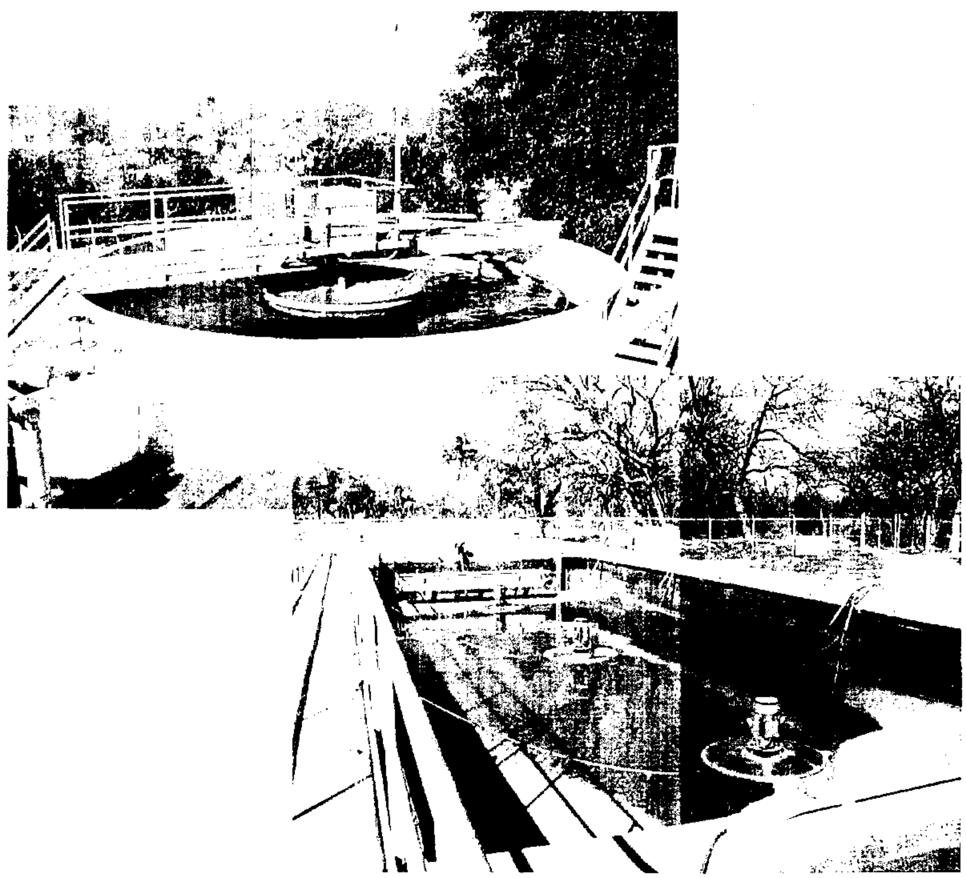
McKee

Final Report

Brazos River Authority

North Bosque River Phosphorus Removal Study for Six Wastewater Treatment Plants

May 2001



Brazos River Authority

North Bosque River
Phosphorus Removal Study

May 2001

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Introduction

Due to elevated phosphorus levels in the North Bosque River, the Texas Natural Resource Conservation Commission (TNRCC) may impose effluent phosphorus limits on wastewater treatment plants to limit their contribution to receiving streams. A monthly average limit of 1.0 milligrams per liter (mg/L) of total phosphorus (TP) is being considered for six treatment facilities, one of the controllable sources of phosphorus, that currently discharge into the North Bosque River. The enactment of this nutrient limit presents potential impacts on the treatment plant operation. These plants are currently not designed for nutrient removal and will require modifications in order to meet the potential new effluent standards.

The objective of this study was to evaluate the current conditions of the wastewater treatment facilities and determine a feasible means of reducing phosphorus at each site. Information collected during site visits was utilized to quantify the current phosphorus loads and develop appropriate design criteria. Conventional chemical and biological treatment methods, as well as innovative approaches, were identified and evaluated for potential application or adaptation to the existing treatment methods. Required additions and modifications for each facility were then developed based on the most viable treatment methods identified. These designs were used to estimate annual treatment costs as well as evaluate nutrient trading to identify the most cost-effective method of meeting the potential phosphorus limits.

Treatment Facilities

As stated previously, this study focused on six municipal wastewater treatment plants discharging into the North Bosque River north of Lake Waco. The six facilities being considered are located in the cities of Clifton, Iredell, Hico, Meridian, Stephenville and Valley Mills. All of the facilities are activated sludge biological treatment plants which use the oxidation ditch process, with the exception of Clifton, which uses a sequencing batch reactor. The Stephenville facility, the largest of the six with a permitted flow of 3 MGD, has some advanced treatment in the form of sand filters. Four facilities, Hico, Iredell, Meridian, and Valley Mills, have 20/20 mg/L biochemical oxygen demand (BOD)/total suspended solids (TSS) discharge limits while two facilities, Clifton and Stephenville, have 10/15 mg/L BOD/TSS discharge limits.

Site evaluations of the treatment facilities identified condition and limitations of the existing treatment processes as well as the potential for upgrading to remove nutrients. All of the facilities were identified as having the potential to add additional treatment basins for biological nutrient removal (BNR); however, two of the facilities, Iredell and Meridian, would require site expansion. Meridian also lacks the land area necessary to accommodate the additional sludge drying beds associated with phosphorus removal, and the Stephenville plant is already too large for a continued reliance on sludge drying beds. Since phosphorus removal will result in more sludge production, these two plants will require the addition of new mechanical sludge handling equipment such as a belt filter press.

Phosphorus Removal Alternatives

Four main treatment alternatives are available for phosphorus removal including chemical removal, biological removal with chemical polishing, wetlands treatment and land treatment. The first two methods involve modifications to the main treatment process through the addition of more treatment units. Phosphorus removal with chemical treatment entails the precipitation of soluble phosphorus by the addition of a precipitate such as alum. Biological treatment is based on the A/O™ process that involves the addition of an anaerobic basin before the existing oxidation ditch at each plant. Chemical polishing with alum is typically included in biological treatment to ensure more reliable phosphorus removal. Both treatment methods require effluent filtration due to the increase in suspended solids from phosphorus treatment. The final two treatment methods, wetlands and land treatment, involve the application of plant effluent to ponds or agricultural areas that readily uptake wastewater constituents.

It should be noted that the City of Clifton wastewater treatment plant, with its sequencing batch reactor process, is already equipped to remove nutrients biologically. However, further chemical polishing and filtration would still be required at Clifton if a total phosphorus limit were added to the discharge permit.

The nutrient removal treatment methods were evaluated for each of the facilities. The evaluations included the sizing of all equipment necessary for process operation as well as the estimation of additional operation and maintenance (O&M) requirements such as chemicals, power, labor, and sludge disposal. Wetlands and land treatment were evaluated on a general feasibility level since a detailed design of each requires a more comprehensive site-specific study. In general, wetlands treatment does not appear to be cost effective for any of the facilities, with the possible exception of Iredell due to the large pond areas required.

Cost Analysis

An estimate of construction costs and annual operations and maintenance costs were developed for each of the chemical and biological phosphorus removal alternatives. Construction costs were then converted to an annualized cost using an effective interest rate of 3.5% and a facilities life of 25 years. When added to the annual O&M costs, the effective annual cost is derived which is used to compare alternatives.

The costs for each site to meet a discharge limit of 1.0 mg/L TP are presented in Table E-1. The most affordable treatment option for each site was identified based on the lowest annualized cost of either chemical or biological phosphorus removal. The estimated construction cost for plant modifications is $4,508,000. These modifications will together require an estimated annual O&M cost of $268,000/year.

Table E-1 shows both the total annual cost of phosphorus removal using a current market interest rate of 6.5%, and the effective annual costs considering the effects of a 3% inflation rate.

Table E-1: Phosphorus Removal Costs

Facility	Flow Rate (MGD)	Proposed Phosphorus Discharged		Phosphorus Removal Method	Construction Cost	Additional Annual O&M Cost	Total Annual Cost[1]	Effective Annual Cost[2]	Annual Cost Per Pound Removed[3]
		(mg/L)	(lbs/yr)				($/yr)		
Clifton WWTP	0.65	1.0	1,979	BNR	$422,000	$21,000	$66,000	$46,000	$23
Hico WWTP	0.2	1.0	609	CHEMICAL	$464,000	$18,000	$55,000	$44,000	$21
Iredell WWTP	0.05	1.0	152	CHEMICAL	$445,000	$10,000	$45,000	$35,000	$66
Meridian WWTP	0.45	1.0	1,370	CHEMICAL	$1,287,000	$47,000	$151,000	$123,000	$26
Stephenville WWTP	3	1.0	9,132	BNR	$1,352,000	$134,000	$244,000	$214,000	$7
Valley Mills WWTP	0.36	1.0	1,096	CHEMICAL	$538,000	$38,000	$81,000	$70,000	$18
Total			**14,338**		**$4,508,000**	**$268,000**	**642,000**	**$532,000**	

[1] Based on a market interest rate of 6.5% .
[2] Based on an effective interest rate of 3.5% after inflation.
[3] Based on effective annual cost.

Nutrient trading between the facilities was also examined, whereby more phosphorus removal is performed at one or more plants while less is removed at others. Based on the cost of phosphorus removal on a per pound basis as shown in Table E-1, it would be more cost effective to concentrate phosphorus removal efforts at Stephenville. Nutrient trading would entail lowering the Stephenville facility to 0.7 mg/L effluent phosphorus, modifying the Meridian, Clifton, and Valley Mills plant to achieve a 1.0 mg/L phosphorus limit, and leaving the Hico and Iredell facilities alone. With this approach, the total phosphorus emitted from the four sites is the same, or less, than from all six sites with 1.0 mg/L TP discharge levels. The costs associated with this alternative are shown in Table E-2. The effective annual cost for this treatment arrangement is $470,000, which represents a savings of $62,000/year compared to the previous treatment scheme.

Table E-2: Nutrient Trading Phosphorus Reduction

Facility	Flow Rate	Estimated Present Phosphorus Discharge		Nutrient Trading Phosphorus Discharge		Cost of Option
	(MGD)	(mg/L)	(lbs/yr)	(mg/L)	(lbs/yr)	(Annualized Cost)[1]
Clifton WWTP	0.65	2.0	3,957	1.0	1,979	$46,000
Hico WWTP	0.2	4.5	2,740	4.5	2,740	N/A
Iredell WWTP	0.05	4.5	685	4.5	685	N/A
Meridian WWTP	0.45	4.5	6,164	1.0	1,370	$123,000
Stephenville WWTP	3	4.5	41,095	0.7	6,393	$231,000
Valley Mills WWTP	0.36	4.5	4,931	1.0	1,096	$70,000
Total			**59,572**		**14,263**	**$470,000**

[1] Annual costs are based upon phosphorus removal to 0.5mg/L to assure that a 1.0mg/L effluent standard is achieved, and using the effective interest rate of 3.5% after inflation.

Summary

To reduce phosphorus loadings on the North Bosque River, an estimated $4,508,000 will be required to upgrade the plants, and an additional $268,000/year will be required in O&M costs. All six plants could then be upgraded to achieve a 1.0 mg/L TP effluent limit.

Should it be decided to implement nutrient trading, some cost savings could be realized. Nutrient trading would entail permitting the Stephenville plant for an effluent discharge limit of 0.7 mg/L TP, permitting the Clifton, Meridian, and Valley Mills plants for an effluent discharge limit of 1.0 mg/L TP, and leaving a TP limit out of the permits for Hico and Iredell entirely. The construction and O&M costs associated with the nutrient trading are summarized in Table E-3. The total construction cost of this approach is estimated at $3,602,000, which represents a capital cost savings of $906,000 compared to modifying all of the facilities. Additionally, the required total annual O&M cost of $256,000/year would save $12,000/year in operational costs by making use of nutrient trading.

Table E-3 Nutrient Trading Cost Summary

Facility	Construction Cost	Annual O&M Cost	Total Annual Cost[1]	Effective Annual Cost[2]
	(Capital Cost)	(Annualized Cost)	($/yr)	(Annualized Cost)
Clifton WWTP	$422,000	$21,000	$66,000	$46,000
Hico WWTP	$-	$-	$-	$-
Iredell WWTP	$-	$-	$-	$-
Meridian WWTP	$1,287,000	$47,000	$151,000	$123,000
Stephenville WWTP	$1,355,000	$150,000	$260,000	$231,000
Valley Mills WWTP	$538,000	$38,000	$81,000	$70,000
Total	**$3,602,000**	**$256,000**	**$492,000**	**$470,000**

[1] Based on a market interest rate of 6.5%.
[2] Based on an effective interest rate of 3.5% after inflation.

Addendum

Since issuance of the draft final report and publication of the required construction costs for implementing phosphorus removal at the six wastewater treatment plants, the authors were made aware of changes being made to the Sequencing Batch Reactor wastewater treatment system serving the City of Clifton. This plant, in the startup phase at the time of the site visit for this project, was subsequently determined by the manufacturer to be in need of modification in order to meet the specified operating performance. Specifically, the originally installed surface aerators were replaced by a diffused aeration system, which consists of air blowers, piping, and air diffusers mounted on the floor of the tanks. The new system will provide better aeration for ammonia removal, but will not provide a separate mixing without aeration cycle which is required for phosphorus removal. Accordingly, separate mechanical mixers will now have to be provided in order to achieve phosphorus removal.

To provide the required mixing, two 5 HP floating mixers could be installed in each SBR basin, plus a single mixer installed in each of the two prereact zones. The cost of adding the 6 mixers including motor controls is estimated at $111,000, although some economies may be possible by reusing the existing controls for the original mechanical aerators, now removed. The additional cost of this equipment and the effect on the overall project is summarized below.

Table E-4 Nutrient Trading Cost Summary

Cost Element	Cost of Additional Clifton Modifications	Revised Cost of Clifton Improvements	Revised Cost of all Recommended Improvements	Revised Cost of Recommended Improvements with Nutrient Trading
Capital Cost	$111,000	$533,000	$4,619,000	$3,713,000
Annual O&M Cost	$3,000	$24,000	$271,000	$259,000
Total Annual Cost[1]	$22,000	$68,000	$644,000	$560,000

[1] Based on a market interest rate of 6.5%.

1 Section One

Section 1
Description of Existing Treatment Facilities

1.1 Introduction

Six municipal wastewater treatment plants (WWTPs) along the North Bosque River were evaluated to determine requirements for reducing effluent phosphorus concentrations. The six municipalities investigated were Clifton, Hico, Iredell, Meridian, Stephenville, and Valley Mills. The location of the facilities are shown on Figure 1.1.

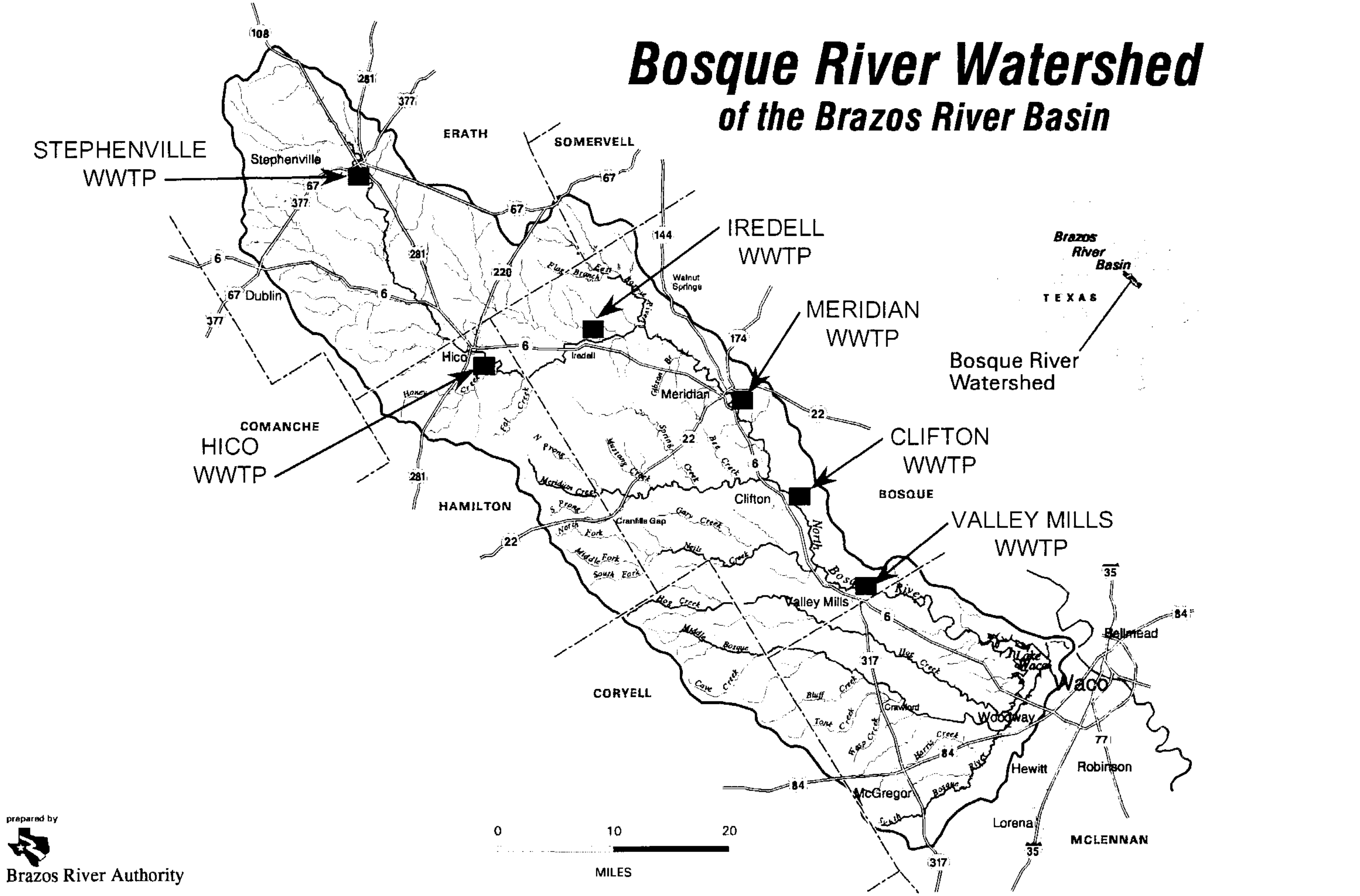
This section describes the characteristics of the existing treatment plants and the treatment process being used. Site evaluations of each facility were performed to identify the current conditions of the plant, the general process and equipment used, basic operating procedures, and historical performance. The plants were also assessed for process modification potential, including equipment, space availability, and staffing limitations. This section identifies potential phosphorus treatment methods for each site; however, the evaluation of the specific methods and concerns are presented in later sections. Photos taken during the site visits are presented in Appendix A.

1.2 Plant Descriptions

Clifton WWTP

The City of Clifton WWTP is a new treatment plant constructed in 1999 on the site of the old WWTP. The layout of the plant and the old process equipment are presented in Figure 1.2. The new plant was designed for an average flow rate of 0.65 MGD and a peak flow of 2 MGD.

Wastewater influent is screened by a climber bar screen and then gravity drained into one of two parallel sequencing batch reactors (SBRs). The reactors utilize the ICEAS (Intermittent Cycle Extended Aeration System) process that includes a pre-react zone and a batch reactor. The pre-react zone is used for the adsorption of biological oxygen demand (BOD_5) into the biomass as well for biological selection. The partially treated influent then flows under a baffle into the main basin and is treated through a three-step cycle: aeration, settlement, and decantation. The aeration step involves further oxidation of BOD_5 and nitrification. During settlement, anoxic BOD_5 reduction, denitrification and clarification occur. The activated biomass is left at the bottom of the reactor and the treated supernatant is then decanted off.



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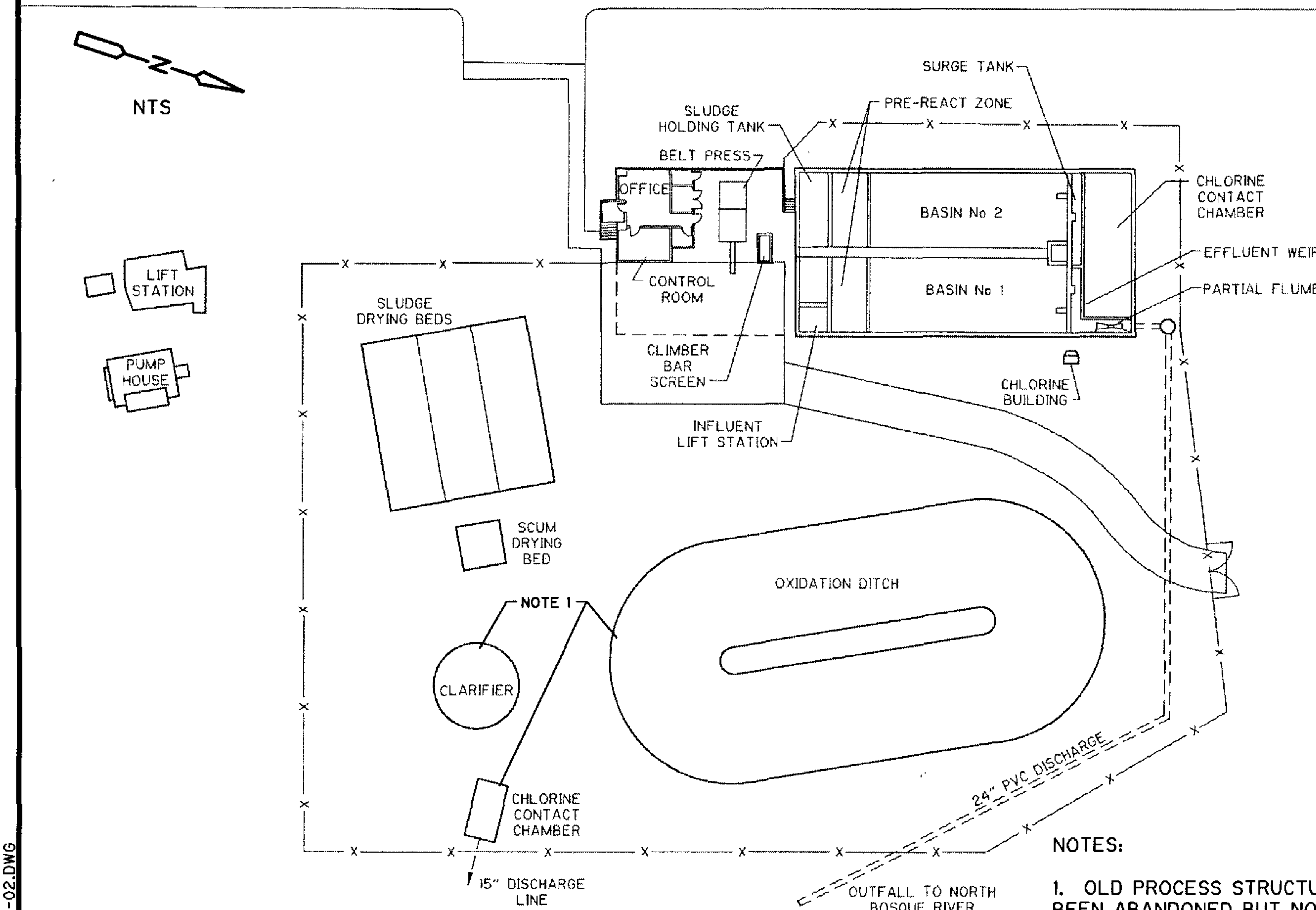
FACILITIES MAP

FIGURE No 1.1



NOTES:

1. OLD PROCESS STRUCTURES HAVE BEEN ABANDONED BUT NOT ELIMINATED.

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CITY OF CLIFTON WWTP

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FIGURE No 1.2

The normal cycle time for treatment is four hours with six cycles per day. During storm flows the treatment cycle is cut to three hours with eight cycles per day. The total cycle time, as well as the length of each treatment stage, can be easily adjusted through the main programmable logic controller (PLC) based on operator discretion. The operation of the two basin cycles is such that only one basin is aerated at a time and the decant periods do not overlap.

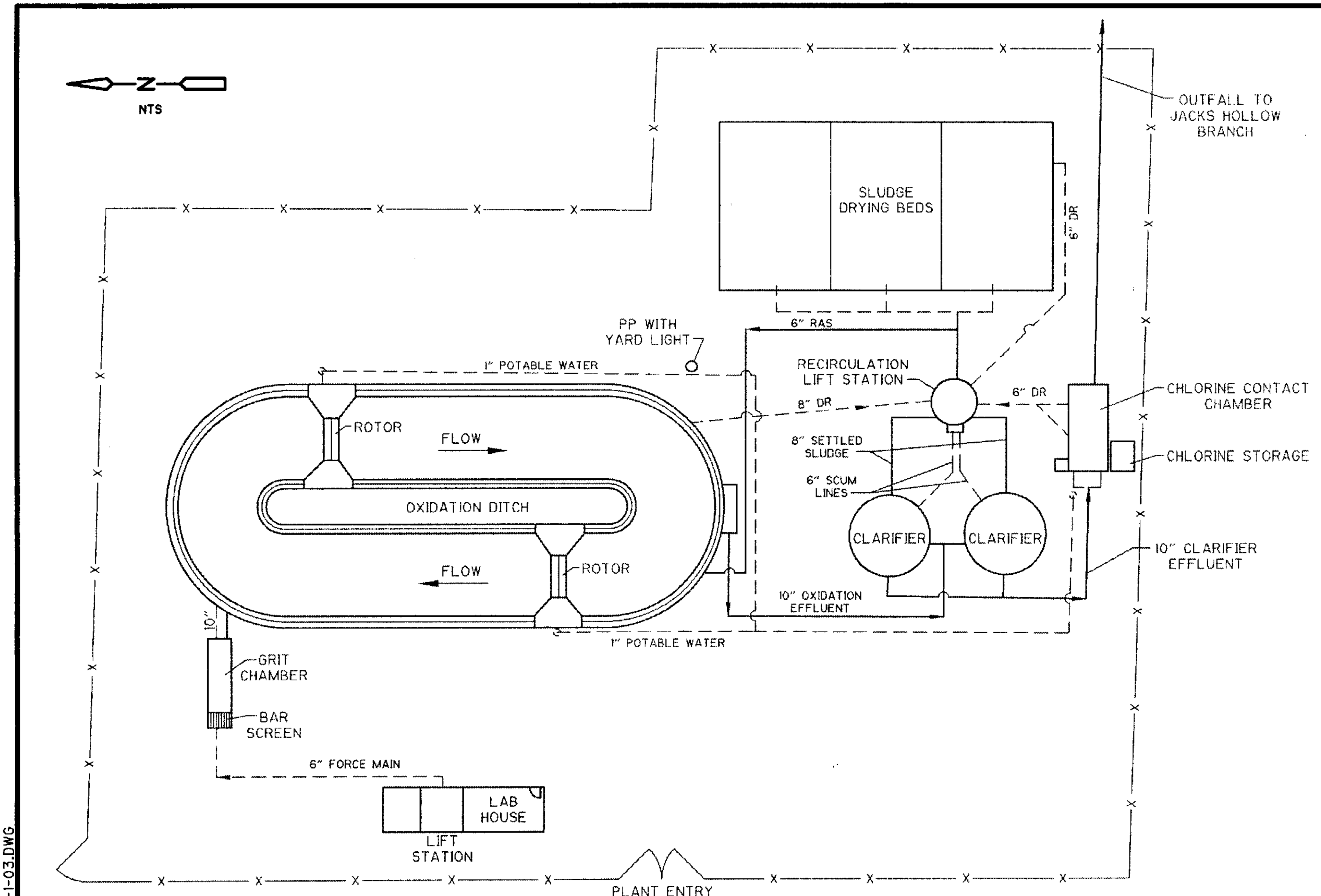
The supernatant collected during decantation is gravity drained into an intermediate surge tank and then into the chlorine contact chamber for disinfection. The final effluent, with a residual chlorine concentration of 1 mg/L, is discharged from the chlorine contact chamber through a Parshall flume and into the North Bosque River in Segment No. 1226.

Activated sludge is wasted from the main reaction chamber when the mixed liquor suspended solids (MLSS) concentration exceeds roughly 5,000 mg/L. The settled sludge is pumped from the bottom of the reactor and into a sludge holding tank (SHT). The wasted activated sludge (WAS) is then pumped from the SHT, thickened with polymer, and dewatered through a Roediger tower belt filter press.

The treatment plant operator, on site during normal working hours, noted that operating the treatment plant was fairly simple due to the PLC. Modifications to the process, for phosphorus removal, could be made through the adjustment of the ICEAS aeration cycle and through chemical polishing with alum. Space is available on site for the addition of chemical storage tanks to the north of the main reactor. The increase in settled solids due to the addition of alum would increase the amount of wasted sludge. This would increase the frequency of sludge dewatering as well as the landfill costs. Phosphorus removal could also potentially require filtration of the effluent prior to disinfection. Filtration equipment could be added through a process expansion to the south of the chlorine contact chamber.

Hico WWTP

The City of Hico WWTP, constructed in 1979, is operated by City staff. It is permitted for a flow of 0.2 MGD and can handle a wet weather flow of up to 0.63 MGD. The layout of the plant and yard piping is presented in Figure 1.3



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CITY OF HICO WWTP

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FIGURE No 1.3

S:\ACAD\31602\FIG-1-03.DWG

Influent wastewater passes through a manual bar screen and grit chamber and is then treated through an activated sludge process. The activated sludge process consists of an oxidation ditch with mechanical brush rotor aerators and two clarifiers. The oxidation ditch has a total volume of 27,585 ft^3, which corresponds to an average residence time of 24.5 hours. The oxidation ditch effluent gravity flows from the effluent weir into one of the clarifiers. The effective volume of each tank is 2,826 ft^3, corresponding to a detention time of 2 hours. Settled sludge gravity flows to the RAS/WAS pump station and is either recycled back to the oxidation ditch or wasted to one of three drying beds.

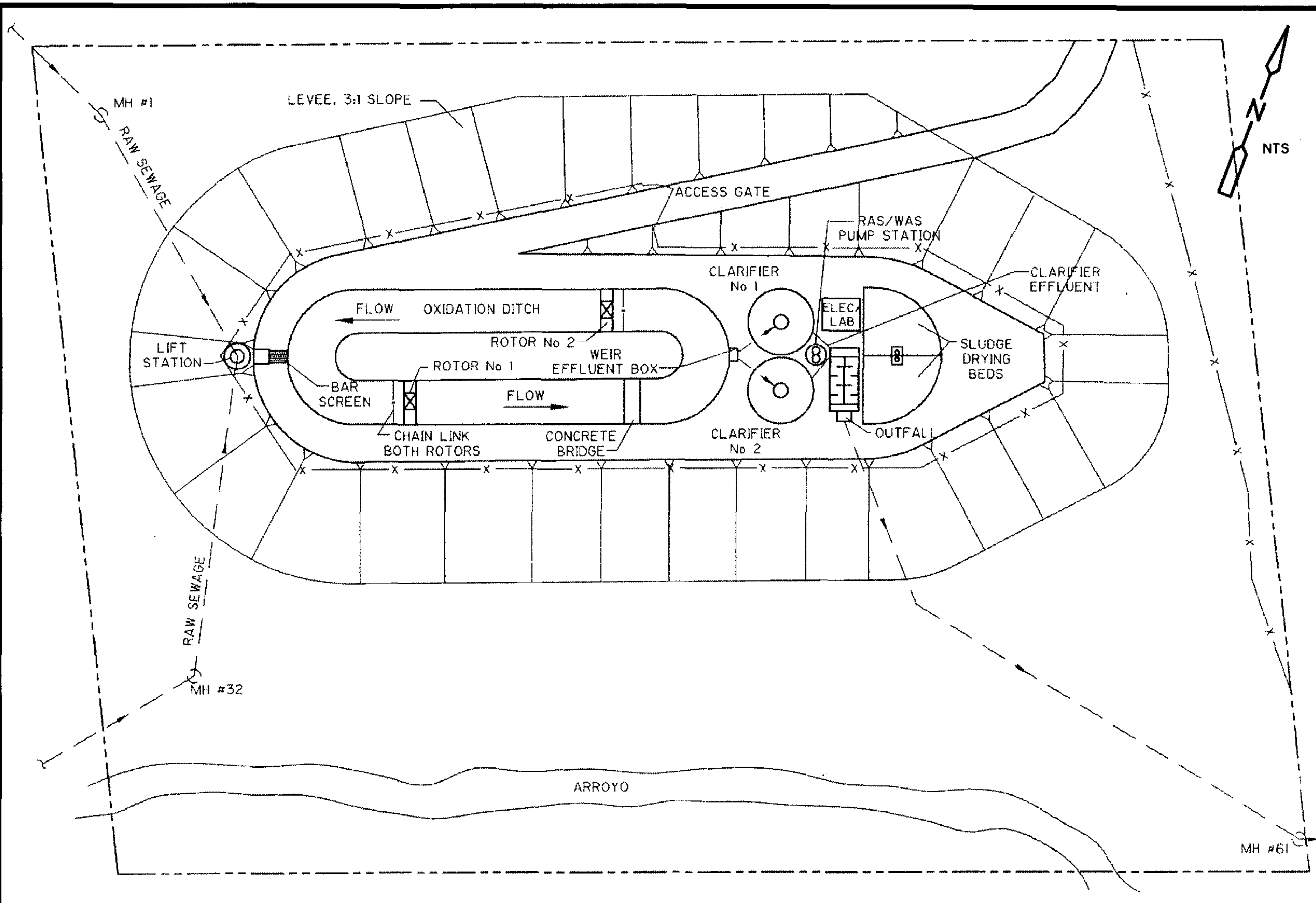
The clarifier effluent is gravity drained to the chlorine contact chamber for disinfection. Following an average chlorination time of 72 minutes, the plant effluent drains from the plant outfall to the Jacks Hollow Branch; thence to the North Bosque River.

Process modification for phosphorus removal at the Hico WWTP would most likely be chemical addition or modification of the existing activated sludge process. The addition of a precipitate such as alum would require on site chemical storage tanks and chemical feed pumps. Space for this additional equipment is available adjacent to the sedimentation tanks, near the plant entrance gate. As stated previously, the addition of alum increases the solids content and the required sludge drying bed area. It must be determined if the existing drying beds can handle the associated sludge volume increase.

Iredell WWTP

The City of Iredell WWTP is the smallest of the six facilities evaluated with a permitted flow of 0.05 MGD. The main treatment train is an activated sludge process. The plant was constructed on an elevated levee and is tightly laid out, as presented in Figure 1.4. A contract operator operates and visits the plant a minimum of five times per week.

Influent sewage is collected in a wet well at the head of the plant. The collected sewage is pumped from the lift station, through a manual bar screen and into an oxidation ditch. The oxidation ditch is mechanically aerated with two brush rotors. Oxidation effluent overflows into one of two clarifiers where solids sedimentation occurs. Settled solids are either recycled back to the oxidation ditch or periodically wasted to either of the two sludge drying beds. Clarified effluent drains to the chlorine contact chamber for disinfection. From the contact chamber, the plant effluent gravity flows through an open channel into Segment No. 1226 of the North Bosque River.



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CITY OF IREDELL WWTP

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FIGURE No 1.4

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While the Iredell WWTP is in good operating condition, its available space is severely limited. Any modifications to the plant would require the expansion of the levee and possible relocation of the driveway. The sludge drying beds are fairly small and would not be able to handle any increase in wasted sludge. The access space around and especially in between each of the clarifiers and contact basin is very limited. Additionally, the lack of handrails around any of the tanks presents a safety concern.

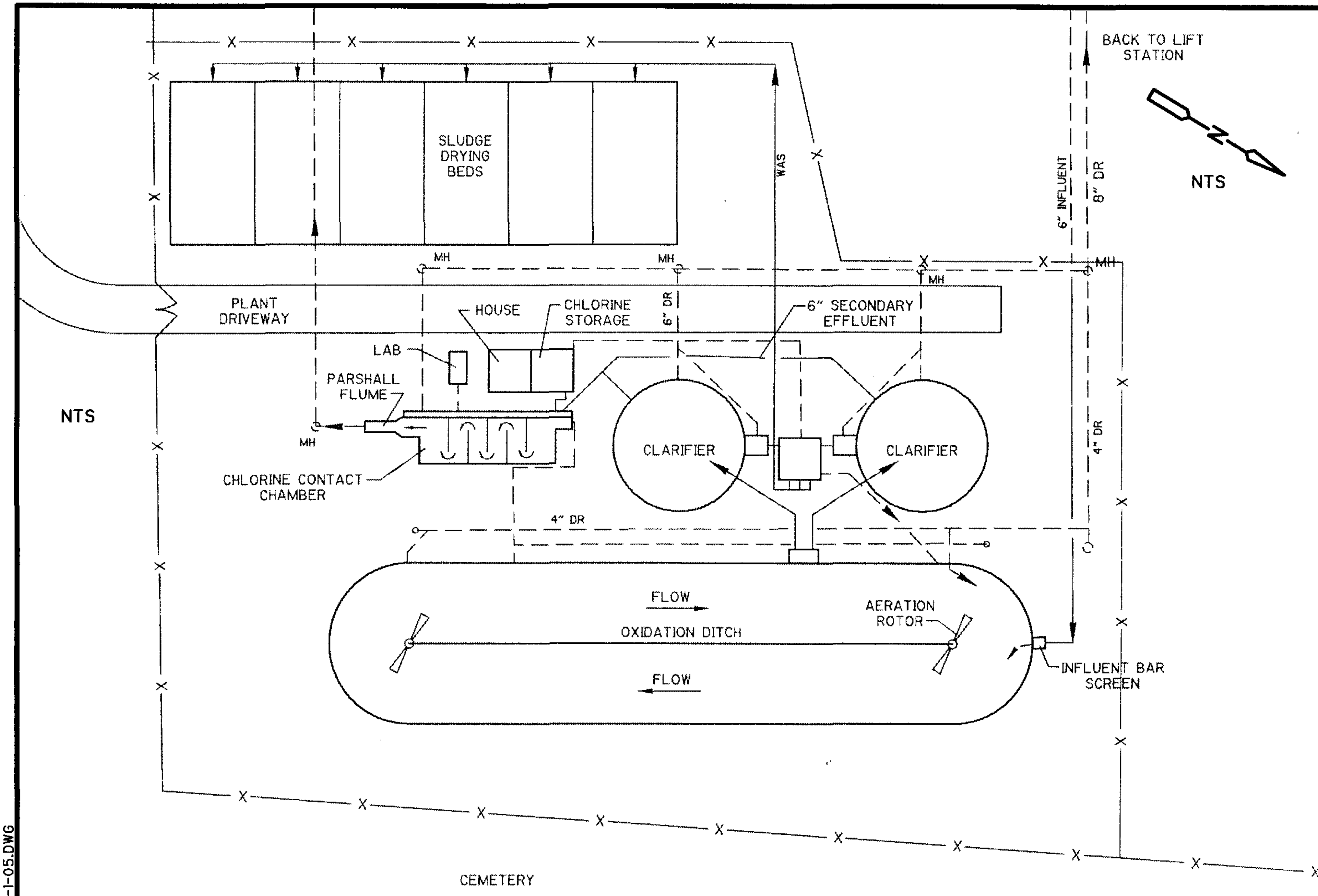
Meridian WWTP

The City of Meridian WWTP, built in 1986, is designed to handle an average flow of 0.45 MGD and a wet weather flow of 1.0 MGD. The plant property and equipment layout is shown in Figure 1.5. The plant site is moderately undersized with limited possibility of expansion beyond the existing fence line. A cemetery borders the plant on the north, and the property drops severely in elevation to the west and south. A private residence borders plant property on the east.

For this plant, influent raw sewage is pumped from an offsite lift station to the influent bar screen. The screened influent then enters a Carousel oxidation ditch where it is treated through an activated sludge process. The ditch is aerated by mechanical aerators, which are operated alternately to avoid solids build up on either end of the ditch. The treated sludge is then drained to one of two clarifiers where the activated sludge is settled out. The clarified effluent then drains to the chlorine contact chamber for approximately 22 minutes of chlorine disinfecting. Once disinfected, the plant effluent is discharged to Moccasin Creek, thence to the North Bosque River.

The settled activated sludge is sent to the WAS/RAS pump station where it can either be recycled to the oxidation ditch or wasted to the sludge drying beds. There are six drying beds with a combined total area of 4,950 ft^2. A stand-by polymer feed system is available for sludge thickening when necessary.

Interviews with the two plant operators revealed areas within the plant that needed improvement. The operators indicated that the influent bar screen, roughly 1.5′ wide and 1′ deep, is too small and gets overloaded when the lift station pumps operate. It requires manual cleaning which is often difficult due to influent splashing. A significant amount of screenable material ends up in the clarifier as a result of the inadequate influent screening. This screenable material is collected during clarifier skimming and is currently recycled back to the oxidation ditch. It would be advantageous to redirect the clarifier skimmings through a manual bar screen before recycling. Also noted was the need for new stems on the oxidation ditch drain valves.



BRAZOS RIVER AUTHORITY
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CITY OF MERIDIAN WWTP

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FIGURE No 1.5

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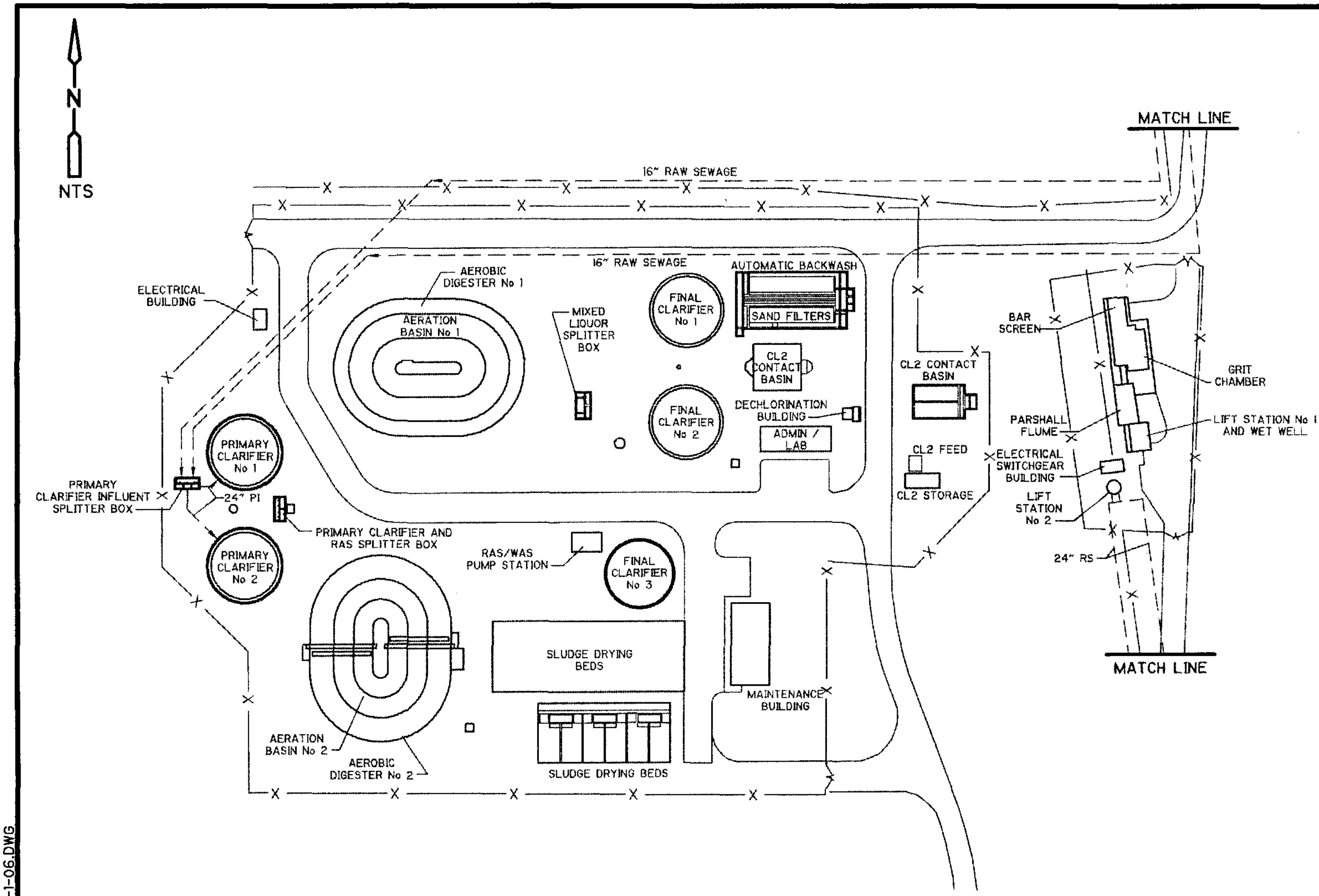
Stephenville WWTP

The Stephenville WWTP is the largest of the six facilities with a permitted flow of 3 MGD. The layout of process equipment and associated structures is presented in Figure 1.6. The plant is spaciously laid out with ample access space between each process structure. The plant has three full-time operators for normal working hours and one on call for after hour emergencies.

The plant influent is pre-treated by screening through a ½" mechanical bar screen and grit removal in a small rectangular grit chamber. The influent flow is measured with a Parshall flume and then passes to one of two raw water lift stations. The pre-treated influent is pumped from the headworks of the plant to the influent splitter box where flow is divided between two primary clarifiers. The primary clarifiers serve to remove settleable solids and scum from the wastewater prior to biological treatment.

Following primary clarification, the wastewater flows by gravity into one of two aeration basins where the activated sludge process begins. The aeration basins at the Stephenville WWTP utilize the Orbal design in which each basin consists of three concentric oval channels. The two inner two rings operate in series as an aeration basin and the third, outer channel is an aerobic sludge digester. Primary clarifier effluent enters the aeration basin in the outer ring, or the middle channel of the basin. The aeration basins are mechanically aerated using horizontal rotating discs. There are a total of six aerators in each basin, four in the outer ring and two in the inner ring, designed to propel the liquid forward while simultaneously entraining air. Aeration basin effluent leaves from the inner channel and gravity flows to the secondary clarifier splitter box.

It is in the three final clarifiers that the activated sludge is settled and recycled back to the front end of the treatment train. The treatment plant includes two sand filters with traveling bridge backwash mechanisms, which are used for clarifier effluent filtering. The effluent is filtered to remove remaining suspended solids, including particulate BOD, from the wastewater prior to chlorine disinfection. Chlorine disinfection occurs in one of two chlorine contact basins, each with a residence time of 22 minutes at peak flow. Due to discharge permit limits, the residual chlorine level must be reduced to 0.1 mg/L following disinfection but prior to discharge. Dechlorination of the plant effluent is performed through the addition of sodium bisulfite immediately upstream of the contact chamber effluent weir. Once dechlorinated, the plant effluent gravity flows to Outfall 002 on the North Bosque River.



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CITY OF STEPHENVILLE
WWTP LAYOUT

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FIGURE No 1.6

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Activated sludge collected from the final clarifiers is periodically wasted in order to maintain an optimum MLSS concentration in the aeration basin. The WAS and the primary clarifier settled solids are transferred to the outer channel of the aeration basin where aerobic digestion takes place. Digestion is performed for sludge stabilization prior to solids disposal. Stabilized solids are drained from the digesters onto the drying beds for dewatering. The plant has two types of drying beds, conventional and wedgewire. The six wedgewire beds, with a combined area of 2,880 ft^2, are the main beds used. The conventional sand drying beds, with a surface area of 7,500 ft^2, are operated as a back up.

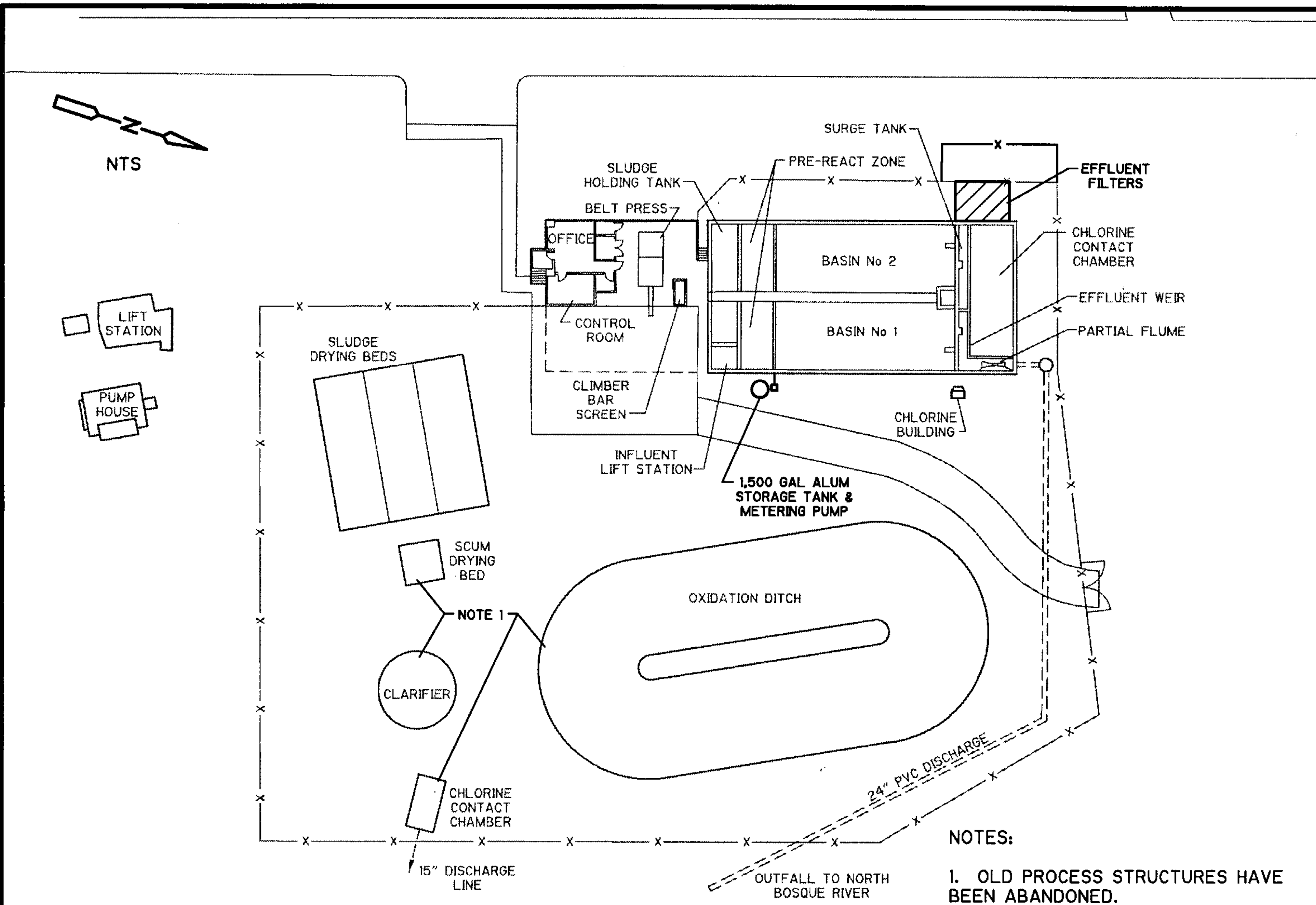
While the plant is fairly new and the equipment is in good mechanical condition, the plant operators noted that a specific operational difficulty had been occurring. The use of a primary clarifier results in low nutrient concentrations in the aeration basins. This creates a situation in which the activated organisms run out of food and die off, reducing the potency of the RAS. To avoid this condition, primary sludge is pumped back into the oxidation ditches rather than into the aerobic digesters. Possible improvements for this situation include bypassing the primary clarifiers or converting them to an alternative process.

Due to existing advanced treatment, there are multiple alternatives available for phosphorus removal. The first alternative is to reconfigure the aeration basins for increased biological nutrient removal. A second alternative is chemical addition to the aeration basin effluent. Ample space is available for additional chemical storage tanks and feed pumps. Available drying bed surface area to handle the increase in waste sludge may be limited, however, which may require the addition of mechanical dewatering. Another alternative available is the use of abandoned ponds east of the plant, which may be feasible for wetlands effluent polishing.

Valley Mills WWTP

The City of Valley Mills WWTP is a small, activated sludge process with a permitted flow of 0.36 MGD. The plant layout, presented in Figure 1.7, includes an abandoned oxidation pond and has space available for expansion. The plant has a contract operator.

The raw sewage influent is pretreated through a manual bar screen and two parallel grit chambers. From the grit chamber, the influent flows into the oxidation ditch where biological treatment begins. The ditch is mechanically aerated through the use of a single horizontal brush rotor. The ditch effluent drains into a final clarifier where the activated sludge is settled out. The clarified effluent is chlorine disinfected and discharged to the Town Creek Branch and thence to the North Bosque River. The settled solids are either recycled to the oxidation ditch influent or wasted to one of four sludge drying beds.



NOTES:

1. OLD PROCESS STRUCTURES HAVE BEEN ABANDONED.

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CITY OF CLIFTON WWTP
BIOLOGICAL PHOSPHORUS REMOVAL

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FIGURE No 5-6

S:\ACAD\31602\FIG-5-06.DWG

Various plant needs were identified during the recent site visit. Currently, the oxidation ditch only has one brush rotor. In the event that this rotor fails, the oxidation ditch is left unaerated; therefore, it is recommended that another rotor be added for aeration reliability. Other needs identified include the replacement of the effluent v-notch weir and repainting of the final clarifier.

As with the other facilities, multiple alternatives are available for decreasing the effluent phosphorus concentration. The biological treatment process could be redesigned to promote nutrient removal. Chemical precipitates could also be added prior to clarification to promote phosphorus precipitation. There is sufficient space available to add new chemical storage tanks and feed pumps. However, the most viable option may be wetland treatment through the use of the abandoned oxidation pond, which would not require a significant increase in manpower or modifications to the plant.

1.3 Conclusions

This section has presented the evaluations of the six WWTPs with outfalls along the North Bosque River. The results of each plant evaluation are summarized in Table 1.1. As stated earlier, the plants were evaluated for the existing treatment method, current staffing practices, and space availability. These criteria were then utilized to identify the most probable treatment modifications for the reduction of effluent phosphorus. All of the plants involve biological treatment of influent sewage through the use of the activated sludge process. While it is possible to modify this treatment process to promote nutrient removal, in some cases it may be easier to either add a chemical precipitate or polish the effluent through land application or wetlands treatment. The extent of treatment modification also depends highly on the quality of effluent currently being discharged.

Table 1-1: Summary of WWTP Evaluations

Facility	Main Treatment Method	Current Manpower	Available Space	Probable Treatment Modification
Clifton	SBR – Activated Sludge	Single, Full-time	Ample	BNR[1], Chemical
Hico	Activated Sludge	Part-time	Ample	BNR[1], Chemical
Iredell	Activated Sludge	Part-time (Contract)	Limited	BNR[1], Wetlands, Chemical
Meridian	Activated Sludge	Full-time	Limited	BNR[1], Chemical
Stephenville	Activated Sludge with Filtration	3 Full-time	Ample	BNR[1], Chemical, Wetlands
Valley Mills	Activated Sludge	Part-time (Contract)	Ample	BNR[1], Chemical, Wetlands

[1] Biological nutrient removal (BNR) entails modifying the existing biological treatment process.

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Section Two

Section 2
Wastewater Characterization

2.1 Introduction

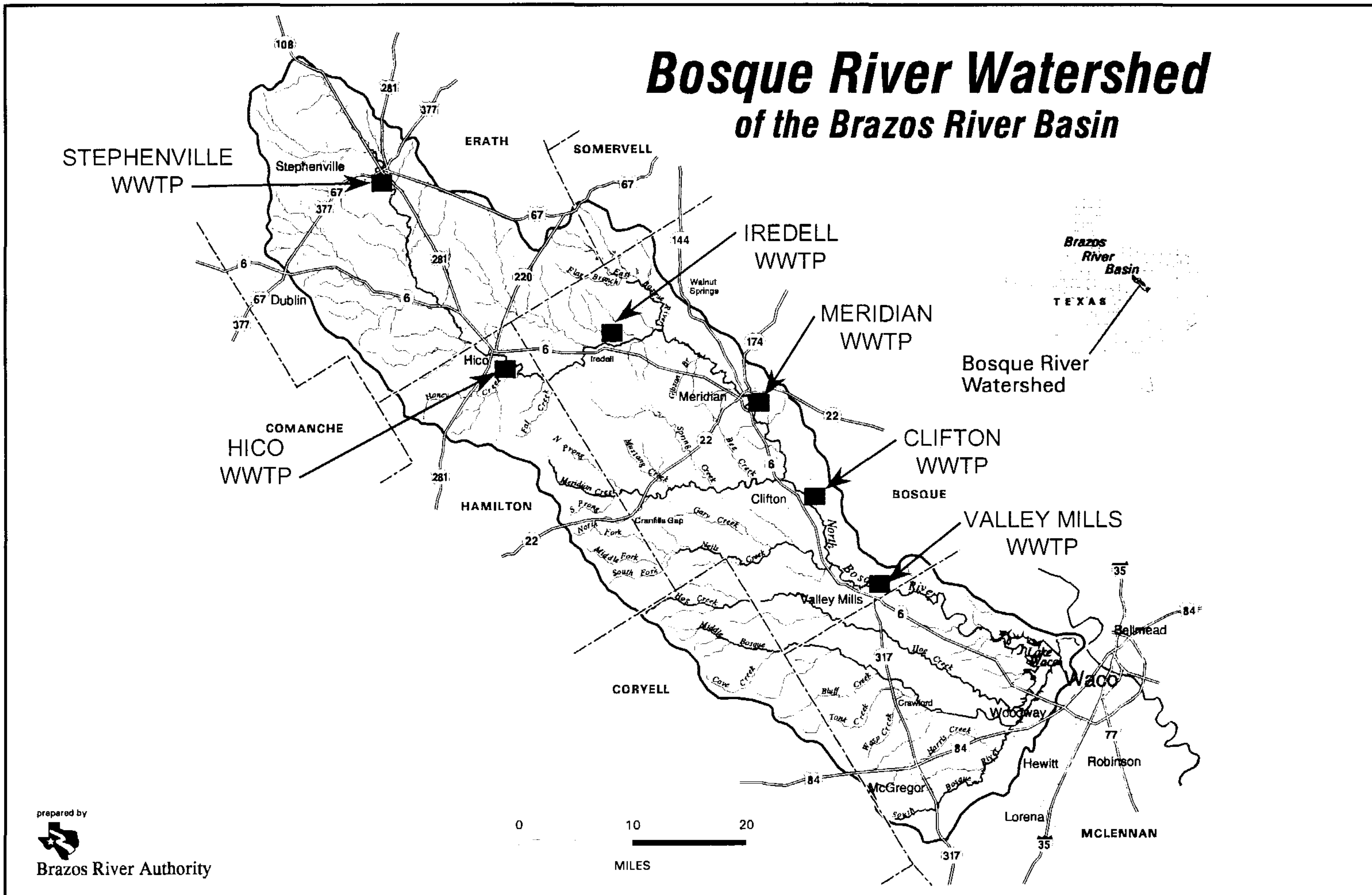
Six municipal wastewater treatment plants (WWTPs) along the North Bosque River were evaluated for the potential reduction of effluent phosphorus concentrations. The six municipalities include Clifton, Hico, Iredell, Meridian, Stephenville, and Valley Mills, which are located to the northwest of Waco in north central Texas. Each city's wastewater effluent discharges into Segment 1226 of the Brazos River Basin, with the exception of Stephenville, which discharges into Segment 1255 of the Brazos River Basin. The study area of this reach of the North Bosque River from Stephenville to Valley Mills covers about 70 river miles. The location of each city and their respective WWTP is presented in Figure 2-1.

The purpose of this section is to review and evaluate existing wastewater flow and quality data that were collected from the respective WWTPs. Data was collected from several sources to create characteristic data sets of the influent and effluent wastewater flows for each evaluated facility. Characterization of the influent and effluent wastewater allows for quantification of existing phosphorus concentrations and WWTP performance. It further provides the basis for the development of WWTP design criteria to control and reduce phosphorus loads in future effluent discharges to the local receiving waters of the North Bosque River watershed.

This section first summarizes the regulatory permit profiles of the six WWTPs evaluated by this study. Next, the condensed influent and effluent wastewater characterization data generated from the data compilation effort are presented and interpreted and any serious data gaps are identified and discussed. Finally, future recommended WWTP design criteria for achieving effluent phosphorus removal are presented for each of the six WWTPs.

2.2 Permit Summary

This section presents the existing wastewater treatment regulatory profiles for each of the six WWTPs located within the North Bosque River study area. A summary table of the existing wastewater discharge permits for these six facilities concludes this section and is presented in Table 2-1. The cumulative average daily flows permitted from the six facilities is 4.71 MGD.



BRAZOS RIVER AUTHORITY
NORTH BOSQUE PHOSPHOROUS REMOVAL STUDY

CDM
environmental engineers, scientists
Planners & management consultants

FACILITIES MAP

FIGURE No 2.1

Clifton WWTP

The City of Clifton WWTP is a new treatment plant constructed in 1999 on the site of the former WWTP. Two parallel sequencing batch reactors (SBRs) treat influent wastewater flows. The Clifton WWTP was designed for an average flow rate of 0.65 million gallons per day (MGD) and a peak flow rate of 2.01 MGD.

The City of Clifton WWTP operates under Texas Pollutant Discharge Elimination System (TPDES) permit number 10043-001 which has a permit expiration date of March 1, 2004. The permitted average daily flow is 0.65 MGD with effluent discharge limitations, expressed in milligrams per liter (mg/L), of 10/15/-/4 (Biochemical Oxygen Demand (BOD)/Total Suspended Solids (TSS)/Ammonia Nitrogen (NH_3)/Dissolved Oxygen (DO)).

The permit further requires self-monitoring of Total Phosphorus (TP) for reporting to the Texas Natural Resource Conservation Commission (TNRCC). The Clifton WWTP is authorized to discharge effluent directly to the North Bosque River.

Hico WWTP

The City of Hico WWTP was constructed in 1979. It is designed for a flow of 0.20 MGD and can handle a wet weather flow of up to 0.63 MGD. The Hico WWTP is an activated sludge process facility that consists of an oxidation ditch with brush rotor aerators and two clarifiers.

The City of Hico WWTP operates under TPDES permit number 10188-001 which has a permit expiration date of March 1, 2004. The permitted average daily flow is 0.2 MGD with effluent discharge limitations of 20/20/-/2 (BOD/TSS/ NH_3/DO). The Hico WWTP is authorized to discharge to Jacks Hollow Branch, a tributary of the North Bosque River.

Iredell WWTP

The City of Iredell WWTP is the smallest of these six facilities and uses an activated sludge treatment process. The Iredell WWTP was constructed on an elevated levee site and is designed for an average flow of 0.05 MGD and a peak flow of 0.12 MGD.

The City of Iredell WWTP is currently operating under TPDES permit number 11565-001 and National Pollutant Discharge Elimination System (NPDES) permit number TX0024848. Permit expiration is July 12, 2001 for these permits. The facility must soon seek a permit renewal that will convert the WWTP to the TPDES program and will result in the issuance of a single permit (TPDES permit number 11565-001). The Iredell WWTP should receive a permit term that will expire in the middle of 2004, to align with the other entities within this portion of the Brazos River Basin. The current permitted average daily flow is 0.05 MGD with effluent discharge limitations of 20/20/-/2 (BOD/TSS/ NH_3/DO). It is unknown if these effluent discharge limitations will remain the same. The possibility of a permit requirement for the self-monitoring of Total Phosphorus (TP) for reporting to the TNRCC is a definite possibility in the new TPDES permit. The Iredell WWTP is authorized to discharge effluent to an unnamed, open channel that flows directly to the North Bosque River.

Meridian WWTP

The City of Meridian WWTP was built in 1986 and is designed to handle an average flow of 0.45 MGD and a wet weather flow of 1.00 MGD. Wastewater treatment is achieved through an activated sludge process that is performed in a carousel oxidation ditch with mechanical rotors providing aeration followed by two clarifiers.

The City of Meridian WWTP operates under TPDES permit number 10113-002 which has a permit expiration date of March 1, 2004. The permitted average daily flow is 0.45 MGD with effluent discharge limitations of 20/20/-/2 (BOD/TSS/ NH_3/DO). The Meridian WWTP is authorized to discharge effluent to Moccasin Creek, a tributary of the North Bosque River.

Stephenville WWTP

The City of Stephenville WWTP is the largest of the six facilities and was designed for an average flow of 3.0 MGD and a wet weather flow of 9.0 MGD. The plant was recently built and it is good condition and is very well maintained. The Stephenville WWTP is an activated sludge facility with filtration.

The City of Stephenville WWTP is currently operating under TNRCC permit number 10290-001 and National Pollutant Discharge Elimination System (NPDES) permit number TX0024228. The facility is currently seeking a permit renewal that will convert the WWTP to the TPDES program and will result in the issuance of a single permit (TPDES permit number 10290-001). The Stephenville WWTP will receive a permit term that should likely expire in the middle of 2004, to align with the other entities within this portion of the Brazos River Basin. The current permitted average daily flow is 3.0 MGD with effluent discharge limitations of 10/15/2/6 (CBOD - Carbonaceous Biochemical Oxygen Demand/TSS/ NH_3/DO). It is unknown if these effluent discharge limitations will remain unaltered. The possibility of a permit requirement for the self-monitoring of Total Phosphorus (TP) for reporting to the TNRCC is a definite possibility in the new TPDES permit. The Stephenville WWTP is authorized to discharge effluent to either the Upper North Bosque River (via Outfall 001) or directly to the North Bosque River (via Outfall 002).

Valley Mills WWTP

The City of Valley Mills WWTP was designed to treat an average flow of 0.36 MGD and a wet weather flow of 1.08 MGD. The Valley Mills WWTP operates as an activated sludge process facility.

The City of Valley Mills WWTP operates under TPDES permit number 10307-001 which has a permit expiration date of March 1, 2004. The permitted average daily flow is 0.36 MGD with effluent discharge limitations of 10/15/-/4 (BOD/TSS/ NH_3/DO). The more stringent discharge limitations for this facility are due to its close proximity to Lake Waco, a drinking water source reservoir. The Valley Mills WWTP lies about 12 miles from the headwaters of Lake Waco. The Valley Mills WWTP is authorized to discharge effluent to Town Creek Branch, a tributary of the North Bosque River.

A summary of the existing wastewater discharge permits for these six facilities is presented below in Table 2-1.

Table 2-1 TNRCC Permit Summary

Facility Name	Permit Number	Permit Capacity (ADF)[1]	Permit Expiration	Discharge Limits (BOD/TSS/NH3/DO)
Clifton WWTP	10043-001	0.65 MGD	3-01-2004	10/15/-/4[2]
Hico WWTP	10188-001	0.20 MGD	3-01-2004	20/20/-/2
Iredell WWTP	11565-001	0.05 MGD	7-12-2001	20/20/-/2
Meridian WWTP	10113-002	0.45 MGD	3-01-2004	20/20/-/2
Stephenville WWTP	10290-001	3.00 MGD	9-1-2000 [3]	10/15/2/6
Valley Mills WWTP	10307-001	0.36 MGD	3-01-2004	10/15/-/4

[1] Permit Capacity as expressed as Average Daily Flow (ADF) volume in million gallons per day (MGD)

[2] Clifton WWTP also monitors Total Phosphorus for monthly Discharge Montoring Reports (DMRs)

[3] Stephenville WWTP permit remains in effect until a new TPDES permit is issued by TNRCC

The cumulative permitted effluent flows for these six WWTPs to the North Bosque River on an average daily flow basis are 4.71 MGD.

2.3 Wastewater Characterization

Wastewater characterization is a vital element used for the development of design criteria for wastewater treatment plants. The six North Bosque River watershed WWTPs involved in this study were specifically evaluated for phosphorus removal capability. Wastewater characterization data of influent and effluent flows were compiled according to water quantity and water quality parameters. No significant contributory industrial flows were noted among the reviewed wastewater data, with the minor exception of the City of Meridian WWTP that is discussed in the influent analysis below. The City of Stephenville has some small industrial operations which have no appreciable effects on the plant; a cheese manufacturing facility which formerly contributed significant industrial loads to the Stephenville facility is no longer in operation.

Data sources for water quantity and water quality data that were compiled into wastewater characterization data sets used for the evaluation of the six WWTPs included:

- Available self-monitoring data from the individual plants;
- Brazos River Authority (BRA);
- Texas Institute for Applied Environmental Research (TIAER);
- Texas Natural Resource Conservation Commission (TNRCC); and
- United States Environment Protection Agency (USEPA).

Wastewater characterization efforts were based on existing effluent flow and water quality data collected from BRA, TIAER, TNRCC, USEPA, and the individual WWTPs, and on a recent sampling of the influent flows to four of the six study area WWTPs for primary influent flow and water quality data. Parameters compiled and reviewed from existing effluent data included wastewater flow rates (average and maximum), 5-day (carbonaceous) biochemical oxygen demand (CBOD/BOD), total suspended solids (TSS), temperature, pH, conductivity, fecal coliform, nitrite (NO_2), nitrate (NO_3), nitrite plus nitrate (NO_2 + NO_3), ammonia (NH_3 -N), organic nitrogen (Organic N), total kjeldahl nitrogen (TKN), total phosphorus (TP), chloride (CL), and sulfate (SO_4). Sampling data derived from influent and effluent grab samples collected on December 20-21, 2000 were analyzed by the Bio Chem Laboratory of West, Texas included BOD, chemical oxygen demand (COD), TSS, TN, NH_3 -N, TP, PO_4, and alkalinity. Condensed versions of the compiled influent and effluent data sets (from January 1999 to the most recent 2000 records) used for the following analysis are presented in Appendix B.

Influent Data Analysis

Historical influent data for total phosphorus (TP) is presented for three of the six WWTPs. Stephenville WWTP provided a data set with a period of record ranging from July 1999 through December 2000. Clifton WWTP provided a data set with a period of record from December 1999 through June 2000 and Meridian WWTP provided a period of record data set for February 2000 through November 2000. Theses three facilities combine to account for about 90 percent of the average wastewater plant effluent flows that are discharged by the six WWTPs in the North Bosque River study area, with Stephenville contributing 67 percent, Clifton contributing 14 percent, and Meridian contributing 8 percent, respectively, based on average daily historical effluent flows. A summary of the influent total phosphorus values recorded at these three facilities is presented in Table 2-2 below.

Table 2-2
Historical Influent Data Summary
Total Phosphorus

Parameter	Clifton WWTP	Meridian WWTP	Stephenville WWTP
Total Phosphorus, mg/L TP	8.9	3.3	12.9

Influent grab samples were also collected from four of the six WWTPs located within the North Bosque River watershed study area for influent data characterization. The four WWTPs that were sampled were Hico, Iredell, Meridian, and Valley Mills. The influent grab samples were collected on December 20-21, 2000 for laboratory analysis. The analytical results of this recent sampling event are presented in Table 2-3. Flow-weighted composite averages from this influent sampling effort are also summarized in this table.

Table 2-3
Influent Grab Sample Data Summary[1]

Parameter	Hico WWTP	Iredell WWTP	Meridian WWTP	Valley Mills WWTP	Weighted Average[2]
BOD	373	276	277	519	396
COD	790	553	831	349	657
TSS	318	249	533	82.5	281
TKN	65	49	56	42	56
NH_3-N	29.6	14.4	24.3	0.64	19.6
Alkalinity	370	389	381	355	368
TP	12.2	8.0	9.7	4.8	9.5
PO_4	37.5	22.1	29.8	15.1	24.9

[1] All parameters expressed as milligrams per liter (mg/L);

[2] Data that represents the flow-weighted composite of the 4 WWTPs sampled.

Phosphorus in wastewater typically occurs as either orthophosphate or organic phosphate. Orthophosphates are mostly inorganic forms originating from detergents and fertilizers discharged to wastewaters. Organic phosphorus is present in waste products and food residues contained in wastewater. Total phosphorus is the sum of the ortho and organic forms, and is reported as phosphorus (TP) or as phosphate (PO4). To convert phosphate to phosphorus, multiply the phosphate value by 0.326 which is the ratio of the molecular weights, or, more commonly, divide by 3.

Influent data that was available for evaluation for the Cities of Hico, Iredell, and Valley Mills was limited to the above grab sample results. For the purposes of this study, the more extensive influent historical data from Stephenville, Clifton, and Meridian are considered sufficient to provide a wastewater characterization for the study area as the contributing service areas for each WWTP facility are substantially equivalent.

One exception is noted for the City of Meridian, whose WWTP receives variable influent from a local bakery facility. According to operators at the Meridian WWTP, the plant occasionally receives slugs of elevated BOD, COD, and TSS.

Effluent Data Analysis

Effluent data was more readily available and abundant than influent data for this study. Historical data for all six WWTPs were merged and compiled from several data sources that include BRA, TIAER, TNRCC, and USEPA. Each city's representative data set contains data from at least January 1995 to about October 2000, or more than a 5-year period of record. Data generated from each WWTP were compiled into comprehensive data sets that are condensed and presented for each city in Appendix B. Average values from each city's data set is presented for each of the 18 water quantity and water quality parameters and are summarized in Table 2-4 below. A flow-weighted average value of the six WWTPs for each parameter is also included in Table 2-4.

Table 2-4
Effluent Historical Data Summary[1]

	Clifton WWTP	Hico WWTP	Iredell WWTP	Meridian WWTP	Stephenville WWTP	Valley Mills WWTP	Weighted Average
AveDayFlow[2]	0.30	0.08	0.03	0.17	1.41	0.10	1.02
MaxDayFlow[2]	0.40	0.14	0.22	0.31	2.20	0.20	1.59
BOD	5.3	2.5	2.9	3.1	3.9	4.7	4.5
TSS	30.5	24.9	45.9	11.9	10.9	12.3	14.8
DO	7.0	5.3	8.5	7.9	8.0	6.2	7.6
TKN	8.1	3.4	3.8	1.5	2.1	2.0	2.9
NH_3-N	4.5	0.2	0.7	0.3	0.7	0.4	1.1
Organic N	3.6	3.2	3.1	1.2	1.4	1.6	1.8
NO_2	0.3	0.1	0.1	0.1	0.2	0.3	0.23
NO_3	2.1	8.4	15.0	16.9	2.8	22.3	5.3
NO_2+NO_3	2.2	9.8	15.1	19.5	5.8	16.9	7.1
TP	2.4	4.1	4.8	3.6	2.8	3.1	2.9
PO_4-P[3]	1.8	3.0	2.5	3.2	2.4	3.3	2.4
Cl	56.6	65.0	49.5	67.0	147.1	149.0	125.7
SO_4	57.5	49.1	49.7	57.0	65.1	132.9	68.5
FC[4]	421.7	59.6	349.1	122.1	201.0	216.8	746.4
pH	7.8	7.4	7.9	7.6	7.7	7.5	7.7
Conductivity[5]	922	882	837	942	1140	1044	1078
Temperature[6]	21.8	20.4	19.7	19.9	21.2	20.7	21.1

[1] All parameters expressed as milligrams per liter (mg/L) except as noted otherwise

[2] Average daily and maximum daily flows are expressed as million gallons per day (mgd)

[3] Phosphate expressed as phosphorus

[4] Fecal Coliform is expressed as colony forming units per 100 milliliters (cfu/100 ml)

[5] Conductivity is expressed as microsiemens

[6] Temperature is the annual average expressed as degrees celsius (C)

2.4 Data Gaps

Following the analysis of influent and effluent wastewater data that was provided by BRA, TIAER, TNRCC, USEPA, and the six participating cities, several data deficiencies or inconsistencies were identified and discussed below. The most significant deficiency was the general lack of influent wastewater data that was available. Except for Stephenville, no comprehensive historical influent data set was identified to characterize influent wastewater contributions to the six WWTPs. Instead, influent data characterization relied largely on the recent sampling of four study area WWTPs conducted on December 20-21, 2000, plus some historical data from Stephenville, Meridian, and Clifton. The four WWTPs that were sampled included Hico, Iredell, Meridian, and Valley Mills.

2.5 Proposed Wastewater Treatment Design Criteria

This section presents recommended design criteria for the six WWTPs located within the study area, as determined from the wastewater influent and effluent characterization. A summary of the recommended design criteria for each of the six North Bosque River study area WWTPs is presented in Table 2-5.

In developing appropriate criteria to use for design, existing influent flows and concentrations were reviewed and compared to normally expected influent water quality for small cities with predominantly domestic wastewater flows. The permitted design flow rates for each plant is indicated as the average daily flow rate and the peak two-hour flow volume. The maximum month condition is used for design since the discharge permit specifies monthly average effluent conditions. Maximum month flows were estimated for these plants as the average flow multiplied by a peaking factor of 1.5, except for Stephenville where 1.3 was used.

The peaking factors for the maximum month condition were selected on an empirical basis using CDM's professional judgment. In Table 2-4, effluent maximum day/average day peaking factors for flow can be reliably computed based on the relatively good record of data collected. These peaking factors are:

Max Day/Avg Day Peaking Factors

Clifton	1.33
Hico	1.75
Iredell	7.33
Meridian	1.82
Stephenville	1.56
Valley Mills	2.00

The maximum month peaking factor is less than the maximum day peaking factor, and typically the peaking factor increases with decreasing flow. Clifton, with its SBR process, provides some dampening of the flow, which may explain its lower observed effluent peak, and Iredell is considered an outlier. A max month/average day peak of 1.5 seems appropriate for the small plants. Because Stephenville is much greater in size, a max month peaking factor of 1.3 was used. These peaking factors are consistent with other similarly sized Texas cities.

Influent grab samples shown in Table 5-3 indicate pollutant levels higher than typical design parameters for BOD and TSS, which more commonly are around 200 mg/L. Based on the influent grab samples, 300 mg/L should be appropriate for design for average conditions, with 400 mg/L as a maximum month condition. An accurate influent pollutant concentration value cannot be determined for these facilities without more detailed wastewater sampling, which would be beneficial prior to final design of improvements. Additional influent sampling was beyond the scope of this study. However, all plants are currently meeting their discharge permits, and none of the plants will be increased in capacity as a result of the phosphorus removal upgrade. For this reason it appears that adequate BOD removal and TSS settling capacity exists in all the plants, which would not be expected to change.

For removal of phosphorus, the levels of total phosphorus observed in the grab samples are well within the capability range of the common removal processes. Therefore, based on past operating histories, the plants should continue to successfully treat the wastewater even if the actual concentrations are higher than typical design. Available influent data from Clifton, Meridian, and Stephenville averaged 9.6, 3.3, and 12.7 mg/L TP, respectively. The value for Meridian seems unusually low, since normal domestic wastewater is in the 5-10 mg/L range. Based on this data record plus the grab samples shown in Table 2-3, an average influent TP level of 10 mg/L is recommended for design purposes, except for Stephenville where 13 mg/L TP is used to be consistent with its higher readings.

Influent ammonia data is unavailable except for Stephenville. The influent grab samples obtained showed a wide variation in ammonia readings. For design purposes, a value of 20 mg/L is recommended which is at the high end of domestic wastewater values, which typically ranges from 15-20 mg/L. An exception is Stephenville, where the data record in Appendix B indicates a much higher than normal influent ammonia level. For this plant a value of 40 mg/L is used in order to be consistent with the existing data and to provide a conservative approach.

The data provided in Table 2-5 is used in sizing of nutrient removal facilities, which are described in Sections 4 and 5.

Table 2-5
Recommended WWTP Design Criteria

WWTP Design Criteria	Clifton WWTP	Hico WWTP	Iredell WWTP	Meridian WWTP	Stephenville WWTP	Valley Mills WWTP
Design (Permitted) Average Daily Flow (MGD)	0.65	0.20	0.05	0.45	3.00	0.36
Design Maximum Month Flow (MGD)	0.98	0.30	0.075	0.68	3.90	0.54
Design (Permitted) Peak 2-Hour Flow (MGD)	2.00	0.63	0.12	1.00	9.00	1.08
Peaking Factor (Peak 2-hour Flow/Average Flow)	3.08	3.15	2.44	2.22	3.00	3.00
Average Influent BOD (mg/L)	300	300	300	300	300	300
Max Month Influent BOD (mg/L)	400	400	400	400	400	400
Max Month Influent BOD (lbs/day)	3,270	1,000	250	2,300	13,000	1,800
Average Influent TSS (mg/L)	300	300	300	300	300	300
Max Month Influent TSS (mg/L)	400	400	400	400	400	400
Max Month Influent TSS (lbs/day)	3,270	1,000	250	2,300	13,000	1,800
Average Influent TP (mg/L)	10	10	10	10	13	10
Max Month Influent TP (mg/L)	12	12	12	12	16	12
Max Month Influent TP (lbs/day)	170	55	15	85	975	90
Average Influent NH3 (mg/L)	20	20	20	20	40	20
Max Month Influent NH3 (mg/L)	25	25	30	25	50	25
Max Month Influent NH3 (lbs/day)	335	105	25	170	3,000	180
Average Influent TKN (mg/L)	30	30	30	30	50	30
Max Month Influent TKN (mg/L)	35	35	35	35	60	35
Max Month Influent TKN (lbs/day)	505	185	40	250	3750	270
Min. Wastewater Temperature (C)	8.4	7.7	5.9	5.1	8.9	7.4
Max. Wastewater Temperature (C)	31.2	29.2	31.5	28.4	28.6	30.1
Average Influent pH	7.8	7.4	7.9	7.7	7.7	7.5
Average Influent Alkalinity (mg/L CaCO3)	350	350	350	350	350	350

3

Section Three

Section 3
Nutrient Removal Alternatives

3.1 Introduction

Domestic wastewater is rich in phosphorus compounds. Prior to the development of synthetic detergents, the content of inorganic phosphorus usually ranged from 2 to 3 mg/L and organic forms varied from 0.5 to 1.0 mg/L. Most of the inorganic phosphorus was contributed by human wastes as a result of the metabolic breakdown of proteins and elimination of the liberated phosphates in urine. The amount of phosphorus released is a function of protein intake, which averages approximately 1.5 g/day in the United States.

Most heavily synthetic detergent formulation designed for the household markets contain large amounts of polyphosphates. Many of these detergents contain 12 to 13 percent phosphorus or over 50 percent of polyphosphates. The use of these materials as a substitute for soap has greatly increased the phosphorus content of domestic wastewater. It has been estimated from the sales of polyphosphates to the detergent industry that domestic wastewater probably contains from two to three times as much inorganic phosphorus at the present time as it did before synthetic detergents became widely used. Local ordinances limiting the use of phosphate-based detergents have a significant impact on the quantity of phosphorus in the community's wastewater.

The primary pollution effect of phosphorus in surface waters is eutrophication. Since phosphorus is the growth-limiting plant nutrient in natural waters, discharge of wastewater high in soluble phosphates leads to accelerated fertilization. Accelerated fertilization results in lakes and reservoirs with excessive growth of algae causing reduced water transparency, depletion of dissolved oxygen, release of foul odors, loss of finer fish species, and dense growth of aquatic weeds in shallow bays.

3.2 Chemical Phosphorus Removal

Chemicals are used for a variety of municipal treatment applications, including enhancement of flocculation/sedimentation, solids conditioning, odor control, algae control, nutrient addition, activated-sludge bulking control, acid/base neutralization, precipitation of phosphorus, and disinfection.

Phosphorus precipitation generally requires the addition of a coagulant aid (flocculant) as well as a coagulant. Coagulants typically used for phosphorus precipitation are:

- Lime
- Alum
- Sodium aluminate
- Ferric chloride
- Ferrous sulfate

Of these chemicals, alum is generally less expensive and is the most widely used for chemical phosphorus removal. Alum would likely also be the chemical of choice for the North Bosque River Plants.

A schematic of the chemical P removal process is shown on Figure 3-1.

Stoichiometric Chemical Requirements

Aluminum sulfate, commonly known as alum, in addition to coagulating colloidal and suspended solids, removes an appreciable amount of the phosphorus from wastewater. The reaction of alum and phosphate is as follows:

$$Al_2(SO_4)_3 \bullet (14H_2O) + 2H_2PO_4^- + 4HCO_3^- \rightarrow 2AlPO_4 + 4CO_2 + 3SO_4^{2-} + 18H_2O$$

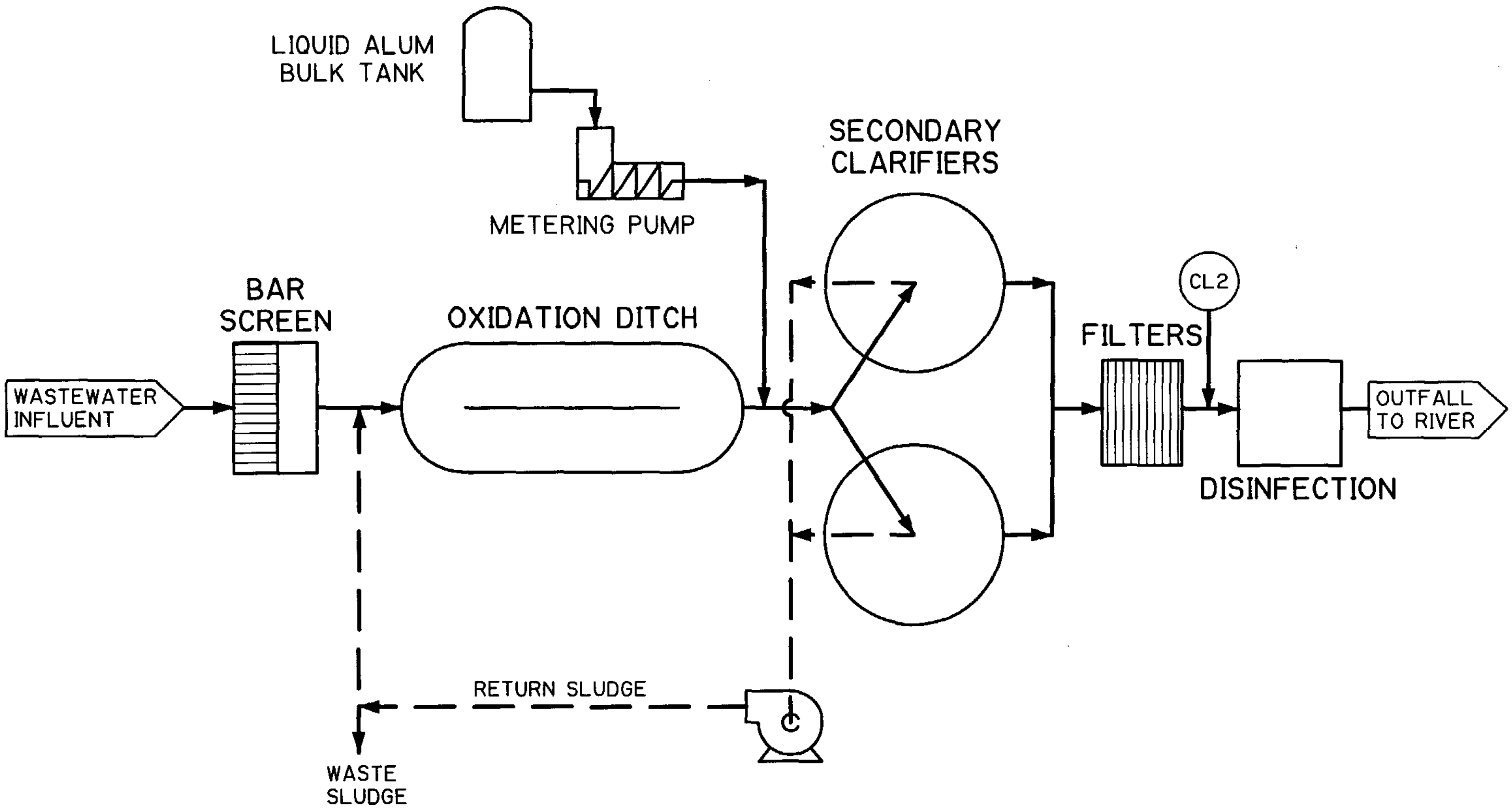
As seen in the above equation, sulfate ions remain in solution and pH is depressed. Using the above equation, the calculated weight ratio of alum to phosphorus is 9.6:1 (0.87 Al:1.0 P). In practice, more alum is required because of side reactions involving wastewater alkalinity and organic matter.

Dosages and Achievable Limits

The determination of chemical dosages for alum and other mineral precipitants is the stoichiometry of the reactions involved. In the case of lime, the degree of phosphorus removal depends directly on the pH of the system. For aluminum and iron salts, phosphorus removal efficiency varies directly with chemical dosage up to the point where mole requirements (molecular weight in grams of any particular compound) for phosphate precipitation and side reactions have been satisfied. Optimum dosages cannot be readily calculated because of the ambiguity of the reactions involved. As a result, laboratory jar tests may be used to determine actual chemical requirements.

The ability to meet a 1.0 mg/L limit for total phosphorus (TP) using chemical removal is largely dependent on the amount of total suspended solids (TSS) in the plant effluent, which in turn depends on the efficiency of the secondary clarifiers. For a 1.0 mg/L TP limit, it is customary to provide effluent filters to insure that the limit is not exceeded.

S:\ACAD\31602\FIG-3.1.DWG



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CHEMICAL PHOSPHORUS REMOVAL

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FIGURE No 3-1

It should also be noted that both aluminum and iron salts, when used as phosphorus precipitants, can increase total dissolved solids (TDS) in plant effluent. However, the impact of metal salts on TDS is typically not significant unless the TDS of the raw wastewater is already high and large doses of metal salts are required.

Sludge Production

Addition of mineral salts for phosphorus precipitation can appreciably increase the quantity of solids generated through production of metal-phosphate precipitates and metal hydroxides and improved SS removal. The production of metal-phosphate precipitates increase the faction of inert solids in the mixed liquor recycle stream. While this has no adverse effects on the biological treatment, it does decrease the maximum sludge retention time and hence increase the rate of sludge wasting.

Solids production increases from 50 to 100% have been observed with the addition of metals upstream of primary clarification. Overall plant solids mass increase is smaller because of reduced secondary sludge production from improved primary removals (for example, a 60 to 70% increase is typical across the entire plant).

For metal addition to secondary processes, waste mixed liquor solids mass may increase by 35 to 45%, and the overall plant solids mass may increase by 5 to 25%. Metal addition to either primary or secondary treatment units not only increases solids mass, but also sludge volume due to a decrease in the settled solids concentration.

In the absence of definitive bench-scale or pilot-scale data, stoichiometric reactions of aluminum ions provide a useful estimate of solids production. The overall reaction is shown below:

$$Al^{3+} + 3H_2O \rightarrow Al(OH)_3 + 3H^+$$

Each mole of cation should react with three moles of water to produce one mole of metal hydroxide and three moles of hydrogen ions. Therefore, one milligram of alum, Al2(SO4)314H2O, will react to produce 0.26 mg of insoluble aluminum hydroxide while consuming 0.5 mg/L of alkalinity as calcium carbonate. Alkalinity reductions are important design considerations for low-alkalinity waters or nitrified effluent. During nitrification, significant alkalinity reductions occur and additional chemical treatment that further reduces alkalinity should be carefully evaluated. However, based on the water quality data for the six treatment plants on the North Bosque River, it appears there is adequate alkalinity available for both chemical P removal and nitrification.

3.3 Biological Phosphorus Removal

During biochemical oxygen demand (BOD) oxidation, conventional secondary biological treatment systems take up phosphorus from solution. Phosphorus becomes an essential cell component, required in intracellular energy transfer. For this reason, phosphorus is taken up in an amount related to the stoichiometric requirement for biosynthesis. A typical phosphorus content of microbial solids is 1.5 to 2% on a dry weight basis.

The stoichiometry and kinetics of phosphorus release and uptake are not fully understood for biological phosphorus removal systems. Therefore, engineers must rely on empirical observations to obtain information for process design and modifications.

A sequence of an anaerobic zone followed by an aerobic zone in an aeration basin promotes the selection of a population rich in organisms capable of phosphorus uptake at levels beyond stoichiometric requirements for growth. Within this environment, the biomass accumulates phosphorus to levels of 4 to 12% of microbial solids. Wastage of these solids results in approximately 2.5 to 4 times more phosphorus removal from the system than that from conventional treatment. The organism most often associated with enhanced biological phosphorus removal belongs to the genus Acinetobacter.

Basic Process Description

The design and operation of a biological phosphorus removal system requires an understanding of the mechanism by which enhanced biological phosphorus uptake occurs. The currently accepted mechanism of enhanced biological phosphorus removal (EBPR) is as follows:

- In the anaerobic zone (stage), acetate and other short-chain fatty acids (fermentation products), produced by fermentation reactions, are stored intracellularly, most commonly as polyhydroxybutyrate (PHB). In performing the anaerobic uptake of soluble organic and forming intracellular storage products, microorganisms must expend energy. These microorganisms obtain this energy anaerobically through the cleavage of high-energy phosphate bonds in stored long-chain inorganic polyphosphates. This process produces orthophosphate that is released from the cell into solution. Thus, removal of soluble BOD with simultaneous release of phosphorus occurs.

- In the aerobic zone (stage), a rapid uptake of soluble orthophosphate provides for the resynthesis of the intracellular polyphosphates. Accompanying this uptake, previously stored PHB is aerobically oxidized to carbon dioxide, water, and new cells. The aerobic metabolism of residual soluble BOD will also occur in this zone.

The rate and extent of phosphate release in the anaerobic zone are related to the type and quantity of soluble substrate available for uptake and storage as PHB. It has been observed that lower molecular weight fatty acids are preferred substrates. Researchers have found that approximately 1 mg/L phosphorus will be released for every 2 mg/L acetate as chemical oxygen demand (COD) removed anaerobically. The actual rate of uptake of readily biodegradable COD (RBCOD) and the rate of release of phosphorus in the anaerobic zone with municipal wastewater are first-order reactions with respect to the readily degradable COD. This implies that the division of the anaerobic zone into two to four compartments will enhance biological release and subsequent uptake of phosphorus. The mechanism of phosphorus removal described above depends on the volatile acid fraction of the readily biodegradable COD and is controlled by the rate of conversion of degradable COD to volatile fatty acids (VFAs). Research has also shown that phosphorus removal improves with decreasing temperature.

The aerobic zone performance for enhanced biological phosphorus removal is dependent on the amount of phosphorus release achieved and the amount of organic matter present for growth. If anaerobic detention time is sufficient for complete excess phosphorus release and a favorable incoming ratio of organic matter to phosphorus exists, rapid soluble phosphorus uptake can be expected in the aerobic zone. Phosphorus removal of approximately 2.0 to 2.5 mg PO_4-P/100 mg influent COD (3 to 4 mg/100 mg/L BOD) has been observed.

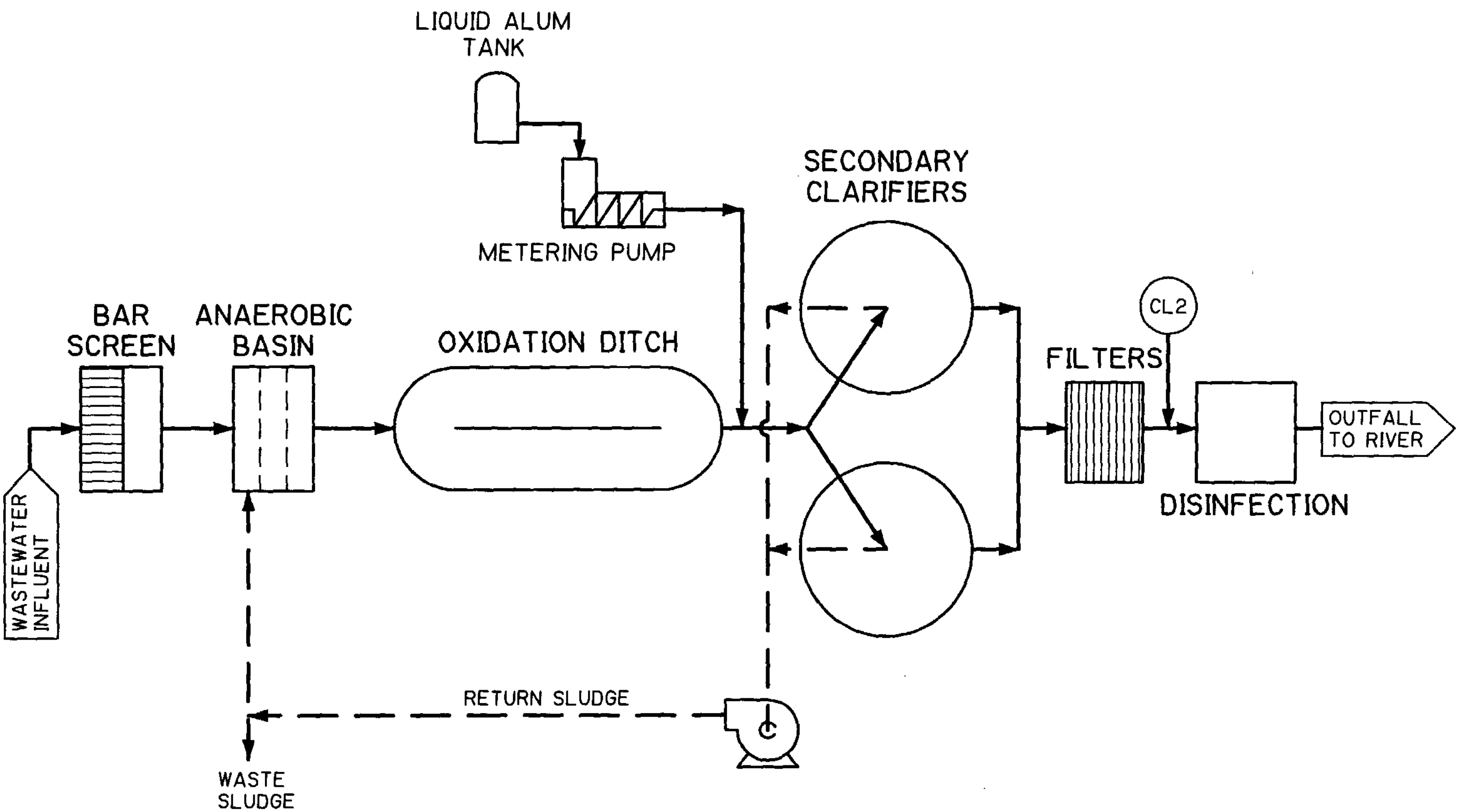
The ability to meet a 1.0 mg/L limit is primarily a function of influent characteristics, %P in the activated sludge, and the effluent suspended solids. A plant can achieve relatively low ortho phosphorus (soluble P) concentrations if there are sufficient VFAs in the biological process feed. However, the removal of the particulate P fraction is dependent on the efficiency of secondary clarification. In general, 1.0 mg/L TP represents the lower limit for biological P removal; however, a limit of 2 mg/L is used for practical design purposes. To insure a 1.0 mg/L TP permit limit, effluent filters are typically used. Additionally, chemical P removal facilities are also generally provided in case of upset of the biological P removal process.

Biological Phosphorus Removal Options

For the North Bosque River plants, two basic biological phosphorus removal schemes are possible. One is to provide an anaerobic basin upstream of the existing aerobic basins. This process is referred to as the A/O™ (anaerobic/oxic) process, and would be applicable to all of the cities except Clifton. Clifton has a sequencing batch reactor (SBR) process, which already incorporates an anaerobic treatment step. The other five plants use the oxidation ditch process that is typically fully aerobic. Adding the anaerobic basin upstream of the oxidation ditches would permit biological P removal. The second approach would be to add precise aerator control to the existing oxidation ditches to create an anaerobic zone within the existing basins. These two options are described below.

A/O™ Process

A number of existing facilities in the United States use the A/O Process, which can attain effluent total phosphorus concentrations as low as 1 to 2 mg/L. The A/O Process consists of two stages, an anaerobic stage followed by an aerobic stage. Each stage is typically divided into equally sized, completely mixed compartments. Clarifier underflow returns to the first stage anaerobic reactor. A schematic of the A/O process is shown on Figure 3-2.



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A/O™ PROCESS FOR
PHOSPHORUS REMOVAL

FIGURE No 3-2

Enhanced biological phosphorus removal processes such as the A/O process have intrinsic limitations as to minimum effluent concentrations of phosphorus attainable. It is considered good practice to provide standby chemical storage and feeding equipment for these processes because standby chemical feed systems will ensure more reliable phosphorus removal at a capital cost of only a small fraction of the overall facility cost. Filters and chemical polishing are generally provided to achieve discharge permits of 1.0 mg/L TP or less. However, because most of the phosphorus is removed biologically, the amount of chemical required for polishing is small. Typical dosages of metal salts for chemical polishing will vary depending on wastewater characteristics and desired effluent concentration. These dosages are determined by performing simple jar tests. The polishing chemicals are added at suitable points in the process where the soluble phosphorus is at a minimum; for example, the end of aeration tanks, before clarifiers, or before effluent filters.

Modified Aeration Control

For oxidation ditch plants, in lieu of adding an upstream anaerobic tank, it may also be possible to provide precise control of the aerators to achieve biological nutrient removal within the existing ditches. Oxidation ditch plants use long detention times to treat wastewater using a variation of the activated sludge process known as extended aeration. Horizontal brush rotor aerators, horizontal rotating discs, and vertical mechanical aerators are typical aeration systems used in oxidation ditches. These plants can be operated to nitrify (convert ammonia to nitrate) and denitrify (convert nitrate to nitrogen gas) as well as remove phosphorus biologically through close control of the oxygen transfer into the wastewater, provided the ditch volume is adequate for the design load.

This control is achieved by operating the ditch aerators to provide a precise amount of oxygen transfer in order to maintain anaerobic, anoxic, and aerated zones between the individual aerators. Thus the required anaerobic zone for phosphorus removal would be maintained within the basin itself. By slowing down the aerators, wastewater passing through the aerated zone would receive less oxygen, which would cause it to gradually become anoxic (absence of dissolved oxygen) then anaerobic (absence of other oxygen sources such as oxygen available in nitrate) before reaching the next aeration zone. Biological phosphorus uptake by the activated sludge microorganisms would occur in the anaerobic zone, and phosphorus would be removed from the flow stream by settling then removing the microorganisms as sludge from the clarifiers.

Although feasible, the degree of aeration control required to create and maintain the various zones is somewhat complex. As normal diurnal wastewater flow rises in the daytime, the aerator speed would have to be slowly increased to closely match oxygen transfer to the influent BOD load in order to maintain the anaerobic zones. Similarly, the aerator speeds would have to be decreased as flows subside in the evening. Because there is no real-time indicator of BOD, the speed control would be based on an algorithm that models the plant diurnal organic loading. Techniques for controlling the process include oxidation-reduction potential (ORP) monitors, dissolved oxygen meters, and ammonia/nitrate sensors. Some ditches can be converted to step-feed and diffused aeration to make better use of existing tank volumes. While this approach is feasible, it is clearly more complex than providing the required anaerobic reactor in a separate tank.

The City of Stephenville has a different style of oxidation ditch known as the Orbal process. It consists of three concentric channels that can be operated in a nutrient removal mode, thus allowing much easier control than trying to maintain separate zones in the same channel. Stephenville currently uses the outer channel as an aerobic sludge digester. If phosphorus removal were to be implemented using modified aeration control at this facility, a new sludge digester would need to be provided.

3.4 Biological Nitrogen Removal

The common forms of nitrogen are organic, ammonia, nitrate, nitrite, and gaseous nitrogen. Bacterial decomposition of nitrogenous organic matter releases ammonia to solution that can be described by the following equation:

$$\text{Organic Nitrogen Compounds} \rightarrow NH_3 \text{ (ammonia)}$$

Under aerobic conditions, nitrifying bacteria oxidize ammonia to nitrite and subsequently to nitrate. In a simplified form, the following equation describes this process:

$$NH_3 + O_2 \rightarrow NO_3^- \text{ (nitrate)}$$

Bacterial denitrification occurs under anaerobic or anoxic conditions when organic matter (AH_2) is oxidized and nitrate is used as a hydrogen acceptor releasing nitrogen gas. The following equations can be used to describe this process:

$$NH_3 + O_2 \rightarrow NO_3^- \text{ (nitrate)}$$

Bacterial denitrification occurs under anaerobic or anoxic conditions when organic matter (AH_2) is oxidized and nitrate is used as a hydrogen acceptor releasing nitrogen gas. The following equations can be used to describe this process:

$$NH_3 + AH_2 \rightarrow A + H_2O + N_2^-$$

Nitrification of a wastewater is practiced where the ammonia content of the effluent causes pollution of the receiving watercourse. The process does not remove the nitrogen, but converts it to the nitrate form. Nitrification - denitrification, which reduces the total nitrogen content, includes conversion of the nitrate to gaseous nitrogen. The latter is a more costly process, and is generally performed only where the receiving watercourse is used as a source for public drinking water supply and the dilution is not adequate to reduce the nitrate concentration to less than 10 mg/L.

Basic Process Description

In general, biological denitrification is a two-step process that requires nitrification in an aerobic environment zone by denitrification in an anoxic zone. As with all biological activity, these reactions are affected by the specific environmental conditions in the reactor, including pH, wastewater temperature, dissolved oxygen concentration, substrate type and concentration, and the presence or absence of any toxic substances.

Because nitrification only oxidizes ammonium to nitrate, denitrification must be incorporated to the process to achieve total nitrogen reduction. This denitrification step is more difficult to achieve than nitrification only because it requires the presence of both a degradable carbon source and nitrate. However, this can be achieved in three general ways:

- Supplying an external carbon source such as methanol or acetate to the denitrification zone or reactor;
- Using carbonaceous BOD in the wastewater as a degradable carbon source by either: (a) Recycling a large amount of nitrified effluent back to an anoxic reactor at the head of the flow scheme, (b) Diverting a portion of the raw influent or primary effluent flow to a zone containing nitrate; or
- Using external carbon present in cell mass as the degradable carbon source.

Several variables have been shown to significantly affect biological denitrification kinetics, including:

- Carbon substrate type and concentration,
- Dissolved oxygen concentration,
- Alkalinity and pH, and
- Temperature.

The various suspended-growth processes for nitrogen removal can be grouped into three categories: single sludge, dual sludge, and triple sludge, of which there are a wide variety of process variations for each type. The most applicable process options for the North Bosque River plants would be the A2/O™ process or one of its many variations, and the Bardenpho process.

A2/O™ Process

The A2/O (anaerobic/anoxic/oxic) process is similar to the A/O process except that an anoxic basin is placed in between the anaerobic and aerobic basins. While the anaerobic basin provides enhanced biological phosphorus removal, the anoxic basin is designed to provide denitrification. This is accomplished by providing an internal recycle pump station to return nitrified effluent from the end of the aeration basin back to the head of the anoxic basin. The nitrified effluent, rich in nitrate (NO3) serves as an oxygen source for the activated sludge bacteria returned to and passing through the anaerobic basin. The bacteria consume the oxygen in the nitrate leaving N_2, or nitrogen gas, which migrates out of the process flow, thus achieving partial denitrification. A schematic of the A2/O process is shown on Figure 3-3.

The A2/O process can attain effluent phosphorus concentrations as low as 1 to 2 mg/L, and total nitrogen concentrations as low as 8.0 mg/L. Total denitrification cannot be achieved since substantial nitrate, contained in the aeration basin effluent, remains in the flow and is discharged from the secondary clarifiers.

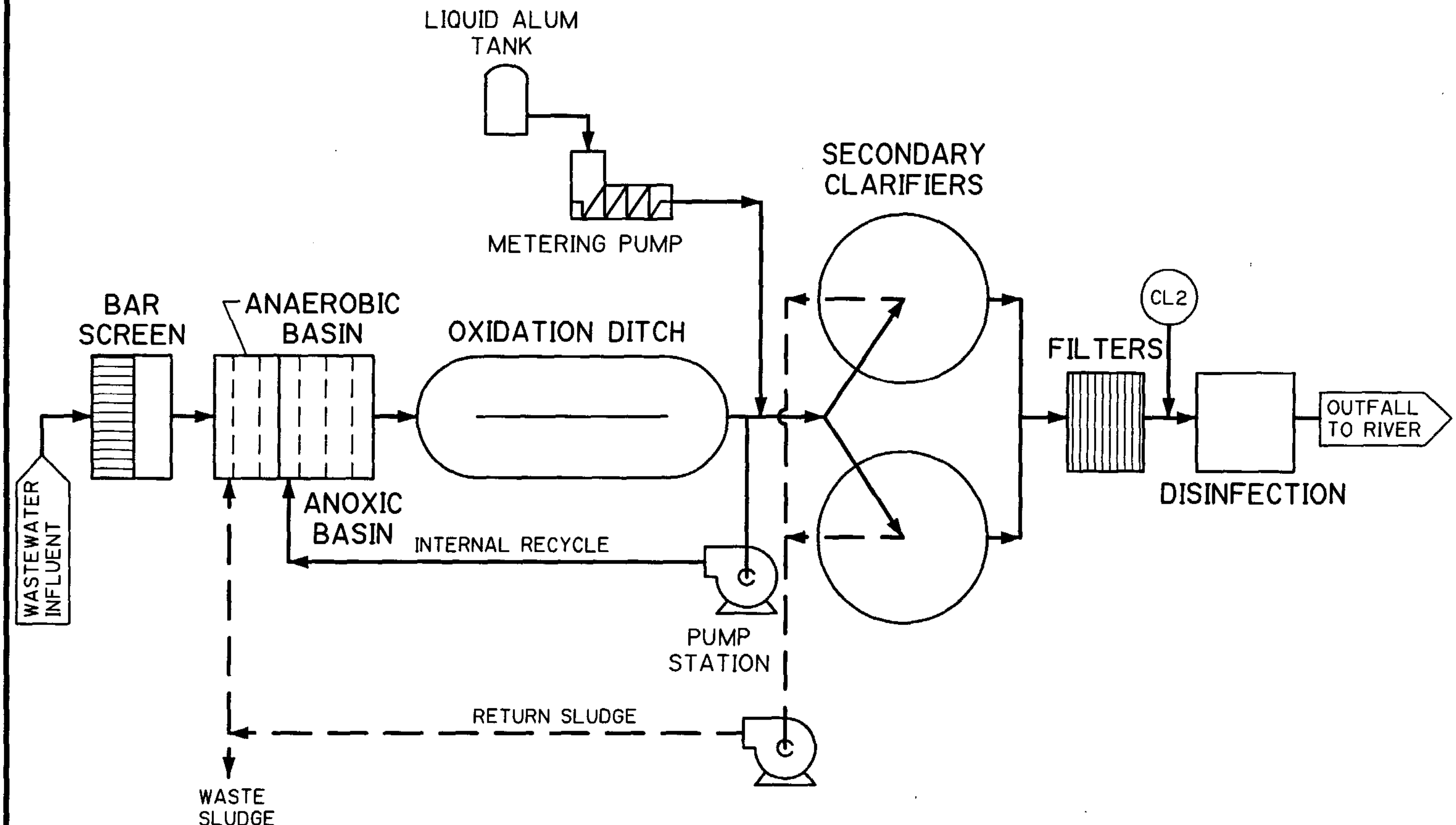
In addition to the A2/O process, a number of other variations have been developed which differ from the A2/O process in minor details. These include the Wuhrmann, the Ludzack-Ettinger, and the University of Cape Town processes. However, the basic A2/O process can be designed to provide substantially the same benefits as these process variations.

Bardenpho™ Process

The Bardenpho process consists of a series of four anoxic and aerobic zones with recycling of mixed liquor from the first aerobic zone to the first anoxic zone at a rate as high as four to six times the influent flow rate. This process is intended to achieve more complete nitrogen removal than is possible with a two- or three-stage process. Complete denitrification cannot be attained with pre-aeration anoxic zones because part of the aerobic stage effluent is not recycled through the anoxic zone. The second anoxic zone provides additional denitrification using nitrate produced in the aerobic stage as the electron acceptor and endogenous organic carbon as the electron donor.

The second (post-aeration) anoxic zone is capable of almost completely removing the nitrate in the aeration tank effluent. The final aeration stage strips residual gaseous nitrogen (N_2) from solution and minimizes phosphorus release in the final clarifier by increasing the oxygen concentration. The Bardenpho process can achieve effluent TP of 1-2 mg/L, and effluent TN of 2-4 mg/L. A schematic of the Bardenpho process is shown on Figure 3-4.

The ability to successfully use the Bardenpho process to achieve an effluent concentration of total nitrogen as low as 2 to 4 mg/L depends on the ratio of oxidizable nitrogen to carbon in the influent to the activated-sludge process. Researchers have indicated that the total Kjeldahl nitrogen (TKN):COD ratio must be less than 0.08 to obtain complete denitrification.



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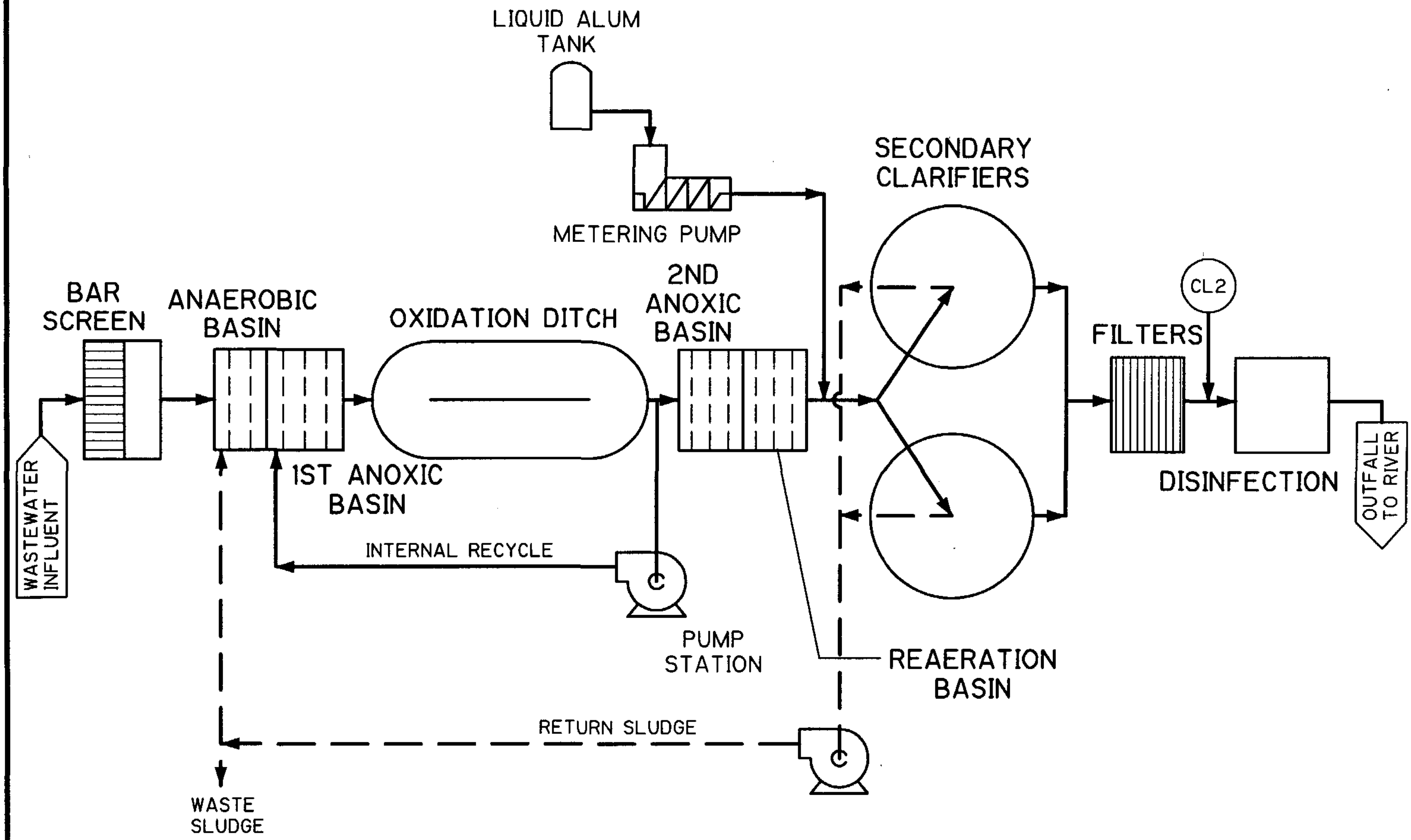
A^2/O^{TM} PROCESS FOR
PHOSPHORUS AND PARTIAL NITROGEN REMOVAL

FIGURE No 3-3

S:\ACAD\31602\FIG-3.4.DWG



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BARDENPHO™ PROCESS FOR
PHOSPHORUS AND NITROGEN REMOVAL

FIGURE No 3-4

3.5 Sequencing Batch Reactors

Biological nitrogen and phosphorus removal can be accomplished in Sequencing Batch Reactors (SBRs), which is the treatment process used by the City of Clifton. SBRs create, in one reactor, the proper combination of aerobic and anoxic conditions in time sequence. Control strategies for biological nutrient removal take into account reaction time, tank water level, and mixed liquor dissolved oxygen concentrations.

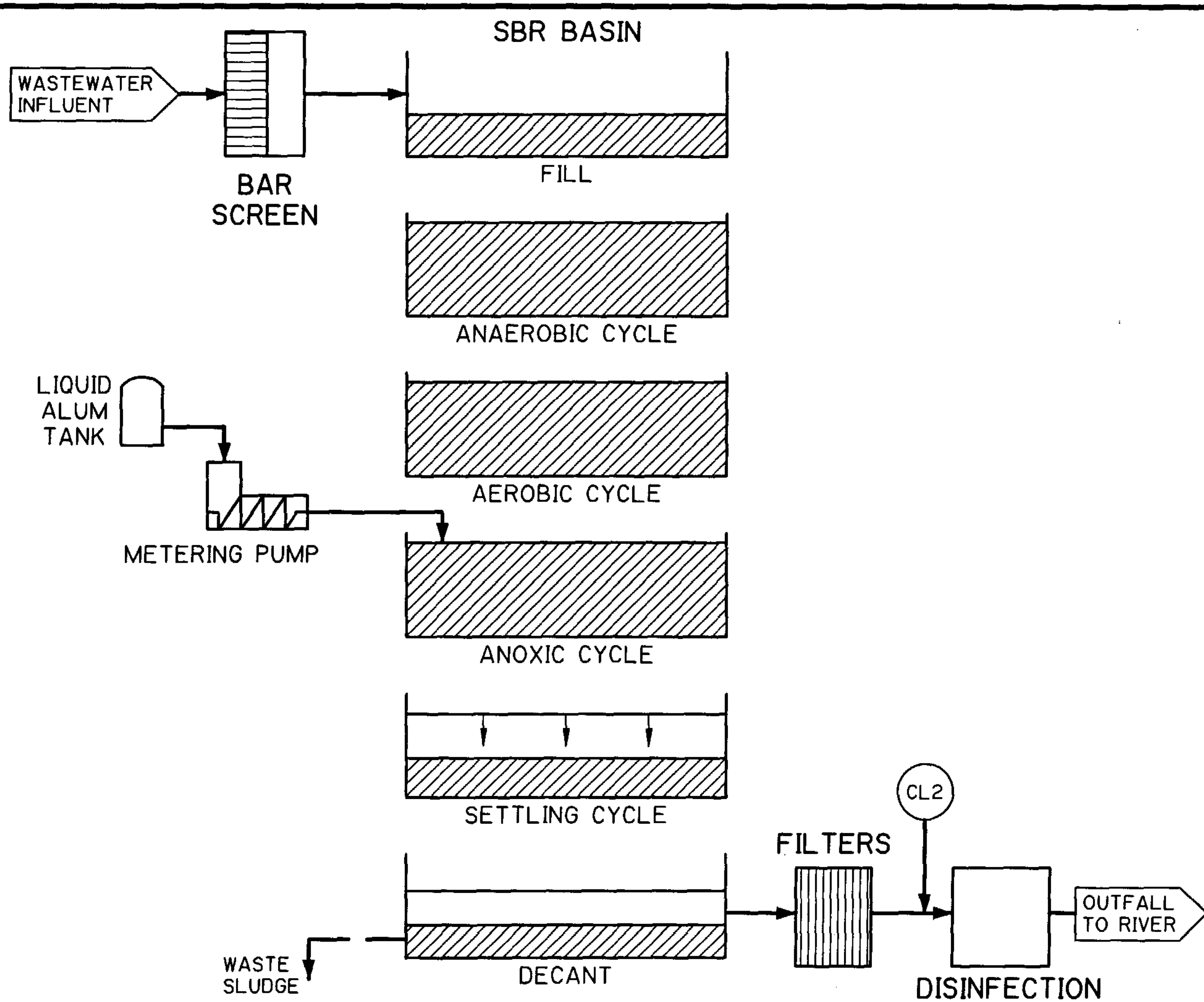
Sequencing batch reactors are used mostly for relatively small systems with variable wastewater flow and strength. Similar to conventional processes, successful operation depends on efficient clarification. To achieve nitrogen removal, fill and react phases are subdivided into static fill, mixed fill, and mixed react. In this configuration, carbon oxidation and nitrification will occur in the aerobic react phase, while denitrification will take place in anoxic fill and react. A carbon source to support denitrification, needed in the anoxic react phase, is present in the beginning of each cycle. Nitrification is attained in SBRs, as in any suspended-growth biological treatment system, by designing for the appropriate aerobic solids retention time. Denitrification results from selecting static fill, mixed fill, and mixed react periods that are long enough to allow use of all dissolved oxygen, thus creating anoxic conditions. For phosphorus removal, the anoxic react phase cycle time is lengthened to allow the basin to become anaerobic. This results in uptake of phosphorus by the activated sludge biomass, which is then removed during subsequent sludge wasting. A schematic of the SBR process is shown on Figure 3-5.

With proper operation, an SBR process can achieve nutrient removal levels similar to the Bardenpho process, with effluent TP of 1-2 mg/L and effluent TN of 2-4 mg/L. Chemical polishing and effluent filters are typically required to achieve a TP limit of 1.0 mg/L or less.

3.6 Wetlands Treatment

A significant amount of research has been performed documenting the ability of wetlands, both natural and constructed, to provide consistent and reliable water quality improvement. With proper execution of design and construction elements, constructed wetlands exhibit characteristics that are similar to natural wetlands, in that they support similar vegetation and microbes to assimilate pollutants. In addition, constructed wetlands provide wildlife habitat and environmental benefits that are similar to natural wetlands. Constructed wetlands are effective in the treatment of BOD, TSS, nitrogen, phosphorus, pathogens, metals, sulfates, organics, and other toxic substances.

S:\ACAD\31602\FIG-3.5.DWG



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SEQUENCING BATCH REACTOR FOR PHOSPHORUS AND NITROGEN REMOVAL

FIGURE No 3-5

Constructed wetlands are effective in nitrogen removal, particularly through denitrification. Nitrification can also occur if sufficient pond area is provided. Where constructed wetlands have not been sized with an adequate degree of conservatism, nitrification and therefore ammonia treatment has been limited. The nitrification rate in wetlands is in part controlled by the flux of dissolved oxygen into the system, which occurs through mass transfer from the atmosphere to the water, and by the plants into the root zone. The theoretical oxygen consumption for nitrification is approximately 4.6 grams of oxygen per gram of ammonia oxidized. The oxygen supply in wetlands is low and the oxygen demand is high for nitrification. Therefore, the process of nitrification is limited in wetlands and the area requirement for ammonia treatment is large. For the six North Bosque River plants, this is less of an issue since the processes used (oxidation ditches and SBR) provide nitrification.

Constructed wetlands are particularly efficient for denitrification. If nitrification is provided to oxidize the ammonia to nitrate, constructed wetlands have been documented to achieve 75 to 95 % total nitrogen removal via denitrification. For effective denitrification there must be an adequate carbon source. Therefore, a start-up period is necessary to build up a carbon source to achieve optimal denitrification.

Constructed wetlands can also be effective for phosphorus treatment. Whereas nitrogen processing is largely biologically mediated, redistribution of phosphorus to internal sinks is a result of adsorption and precipitation reactions. Therefore, the magnitude of phosphorus retention capacity is finite and varies considerably and is related to the concentration of aluminum and iron in the soil as well as the organic matter content. Under aerobic conditions, phosphorus will form complexes with aluminum and iron hydroxides and thereby be removed from the water column. Anaerobic conditions can reverse this process. The removal of total suspended solids involves physical settling processes and therefore minimum detention time is a critical design criteria and erosion must be avoided.

Several factors are important in determining the appropriate design of a wetland treatment system. For natural wetlands these include the type of wetlands as defined by the dominant vegetation and soils, the direction and extent of surface water flow to and from the wetland, location and type of downstream water bodies, the presence of protected species, and regulatory requirements. For constructed wetlands these include a topographic survey, geotechnical determination, water budget determination, wetland jurisdictional determinations, distribution system and discharge system design, and a cost estimate. In addition, permits are required to address dredge and fill activities and stormwater management.

For the North Bosque River watershed, the development of constructed wetlands are being considered as a nutrient removal alternative to reduce and control total phosphorus (TP) at the study area WWTPs. Constructed wetlands are very effective at polishing both total nitrogen (TN) and TP. For example, if the WWTP can remove TP to an effluent concentration of 2 mg/L following biological and chemical process treatment, then constructed wetlands may be suitable for further polishing the effluent through nutrient uptake by wetland plants to achieve TP concentrations less than 1 mg/L. Site-specific feasibility analyses is required for the implementation of constructed wetlands at each plant to achieve adequate phosphorus removal. These site-specific analyses are required to determine if a given WWTP has an available site of sufficient area and with the proper soil characteristics (i.e., enough iron (Fe) and aluminum (Al) content) for implementing constructed wetlands.

Constructed wetlands must also be evaluated for winter performance. Generally, constructed wetlands should remain efficient at achieving TP removal during the winter months in north central Texas due to the usually mild winters, although removal performance is lower in cold weather. Provisions may also need to be made to minimize wetland freezing. During the winter months, chemical polishing could be performed to insure target effluent TP concentrations are met. In summary, more detailed site characterization is required to accurately determine constructed wetlands viability for the North Bosque River plants.

3.7 Land Treatment

In lieu of providing a higher level of treatment to remove nutrients, it may also be possible to convert some of the plants to a land disposal scheme and avoid discharging altogether. Land application of secondary treated effluent is a permissible treatment technique used by several municipalities in Texas. Typically, city-owned land is required for the effluent disposal site so that absolute control over the application process can be assured. Facilities requirements include an effluent pump station, force main to the application site, and irrigation equipment. Additionally, an effluent storage pond is required to store effluent during wet weather periods.

The size of the land area required for effluent disposal is dependent on achieving a hydraulic balance to prevent runoff, which in turn is dependent upon soil permeability of the site. Land application is generally not feasible for clay soils, nor in flood plains. Additionally, for nutrient removal, effluent application must be tailored to the crops grown on the application site. Effluent is applied at rates that do not exceed the agronomic uptake rates for nitrogen and phosphorus. Typically, crops requiring high nitrogen, such as coastal bermuda hay, are grown on the application site. Revenue from the crops can be used to offset a portion of the land treatment costs.

Land treatment may be feasible for the smaller North Bosque River plants. Valley Mills, for example, has an abandoned pond adjacent to the plant that could be used for effluent storage, as well as adjacent hay fields. This site, as well as the other comparable sites for the remaining plants, requires more detailed investigation to determine suitability for providing land treatment.

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4
Section Four

Section 4
Phosphorus Removal Process Design

4.1 Introduction

Section 4 presents the designs of the proposed phosphorus removal schemes for each of the six WWTPs evaluated. Two designs are described for each plant; one for chemical removal of phosphorus through alum addition and the other for biological nutrient removal with chemical polishing. This section also estimates the increased sludge handling requirements due to phosphorus removal.

A description of the design methods for each removal scheme is presented first, followed by the designs for both treatment schemes at each plant. These equipment designs are used in Section 5 for the economic evaluation of the two proposed treatments.

4.2 Design Methods

The design of each treatment unit was based on recommended design criteria, as presented in Section 3, and TNRCC regulations. The TP effluent concentrations from the existing plants vary, but are in the general range from 2-4 mg/L. For design purposes, it is assumed that the existing plants can reliably produce 4.5 mg/L effluent TP on a daily basis, so an effluent of 4.5 mg/L is assumed for planning of further phosphorus removal. Each process design is based on a target effluent of 0.5 mg/L to insure that the required 1.0 mg/L effluent TP limit is achieved. The amount of phosphorus to be removed by the additional treatment is determined based on the difference between the existing plant effluent concentration and the target effluent concentration. Therefore, while the plant influent is 10 mg/L Total P, the additional phosphorus treatment is designed to remove 4 mg/L, which is the difference between the existing effluent concentration of 4.5 mg/L and the target effluent concentration of 0.5 mg/L.

The flow used to design equipment is determined by multiplying the permitted flow times a flow peaking factor. A peaking factor of 1.5 was used for the five smaller plants, while a value of 1.3 was used for the Stephenville facility due to its larger overall plant flowrate which results in a lower peak to average flow ratio.

Chemical Phosphorus Removal

Chemical treatment for phosphorus removal is based on the general treatment schematic shown in Figure 4.1. Liquid alum is added to the oxidation ditch effluent prior to the final clarifiers. The main equipment associated with this treatment option is a chemical feed pump, a chemical storage tank and a weatherproof enclosure for pump shelter.

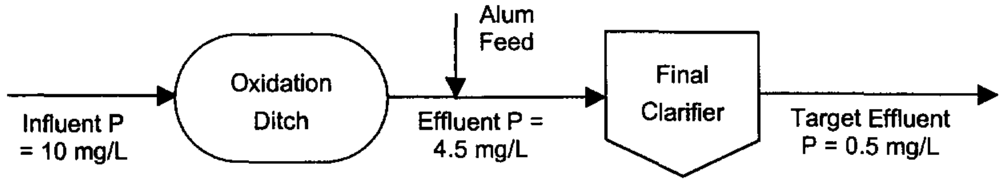

Figure 4.1: Schematic diagram of chemical phosphorus removal

An alum dose rate must be determined in order to design the feed pumps and storage tanks. The dose rate is determined by a ratio of alum added to the total amount of phosphorus removed. As discussed in Section 3, the theoretical weight ratio of Al to P is 0.87:1, a feed ratio of 2.2:1 moles Al to moles P is used for wastewater treatment design. For the example shown in Figure 4.1, the required alum concentration is 84 mg/L (or 21.1 mg/L of alum per 1 mg/L of phosphorus removed). The feed rate of the alum for each plant is then determined by multiplying the alum concentration by the plant flow rate and dividing by the concentration of the alum stock solution. For a peak plant flow of 1 MGD, the alum feed rate is roughly 130 gpd, or 0.09 gpm. Chemical storage tanks are estimated assuming a 30-day storage; therefore, the example plant will need a 4,000 gal alum storage tank.

Biological Nutrient Removal

A phosphorus removal diagram for biological nutrient removal is presented in Figure 4.2. The BNR begins in the anaerobic basin prior to the oxidation ditch. The anaerobic basins are designed to remove approximately 2.5 mg/L of P. For design purposes, it is assumed that BNR will produce an effluent TP of 2.0 mg/L, although normal operation would be in the 1.0-2.0 mg/L range. The remaining P, approximately 1.5 mg/L, is to be removed through chemical polishing with alum. The equipment associated with this treatment method is an anaerobic basin, a chemical feed pump, a chemical storage tank, and weatherproof enclosure for pump storage.

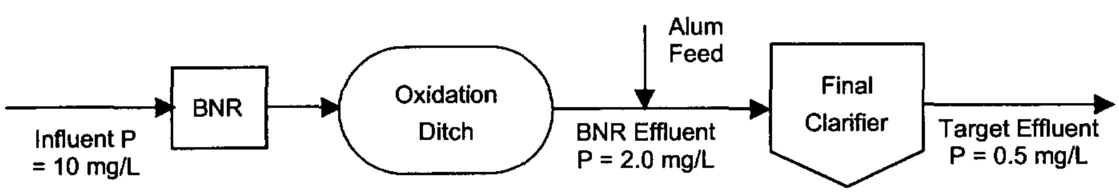

Figure 4.2: Phosphorus removal with BNR and chemical polishing

The BNR of 2.5 mg/L of P requires approximately one hour of hydraulic residence time in an anaerobic basin. Therefore, an average daily flow of 1.0 MGD with a peaking factor of 1.5 corresponds to a basin volume of 62,500 gals. The chemical system for chemical polishing is designed using the same criteria as given above; however, the amount of phosphorus to be removed by chemical polishing is considerably smaller.

Sludge Handling

The additional treatment of wastewater for the removal of phosphorus creates an increase in the process sludge production. This is due to the addition of alum and/or the increase of biomass during BNR. Waste sludge is generally increased by approximately 70% when chemical phosphorus treatment is added. BNR increases the current waste sludge volume by 25%. The current waste sludge production is estimated using the relationship that one pound of influent BOD results in 0.6 lbs of waste sludge.

Though many options are available for dewatering waste activated sludge, the two considered for this study were sludge drying beds and belt filter presses. Sludge drying beds require enough bed area to satisfy TNRCC Rule 317.12, which requires 7.5 ft^2/lb influent BOD. The belt filter press option requires a sludge holding tank in order to supply sludge to the belt press feed pumps during operation of the press. The sludge holding tanks are sized assuming a 12-hour retention time since most sludge storage would continue to be maintained in the oxidation ditches.

The optimum sludge handling methods for each facility were developed based on the results of the site evaluations. The treatment plants for the Cities of Hico, Iredell, and Valley Mills were determined to have sufficient space available for sludge drying bed expansion, although bed expansion at Iredell will be expensive due to the need to enlarge the elevated site. Enlarging the sludge drying beds at Iredell should still be less expensive than installing mechanical dewatering equipment. The Clifton facility recently installed a belt filter press as part of the plant improvements and does not require any sludge handling upgrades. The Meridian plant existing bed area is already significantly limited and the site lacks land area available for bed expansion. Therefore, this plant would require a belt filter press and a sludge holding tank for any phosphorus removal treatment modifications. Similarly, Stephenville, at 3.0 MGD, is too large a plant for continued reliance on drying beds for any increase in sludge volume. A belt press and sludge holding tanks would also be required for this facility. The sludge handling equipment were sized for both chemical and biological phosphorus removal based on the percent sludge increases presented above, 70% and 25%, respectively.

4.3 Facility Design

This section presents the designs for each treatment process at each facility. The supporting calculations for the process designs are presented in Appendix C. Tables C-1 and C-2 present the design and operating calculations for chemical phosphorus removal while Tables C-3-5 present the design and operating calculations for BNR. The final table, Table C-6, contains the sludge production calculations for both treatment schemes. Each plant was designed individually and the current needs were also taken into consideration. The equipment designed for each facility is summarized in Table 4.1. The sludge handling equipment is presented in Table 4.2.

Table 4.1: Summary of Equipment Designs

Facility	*Chemical Treatment*		*BNR and Chemical Polishing*		
	Alum Dose Rate (gpm)	**Storage Volume (gal)**	**Anaerobic Basin Volume (ft^3)**	**Alum Dose Rate (gpm)**	**Storage Volume (gal)**
Clifton	N/A[1]	N/A[1]	N/A[1]	0.034	1,500
Hico	0.027	1,200	1,671	0.010	500
Iredell	0.007	400	418	0.003	150
Meridian	0.062	3,000	3,760	0.023	1,000
Stephenville	0.357	2 @ 8,000	21,725	0.156	6,400
Valley Mills	0.049	2,500	3,008	0.019	1,000

[1] The Clifton WWTP was only evaluated for BNR with chemical polishing due to the existing SBR treatment scheme.

Clifton

The City of Clifton WWTP uses a sequencing batch reactor (SBR) that can be operated for biological nutrient removal through the reconfiguration of the treatment cycle. Therefore, the design of this plant included only the addition of chemical polishing equipment and effluent filtration. As presented in Table 4.1, chemical polishing will be performed through the addition of alum at a rate of 0.034 gpm. This feed rate requires a 1,500 gal tank for a 30-day chemical storage.

The Clifton facility was not designed with a new sludge handling facility due to the new belt filter press and sludge holding tanks (SHTs) installed in 1999. The existing belt filter press and SHTs have the capacity to handle the 25% increase in solids due to the addition of BNR and chemical polishing. However, the additional treatment for phosphorus removal creates additional hauled sludge of approximately 197 yd^3/yr and 70 yd^3/yr for chemical and biological treatment, respectively.

Table 4.2: Summary of Required Sludge Handling Equipment

Facility	Projected WAS (gpd)	Phosphorus Removal WAS (gpd)	Drying Bed Area (ft^2)	SHT Volume (gal)	Additional Hauled Sludge (yd^3/yr)
Chemical Phosphorus Removal					
Clifton	14,625	24,863	N/A[1]	N/A[1]	197
Hico	4,500	7,650	7,115	N/A[3]	61
Iredell	1,125	1,913	1,122	N/A[3]	15
Meridian	10,125	17,213	N/A[2]	8,606	137
Stephenville	67,500	114,750	N/A[2]	N/A[4]	911
Valley Mills	8,100	13,770	4,208	N/A[3]	109
Biological Phosphorus Removal					
Facility	**Projected WAS (gpd)**	**Phosphorus Removal WAS (gpd)**	**Drying Bed Area (ft^2)**	**SHT Volume (gal)**	**Additional Hauled Sludge (yd^3/yr)**
Clifton	14,625	18,281	N/A[1]	N/A[1]	70
Hico	4,500	5,625	5,231	N/A[3]	22
Iredell	1,125	1,406	825	N/A[3]	5
Meridian	10,125	12,656	N/A[2]	6,328	49
Stephenville	67,500	84,375	N/A[2]	N/A[4]	325
Valley Mills	8,100	10,125	3,094	N/A[3]	39

[1] Clifton did not need sludge handling renovations due to the belt filter press installed in 1999.
[2] Meridian and Stephenville require belt presses for any increase in sludge volume.
[3] The Hico, Iredell, and Valley Mills WWTPs were evaluated solely for the less costly method of sludge drying beds.
[4] Stephenville does not need a sludge holding tank due to the existing digesters.
Note: WAS= Waste Activated Sludge Projected WAS based on plant operating at full design capacity.

Hico

Designs were made for both treatment options at the Hico WWTP. The main equipment sizes for each treatment scheme are presented in Table 4.1. Phosphorus removal strictly through chemical addition requires an alum feed rate of 0.027 gpm and a 30-day storage volume of 1,200 gals. Biological treatment for phosphorus removal requires a 1,671 ft^3 anaerobic basin prior to the oxidation ditch. The chemical polishing associated with BNR requires a chemical dose of 0.01 gpm and 500 gals for 30-day storage.

Sludge handling at the Hico facility was designed based on sludge drying beds because sufficient land is available for the expansion of existing beds. The sludge drying bed area required for chemical treatment is 7,115 ft^2, while only 5,231 ft^2 is needed for biological treatment. The additional hauled sludge volumes are 61 yd^3/yr for chemical and 22 yd^3/yr for biological.

Iredell

The equipment designs for each treatment scheme at the Iredell treatment facility are presented in Table 4.1. Chemical phosphorus removal at Iredell requires an alum feed rate of 0.007 gpm and a 30-day storage volume of 400 gals. Biological treatment for phosphorus removal will require a 418 ft^3 anaerobic basin prior to the oxidation ditch. BNR chemical polishing requires an alum dose of 0.003 gpm and 150 gals for 30-day storage.

Due to the severely limited space available, either of the sludge handling techniques evaluated would require expansion of the plant levee at the Iredell WWTP. The existing beds are much too small for any increase in sludge volume and are further limited by requiring sludge removal by hand. For this reason, these existing beds would be replaced with new, larger beds. The sludge drying bed area requirements for the proposed treatments are 1,122 ft^2 for chemical and 825 ft^2 for biological. The amount of dried sludge hauled from the facility would increase by 15 yd^3/yr and 5 yd^3/yr for chemical and biological treatment, respectively.

Meridian

The Meridian WWTP equipment designs for each treatment scheme are presented in Table 4.1. Phosphorus removal through chemical treatment requires an alum feed rate of 0.062 gpm and a 30-day storage volume of 3,000 gals. An anaerobic basin with a volume of 3,760 ft^3 must be added prior to the oxidation ditch for BNR of phosphorus. BNR chemical polishing requires an alum dose of 0.023 gpm and 1,000 gals for 30-day storage.

Space at the Meridian treatment plant is also severely limited, and due to the topography surrounding the plant few options are available for site modification. Therefore, the Meridian plant was designed to eliminate the already insufficient drying bed area and replace it with a sludge holding tank and belt filter press. Chemical phosphorus removal will increase the existing WAS rate to 17,213 gpd and will require a 12-hour SHT volume of 8,606 gals. The WAS rate increases to 12,656 gpd for BNR and requires a SHT capacity of 6,328 gals. Chemical treatment will increase the plant sludge production by 137 yd^3/yr, while biological increases the waste sludge by 49 yd^3/yr.

Stephenville

Equipment designs for each treatment scheme at the Stephenville WWTP are presented in Table 4.1. Chemical phosphorus removal requires an alum feed rate of 0.357 gpm and two 8,000 gal tanks for 30-day chemical storage. Biological treatment for phosphorus removal requires an anaerobic basin volume of 21,725 ft^3 prior to the aeration basins. This basin will be created through the modification of the existing primary clarifiers, which have a singular volume of 31,705 ft^3. BNR chemical polishing requires an alum dose of 0.134 gpm and 6,400 gals for 30-day storage.

Due to the large capacity of the Stephenville WWTP, the associated increases in the WAS production would require significant increases in the already considerable sludge drying bed area. Therefore, the Stephenville plant sludge handling was designed around the addition of a 2-meter width belt filter press. No sludge holding tanks were designed because the existing sludge digesters can be used for sludge storage. However, it is important to consider the increased amount of sludge created that must be hauled from the treatment facility. Chemical treatment increases the waste sludge by 911 yd^3/yr, while biological increases it by 325 yd^3/yr.

Valley Mills

Designs were made for both treatment options at the Valley Mills WWTP. The main equipment sizes for each treatment scheme are presented in Table 4.1. Phosphorus removal strictly through chemical addition requires an alum feed rate of 0.049 gpm and a 30-day storage volume of 2,500 gals. Biological treatment for phosphorus removal requires a 3,008 ft^3 anaerobic basin prior to the oxidation ditch. The chemical polishing associated with BNR requires a chemical dose of 0.019 gpm and 1,000 gals for 30-day storage.

Because sufficient land is available for existing bed expansion, sludge handling at the Valley Mills facility was designed based on increasing the sludge drying bed area. The sludge drying bed area requirements for the proposed treatments are presented in Table 4.2. The addition of phosphorus removal results in bed areas of 4,208 ft^2 and 3,094 ft^2, and hauled sludge increases of 109 yd^3/yr and 39 yd^3/yr for chemical and biological treatment, respectively.

5 Section Five

Section 5
Evaluation of Nutrient Removal Alternatives

5.1 Introduction

This section contains the results of evaluation of alternative methods investigated to remove phosphorus at six existing wastewater treatment plants that discharge into the North Bosque River Basin. These wastewater treatment plants serve the cities of:

- Clifton
- Hico
- Iredell
- Meridian
- Stephenville
- Valley Mills

Details on the nutrient removal processes being considered are provided in Section 3, while the sizing criteria for the required additional treatment process units is provided in Section 4.

Also described in this section are the added requirements for removal of nitrogen, and the benefits that may be realized by nutrient trading, whereby phosphorus removal would be eliminated for some smaller plants and increased at larger plants such that the overall effect on the watershed remains the same. Section 5 also presents costs for the required nutrient removal improvements, together with recommendations for implementation.

5.2 Chemical Phosphorus Removal Improvements

This section describes improvement needs at the five wastewater treatment plants using chemical phosphorus removal technology. The Clifton Wastewater Treatment Plant uses the Sequencing Batch Reactor (SBR) process that is already capable of biologically removing phosphorus. Because of this, chemical phosphorus removal alone at Clifton was not included in this analysis.

As described in Sections 3 and 4, the most appropriate chemical for phosphorus removal for these facilities is alum. Therefore, all storage tanks, feed pumps, and pipelines were based on storing, pumping, and delivering alum. In actuality, other coagulating chemicals could be used with little difference in capital costs, although operating costs would change due to varying chemical costs.

This section also includes site plans of each treatment plant investigated in this study. Included in each figure are the existing facilities and required improvements. Also included are capital costs, operations and maintenance costs, and total annual costs for chemical phosphorus removal.

Hico

Figure 5-1 contains a site plan of the City of Hico Wastewater Treatment Plant. Shown in this figure is the proposed location of additional equipment needed for chemical phosphorus removal at this plant. These improvements primarily consist of:

- New 1,200-gallon alum storage tank and metering pumps
- New effluent filters
- Additional sludge drying beds
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains

Iredell

Figure 5-2 contains a site plan of the City of Iredell Wastewater Treatment Plant. This figure shows the required equipment needed if chemical phosphorus removal is used at this plant. Due to space limitations at this site, implementing chemical phosphorus at this plant is more involved than at the Hico Wastewater Treatment Plant. Because of the need to expand the drying beds, it will be necessary to import fill and enlarge the existing elevated treatment plant levee. The relocation of the beds off of the levee is not possible due to the potential flooding area surrounding the treatment plant. The improvements at the Iredell Wastewater Treatment Plant consist of:

- New 400-gallon alum storage tank and metering pumps
- New effluent filter
- New chlorine contact chamber
- New sludge drying beds
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains

In order to install the required effluent filter between the existing clarifiers and the chlorine contact chamber, it will be necessary to completely demolish the existing chlorine contact basin due to the very constricted layout of the existing facilities. The proposed layout depicts a new filter unit/chlorine contact basin structure. Also, the existing sludge drying beds are undersized and so small as to require sludge removal by hand. For this reason new, larger sludge drying beds are shown, which will be capable of handling all sludge from the new process as well as allow sludge removal using a small front-end loader.

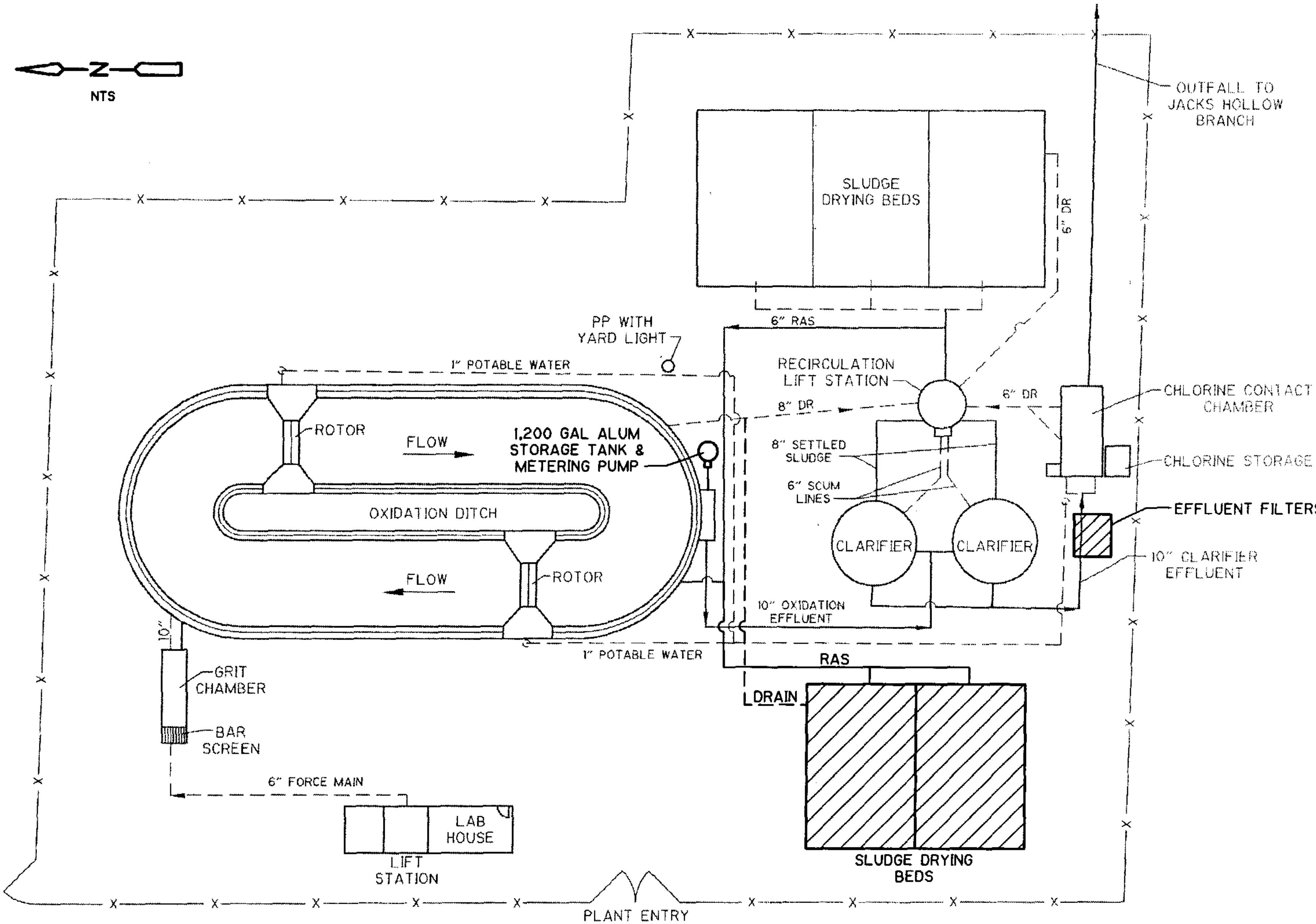

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FIGURE No 5-1

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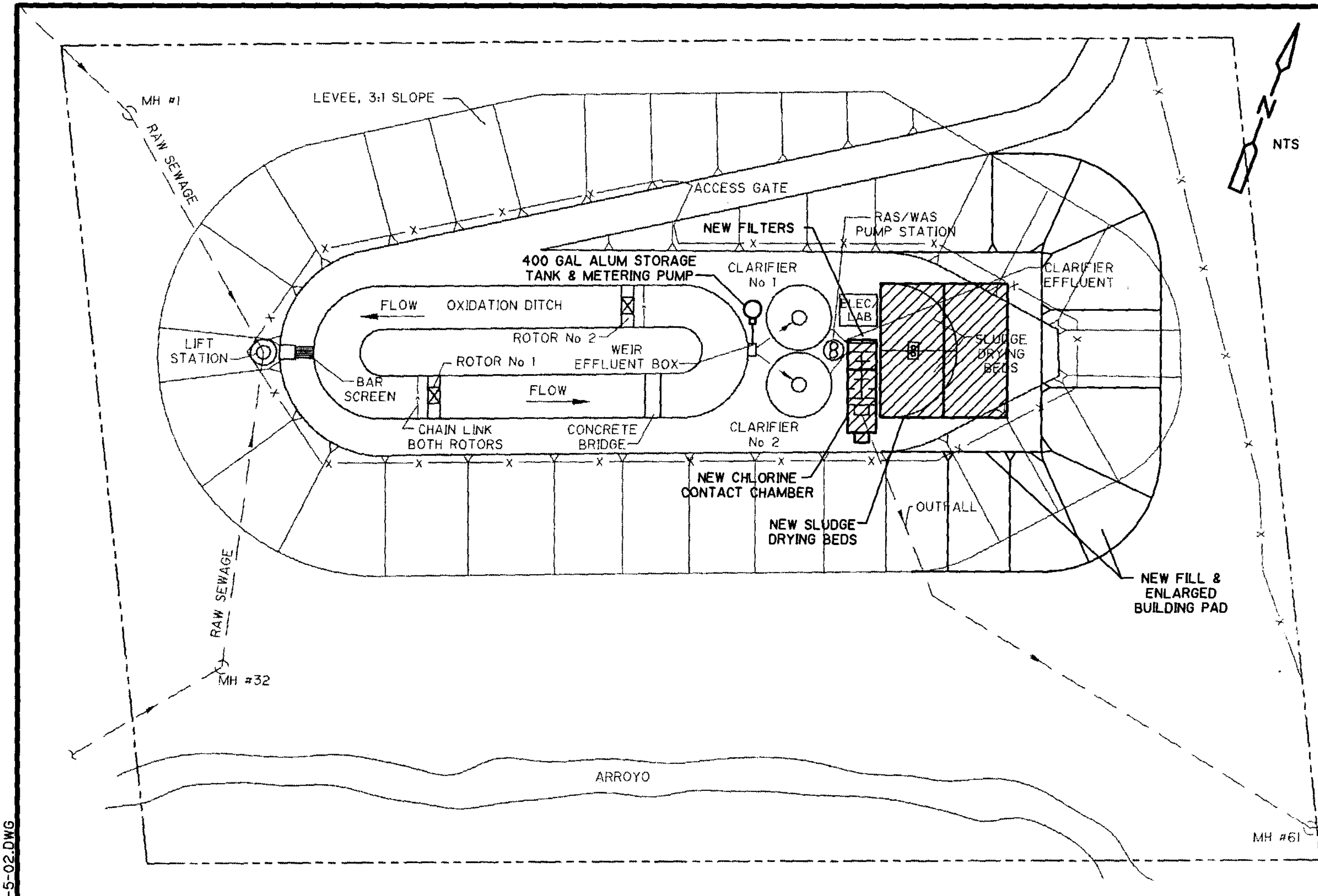

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FIGURE No 5-2

Meridian

Figure 5-3 contains a site plan of the Meridian Wastewater Treatment Plant. The principal improvements needed at this plant for chemical phosphorus removal are similar to those described for Hico and Iredell. These improvements are:

- New 3,000-gallon alum storage tank and metering pumps
- New effluent filter and chlorine contact chamber
- New mechanical dewatering facility
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains

A requirement for Meridian is the addition of a new sludge storage tank and a new sludge dewatering building containing a new 1-meter belt filter press. These improvements are needed because of the increased sludge production anticipated when chemical phosphorus removal is implemented. The existing sludge drying beds are undersized, and site limitations prevent expansion of the existing beds.

As at Iredell, there is insufficient space between the existing clarifiers and chlorine basin to install the required effluent filters. To avoid constructing an additional pump station, the existing chlorine contact basin would have to be demolished and a new basin constructed further to the east, with the new filters located on the site of the old chlorine basin.

Stephenville

Figure 5-4 contains a site plan of the Stephenville Wastewater Treatment Plant with the improvements required for chemically removing phosphorus. The additional improvements required at this plant are reduced since this plant already contains automatic backwash sand filters. The principal improvements required for chemical phosphorus removal are as follows:

- Two new 8,000-gallon alum storage tanks and metering pumps
- New mechanical dewatering facility
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains

The Stephenville plant currently relies on sludge drying beds, which are barely adequate for existing sludge volumes. To efficiently dewater the additional sludge resulting from chemical phosphorus removal, a new mechanical dewatering facility is required. This would consist of a single 2-meter belt filter press, polymer feed unit, conveyor, and building.

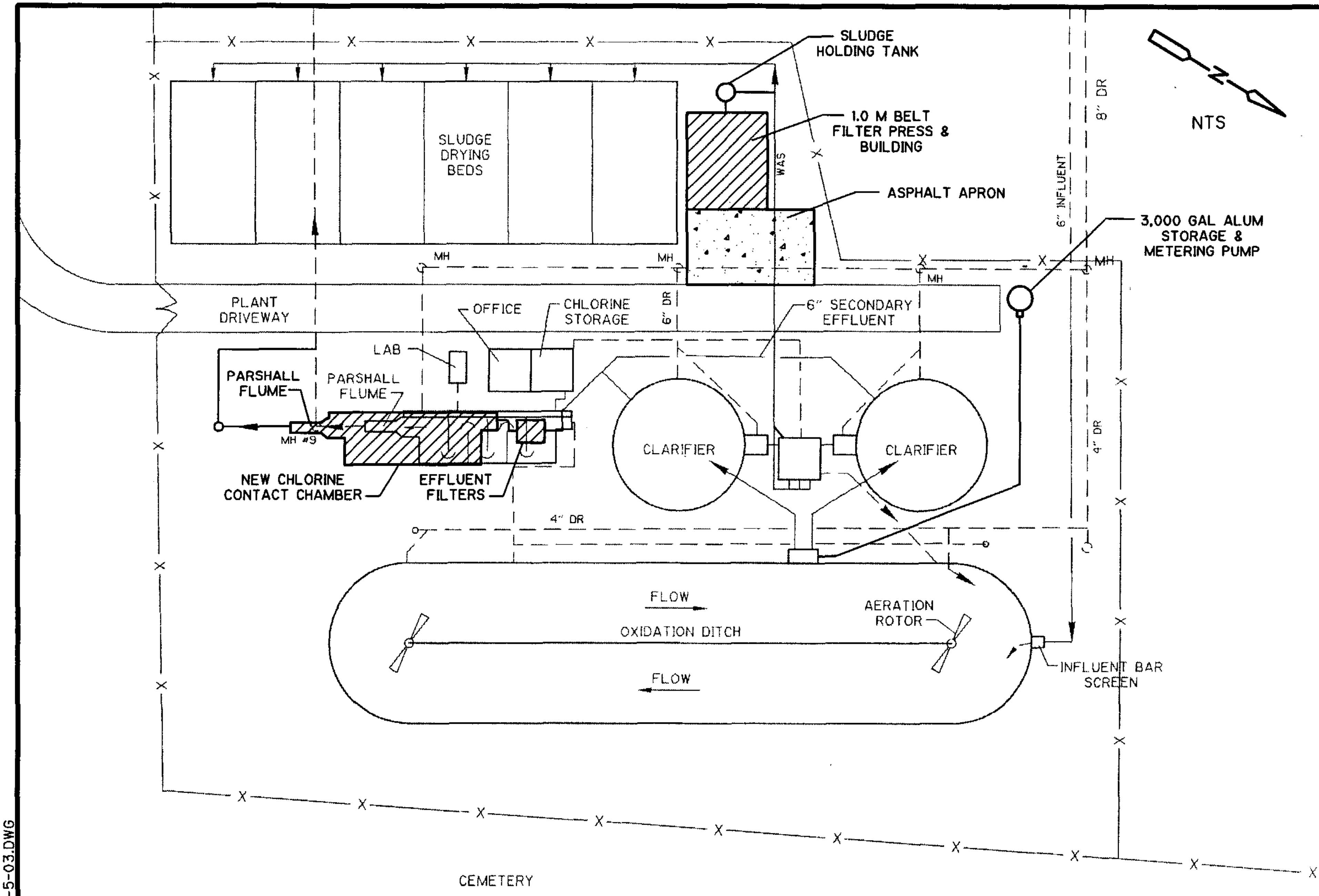

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FIGURE No 5-3

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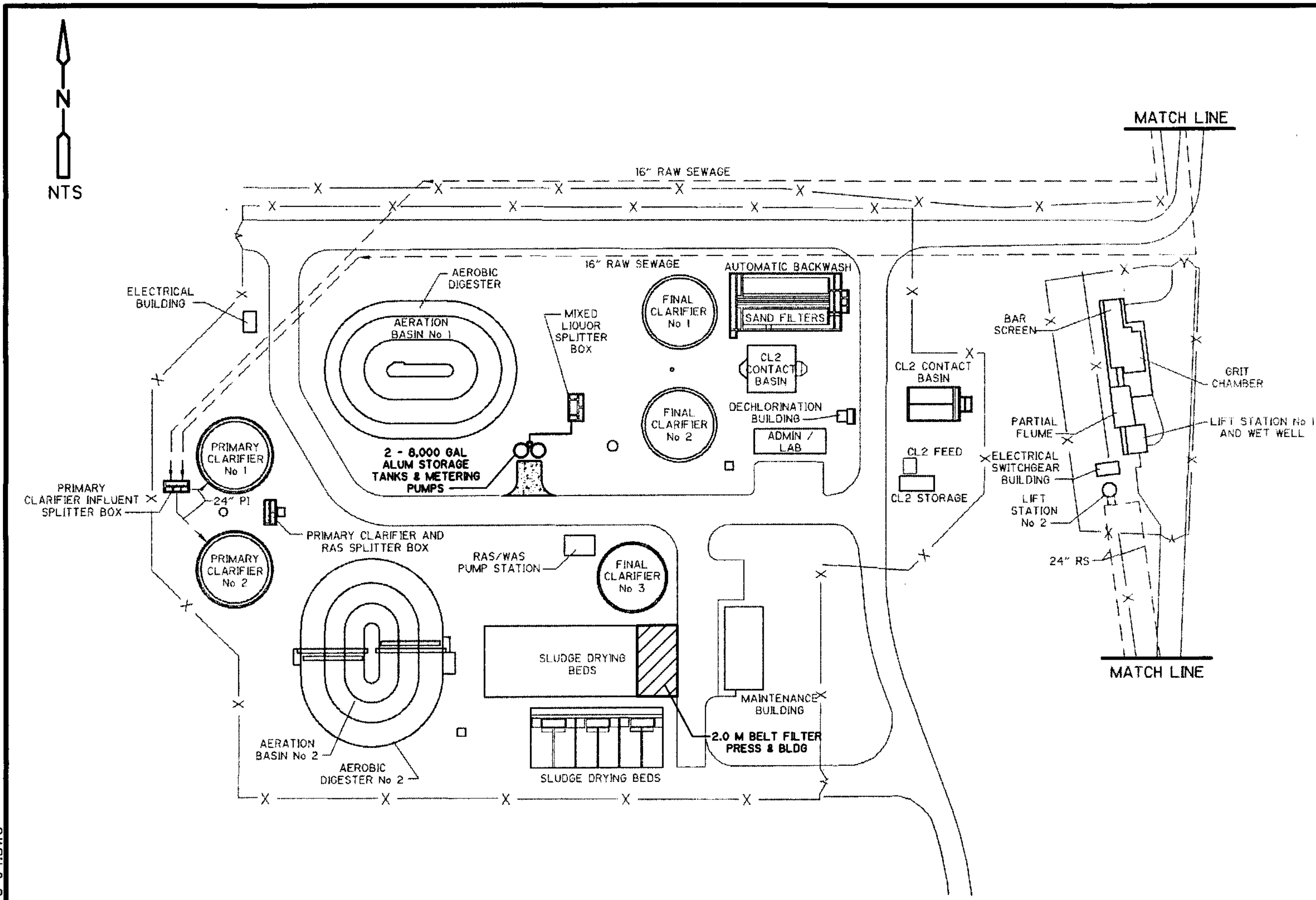

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FIGURE No 5-4

Valley Mills

Figure 5-5 contains a site plan of the City of Valley Mills Wastewater Treatment Plant. Proposed improvements for chemical phosphorus removal are also shown in the figure. These consist of:

- New 2,500-gallon alum storage tank and metering pumps
- New effluent filter
- New sludge drying beds
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains
- New brush rotor aerator

The Valley Mills plant oxidation ditch currently has only a single aerator, which is inadequate to insure treatment reliability. When this aerator is taken off line for maintenance or repair, the treatment process is interrupted. To provide the required degree of reliability at this plant in accordance with current TNRCC regulations, a second brush rotor aerator should be installed in the existing oxidation ditch.

5.3 Biological Phosphorus Removal with Effluent Polishing

In this section, required improvements to the six wastewater treatment plants for biological phosphorus removal technology are described. The biological process used for all plants (except the City of Clifton Wastewater Treatment Plant) is the A/O ™ process. A description of this process is provided in Section 3. All plants with biological phosphorus removal also include chemical addition and effluent filtration for further polishing to insure that a 1.0 mg/L TP limit is achieved, since BNR processes can reliably achieve only a 2.0 mg/L TP effluent.

Clifton

Figure 5-6 contains a site plan of the City of Clifton Wastewater Treatment Plant. It consists of the new SBR process completed in 1999 on the west side of the site. The old oxidation ditch, clarifiers, and appurtenant facilities have now been abandoned. As discussed previously, this plant uses the SBR process that is already capable of biologically removing phosphorus. All that is required to optimize phosphorus removal is to reconfigure the cycle times for the SBR process using the existing programmable controls. All that is needed to meet the 1.0 mg/L TP limit are the effluent polishing facilities consisting of the following:

- New 1,500-gallon alum storage tank and metering pumps
- New effluent filter
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains

No additional sludge processing facilities are required since the new plant is equipped with a belt press for sludge dewatering.

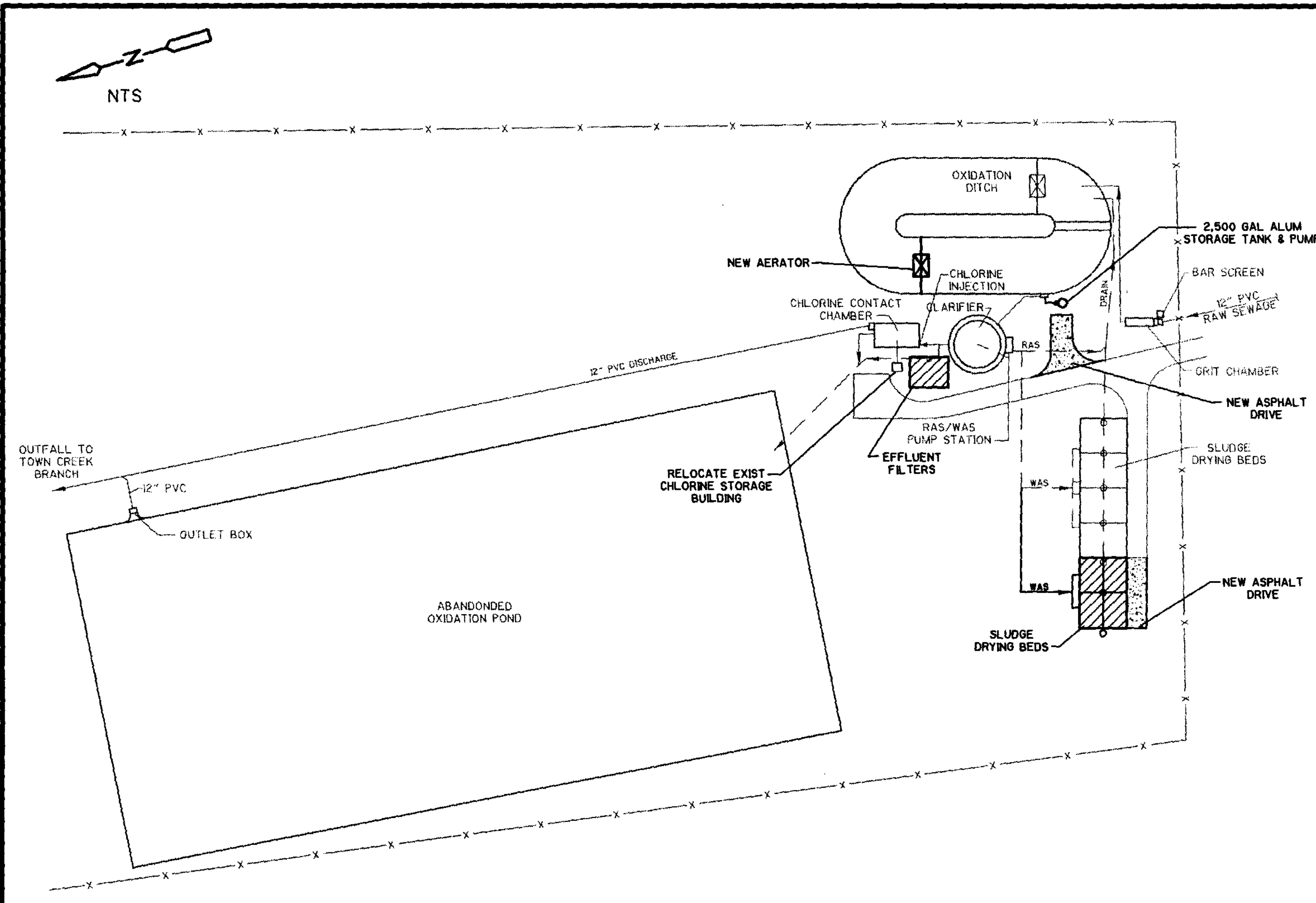

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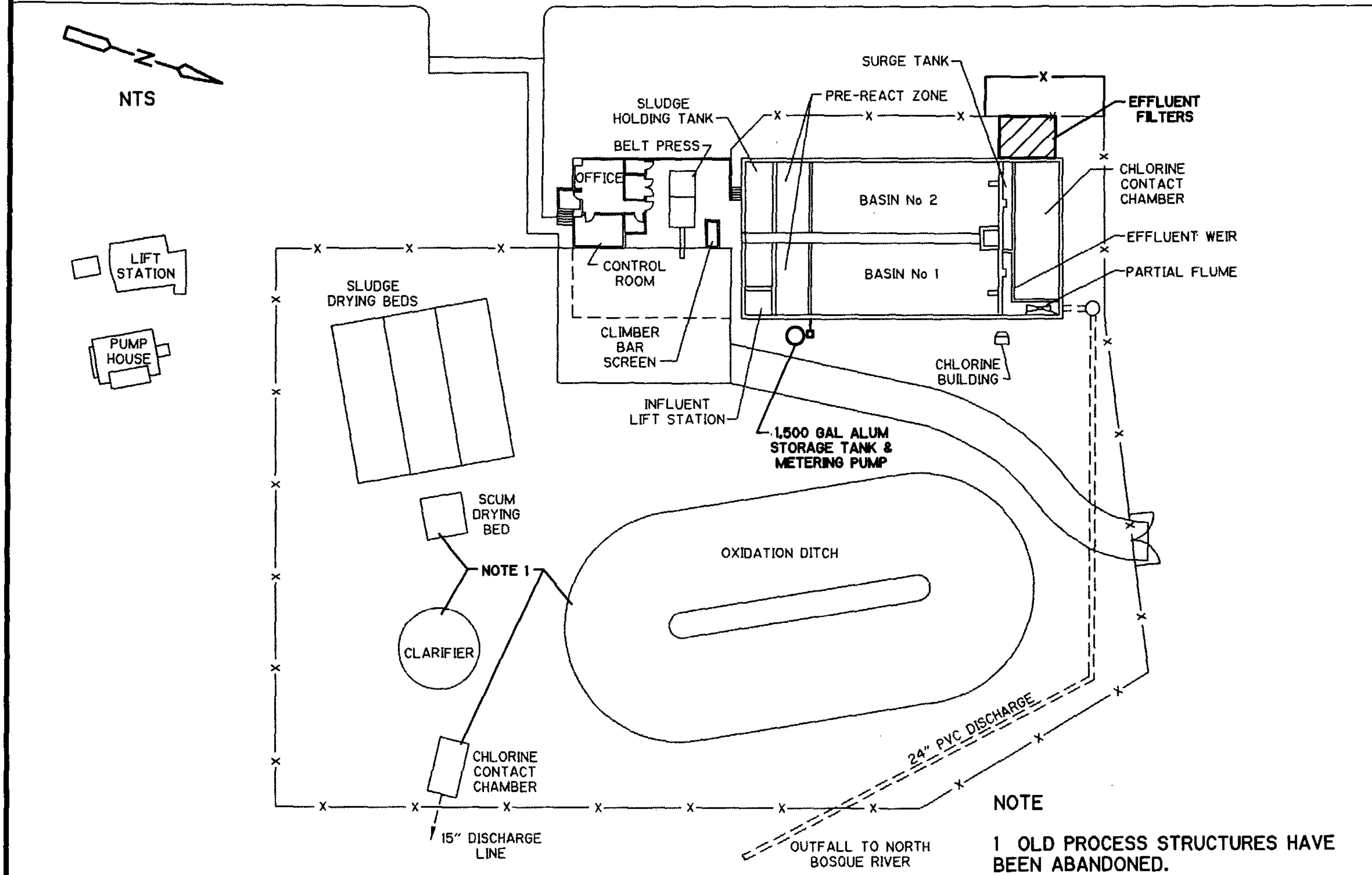
FIGURE No 5-5



NOTE

1 OLD PROCESS STRUCTURES HAVE BEEN ABANDONED.

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3160Z\FIG-5-06

FIGURE No 5-6

Hico

Improvements needed at the City of Hico Wastewater Treatment Plant for biologically removing phosphorus are shown in Figure 5-7. Additional improvements required for biological phosphorus removal consist of a new anaerobic selector basin. Piping modifications will be needed to route the raw wastewater entering the plant to the new basin where it will be mixed with return activated sludge (RAS). As previously discussed, effluent polishing is accomplished by the addition of alum and effluent filtration. Improvements required consist of:

- New anaerobic selector basin
- A 500-gallon alum storage tank and metering pumps
- Effluent filter
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains
- Additional sludge drying beds

Since more of the phosphorus would be removed biologically, the alum storage tank can be reduced in size. Additionally, the excess sludge produced will be less than with chemical phosphorus removal, but still greater than the existing sludge drying beds can handle. The required additional sludge drying beds for this alternative are also shown in Figure 5-7.

The Hico plant does not have an influent pump station. To install the new anaerobic selector, it is assumed that adequate head is available to allow gravity flow of the wastewater from the existing grit chamber through the selector and into the oxidation ditch without adding a new pump station. This would reduce the operating level in the oxidation ditch by several inches, and may also require lowering the clarifier weirs. More detailed hydraulic analysis, including a survey of existing structure elevations, is necessary to confirm that this approach is feasible.

Iredell

At the constricted site of the Iredell Wastewater Treatment Plant, additional fill to enlarge the building pad on the west side of the site will be necessary to create space for a new bar screen and new selector basin. New influent pumps will also be required to provide adequate head to pump into the selector basin. Additional RAS piping to the new selector basin will also be required. These improvements are shown in Figure 5-8 and consist of:

- New influent pumps and bar screen
- New anaerobic selector basin
- A 150-gallon alum storage tank and associated metering pumps
- Effluent filter
- New chlorine contact basin
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains
- Additional sludge drying beds

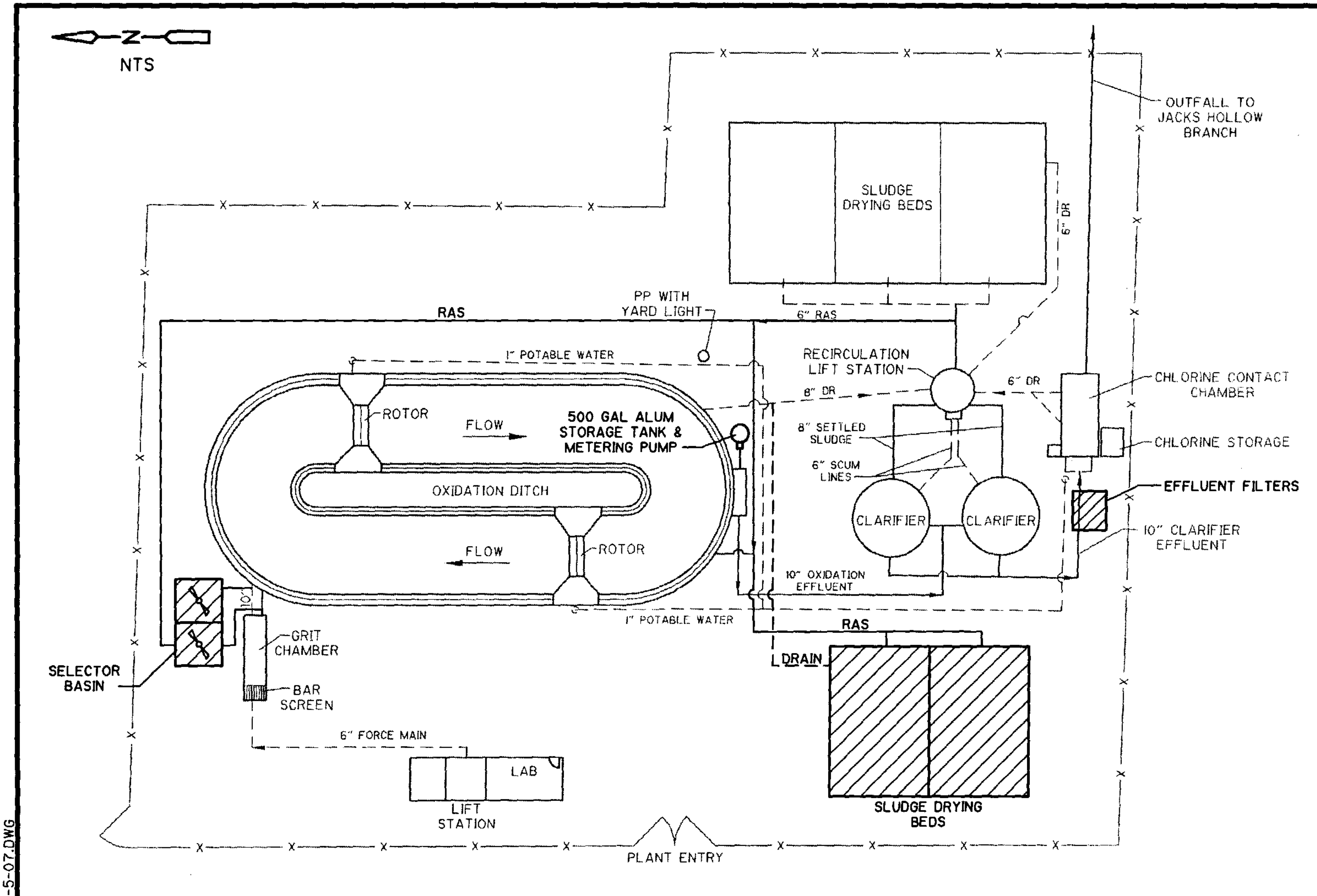

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FIGURE No 5-7

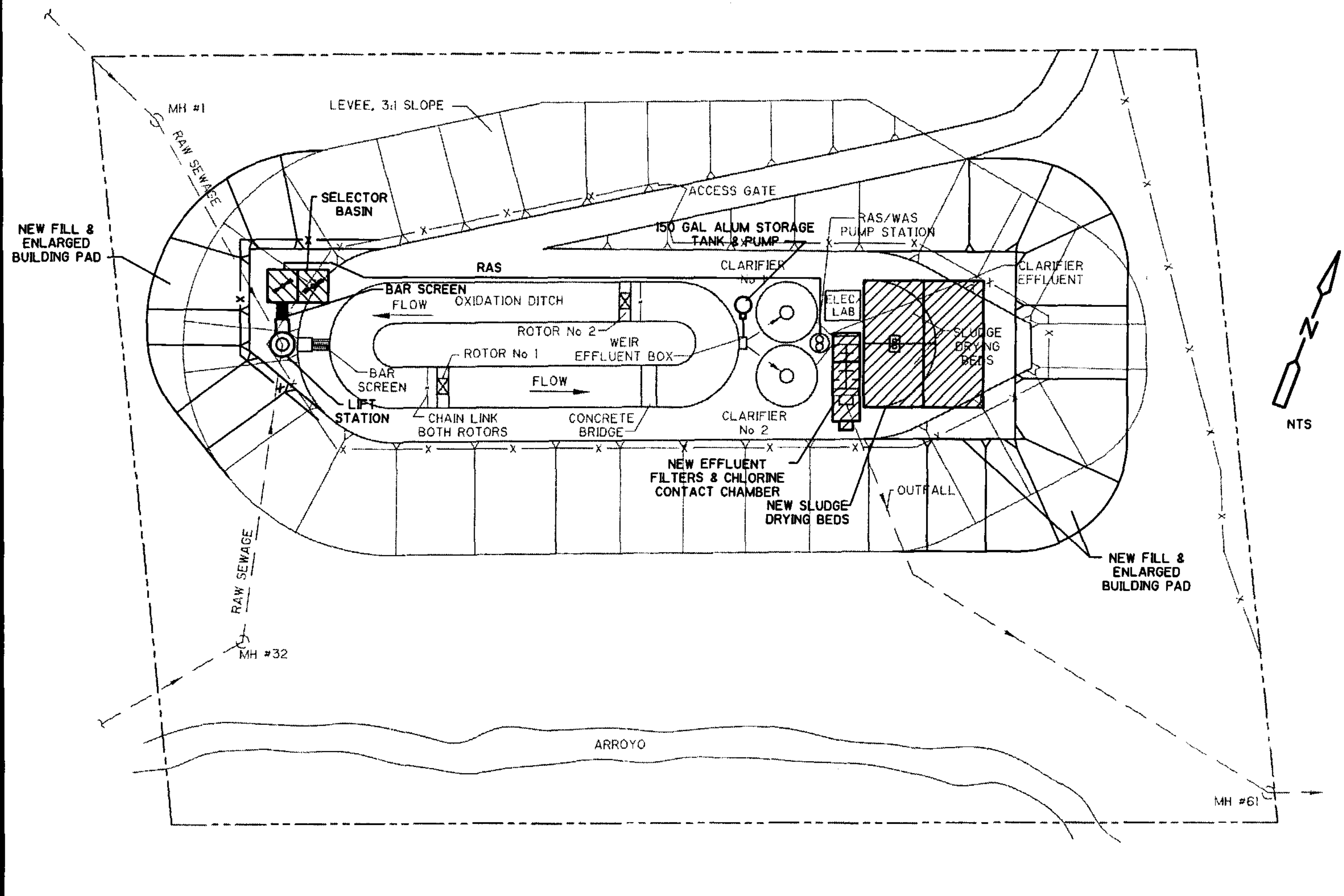

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FIGURE No 5-8

Effluent polishing is accomplished at the Iredell Wastewater Treatment Plant by means of alum addition at the oxidation ditch discharge box prior to clarification in the existing clarifiers. In order to provide effluent filtration prior to chlorination, the existing chlorine contact basin must be demolished and moved south of its current location. To allow for the increased dewatering needs at this plant, additional drying beds will be required. As with the chemical removal option, entirely new sludge drying beds are needed to provide the proper area for the anticipated sludge volumes and to allow more efficient and less labor intensive sludge removal.

Meridian

Incorporating the new selector basin into the process flow scheme and topography at the Meridian Wastewater Treatment Plant would require the construction of the basin near the northeast corner of the plant site. Additional fill would be needed to enlarge the elevated building site to make room for the new basin. Additional RAS piping will also be required. Other improvements needed are similar to those identified for chemical phosphorus removal, and consist of:

- New anaerobic selector basin
- New 1,000-gallon alum storage tank and metering pumps
- New effluent filter
- New chlorine contact chamber and Parshall flume
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains
- New mechanical dewatering facility

Because most of the phosphorus is removed biologically, the alum storage tank can be reduced in size for this alternative. However, addition of a mechanical dewatering facility would still be required due to the inadequate existing sludge drying bed area. Improvements required for biological phosphorus removal at this plant are shown in Figure 5-9.

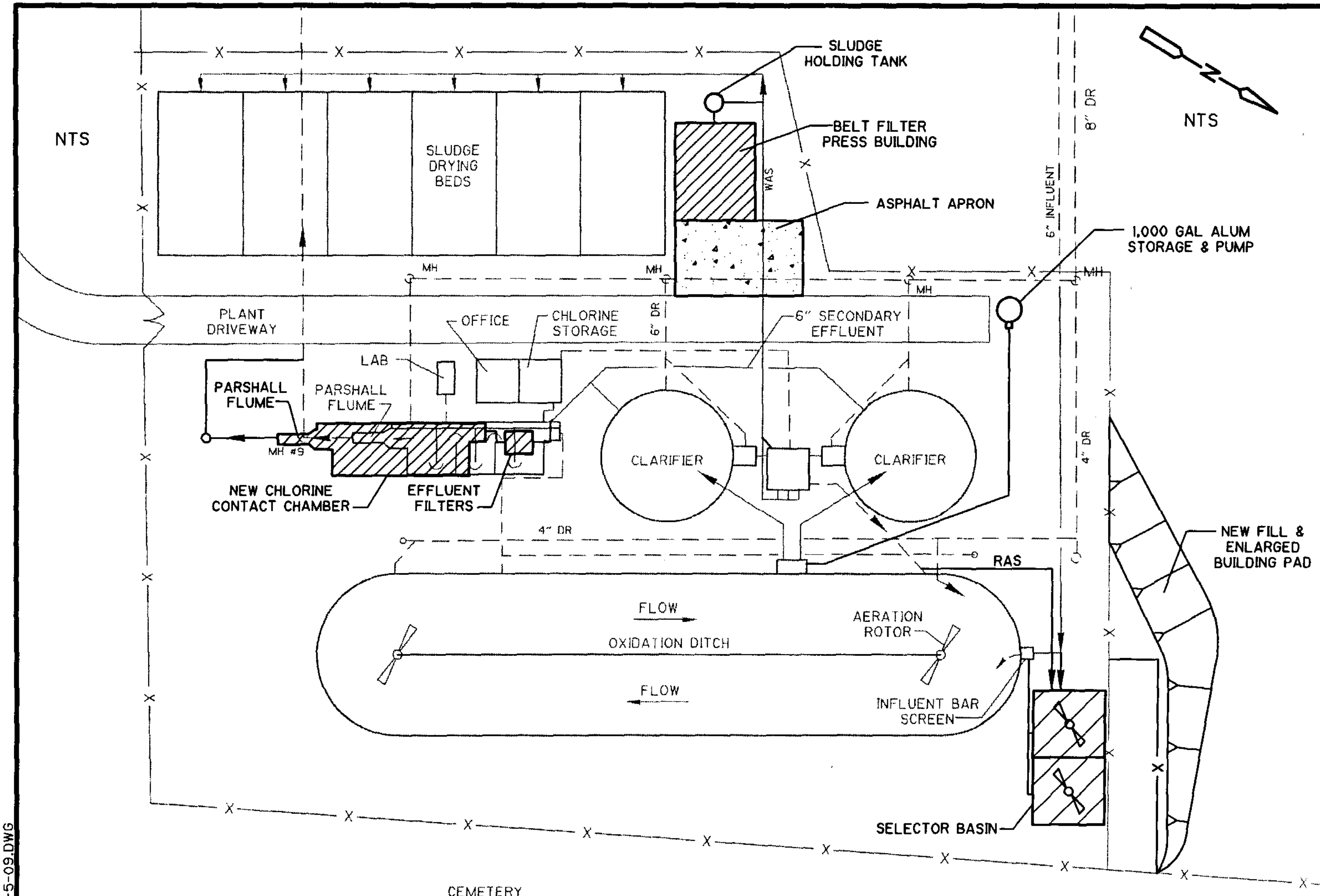

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FIGURE No 5-9

Stephenville

Figure 5-10 contains a site layout of the Stephenville Wastewater Treatment Plant with improvements needed for biological phosphorus removal. Requirements for new construction are reduced at this plant through the reuse of existing structures. To create a selector basin at the plant, the existing primary clarifiers, that are unnecessary for the oxidation ditch process, would be modified to serve as anaerobic selectors. Only one of the clarifiers would be needed for the new basin; however, due to the modest expense involved both units should be converted which would improve reliability. Modifying the primary clarifiers would consist of removing the existing sludge collection units, installation of a fiberglass baffle to partition the basin into zones, and installation of a mixer to keep solids from settling in the tank. The required BNR upgrade improvements consist of the following:

- Conversion of the existing primary clarifiers into anaerobic selector basins
- One new 6,400-gallon alum storage tank and metering pumps
- New mechanical dewatering facility
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains

Effluent polishing improvements are similar to those for the other plants. Alum storage can be reduced to a single 6,400-gallon tank in lieu of the two 8,000 gallon storage tank needed for chemical phosphorus removal. However, a new mechanical dewatering facility is still required for this option.

Valley Mills

Proposed improvements at the Valley Mills Wastewater Treatment Plant to biologically remove phosphorus are shown in Figure 5-11. Similar to the improvements needed at the other plants, a new anaerobic selector basin is required together with new RAS piping. The additional improvements needed consist of:

- New anaerobic selector basin
- New 1,000-gallon alum storage tank and metering pumps
- New effluent filter
- New sludge drying beds
- Associated piping modifications for chemical feed, effluent filtration, sludge wasting, and drains
- New brush rotor aerator

As at Hico, the Valley Mills plant does not have an influent pump station. To install the new anaerobic selector, it is assumed that adequate head is available to allow gravity flow of the wastewater from the existing grit chamber through the selector and into the oxidation ditch without adding a new pump station. This would reduce the operating level in the oxidation ditch by several inches, and may also require lowering the clarifier weirs. More detailed hydraulic analysis, including a survey of existing structure elevations, is necessary to confirm that this approach is feasible.

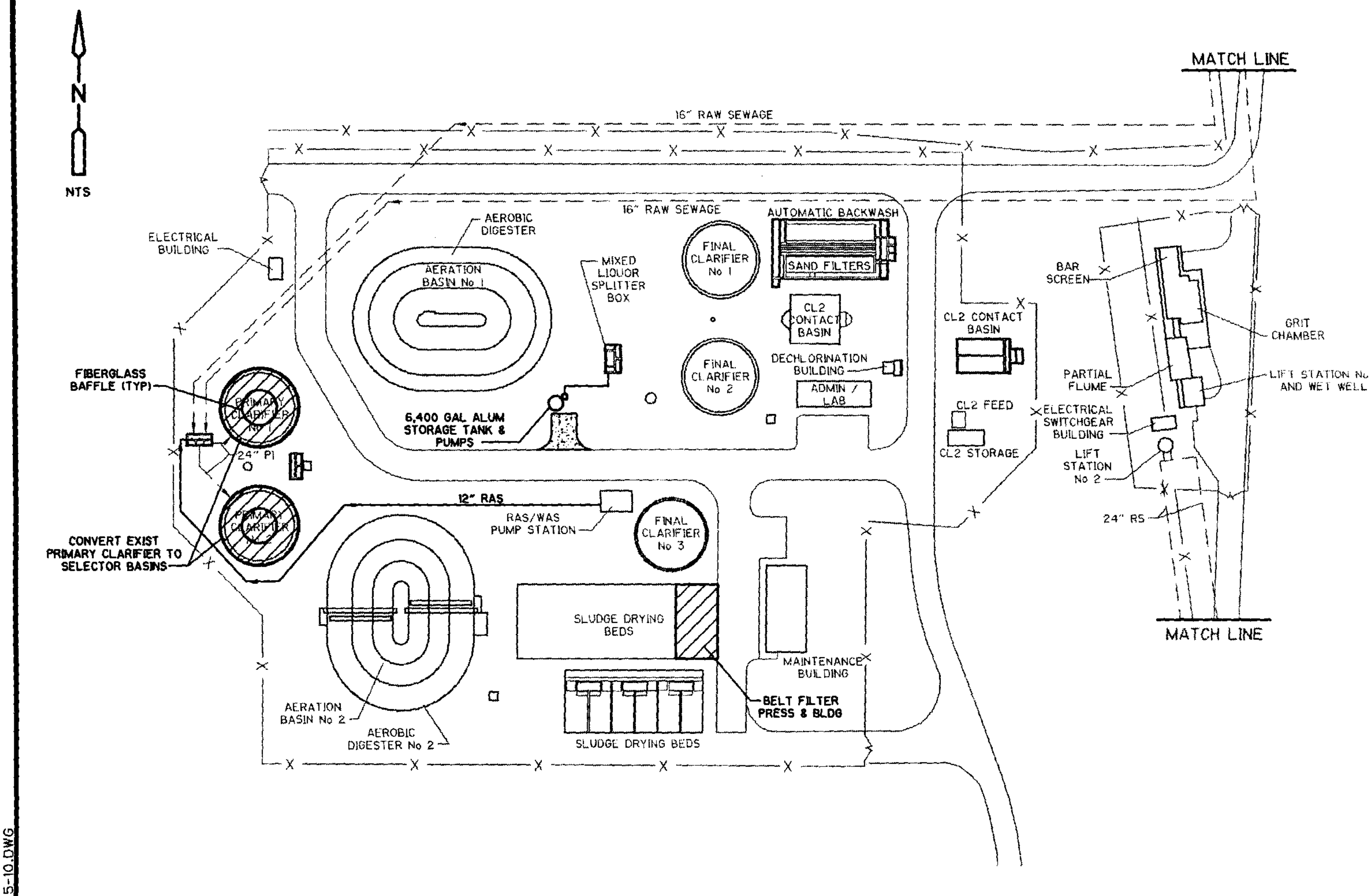

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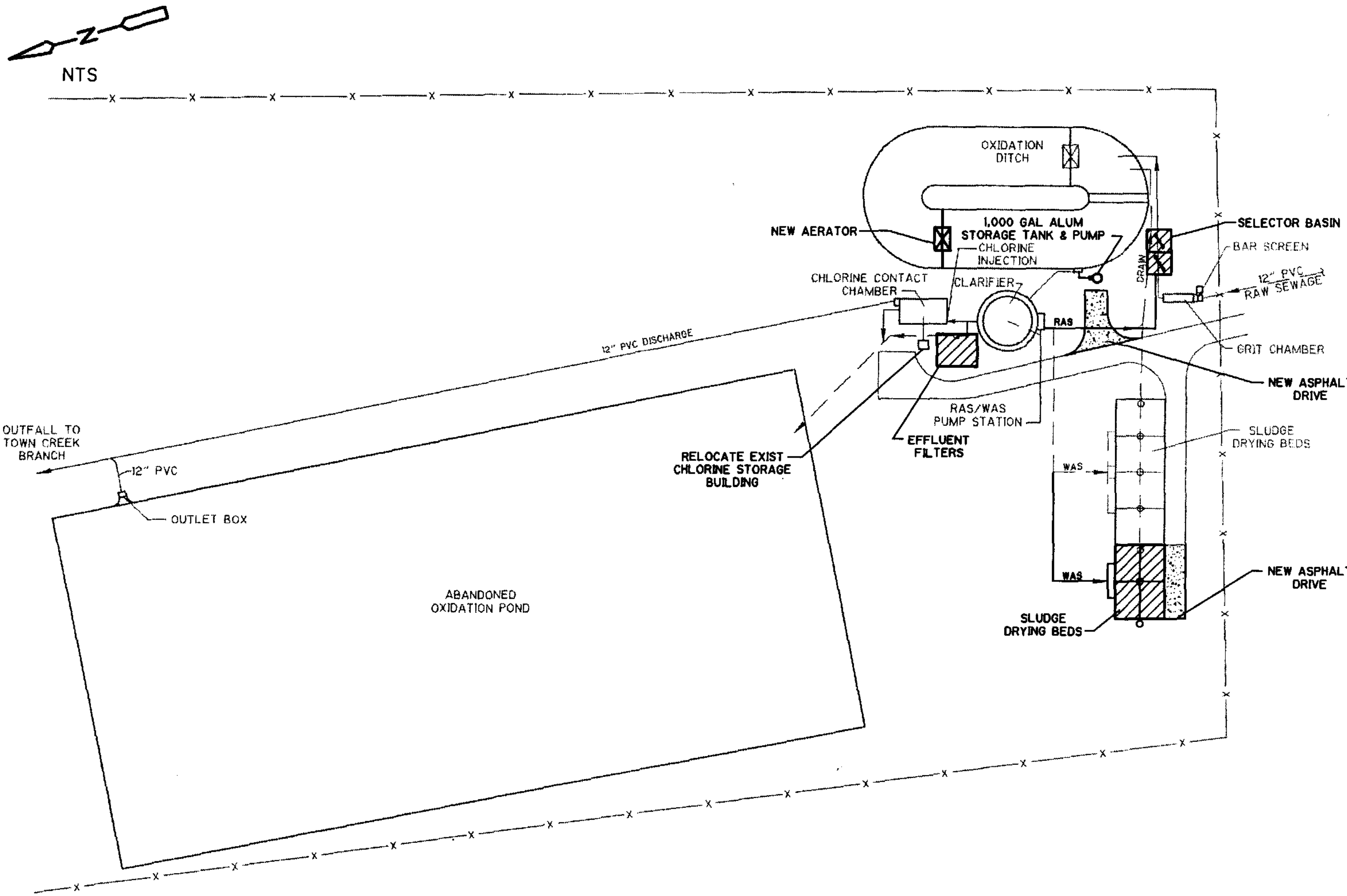
FIGURE No 5-10



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BRAZOS RIVER AUTHORITY
NORTH BOSQUE RIVER PHOSPHORUS REMOVAL STUDY

CITY OF VALLEY MILLS WWTP
BIOLOGICAL PHOSPHORUS REMOVAL

CDM
environmental engineers, scientists, planners, & management consultants

FIGURE No 5-11

5.4 Cost Estimates

An estimate of construction costs and annual Operations and Maintenance (O&M) costs was developed for each of the chemical and biological phosphorus removal alternatives described above. Construction costs were then converted to an annualized cost using an effective interest rate of 3.5% and a facilities life of 25 years. Adding this to the O&M costs yields the total annual cost, which is used to compare alternatives.

The interest rate used in the cost estimates (3.5%) is the effective interest rate based on a market interest rate of 6.5% and annual inflation of 3%. It is calculated as follows:

Effective Interest Rate (i') = The actual growth of money.

Market Interest Rate (i) = Rate of interest obtainable in the general marketplace.

Inflation Rate (f) = Decrease in the purchasing power of money.

The basic relationship between these three is:

$i = i' + f$ (Market = Effective + Inflation)

Solving for i' with a market rate of 6.5% and an inflation rate of 3% yields an effective interest rate of 3.5%.

Cost estimate summaries are described below. Cost detail for each alternative is provided in Appendix D.

The construction, annual O&M, and total annual cost for each alternative is summarized in Table 5-1. The cost totals shown include contractor overhead and profit (15%), professional services for engineering, surveying, and geotechnical investigation (15%), and contingencies (25%). As can be seen in the table, the construction cost to install phosphorus removal equipment ranges from $422,000 at Clifton to $1,444,000 at Meridian, depending on the alternative selected. It should be noted that the required increase in annual O&M costs shown are based on the permitted flow from each plant to allow equitable comparison. Since actual flows are less than the permitted limit, the actual increase in annual O&M costs for each plant would be less.

Table 5-1: Phosphorus Removal Cost Summary

Chemical Phosphorus Removal			
Facility	**Construction Cost**	**Annual O&M Cost**	**Effective Annual Cost**
	(Capital Cost)	(Annualized Cost)	(Annualized Cost)
Clifton WWTP	N/A	N/A	N/A
Hico WWTP	$ 464,000	$ 18,000	$ 44,000
Iredell WWTP	$ 445,000	$ 10,000	$ 35,000
Meridian WWTP	$ 1,287,000	$ 47,000	$ 123,000
Stephenville WWTP	$ 1,087,000	$ 205,000	$ 269,000
Valley Mills WWTP	$ 538,000	$ 38,000	$ 70,000
Total	**$ 3,821,000**	**$ 318,000**	**$ 541,000**
Biological Phosphorus Removal			
Facility	**Construction Cost**	**Annual O&M Cost**	**Effective Annual Cost**
	(Capital Cost)	(Annualized Cost)	(Annualized Cost)
Clifton WWTP	$ 422,000	$ 21,000	$ 46,000
Hico WWTP	$ 619,000	$ 26,000	$ 61,000
Iredell WWTP	$ 611,000	$ 18,000	$ 53,000
Meridian WWTP	$ 1,444,000	$ 48,000	$ 132,000
Stephenville WWTP	$ 1,352,000	$ 134,000	$ 214,000
Valley Mills WWTP	$ 653,000	$ 40,000	$ 78,000
Total	**$ 5,101,000**	**$ 287,000**	**$ 584,000**

To identify the plants that have the most cost effective phosphorus removal, the cost per pound of phosphorus removed was calculated for each plant and are presented in Table 5-2. This table shows that the cost of phosphorus removal is most economical for Stephenville ($7/lb/yr using BNR) and most expensive for Iredell and Hico ($99 and $29/lb/yr, respectively, using BNR).

Table 5-2: Cost Per Pound of Phosphorus Removed

Facility	Flow Rate	Chemical Removal - Annual Cost Per Pound Phophorus Removed Per Year	BNR Removal - Annual Cost Per Pound Phophorus Removed Per Year
	(MGD)	($/lb/yr)	($/lb/yr)
Stephenville WWTP	3.0	$8	$7
Clifton WWTP	0.65	N/A	$23
Valley Mills WWTP	0.36	$18	$20
Meridian WWTP	0.45	$26	$28
Hico WWTP	0.2	$21	$29
Iredell WWTP	0.05	$66	$99

The chemical and biological removal alternatives are compared in Table 5-3, which indicates that chemical phosphorus removal is the most cost effective approach for all plants except Clifton and Stephenville. However, for Meridian, there is only a 7% cost difference between the two approaches.

Table 5-3: Comparison of Chemical v. Biological Phosphorus Removal Costs

Facility	Flow Rate	Chemical Removal Cost	Biological Removal Cost	Most Affordable Option	Cost Difference	Percent Cost Difference
	(MGD)	(Annualized Cost)	(Annualized Cost)			
Clifton WWTP	0.65	N/A	$46,000	BNR	N/A	N/A
Hico WWTP	0.2	$44,000	$61,000	CHEMICAL	$17,000	39%
Iredell WWTP	0.05	$35,000	$53,000	CHEMICAL	$18,000	51%
Meridian WWTP	0.45	$123,000	$132,000	CHEMICAL	$9,000	7%
Stephenville WWTP	3	$269,000	$214,000	BNR	$55,000	26%
Valley Mills WWTP	0.36	$70,000	$78,000	CHEMICAL	$8,000	11%

A summary of the total cost associated with phosphorus removal, utilizing the most affordable methods is presented in Table 5-4. The total capital investment required using the most economical approach at each plant is estimated at $4,508,000. The total annual O&M cost is $268,000.

While the effective interest rate of 3.5% is appropriate for making comparisons between alternatives, the total annual cost derived from the effective interest rate is not indicative of the true annual cost of debt service. For debt service costs, the total annual cost using the market interest rate should be used. Accordingly, the total annual cost based on a market rate of 6.5% is also provided in Table 5-4, which may be relevant if the capital costs are financed.

Table 5-4: Most Affordable Phosphorus Removal Option Cost Summary

Facility	Flow Rate	Affordable Option	Construction Cost	Annual O&M Cost	Total Annual Cost[1]	Effective Annual Cost[2]
-	(MGD)		($)	($/yr)	($/yr)	($/yr)
Clifton WWTP	0.65	BNR	$422,000	$21,000	$66,000	$46,000
Hico WWTP	0.2	CHEMICAL	$464,000	$18,000	$55,000	$44,000
Iredell WWTP	0.05	CHEMICAL	$445,000	$10,000	$45,000	$35,000
Meridian WWTP	0.45	CHEMICAL	$1,287,000	$47,000	$151,000	$123,000
Stephenville WWTP	3	BNR	$1,352,000	$134,000	$244,000	$214,000
Valley Mills WWTP	0.36	CHEMICAL	$538,000	$38,000	$81,000	$70,000
Total			**$4,508,000**	**$268,000**	**$642,000**	**$532,000**

[1] Based on a current market interest rate of 6.5%.

[2] Based on an effective interest ate of 3.5% after inflation.

5.5 Nutrient Trading

To optimize the phosphorus removal scheme for the North Bosque River, the concept of nutrient trading was also examined. Nutrient trading involves reducing the effluent phosphorus limit for one or more of the plants while increasing the limit for other plants, such that the total pounds of phosphorus discharged to the North Bosque River remain the same. The nutrient trading approach is shown in Table 5-5.

Table 5-5: Cost Differences with Nutrient Trading

Alternative 1: Phosphorus Reduction at All Plants							
Facility	Flow Rate	Estimated Present Phosphorus Discharge		Estimated Alternative 1 Phosphorus Discharge		Cost of Most Economical Option	Annual Cost Per Pound Phophorus Removed Per Year[1]
	(MGD)	(mg/L)	(lbs/yr)	(mg/L)	(lbs/yr)	(Annualized Cost)	($/lb/yr)
Clifton WWTP	0.65	2.0	3,957	1.0	1,979	$ 46,000	$ 23
Hico WWTP	0.2	4.5	2,740	1.0	609	$ 44,000	$ 21
Iredell WWTP	0.05	4.5	685	1.0	152	$ 35,000	$ 66
Meridian WWTP	0.45	4.5	6,164	1.0	1,370	$ 123,000	$ 26
Stephenville WWTP	3	4.5	41,095	1.0	9,132	$ 214,000	$ 7
Valley Mills WWTP	0.36	4.5	4,931	1.0	1,096	$ 70,000	$ 18
		Total	**59,572**		**14,338**	**$ 532,000**	

Alternative 2: Nutrient Trading Phosphorus Reduction							
Facility	Flow Rate	Estimated Present Phosphorus Discharge		Estimated Alternative 2 Phosphorus Discharge		Cost of Option	Annual Cost Per Pound Phophorus Removed Per Year[1]
	(MGD)	(mg/L)	(lbs/yr)	(mg/L)	(lbs/yr)	(Annualized Cost)	($/lb/yr)
Clifton WWTP	0.65	2.0	3,957	1.0	1,979	$ 46,000	$ 23
Hico WWTP	0.2	4.5	2,740	4.5	2,740	$ -	$ -
Iredell WWTP	0.05	4.5	685	4.5	685	$ -	$ -
Meridian WWTP	0.45	4.5	6,164	1.0	1,370	$ 123,000	$ 26
Stephenville WWTP	3	4.5	41,095	0.7	6,393	$ 231,000	$ 7
Valley Mills WWTP	0.36	4.5	4,931	1.0	1,096	$ 70,000	$ 18
		Total	**59,572**		**14,263**	**$ 470,000**	

[1] Annual costs are based upon phosphorus removal to 0.5mg/L to assure that a 1.0mg/L effluent standard is achieved, and using the effective interest rate of 3.5% after inflation.

Alternative 1 in Table 5-5 lists the phosphorus discharge and total cost if phosphorus removal is implemented at all six plants. With a 1.0 mg/L effluent limit at each plant, a total of 14,338 pounds of phosphorus would be discharged annually based on permitted flows. Actual phosphorus discharge would be less, since current wastewater flows at all of the plants are less than the permitted limit, and because the plants would target a lower level, say 0.5 mg/L, to insure that the permit limit is achieved. This approach would require an estimated total investment of $532,000/year on an annualized basis.

Alternative 2 shows the benefits of nutrient trading. The three most expensive plants for removing phosphorus on a per pound basis, using the most cost-effective option, are Iredell, Meridian, and Hico. If Iredell and Hico remain at their existing status, they would discharge a combined 3,425 lb/yr of phosphorus based on current data. This quantity can be offset entirely by reducing the effluent permit limit for Stephenville from 1.0 mg/L to 0.7 mg/L TP. Since Stephenville has most cost effective phosphorus removal scheme and is the largest plant, it would be logical to concentrate further reductions through nutrient trading at this facility. With this approach, the total phosphorus discharge from Stephenville at 0.7 mg/L effluent TP and Clifton, Meridian, and Valley Mills at 1.0 mg/L effluent TP would be 14,263lb/yr which is essentially the same as Alternative 1. Total annual cost using nutrient trading would be approximately $470,000/yr, and that represents a estimated savings of $62,000/yr over phosphorus removal at all of the plants.

Table 5-6 presents a summary of the implementation costs by incorporating nutrient trading. The total capital investment required for this approach is estimated at $3,602,000. Nutrient trading would, therefore, permit a construction cost savings of $906,000 and an annual O&M cost savings of $12,000 compared to removing phosphorus at all six plants. Both the total annual cost using a current market interest rate of 6.5% and the effective annual cost considering inflation are shown in Table 5-6.

Table 5-6: Nutrient Trading Cost Summary

Facility	Construction Cost	Annual O&M Cost	Total Annual Cost[1]	Effective Annual Cost[2]
	(Capital Cost)	(Annualized Cost)	(Annualized Cost	(Annualized Cost)
Clifton WWTP	$ 422,000	$ 21,000	$ 66,000	$ 46,000
Hico WWTP	$ -	$ -	$ -	$ -
Iredell WWTP	$ -	$ -	$ -	$ -
Meridian WWTP	$ 1,287,000	$ 47,000	$ 151,000	$ 123,000
Stephenville WWTP	$ 1,355,000	$ 150,000	$ 260,000	$ 231,000
Valley Mills WWTP	$ 538,000	$ 38,000	$ 81,000	$ 70,000
Total	**$ 3,602,000**	**$ 256,000**	**$ 558,000**	**$ 470,000**

[1] Based on a current market interest rate of 6.5%.

[2] Based on an effective interest ate of 3.5% after inflation.

5.6 Nitrogen Removal

As discussed in TM 3, processes are available to remove nitrogen from wastewater to meet a TN limit as low as 4.0 mg/L. If a TN limit of 10 mg/L is acceptable, costs for adding denitrification are reduced significantly. Since drinking water standards allow nitrate concentrations up to 10.0 mg/L, for purposes of this analysis it is assumed that a 10.0 mg/L TN limit would be the likely outcome of any future TMDL studies of nitrogen in the North Bosque River. The means of achieving a 10 mg/L nitrogen removal at each of the six plants, together with representative costs, are described below. To achieve nitrogen removal, it would also be necessary to first implement the biological nutrient removal alternative for phosphorus at each plant (A/O process).

Clifton

The Clifton WWTP uses the Sequencing Batch Reactor process, which is already configured to achieve both nitrogen and phosphorus removal. Thus no additional cost should be required to achieve a TN limit of 10.0 mg/L, although actual testing of the process should be performed to verify achievable limits. The chemical polishing and effluent filters are still required to meet the 1.0 mg/L TP limit. The effect of adding a TN limit should have no effect on the sludge handling facilities for this or any of the other plants.

Hico

For the Hico WWTP, a conversion to the A2/O process would be required to achieve a 10.0 mg/L TN limit. The brush rotor aerators in the existing ditch cannot be controlled accurately enough to provide nitrogen removal within the basin. The A2/O modification would be similar to the A/O process described earlier, except that an anoxic basin would be added to the A/O anaerobic basin, together with an internal recycle pump station. The new anoxic basin would be approximately twice as large as the anaerobic basin. The additional cost of providing the A2/O process is initially estimated at approximately $387,000 in additional construction costs and $23,000 in additional annual O&M costs.

To achieve an effluent TN limit of 4.0 mg/L, upgrade to a full Bardenpho process would be required. This would consist of adding a second anoxic basin and a reaeration basin between the existing oxidation ditch and the secondary clarifiers. A second new pump station would also be required to lift the flow into the second stage anoxic and reaeration basins, since insufficient head is available to flow through the additional tankage by gravity. The cost of constructing these additional units would be approximately twice the cost of the A2/O upgrade presented above. This would also be the case for the other oxidation ditch plants.

Iredell

For the Iredell plant, conversion of the oxidation ditch to the A2/O process would be more difficult than at Hico due to the constraints of the existing site. Additional fill and building area would be required to provide room for the required anoxic basin. A new internal recycle pump to the first stage anoxic basin would also be required. Cost of this upgrade is estimated at approximately $404,000 in additional construction costs and $11,000 in additional annual O&M costs.

Meridian

The A2/O process upgrade at the Meridian plant would require the same additional basin and pump station as the Hico and Iredell facilities. The Meridian plant is also constrained by the small developable site that would require additional earthwork expense to enlarge the buildable area. The incremental cost of upgrading the Meridian plant to the A2/O process is estimated at approximately $421,000 in additional capital costs and $11,000 in annual O&M costs.

Stephenville

It appears that an A2/O process upgrade for Stephenville would be more economical to achieve a 10.0 mg/L TN limit than reconfiguring the existing multi-channel oxidation ditches to denitrify, since this would require construction of new sludge digesters. The A/O process upgrade for Stephenville, described earlier, makes use of the existing primary clarifiers by converting them to the required anaerobic basins. Further upgrading the plant to the A2/O process would require a new stand-alone anoxic basin between the converted clarifiers and the oxidation ditches, plus construction of an internal recycle pump station. The incremental cost of the additional A2/O units is estimated at approximately $1,322,000 in additional capital costs and $16,000 in annual O&M costs.

Valley Mills

Upgrade of the Valley Mills plant to the A2/O process would require the same additional units as Hico, Iredell, and Meridian. The incremental cost of adding the additional facilities is estimated at approximately $340,000. These additional facilities would be required together with the A/O facilities described earlier. Annual O&M cost would also increase by an estimated $12,000 per year.

Summary

In summary, to further upgrade the six plants to achieve an effluent TN limit of 10 mg/L, an additional capital investment of approximately $9.08 million would be required above and beyond the costs to remove phosphorus, with added total annual O&M costs of about $73,000 per year.

5.7 Wetlands Treatment

As discussed in Section 3, constructed wetlands could be used to remove nutrients from the plants along the North Bosque River. To determine the wetlands treatment area required, a specific first-order area-based model was used to provide a preliminary estimate of area requirements. The model was based on using Free Water Surface (FWS) constructed wetland treatment. This model is used to estimate the constructed treatment wetland area necessary to reduce the wetland influent concentration of a specific pollutant to a target wetland effluent concentration for that pollutant. The wetland influent concentration, target wetland effluent concentration, and the first-order areal rate constant (k), for the specific pollutant are used in the model equation to estimate constructed wetland treatment area requirements.

This area-based first-order k-C* model solves for required treatment area as follows:

$$A = \frac{0.0365 \times Q}{k} \times \ln \frac{Ci - C^*}{Ce - C^*}$$

where A = required wetland area in hectares
Q = water flow rate in m3/d
k = first order areal rate constant in m/yr
Ci = wetland influent concentration in mg/l
Ce = target wetland effluent concentration in mg/L
C* = background concentration in mg/L

These first order processes are dependent on wetland area and are limited to non-zero pollutant levels that naturally occur in wetlands, as specified for each pollutant in the model (C*). Knowledge of areal rate constants (k) for specific pollutants from an empirical database, the wetland influent concentration (wastewater effluent) for the specific pollutants, and the target effluent concentration indicates which specific pollutant is critical for estimating constructed wetland treatment area requirements. The target effluent concentration that has been established for this analysis is a TP concentration of 1.0 mg/l. This effluent target and an evaluation of the wastewater effluent data (wetland influent) from the six facilities indicates that total phosphorus is the critical pollutant for estimating constructed wetland treatment area requirements. The critical pollutant is used to determine the necessary wetland area.

Table 5-7 is a summary of the pertinent wastewater effluent data. The results of the model for the six facilities are presented in Table 5-8. The model provides wetland effluent concentrations for TSS, BOD, and nitrogen species based on the wetland influent data. The results indicate that the proposed wetlands would provide excellent treatment of TSS, BOD, and nitrates. Some of the facilities, such as Hico, Iredell, and Meridian, have an influent BOD concentration that is lower than the wetland effluent. This seemingly erroneous data is due to the fact that the model accounts for the BOD background concentration, which is roughly 3.7 mg/L. The influent concentration of TKN for each of the facilities are considerably lower than the effluent concentrations due to the denitrification of the nitrite and nitrate species into ammonia.

Of greatest interest are the wetland area requirements to treat phosphorus to 1.0 mg/l. The phosphorus influent to the wetlands ranges from 2.39 mg/l to 4.78 mg/l. As indicated in Table 5-8, wetland treatment area requirements are:

Iredell	3.5 acres
Hico	12.3 acres
Valley Mills	17.0 acres
Meridian	22.1 acres
Clifton	22.3 acres
Stephenville	129.3 acres

The constructed wetland area requirements indicate the potential of this technology for phosphorus removal at the six facilities. Because area requirements are large for phosphorus removal, it may be possible to use wetlands only for polishing after BNR treatment. This would provide a lower wetlands influent TP concentration which would reduce the area requirement by approximately one-third.

Except for Iredell, land area requirements for wetlands treatment are rather extensive. To determine the cost effectiveness of this approach, it would be necessary to identify specific wetlands sites at each city and then determine the cost to develop the wetlands, including costs for conveying the effluent to the proposed site. In general, the cost of constructed wetlands ranges from about $55,000/acre for a 10 acre pond to about $35,000/acre for a 150 acre pond, due to economies of scale, and not including conveyance costs. Based on these costs, constructed wetlands would only be potentially feasible for Iredell. Constructed wetlands treatment could be examined further during the implementation phase of this project, if desired. However, based on the large area requirements and, with the possible exception of Iredell, it is unlikely that wetlands polishing would be less expensive than phosphorus removal at the individual plants.

It should be noted that both Stephenville and Meridian are considering wetlands in conjunction with the U.S. Corps of Engineers. Should these projects be implemented, these wetlands would have a positive effect on reducing nutrients in the North Bosque River. However, some phosphorus removal at the treatment plants would likely still be required.

5.8 Land Treatment

As with wetlands, the cost effectiveness of land treatment cannot be reliably determined without more detailed site-specific studies. This would entail identifying a suitable agricultural area as close to the plant as practical, which the city would potentially acquire for a wastewater land application site. With the potential site identified, the cost of conveying treated wastewater to the site and constructing the required effluent holding pond could be determined. If desired, this approach could be evaluated in greater detail during the implementation phase of the project.

5.9 Recommendations

To reduce phosphorus loadings on the North Bosque River, the most cost-effective approach is to employ nutrient trading. This would entail permitting the Stephenville plant for an effluent discharge limit of 0.7 mg/L TP, permitting the Clifton, Meridian, and Valley Mills plants for an effluent discharge limit of 1.0 mg/L TP, and leaving a TP limit out of the permits for Hico and Iredell entirely. Biological nutrient removal would be used at Clifton and Stephenville, and chemical phosphorus removal would be used at Meridian and Valley Mills. Total construction cost of this approach is estimated at $3,602,000. Since this option would save an estimated $906,000 in capital costs, or $62,000 annually, the nutrient trading approach is recommended.

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Appendix A

Appendix A: Site Photos
Brazos River Authority
North Bosque River Phosphorous Removal Study

1.1 Clifton WWTP

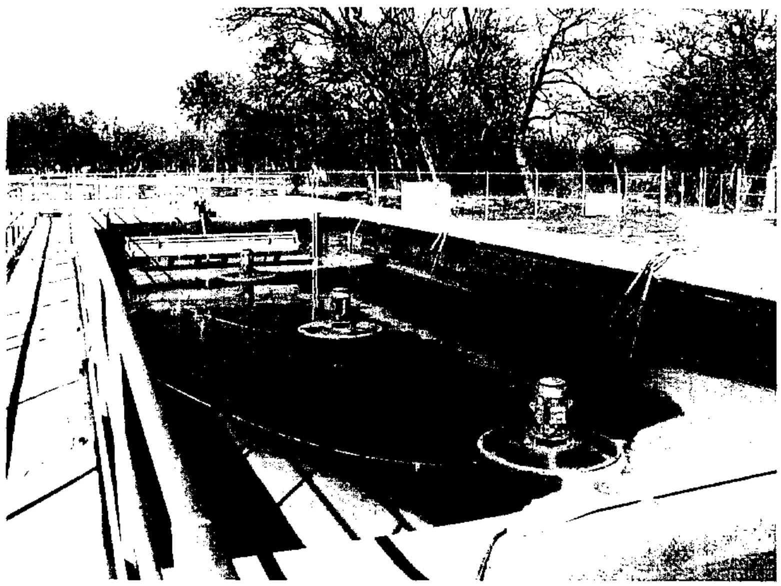

Figure A-1: Stage batch reactor during the settlement stage of treatment cycle.

Figure A-2: Effluent Chlorine Contact Chamber

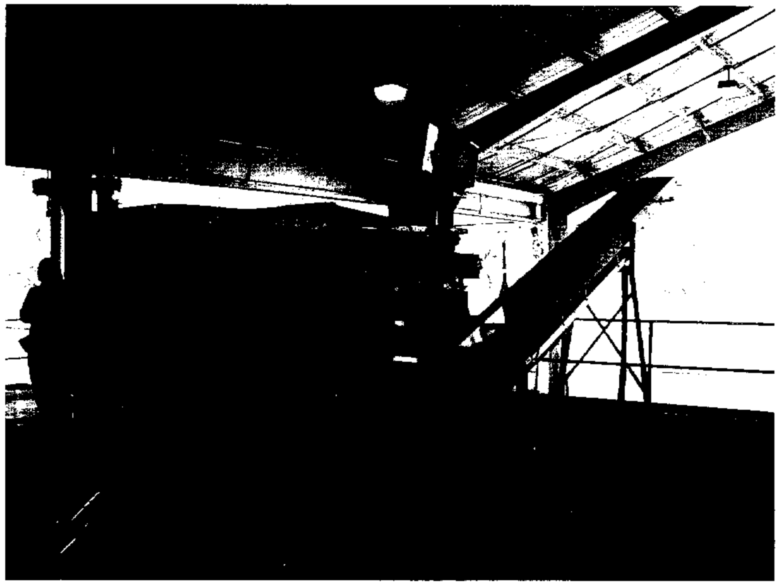

Figure A-3: Belt Filter Press used for WAS dewatering.

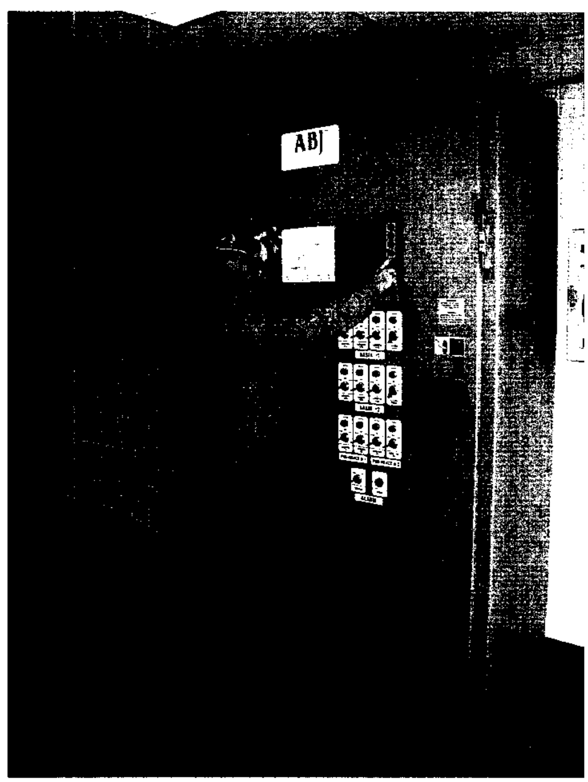

Figure A-4: Plant Operator demonstrating the easy operation of the ICEAS PLC.

1.2 Hico WWTP

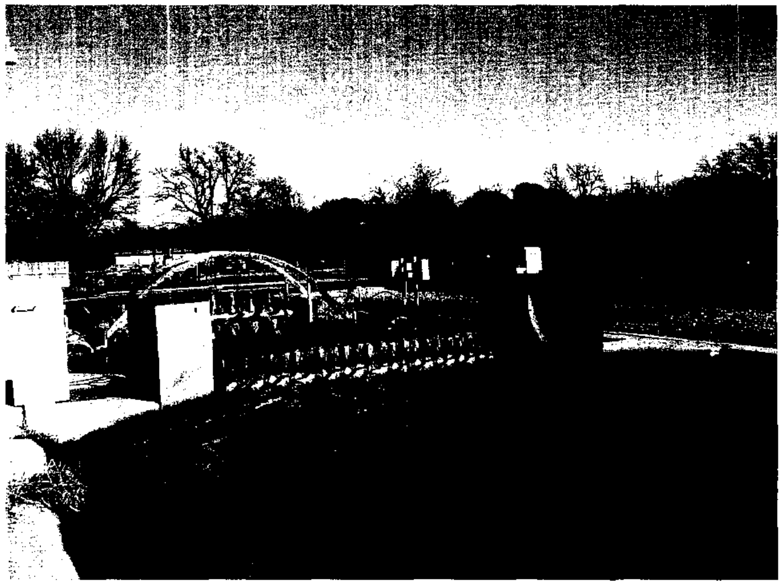

Figure A-5: Oxidation ditch and rotor brush aerators.

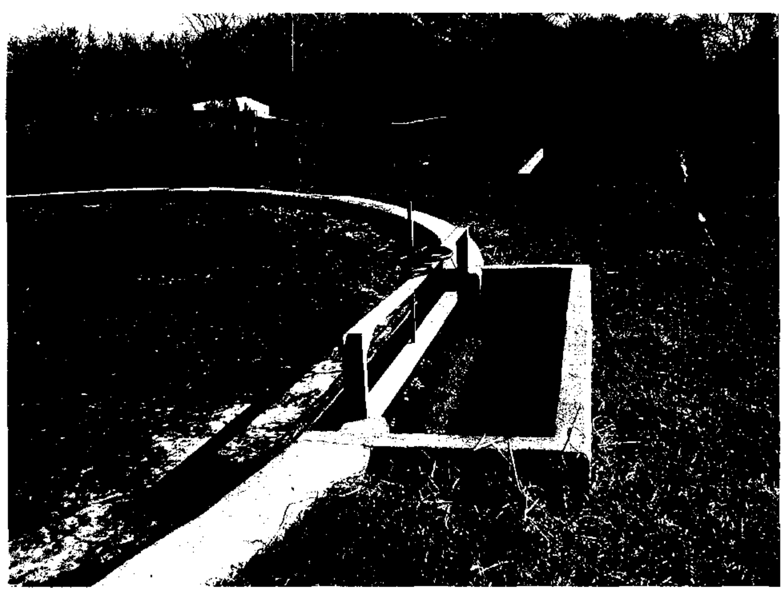

Figure A-6: Oxidation ditch outfall and sludge drying beds (in the background).

Figure A-7: Mixed liquor final clarifiers.

Figure A-8: Hico WWTP Operator.

1.3 Iredell WWTP

Figure A-9: Oxidation ditch with two mechanical aerators.

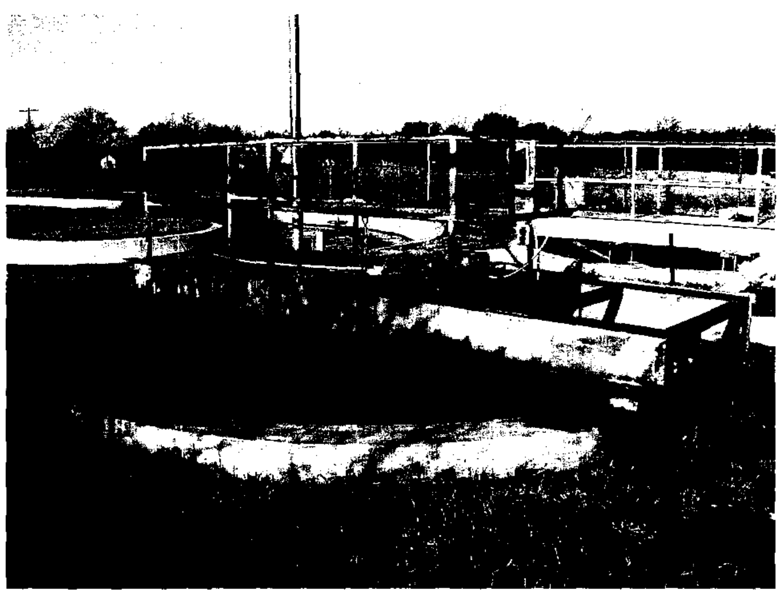

Figure A-10: Two final clarifiers, operated alternately.

Figure A-11: Mayor of Iredell.

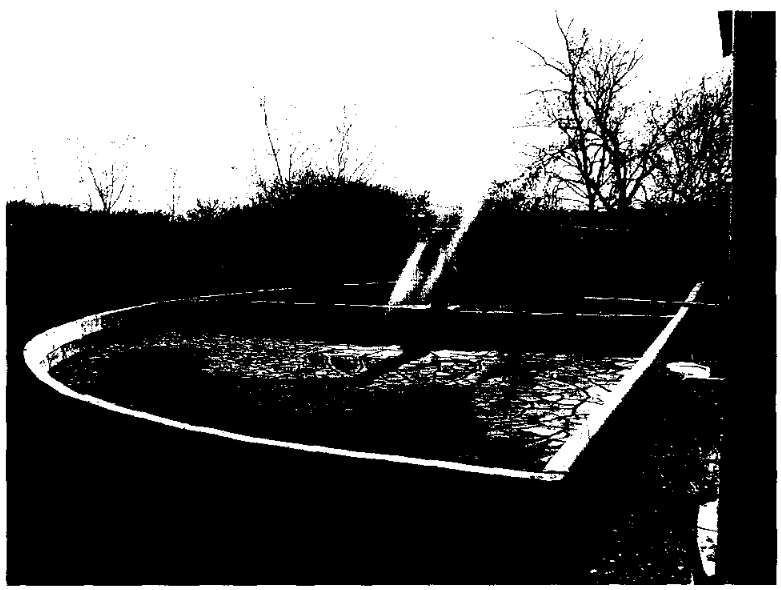

Figure A-12: Limited area in existing sludge drying beds.

1.4 Meridian WWTP

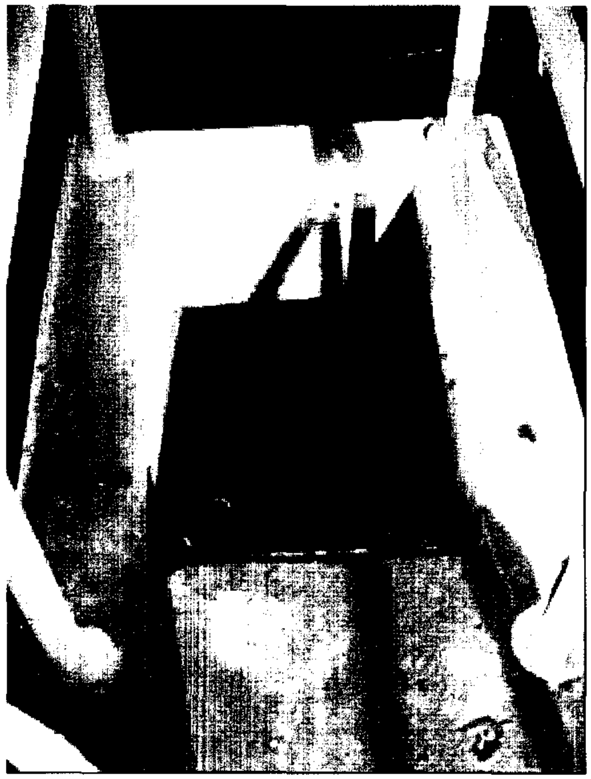

Figure A-13: Influent manual bar screen.

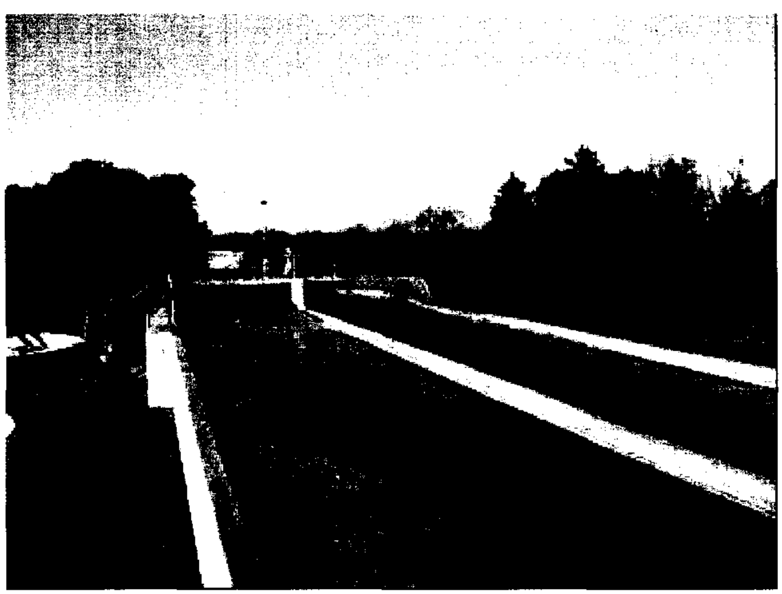

Figure A-14: Carousel oxidation ditch with vertical rotors at each end.

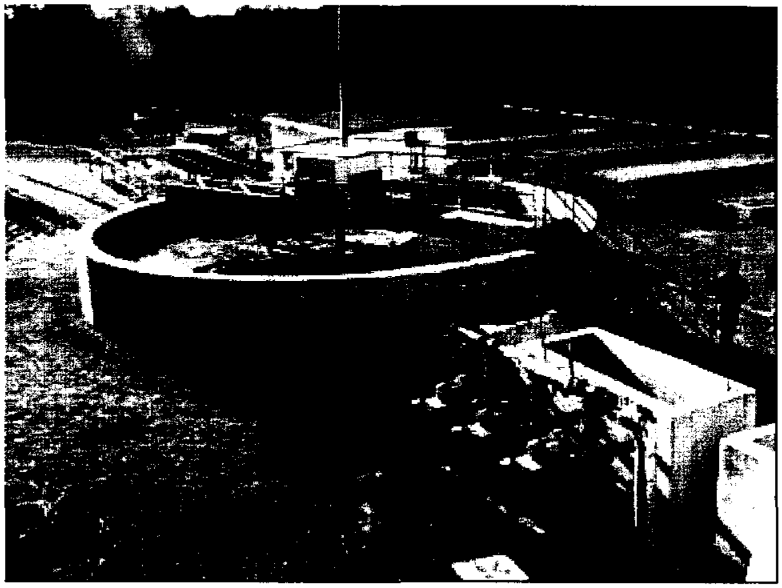

Figure A-15: South final clarifier, WAS/RAS pump station, and sludge drying beds (in background).

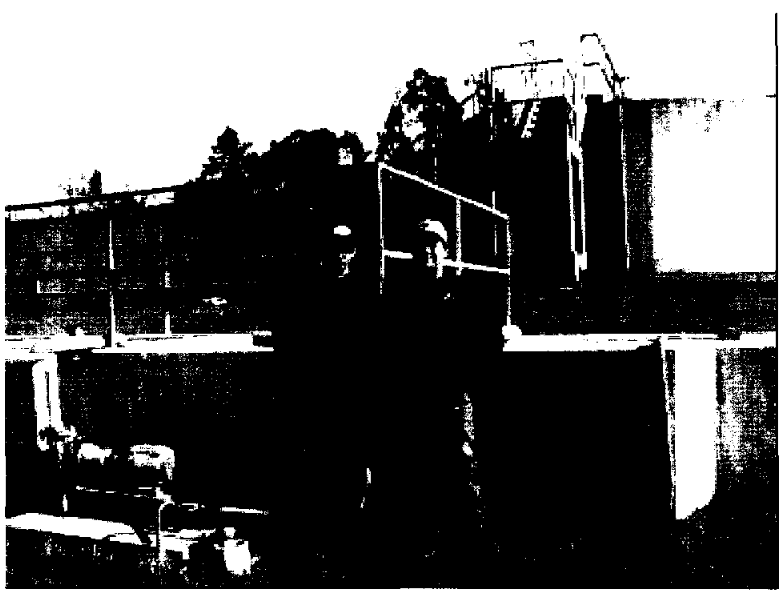

Figure A-16: Meridian WWTP Operators.

1.5 Stephenville WWTP

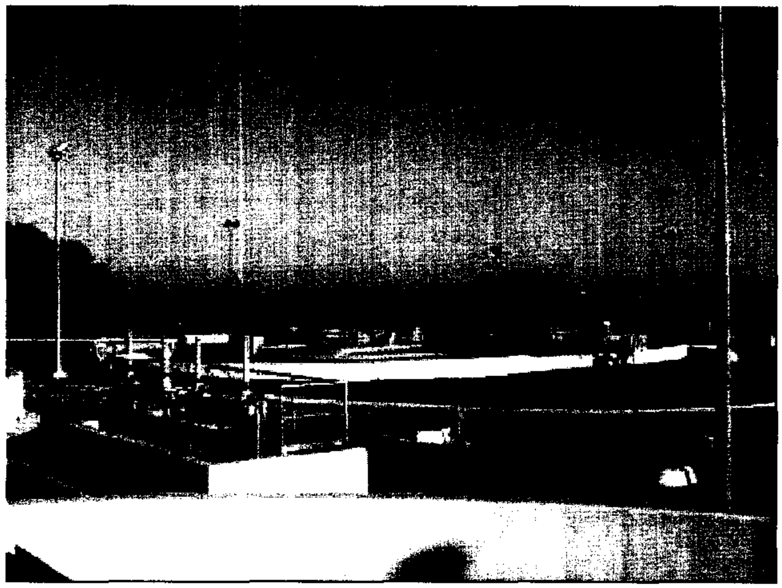

Figure A-18: One of three final clarifiers.

Figure A-17: Orbal System Aeration Basin and Aerobic Digester.

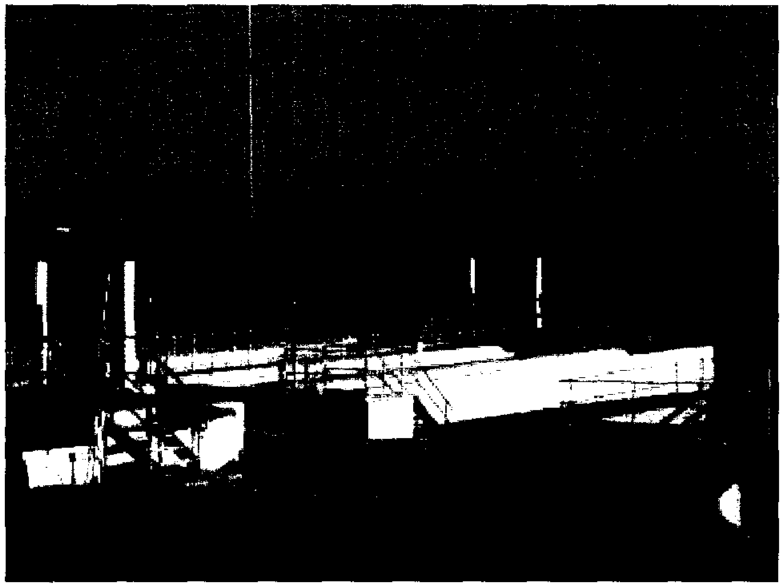

Figure A-19: Final effluent filter beds.

Figure A-20: One of three Stephenville WWTP Operators.

1.6 Valley Mills WWTP

Figure A-21: Influent manual bar screen and grit chamber.

Figure A-22: Oxidation ditch with single rotor brush aerator.

Figure A-23: Existing sludge drying beds.

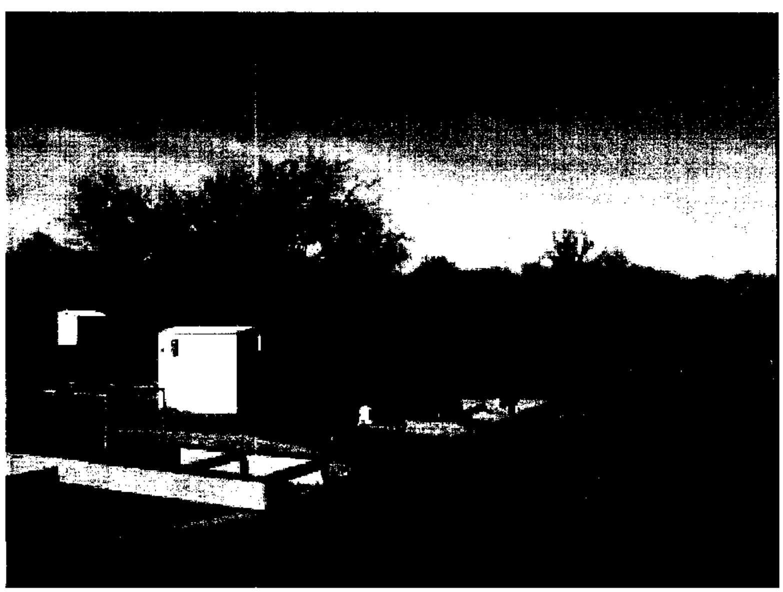

Figure A-24: Final clarifier, chlorine contact basin, and abandoned oxidation ditch.

Appendix B

Appendix B: Wastewater Characterization
Brazos River Authority
North Bosque River Phosphorous Removal Study

CDM Camp Dresser & McKee Inc. — Table B-1a

Brazos River Authority — **Clifton WWTP**

North Bosque River Phosphorus Removal — **Effluent BOD Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Clifton WWTP	COC	Jan-99	BOD (mg/l) Daily Ave.	NR
Clifton WWTP	COC	Feb-99	BOD (mg/l) Daily Ave.	NR
Clifton WWTP	COC	Mar-99	BOD (mg/l) Daily Ave.	NR
Clifton WWTP	COC	Apr-99	BOD (mg/l) Daily Ave.	NR
Clifton WWTP	COC	May-99	BOD (mg/l) Daily Ave.	NR
Clifton WWTP	COC	Jun-99	BOD (mg/l) Daily Ave.	NR
Clifton WWTP	COC	Jul-99	BOD (mg/l) Daily Ave.	NR
Clifton WWTP	COC	Aug-99	BOD (mg/l) Daily Ave.	NR
Clifton WWTP	COC	Sep-99	BOD (mg/l) Daily Ave.	8.80
Clifton WWTP	COC	Oct-99	BOD (mg/l) Daily Ave.	9.92
Clifton WWTP	COC	Nov-99	BOD (mg/l) Daily Ave.	5.34
Clifton WWTP	COC	Dec-99	BOD (mg/l) Daily Ave.	4.25
Clifton WWTP	COC	Jan-00	BOD (mg/l) Daily Ave.	4.10
Clifton WWTP	COC	Feb-00	BOD (mg/l) Daily Ave.	3.68
Clifton WWTP	COC	Mar-00	BOD (mg/l) Daily Ave.	3.68
Clifton WWTP	COC	Apr-00	BOD (mg/l) Daily Ave.	6.00
Clifton WWTP	COC	May-00	BOD (mg/l) Daily Ave.	5.40
Clifton WWTP	COC	Jun-00	BOD (mg/l) Daily Ave.	3.25
Clifton WWTP	COC	Jul-00	BOD (mg/l) Daily Ave.	5.75
Clifton WWTP	COC	Aug-00	BOD (mg/l) Daily Ave.	5.60
Clifton WWTP	COC	Sep-00	BOD (mg/l) Daily Ave.	5.00
Clifton WWTP	COC	Oct-00	BOD (mg/l) Daily Ave.	3.80
Clifton WWTP	COC	Nov-00	BOD (mg/l) Daily Ave.	NR
Clifton WWTP	COC	Dec-00	BOD (mg/l) Daily Ave.	NR

COC = City of Clifton
NR = No Record

CDM Camp Dresser & McKee Inc. — **Table B-1b**

Brazos River Authority — **Clifton WWTP**

North Bosque River Phosphorus Removal — **Effluent TSS Data**

Site Location	Collecting Agency	Date	Parameter Description	<	Value
Clifton WWTP	COC	01/1999	Total Suspended Solids (mg/L)		NR
Clifton WWTP	BRA	01/[illegible]/1999	Total Suspended Solids (mg/L)	<	4
Clifton WWTP	TIAER	01/11/1999	Total Suspended Solids (mg/L)	<	6
Clifton WWTP	COC	02/1999	Total Suspended Solids (mg/L)		NR
Clifton WWTP	TIAER	02/09/1999	Total Suspended Solids (mg/L)	<	6
Clifton WWTP	COC	03/1999	Total Suspended Solids (mg/L)		NR
Clifton WWTP	BRA	03/01/1999	Total Suspended Solids (mg/L)		4
Clifton WWTP	TIAER	03/09/1999	Total Suspended Solids (mg/L)	<	6
Clifton WWTP	COC	04/1999	Total Suspended Solids (mg/L)		NR
Clifton WWTP	TIAER	04/06/1999	Total Suspended Solids (mg/L)	<	6
Clifton WWTP	COC	05/1999	Total Suspended Solids (mg/L)		NR
Clifton WWTP	TIAER	05/04/1999	Total Suspended Solids (mg/L)		NR
Clifton WWTP	BRA	05/05/1999	Total Suspended Solids (mg/L)		6
Clifton WWTP	TIAER	05/27/1999	Total Suspended Solids (mg/L)		21
Clifton WWTP	COC	06/1999	Total Suspended Solids (mg/L)		NR
Clifton WWTP	BRA	06/03/1999	Total Suspended Solids (mg/L)		61
Clifton WWTP	TIAER	06/15/1999	Total Suspended Solids (mg/L)		6
Clifton WWTP	COC	07/1999	Total Suspended Solids (mg/L)		NR
Clifton WWTP	BRA	07/06/1999	Total Suspended Solids (mg/L)		71
Clifton WWTP	COC	08/1999	Total Suspended Solids (mg/L)		NR
Clifton WWTP	BRA	08/02/1999	Total Suspended Solids (mg/L)		13
Clifton WWTP	TIAER	08/23/1999	Total Suspended Solids (mg/L)		26
Clifton WWTP	COC	09/1999	Total Suspended Solids (mg/L)		17.3
Clifton WWTP	TIAER	09/20/1999	Total Suspended Solids (mg/L)		8
Clifton WWTP	COC	10/1999	Total Suspended Solids (mg/L)		9
Clifton WWTP	TIAER	10/18/1999	Total Suspended Solids (mg/L)		55
Clifton WWTP	COC	11/1999	Total Suspended Solids (mg/L)		6.2
Clifton WWTP	TIAER	11/15/1999	Total Suspended Solids (mg/L)		4
Clifton WWTP	COC	12/1999	Total Suspended Solids (mg/L)		3.2
Clifton WWTP	TIAER	12/13/1999	Total Suspended Solids (mg/L)	<	6
Clifton WWTP	COC	01/2000	Total Suspended Solids (mg/L)		5.8
Clifton WWTP	TIAER	01/10/2000	Total Suspended Solids (mg/L)		6
Clifton WWTP	COC	02/2000	Total Suspended Solids (mg/L)		2.32
Clifton WWTP	TIAER	02/08/2000	Total Suspended Solids (mg/L)		6
Clifton WWTP	COC	03/2000	Total Suspended Solids (mg/L)		6.6
Clifton WWTP	TIAER	03/06/2000	Total Suspended Solids (mg/L)	<	6
Clifton WWTP	COC	04/2000	Total Suspended Solids (mg/L)		6.73
Clifton WWTP	TIAER	04/03/2000	Total Suspended Solids (mg/L)	<	6
Clifton WWTP	COC	05/2000	Total Suspended Solids (mg/L)		8.3
Clifton WWTP	TIAER	05/01/2000	Total Suspended Solids (mg/L)		13
Clifton WWTP	COC	06/2000	Total Suspended Solids (mg/L)		5.25
Clifton WWTP	COC	07/2000	Total Suspended Solids (mg/L)		8.4
Clifton WWTP	COC	08/2000	Total Suspended Solids (mg/L)		8.84
Clifton WWTP	COC	09/2000	Total Suspended Solids (mg/L)		4.125
Clifton WWTP	COC	10/2000	Total Suspended Solids (mg/L)		7.16

COC = City of Clifton
TIAER = Texas Institute for Applied Environmental Research
NR = No Record

CDM Camp Dresser & McKee Inc.				**Table B-1c**
Brazos River Authority				**Clifton WWTP**
North Bosque River Phosphorus Removal				**Effluent NH3 Data**
Site Location	Collecting Agency	Date	Parameter Description	Value
Clifton WWTP	TIAER	01/11/1999	Ammonia-nitrogen (mg/L)	0.11
Clifton WWTP	TIAER	02/08/1999	Ammonia-nitrogen (mg/L)	1.34
Clifton WWTP	TIAER	03/09/1999	Ammonia-nitrogen (mg/L)	0.48
Clifton WWTP	TIAER	04/05/1999	Ammonia-nitrogen (mg/L)	1.35
Clifton WWTP	TIAER	05/17/1999	Ammonia-nitrogen (mg/L)	9.18
Clifton WWTP	TIAER	06/15/1999	Ammonia-nitrogen (mg/L)	21.10
Clifton WWTP	TIAER	08/23/1999	Ammonia-nitrogen (mg/L)	32.60
Clifton WWTP	TIAER	09/20/1999	Ammonia-nitrogen (mg/L)	22.90
Clifton WWTP	TIAER	10/18/1999	Ammonia-nitrogen (mg/L)	20.40
Clifton WWTP	TIAER	11/15/1999	Ammonia-nitrogen (mg/L)	17.70
Clifton WWTP	TIAER	12/13/1999	Ammonia-nitrogen (mg/L)	1.66
Clifton WWTP	TIAER	01/10/2000	Ammonia-nitrogen (mg/L)	0.96
Clifton WWTP	TIAER	02/08/2000	Ammonia-nitrogen (mg/L)	3.72
Clifton WWTP	TIAER	03/06/2000	Ammonia-nitrogen (mg/L)	13.40
Clifton WWTP	TIAER	04/03/2000	Ammonia-nitrogen (mg/L)	13.30
Clifton WWTP	TIAER	05/01/2000	Ammonia-nitrogen (mg/L)	14.60

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — **Table B-1d**

Brazos River Authority — **Clifton WWTP**

North Bosque River Phosphorus Removal — **Effluent PO4 Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Clifton WWTP	BRA	01/04/1999	Orthophosphate Phosphorus (mg/L)	1.40
Clifton WWTP	TIAER	01/11/1999	Orthophosphate Phosphorus (mg/L)	1.20
Clifton WWTP	TIAER	02/09/1999	Orthophosphate Phosphorus (mg/L)	2.19
Clifton WWTP	BRA	03/01/1999	Orthophosphate Phosphorus (mg/L)	1.14
Clifton WWTP	TIAER	03/09/1999	Orthophosphate Phosphorus (mg/L)	0.98
Clifton WWTP	TIAER	04/06/1999	Orthophosphate Phosphorus (mg/L)	0.59
Clifton WWTP	BRA	05/05/1999	Orthophosphate Phosphorus (mg/L)	0.64
Clifton WWTP	TIAER	05/17/1999	Orthophosphate Phosphorus (mg/L)	1.01
Clifton WWTP	BRA	06/03/1999	Orthophosphate Phosphorus (mg/L)	2.67
Clifton WWTP	TIAER	06/15/1999	Orthophosphate Phosphorus (mg/L)	0.73
Clifton WWTP	BRA	07/06/1999	Orthophosphate Phosphorus (mg/L)	2.06
Clifton WWTP	BRA	08/02/1999	Orthophosphate Phosphorus (mg/L)	2.61
Clifton WWTP	TIAER	08/23/1999	Orthophosphate Phosphorus (mg/L)	6.08
Clifton WWTP	TIAER	09/20/1999	Orthophosphate Phosphorus (mg/L)	3.25
Clifton WWTP	TIAER	10/18/1999	Orthophosphate Phosphorus (mg/L)	1.86
Clifton WWTP	TIAER	11/15/1999	Orthophosphate Phosphorus (mg/L)	2.09
Clifton WWTP	TIAER	12/13/1999	Orthophosphate Phosphorus (mg/L)	0.62
Clifton WWTP	TIAER	01/10/2000	Orthophosphate Phosphorus (mg/L)	0.30
Clifton WWTP	TIAER	02/08/2000	Orthophosphate Phosphorus (mg/L)	0.56
Clifton WWTP	TIAER	03/06/2000	Orthophosphate Phosphorus (mg/L)	0.47
Clifton WWTP	TIAER	04/03/2000	Orthophosphate Phosphorus (mg/L)	0.23
Clifton WWTP	TIAER	05/01/2000	Orthophosphate Phosphorus (mg/L)	1.95

BRA = Brazos River Authority
TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — Table B-1e

Brazos River Authority — **Clifton WWTP**

North Bosque River Phosphorus Removal — **Effluent TP Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Clifton WWTP	TIAER	01/11/1999	Total Phosphorus (mg/L)	1.22
Clifton WWTP	TIAER	02/09/1999	Total Phosphorus (mg/L)	2.52
Clifton WWTP	TIAER	03/09/1999	Total Phosphorus (mg/L)	1.30
Clifton WWTP	TIAER	04/06/1999	Total Phosphorus (mg/L)	0.79
Clifton WWTP	TIAER	05/17/1999	Total Phosphorus (mg/L)	1.41
Clifton WWTP	TIAER	06/15/1999	Total Phosphorus (mg/L)	1.00
Clifton WWTP	TIAER	08/23/1999	Total Phosphorus (mg/L)	6.37
Clifton WWTP	TIAER	09/20/1999	Total Phosphorus (mg/L)	3.41
Clifton WWTP	TIAER	10/18/1999	Total Phosphorus (mg/L)	2.82
Clifton WWTP	TIAER	11/16/1999	Total Phosphorus (mg/L)	2.30
Clifton WWTP	TIAER	12/13/1999	Total Phosphorus (mg/L)	0.85
Clifton WWTP	TIAER	01/10/2000	Total Phosphorus (mg/L)	0.65
Clifton WWTP	TIAER	02/08/2000	Total Phosphorus (mg/L)	0.78
Clifton WWTP	TIAER	03/06/2000	Total Phosphorus (mg/L)	0.44
Clifton WWTP	TIAER	04/03/2000	Total Phosphorus (mg/L)	0.32
Clifton WWTP	TIAER	05/01/2000	Total Phosphorus (mg/L)	2.41

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — **Table B-2a**

Brazos River Authority — **Hico WWTP**

North Bosque River Phosphorus Removal — **Effluent BOD Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Hico WWTP	COH	Jan-99	BOD (mg/l) Daily Ave.	NR
Hico WWTP	COH	Feb-99	BOD (mg/l) Daily Ave.	NR
Hico WWTP	COH	Mar-99	BOD (mg/l) Daily Ave.	NR
Hico WWTP	COH	Apr-99	BOD (mg/l) Daily Ave.	NR
Hico WWTP	COH	May-99	BOD (mg/l) Daily Ave.	NR
Hico WWTP	COH	Jun-99	BOD (mg/l) Daily Ave.	NR
Hico WWTP	COH	Jul-99	BOD (mg/l) Daily Ave.	NR
Hico WWTP	COH	Aug-99	BOD (mg/l) Daily Ave.	NR
Hico WWTP	COH	Sep-99	BOD (mg/l) Daily Ave.	2.10
Hico WWTP	COH	Oct-99	BOD (mg/l) Daily Ave.	2.10
Hico WWTP	COH	Nov-99	BOD (mg/l) Daily Ave.	5.80
Hico WWTP	COH	Dec-99	BOD (mg/l) Daily Ave.	4.60
Hico WWTP	COH	Jan-00	BOD (mg/l) Daily Ave.	3.10
Hico WWTP	COH	Feb-00	BOD (mg/l) Daily Ave.	4.40
Hico WWTP	COH	Mar-00	BOD (mg/l) Daily Ave.	2.90
Hico WWTP	COH	Apr-00	BOD (mg/l) Daily Ave.	2.70
Hico WWTP	COH	May-00	BOD (mg/l) Daily Ave.	2.10
Hico WWTP	COH	Jun-00	BOD (mg/l) Daily Ave.	2.00
Hico WWTP	COH	Jul-00	BOD (mg/l) Daily Ave.	NR
Hico WWTP	COH	Aug-00	BOD (mg/l) Daily Ave.	2.00
Hico WWTP	COH	Sep-00	BOD (mg/l) Daily Ave.	2.10
Hico WWTP	COH	Oct-00	BOD (mg/l) Daily Ave.	2.20
Hico WWTP	COH	Nov-00	BOD (mg/l) Daily Ave.	NR
Hico WWTP	COH	Dec-00	BOD (mg/l) Daily Ave.	NR

COH = City of Hico
NR = No Record

CDM Camp Dresser & McKee Inc. — **Table B-2b**

Brazos River Authority — **Hico WWTP**

North Bosque River Phosphorus Removal — **Effluent TSS Data**

Site Location	Collecting Agency	Date	Parameter Description	<	Value
Hico WWTP	COH	01/1999	Total Suspended Solids (mg/L)		NR
Hico WWTP	BRA	01/04/1999	Total Suspended Solids (mg/L)		6
Hico WWTP	TIAER	01/11/1999	Total Suspended Solids (mg/L)	<	6
Hico WWTP	COH	02/1999	Total Suspended Solids (mg/L)		NR
Hico WWTP	TIAER	02/09/1999	Total Suspended Solids (mg/L)	<	6
Hico WWTP	COH	03/1999	Total Suspended Solids (mg/L)		NR
Hico WWTP	TIAER	03/09/1999	Total Suspended Solids (mg/L)	<	6
Hico WWTP	COH	04/1999	Total Suspended Solids (mg/L)		NR
Hico WWTP	BRA	04/05/1999	Total Suspended Solids (mg/L)		8
Hico WWTP	TIAER	04/06/1999	Total Suspended Solids (mg/L)		9
Hico WWTP	COH	05/1999	Total Suspended Solids (mg/L)		NR
Hico WWTP	BRA	05/05/1999	Total Suspended Solids (mg/L)	<	4
Hico WWTP	TIAER	05/17/1999	Total Suspended Solids (mg/L)	<	6
Hico WWTP	COH	06/1999	Total Suspended Solids (mg/L)		NR
Hico WWTP	BRA	06/03/1999	Total Suspended Solids (mg/L)	<	4
Hico WWTP	TIAER	06/15/1999	Total Suspended Solids (mg/L)	<	4
Hico WWTP	COH	07/1999	Total Suspended Solids (mg/L)		NR
Hico WWTP	BRA	07/06/1999	Total Suspended Solids (mg/L)	<	4
Hico WWTP	TIAER	07/26/1999	Total Suspended Solids (mg/L)	<	4
Hico WWTP	COH	08/1999	Total Suspended Solids (mg/L)		NR
Hico WWTP	BRA	08/02/1999	Total Suspended Solids (mg/L)		6
Hico WWTP	TIAER	08/23/1999	Total Suspended Solids (mg/L)	<	4
Hico WWTP	COH	09/1999	Total Suspended Solids (mg/L)		4.2
Hico WWTP	TIAER	09/20/1999	Total Suspended Solids (mg/L)	<	4
Hico WWTP	COH	10/1999	Total Suspended Solids (mg/L)		7.2
Hico WWTP	TIAER	10/18/1999	Total Suspended Solids (mg/L)		12
Hico WWTP	COH	11/1999	Total Suspended Solids (mg/L)		13
Hico WWTP	TIAER	11/15/1999	Total Suspended Solids (mg/L)		8
Hico WWTP	COH	12/1999	Total Suspended Solids (mg/L)		14
Hico WWTP	TIAER	12/13/1999	Total Suspended Solids (mg/L)		24
Hico WWTP	COH	01/2000	Total Suspended Solids (mg/L)		7.1
Hico WWTP	TIAER	01/10/2000	Total Suspended Solids (mg/L)	<	6
Hico WWTP	COH	02/2000	Total Suspended Solids (mg/L)		8.5
Hico WWTP	TIAER	02/08/2000	Total Suspended Solids (mg/L)		10
Hico WWTP	COH	03/2000	Total Suspended Solids (mg/L)		4.9
Hico WWTP	TIAER	03/06/2000	Total Suspended Solids (mg/L)		6
Hico WWTP	COH	04/2000	Total Suspended Solids (mg/L)		7.2
Hico WWTP	TIAER	04/03/2000	Total Suspended Solids (mg/L)	<	6
Hico WWTP	COH	05/2000	Total Suspended Solids (mg/L)		10
Hico WWTP	TIAER	05/01/2000	Total Suspended Solids (mg/L)		12
Hico WWTP	COH	06/2000	Total Suspended Solids (mg/L)		8.8
Hico WWTP	COH	07/2000	Total Suspended Solids (mg/L)		NR
Hico WWTP	COH	08/2000	Total Suspended Solids (mg/L)		4.4
Hico WWTP	COH	09/2000	Total Suspended Solids (mg/L)		7.9
Hico WWTP	COH	10/2000	Total Suspended Solids (mg/L)		8.3

BRA = Brazos River Authority

COH = City of Hico

TIAER = Texas Institute for Applied Environmental Research

NR = No Record

CDM Camp Dresser & McKee Inc. — **Table B-2c**

Brazos River Authority — **Hico WWTP**

North Bosque River Phosphorus Removal — **Effluent NH3 Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Hico WWTP	TIAER	01/11/1999	Ammonia-nitrogen (mg/L)	0.88
Hico WWTP	TIAER	02/09/1999	Ammonia-nitrogen (mg/L)	0.04
Hico WWTP	TIAER	03/09/1999	Ammonia-nitrogen (mg/L)	0.16
Hico WWTP	TIAER	04/06/1999	Ammonia-nitrogen (mg/L)	0.03
Hico WWTP	TIAER	05/17/1999	Ammonia-nitrogen (mg/L)	0.03
Hico WWTP	TIAER	06/15/1999	Ammonia-nitrogen (mg/L)	0.02
Hico WWTP	TIAER	07/26/1999	Ammonia-nitrogen (mg/L)	0.10
Hico WWTP	TIAER	08/23/1999	Ammonia-nitrogen (mg/L)	0.12
Hico WWTP	TIAER	09/20/1999	Ammonia-nitrogen (mg/L)	0.04
Hico WWTP	TIAER	10/18/1999	Ammonia-nitrogen (mg/L)	0.06
Hico WWTP	TIAER	11/15/1999	Ammonia-nitrogen (mg/L)	0.10
Hico WWTP	TIAER	12/13/1999	Ammonia-nitrogen (mg/L)	0.04
Hico WWTP	TIAER	01/10/2000	Ammonia-nitrogen (mg/L)	0.04
Hico WWTP	TIAER	02/08/2000	Ammonia-nitrogen (mg/L)	0.06
Hico WWTP	TIAER	03/06/2000	Ammonia-nitrogen (mg/L)	0.40
Hico WWTP	TIAER	04/03/2000	Ammonia-nitrogen (mg/L)	0.07
Hico WWTP	TIAER	05/01/2000	Ammonia-nitrogen (mg/L)	0.04

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc.				**Table B-2d**
Brazos River Authority				**Hico WWTP**
North Bosque River Phosphorus Removal				**Effluent PO4 Data**
Site Location	Collecting Agency	Date	Parameter Description	Value
Hico WWTP	BRA	01/04/1999	Orthophosphate Phosphorus (mg/L)	2.46
Hico WWTP	TIAER	01/11/1999	Orthophosphate Phosphorus (mg/L)	2.95
Hico WWTP	TIAER	02/09/1999	Orthophosphate Phosphorus (mg/L)	4.26
Hico WWTP	TIAER	03/09/1999	Orthophosphate Phosphorus (mg/L)	3.6
Hico WWTP	BRA	04/05/1999	Orthophosphate Phosphorus (mg/L)	3.80
Hico WWTP	TIAER	04/06/1999	Orthophosphate Phosphorus (mg/L)	3.69
Hico WWTP	BRA	05/05/1999	Orthophosphate Phosphorus (mg/L)	4.06
Hico WWTP	TIAER	05/17/1999	Orthophosphate Phosphorus (mg/L)	4.13
Hico WWTP	BRA	06/03/1999	Orthophosphate Phosphorus (mg/L)	3.29
Hico WWTP	TIAER	06/15/1999	Orthophosphate Phosphorus (mg/L)	3.12
Hico WWTP	BRA	07/06/1999	Orthophosphate Phosphorus (mg/L)	3.38
Hico WWTP	TIAER	07/26/1999	Orthophosphate Phosphorus (mg/L)	3.94
Hico WWTP	BRA	08/02/1999	Orthophosphate Phosphorus (mg/L)	4.55
Hico WWTP	TIAER	08/23/1999	Orthophosphate Phosphorus (mg/L)	4.4
Hico WWTP	TIAER	09/20/1999	Orthophosphate Phosphorus (mg/L)	3.5
Hico WWTP	TIAER	10/18/1999	Orthophosphate Phosphorus (mg/L)	2.76
Hico WWTP	TIAER	11/15/1999	Orthophosphate Phosphorus (mg/L)	4.09
Hico WWTP	TIAER	12/13/1999	Orthophosphate Phosphorus (mg/L)	3.46
Hico WWTP	TIAER	01/10/2000	Orthophosphate Phosphorus (mg/L)	2.98
Hico WWTP	TIAER	02/08/2000	Orthophosphate Phosphorus (mg/L)	4.04
Hico WWTP	TIAER	03/06/2000	Orthophosphate Phosphorus (mg/L)	4.17
Hico WWTP	TIAER	04/03/2000	Orthophosphate Phosphorus (mg/L)	3.75
Hico WWTP	TIAER	05/01/2000	Orthophosphate Phosphorus (mg/L)	3.91

BRA = Brazos River Authority
TIAER = Texas Institute for Applied Environmental Research
NR = No Record

CDM Camp Dresser & McKee Inc. — **Table B-2e**

Brazos River Authority — **Hico WWTP**

North Bosque River Phosphorus Removal — **Effluent TP Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Hico WWTP	TIAER	01/11/1999	Total Phosphorus (mg/L)	3.29
Hico WWTP	TIAER	02/09/1999	Total Phosphorus (mg/L)	4.3
Hico WWTP	TIAER	03/09/1999	Total Phosphorus (mg/L)	4.18
Hico WWTP	TIAER	04/06/1999	Total Phosphorus (mg/L)	3.61
Hico WWTP	TIAER	05/17/1999	Total Phosphorus (mg/L)	4.85
Hico WWTP	TIAER	06/15/1999	Total Phosphorus (mg/L)	3.49
Hico WWTP	TIAER	07/26/1999	Total Phosphorus (mg/L)	4.1
Hico WWTP	TIAER	08/23/1999	Total Phosphorus (mg/L)	4.23
Hico WWTP	TIAER	09/20/1999	Total Phosphorus (mg/L)	3.7
Hico WWTP	TIAER	10/18/1999	Total Phosphorus (mg/L)	4.17
Hico WWTP	TIAER	11/15/1999	Total Phosphorus (mg/L)	4.41
Hico WWTP	TIAER	12/13/1999	Total Phosphorus (mg/L)	4.03
Hico WWTP	TIAER	01/10/2000	Total Phosphorus (mg/L)	3.79
Hico WWTP	TIAER	02/08/2000	Total Phosphorus (mg/L)	4.59
Hico WWTP	TIAER	03/06/2000	Total Phosphorus (mg/L)	4.51
Hico WWTP	TIAER	04/03/2000	Total Phosphorus (mg/L)	4.3
Hico WWTP	TIAER	05/01/2000	Total Phosphorus (mg/L)	4.13

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. | Table B-3a

Brazos River Authority | **Iredell WWTP**

North Bosque River Phosphorus Removal | **Effluent BOD Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Iredell WWTP	COI	Jan-99	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	Feb-99	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	Mar-99	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	Apr-99	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	May-99	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	Jun-99	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	Jul-99	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	Aug-99	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	Sep-99	BOD (mg/l) Daily Ave.	7.25
Iredell WWTP	COI	Oct-99	BOD (mg/l) Daily Ave.	8.25
Iredell WWTP	COI	Nov-99	BOD (mg/l) Daily Ave.	3.40
Iredell WWTP	COI	Dec-99	BOD (mg/l) Daily Ave.	1.75
Iredell WWTP	COI	Jan-00	BOD (mg/l) Daily Ave.	2.33
Iredell WWTP	COI	Feb-00	BOD (mg/l) Daily Ave.	1.60
Iredell WWTP	COI	Mar-00	BOD (mg/l) Daily Ave.	2.20
Iredell WWTP	COI	Apr-00	BOD (mg/l) Daily Ave.	2.72
Iredell WWTP	COI	May-00	BOD (mg/l) Daily Ave.	2.90
Iredell WWTP	COI	Jun-00	BOD (mg/l) Daily Ave.	2.50
Iredell WWTP	COI	Jul-00	BOD (mg/l) Daily Ave.	1.75
Iredell WWTP	COI	Aug-00	BOD (mg/l) Daily Ave.	2.00
Iredell WWTP	COI	Sep-00	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	Oct-00	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	Nov-00	BOD (mg/l) Daily Ave.	NR
Iredell WWTP	COI	Dec-00	BOD (mg/l) Daily Ave.	NR

COI = City of Iredell

NR = No Record

CDM Camp Dresser & McKee Inc. — **Table B-3c**

Brazos River Authority — **Iredell WWTP**

North Bosque River Phosphorus Removal — **Effluent NH3 Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Iredell WWTP	TIAER	01/11/1999	Ammonia-nitrogen (mg/L)	3.54
Iredell WWTP	TIAER	02/09/1999	Ammonia-nitrogen (mg/L)	0.12
Iredell WWTP	TIAER	03/09/1999	Ammonia-nitrogen (mg/L)	15.80
Iredell WWTP	TIAER	04/06/1999	Ammonia-nitrogen (mg/L)	7.38
Iredell WWTP	TIAER	05/17/1999	Ammonia-nitrogen (mg/L)	0.01
Iredell WWTP	TIAER	06/15/1999	Ammonia-nitrogen (mg/L)	0.02
Iredell WWTP	TIAER	07/26/1999	Ammonia-nitrogen (mg/L)	0.02
Iredell WWTP	TIAER	08/23/1999	Ammonia-nitrogen (mg/L)	3.52
Iredell WWTP	TIAER	09/20/1999	Ammonia-nitrogen (mg/L)	0.10
Iredell WWTP	TIAER	10/18/1999	Ammonia-nitrogen (mg/L)	0.18
Iredell WWTP	TIAER	11/15/1999	Ammonia-nitrogen (mg/L)	0.54
Iredell WWTP	TIAER	12/13/1999	Ammonia-nitrogen (mg/L)	7.33
Iredell WWTP	TIAER	01/10/2000	Ammonia-nitrogen (mg/L)	0.84
Iredell WWTP	TIAER	02/08/2000	Ammonia-nitrogen (mg/L)	0.02
Iredell WWTP	TIAER	03/06/2000	Ammonia-nitrogen (mg/L)	0.50
Iredell WWTP	TIAER	04/03/2000	Ammonia-nitrogen (mg/L)	0.54
Iredell WWTP	TIAER	05/01/2000	Ammonia-nitrogen (mg/L)	0.11

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc.				**Table B-3d**
Brazos River Authority				**Iredell WWTP**
North Bosque River Phosphorus Removal				**Effluent PO4 Data**
Site Location	Collecting Agency	Date	Parameter Description	Value
Iredell WWTP	BRA	01/04/1999	Orthophosphate Phosphorus (mg/L)	3.50
Iredell WWTP	TIAER	01/11/1999	Orthophosphate Phosphorus (mg/L)	2.66
Iredell WWTP	TIAER	02/09/1999	Orthophosphate Phosphorus (mg/L)	3.27
Iredell WWTP	TIAER	03/09/1999	Orthophosphate Phosphorus (mg/L)	3.71
Iredell WWTP	BRA	04/05/1999	Orthophosphate Phosphorus (mg/L)	3.64
Iredell WWTP	TIAER	04/06/1999	Orthophosphate Phosphorus (mg/L)	3.88
Iredell WWTP	BRA	05/05/1999	Orthophosphate Phosphorus (mg/L)	2.22
Iredell WWTP	TIAER	05/17/1999	Orthophosphate Phosphorus (mg/L)	2.67
Iredell WWTP	BRA	06/03/1999	Orthophosphate Phosphorus (mg/L)	1.14
Iredell WWTP	TIAER	06/15/1999	Orthophosphate Phosphorus (mg/L)	1.80
Iredell WWTP	BRA	07/06/1999	Orthophosphate Phosphorus (mg/L)	0.84
Iredell WWTP	TIAER	07/26/1999	Orthophosphate Phosphorus (mg/L)	2.70
Iredell WWTP	BRA	08/02/1999	Orthophosphate Phosphorus (mg/L)	3.38
Iredell WWTP	TIAER	08/23/1999	Orthophosphate Phosphorus (mg/L)	2.26
Iredell WWTP	TIAER	09/20/1999	Orthophosphate Phosphorus (mg/L)	1.78
Iredell WWTP	TIAER	10/18/1999	Orthophosphate Phosphorus (mg/L)	1.65
Iredell WWTP	TIAER	11/15/1999	Orthophosphate Phosphorus (mg/L)	2.01
Iredell WWTP	TIAER	12/13/1999	Orthophosphate Phosphorus (mg/L)	3.47
Iredell WWTP	TIAER	01/10/2000	Orthophosphate Phosphorus (mg/L)	3.56
Iredell WWTP	TIAER	02/08/2000	Orthophosphate Phosphorus (mg/L)	1.71
Iredell WWTP	TIAER	03/06/2000	Orthophosphate Phosphorus (mg/L)	2.58
Iredell WWTP	TIAER	04/03/2000	Orthophosphate Phosphorus (mg/L)	2.47
Iredell WWTP	TIAER	05/01/2000	Orthophosphate Phosphorus (mg/L)	3.64

BRA = Brazos River Authority
TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — **Table B-3e**

Brazos River Authority — **Iredell WWTP**

North Bosque River Phosphorus Removal — **Effluent TP Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Iredell WWTP	TIAER	01/11/1999	Total Phosphorus (mg/L)	3.17
Iredell WWTP	TIAER	02/09/1999	Total Phosphorus (mg/L)	3.51
Iredell WWTP	TIAER	03/09/1999	Total Phosphorus (mg/L)	4.77
Iredell WWTP	TIAER	04/06/1999	Total Phosphorus (mg/L)	4.43
Iredell WWTP	TIAER	05/17/1999	Total Phosphorus (mg/L)	2.73
Iredell WWTP	TIAER	06/15/1999	Total Phosphorus (mg/L)	2.17
Iredell WWTP	TIAER	07/26/1999	Total Phosphorus (mg/L)	2.94
Iredell WWTP	TIAER	08/23/1999	Total Phosphorus (mg/L)	2.43
Iredell WWTP	TIAER	09/20/1999	Total Phosphorus (mg/L)	2.82
Iredell WWTP	TIAER	10/18/1999	Total Phosphorus (mg/L)	2.09
Iredell WWTP	TIAER	11/15/1999	Total Phosphorus (mg/L)	2.49
Iredell WWTP	TIAER	12/13/1999	Total Phosphorus (mg/L)	8.62
Iredell WWTP	TIAER	01/10/2000	Total Phosphorus (mg/L)	5.11
Iredell WWTP	TIAER	02/08/2000	Total Phosphorus (mg/L)	1.84
Iredell WWTP	TIAER	03/06/2000	Total Phosphorus (mg/L)	3.38
Iredell WWTP	TIAER	04/03/2000	Total Phosphorus (mg/L)	3.33
Iredell WWTP	TIAER	05/01/2000	Total Phosphorus (mg/L)	3.62

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc.				**Table B-4a**
Brazos River Authority				**Meridian WWTP**
North Bosque River Phosphorus Removal				**Effluent BOD Data**
Site Location	Collecting Agency	Date	Parameter Description	Value
Meridian WWTP	COM	Jan-99	BOD (mg/l) Daily Ave.	3.00
Meridian WWTP	COM	Feb-99	BOD (mg/l) Daily Ave.	NR
Meridian WWTP	COM	Mar-99	BOD (mg/l) Daily Ave.	3.80
Meridian WWTP	COM	Apr-99	BOD (mg/l) Daily Ave.	3.50
Meridian WWTP	COM	May-99	BOD (mg/l) Daily Ave.	3.00
Meridian WWTP	COM	Jun-99	BOD (mg/l) Daily Ave.	2.00
Meridian WWTP	COM	Jul-99	BOD (mg/l) Daily Ave.	2.20
Meridian WWTP	COM	Aug-99	BOD (mg/l) Daily Ave.	2.25
Meridian WWTP	COM	Sep-99	BOD (mg/l) Daily Ave.	3.75
Meridian WWTP	COM	Oct-99	BOD (mg/l) Daily Ave.	2.75
Meridian WWTP	COM	Nov-99	BOD (mg/l) Daily Ave.	2.40
Meridian WWTP	COM	Dec-99	BOD (mg/l) Daily Ave.	NR
Meridian WWTP	COM	Jan-00	BOD (mg/l) Daily Ave.	NR
Meridian WWTP	COM	Feb-00	BOD (mg/l) Daily Ave.	NR
Meridian WWTP	COM	Mar-00	BOD (mg/l) Daily Ave.	5.00
Meridian WWTP	COM	Apr-00	BOD (mg/l) Daily Ave.	2.00
Meridian WWTP	COM	May-00	BOD (mg/l) Daily Ave.	3.00
Meridian WWTP	COM	Jun-00	BOD (mg/l) Daily Ave.	3.00
Meridian WWTP	COM	Jul-00	BOD (mg/l) Daily Ave.	NR
Meridian WWTP	COM	Aug-00	BOD (mg/l) Daily Ave.	2.20
Meridian WWTP	COM	Sep-00	BOD (mg/l) Daily Ave.	NR
Meridian WWTP	COM	Oct-00	BOD (mg/l) Daily Ave.	NR
Meridian WWTP	COM	Nov-00	BOD (mg/l) Daily Ave.	NR
Meridian WWTP	COM	Dec-00	BOD (mg/l) Daily Ave.	NR

COM = City of Meridian
NR = No Record

CDM Camp Dresser & McKee Inc.

Brazos River Authority

North Bosque River Phosphorus Removal

Table B-4b

Meridian WWTP

Effluent TSS Data

Site Location	Collecting Agency	Date	Parameter Description	<	Value
Meridian WWTP	COM	01/1999	Solids (mg/L)		3.75
Meridian WWTP	BRA	01/04/1999	Solids (mg/L)		7
Meridian WWTP	TIAER	01/11/1999	Solids (mg/L)		10
Meridian WWTP	COM	02/1999	Solids (mg/L)		NR
Meridian WWTP	COM	03/1999	Solids (mg/L)		7.2
Meridian WWTP	TIAER	03/09/1999	Solids (mg/L)		8
Meridian WWTP	COM	04/1999	Solids (mg/L)		12.25
Meridian WWTP	BRA	04/05/1999	Solids (mg/L)		18
Meridian WWTP	TIAER	04/06/1999	Solids (mg/L)		23
Meridian WWTP	COM	05/1999	Solids (mg/L)		14.5
Meridian WWTP	BRA	05/05/1999	Solids (mg/L)		8
Meridian WWTP	TIAER	05/17/1999	Solids (mg/L)		32
Meridian WWTP	COM	06/1999	Solids (mg/L)		3.25
Meridian WWTP	BRA	06/03/1999	Solids (mg/L)		9
Meridian WWTP	TIAER	06/15/1999	Solids (mg/L)		10
Meridian WWTP	COM	07/1999	Solids (mg/L)		10.75
Meridian WWTP	BRA	07/06/1999	Solids (mg/L)		29
Meridian WWTP	TIAER	07/26/1999	Solids (mg/L)	<	4
Meridian WWTP	COM	08/1999	Solids (mg/L)		5.36
Meridian WWTP	BRA	08/02/1999	Solids (mg/L)		5
Meridian WWTP	TIAER	08/23/1999	Solids (mg/L)	<	4
Meridian WWTP	COM	09/1999	Solids (mg/L)		4
Meridian WWTP	TIAER	09/20/1999	Solids (mg/L)	<	4
Meridian WWTP	COM	10/1999	Solids (mg/L)		3.5
Meridian WWTP	TIAER	10/18/1999	Solids (mg/L)		5
Meridian WWTP	COM	11/1999	Solids (mg/L)		7.6
Meridian WWTP	TIAER	11/15/1999	Solids (mg/L)		9
Meridian WWTP	COM	12/1999	Solids (mg/L)		NR
Meridian WWTP	TIAER	12/13/1999	Solids (mg/L)		8
Meridian WWTP	COM	01/2000	Solids (mg/L)		NR
Meridian WWTP	TIAER	01/10/2000	Solids (mg/L)	<	6
Meridian WWTP	COM	02/2000	Solids (mg/L)		NR
Meridian WWTP	TIAER	02/08/2000	Solids (mg/L)		15
Meridian WWTP	COM	03/1999	Solids (mg/L)		5
Meridian WWTP	TIAER	03/06/2000	Solids (mg/L)		6
Meridian WWTP	COM	04/2000	Solids (mg/L)		10
Meridian WWTP	TIAER	04/03/2000	Solids (mg/L)		17
Meridian WWTP	COM	05/01/2000	Solids (mg/L)		8
Meridian WWTP	TIAER	05/01/2000	Solids (mg/L)		10
Meridian WWTP	COM	06/2000	Solids (mg/L)		6
Meridian WWTP	COM	08/2000	Solids (mg/L)		5

BRA = Brazos River Authority
COM = City of Meridian
TIAER = Texas Institute for Applied Environmental Research
NR = No Record

CDM Camp Dresser & McKee Inc. — **Table B-4c**

Brazos River Authority — **Meridian WWTP**

North Bosque River Phosphorus Removal — **Effluent NH3 Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Meridian WWTP	TIAER	01/11/1999	Ammonia-nitrogen (mg/L)	0.26
Meridian WWTP	TIAER	02/09/1999	Ammonia-nitrogen (mg/L)	0.04
Meridian WWTP	TIAER	03/09/1999	Ammonia-nitrogen (mg/L)	0.32
Meridian WWTP	TIAER	04/06/1999	Ammonia-nitrogen (mg/L)	0.07
Meridian WWTP	TIAER	05/17/1999	Ammonia-nitrogen (mg/L)	0.12
Meridian WWTP	TIAER	06/15/1999	Ammonia-nitrogen (mg/L)	0.07
Meridian WWTP	TIAER	07/26/1999	Ammonia-nitrogen (mg/L)	0.13
Meridian WWTP	TIAER	08/23/1999	Ammonia-nitrogen (mg/L)	0.15
Meridian WWTP	TIAER	09/20/1999	Ammonia-nitrogen (mg/L)	0.10
Meridian WWTP	TIAER	10/18/1999	Ammonia-nitrogen (mg/L)	0.26
Meridian WWTP	TIAER	11/15/1999	Ammonia-nitrogen (mg/L)	0.07
Meridian WWTP	TIAER	12/13/1999	Ammonia-nitrogen (mg/L)	0.04
Meridian WWTP	TIAER	01/10/2000	Ammonia-nitrogen (mg/L)	0.06
Meridian WWTP	TIAER	02/08/2000	Ammonia-nitrogen (mg/L)	0.04
Meridian WWTP	TIAER	03/06/2000	Ammonia-nitrogen (mg/L)	0.07
Meridian WWTP	TIAER	04/03/2000	Ammonia-nitrogen (mg/L)	0.06
Meridian WWTP	TIAER	05/01/2000	Ammonia-nitrogen (mg/L)	1.56

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — **Table B-4d**

Brazos River Authority — **Meridian WWTP**

North Bosque River Phosphorus Removal — **Effluent PO4 Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Meridian WWTP	BRA	01/04/1999	Orthophosphate Phosphorus (mg/L)	2.74
Meridian WWTP	TIAER	01/11/1999	Orthophosphate Phosphorus (mg/L)	2.73
Meridian WWTP	TIAER	02/09/1999	Orthophosphate Phosphorus (mg/L)	2.77
Meridian WWTP	TIAER	03/09/1999	Orthophosphate Phosphorus (mg/L)	2.50
Meridian WWTP	BRA	04/05/1999	Orthophosphate Phosphorus (mg/L)	3.55
Meridian WWTP	TIAER	04/06/1999	Orthophosphate Phosphorus (mg/L)	3.51
Meridian WWTP	BRA	05/05/1999	Orthophosphate Phosphorus (mg/L)	2.96
Meridian WWTP	TIAER	05/17/1999	Orthophosphate Phosphorus (mg/L)	3.72
Meridian WWTP	BRA	06/03/1999	Orthophosphate Phosphorus (mg/L)	3.67
Meridian WWTP	TIAER	06/15/1999	Orthophosphate Phosphorus (mg/L)	3.48
Meridian WWTP	BRA	07/06/1999	Orthophosphate Phosphorus (mg/L)	4.52
Meridian WWTP	TIAER	07/26/1999	Orthophosphate Phosphorus (mg/L)	4.13
Meridian WWTP	BRA	08/02/1999	Orthophosphate Phosphorus (mg/L)	4.30
Meridian WWTP	TIAER	08/23/1999	Orthophosphate Phosphorus (mg/L)	3.93
Meridian WWTP	TIAER	09/20/1999	Orthophosphate Phosphorus (mg/L)	4.44
Meridian WWTP	TIAER	10/18/1999	Orthophosphate Phosphorus (mg/L)	4.10
Meridian WWTP	TIAER	11/15/1999	Orthophosphate Phosphorus (mg/L)	3.98
Meridian WWTP	TIAER	12/13/1999	Orthophosphate Phosphorus (mg/L)	3.48
Meridian WWTP	TIAER	01/10/2000	Orthophosphate Phosphorus (mg/L)	2.58
Meridian WWTP	TIAER	02/08/2000	Orthophosphate Phosphorus (mg/L)	3.84
Meridian WWTP	TIAER	03/06/2000	Orthophosphate Phosphorus (mg/L)	3.28
Meridian WWTP	TIAER	04/03/2000	Orthophosphate Phosphorus (mg/L)	3.71
Meridian WWTP	TIAER	05/01/2000	Orthophosphate Phosphorus (mg/L)	5.09

BRA = Brazos River Authority
TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — **Table B-5a**

Brazos River Authority — **Stephenville WWTP**

North Bosque River Phosphorus Removal — **Effluent CBOD Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Stephenville WWTP	COS	Jan-99	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	Feb-99	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	Mar-99	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	Apr-99	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	May-99	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	Jun-99	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	Jul-99	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	Aug-99	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	Sep-99	CBOD (mg/l) Daily Ave.	4.80
Stephenville WWTP	COS	Oct-99	CBOD (mg/l) Daily Ave.	13.50
Stephenville WWTP	COS	Nov-99	CBOD (mg/l) Daily Ave.	3.20
Stephenville WWTP	COS	Dec-99	CBOD (mg/l) Daily Ave.	2.80
Stephenville WWTP	COS	Jan-00	CBOD (mg/l) Daily Ave.	4.30
Stephenville WWTP	COS	Feb-00	CBOD (mg/l) Daily Ave.	7.20
Stephenville WWTP	COS	Mar-00	CBOD (mg/l) Daily Ave.	7.00
Stephenville WWTP	COS	Apr-00	CBOD (mg/l) Daily Ave.	5.60
Stephenville WWTP	COS	May-00	CBOD (mg/l) Daily Ave.	6.40
Stephenville WWTP	COS	Jun-00	CBOD (mg/l) Daily Ave.	5.90
Stephenville WWTP	COS	Jul-00	CBOD (mg/l) Daily Ave.	2.70
Stephenville WWTP	COS	Aug-00	CBOD (mg/l) Daily Ave.	2.20
Stephenville WWTP	COS	Sep-00	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	Oct-00	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	Nov-00	CBOD (mg/l) Daily Ave.	NR
Stephenville WWTP	COS	Dec-00	CBOD (mg/l) Daily Ave.	NR

COS = City of Stephenville

NR = No Record

CDM Camp Dresser & McKee Inc.					**Table B-5b**
Brazos River Authority					**Stephenville WWTP**
North Bosque River Phosphorus Removal					**Effluent TSS Data**
Site Location	Collecting Agency	Date	Parameter Description	<	Value
Stephenville WWTP	COS	01/1999	Total Suspended Solids (mg/L)		NR
Stephenville WWTP	BRA	01/04/1999	Total Suspended Solids (mg/L)		8
Stephenville WWTP	TIAER	01/11/1999	Total Suspended Solids (mg/L)	<	3
Stephenville WWTP	BRA	03/01/1999	Total Suspended Solids (mg/L)	<	4
Stephenville WWTP	TIAER	03/09/1999	Total Suspended Solids (mg/L)	<	3
Stephenville WWTP	COS	04/1999	Total Suspended Solids (mg/L)		NR
Stephenville WWTP	BRA	04/05/1999	Total Suspended Solids (mg/L)		11
Stephenville WWTP	TIAER	04/06/1999	Total Suspended Solids (mg/L)		13
Stephenville WWTP	BRA	05/05/1999	Total Suspended Solids (mg/L)	<	4
Stephenville WWTP	TIAER	05/17/1999	Total Suspended Solids (mg/L)	<	3
Stephenville WWTP	BRA	06/03/1999	Total Suspended Solids (mg/L)		10
Stephenville WWTP	BRA	07/06/1999	Total Suspended Solids (mg/L)		9
Stephenville WWTP	COS	08/1999	Total Suspended Solids (mg/L)		NR
Stephenville WWTP	BRA	08/02/1999	Total Suspended Solids (mg/L)		4
Stephenville WWTP	TIAER	08/23/1999	Total Suspended Solids (mg/L)	<	4
Stephenville WWTP	COS	09/1999	Total Suspended Solids (mg/L)		6.1
Stephenville WWTP	TIAER	09/20/1999	Total Suspended Solids (mg/L)	<	4
Stephenville WWTP	COS	10/1999	Total Suspended Solids (mg/L)		6
Stephenville WWTP	TIAER	10/18/1999	Total Suspended Solids (mg/L)	<	4
Stephenville WWTP	COS	11/1999	Total Suspended Solids (mg/L)		2.3
Stephenville WWTP	TIAER	11/15/1999	Total Suspended Solids (mg/L)	<	4
Stephenville WWTP	COS	12/1999	Total Suspended Solids (mg/L)		4.2
Stephenville WWTP	TIAER	12/13/1999	Total Suspended Solids (mg/L)	<	6
Stephenville WWTP	COS	01/2000	Total Suspended Solids (mg/L)		6.4
Stephenville WWTP	TIAER	01/10/2000	Total Suspended Solids (mg/L)	<	6
Stephenville WWTP	COS	02/2000	Total Suspended Solids (mg/L)		5.9
Stephenville WWTP	TIAER	02/08/2000	Total Suspended Solids (mg/L)	<	6
Stephenville WWTP	COS	03/2000	Total Suspended Solids (mg/L)		6.6
Stephenville WWTP	TIAER	03/06/2000	Total Suspended Solids (mg/L)	<	6
Stephenville WWTP	COS	04/2000	Total Suspended Solids (mg/L)		6.5
Stephenville WWTP	TIAER	04/03/2000	Total Suspended Solids (mg/L)	<	6
Stephenville WWTP	COS	05/2000	Total Suspended Solids (mg/L)		9.6
Stephenville WWTP	TIAER	05/01/2000	Total Suspended Solids (mg/L)		58
Stephenville WWTP	COS	06/2000	Total Suspended Solids (mg/L)		6.2
Stephenville WWTP	TIAER	06/13/2000	Total Suspended Solids (mg/L)	<	8
Stephenville WWTP	TIAER	06/26/2000	Total Suspended Solids (mg/L)	<	8
Stephenville WWTP	COS	07/2000	Total Suspended Solids (mg/L)		9
Stephenville WWTP	TIAER	07/11/2000	Total Suspended Solids (mg/L)	<	8
Stephenville WWTP	TIAER	07/26/2000	Total Suspended Solids (mg/L)	<	8
Stephenville WWTP	COS	08/2000	Total Suspended Solids (mg/L)		4.9
Stephenville WWTP	TIAER	08/08/2000	Total Suspended Solids (mg/L)	<	8
Stephenville WWTP	TIAER	08/23/2000	Total Suspended Solids (mg/L)	<	8
Stephenville WWTP	COS	09/2000	Total Suspended Solids (mg/L)		NR
Stephenville WWTP	TIAER	09/07/2000	Total Suspended Solids (mg/L)	<	8
Stephenville WWTP	TIAER	09/20/2000	Total Suspended Solids (mg/L)	<	8

BRA = Brazos River Authority

COS = City of Stephenville

TIAER = Texas Institute for Applied Environmental Research

NR = No Record

CDM Camp Dresser & McKee Inc.				**Table B-5c**
Brazos River Authority				**Stephenville WWTP**
North Bosque River Phosphorus Removal				**Effluent NH3 Data**
Site Location	Collecting Agency	Date	Parameter Description	Value
Stephenville WWTP	TIAER	01/11/1999	Ammonia Nitrogen (mg/L)	0.18
Stephenville WWTP	TIAER	02/09/1999	Ammonia Nitrogen (mg/L)	0.11
Stephenville WWTP	TIAER	03/09/1999	Ammonia Nitrogen (mg/L)	0.80
Stephenville WWTP	TIAER	04/06/1999	Ammonia Nitrogen (mg/L)	0.97
Stephenville WWTP	TIAER	05/17/1999	Ammonia Nitrogen (mg/L)	1.77
Stephenville WWTP	TIAER	06/15/1999	Ammonia Nitrogen (mg/L)	0.86
Stephenville WWTP	TIAER	07/26/1999	Ammonia Nitrogen (mg/L)	0.56
Stephenville WWTP	TIAER	08/23/1999	Ammonia Nitrogen (mg/L)	1.77
Stephenville WWTP	TIAER	09/20/1999	Ammonia Nitrogen (mg/L)	0.11
Stephenville WWTP	TIAER	10/18/1999	Ammonia Nitrogen (mg/L)	0.06
Stephenville WWTP	TIAER	11/15/1999	Ammonia Nitrogen (mg/L)	0.05
Stephenville WWTP	TIAER	12/13/1999	Ammonia Nitrogen (mg/L)	0.14
Stephenville WWTP	TIAER	01/10/2000	Ammonia Nitrogen (mg/L)	3.68
Stephenville WWTP	TIAER	02/08/2000	Ammonia Nitrogen (mg/L)	3.00
Stephenville WWTP	TIAER	03/06/2000	Ammonia Nitrogen (mg/L)	2.96
Stephenville WWTP	TIAER	04/03/2000	Ammonia Nitrogen (mg/L)	0.98
Stephenville WWTP	TIAER	05/01/2000	Ammonia Nitrogen (mg/L)	8.27
Stephenville WWTP	TIAER	06/13/2000	Ammonia Nitrogen (mg/L)	0.16
Stephenville WWTP	TIAER	06/26/2000	Ammonia Nitrogen (mg/L)	0.08
Stephenville WWTP	TIAER	07/11/2000	Ammonia Nitrogen (mg/L)	0.05
Stephenville WWTP	TIAER	07/26/2000	Ammonia Nitrogen (mg/L)	0.05
Stephenville WWTP	TIAER	08/08/2000	Ammonia Nitrogen (mg/L)	0.04
Stephenville WWTP	TIAER	08/23/2000	Ammonia Nitrogen (mg/L)	0.03
Stephenville WWTP	TIAER	09/07/2000	Ammonia Nitrogen (mg/L)	0.01
Stephenville WWTP	TIAER	09/20/2000	Ammonia Nitrogen (mg/L)	0.02

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — **Table B-5d**

Brazos River Authority — **Stephenville WWTP**

North Bosque River Phosphorus Removal — **Effluent PO4 Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Stephenville WWTP	BRA	01/04/1999	Orthophosphate Phosphorus (mg/L)	1.50
Stephenville WWTP	TIAER	01/11/1999	Orthophosphate Phosphorus (mg/L)	2.60
Stephenville WWTP	TIAER	02/09/1999	Orthophosphate Phosphorus (mg/L)	1.23
Stephenville WWTP	BRA	03/01/1999	Orthophosphate Phosphorus (mg/L)	0.56
Stephenville WWTP	TIAER	03/09/1999	Orthophosphate Phosphorus (mg/L)	0.86
Stephenville WWTP	BRA	04/05/1999	Orthophosphate Phosphorus (mg/L)	3.36
Stephenville WWTP	TIAER	04/06/1999	Orthophosphate Phosphorus (mg/L)	0.58
Stephenville WWTP	BRA	05/05/1999	Orthophosphate Phosphorus (mg/L)	3.44
Stephenville WWTP	TIAER	05/17/1999	Orthophosphate Phosphorus (mg/L)	0.96
Stephenville WWTP	BRA	06/03/1999	Orthophosphate Phosphorus (mg/L)	1.97
Stephenville WWTP	TIAER	06/15/1999	Orthophosphate Phosphorus (mg/L)	1.44
Stephenville WWTP	BRA	07/06/1999	Orthophosphate Phosphorus (mg/L)	1.66
Stephenville WWTP	TIAER	07/26/1999	Orthophosphate Phosphorus (mg/L)	2.76
Stephenville WWTP	BRA	08/02/1999	Orthophosphate Phosphorus (mg/L)	3.13
Stephenville WWTP	TIAER	08/23/1999	Orthophosphate Phosphorus (mg/L)	2.42
Stephenville WWTP	TIAER	09/20/1999	Orthophosphate Phosphorus (mg/L)	3.61
Stephenville WWTP	TIAER	10/18/1999	Orthophosphate Phosphorus (mg/L)	2.75
Stephenville WWTP	TIAER	11/15/1999	Orthophosphate Phosphorus (mg/L)	3.00
Stephenville WWTP	TIAER	12/13/1999	Orthophosphate Phosphorus (mg/L)	2.02
Stephenville WWTP	TIAER	01/10/2000	Orthophosphate Phosphorus (mg/L)	1.91
Stephenville WWTP	TIAER	02/08/2000	Orthophosphate Phosphorus (mg/L)	1.48
Stephenville WWTP	TIAER	03/06/2000	Orthophosphate Phosphorus (mg/L)	1.00
Stephenville WWTP	TIAER	04/03/2000	Orthophosphate Phosphorus (mg/L)	1.04
Stephenville WWTP	TIAER	05/01/2000	Orthophosphate Phosphorus (mg/L)	1.47
Stephenville WWTP	TIAER	06/13/2000	Orthophosphate Phosphorus (mg/L)	2.11
Stephenville WWTP	TIAER	06/26/2000	Orthophosphate Phosphorus (mg/L)	2.21
Stephenville WWTP	TIAER	07/11/2000	Orthophosphate Phosphorus (mg/L)	5.83
Stephenville WWTP	TIAER	07/26/2000	Orthophosphate Phosphorus (mg/L)	4.19
Stephenville WWTP	TIAER	08/08/2000	Orthophosphate Phosphorus (mg/L)	3.50
Stephenville WWTP	TIAER	08/23/2000	Orthophosphate Phosphorus (mg/L)	3.28
Stephenville WWTP	TIAER	09/07/2000	Orthophosphate Phosphorus (mg/L)	2.80
Stephenville WWTP	TIAER	09/20/2000	Orthophosphate Phosphorus (mg/L)	3.38

BRA = Brazos River Authority

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — **Table B-5e**

Brazos River Authority — **Stephenville WWTP**

North Bosque River Phosphorus Removal — **Effluent TP Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Stephenville WWTP	TIAER	01/11/1999	Total Phosphorus (mg/L)	2.72
Stephenville WWTP	TIAER	02/09/1999	Total Phosphorus (mg/L)	1.40
Stephenville WWTP	TIAER	03/09/1999	Total Phosphorus (mg/L)	1.33
Stephenville WWTP	TIAER	04/06/1999	Total Phosphorus (mg/L)	0.82
Stephenville WWTP	TIAER	05/17/1999	Total Phosphorus (mg/L)	1.20
Stephenville WWTP	TIAER	06/15/1999	Total Phosphorus (mg/L)	1.92
Stephenville WWTP	TIAER	07/26/1999	Total Phosphorus (mg/L)	3.20
Stephenville WWTP	TIAER	08/23/1999	Total Phosphorus (mg/L)	2.35
Stephenville WWTP	TIAER	09/20/1999	Total Phosphorus (mg/L)	3.81
Stephenville WWTP	TIAER	10/18/1999	Total Phosphorus (mg/L)	2.86
Stephenville WWTP	TIAER	11/15/1999	Total Phosphorus (mg/L)	3.36
Stephenville WWTP	TIAER	12/13/1999	Total Phosphorus (mg/L)	2.09
Stephenville WWTP	TIAER	01/10/2000	Total Phosphorus (mg/L)	2.55
Stephenville WWTP	TIAER	02/08/2000	Total Phosphorus (mg/L)	1.68
Stephenville WWTP	TIAER	03/06/2000	Total Phosphorus (mg/L)	1.88
Stephenville WWTP	TIAER	04/03/2000	Total Phosphorus (mg/L)	1.29
Stephenville WWTP	TIAER	05/01/2000	Total Phosphorus (mg/L)	4.26
Stephenville WWTP	TIAER	06/13/2000	Total Phosphorus (mg/L)	3.22
Stephenville WWTP	TIAER	06/26/2000	Total Phosphorus (mg/L)	2.45
Stephenville WWTP	TIAER	07/11/2000	Total Phosphorus (mg/L)	5.61
Stephenville WWTP	TIAER	07/26/2000	Total Phosphorus (mg/L)	3.99
Stephenville WWTP	TIAER	08/08/2000	Total Phosphorus (mg/L)	3.63
Stephenville WWTP	TIAER	08/23/2000	Total Phosphorus (mg/L)	3.40
Stephenville WWTP	TIAER	09/07/2000	Total Phosphorus (mg/L)	2.58
Stephenville WWTP	TIAER	09/20/2000	Total Phosphorus (mg/L)	3.42

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — **Table B-6a**

Brazos River Authority — **Valley Mills WWTP**

North Bosque River Phosphorus Removal — **Effluent BOD Data**

Site Location	Collection Agency	Date	Parameter Description	Value
Valley Mills WWTP	COVM	Jan-99	BOD (mg/l) Daily Ave.	NR
Valley Mills WWTP	COVM	Feb-99	BOD (mg/l) Daily Ave.	NR
Valley Mills WWTP	COVM	Mar-99	BOD (mg/l) Daily Ave.	NR
Valley Mills WWTP	COVM	Apr-99	BOD (mg/l) Daily Ave.	NR
Valley Mills WWTP	COVM	May-99	BOD (mg/l) Daily Ave.	NR
Valley Mills WWTP	COVM	Jun-99	BOD (mg/l) Daily Ave.	NR
Valley Mills WWTP	COVM	Jul-99	BOD (mg/l) Daily Ave.	NR
Valley Mills WWTP	COVM	Aug-99	BOD (mg/l) Daily Ave.	10.42
Valley Mills WWTP	COVM	Sep-99	BOD (mg/l) Daily Ave.	5.37
Valley Mills WWTP	COVM	Oct-99	BOD (mg/l) Daily Ave.	2.40
Valley Mills WWTP	COVM	Nov-99	BOD (mg/l) Daily Ave.	2.26
Valley Mills WWTP	COVM	Dec-99	BOD (mg/l) Daily Ave.	2.86
Valley Mills WWTP	COVM	Jan-00	BOD (mg/l) Daily Ave.	3.00
Valley Mills WWTP	COVM	Feb-00	BOD (mg/l) Daily Ave.	3.55
Valley Mills WWTP	COVM	Mar-00	BOD (mg/l) Daily Ave.	NR
Valley Mills WWTP	COVM	Apr-00	BOD (mg/l) Daily Ave.	3.60
Valley Mills WWTP	COVM	May-00	BOD (mg/l) Daily Ave.	4.00
Valley Mills WWTP	COVM	Jun-00	BOD (mg/l) Daily Ave.	3.30
Valley Mills WWTP	COVM	Jul-00	BOD (mg/l) Daily Ave.	3.00
Valley Mills WWTP	COVM	Aug-00	BOD (mg/l) Daily Ave.	3.00
Valley Mills WWTP	COVM	Sep-00	BOD (mg/l) Daily Ave.	3.57
Valley Mills WWTP	COVM	Oct-00	BOD (mg/l) Daily Ave.	NR
Valley Mills WWTP	COVM	Nov-00	BOD (mg/l) Daily Ave.	NR
Valley Mills WWTP	COVM	Dec-00	BOD (mg/l) Daily Ave.	NR

COVM = City of Valley Mills

NR = No Record

CDM Camp Dresser & McKee Inc. — **Table B-6b**

Brazos River Authority — **Valley Mills WWTP**

North Bosque River Phosphorus Removal — **Effluent TSS Data**

Site Location	Collecting Agency	Date	Parameter Description	<	Value
Valley Mills WWTP	BRA	01/04/1999	Total Suspended Solids (mg/L)	<	4
Valley Mills WWTP	TIAER	01/11/1999	Total Suspended Solids (mg/L)	<	6
Valley Mills WWTP	TIAER	02/09/1999	Total Suspended Solids (mg/L)	<	6
Valley Mills WWTP	COVM	03/1999	Total Suspended Solids (mg/L)		NR
Valley Mills WWTP	BRA	03/01/1999	Total Suspended Solids (mg/L)	<	4
Valley Mills WWTP	TIAER	03/09/1999	Total Suspended Solids (mg/L)	<	6
Valley Mills WWTP	COVM	04/1999	Total Suspended Solids (mg/L)		NR
Valley Mills WWTP	BRA	04/05/1999	Total Suspended Solids (mg/L)		8
Valley Mills WWTP	TIAER	04/06/1999	Total Suspended Solids (mg/L)	<	6
Valley Mills WWTP	COVM	05/1999	Total Suspended Solids (mg/L)		NR
Valley Mills WWTP	TIAER	05/04/1999	Total Suspended Solids (mg/L)		14
Valley Mills WWTP	BRA	05/05/1999	Total Suspended Solids (mg/L)		35
Valley Mills WWTP	TIAER	05/17/1999	Total Suspended Solids (mg/L)	<	6
Valley Mills WWTP	COVM	06/1999	Total Suspended Solids (mg/L)		NR
Valley Mills WWTP	BRA	06/03/1999	Total Suspended Solids (mg/L)		63
Valley Mills WWTP	COVM	07/1999	Total Suspended Solids (mg/L)		NR
Valley Mills WWTP	BRA	07/06/1999	Total Suspended Solids (mg/L)		6
Valley Mills WWTP	TIAER	07/26/1999	Total Suspended Solids (mg/L)	<	4
Valley Mills WWTP	COVM	08/1999	Total Suspended Solids (mg/L)		9
Valley Mills WWTP	BRA	08/02/1999	Total Suspended Solids (mg/L)		6
Valley Mills WWTP	TIAER	08/23/1999	Total Suspended Solids (mg/L)		56
Valley Mills WWTP	COVM	09/1999	Total Suspended Solids (mg/L)		6.7
Valley Mills WWTP	COVM	10/1999	Total Suspended Solids (mg/L)		2
Valley Mills WWTP	COVM	11/1999	Total Suspended Solids (mg/L)		3
Valley Mills WWTP	TIAER	11/15/1999	Total Suspended Solids (mg/L)	<	4
Valley Mills WWTP	COVM	12/1999	Total Suspended Solids (mg/L)		2.7
Valley Mills WWTP	TIAER	12/13/1999	Total Suspended Solids (mg/L)	<	6
Valley Mills WWTP	COVM	01/2000	Total Suspended Solids (mg/L)		4.15
Valley Mills WWTP	TIAER	01/10/2000	Total Suspended Solids (mg/L)	<	6
Valley Mills WWTP	COVM	02/2000	Total Suspended Solids (mg/L)		4.17
Valley Mills WWTP	TIAER	02/08/2000	Total Suspended Solids (mg/L)	<	6
Valley Mills WWTP	COVM	03/2000	Total Suspended Solids (mg/L)		NR
Valley Mills WWTP	TIAER	03/06/2000	Total Suspended Solids (mg/L)	<	6
Valley Mills WWTP	COVM	04/2000	Total Suspended Solids (mg/L)		4.8
Valley Mills WWTP	TIAER	04/03/2000	Total Suspended Solids (mg/L)		269
Valley Mills WWTP	COVM	05/2000	Total Suspended Solids (mg/L)		4.2
Valley Mills WWTP	TIAER	05/01/2000	Total Suspended Solids (mg/L)		10
Valley Mills WWTP	COVM	06/2000	Total Suspended Solids (mg/L)		6.16
Valley Mills WWTP	COVM	07/2000	Total Suspended Solids (mg/L)		1.45
Valley Mills WWTP	COVM	08/2000	Total Suspended Solids (mg/L)		2
Valley Mills WWTP	COVM	09/2000	Total Suspended Solids (mg/L)		2.9

BRA = Brazos River Authority
COVM = City of Valley Mills
TIAER = Texas Institute for Applied Environmental Research
NR = No Record

CDM Camp Dresser & McKee Inc. — **Table B-6c**

Brazos River Authority — **Valley Mills WWTP**

North Bosque River Phosphorus Removal — **Effluent NH3 Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Valley Mills WWTP	TIAER	01/11/1999	Ammonia-nitrogen (mg/L)	0.08
Valley Mills WWTP	TIAER	02/09/1999	Ammonia-nitrogen (mg/L)	0.02
Valley Mills WWTP	TIAER	03/09/1999	Ammonia-nitrogen (mg/L)	0.19
Valley Mills WWTP	TIAER	04/06/1999	Ammonia-nitrogen (mg/L)	0.04
Valley Mills WWTP	TIAER	05/17/1999	Ammonia-nitrogen (mg/L)	0.09
Valley Mills WWTP	TIAER	07/26/1999	Ammonia-nitrogen (mg/L)	0.09
Valley Mills WWTP	TIAER	08/23/1999	Ammonia-nitrogen (mg/L)	0.42
Valley Mills WWTP	TIAER	11/15/1999	Ammonia-nitrogen (mg/L)	0.05
Valley Mills WWTP	TIAER	12/13/1999	Ammonia-nitrogen (mg/L)	0.17
Valley Mills WWTP	TIAER	01/10/2000	Ammonia-nitrogen (mg/L)	0.06
Valley Mills WWTP	TIAER	02/08/2000	Ammonia-nitrogen (mg/L)	0.06
Valley Mills WWTP	TIAER	03/06/2000	Ammonia-nitrogen (mg/L)	0.04
Valley Mills WWTP	TIAER	04/03/2000	Ammonia-nitrogen (mg/L)	0.24
Valley Mills WWTP	TIAER	05/01/2000	Ammonia-nitrogen (mg/L)	0.09

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — **Table B-6d**

Brazos River Authority — **Valley Mills WWTP**

North Bosque River Phosphorus Removal — **Effluent PO4 Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Valley Mills WWTP	BRA	01/04/1999	Orthophosphate Phosphorus (mg/L)	3.55
Valley Mills WWTP	TIAER	01/11/1999	Orthophosphate Phosphorus (mg/L)	3.63
Valley Mills WWTP	TIAER	02/09/1999	Orthophosphate Phosphorus (mg/L)	3.8
Valley Mills WWTP	BRA	03/01/1999	Orthophosphate Phosphorus (mg/L)	3.91
Valley Mills WWTP	TIAER	03/09/1999	Orthophosphate Phosphorus (mg/L)	3.55
Valley Mills WWTP	BRA	04/05/1999	Orthophosphate Phosphorus (mg/L)	2.67
Valley Mills WWTP	TIAER	04/06/1999	Orthophosphate Phosphorus (mg/L)	2.81
Valley Mills WWTP	BRA	05/05/1999	Orthophosphate Phosphorus (mg/L)	3.10
Valley Mills WWTP	TIAER	05/17/1999	Orthophosphate Phosphorus (mg/L)	4.37
Valley Mills WWTP	BRA	06/03/1999	Orthophosphate Phosphorus (mg/L)	4.36
Valley Mills WWTP	BRA	07/06/1999	Orthophosphate Phosphorus (mg/L)	3.26
Valley Mills WWTP	TIAER	07/26/1999	Orthophosphate Phosphorus (mg/L)	4.48
Valley Mills WWTP	BRA	08/02/1999	Orthophosphate Phosphorus (mg/L)	4.48
Valley Mills WWTP	TIAER	08/23/1999	Orthophosphate Phosphorus (mg/L)	3.41
Valley Mills WWTP	TIAER	11/15/1999	Orthophosphate Phosphorus (mg/L)	3.44
Valley Mills WWTP	TIAER	12/13/1999	Orthophosphate Phosphorus (mg/L)	0.71
Valley Mills WWTP	TIAER	01/10/2000	Orthophosphate Phosphorus (mg/L)	2.13
Valley Mills WWTP	TIAER	02/08/2000	Orthophosphate Phosphorus (mg/L)	3.11
Valley Mills WWTP	TIAER	03/06/2000	Orthophosphate Phosphorus (mg/L)	3.26
Valley Mills WWTP	TIAER	04/03/2000	Orthophosphate Phosphorus (mg/L)	2.48
Valley Mills WWTP	TIAER	05/01/2000	Orthophosphate Phosphorus (mg/L)	3.73

BRA = Brazos River Authority
TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc. — **Table B-6e**

Brazos River Authority — **Valley Mills WWTP**

North Bosque River Phosphorus Removal — **Effluent TP Data**

Site Location	Collecting Agency	Date	Parameter Description	Value
Valley Mills WWTP	TIAER	01/11/1999	Total Phosphorus (mg/L)	3.83
Valley Mills WWTP	TIAER	02/09/1999	Total Phosphorus (mg/L)	3.9
Valley Mills WWTP	TIAER	03/09/1999	Total Phosphorus (mg/L)	4.21
Valley Mills WWTP	TIAER	04/06/1999	Total Phosphorus (mg/L)	3.16
Valley Mills WWTP	TIAER	05/04/1999	Total Phosphorus (mg/L)	NR
Valley Mills WWTP	TIAER	05/17/1999	Total Phosphorus (mg/L)	4.71
Valley Mills WWTP	TIAER	07/26/1999	Total Phosphorus (mg/L)	4.7
Valley Mills WWTP	TIAER	08/23/1999	Total Phosphorus (mg/L)	3.65
Valley Mills WWTP	TIAER	11/15/1999	Total Phosphorus (mg/L)	3.67
Valley Mills WWTP	TIAER	12/13/1999	Total Phosphorus (mg/L)	[illegible]
Valley Mills WWTP	TIAER	01/10/2000	Total Phosphorus (mg/L)	2.34
Valley Mills WWTP	TIAER	02/08/2000	Total Phosphorus (mg/L)	3.26
Valley Mills WWTP	TIAER	03/06/2000	Total Phosphorus (mg/L)	3.39
Valley Mills WWTP	TIAER	04/03/2000	Total Phosphorus (mg/L)	6.39
Valley Mills WWTP	TIAER	05/01/2000	Total Phosphorus (mg/L)	4.42

TIAER = Texas Institute for Applied Environmental Research

CDM Camp Dresser & McKee Inc.
Brazos River Authority
North Bosque River Phosphorus Removal Study

Table B-7
Clifton WWTP
Influent /Effluent Phosphorus Data

Date (mmddyy)	Estimated Influent PO4 (mg/l)	Influent Total Phosphorus (mg/l)	Effluent Total Phosphorus (mg/l)	Date (mmddyy)	Estimated Influent PO4 (mg/l)	Influent Total Phosphorus (mg/l)	Effluent Total Phosphorus (mg/l)
12/07/99	24.8	8.1	1.0	04/05/00	17.8	5.8	0.45
12/14/99	24.8	8.1	1.5	04/11/00	20.2	6.6	0.7
12/21/99	0	0	1.7	04/18/00	23.0	7.5	1.3
12/28/99	0	0	1.3	04/25/00	38.0	12.4	0.78
01/03/00	20.9	6.8	0.85	05/04/00	23.0	7.5	1.0
01/18/00	23.0	7.5	1.9	05/16/00	65.6	21.4	1.3
02/09/00	35.3	11.5	0.85	05/23/00	20.2	6.6	1.5
02/19/00	24.8	8.1	0.45	05/30/00	33.7	11.0	2.2
02/23/00	88.3	28.8	0.4	06/06/00	22.4	7.3	0.2
03/01/00	21.5	7.0	0.6	06/13/00	26.7	8.7	0.88
03/08/00	21.2	6.9	0.8	06/20/00			1.4
03/15/00	32.5	10.6	0.65	06/27/00	23.9	7.8	2.3
03/22/00	25.5	8.3	0.75				
03/29/00	23.9	7.8	1.2	Ave. Values	27.3	8.9	1.1

Table B-8
Meridian WWTP
Influent /Effluent Phosphorus Data

Date (mmddyy)	Influent PO4 (mg/l)	Estimated Influent Total P (mg/l)	Effluent PO4 (mg/l)	Date (mmddyy)	Influent PO4 (mg/l)	Estimated Influent Total P (mg/l)	Effluent PO4 (mg/l)
02/15/00	14.9	4.9	17.0	07/18/00	11.5	3.0	9.15
02/22/00	17.3	5.7	27.3	07/25/00	10.9	4.0	12.0
02/29/00	22.0	7.3	9.3	08/01/00	5.05	1.1	3.35
03/07/00	12.4	4.1	10.6	08/08/00	11.4	3.1	9.31
03/14/00	6.77	2.2	9.1	08/15/00	11.5	3.0	8.94
03/21/00	10.0	3.3	8.65	08/22/00	10.5	0.0	0.0
03/27/00	10.8	3.6	11.0	08/24/00	NR	3.9	11.9
04/04/00	12.9	4.3	9.8	08/29/00	11.0	2.7	8.14
04/11/00	10.3	3.4	13.5	09/08/00	11.8	2.9	8.74
04/18/00	9.1	3.0	8.68	09/12/00	10.2	3.4	10.3
04/25/00	11.0	3.6	13.0	09/19/00	9.76	3.0	9.16
05/10/00	14.4	4.8	12.9	09/26/00	8.05	4.2	12.7
05/16/00	13.0	4.3	13.8	10/03/00	9.29	2.5	7.45
05/23/00	12.6	4.2	12.0	10/10/00	10.8	3.4	10.4
05/30/00	11.1	3.7	11.9	10/17/00	8.39	3.1	9.39
06/06/00	8.06	2.7	2.86	10/24/00	7.57	3.0	8.99
06/13/00	8.44	2.8	4.01	10/31/00	7.77	3.4	10.2
06/20/00	6.12	2.0	6.7	11/07/00	4.0	2.6	7.85
06/27/00	8.03	2.6	11.1	11/14/00	4.77	2.9	8.81
07/05/00	10.1	3.3	11.3				
07/11/00	7.26	2.4	11.1	Ave. Values	10.28	3.33	10.06

CDM Camp Dresser & McKee Inc. — **Table B-9**

Brazos River Authority — **Stephenville WWTP**

North Bosque River Phosphorus Removal Study — **Influent /Effluent Monitoring Data**

Date (mmddyy)	Influent PO4 (mg/l)	Estimated Influent Total P (mg/l)	Effluent PO4 (mg/l)	Estimated Effluent Total P (mg/l)	Influent CBOD (mg/l)	Influent TSS (mg/l)	Influent NH3 (mg/l)
07/14/99	40.0	13.2	NR	NR	NR	NR	NR
07/15/99	37.5	12.4	8.9	2.9	NR	NR	NR
07/15/99	23.0	7.6	NR	NR	NR	NR	NR
07/17/99	27.5	9.1	51.3	16.9	NR	NR	NR
07/17/99	32.5	10.7	NR	NR	NR	NR	NR
08/03/99	55.0	18.2	21.5	7.1	NR	NR	NR
08/10/99	50.0	16.5	15	5.0	NR	NR	NR
08/11/99	37.5	12.4	15	5.0	NR	NR	NR
08/23/99	10.0	3.3	10.4	3.4	NR	NR	NR
08/24/99	60.0	19.8	11.9	3.9	NR	NR	NR
08/25/99	27.5	9.1	8.9	2.9	NR	NR	NR
09/07/99	37.5	12.4	8.2	2.7	NR	NR	NR
09/16/99	30.0	9.9	9.7	3.2	NR	NR	NR
09/20/99	40.0	13.2	13.9	4.6	NR	NR	NR
10/12/99	28.0	9.2	11.4	3.8	NR	NR	NR
10/21/99	32.5	10.7	11.1	3.7	NR	NR	NR
10/26/99	17.5	5.8	18.8	6.2	NR	NR	NR
10/27/99	47.5	15.7	NR	NR	NR	NR	NR
10/28/99	27.5	9.1	NR	NR	NR	NR	NR
11/04/99	40	13.2	NR	NR	NR	NR	NR
11/08/99	40	13.2	9.9	3.3	NR	NR	NR
11/10/99	68	22.4	8	2.6	NR	NR	NR
11/19/99	37.5	12.4	12	4.0	NR	NR	45.0
11/23/99	45	14.9	12.4	4.1	NR	NR	NR
11/30/99	37.5	12.4	13.2	4.4	NR	NR	NR
12/01/99	42.5	14	14.2	4.7	NR	NR	NR
12/08/99	55	18.2	13.1	4.3	NR	NR	NR
12/08/99	50	16.5	NR	NR	NR	NR	NR
01/12/00	42.5	14	5.9	1.9	NR	NR	40
01/18/00	60	19.8	10.9	3.6	312	206	NR
01/25/00	158	52.1	1.8	0.6	NR	NR	NR
02/11/00	48	15.8	7.3	2.4	NR	NR	NR
02/15/00	NR	NR	NR	NR	231	362	NR
02/22/00	NR	NR	NR	NR	287	238	45
02/24/00	43	14.2	4.5	1.5	NR	NR	NR
02/28/00	43	14.2	9.8	3.2	NR	NR	NR
03/07/00	50	16.5	10.8	3.6	310	226	40
03/08/00	NR	NR	NR	NR	280	214	NR
03/14/00	45	14.9	5.3	1.7	282	350	41

Table B-9 (Cont'd.)
Stephenville WWTP
Influent /Effluent Monitoring Data

Date (mmddyy)	Influent PO4 (mg/l)	Estimated Influent Total P (mg/l)	Effluent PO4 (mg/l)	Estimated Effluent Total P (mg/l)	Influent CBOD (mg/l)	Influent TSS (mg/l)	Influent NH3 (mg/l)
03/15/00	NR	NR	NR	NR	232	258	32.5
03/17/00	40	13.2	2.6	0.9	NR	NR	40
03/21/00	NR	NR	NR	NR	278	NR	NR
03/22/00	47.2	15.6	8.6	2.8	260	NR	40
03/29/00	NR	NR	NR	NR	310	NR	41
04/04/00	50	16.5	6.9	2.3	252	368	42
04/05/00	50	16.5	6.6	2.2	208	232	NR
04/18/00	NR	NR	NR	NR	340	866	38.5
04/19/00	NR	NR	NR	NR	298	240	40
05/09/00	NR	NR	NR	NR	141	318	NR
05/10/00	NR	NR	NR	NR	216	207	NR
05/30/00	NR	NR	NR	NR	NR	236	33.5
06/14/00	NR	NR	NR	NR	312	NR	38
06/15/00	NR	NR	NR	NR	212	NR	46
08/01/00	NR	NR	NR	NR	196	256	NR
08/08/00	NR	NR	NR	NR	199	212	NR
08/09/00	NR	NR	NR	NR	375	222	NR
08/23/00	NR	NR	NR	NR	212	202	NR
08/30/00	NR	NR	NR	NR	705	228	NR
09/12/00	NR	NR	NR	NR	353	220	NR
09/19/00	NR	NR	NR	NR	295	150	NR
09/26/00	NR	NR	NR	NR	284	268	NR
10/03/00	27.5	9.1	13.4	4.4	257	190	NR
10/04/00	40.0	13.2	14.4	4.8	NR	NR	NR
10/10/00	NR	NR	NR	NR	272	240	NR
10/11/00	NR	NR	NR	NR	316	244	NR
10/17/00	47.5	15.7	13.0	4.3	NR	NR	35
10/18/00	27.5	9.1	10.8	3.6	NR	284	41
10/24/00	2.5	0.8	2.5	0.8	278	214	38
10/25/00	NR	NR	NR	NR	262	200	NR
11/03/00	0.0	0.0	7.8	2.6	NR	NR	NR
11/15/00	0.0	0.0	5.4	1.8	NR	NR	NR
11/28/00	36.0	11.9	2.0	0.7	NR	NR	NR
12/06/00	12.4	4.1	15.0	5.0	NR	NR	NR
12/07/00	25.6	8.4	10.4	3.4	NR	NR	NR
12/13/00	15.0	5.0	10.8	3.6	NR	NR	NR
Averages	**39.0**	**12.9**	**11.0**	**3.6**	**283**	**266**	**39.8**

NR = No Record

Appendix C: Design Calculations

Brazos River Authority

North Bosque River Phosphorous Removal Study

CDM Camp Dresser & McKee Inc.
Brazos River Authority
North Bosque River Phosphorus Removal Study

Table C-1
Chemical Treatment Sizing Calculations

Chemical Phosphorus Removal

THIS SHEET USED FOR EQUIPMENT SIZING (Pumps and Storage Tanks)

Liquid aluminum sulfate, alum, is available as 4.37% aluminum, 8.3% Al_2SO_3 or 49% $Al_2(SO_4)_3\ 14H_2O$. The unit weight is 11.1 lb/gal.
The molecular weight is 594.
The stoichiometric molar ratio of Al:PO_4 is 1:1. The stoichiometric weight ratio of Al:P is 0.87:1, and for alum:P is 9.6:1.
Chemical treatment with Alum at a rate of 2.2 mole of Al/mole of P removed.

Facility	Design Flow Rate[1] (MGD)	Influent P (mg/L)	Aeration Basin Effluent P (mg/L)	Target Effluent P (mg/L)	Required Alum Conc. (mg/L)	Peak Alum Dose (gpd)	*Peak Alum Dose (gpm)*	Storage[2] (gals)	*Tank Volume (gal)*	Tank Diameter (ft)
Clifton WWTP	0.975	10	4.5	0.5	84	129	*0.089*	3,860	*4,000*	7.8
Hico WWTP	0.3	10	4.5	0.5	84	40	*0.027*	1,188	*1,200*	5.3
Iredell WWTP	0.075	10	4.5	0.5	84	10	*0.007*	297	*400*	2.8
Meridian WWTP	0.675	10	4.5	0.5	84	89	*0.062*	2,672	*3,000*	8.0
Stephenville WWTP	3.9	13	4.5	0.5	84	515	*0.357*	15,441	*2 @ 8,000*	11.9
Valley Mills WWTP	0.54	10	4.5	0.5	84	71	*0.049*	2,138	*2,500*	8.0

[1] Design Flow Rate = Average Daily Flow Rate * Peaking Factor of 1.5, (Stephenville = 1.3)
[2] Based on 30 day storage

Note: This table computes the peak chemical demand and is used for sizing pumps, tanks, and piping.

Chemical Phosphorus Removal

THIS SHEET USED FOR OPERATING COST ESTIMATION

Liquid aluminum sulfate, alum, is available as 4.37% aluminum, 8.3% Al_2SO_3 or 49% $Al_2(SO_4)_3\ 14H_2O$. The unit weight is 11.1 lb/gal.
The molecular weight is 594.
The stoichiometric molar ratio of Al:PO_4 is 1:1. The stoichiometric weight ratio of Al:P is 0.87:1, and for alum:P is 9.6:1.
Chemical treatment with Alum at a rate of 2.2 mole of Al/mole of P removed.

Facility	Average Daily Flow Rate (MGD)	Influent P (mg/L)	Aeration Basin Effluent P (mg/L)	Target Effluent P (mg/L)	Required Alum Conc. (mg/L)	Average Alum Dose[1] (gpd)	*Average Alum Dose[1] (gpm)*	*Average Alum Use[1] (gpy)*
Clifton WWTP	0.65	10	4.5	0.5	84	86	0.060	31,310
Hico WWTP	0.2	10	4.5	0.5	84	26	0.018	9,634
Iredell WWTP	0.05	10	4.5	0.5	84	7	0.005	2,408
Meridian WWTP	0.45	10	4.5	0.5	84	59	0.038	20,051
Stephenville WWTP	3	13	4.5	0.5	84	396	0.275	144,508
Valley Mills WWTP	0.56	10	4.5	0.5	84	48	0.033	17,341

[1] Dose rate based on a 48% Alum solution with a density of 11.1 lb/gal

Note: This table computes the average chemical demand and is used for computing the annual operating cost.

CDM Camp Dresser & McKee Inc. | **Table C-3**

Brazos River Authority | **Biological Nutrient Removal Design Calculations**

North Bosque River Phosphorus Removal Study

Anaerobic basin volume requirements to remove phosphorus to the effluent concentration

Facility	Average Daily Flow Rate (MGD)	Peaking Factor	Influent P (mg/L)	Existing Effluent P (mg/L)	Assumed BNR Effluent P (mg/L)	Estimated P Removed by BNR (mg/L)	Anaerobic HRT (hr)	Anaerobic Basin Volume[2] (gal)	Anaerobic Basin Volume (ft^3)
Clifton WWTP	0.65	1.5	10	4.5	2	2.5	N/A[1]	N/A[1]	N/A[1]
Hico WWTP	0.2	1.5	10	4.5	2	2.5	1	12,500	1,671
Iredell WWTP	0.05	1.5	10	4.5	2	2.5	1	3,125	418
Meridian WWTP	0.45	1.5	10	4.5	2	2.5	1	28,125	3,760
Stephenville WWTP	3	1.3	13	4.5	2	2.5	1	162,500	21,725
Valley Mills WWTP	0.36	1.5	10	4.5	2	2.5	1	22,500	3,008

[1] Existing SBR capable of BNR without further modifications except chemical polishing filtration. Existing effluent P of 4.5 mg/L assumed as a conservative design parameter.

[2] Basin volume determined using Permitted Average Daily Flow * Peaking Factor

BNR - Chemical Polishing Dose and Storage Requirements

THIS SHEET USED FOR EQUIPMENT SIZING

Liquid aluminum sulfate, alum, is available as 4.37% aluminum, 8.3% Al_2SO_3 or 49% $Al_2(SO_4)_3$ $14H_2O$. The unit weight is 11.1 lb/gal.
The molecular weight is 594.
The stoichiometric molar ratio of Al:PO_4 is 1:1. The stoichiometric weight ratio of Al:P is 0.87:1, and for alum:P is 9.6:1.
Chemical treatment with Alum at a rate of 2.2 mole of Al/mole of P removed.

Facility	Design Flow Rate[1] (MGD)	Influent P (mg/L)	BNR Effluent P (mg/L)	Target Effluent P (mg/L)	Required Alum Conc. (mg/L)	Peak Alum Dose[1] (gpd)	*Peak Alum Dose[1] (gpm)*	Storage[2] (gals)	*Tank Volume (gal)*	Tank Diameter (ft)
Clifton WWTP	0.975	10	2	0.5	32	48	*0.034*	1,448	*1,500*	5.3
Hico WWTP	0.3	10	2	0.5	32	15	*0.010*	445	*500*	[illegible]
Iredell WWTP	0.075	10	2	0.5	32	4	*0.003*	111	*160*	2.6
Meridian WWTP	0.675	10	2	0.5	32	33	*0.023*	1,002	*1,050*	[illegible]
Stephenville WWTP[3]	3.9	13	2	0.25	37	225	*0.156*	6,755	*6,400*	10.0
Valley Mills WWTP	0.54	10	2	0.5	32	27	*0.019*	802	*1,000*	5.3

[1] Design Flow Rate = Average Daily Flow Rate * Peaking Factor of 1.5, (Stephenville = 1.3)
[2] Based on 30 day storage
[3] The Stephenville WWTP will reguire a 6,800 gal storage tank for an effluent limit of 0.7 mg/L TP.

Note: This table computes the peak chemical demand and is used for sizing pumps, tanks, and piping.

CDM Camp Dresser & McKee Inc.
Brazos River Authority
North Bosque River Phosphorus Removal Study

Table C-5
Chemical Polishing Operating Calculations

BNR - Chemical Polishing Dose and Storage Requirements

THIS SHEET USED FOR OPERATING COST ESTIMATION

Facility	Average Daily Flow Rate (MGD)	Influent P (mg/L)	BNR Effluent P (mg/L)	Target Effluent P (mg/L)	Required Alum Conc. (mg/L)	Average Alum Dose[1] (gpd)	*Average Alum Dose[1] (gpm)*	*Average Alum Use[1] (gpy)*
Clifton WWTP	0.65	10	2	0.5	32	32	0.022	11,741
Hico WWTP	0.2	10	2	0.5	32	10	0.007	3,613
Iredell WWTP	0.05	10	2	0.5	32	2	0.002	903
Meridian WWTP	0.45	10	2	0.5	32	22	0.015	8,129
Stephenville WWTP	3	13	2	0.25	37	173	0.120	63,222
Valley Mills WWTP	0.36	10	2	0.5	32	18	0.012	6,503

[1] Dose rate based on a 48% Alum solution with a density of 11.1 lb/gal

[2] Based on 30 day storage

Note: This table computes the average chemical demand and is used for computing the annual operating cost.

Biological Phosphorus Removal Sludge Production:
Phosphorus removal through Biological treatment and chemical polishing results in an estimated 25% increase in the total solids produced

Facility	Projected WAS (gpd)	Phosphorus Removal WAS (gpd)	SHT[2] Volume (gal)	Existing Drying Bed Area (ft^2)	Phos. Removal Bed Area (ft^2)	Additional Hauled Sludge (yd^3/yr)
Clifton WWTP	14,625	18,281	-[4]	-	-	70
Hico WWTP	4,500	5,625	-	4,185	5,231	22
Iredell WWTP	1,125	1,406	-	660	825	5
Meridian WWTP	10,125	12,656	6,328	-	-	49
Stephenville WWTP[3]	67,500	84,375	-[1]	-	-	325
Valley Mills WWTP	8,100	10,125	-	2,475	3,094	39

[1]The Stephenville WWTP sludge digesters will serve as the sludge holding tanks.

[2]SHT = Sludge Holding Tank

[3]The Stephenville facility will have 586 yd^3/yr of additional sludge for an effluent limit of 0.7 mg/L. The additional 0.3 mg/L removed results in an overall increase of 30%.

[4] Sludge holding tank not required at Clifton due to reliance on mechanical dewatering.

Appendix D: Cost Estimates
Brazos River Authority
North Bosque River Phosphorous Removal Study

Table D-1
Chemical Phosphorus Removal at Hico WWTP
Preliminary Cost Opinion [1]

I. *Capital Costs*

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$7,816	NA	$0	$7,800
Site Preparation	1	L.S.	5%	$7,443	NA	$0	$7,400
1 - 1200 gal Alum Storage Tank	1	Each	$3,000	$3,000	35%	$1,050	$4,100
1" Alum Feed Line	10	L.F.	$20	$200	NA	$0	$200
Alum Feed Pumps	2	Each	$4,800	$9,600	35%	$3,360	$13,000
2-Disk Filter Unit	1	Each	$115,000	$115,000	35%	$40,250	$155,300
Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
Sludge Drying Bed 1" Water Line	100	L.F.	$20	$2,000	NA	$0	$2,000
Sludge Drying Bed 6" RAS Piping	100	L.F.	$35	$3,500	NA	$0	$3,500
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	200	L.F.	$30	$6,000	NA	$0	$6,000
Electrical Conduit to Filters	50	L.F.	$30	$1,500	NA	$0	$1,500
Motor Controls, Instrumentation, Misc.	1	L.S.	$30,000	$30,000	NA	$0	$30,000
Sedimentation/Erosion Control	900	L.F.	$2	$1,800	NA	$0	$1,800
Loaming/Hydroseeding	56	S.Y.	$1.20	$67	NA	$0	$100
						Subtotal	$239,000
						Prof. Services [2] (15%)	$36,000
						Contingencies (25%)	$60,000
						OH&P (15%)	$36,000
						Total Equipment Cost	**$371,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$2,874	NA	$0	$2,900
Site Preparation	1	L.S.	5%	$2,737	NA	$0	$2,700
Concrete Pad for Chemical Tank	2	C.Y.	$350	$635	NA	$0	$600
Concrete Pad for Filter Unit	4	C.Y.	$350	$1,225	NA	$0	$1,200
Sludge Drying Beds	151	C.Y.	$350	$52,889	NA	$0	$52,900
						Subtotal	$60,000
						Prof. Services [2] (15%)	$9,000
						Contingencies (25%)	$15,000
						OH&P (15%)	$9,000
						Total Structures Cost	**$93,000**
						Total Capital Cost	**$464,000**

II. *Annual Operation and Maintenance (O&M) Cost*

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Alum	9,490	GAL	$1.00	$9,490	NA	$0	$9,500
Maintenance	1	Per Yea	3%	$5,049	NA	$0	$5,000
Power	4,355	kW-HR	$0.07	$305	NA	$0	$300
Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
Additional Sludge Disposal	61	C.Y.	$15	$915	NA	$0	$900
						Total Annual O&M Cost	**$18,000**

III. *Annualized Cost*

Annualized Capital Cost	$ 26,000
Annual O&M Cost	$ 18,000
TOTAL ANNUALIZED COST	**$ 44,000**
Cost per Pound Phosphorus Removed Per Year [4]	**$ 20.65**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-2
Chemical Phosphorus Removal at Iredell WWTP
Preliminary Cost Opinion [1]

I. *Capital Costs*

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$6,929	NA	$0	$6,900
Site Preparation	1	L.S.	5%	$6,600	NA	$0	$6,600
1 - 400 gal Alum Storage Tank	1	Each	$1,350	$1,350	35%	$473	$1,800
1" Alum Feed Line	100	L.F.	$20	$2,000	NA	$0	$2,000
Alum Feed Pumps	2	Each	$4,800	$9,600	35%	$3,360	$13,000
1-Disk Filter Unit	1	Each	$110,000	$110,000	35%	$38,500	$148,500
Filter Piping	20	L.F.	$30	$600	NA	$0	$600
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	40	L.F.	$30	$1,200	NA	$0	$1,200
Electrical Conduit to Filters	20	L.F.	$30	$600	NA	$0	$600
Motor Controls, Instrumentation, Misc.	1	L.S.	$26,000	$26,000	NA	$0	$26,000
Sedimentation/Erosion Control	260	L.F.	$2	$520	NA	$0	$500
Loaming/Hydroseeding	933	S.Y.	$1.20	$1,120	NA	$0	$1,100
						Subtotal	$214,000
						Prof. Services [2] (15%)	$32,000
						Contingencies (25%)	$54,000
						OH&P (15%)	$32,000
						Total Equipment Cost	**$332,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$3,486	NA	$0	$3,500
Site Preparation	1	L.S.	5%	$3,320	NA	$0	$3,300
Concrete Pad for Chemical Tank	1	C.Y.	$350	$324	NA	$0	$300
Concrete Pad for Filter Unit	4	C.Y.	$350	$1,225	NA	$0	$1,200
Demo Chlorine Basin	1	L.S.	$10,000	$10,000	NA	$0	$10,000
New Chlorine Contact Basin	40	C.Y.	$500	$20,069	NA	$0	$20,100
Sludge Drying Beds	55	C.Y.	$350	$19,185	NA	$0	$19,200
Fence Modifications	180	L.F.	$20	$3,600	NA	$0	$3,600
Structural Fill	1,000	C.Y.	$12	$12,000	NA	$0	$12,000
						Subtotal	$73,000
						Prof. Services [2] (15%)	$11,000
						Contingencies (25%)	$18,000
						OH&P (15%)	$11,000
						Total Structures Cost	**$113,000**

Total Capital Cost $445,000

II. *Annual Operation and Maintenance (O&M) Cost*

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Alum	2,555	GAL	$1.00	$2,555	NA	$0	$2,600
Maintenance	1	Per Year	3%	$4,845	NA	$0	$4,800
Power	4,355	kW-HR	$0.07	$305	NA	$0	$300
Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
Additional Sludge Disposal	15	C.Y.	$15	$225	NA	$0	$230
						Total Annual O&M Cost	**$10,000**

III. *Annualized Cost*

Annualized Capital Cost	$ 25,000
Annual O&M Cost	$ 10,000
TOTAL ANNUALIZED COST	**$ 35,000**
Cost per Pound Phosphorus Removed Per Year [4]	**$ 65.67**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-3
Chemical Phosphorus Removal at Meridian WWTP
Preliminary Cost Opinion (1)

I. *Capital Costs*

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$22,056	NA	$0	$22,100
Site Preparation	1	L.S.	5%	$21,006	NA	$0	$21,000
1 - 3,000 gal Alum Storage Tank	1	Each	$7,000	$7,000	35%	$2,450	$9,500
1" Alum Feed Line	100	L.F.	$20	$2,000	NA	$0	$2,000
Alum Feed Pumps	2	Each	$5,200	$10,400	35%	$3,640	$14,000
4-Disk Filter Unit	1	Each	$135,000	$135,000	35%	$47,250	$182,300
Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
1 - 10,000 gal Sludge Storage Tank	1	Each	$14,500	$14,500	35%	$5,075	$19,600
Sludge Feed Pumps	2	Each	$15,000	$30,000	35%	$10,500	$40,500
4" Sludge Feed Line	20	L.F.	$30	$600	NA	$0	$600
Polymer Feed Unit	1	Each	$15,000	$15,000	35%	$5,250	$20,300
Conveyor	1	Each	$25,000	$25,000	35%	$8,750	$33,800
1-Meter Belt Press	1	Each	$160,000	$160,000	65%	$104,000	$264,000
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
Electrical Conduit to Filters	50	L.F.	$30	$1,500	NA	$0	$1,500
Electrical Conduit to Belt Filter Presses	100	L.F.	$30	$3,000	NA	$0	$3,000
Motor Controls, Instrumentation, Misc.	1	L.S.	$93,000	$93,000	NA	$0	$93,000
Relocate Yard Piping	80	L.F.	$50	$4,000	NA	$0	$4,000
Sedimentation/Erosion Control	1,400	L.F.	$2	$2,800	NA	$0	$2,800
Loaming/Hydroseeding	101	S.Y.	$1.20	$121	NA	$0	$100
						Subtotal	$743,000
						Prof. Services (2) (15%)	$111,000
						Contingencies (25%)	$186,000
						OH&P (15%)	$111,000
						Total Equipment Cost	**$1,151,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$4,175	NA	$0	$4,200
Site Preparation	1	L.S.	5%	$3,976	NA	$0	$4,000
Concrete Pad for Chemical Tank	4	C.Y.	$350	$1,296	NA	$0	$1,300
Concrete Pad for Filter Unit	4	C.Y.	$350	$1,497	NA	$0	$1,500
Belt Filter Press Building	900	S.F.	$50	$45,000	NA	$0	$45,000
New Chlorine Contact Basin	56	C.Y.	$500	$27,833	NA	$0	$27,800
Paving	111	S.Y.	$35	$3,889	NA	$0	$3,900
						Subtotal	$88,000
						Prof. Services (2) (15%)	$13,000
						Contingencies (25%)	$22,000
						OH&P (15%)	$13,000
						Total Structures Cost	**$136,000**

Total Capital Cost **$1,287,000**

II. *Annual Operation and Maintenance (O&M) Cost*

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Alum	20,051	GAL	$1.00	$20,051	NA	$0	$20,100
Polymer	730	LB	$2.50	$1,825	NA	$0	$1,800
Maintenance	1	Per Year	3%	$16,647	NA	$0	$16,600
Power	32,351	kW-HR	$0.07	$2,265	NA	$0	$2,300
Labor	208	hrs/yr	$20.00	$4,160	NA	$0	$4,200
Additional Sludge Disposal	137	C.Y.	$15	$2,055	NA	$0	$2,100
						Total Annual O&M Cost	**$47,000**

III. *Annualized Cost*

Annualized Capital Cost	$ 76,000
Annual O&M Cost	$ 47,000
TOTAL ANNUALIZED COST	**$ 123,000**
Cost per Pound Phosphorus Removed Per Year*	**$ 25.66**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-4
Chemical Phosphorus Removal at Stephenville WWTP
Preliminary Cost Opinion (1)

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
I. Capital Costs							
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$18,556	NA	$0	$18,600
Site Preparation	1	L.S.	5%	$17,673	NA	$0	$17,700
2 - 8,000 gal Alum Storage Tanks	2	Each	$14,500	$29,000	35%	$10,150	$39,200
1" Alum Feed Line	50	L.F.	$20	$1,000	NA	$0	$1,000
Alum Feed Pumps	2	Each	$5,200	$10,400	35%	$3,640	$14,000
Sludge Feed Pumps	2	Each	$5,200	$10,400	35%	$3,640	$14,000
4" Sludge Feed Line	500	L.F.	$30	$15,000	NA	$0	$15,000
Polymer Feed Unit	1	Each	$15,000	$15,000	35%	$5,250	$20,300
Conveyor	1	Each	$25,000	$25,000	35%	$8,750	$33,800
2-Meter Belt Press	1	Each	$225,000	$225,000	65%	$146,250	$371,300
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	400	L.F.	$30	$12,000	NA	$0	$12,000
Electrical Conduit to Belt Filter Presses	100	L.F.	$30	$3,000	NA	$0	$3,000
Motor Controls, Instrumentation, Misc.	1	L.S.	$78,000	$78,000	NA	$0	$78,000
Sedimentation/Erosion Control	1,260	L.F.	$2	$2,520	NA	$0	$2,500
Loaming/Hydroseeding	111	S.Y.	$1.20	$133	NA	$0	$100
						Subtotal	$646,000
						Prof. Services (2) (15%)	$97,000
						Contingencies (25%)	$162,000
						OH&P (15%)	$97,000
						Total Equipment Cost	**$1,002,000**
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$2,608	NA	$0	$2,600
Site Preparation	1	L.S.	5%	$2,484	NA	$0	$2,500
Concrete Pad For Chemical Tanks	4	C.Y.	$350	$1,569	NA	$0	$1,600
Belt Filter Press Building	900	S.F.	$50	$45,000	NA	$0	$45,000
Paving	89	S.Y.	$35	$3,111	NA	$0	$3,100
						Subtotal	$55,000
						Prof. Services (2) (15%)	$8,000
						Contingencies (25%)	$14,000
						OH&P (15%)	$8,000
						Total Structures Cost	**$85,000**
						Total Capital Cost	**$1,087,000**
II. Annual Operation and Maintenance (O&M) Cost							
Alum	144,540	GAL	$1.00	$144,540	NA	$0	$144,500
Polymer	3,285	LB	$2.50	$8,213	NA	$0	$8,200
Maintenance	1	Per Year	3%	$13,602	NA	$0	$13,600
Power	261,838	kW-HR	$0.07	$18,329	NA	$0	$18,300
Labor	312	hrs/yr	$20.00	$6,240	NA	$0	$6,200
Additional Sludge Disposal	911	C.Y.	$15	$13,665	NA	$0	$13,700
						Total Annual O&M Cost	**$205,000**

III. Annualized Cost

Annualized Capital Cost	$ 64,000
Annual O&M Cost	$ 205,000
TOTAL ANNUALIZED COST	**$ 269,000**
Cost per Pound Phosphorus Removed Per Year [4]	**$ 8.42**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.

Table D-5
Chemical Phosphorus Removal at Valley Mills WWTP
Preliminary Cost Opinion [1]

I. Capital Costs

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$9,970	NA	$0	$10,000
Site Preparation	1	L.S.	5%	$8,305	NA	$0	$8,300
Oxidation Ditch Rotor and Wiring	1	Each	$25,000	$25,000	35%	$8,750	$33,800
1 - 2500 gal Alum Storage Tank	1	Each	$6,000	$6,000	35%	$2,100	$8,100
1" Alum Feed Line	20	L.F.	$20	$400	NA	$0	$400
Alum Feed Pumps	2	Each	$5,200	$10,400	35%	$3,640	$14,000
4-Disk Filter Unit	1	Each	$135,000	$135,000	35%	$47,250	$182,300
Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
Relocate Chlorine Lines	40	L.F.	$20	$800	NA	$0	$800
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
Electrical Conduit to Filters	100	L.F.	$30	$3,000	NA	$0	$3,000
Motor Controls, Instrumentation, Misc.	1	L.S.	$42,000	$42,000	NA	$0	$42,000
Sedimentation/Erosion Control	620	L.F.	$2	$1,240	NA	$0	$1,200
Loaming/Hydroseeding	50	S.Y.	$1.20	$60	NA	$0	$100
						Subtotal	$313,000
						Prof. Services [2] (15%)	$47,000
						Contingencies (25%)	$78,000
						OH&P (15%)	$47,000
						Total Equipment Cost	**$485,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$1,598	NA	$0	$1,600
Site Preparation	1	L.S.	5%	$1,471	NA	$0	$1,500
Concrete Pad for Chemical Tank	3	C.Y.	$350	$1,050	NA	$0	$1,100
Concrete Pad for Filter Unit	4	C.Y.	$350	$1,497	NA	$0	$1,500
Relocate Chlorine Building	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Sludge Drying Beds	55	C.Y.	$350	$19,081	NA	$0	$19,100
Paving	110	S.Y.	$35	$3,850	NA	$0	$3,900
						Subtotal	$34,000
						Prof. Services [2] (15%)	$5,000
						Contingencies (25%)	$9,000
						OH&P (15%)	$5,000
						Total Structures Cost	**$53,000**
						Total Capital Cost	**$538,000**

II. Annual Operation and Maintenance (O&M) Cost

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Alum	17,520	GAL	$1.00	$17,520	NA	$0	$17,500
Maintenance	1	Per Year	3%	$6,903	NA	$0	$6,900
Power	135,002	kW-HR	$0.07	$9,450	NA	$0	$9,500
Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
Additional Sludge Disposal	109	C.Y.	$15	$1,635	NA	$0	$1,600
						Total Annual O&M Cost	**$38,000**

III. Annualized Cost

Annualized Capital Cost	$ 32,000
Annual O&M Cost	$ 38,000
TOTAL ANNUALIZED COST	$ 70,000
Cost per Pound Phosphorus Removed Per Year [4]	$ 18.25

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-6
Biological Phosphorus Removal at Clifton WWTP
Preliminary Cost Opinion [1]

I. *Capital Costs*

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$11,431	NA	$0	$11,400
Site Preparation	1	L.S.	5%	$10,887	NA	$0	$10,900
1 - 1500 gal Alum Storage Tank	1	Each	$4,000	$4,000	35%	$1,400	$5,400
1" Alum Feed Line	50	L.F.	$20	$1,000	NA	$0	$1,000
Alum Feed Pumps	2	Each	$5,200	$10,400	35%	$3,640	$14,000
4-Disk Filter Unit	1	Each	$135,000	$135,000	35%	$47,250	$182,300
Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
Ten Mixers for Anaerobic Cycle	6	Each	$6,976	$41,856	35%	$14,650	$56,500
Additional Electrical for Mixers	1	L.S.	$12,000	$12,000	NA	$0	$12,000
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	80	L.F.	$30	$2,400	NA	$0	$2,400
Electrical Conduit to Filter Unit	150	L.F.	$30	$4,500	NA	$0	$4,500
Motor Controls, Instrumentation, Misc.	1	L.S.	$48,000	$48,000	NA	$0	$48,000
Sedimentation/Erosion Control	160	L.F.	$2	$320	NA	$0	$300
Loaming/Hydroseeding	50	S.Y.	$1.20	$60	NA	$0	$100
						Subtotal	$355,000
						Prof. Services [2] (15%)	$53,000
						Contingencies (25%)	$89,000
						OH&P (15%)	$53,000
						Total Equipment Cost	**$527,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$162	NA	$0	$200
Site Preparation	1	L.S.	5%	$155	NA	$0	$200
Concrete Pad for Filter Unit	4.1	C.Y.	$350	$1,426	NA	$0	$1,400
Concrete Pad For Chemical Tank	1.3	C.Y.	$350	$467	NA	$0	$500
Fence Modifications	60	L.F.	$20	$1,200	NA	$0	$1,200
						Subtotal	$4,000
						Prof. Services [2] (15%)	$600
						Contingencies (25%)	$1,000
						OH&P (15%)	$600
						Total Structures Cost	**$6,000**

Total Capital Cost $533,000

II. *Annual Operation and Maintenance (O&M) Cost*

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Alum	11,680	GAL	$1.00	$11,680	NA	$0	$11,700
Maintenance	1	Per Year	3%	$5,889	NA	$0	$5,900
Power	4,355	kW-HR	$0.07	$305	NA	$0	$300
Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
Additional Elec. For Mixers	1	LS	$3,000	$3,000	NA	$0	$3,000
Additional Sludge Disposal	70	C.Y.	$15	$1,050	NA	$0	$1,100
						Total Annual O&M Cost	**$24,000**

III. *Annualized Cost*

Annualized Capital Cost	$ 32,000
Annual O&M Cost	$ 24,000
TOTAL ANNUALIZED COST	$ 56,000
Cost per Pound Phosphorus Removed Per Year[4]	$ 28.31

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-6a
Chemical Phosphorus Removal at Clifton WWTP
Preliminary Cost Opinion (1)

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
I. Capital Costs							
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$8,919	NA	$0	$8,900
Site Preparation	1	L.S.	5%	$8,494	NA	$0	$8,500
1 - 4000 gal Alum Storage Tank	1	Each	$10,000	$10,000	35%	$3,500	$13,500
1" Alum Feed Line	50	L.F.	$20	$1,000	NA	$0	$1,000
Alum Feed Pumps	2	Each	$5,200	$10,400	35%	$3,640	$14,000
4-Disk Filter Unit	1	Each	$135,000	$135,000	35%	$47,250	$182,300
Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	80	L.F.	$30	$2,400	NA	$0	$2,400
Electrical Conduit to Filter Unit	150	L.F.	$30	$4,500	NA	$0	$4,500
Motor Controls, Instrumentation, Misc.	1	L.S.	$37,000	$37,000	NA	$0	$37,000
Sedimentation/Erosion Control	160	L.F.	$2	$320	NA	$0	$300
Loaming/Hydroseeding	50	S.Y.	$1.20	$60	NA	$0	$100
						Subtotal	$279,000
						Prof. Services (2) (15%)	$42,000
						Contingencies (25%)	$70,000
						OH&P (15%)	$42,000
						Total Equipment Cost	**$433,000**
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$206	NA	$0	$200
Site Preparation	1	L.S.	5%	$196	NA	$0	$200
Concrete Pad for Filter Unit	4.1	C.Y.	$350	$1,426	NA	$0	$1,400
Concrete Pad For Chemical Tank	4	C.Y.	$350	$1,296	NA	$0	$1,300
Fence Modifications	60	L.F.	$20	$1,200	NA	$0	$1,200
						Subtotal	$4,000
						Prof. Services (2) (15%)	$600
						Contingencies (25%)	$1,000
						OH&P (15%)	$600
						Total Structures Cost	**$6,000**
						Total Capital Cost	**$439,000**
II. Annual Operation and Maintenance (O&M) Cost							
Alum	31,310	GAL	$1.00	$31,310	NA	$0	$31,300
Maintenance	1	Per Year	3%	$5,889	NA	$0	$5,900
Power	4,355	kW-HR	$0.07	$305	NA	$0	$300
Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
Additional Sludge Disposal	70	C.Y.	$15	$1,050	NA	$0	$1,100
						Total Annual O&M Cost	**$41,000**

III. Annualized Cost

Annualized Capital Cost	$ 27,000
Annual O&M Cost	$ 41,000
TOTAL ANNUALIZED COST	**$ 68,000**
Cost per Pound Phosphorus Removed Per Year [4]	**$ 34.38**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services

(3) Item costs and subtotals are rounded to an appropriate number of significant figures.

(4) Based on a discharge of 0.5 ppm.

Table D-7
Biological Phosphorus Removal at Hico WWTP
Preliminary Cost Opinion (1)

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
I. Capital Costs							
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$10,320	NA	$0	$10,300
Site Preparation	1	L.S.	5%	$9,828.19	NA	$0	$9,800
1 - 500 gal Alum Storage Tank	1	Each	$1,600	$1,600	35%	$560	$2,200
1" Alum Feed Line	100	L.F.	$20	$2,000	NA	$0	$2,000
Alum Feed Pumps	2	Each	$4,800	$9,600	35%	$3,360	$13,000
2-Disk Filter Unit	1	Each	$115,000	$115,000	35%	$40,250	$155,300
Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
Mixers in Anaerobic Digester	2	Each	$15,000	$30,000	35%	$10,500	$40,500
6" RAS/Raw Water Lines	390	L.F.	$35	$13,650	NA	$0	$13,700
Sludge Drying Bed 1" Water Line	100	L.F.	$20	$2,000	NA	$0	$2,000
Sludge Drying Bed 6" RAS Piping	100	L.F.	$35	$3,500	NA	$0	$3,500
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	200	L.F.	$30	$6,000	NA	$0	$6,000
Electrical Conduit to Filters	50	L.F.	$30	$1,500	NA	$0	$1,500
Electrical Conduit to Anaerobic Mixers	120	L.F.	$30	$3,600	NA	$0	$3,600
Motor Controls, Instrumentation, Misc.	1	L.S.	$43,000	$43,000	NA	$0	$43,000
Sedimentation/Erosion Control	900	L.F.	$2	$1,800	NA	$0	$1,800
Loaming/Hydroseeding	95	S.Y.	$1.20	$114	NA	$0	$100
						Subtotal	$315,000
						Prof. Services (2) (15%)	$47,000
						Contingencies (25%)	$79,000
						OH&P (15%)	$47,000
						Total Equipment Cost	**$488,000**
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$4,020	NA	$0	$4,000
Site Preparation	1	L.S.	5%	$3,829	NA	$0	$3,800
Anaerobic Basin	44	C.Y.	$500	$22,000	NA	$0	$22,000
Concrete Pad for Filter Unit	4	C.Y.	$350	$1,225	NA	$0	$1,200
Concrete Pad For Chemical Tank	1	C.Y.	$350	$467	NA	$0	$500
Sludge Drying Beds	151	C.Y.	$350	$52,889	NA	$0	$52,900
						Subtotal	$84,000
						Prof. Services (2) (15%)	$13,000
						Contingencies (25%)	$21,000
						OH&P (15%)	$13,000
						Total Structures Cost	**$131,000**
						Total Capital Cost	**$619,000**

II. Annual Operation and Maintenance (O&M) Cost

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Alum	3,650	GAL	$1.00	$3,650	NA	$0	$3,700
Maintenance	1	Per Year	3%	$6,264	NA	$0	$6,300
Power	200,325	kW-HR	$0.07	$14,023	NA	$0	$14,000
Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
Additional Sludge Disposal	22	C.Y.	$15	$330	NA	$0	$330
						Total Annual O&M Cost	**$26,000**

III. Annualized Cost

Annualized Capital Cost	$ 35,000
Annual O&M Cost	$ 26,000
TOTAL ANNUALIZED COST	**$ 61,000**
Cost per Pound Phosphorus Removed Per Year[4]	**$ 28.63**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-8
Biological Phosphorus Removal at Iredell WWTP
Preliminary Cost Opinion (1)

	Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
I.	***Capital Costs***							
	Equipment							
	Insurance, Bonds Move-In, etc.	1	L.S.	5%	$10,090	NA	$0	$10,100
	Site Preparation	1	L.S.	5%	$9,609	NA	$0	$9,600
	1 - 150 gal Alum Storage Tank	1	Each	$1,000	$1,000	35%	$350	$1,400
	1" Alum Feed Line	100	L.F.	$20	$2,000	NA	$0	$2,000
	Alum Feed Pumps	2	Each	$4,800	$9,600	35%	$3,360	$13,000
	1-Disk Filter Unit	1	Each	$110,000	$110,000	35%	$38,500	$148,500
	Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
	Mixers in Anaerobic Digester	2	Each	$15,000	$30,000	35%	$10,500	$40,500
	4" RAS Line	200	L.F.	$30	$6,000	NA	$0	$6,000
	4" Influent Line	20	L.F.	$30	$600	NA	$0	$600
	Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
	Electrical Conduit to Alum Feed Pumps	20	L.F.	$30	$600	NA	$0	$600
	Electrical Conduit to Filters	20	L.F.	$30	$600	NA	$0	$600
	Electrical Conduit to Anaerobic Mixers	200	L.F.	$30	$6,000	NA	$0	$6,000
	Motor Controls, Instrumentation, Misc.	1	L.S.	$42,000	$42,000	NA	$0	$42,000
	Sedimentation/Erosion Control	1,000	L.F.	$2	$2,000	NA	$0	$2,000
	Loaming/Hydroseeding	1,319	S.Y.	$1.20	$1,583	NA	$0	$1,600
	Lift Station Pump Modifications	1	L.S.	$15,000	$15,000	NA	$0	$15,000
	New Bar Screen	1	L.S.	$1,000	$1,000	NA	$0	$1,000
							Subtotal	$307,000
							Prof. Services (2) (15%)	$46,000
							Contingencies (25%)	$77,000
							OH&P (15%)	$46,000
							Total Equipment Cost	**$476,000**

	Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
	Structures							
	Insurance, Bonds Move-In, etc.	1	L.S.	5%	$4,136	NA	$0	$4,100
	Site Preparation	1	L.S.	5%	$3,939	NA	$0	$3,900
	Anaerobic Basin	10	C.Y.	$500	$5,243	NA	$0	$5,200
	Concrete Pad for Filter Unit	4	C.Y.	$350	$1,225	NA	$0	$1,200
	Demo Chlorine Basin	1	L.S.	$10,000	$10,000	NA	$0	$10,000
	New Chlorine Contact Basin	40	C.Y.	$500	$20,069	NA	$0	$20,100
	New Sludge Drying Beds	55	C.Y.	$350	$19,185	NA	$0	$19,200
	Fence Modifications	320	L.F.	$20	$6,400	NA	$0	$6,400
	Structural Fill	1,389	C.Y.	$12	$16,667	NA	$0	$16,700
							Subtotal	$87,000
							Prof. Services (2) (15%)	$13,000
							Contingencies (25%)	$22,000
							OH&P (15%)	$13,000
							Total Structures Cost	**$135,000**
							Total Capital Cost	**$611,000**

	Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
II.	***Annual Operation and Maintenance (O&M) Cost***							
	Alum	730	GAL	$1.00	$730	NA	$0	$700
	Maintenance	1	Per Year	3%	$6,060	NA	$0	$6,100
	Power	135,002	kW-HR	$0.07	$9,450	NA	$0	$9,500
	Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
	Additional Sludge Disposal	5	C.Y.	$15	$75	NA	$0	$80
							Total Annual O&M Cost	**$18,000**

III. Annualized Cost

Annualized Capital Cost	$ 35,000
Annual O&M Cost	$ 18,000
TOTAL ANNUALIZED COST	**$ 53,000**
Cost per Pound Phosphorus Removed Per Year (4)	**$ 99.44**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-9
Biological Phosphorus Removal at Meridian WWTP
Preliminary Cost Opinion (1)

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
I. Capital Costs							
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$23,739	NA	$0	$23,700
Site Preparation	1	L.S.	5%	$22,609	NA	$0	$22,600
1 - 1,000 gal Alum Storage Tank	1	Each	$2,900	$2,900	35%	$1,015	$3,900
1" Alum Feed Line	100	L.F.	$20	$2,000	NA	$0	$2,000
Alum Feed Pumps	2	Each	$4,800	$9,600	35%	$3,360	$13,000
4-Disk Filter Unit	1	Each	$135,000	$135,000	35%	$47,250	$182,300
Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
1 - 7300 gal Sludge Storage Tank	1	Each	$12,500	$12,500	35%	$4,375	$16,900
Sludge Feed Pumps	2	Each	$15,000	$30,000	35%	$10,500	$40,500
4" Sludge Feed Line	20	L.F.	$30	$600	NA	$0	$600
Polymer Feed Unit	1	Each	$15,000	$15,000	35%	$5,250	$20,300
Conveyor	1	Each	$25,000	$25,000	35%	$8,750	$33,800
1-Meter Belt Press	1	Each	$160,000	$160,000	65%	$104,000	$264,000
6" RAS Line	120	L.F.	$35	$4,200	NA	$0	$4,200
Mixers in Anaerobic Digester	2	Each	$15,000	$30,000	35%	$10,500	$40,500
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
Electrical Conduit to Filters	50	L.F.	$30	$1,500	NA	$0	$1,500
Electrical Conduit to Belt Filter Presses	100	L.F.	$30	$3,000	NA	$0	$3,000
Electrical Conduit to Anaerobic Mixers	150	L.F.	$30	$4,500	NA	$0	$4,500
Motor Controls, Instrumentation, Misc.	1	L.S.	$100,000	$100,000	NA	$0	$100,000
Relocate Yard Piping	80	L.F.	$50	$4,000	NA	$0	$4,000
Sedimentation/Erosion Control	1,368	L.F.	$2	$2,736	NA	$0	$2,700
Loaming/Hydroseeding	365	S.Y.	$1.20	$438	NA	$0	$400
						Subtotal	$794,000
						Prof. Services (2) (15%)	$119,000
						Contingencies (25%)	$199,000
						OH&P (15%)	$119,000
						Total Equipment Cost	**$1,231,000**
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$6,506	NA	$0	$6,500
Site Preparation	1	L.S.	5%	$6,196	NA	$0	$6,200
Anaerobic Basin	67	C.Y.	$500	$33,630	NA	$0	$33,600
Concrete Pad for Filter Unit	4	C.Y.	$350	$1,497	NA	$0	$1,500
Concrete Pad For Chemical Tank	1	C.Y.	$350	$467	NA	$0	$500
Belt Filter Press Building	900	S.F.	$50	$45,000	NA	$0	$45,000
Fence Modifications	100	L.F.	$20	$2,000	NA	$0	$2,000
Structural Fill	800	C.Y.	$12	$9,600	NA	$0	$9,600
New Chlorine Contact Basin	56	C.Y.	$500	$27,833	NA	$0	$27,800
Paving	111	S.Y.	$35	$3,889	NA	$0	$3,900
						Subtotal	$137,000
						Prof. Services (2) (15%)	$21,000
						Contingencies (25%)	$34,000
						OH&P (15%)	$21,000
						Total Structures Cost	**$213,000**
						Total Capital Cost	**$1,444,000**
II. Annual Operation and Maintenance (O&M) Cost							
Alum	8,030	GAL	$1.00	$8,030	NA	$0	$8,000
Polymer	548	LB	$2.50	$1,369	NA	$0	$1,400
Maintenance	1	Per Year	3%	$17,832	NA	$0	$17,800
Power	228,321	kW-HR	$0.07	$15,982	NA	$0	$16,000
Labor	208	hrs/yr	$20.00	$4,160	NA	$0	$4,200
Additional Sludge Disposal	49	C.Y.	$15	$735	NA	$0	$740
						Total Annual O&M Cost	**$48,000**

III. Annualized Cost

Annualized Capital Cost	$ 84,000
Annual O&M Cost	$ 48,000
TOTAL ANNUALIZED COST	**$ 132,000**
Cost per Pound Phosphorus Removed Per Year [4]	**$ 27.53**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-10
Biological Phosphorus Removal at Stephenville WWTP
Preliminary Cost Opinion [1]

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
I. Capital Costs							
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$24,393	NA	$0	$24,400
Site Preparation	1	L.S.	5%	$17,803	NA	$0	$17,800
Demo Clarifier Mechanism	2	Each	$10,000	$20,000	NA	$0	$20,000
Selector Basin Fiberglass Baffle Wall	2	Each	$20,000	$40,000	35%	$14,000	$54,000
12" RAS Line	400	L.F.	$60	$24,000	NA	$0	$24,000
Selector Basin Mixers	2	Each	$15,000	$30,000	35%	$10,500	$40,500
1 - 6,400 gal Alum Storage Tank	1	Each	$12,000	$12,000	35%	$4,200	$16,200
1" Alum Feed Line	50	L.F.	$20	$1,000	NA	$0	$1,000
Alum Feed Pumps	2	Each	$5,200	$10,400	35%	$3,640	$14,000
Sludge Feed Pumps	2	Each	$15,000	$30,000	35%	$10,500	$40,500
4" Sludge Feed Line	500	L.F.	$30	$15,000	NA	$0	$15,000
Polymer Feed Unit	1	Each	$15,000	$15,000	35%	$5,250	$20,300
Conveyor	1	Each	$25,000	$25,000	35%	$8,750	$33,800
2-Meter Belt Press	1	Each	$225,000	$225,000	65%	$146,250	$371,300
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	400	L.F.	$30	$12,000	NA	$0	$12,000
Electrical Conduit to Belt Filter Presses	100	L.F.	$30	$3,000	NA	$0	$3,000
Motor Controls, Instrumentation, Misc.	1	L.S.	$102,000	$102,000	NA	$0	$102,000
Sedimentation/Erosion Control	1,260	L.F.	$2	$2,520	NA	$0	$2,500
Loaming/Hydroseeding	111	S.Y.	$1.20	$133	NA	$0	$100
						Subtotal	$817,000
						Prof. Services [2] (15%)	$123,000
						Contingencies (25%)	$204,000
						OH&P (15%)	$123,000
						Total Equipment Cost	**$1,267,000**
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$2,608	NA	$0	$2,600
Site Preparation	1	L.S.	5%	$2,484	NA	$0	$2,500
Concrete Pad For Chemical Tank	4	C.Y.	$350	$1,569	NA	$0	$1,600
Belt Filter Press Building	900	S.F.	$50	$45,000	NA	$0	$45,000
Paving	89	S.Y.	$35	$3,111	NA	$0	$3,100
						Subtotal	$55,000
						Prof. Services [2] (15%)	$8,000
						Contingencies (25%)	$14,000
						OH&P (15%)	$8,000
						Total Structures Cost	**$85,000**
						Total Capital Cost	**$1,352,000**
II. Annual Operation and Maintenance (O&M) Cost							
Alum	54,020	GAL	$1.00	$54,020	NA	$0	$54,000
Polymer	3,103	LB	$2.50	$7,756	NA	$0	$7,800
Maintenance	1	Per Year	3%	$15,612	NA	$0	$15,600
Power	653,505	kW-HR	$0.07	$45,745	NA	$0	$45,700
Labor	312	hrs/yr	$20.00	$6,240	NA	$0	$6,200
Additional Sludge Disposal	325	C.Y.	$15	$4,875	NA	$0	$4,900
						Total Annual O&M Cost	**$134,000**

III. Annualized Cost

Annualized Capital Cost	$ 80,000
Annual O&M Cost	$ 134,000
TOTAL ANNUALIZED COST	**$ 214,000**
Cost per Pound Phosphorus Removed Per Year [4]	**$ 6.70**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-10a
Biological Phosphorus Removal to 0.7mg/L at Stephenville WWTP
Preliminary Cost Opinion [1]

I. Capital Costs

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$24,419	NA	$0	$24,400
Site Preparation	1	L.S.	5%	$17,828	NA	$0	$17,800
Demo Clarifier Mechanism	2	Each	$10,000	$20,000	NA	$0	$20,000
Selector Basin Fiberglass Baffle Wall	2	Each	$20,000	$40,000	35%	$14,000	$54,000
12" RAS Line	400	L.F.	$60	$24,000	NA	$0	$24,000
Selector Basin Mixers	2	Each	$15,000	$30,000	35%	$10,500	$40,500
1 - 6,800 gal Alum Storage Tank	1	Each	$12,500	$12,500	35%	$4,375	$16,900
1" Alum Feed Line	50	L.F.	$20	$1,000	NA	$0	$1,000
Alum Feed Pumps	2	Each	$5,200	$10,400	35%	$3,640	$14,000
Sludge Feed Pumps	2	Each	$15,000	$30,000	35%	$10,500	$40,500
4" Sludge Feed Line	500	L.F.	$30	$15,000	NA	$0	$15,000
Polymer Feed Unit	1	Each	$15,000	$15,000	35%	$5,250	$20,300
Conveyor	1	Each	$25,000	$25,000	35%	$8,750	$33,800
2-Meter Belt Press	1	Each	$225,000	$225,000	65%	$146,250	$371,300
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	400	L.F.	$30	$12,000	NA	$0	$12,000
Electrical Conduit to Belt Filter Presses	100	L.F.	$30	$3,000	NA	$0	$3,000
Motor Controls, Instrumentation, Misc.	1	L.S.	$103,000	$103,000	NA	$0	$103,000
Sedimentation/Erosion Control	1,260	L.F.	$2	$2,520	NA	$0	$2,500
Loaming/Hydroseeding	111	S.Y.	$1.20	$133	NA	$0	$100
						Subtotal	$819,000
						Prof. Services [2] (15%)	$123,000
						Contingencies (25%)	$205,000
						OH&P (15%)	$123,000
						Total Equipment Cost	**$1,270,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$2,608	NA	$0	$2,600
Site Preparation	1	L.S.	5%	$2,484	NA	$0	$2,500
Concrete Pad For Chemical Tank	4	C.Y.	$350	$1,569	NA	$0	$1,600
Belt Filter Press Building	900	S.F.	$50	$45,000	NA	$0	$45,000
Paving	89	S.Y.	$35	$3,111	NA	$0	$3,100
						Subtotal	$55,000
						Prof. Services [2] (15%)	$8,000
						Contingencies (25%)	$14,000
						OH&P (15%)	$8,000
						Total Structures Cost	**$85,000**
						Total Capital Cost	**$1,355,000**

II. Annual Operation and Maintenance (O&M) Cost

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Alum	63,145	GAL	$1.00	$63,145	NA	$0	$63,100
Polymer	3,700	LB	$2.50	$9,250	NA	$0	$9,300
Maintenance	1	Per Year	3%	$15,612	NA	$0	$15,600
Power	653,778	kW-HR	$0.07	$45,764	NA	$0	$45,800
Labor	364	hrs/yr	$20.00	$7,280	NA	$0	$7,300
Additional Sludge Disposal	586	C.Y.	$15	$8,790	NA	$0	$8,800
						Total Annual O&M Cost	**$150,000**

III. Annualized Cost

Annualized Capital Cost	$ 81,000
Annual O&M Cost	$ 150,000
TOTAL ANNUALIZED COST	$ 231,000
Cost per Pound Phosphorus Removed Per Year [4]	$ 7.23

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services

(3) Item costs and subtotals are rounded to an appropriate number of significant figures.

(4) Based on a discharge of 0.5 ppm.

Table D-11
Biological Phosphorus Removal at Valley Mills WWTP
Preliminary Cost Opinion [1]

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
I. Capital Costs							
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$11,577	NA	$0	$11,600
Site Preparation	1	L.S.	5%	$9,835	NA	$0	$9,800
Oxidation Ditch Rotor and Wiring	1	L.S.	$25,000	$25,000	NA	$0	$25,000
1 - 1000 gal Alum Storage Tank	1	Each	$2,800	$2,800	35%	$980	$3,800
1" Alum Feed Line	100	L.F.	$20	$2,000	35%	$700	$2,700
Alum Feed Pumps	2	Each	$4,800	$9,600	35%	$3,360	$13,000
4-Disk Filter Unit	1	Each	$135,000	$135,000	35%	$47,250	$182,300
Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
Mixers in Anaerobic Digester	2	Each	$15,000	$30,000	35%	$10,500	$40,500
Relocate Chlorine Lines	40	L.F.	$20	$800	NA	$0	$800
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
Electrical Conduit to Filters	100	L.F.	$30	$3,000	NA	$0	$3,000
Electrical Conduit to Anaerobic Mixers	100	L.F.	$30	$3,000	NA	$0	$3,000
Motor Controls, Instrumentation, Misc.	1	L.S.	$49,000	$49,000	NA	$0	$49,000
Sedimentation/Erosion Control	620	L.F.	$2	$1,240	NA	$0	$1,200
Loaming/Hydroseeding	50	S.Y.	$1.20	$60	NA	$0	$100
						Subtotal	$355,000
						Prof. Services [2] (15%)	$53,000
						Contingencies (25%)	$89,000
						OH&P (15%)	$53,000
						Total Equipment Cost	**$550,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$3,120	NA	$0	$3,100
Site Preparation	1	L.S.	5%	$2,972	NA	$0	$3,000
Anaerobic Basin	59	C.Y.	$500	$29,537	NA	$0	$29,500
Concrete Pad for Filter Unit	4	C.Y.	$350	$1,497	NA	$0	$1,500
Concrete Pad For Chemical Tank	1	C.Y.	$350	$467	NA	$0	$500
Relocate Chlorine Building	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Sludge Drying Beds	55	C.Y.	$350	$19,081	NA	$0	$19,100
Paving	110	S.Y.	$35	$3,850	NA	$0	$3,900
						Subtotal	$66,000
						Prof. Services [2] (15%)	$10,000
						Contingencies (25%)	$17,000
						OH&P (15%)	$10,000
						Total Structures Cost	**$103,000**
						Total Capital Cost	**$653,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
II. Annual Operation and Maintenance (O&M) Cost							
Alum	6,570	GAL	$1.00	$6,570	NA	$0	$6,600
Maintenance	1	Per Year	3%	$7,074	NA	$0	$7,100
Power	330,971	kW-HR	$0.07	$23,168	NA	$0	$23,200
Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
Additional Sludge Disposal	39	C.Y.	$15	$585	NA	$0	$600
						Total Annual O&M Cost	**$40,000**

III. Annualized Cost

Annualized Capital Cost	$ 38,000
Annual O&M Cost	$ 40,000
TOTAL ANNUALIZED COST	**$ 78,000**
Cost per Pound Phosphorus Removed Per Year[4]	**$ 20.34**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services

(3) Item costs and subtotals are rounded to an appropriate number of significant figures.

(4) Based on a discharge of 0.5 ppm.

Table D-12
A2/O Phosphorus and Nitrogen Removal at Hico WWTP
Preliminary Cost Opinion [1]

I. *Capital Costs*

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$12,258	NA	$0	$12,300
Site Preparation	1	L.S.	5%	$11,673.89	NA	$0	$11,700
1 - 500 gal Alum Storage Tank	1	Each	$1,600	$1,600	35%	$560	$2,200
1" Alum Feed Line	100	L.F.	$20	$2,000	NA	$0	$2,000
Alum Feed Pumps	2	Each	$4,800	$9,600	35%	$3,360	$13,000
2-Disk Filter Unit	1	Each	$115,000	$115,000	35%	$40,250	$155,300
Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
Mixers in Anaerobic Digester	2	Each	$15,000	$30,000	35%	$10,500	$40,500
6" RAS/Raw Water Lines	390	L.F.	$35	$13,650	NA	$0	$13,700
Sludge Drying Bed 1" Water Line	100	L.F.	$20	$2,000	NA	$0	$2,000
Sludge Drying Bed 6" RAS Piping	100	L.F.	$35	$3,500	NA	$0	$3,500
Anoxic Basin Pumps	3	Each	$10,000	$30,000	35%	$10,500	$40,500
10" Anoxic Basin Lines	100	L.F.	$50	$5,000	NA	$0	$5,000
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	200	L.F.	$30	$6,000	NA	$0	$6,000
Electrical Conduit to Filters	50	L.F.	$30	$1,500	NA	$0	$1,500
Electrical Conduit to Anaerobic Mixers	120	L.F.	$30	$3,600	NA	$0	$3,600
Electrical Conduit to Anoxic Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
Motor Controls, Instrumentation, Misc.	1	L.S.	$52,000	$52,000	NA	$0	$52,000
Sedimentation/Erosion Control	1,800	L.F.	$2	$3,600	NA	$0	$3,600
Loaming/Hydroseeding	190	S.Y.	$1.20	$228	NA	$0	$200
						Subtotal	$378,000
						Prof. Services [2] (15%)	$57,000
						Contingencies (25%)	$95,000
						OH&P (15%)	$57,000
						Total Equipment Cost	**$587,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$7,622	NA	$0	$7,600
Site Preparation	1	L.S.	5%	$7,259	NA	$0	$7,300
Anaerobic Basin	44	C.Y.	$500	$22,000	NA	$0	$22,000
Anoxic Basin	132	C.Y.	$500	$66,000	NA	$0	$66,000
Concrete Pad for Anoxic Pumps	7	C.Y.	$350	$2,593	NA	$0	$2,600
Concrete Pad for Filter Unit	4	C.Y.	$350	$1,225	NA	$0	$1,200
Concrete Pad For Chemical Tank	1	C.Y.	$350	$467	NA	$0	$500
Sludge Drying Beds	151	C.Y.	$350	$52,889	NA	$0	$52,900
						Subtotal	$160,000
						Prof. Services [2] (15%)	$40,000
						Contingencies (25%)	$40,000
						OH&P (15%)	$24,000
						Total Structures Cost	**$264,000**
						Total Capital Cost	**$851,000**

II. *Annual Operation and Maintenance (O&M) Cost*

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Alum	3,650	GAL	$1.00	$3,650	NA	$0	$3,700
Maintenance	1	Per Year	3%	$7,479	NA	$0	$7,500
Power	396,295	kW-HR	$0.07	$27,741	NA	$0	$27,700
Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
Additional Sludge Disposal	22	C.Y.	$15	$330	NA	$0	$330
						Total Annual O&M Cost	**$41,000**

III. *Annualized Cost*

Annualized Capital Cost	$ 47,000
Annual O&M Cost	$ 41,000
TOTAL ANNUALIZED COST	**$ 88,000**
Cost per Pound Phosphorus Removed Per Year [4]	**$ 41.30**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services

(3) Item costs and subtotals are rounded to an appropriate number of significant figures.

(4) Based on a discharge of 0.5 ppm.

Table D-13
A2/O Phosphorus and Nitrogen Removal at Iredell WWTP
Preliminary Cost Opinion [1]

I. Capital Costs

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$11,215	NA	$0	$11,200
Site Preparation	1	L.S.	5%	$10,681	NA	$0	$10,700
1 - 150 gal Alum Storage Tank	1	Each	$1,000	$1,000	35%	$350	$1,400
1" Alum Feed Line	100	L.F.	$20	$2,000	NA	$0	$2,000
Alum Feed Pumps	2	Each	$4,800	$9,600	35%	$3,360	$13,000
1-Disk Filter Unit	1	Each	$110,000	$110,000	35%	$38,500	$148,500
Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
Mixers in Anaerobic Digester	2	Each	$15,000	$30,000	35%	$10,500	$40,500
4" RAS Line	200	L.F.	$30	$6,000	NA	$0	$6,000
4" Influent Line	20	L.F.	$30	$600	NA	$0	$600
Anoxic Basin Pumps	2	Each	$7,500	$15,000	35%	$5,250	$20,300
6" Anoxic Basin Lines	100	L.F.	$35	$3,500	NA	$0	$3,500
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	20	L.F.	$30	$600	NA	$0	$600
Electrical Conduit to Filters	20	L.F.	$30	$600	NA	$0	$600
Electrical Conduit to Anaerobic Mixers	200	L.F.	$30	$6,000	NA	$0	$6,000
Electrical Conduit to Anoxic Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
Motor Controls, Instrumentation, Misc.	1	L.S.	$48,000	$48,000	NA	$0	$48,000
Sedimentation/Erosion Control	1,680	L.F.	$2	$3,360	NA	$0	$3,400
Loaming/Hydroseeding	2,638	S.Y.	$1.20	$3,165	NA	$0	$3,200
Lift Station Pump Modifications	1	L.S.	$15,000	$15,000	NA	$0	$15,000
New Bar Screen	1	L.S.	$1,000	$1,000	NA	$0	$1,000
						Subtotal	$345,000
						Prof. Services [2] (15%)	$52,000
						Contingencies (25%)	$86,000
						OH&P (15%)	$52,000
						Total Equipment Cost	**$535,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$5,962	NA	$0	$6,000
Site Preparation	1	L.S.	5%	$5,678	NA	$0	$5,700
Anaerobic Basin	10	C.Y.	$500	$5,243	NA	$0	$5,200
Anoxic Basin	31	C.Y.	$500	$15,729	NA	$0	$15,700
Concrete Pad for Anoxic Pumps	7	C.Y.	$350	$2,593	NA	$0	$2,600
Demo Chlorine Basin	1	L.S.	$10,000	$10,000	NA	$0	$10,000
New Chlorine Contact Basin	40	C.Y.	$500	$20,069	NA	$0	$20,100
New Sludge Drying Beds	55	C.Y.	$350	$19,185	NA	$0	$19,200
Fence Modifications	370	L.F.	$20	$7,400	NA	$0	$85,000
Structural Fill	2,778	C.Y.	$12	$33,333	NA	$0	$33,300
						Subtotal	$203,000
						Prof. Services [2] (15%)	$30,000
						Contingencies (25%)	$51,000
						OH&P (15%)	$30,000
						Total Structures Cost	**$314,000**
						Total Capital Cost	**$849,000**

II. Annual Operation and Maintenance (O&M) Cost

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Alum	730	GAL	$1.00	$730	NA	$0	$700
Maintenance	1	Per Year	3%	$6,669	NA	$0	$6,700
Power	167,663	kW-HR	$0.07	$11,736	NA	$0	$11,700
Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
Additional Sludge Disposal	5	C.Y.	$15	$75	NA	$0	$80
						Total Annual O&M Cost	**$21,000**

III. Annualized Cost

Annualized Capital Cost	$ 46,000
Annual O&M Cost	$ 21,000
TOTAL ANNUALIZED COST	$ 67,000
Cost per Pound Phosphorus Removed Per Year [4]	$ 125.70

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-14
A2/O Phosphorus and Nitrogen Removal at Meridian WWTP
Preliminary Cost Opinion [1]

	Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
I.	***Capital Costs***							
	Equipment							
	Insurance, Bonds Move-In, etc.	1	L.S.	5%	$25,251	NA	$0	$25,300
	Site Preparation	1	L.S.	5%	$24,048	NA	$0	$24,000
	1 - 1,000 gal Alum Storage Tank	1	Each	$2,800	$2,800	35%	$980	$3,800
	1" Alum Feed Line	100	L.F.	$20	$2,000	NA	$0	$2,000
	Alum Feed Pumps	2	Each	$4,800	$9,600	35%	$3,360	$13,000
	4-Disk Filter Unit	1	Each	$135,000	$135,000	35%	$47,250	$182,300
	Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
	1 - 7300 gal Sludge Storage Tank	1	Each	$12,500	$12,500	35%	$4,375	$16,900
	Sludge Feed Pumps	2	Each	$15,000	$30,000	35%	$10,500	$40,500
	4" Sludge Feed Line	20	L.F.	$30	$600	NA	$0	$600
	Polymer Feed Unit	1	Each	$15,000	$15,000	35%	$5,250	$20,300
	Conveyor	1	Each	$25,000	$25,000	35%	$8,750	$33,800
	1-Meter Belt Press	1	Each	$160,000	$160,000	65%	$104,000	$264,000
	6" RAS Line	120	L.F.	$35	$4,200	NA	$0	$4,200
	Mixers in Anaerobic Digester	2	Each	$15,000	[illegible]0,000	35%	$10,500	$40,500
	Anoxic Basin Pumps	2	Each	$10,000	$20,000	35%	$7,000	$27,000
	10" Anoxic Basin Lines	100	L.F.	$50	$5,000	NA	$0	$5,000
	Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
	Electrical Conduit to Alum Feed Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
	Electrical Conduit to Filters	50	L.F.	$30	$1,500	NA	$0	$1,500
	Electrical Conduit to Belt Filter Presses	100	L.F.	$30	$3,000	NA	$0	$3,000
	Electrical Conduit to Anaerobic Mixers	150	L.F.	$30	$4,500	NA	$0	$4,500
	Electrical Conduit to Anoxic Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
	Motor Controls, Instrumentation, Misc.	1	L.S.	$107,000	$107,000	NA	$0	$107,000
	Relocate Yard Piping	80	L.F.	$50	$4,000	NA	$0	$4,000
	Sedimentation/Erosion Control	3,096	L.F.	$2	$6,192	NA	$0	$6,200
	Loaming/Hydroseeding	730	S.Y.	$1.20	$876	NA	$0	$900
							Subtotal	$843,000
							Prof. Services [2] (15%)	$126,000
							Contingencies (25%)	$211,000
							OH&P (15%)	$126,000
							Total Equipment Cost	**$1,306,000**
	Structures							
	Insurance, Bonds Move-In, etc.	1	L.S.	5%	$12,337	NA	$0	$12,300
	Site Preparation	1	L.S.	5%	$11,750	NA	$0	$11,700
	Anaerobic Basin	67	C.Y.	$500	$33,630	NA	$0	$33,600
	Anoxic Basin	202	C.Y.	$500	$100,889	NA	$0	$100,900
	Concrete Pad for Anoxic Pumps	7	C.Y.	$350	$2,593	NA	$0	$2,600
	Concrete Pad for Filter Unit	4	C.Y.	$350	$1,497	NA	$0	$1,500
	Concrete Pad For Chemical Tank	1	C.Y.	$350	$467	NA	$0	$500
	Belt Filter Press Building	900	S.F.	$50	$45,000	NA	$0	$45,000
	Fence Modifications	120	L.F.	$20	$2,400	NA	$0	$2,400
	Structural Fill	1,400	C.Y.	$12	$16,800	NA	$0	$16,800
	New Chlorine Contact Basin	56	C.Y.	$500	$27,833	NA	$0	$27,800
	Paving	111	S.Y.	$35	$3,889	NA	$0	$3,900
							Subtotal	$259,000
							Prof. Services [2] (15%)	$39,000
							Contingencies (25%)	$65,000
							OH&P (15%)	$39,000
							Total Structures Cost	**$402,000**
							Total Capital Cost	**$1,708,000**
II.	***Annual Operation and Maintenance (O&M) Cost***							
	Alum	8,030	GAL	$1.00	$8,030	NA	$0	$8,000
	Polymer	548	LB	$2.50	$1,369	NA	$0	$1,400
	Maintenance	1	Per Year	3%	$18,642	NA	$0	$18,600
	Power	358,967	kW-HR	$0.07	$25,128	NA	$0	$25,100
	Labor	208	hrs/yr	$20.00	$4,160	NA	$0	$4,200
	Additional Sludge Disposal	49	C.Y.	$15	$735	NA	$0	$700
							Total Annual O&M Cost	**$58,000**

III. Annualized Cost

Annualized Capital Cost	$ 96,000
Annual O&M Cost	$ 58,000
TOTAL ANNUALIZED COST	**$ 154,000**
Cost per Pound Phosphorus Removed Per Year [4]	**$ 32.12**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services

(3) Item costs and subtotals are rounded to an appropriate number of significant figures.

(4) Based on a discharge of 0.5 ppm.

Table D-15
A2/O Phosphorus and Nitrogen Removal at Stephenville WWTP
Preliminary Cost Opinion [1]

I. Capital Costs

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Equipment							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$27,787	NA	$0	$27,800
Site Preparation	1	L.S.	5%	$21,035	NA	$0	$21,000
Demo Clarifier Mechanism	2	Each	$10,000	$20,000	NA	$0	$20,000
Selector Basin Fiberglass Baffle Wall	2	Each	$20,000	$40,000	35%	$14,000	$54,000
12" RAS Line	400	L.F.	$60	$24,000	NA	$0	$24,000
Selector Basin Mixers	2	Each	$15,000	$30,000	35%	$10,500	$40,500
1 - 6,400 gal Alum Storage Tank	1	Each	$12,000	$12,000	35%	$4,200	$16,200
1" Alum Feed Line	50	L.F.	$20	$1,000	NA	$0	$1,000
Alum Feed Pumps	2	Each	$5,200	$10,400	35%	$3,640	$14,000
Sludge Feed Pumps	2	Each	$15,000	$30,000	35%	$10,500	$40,500
4" Sludge Feed Line	500	L.F.	$30	$15,000	NA	$0	$15,000
Polymer Feed Unit	1	Each	$15,000	$15,000	35%	$5,250	$20,300
Conveyor	1	Each	$25,000	$25,000	35%	$8,750	$33,800
2-Meter Belt Press	1	Each	$225,000	$225,000	65%	$146,250	$371,300
Anoxic Basin Pumps	4	Each	$12,500	$50,000	35%	$17,500	$67,500
24" Anoxic Basin Lines	100	L.F.	$120	$12,000	NA	$0	$12,000
Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
Electrical Conduit to Alum Feed Pumps	400	L.F.	$30	$12,000	NA	$0	$12,000
Electrical Conduit to Belt Filter Presses	100	L.F.	$30	$3,000	NA	$0	$3,000
Electrical Conduit to Anoxic Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
Motor Controls, Instrumentation, Misc.	1	L.S.	$117,000	$117,000	NA	$0	$117,000
Sedimentation/Erosion Control	2,520	L.F.	$2	$5,040	NA	$0	$5,000
Loaming/Hydroseeding	222	S.Y.	$1.20	$267	NA	$0	$300
						Subtotal	$924,000
						Prof. Services [2] (15%)	$139,000
						Contingencies (25%)	$231,000
						OH&P (15%)	$139,000
						Total Equipment Cost	**$1,433,000**

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Structures							
Insurance, Bonds Move-In, etc.	1	L.S.	5%	$38,123	NA	$0	$38,100
Site Preparation	1	L.S.	5%	$36,308	NA	$0	$36,300
Concrete Pad For Chemical Tank	4	C.Y.	$350	$1,569	NA	$0	$1,600
Anoxic Basin	1,345	C.Y.	$500	$672,593	NA	$0	$672,600
Concrete Pad for Anoxic Pumps	11	C.Y.	$350	$3,889	NA	$0	$3,900
Belt Filter Press Building	900	S.F.	$50	$45,000	NA	$0	$45,000
Paving	89	S.Y.	$35	$3,111	NA	$0	$3,100
						Subtotal	$801,000
						Prof. Services [2] (15%)	$120,000
						Contingencies (25%)	$200,000
						OH&P (15%)	$120,000
						Total Structures Cost	**$1,241,000**
						Total Capital Cost	**$2,674,000**

II. Annual Operation and Maintenance (O&M) Cost

Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
Alum	54,020	GAL	$1.00	$54,020	NA	$0	$54,000
Polymer	3,103	LB	$2.50	$7,756	NA	$0	$7,800
Maintenance	1	Per Year	3%	$17,637	NA	$0	$17,600
Power	849,475	kW-HR	$0.07	$59,463	NA	$0	$59,500
Labor	312	hrs/yr	$20.00	$6,240	NA	$0	$6,200
Additional Sludge Disposal	325	C.Y.	$15	$4,875	NA	$0	$4,900
						Total Annual O&M Cost	**$150,000**

III. Annualized Cost

Annualized Capital Cost	$ 140,000
Annual O&M Cost	$ 150,000
TOTAL ANNUALIZED COST	**$ 290,000**
Cost per Pound Phosphorus Removed Per Year [4]	**$ 9.07**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.

Table D-16
A2/O Phosphorus and Nitrogen Removal at Valley Mills WWTP
Preliminary Cost Opinion [1]

	Item	No.	Unit	Unit Cost	Estimated Raw Cost	Installation Factor	Installation Cost	Item Cost
I.	***Capital Costs***							
	Equipment							
	Insurance, Bonds Move-In, etc.	1	L.S.	5%	$12,958	NA	$0	$13,000
	Site Preparation	1	L.S.	5%	$11,150	NA	$0	$11,200
	Oxidation Ditch Rotor and Wiring	1	L.S.	$25,000	$25,000	NA	$0	$25,000
	1 - 1000 gal Alum Storage Tank	1	Each	$2,800	$2,800	35%	$980	$3,800
	1" Alum Feed Line	100	L.F.	$20	$2,000	35%	$700	$2,700
	Alum Feed Pumps	2	Each	$4,800	$9,600	35%	$3,360	$13,000
	4-Disk Filter Unit	1	Each	$135,000	$135,000	35%	$47,250	$182,300
	Filter Piping	40	L.F.	$30	$1,200	NA	$0	$1,200
	Mixers in Anaerobic Digester	2	Each	$15,000	$30,000	35%	$10,500	$40,500
	Relocate Chlorine Lines	40	L.F.	$20	$800	NA	$0	$800
	Anoxic Basin Pumps	2	Each	$10,000	$20,000	35%	$7,000	$27,000
	10" Anoxic Basin Lines	100	L.F.	$50	$5,000	NA	$0	$5,000
	Electrical Junction Boxes	1	L.S.	$5,000	$5,000	NA	$0	$5,000
	Electrical Conduit to Alum Feed Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
	Electrical Conduit to Filters	100	L.F.	$30	$3,000	NA	$0	$3,000
	Electrical Conduit to Anaerobic Mixers	100	L.F.	$30	$3,000	NA	$0	$3,000
	Electrical Conduit to Anoxic Pumps	100	L.F.	$30	$3,000	NA	$0	$3,000
	Motor Controls, Instrumentation, Misc.	1	L.S.	$55,000	$55,000	NA	$0	$55,000
	Sedimentation/Erosion Control	1,240	L.F.	$2	$2,480	NA	$0	$2,500
	Loaming/Hydroseeding	100	S.Y.	$1.20	$120	NA	$0	$100
							Subtotal	$400,000
							Prof. Services [2] (15%)	$60,000
							Contingencies (25%)	$100,000
							OH&P (15%)	$60,000
							Total Equipment Cost	**$620,000**
	Structures							
	Insurance, Bonds Move-In, etc.	1	L.S.	5%	$7,908	NA	$0	$7,900
	Site Preparation	1	L.S.	5%	$7,532	NA	$0	$7,500
	Anaerobic Basin	59	C.Y.	$500	$29,537	NA	$0	$29,500
	Anoxic Basin	177	C.Y.	$500	$88,611	NA	$0	$88,600
	Concrete Pad for Anoxic Pumps	7	C.Y.	$350	$2,593	NA	$0	$2,600
	Concrete Pad for Filter Unit	4	C.Y.	$350	$1,497	NA	$0	$1,500
	Concrete Pad For Chemical Tank	1	C.Y.	$350	$467	NA	$0	$500
	Relocate Chlorine Building	1	L.S.	$5,000	$5,000	NA	$0	$5,000
	Sludge Drying Beds	55	C.Y.	$350	$19,081	NA	$0	$19,100
	Paving	110	S.Y.	$35	$3,850	NA	$0	$3,900
							Subtotal	$166,000
							Prof. Services [2] (15%)	$25,000
							Contingencies (25%)	$42,000
							OH&P (15%)	$25,000
							Total Structures Cost	**$258,000**
							Total Capital Cost	**$878,000**
II.	***Annual Operation and Maintenance (O&M) Cost***							
	Alum	6,570	GAL	$1.00	$6,570	NA	$0	$6,600
	Maintenance	1	Per Year	3%	$7,884	NA	$0	$7,900
	Power	461,618	kW-HR	$0.07	$32,313	NA	$0	$32,300
	Labor	104	hrs/yr	$20.00	$2,080	NA	$0	$2,100
	Additional Sludge Disposal	39	C.Y.	$15	$585	NA	$0	$600
							Total Annual O&M Cost	**$50,000**

III. ***Annualized Cost***

Annualized Capital Cost	$ 49,000
Annual O&M Cost	$ 50,000
TOTAL ANNUALIZED COST	**$ 99,000**
Cost per Pound Phosphorus Removed Per Year [4]	**$ 25.81**

(1) Estimates do not include:
- legal and administrative expenses
- easements/land acquisition
- permits and fees
- private utility adjustments

(2) Includes engineering, surveying, geotechnical and other professional services
(3) Item costs and subtotals are rounded to an appropriate number of significant figures.
(4) Based on a discharge of 0.5 ppm.