1.8				<2.5			<2.5
TPH	µg/L	<50	5,500			260	450		<12
THMs									
DBCM	mg/L	0.41				6.57			
BDCM	mg/L	0.56				16.2			

BDCM = bromodichloromethane
BEHP = bis(2-ethylhexyl)phthalate
CCB = Chlorine Contact Basin
DBCM = dibromochloromethane
LBD = land-based discharge
mg/L = milligrams per liter
NH_4-N = ammonia (as nitrogen)
NO_3-N = nitrate (as nitrogen)
NTU = nephelometric turbidity unit
PAB = Post-Aeration Basin
SC = secondary clarifier
TDS = total dissolved solids
THMs = trihalomethanes
TPH = total petroleum hydrocarbons
TSS = total suspended solids
µg/L = micrograms per liter

Table 3-4. Planned Annual Irrigation Practice

Item	Units	Value
Golf	Acres	
Nominal		120
Wetted		120
Irrigation	Acres	
Nominal		100
Wetted		75
Total Wetted Area	Acres	195
Irrigated Water	mgy	230
Precipitation	feet	2.6
Evapotranspiration	feet	4.4
Percolation	feet	1.8

Table 4-1. Beale AFB WWTP – Unit Sizes and Description – Complete WWTP Upgrade

Item	Units	Value	Comment
BASIS FOR DESIGN			
Service Population		8,000 to 15,000	
Flow (mgd)			
Average Yearly		0.75	94 gpd/capita
Maximum Month		1.5	188 gpd/capita
Peak Day		4.0	500 gpd/capita
Design		5.0	625 gpd/capita
Wastewater Average Temperature			
Winter	^{o} C	15	minimum
Summer	^{o} C	25	maximum
Maximum Month Wastewater Load			
Raw Wastewater			
BOD	lb/d	1,700	130 mg/L
TSS	lb/d	2,200	170 mg/L
Ammonia	lb/d	313	25 mg/L
Primary Effluent			
BOD	lb/d	820	65 mg/L
TSS	lb/d	510	40 mg/L
Ammonia	lb/d	260	20 mg/L
Solids Loading			
Yearly Average			
Primary Solids	lb TSS/d	800	
Secondary Solids	lb TSS/d	200	
Co-thickened Primary Sludge			
TSS Solids Load	lb TSS/d	1,000	
Sludge Flow	gpd	6,000	
Maximum Month			
Secondary Solids	lb TSS/d	400	
Primary Digester Influent			
TSS Solids Load	lb TSS/d	3,600	
Average Concentration	%	2%	
Flow	gpd	21,600	
Secondary Digester Effluent			
TSS Solids Load	lb TSS/d	2,100	
Average Concentration	%	4%	
Flow	gpd	6,300	
Sludge Drying Beds			
TSS Solids Load	lb TSS/d	1,600	
Average Concentration	%	15%	
Flow	gpd	1,300	

Table 4-1. (Continued)

	Item	Units	Value	Comment
	EXISTING UNITS			
1	**Headworks**			
	Screenings Press			
	Type		Hycor - Fine Screen	
	Number of Units		1	
	Sewage Grinder			
	Type		Muffin Monster	
	Parshall Flume, capacity in mgd			
	Throat Size	ft	1.5	
	Capacity	mgd	15.9	
	Meter Type		Miltronics OCM III	
2	**Influent Pump Station**			
	Pumps			
	Number 500 gpm pumps@ 8" dia		1	
	Number 1,000 gpm pumps@ 8" dia		1	
	Number 2, 500 gpm pumps @ 10" dia		2	
	Capacity w/ largest pump out of service	mgd	5.7	
	Capacity w/ all pumps in service	mgd	9.3	
3	**Primary Clarifier**			
	Description			
	Number		1	
	Diameter	ft	100	
	Side Water Depth	ft	13	
	Surface Area	sq ft	7,854	
	Volume	gal	763,723	
	Loading			
	Hydraulic Retention Time	hrs	12	
	Overflow Rate			
	Average Yearly	gpd/sq ft	95	
	Maximum Month	gpd/sq ft	200	
	Peak Day	gpd/sq ft	510	
4	**Trickling Filter (TF)**			
	Number and Media Diameter	#*ft	2*100	
	Ventilation			
	Type		Natural Air	
	Filter Media - each unit			
	Type		Rock	
	Depth	ft	5.5 to 6.0	
	Horizontal Surface Area	sq ft	7850	
	Volume	1,000 cu ft	45.1	
	Filter Loading - 1 unit on line only			
	Total Organic Load (maximum month)	lb BOD/d/1000 cu ft	18	
	Hydraulic Loading			
	1-TF Pump	gpm/sq ft	0.27	
	2-TF Pumps	gpm/sq ft	0.54	
	3-TF Pumps	gpm/sq ft	0.80	

Table 4-1. (Continued)

Item	Units	Value	Comment
EXISTING UNITS (cont'd)			
5 **Secondary Clarifier**			
Description			
Number 100 ft dia Clarifiers		1	
Side Water Depth	ft	13	
Surface Area	sq ft	7,854	
Volume in gal	gal	763,723	
Loading			
Hydraulic Retention Time	hrs	12	
Overflow Rate			
Average Yearly	gpd/sq ft	95	
Maximum Month	gpd/sq ft	200	
Peak Day	gpd/sq ft	510	
6 **Chlorine Contact Basin (CCB)**			
Unit Description			
Features			
Chlorination		Sodium Hypochlorite	
Dechlorination		Sulfur Dioxide Generator	
Description			
Number of Basins		1	
Number of Channels per basin		3	
Type		Concrete - Rectangular	
Dimensions, each L x W x SWD	ft	25.67 x 12.67 x 7	
Total Volume	gal	51,000	
Loading			
Hydraulic Retention Time			
Average Yearly	min	90	
Maximum Month	min	40	
Peak Day	min	10	
Allowable Peak Dry Weather Flow @ 90 min	mgd	0.8	
7 **Post Aeration Pond**			
Unit Description			
Number			
Size	Acres	1.63	
Depth	ft	6.0	
Volume	MG	2.6	
Unit Loading			
Hydraulic Retention Time in days			
Average	days	3.5	
Maximum Month	days	1.7	
8 **Irrigation Pump Station**			
Pumps			
Type		Horizontal Centrifugal	
Number			
560 gpm capacity		2	
170 gpm capacity		2	
Total No Pumps		4	

Item		Units	Value	Comment
	Table 4-1. (Continued)			
	EXISTING UNITS (cont'd)			
9	**Primary Digestion**			
	Unit Description			
	Number		1	
	Size, dia x SWD	ft	51 x 27	
	Volume	cu ft	51,070	
	Unit Loading			
	Hydraulic Retention Time in days	days	18	
	Solids Loading	lb VSS/d/cu ft	0.06	
10	**Secondary Digestion**			
	Unit Description			
	Number		1	
	Size, dia x SWD	ft	51 x 27	
	Volume	cu ft	51,070	
	Unit Loading			
	Hydraulic Retention Time	days	18	
11.	**Sludge Holding Tank**			
	Unit Description			
	Number		1	
	Size, dia x SWD	ft	52.5 x 27	
	Volume	cu ft	54,118	
12.	**Sludge Drying Beds**			
	Drying Beds			
	Number		31	
	Size each, L x W x D	ft	110 x 16 x 1.5	
	Total Area	sq ft	54,560	
	Annual Loading Rate	lb TSS/sq ft/yr	11	
	BASIC PROJECT UPGRADE			
A.	**TF Recirculation Pump Station (TFR P/S)**			
	TF Pumps			
	Type		Vertical Turbine	
	Number Pumps		3	
	Total Dynamic Head	ft	20	
	Motor Requirements	hp	20	
	Capacity			
	Each	gpm	2,100	
	w/ largest pump out of service	mgd	6.0	
	w/ all pumps in service	mgd	9.0	
	PC Bypass Pump			
	Type			
			Submersible - with VFD	
	Number Pumps		1	
	Total Dynamic Head	ft	15	
	Motor Requirements	hp	3	
	Capacity, each	gpm	200	

Table 4-1. (Continued)

Item	Units	Value	Comment
BASIC PROJECT UPGRADE (cont'd)			
B. Return Secondary Sludge Channels (existing grit channels)			
Number		2	
Type		Anoxic Velocity - Slopped Bottom	
Dimensions, W x L x SWD (each)	ft	11 to 1.0 x 58.5 x 3.0	
Total Volume	gal	15,000	
Unit Loading (Annual)			
RSS	mg/L	10,000	
MCRT	days	6	
Hydraulic Retention Time at $Q_{RSS} = Q_{INF}$ = 0.75 mgd	min	29	
C. Return Secondary Sludge Pump Station			
Pumps			
Type		Submersible Centrifugal with VFDs Solids Handling	
Number		2	
Total Dynamic Head	ft	15	
Motor Requirements	hp	3	
Capacity			
Each	gpm	695	
w/ largest pump out of service	mgd	1.0	
w/ all pumps in service	mgd	2.0	
D. Methanol Feed System			
Unit Description			
Capacity of Each Pump in gpm		TBD	
Pump Type		Peristaltic	
E. UV Disinfection System			
Unit Description		Closed Vessel	
Number Vessels		2	
Type			
Lamps			
Pressure		Medium	
Total Number both vessels		16	
Average Power Use	kWh	40 to 53	
Capacity	mgd	2.0	
TERTIARY TREATMENT (BID OPTION 1) UPGRADE			
Influent Flow			
Maximum Month	mgd	0.75	
Peak Day	mgd	1.20	
Design	mgd	1.80	
F. **Solids Contact Basin (SCB)**			
Unit Description			
Basin			
Number		1	
MLSS	mg/L	2,000	
Zones per Basin		2	

Table 4-1. (Continued)

Item	Units	Value	Comment
TERTIARY TREATMENT (BID OPTION 1) UPGRADE (cont'd)			
Dimensions, each Zone L x W x SWD	ft	27 x 13.5 x 16	
Total Volume - all Zones	gal	87,000	
Number of Stages per Zone		2	
Loading			
MCRT	days		
Yearly Average		7.3	
Maximum Month		3.6	
HRT	minutes		
Yearly Average		167	
Maximum Month		84	
Anoxic Zones			
Number		1	
Mixer			
Number		2	
Type		Floating Pontoon	
Total Volume	gal	43,500	
Number of Stages		2	
Oxic or Switch Zones			
Number		1	
Mixer		None	
Total Volume	gal	43,500	
Number of Stages		2	
Re-aeration Blower			
Number		2	
Capacity each at 4.5 psi	scfm	55	
Motor size each	hp	2	
G. Effluent Filters (EF)			
Unit Description			
Number		2	
Type		disk filters	
Total Number Disks		4	
Total Surface Area	sq ft	215	
Media Type		Cloth	
Loading			
Overflow Rate in gpd/sq ft			
Maximum Month		2.4	
Peak Day		3.9	
Design		5.8	
H. EF Pump Station			
Pumps			
Type		Submersible Propeller	
Number		3	
Total Dynamic Head	ft	8	
Capacity			
Each	gpm	525	
w/ largest pump out of service	mgd	1.5	
w/ all pumps in service	mgd	2.2	

Table 4-1. (Continued)

Item	Units	Value	Comment
ADVANCED TREATMENT (BID OPTION 2) UPGRADE			
I. Chemical Clarifier			
Number		1	
Size			
Diameter	ft	60	
Side Water Depth	ft	18	
Surface Area	sq ft	1,826	
Volume	gal	245,800	
Loading			
Hydraulic Retention Time	hrs	7.9	
Overflow Rate	gpd/sq ft		
Maximum Month		420	
Peak Day		660	
J. Ammonia Feed System			
Unit Description			
Pump Type		Peristaltic	
K. Chemical Feed System			
Unit Description			
Pump Type		Peristaltic	

Table 5-1. TF/SC Case Histories

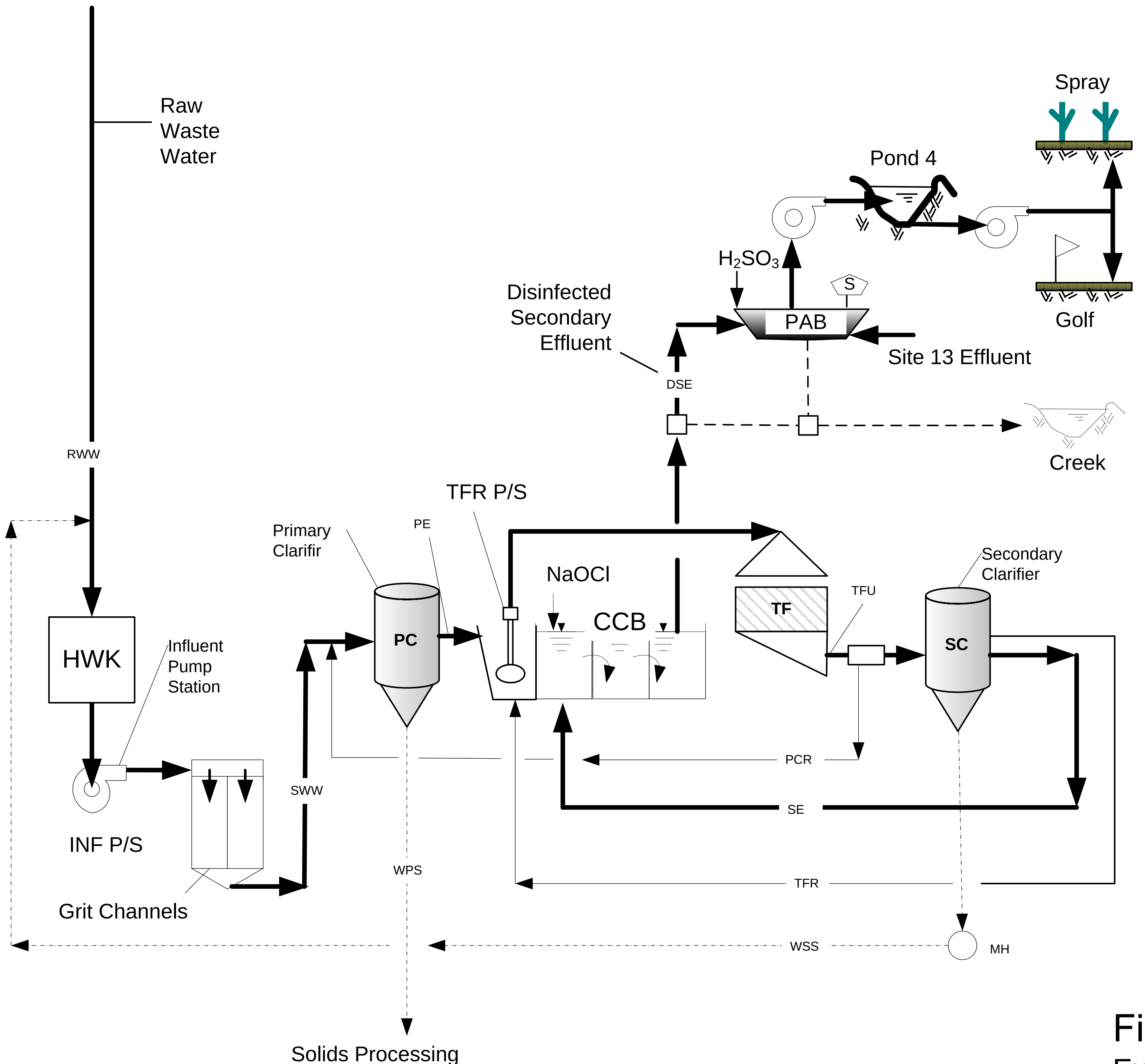
Corvallis, Oregon	Contains rock media, plant nitrifies and denitrifies
Coeur D'Alene, Idaho	Plastic media, plant uses re-aeration of RSS
Estacada, Oregon	Rock media, plant reduces turbidity through SCB
Eureka, California	Plastic media with both solids contact and re-aeration
Brookings, Oregon	Plastic media with both solids contact and re-aeration
Englewood, Colorado	Plastic media with both solids contact and re-aeration

Table 5-2. Bench-Scale Filtration Tests

Item	Units	Future Limit	Unfiltered Secondary Effluent	Filtered Secondary Effluent	Filtered Solids Contact Effluent
TSS	mg/L	30	ND to 4.0	No Test	No Test
Turbidity	NTU	2.0	3.3	3.3	7.7
Silver	µg/L	None	ND	ND	ND
Copper	µg/L	None	ND	ND	ND
TPH	µg/L	<50	360	430	320

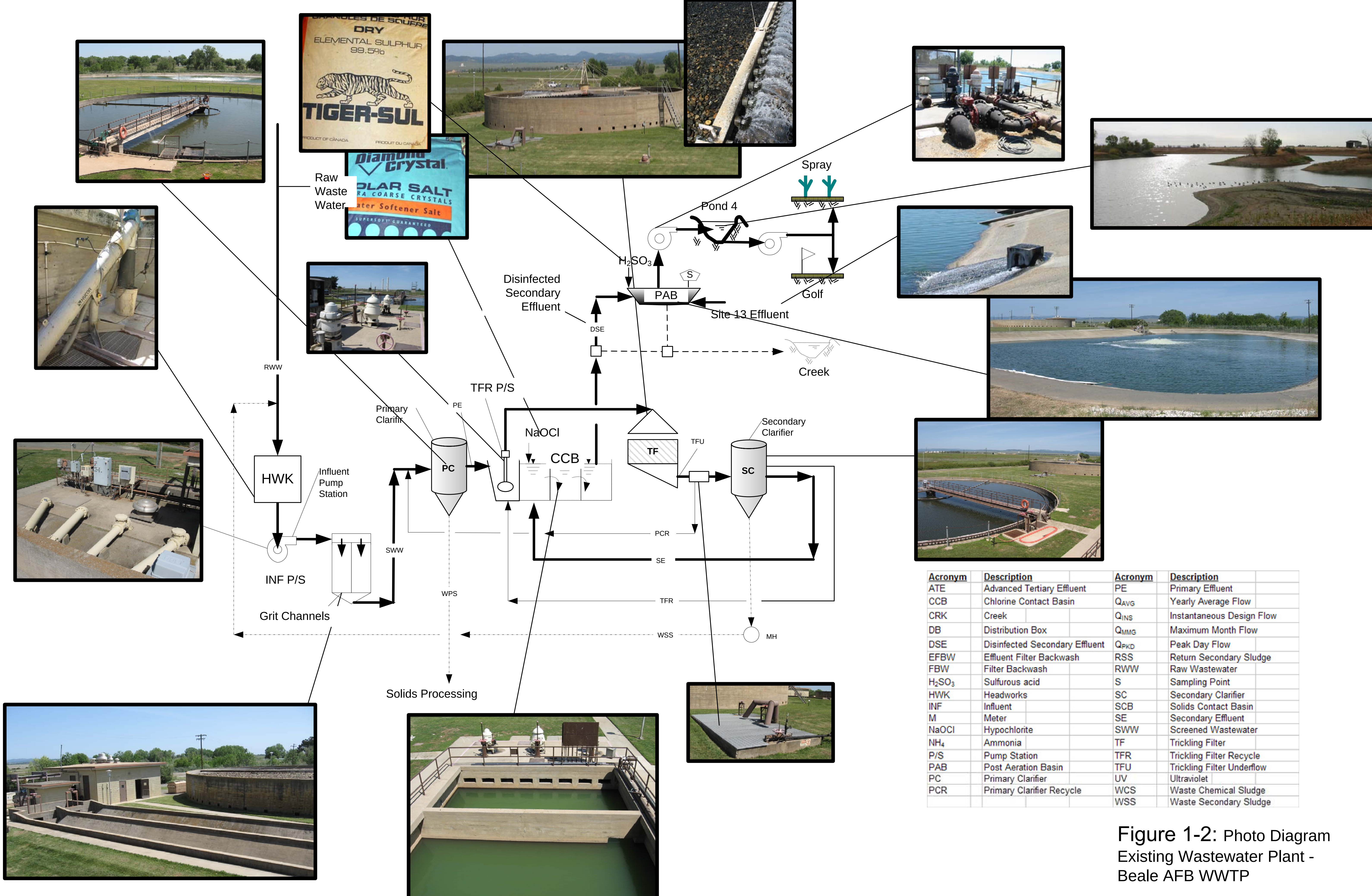
mg/L = milligrams per liter
ND = not detected
NTU = nephelometric turbidity unit
TPH = total petroleum hydrocarbons as motor oil
TSS = total suspended solids
µg/L = micrograms per liter

FIGURES



Acronym	Description
ATE	Advanced Tertiary Effluent
CCB	Chlorine Contact Basin
CRK	Creek
DB	Distribution Box
DSE	Disinfected Secondary Effluent
EFBW	Effluent Filter Backwash
FBW	Filter Backwash
H_2SO_3	Sulfurous acid
HWK	Headworks
INF	Influent
M	Meter
NaOCl	Hypochlorite
NH_4	Ammonia
P/S	Pump Station
PAB	Post Aeration Basin
PC	Primary Clarifier
PCR	Primary Clarifier Recycle
PE	Primary Effluent
RSS	Return Secondary Sludge
RWW	Raw Wastewater
S	Sampling Point
SC	Secondary Clarifier
SCB	Solids Contact Basin
SE	Secondary Effluent
SWW	Screened Wastewater
TF	Trickling Filter
TFR	Trickling Filter Recycle
TFU	Trickling Filter Underflow
UV	Ultraviolet
WCS	Waste Chemical Sludge
WSS	Waste Secondary Sludge

Figure 1-1: Flow Diagram
Existing Wastewater Plant -
Beale AFB WWTP



Acronym	Description	Acronym	Description
ATE	Advanced Tertiary Effluent	PE	Primary Effluent
CCB	Chlorine Contact Basin	Q_{AVG}	Yearly Average Flow
CRK	Creek	Q_{INS}	Instantaneous Design Flow
DB	Distribution Box	Q_{MMG}	Maximum Month Flow
DSE	Disinfected Secondary Effluent	Q_{PKD}	Peak Day Flow
EFBW	Effluent Filter Backwash	RSS	Return Secondary Sludge
FBW	Filter Backwash	RWW	Raw Wastewater
H_2SO_3	Sulfurous acid	S	Sampling Point
HWK	Headworks	SC	Secondary Clarifier
INF	Influent	SCB	Solids Contact Basin
M	Meter	SE	Secondary Effluent
NaOCl	Hypochlorite	SWW	Screened Wastewater
NH_4	Ammonia	TF	Trickling Filter
P/S	Pump Station	TFR	Trickling Filter Recycle
PAB	Post Aeration Basin	TFU	Trickling Filter Underflow
PC	Primary Clarifier	UV	Ultraviolet
PCR	Primary Clarifier Recycle	WCS	Waste Chemical Sludge
		WSS	Waste Secondary Sludge

Figure 1-2: Photo Diagram
Existing Wastewater Plant -
Beale AFB WWTP

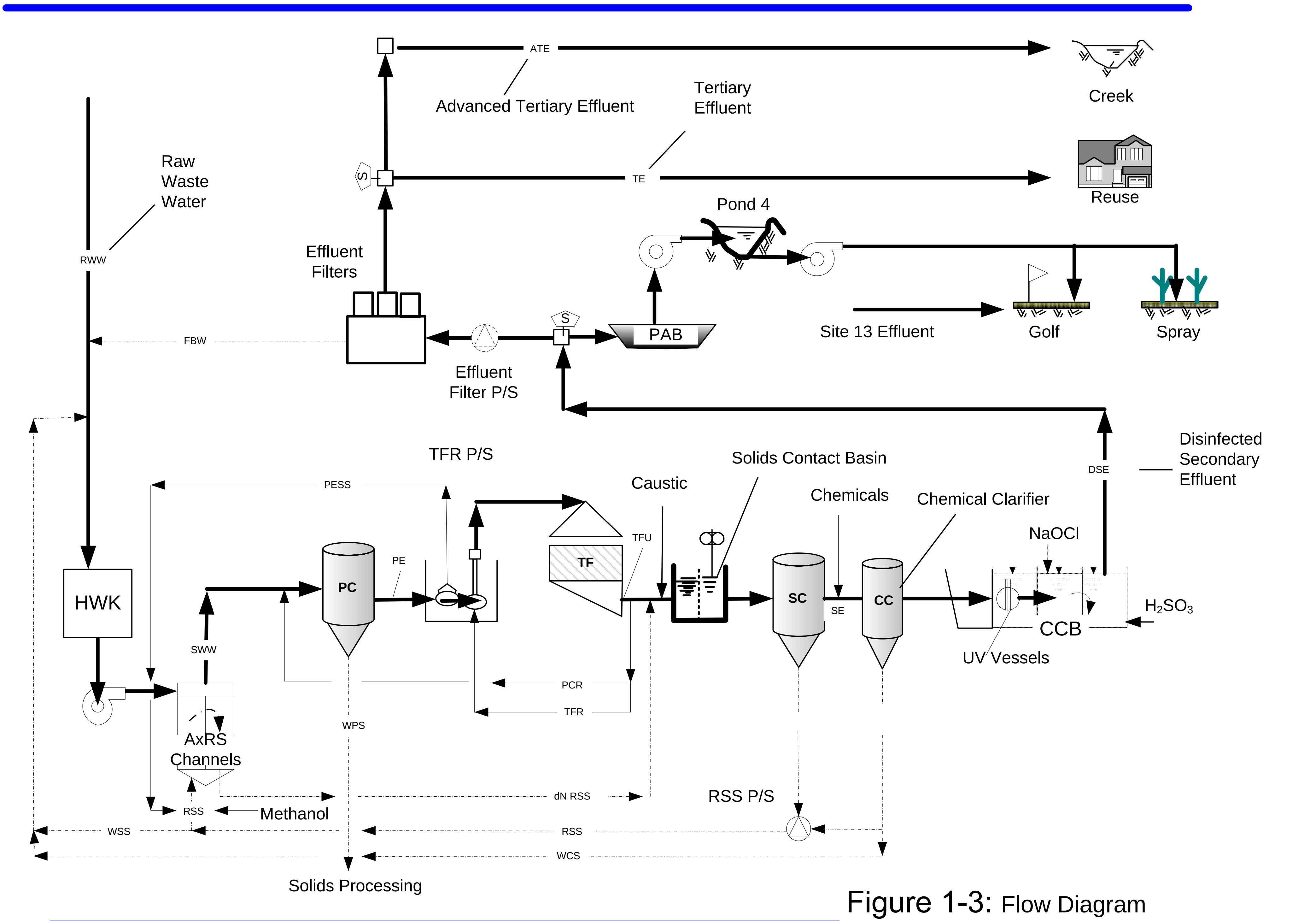


Figure 1-3: Flow Diagram
Complete Upgrade - Beale AFB WWTP

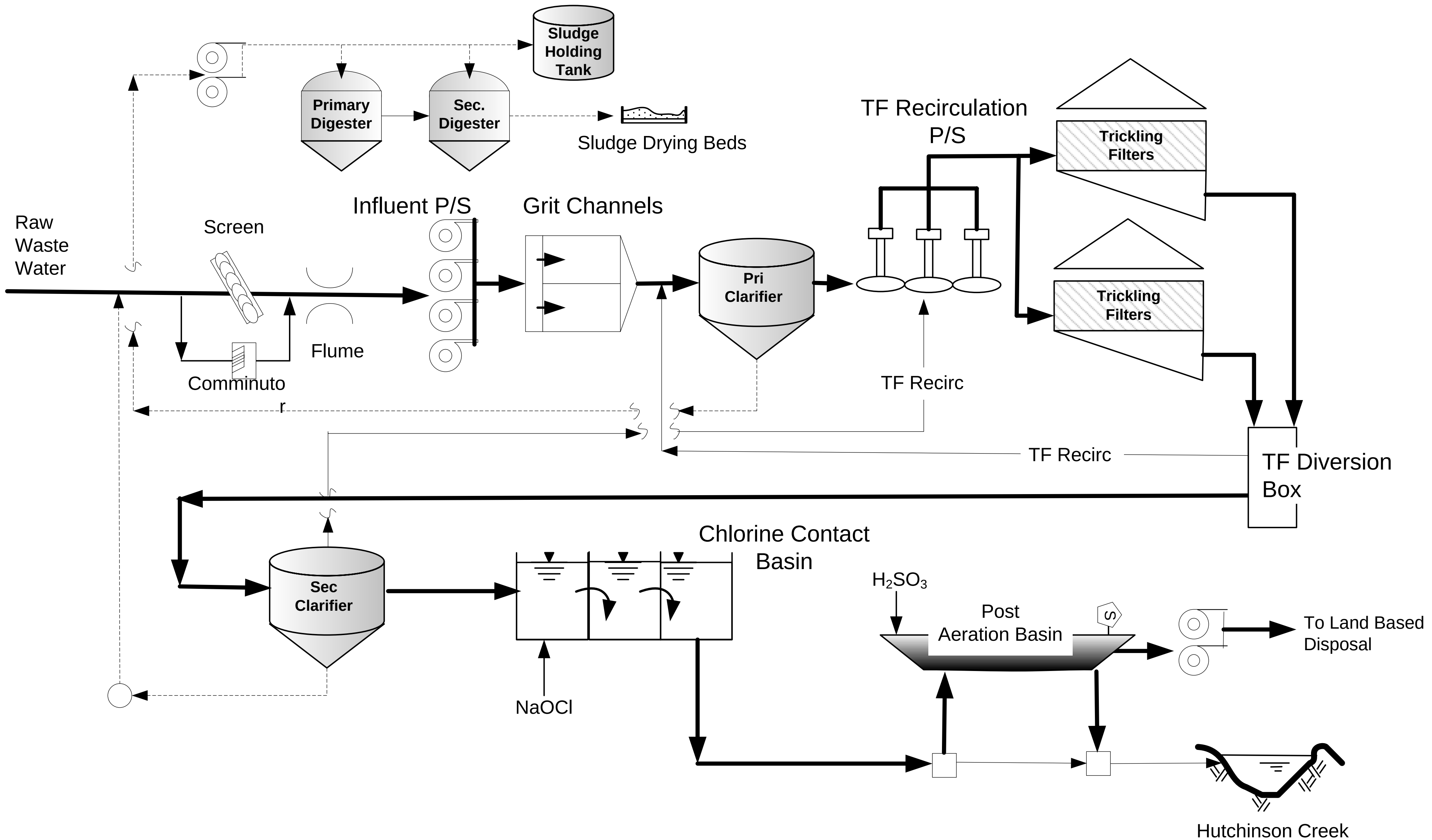
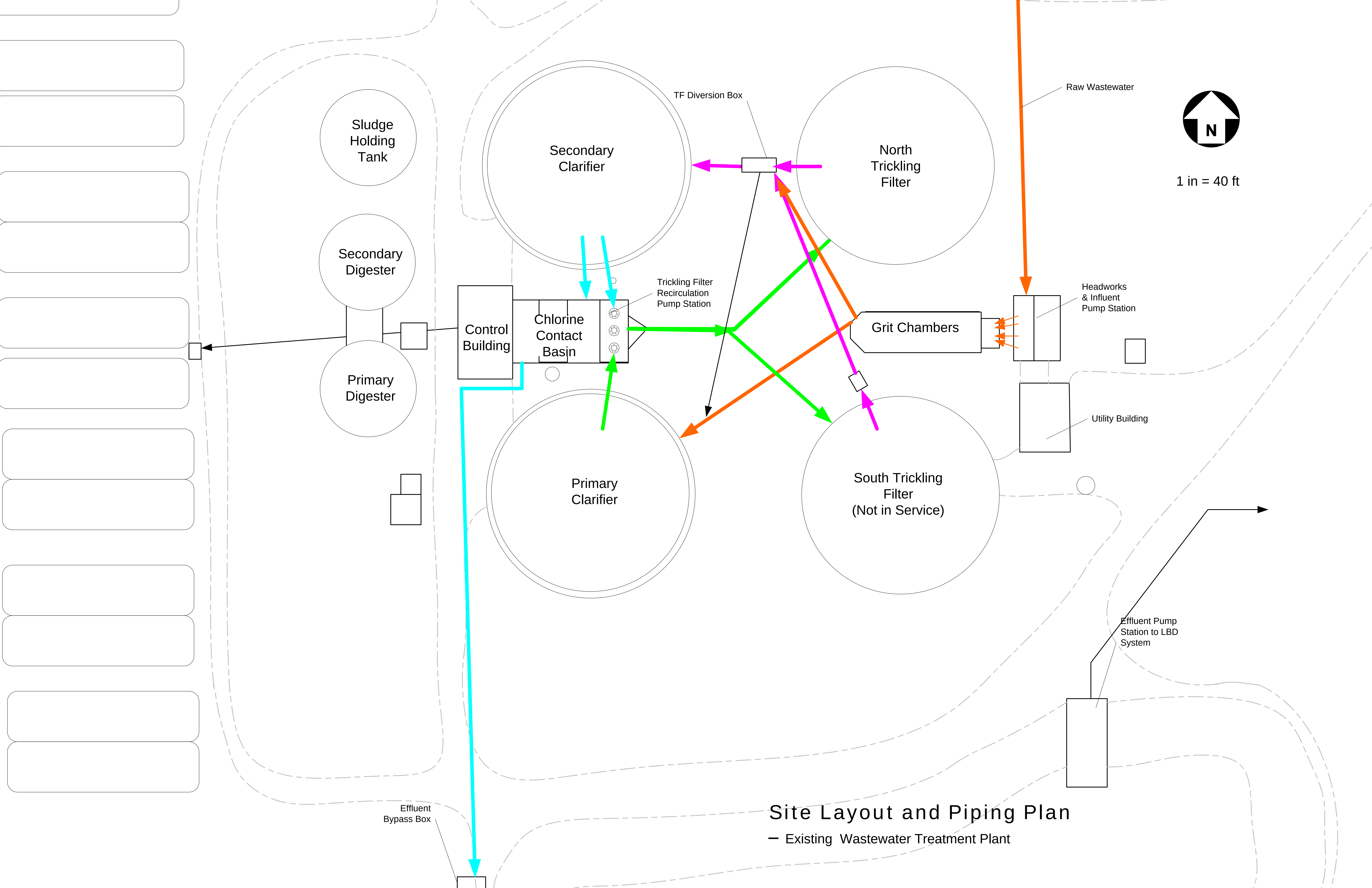


Figure 3-1: Flow Schematic Existing Wastewater Plant - Beale AFB WWTP



Site Layout and Piping Plan

– Existing Wastewater Treatment Plant

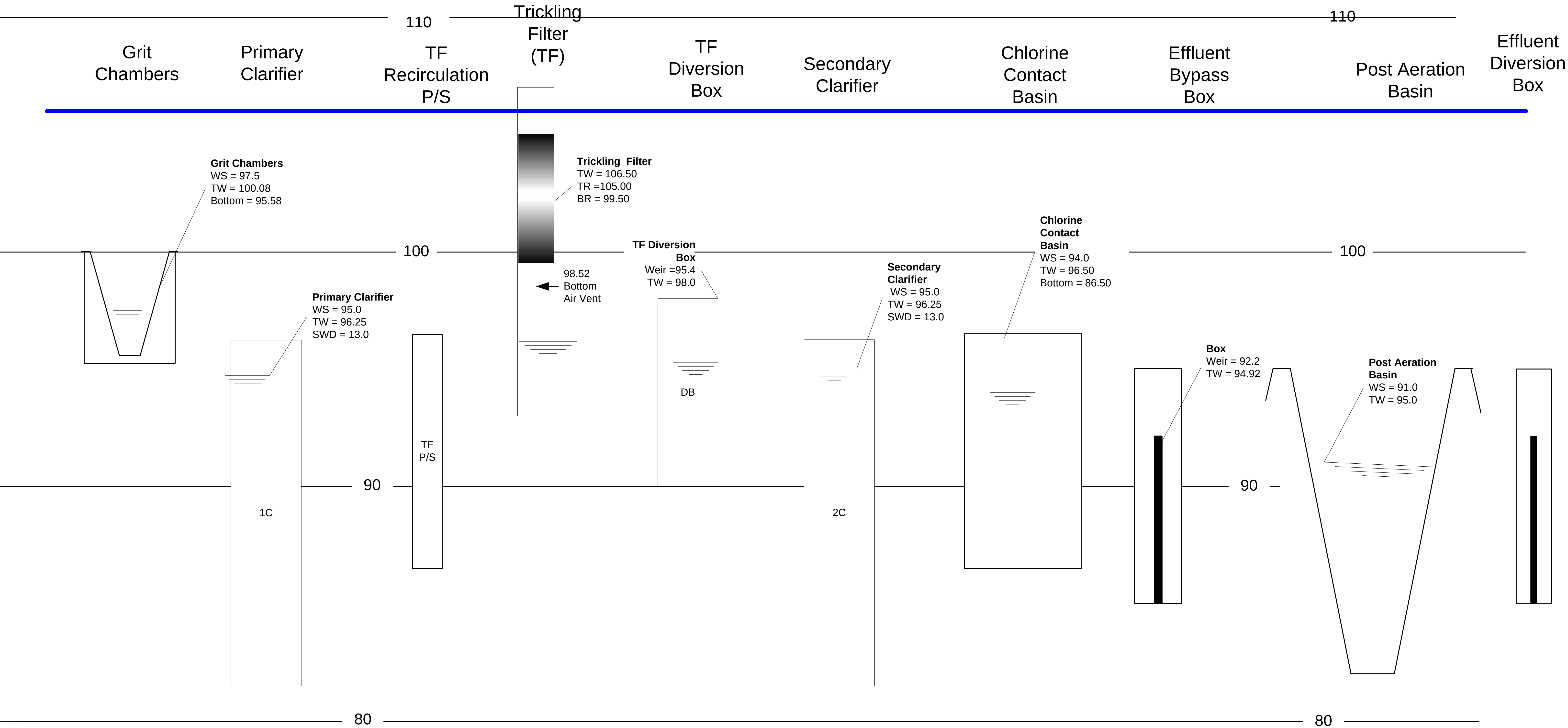


Figure 3-3 – Hydraulic Profile

– Existing Wastewater Treatment Plant

Figure 3-4: Annual Water Balance - Existing Wastewater Facility

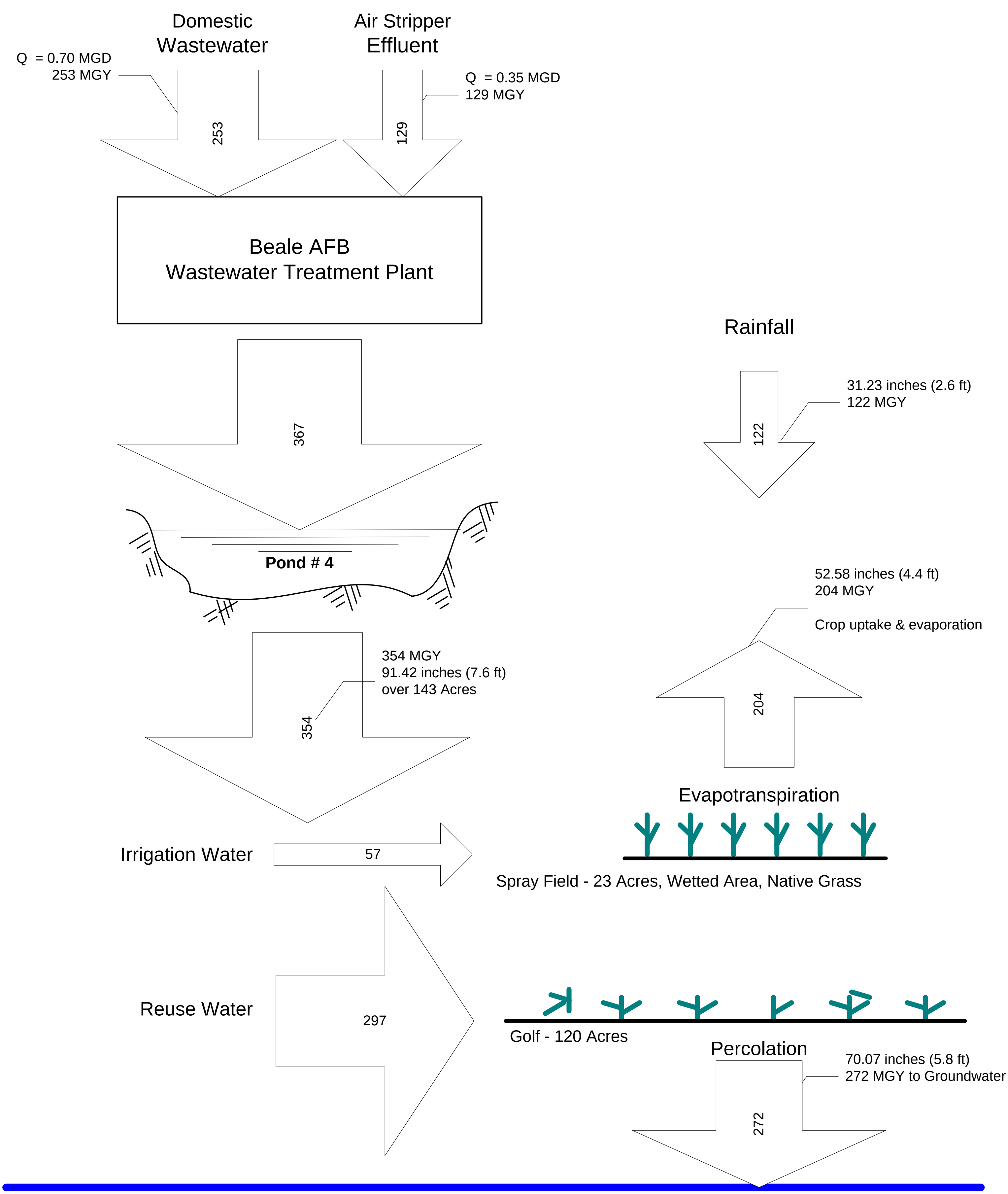
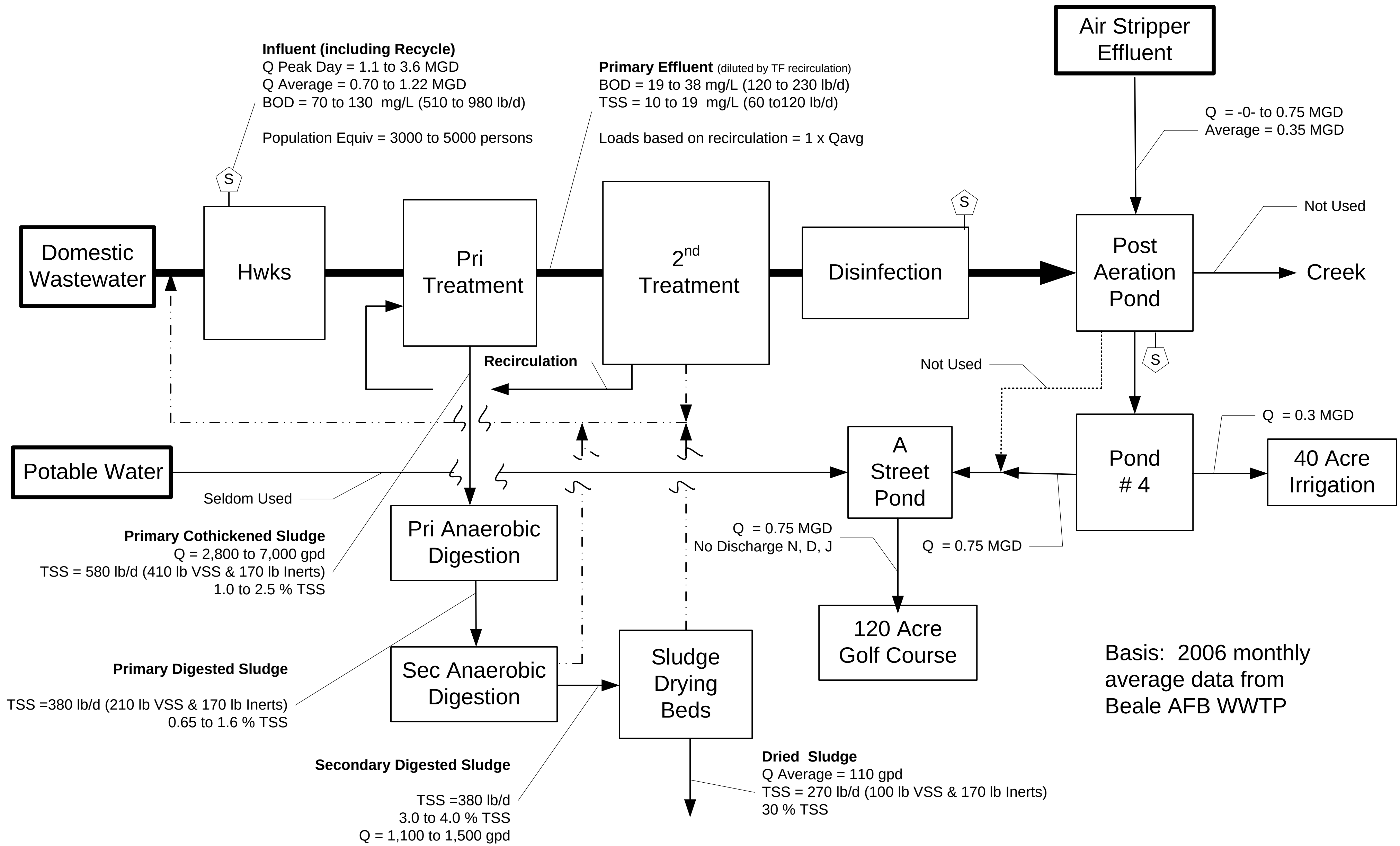
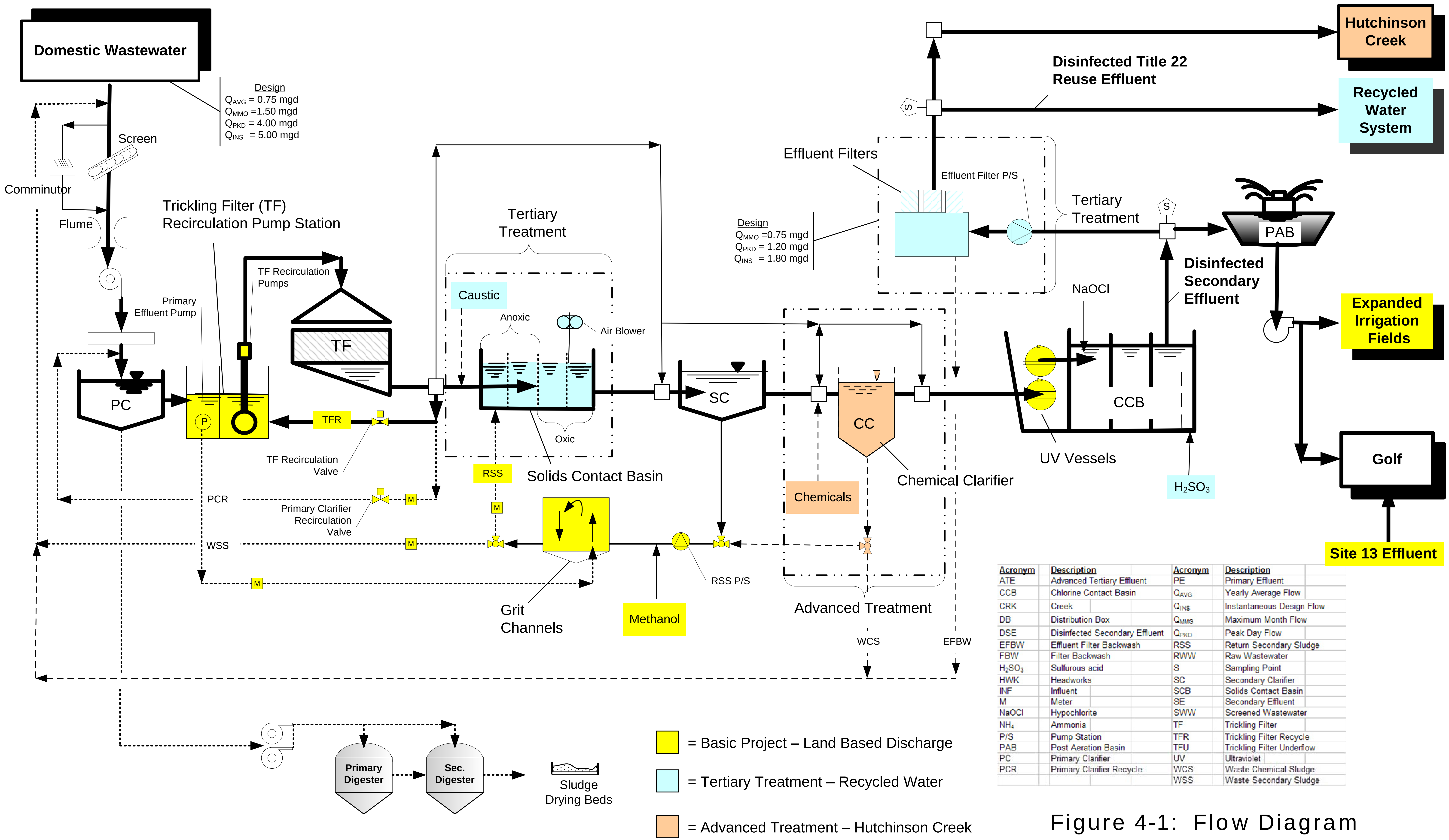


Figure 3-5 –Mass Balance - Existing Wastewater Facility





Acronym	Description	Acronym	Description
ATE	Advanced Tertiary Effluent	PE	Primary Effluent
CCB	Chlorine Contact Basin	Q_{AVG}	Yearly Average Flow
CRK	Creek	Q_{INS}	Instantaneous Design Flow
DB	Distribution Box	Q_{MMG}	Maximum Month Flow
DSE	Disinfected Secondary Effluent	Q_{PKD}	Peak Day Flow
EFBW	Effluent Filter Backwash	RSS	Return Secondary Sludge
FBW	Filter Backwash	RWW	Raw Wastewater
H_2SO_3	Sulfurous acid	S	Sampling Point
HWK	Headworks	SC	Secondary Clarifier
INF	Influent	SCB	Solids Contact Basin
M	Meter	SE	Secondary Effluent
NaOCl	Hypochlorite	SWW	Screened Wastewater
NH_4	Ammonia	TF	Trickling Filter
P/S	Pump Station	TFR	Trickling Filter Recycle
PAB	Post Aeration Basin	TFU	Trickling Filter Underflow
PC	Primary Clarifier	UV	Ultraviolet
PCR	Primary Clarifier Recycle	WCS	Waste Chemical Sludge
		WSS	Waste Secondary Sludge

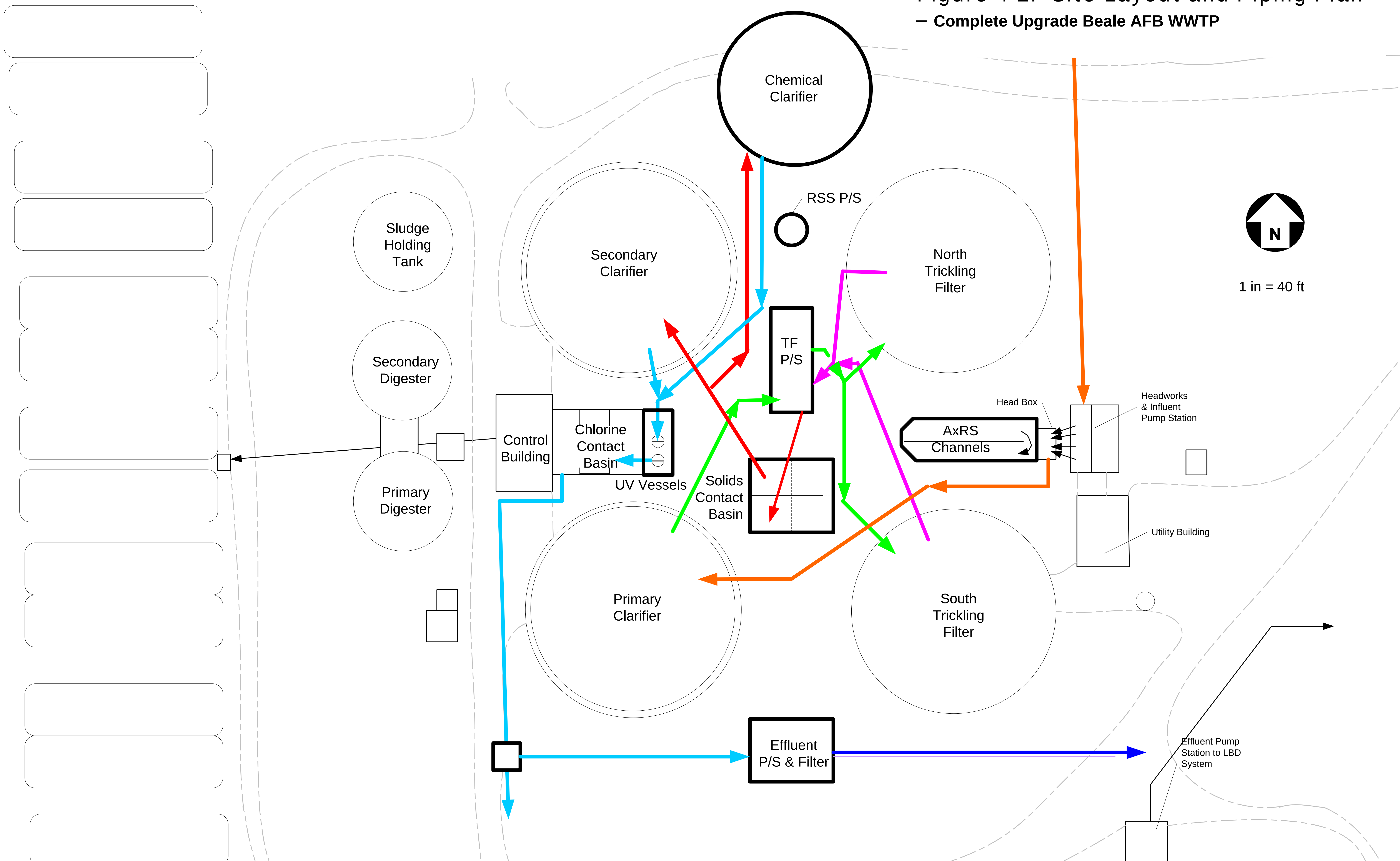
Figure 4-1: Flow Diagram

– Complete Upgrade

Beale AFB Wastewater Treatment Plant

Figure 4-2: Site Layout and Piping Plan

– Complete Upgrade Beale AFB WWTP



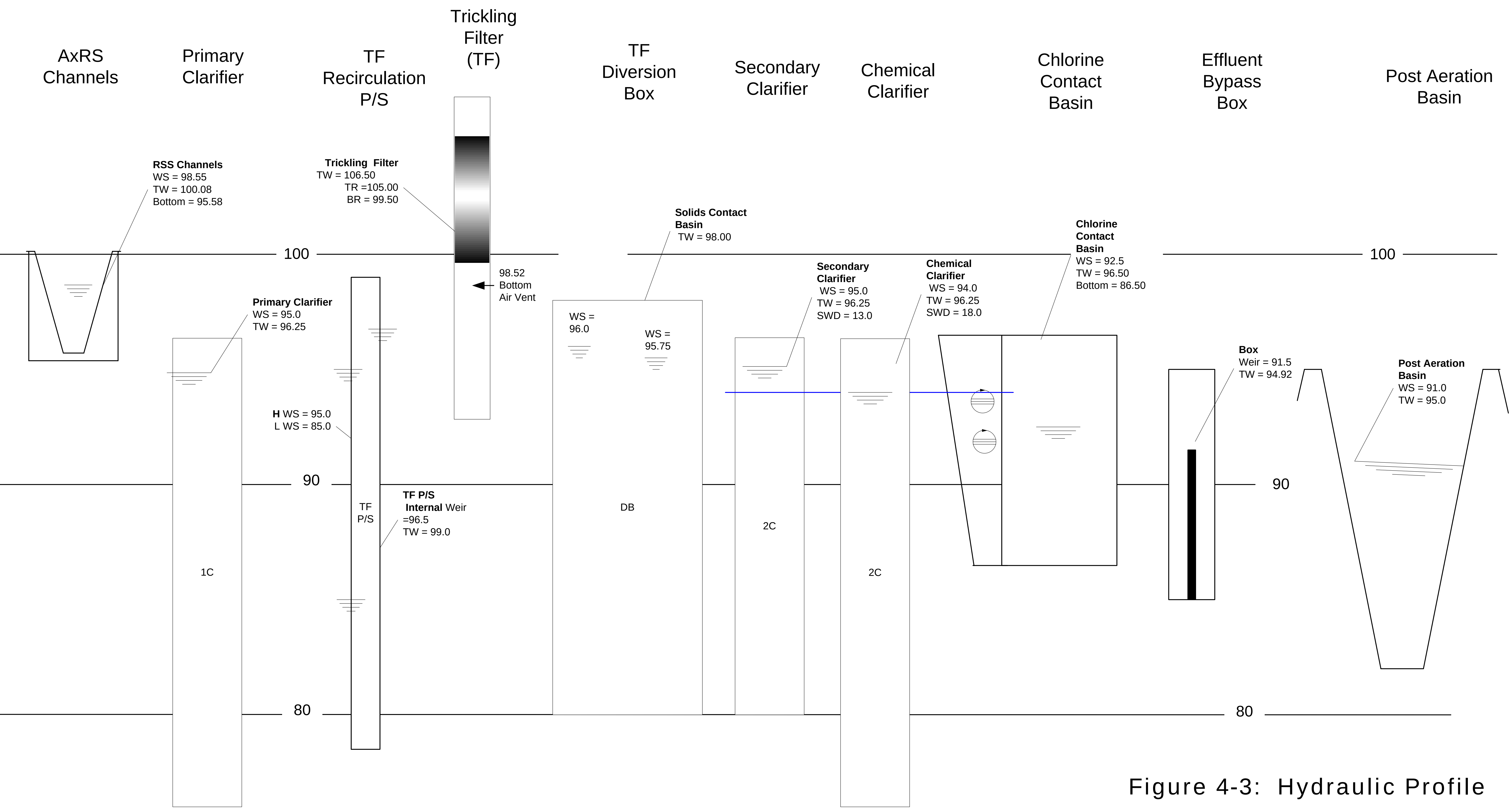


Figure 4-3: Hydraulic Profile
– **Complete Upgrade Beale AFB WWTP**

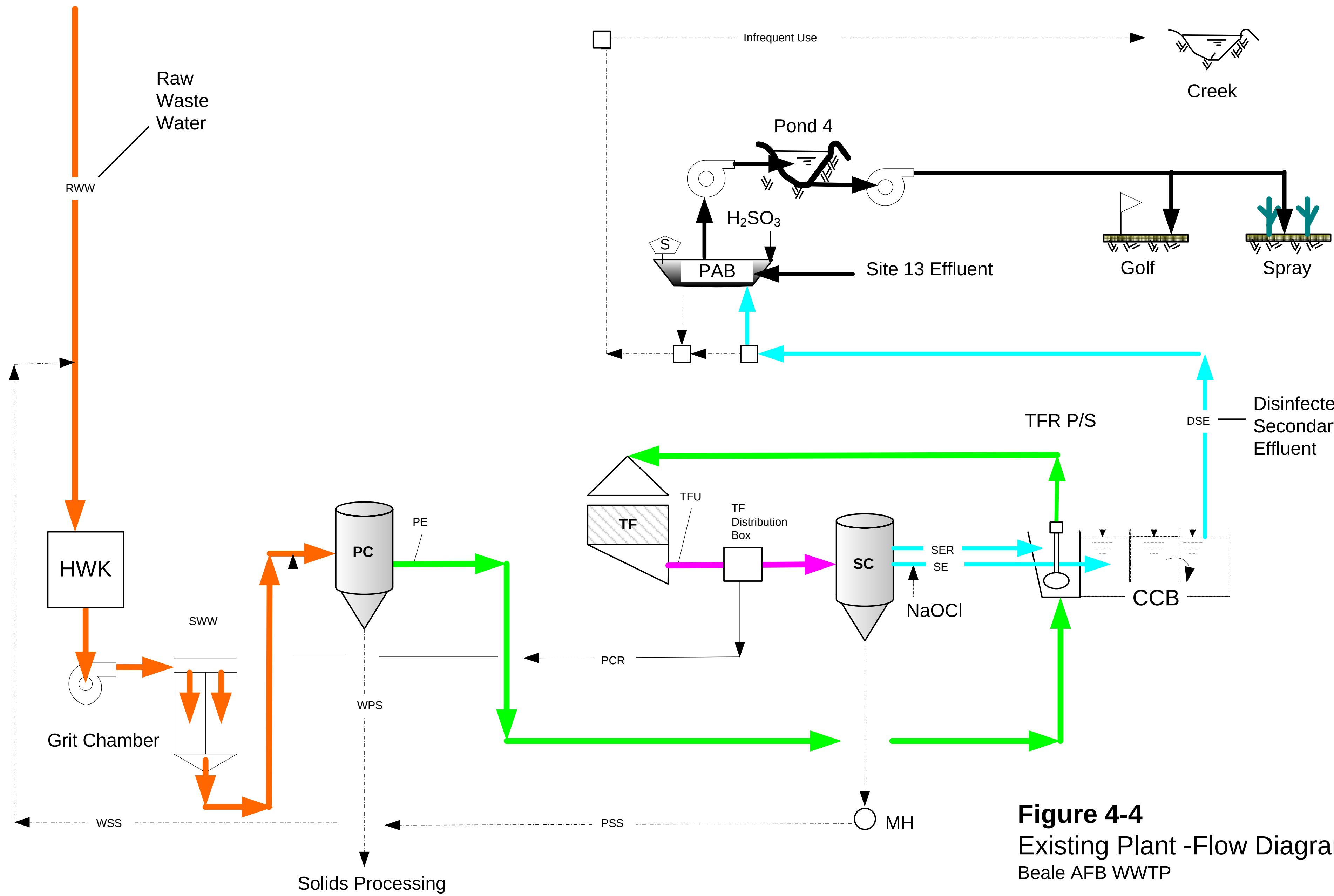


Figure 4-4

Existing Plant -Flow Diagram

Beale AFB WWTP

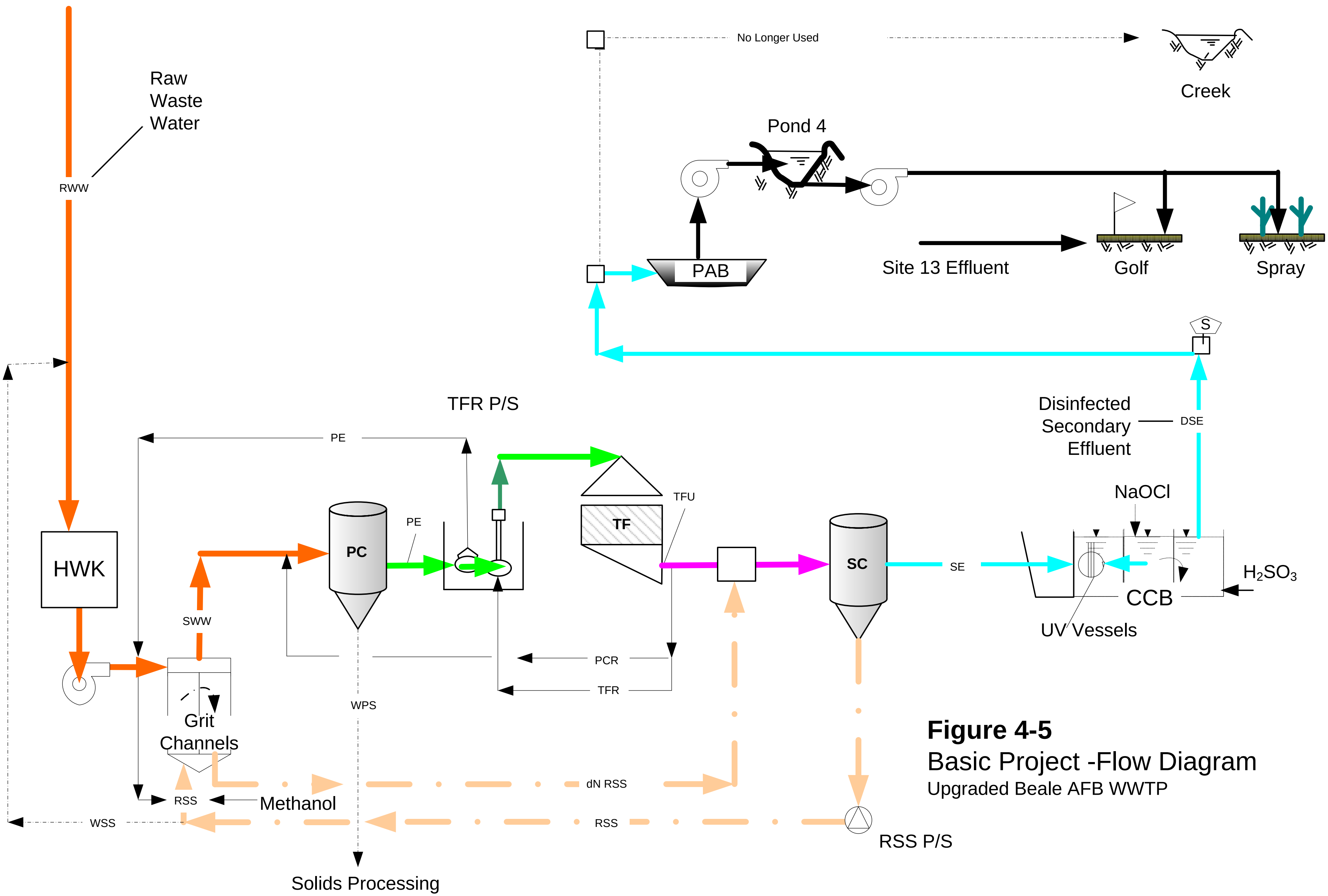


Figure 4-5

Basic Project -Flow Diagram

Upgraded Beale AFB WWTP

Figure 4-6: Site Layout and Piping Plan

– Basic Project Upgraded Beale AFB WWTP