The use of fixed media in aeration tanks has had operational issues. The stagnant biofilm on the fixed media can encourage the growth of higher life forms (red worms), or predators, which graze on the nitrifying bacteria, decreasing the nitrification capacity of the system.

Possible media deterioration can occur due to stretching of media.

The process would have less redundancy than the other two processes because there would be only five treatment trains compared to ten for the other two alternatives.

Experience from pilot and full-scale test facilities has shown that the process is difficult to operate and control. Operational and control parameters are not well known because of the competition between the heterotrophic and autotrophic micro-organisms in their relatively fixed locations within the aeration basins.

Fine screens would be required to reduce the potential for fouling and plugging of the rope media. The fine screening facility would reduce the amount of material that accumulates in the aeration basins but would require additional operation cost and complexity.

III.2.8.4 Reliability

III.2.8.4.1 Step Feed Alternative

The step feed process has been applied to numerous wastewater treatment facilities for biological nitrogen removal. There is considerable operating history for the design of the process to achieve reliability. Consequently, a step feed process can be designed without pilot studies. Operational flexibility of the multiple passes provides redundancy for removal of trains from service. Access to fine bubble diffusers and air piping is relatively easy when taking a cell out of service.

III.2.8.4.2 IFAS Free Floating Media Alternative

IFAS free floating media is being applied to a number of facilities and the operational history and reliability for this process is maturing. In the last five years, several treatment plants, including Broomfield, Colorado and Westerly, Rhode Island have successfully converted to IFAS Free Floating Media processes.

III.2.8.4.3 IFAS Fixed Media Alternative

IFAS fixed media has undergone several changes to reduce the potential for operational issues associated with predation and infestation with red worms. These include retrofitting basins with coarse bubble diffusers to supplement the air requirements and with wasting controls that remove predators or lower their growth rate. However, the process is prone to operational problems due to an inability to continually slough the media and maintain an efficient biofilm thickness. The possibility of anaerobic conditions within the media also is a problem that can have a detrimental effect on plant operations.

III.2.8.5 Constructability

III.2.8.5.1 Step Feed Alternative

Construction of the step feed alternative would be more complex to sequence than the IFAS alternatives because of the configuration of the five-pass process and the need to perform construction in the existing aeration tank influent channels. The treatment plant would need to undergo significant hydraulic modifications during the construction of step feed upgrades. This is a disadvantage that would likely require a longer construction period and impact plant operations for a longer time frame compared to construction of the IFAS free floating media alternative.

III.2.8.5.2 IFAS Free Floating Media Alternative

In contrast to the step feed alternative, the IFAS free floating media retrofit of the existing aeration basins would be much easier to construct. Even if hydraulic modifications were required, each complete mix reactor could be taken out of service one at a time. The construction period would very likely be shorter and there would be less impact to plant operations compared to both the step feed alternative and the IFAS fixed media alternative. Constructability is a distinct advantage of the IFAS free floating media alternative.

III.2.8.5.3 IFAS Fixed Media Alternative

The IFAS fixed media alternative does not have the same advantage as the IFAS free floating media in constructability due to the configuration of the basins and the need to have more aeration volume for the process. The IFAS fixed media alternative requires construction of additional BNR reactors, which would require demolition and replacement of other existing structures at the site. The constructability of this alternative is much more complex, would take considerably more time to complete, and would result in greater impacts to plant operations than the step feed or IFAS free floating media alternatives.

III.2.8.6 Hydraulic Considerations

III.2.8.6.1 General

Currently, primary effluent is lifted approximately 13 feet to the aeration tank influent channel with screw pumps. There are three pumps rated at 37.5 mgd each and one rated at 14 mgd. Two of the 37.5 mgd pumps handle the sustained maximum flow of 77 mgd. The 14 mgd pump adds the capacity to handle the 91 mgd peak hour flow. The pumps lift the flow to a lip at elevation 130.33. The flow spills over the lip into the aeration tank influent channel.

The maximum head available for flow through the aeration tank influent channel and the aeration tanks is the difference in elevation between the screw pump lip and the aeration tank effluent weir. The maximum head available is 1.61 feet. For the hydraulic analyses, the effluent weir elevation was held constant to maintain the original freeboard of 0.25 ft. above the 25-year flood elevation in the aeration effluent channel.

Screw pumps lift flow by pulling it up a trough with rotating spiral flights. The lift capability of the pumps is the physical height of the pump. For reference, Figure III.2.8.5.1-1 shows the type of screw pumps installed at the FPWWTF. Three of the pumps in the photo are installed and one is being lowered into position.

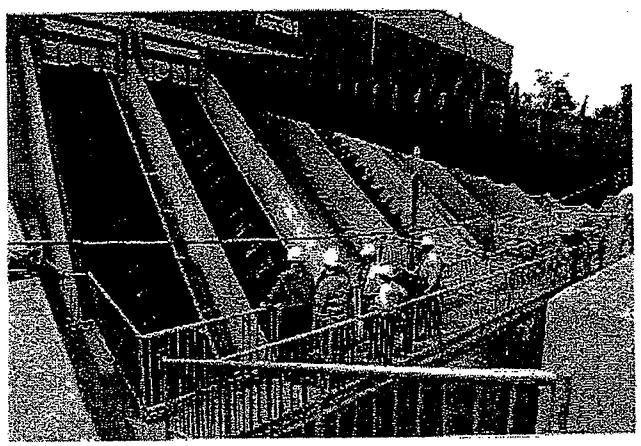

FIGURE III.2.8.5.1-1: SCREW PUMP INSTALLATION

Because the lift of a screw pump depends on its height, the lift of the pump cannot be changed. In comparison, the lift capability of a centrifugal pump can often be changed by simply changing the impeller size or the pump operating speed.

The hydraulic requirements of the three BNR processes were analyzed to determine whether the existing screw pumps could provide sufficient lift to maintain flow through the process tankage. In the existing aeration tanks, hydraulic losses ("head losses") are induced by the aeration tank effluent weirs, the aeration tank influent gates, and the aeration tank influent channels. With the alternative BNR processes, additional hydraulic losses result from flow over and through walls between anoxic and aerobic zones and from primary effluent flow control valves, which are required to balance flow between the process trains. Discussion of the hydraulic analysis for each alternative is presented below.

III.2.8.6.2 Step Feed Alternative

For the step feed process, the existing aeration tanks would be modified by installing baffle walls to isolate the anoxic zones from the aerobic zones and by installing openings and weirs in the walls between the tanks. The flow route would start at existing Tank Nos. 1 and 6 and would end at existing Tank Nos. 5 and 10. Half the return sludge flow would enter Tank No. 1 and half would enter Tank No. 6. One tenth of the primary effluent would enter each tank, and it would enter through a flow meter and control valve so flow to each tank would be equal. A large outflow weir would be installed in Tank Nos. 5 and 10.

The results of the analysis of these three conditions are presented in Table III.2.8.5.2-1.

Table III.2.8.5.2-1: Step Feed Alternative - Hydraulic Analysis

Tanks in Service/Total Plant Flow	Calculated Water Elevation at Aeration Tank Influent Channel and Screw Pump Lip	Screw Pump Lip Elevation	Top of Concrete at Aeration Tanks	Top of Grating Haunch at Aeration Tanks	Aeration Tank Effluent Weir Elevation
10 Tnks/91mgd	131.97	130.33	132.00	131.17	128.72
9Tnks/91 mgd	132.53	130.33	132.00	131.17	128.72
9 Tnks/77 mgd	132.12	130.33	132.00	131.17	128.72

As the table indicates, the water level at the screw pump lip and in the aeration tank influent channel would be above the screw pump lip by approximately 1.5-2 feet. The water level in the channel would also be above the underside of the existing grating and at or over the top of the aeration tank concrete.

New pumps would be required to provide the additional 1.5-2 feet of lift. These pumps are discussed below under "Screw Pump Replacement". Additionally, the top of concrete of the aeration tanks and influent channels would need to be raised by approximately one foot to contain flow and to provide some freeboard.

III.2.8.6.3 IFAS Free Floating Media Alternative

With this alternative, the aeration tanks will remain intact with new walls installed to isolate the anoxic and aerobic zones and a new divider wall installed along the length of each tank to create two independent cells in each tank, or a total of 20 cells. Under normal operation with all cells in service, one twentieth of the plant flow and one twentieth of the return sludge flow would flow to each cell. Flow up to a maximum of 300% of the primary influent flow (based on 77 mgd maximum design primary influent flow) would be recycled back to the anoxic zone from the end of the aerobic zone.

The hydraulic analysis was conducted under three assumptions:

1. All 10 tanks in service at a plant flow of 91 mgd
2. Nine tanks in service at a plant flow of 91 mgd
3. Nine tanks in service at a plant flow of 77 mgd

Table III.2.8.5.3-1 presents the results of the hydraulic analysis of the IFAS free floating media alternative.

Table III.2.8.5.3-1: IFAS Free Floating Media Alternative - Hydraulic Analysis

Trains in Service/Total Plant Flow	Calculated Water Elevation at Aeration Tank Influent Channel and Screw Pump Lip	Screw Pump Lip Elevation	Top of Concrete at Aeration Tanks	Top of Grating Haunch at Aeration Tanks	Aeration Tank Effluent Weir Elevation
20 Trns/91mgd	130.59	130.33	132.00	131.17	128.72
18Trns/91 mgd	130.73	130.33	132.00	131.17	128.72
18 Trns/77 mgd	130.59	130.33	132.00	131.17	128.72

Water levels at the screw pump lip and in the aeration influent channel are above the screw pump lip elevations but are below the grating in the aeration tank channel and below the top of concrete of the aeration tank walls. Because of the small difference in elevation between the screw pump lip and the water level at this point, the hydraulics of the process could be designed to use the screw pumps. The water level at the screw pump lip could be lowered by approximately 0.15-0.20 ft. by lowering the aeration tank effluent weir by this amount. Along with other possible small reductions in hydraulic losses, the water level at the screw pump lip could be lowered to just below the lip. However, this offers virtually no safety factor.

In addition to the very close margin in operating hydraulic conditions, there is also a concern that the existing screw pumps will aerate the wastewater to an unacceptable level for entering the anoxic zone of the IFAS process. Another consideration is that two of the four existing screw pumps are old and are scheduled for replacement in the near future. Replacement of the screw pumps with new higher lift centrifugal or axial flow pumps is recommended to overcome the IFAS processes head losses and to minimize the dissolved oxygen concentration of the influent to the BNR reactors.

III.2.8.6.4 IFAS Fixed Media Alternative

Five cells are required for the fixed media alternative. The pre-anoxic zones of the first two cells are combined as are the pre-anoxic zones of the second two cells. The fifth cell has a dedicated pre-anoxic zone.

With all cells in service, two-fifths of the primary effluent and two-fifths of the return sludge would enter the pre-anoxic zone. Baffles in these zones would force the flow in a serpentine pattern. Following the anoxic zone, the flow would split into two streams, one to each aerobic zone. From the aerobic zone, the flow would enter a post-anoxic zone and a re-aeration zone, and then exit into the effluent channel over a weir.

Flow would be recycled from the re-aeration zone back to the head end of the anoxic zone. The recycle rate would be a maximum of 300% of the primary influent rate based on the design maximum primary effluent flow of 77 mgd.

The hydraulic analysis was conducted under three assumptions

1. All five cells in service at a plant flow of 91 mgd
2. Four cells in service at a plant flow of 91 mgd
3. Four cells in service at a plant flow of 77 mgd

Table III.2.8.5.4-1 presents the results of the hydraulic analysis of the fixed media alternative.

Table III.2.8.5.4-1: IFAS FIXED MEDIA ALTERNATIVE - HYDRAULIC ANALYSIS

Trains in Service/Total Plant Flow	Calculated Water Elevation at Aeration Tank Influent Channel and Screw Pump Lip	Screw Pump Lip Elevation	Top of Concrete at Aeration Tanks	Top of Grating Haunch at Aeration Tank (Underside of Grating)	Aeration Tank Effluent Weir Elevation
5 Trns/91mgd	130.98	130.33	132.00	131.17	128.72
4 Trns/91 mgd	131.66	130.33	132.00	131.17	128.72
4 Trns/77 mgd	131.37	130.33	132.00	131.17	128.72

As the table indicates, the water level at the screw pump lip is above the lip in all cases. It is, however, below the top of the concrete at the aeration tanks. Also, with one train out of service, the water level in the aeration tank influent channel would be higher than the underside of the grating in the channel.

This alternative would require new pumps to provide adequate lift for 91 mgd with all trains in service and for 91 and 77 mgd when one train is out of service. Because the water level would rise to the grating, the grating would have to be raised. No aeration tank walls, however, need be raised because of hydraulic requirements, but raising them by approximately 0.5 ft. should be considered to provide some additional freeboard.

III.2.8.6.5 Screw Pump Replacement

As discussed above, under all three alternatives the screw pumps would be replaced with higher lift pumps. The replacement pumps would be axial flow, vertical type, which are well suited for high volume, low head service. Five pumps rated at 26 mgd each would be provided such that three could handle the maximum design flow of 77 mgd and four could handle the peak hour flow of 91 mgd. The fifth pump would be a standby unit.

The new pumps would be variable speed controlled to match the primary effluent flow. Pump control would be required to be sensitive enough to respond to pump rate changes at the Ernest Street Pumping Station.

For the step feed alternative, the new pumps would be installed in the screw pump inlet wells. One of the wells for the 37.5 mgd screw pumps would be modified with a divider wall to provide two pump wells. The screw pump troughs would be demolished to provide space for a new electric room to house the pump variable speed equipment.

For the fixed and the floating media alternatives, the new pumps would be installed downstream of new fine screens. The screens would be installed in the existing screw pump inlet wells. This would require the screw pump troughs to be demolished and new pump wet wells installed in their place. Additionally, a new electric room would be constructed in the demolished trough area to house the pumps' variable speed equipment.

The new pumps would discharge into the existing screw pump discharge channel, which would be modified to raise the screw pump lip above the maximum expected water level. Because aerated primary effluent would be detrimental to the anoxic zones, the pump discharge piping would terminate below the water surface.

III.2.8.7 Cost Evaluation

The cost of implementing each alternative was developed on a present worth basis, and includes capital and operation/maintenance costs over the 20-year planning period. Table III.2.8.6-1 summarizes these costs for each alternative for the 5 mg/L TN case.

Table III.2.8.6-1: Present Worth Costs and Major Capital Cost Items at 5 mg/L TN *

Present Worth Costs	Step Feed	Floating Media	Fixed Media
Capital Cost, $Million ($M)	21	28	85
Annual Operation and Maintenance (O&M)Cost, $M	1.7	1.8	1.9
Present Worth of O&M Cost, $M (5.125% discount rate, 20 yrs.)	21	22	23
Total Present Worth Cost, $M	42	50	108
Cost Item			
Anoxic Mixers	x	x	x
Nitrate Recycle Pumps		x	x
Internal Recycle Pumps	x		
Replace Existing Screw Pumps	x	x	x
Aeration Grids	x	x	x
Additional Air Blowers	x	x	x
Computer Upgrade	x	x	x
Existing Aeration Tank Structural Modifications	x	x	x
IFAS Media and Tank Components		x	x
Relocate Existing Wet Weather Clarifiers			x
Fine Screens		x	x

* x = cost item is included in alternative

Detailed cost tables are provided in Appendix E.

As Table III.2.8.6-2 shows, the Step Feed process has the lowest capital, operation/maintenance, and total present worth costs of the three alternatives. The major capital cost difference between the step feed process and the floating media process is the cost of the media and media related equipment such as the media retention screens and the screen scouring air system. The total present worth of the floating media system is estimated to be approximately 19% higher than the total present worth cost of the step feed process.

The major capital cost difference between the fixed media process and the step feed process is the media and the additional required aeration tank. To construct the added tank, the wet weather clarifiers must be relocated, which is a significant cost item. At an estimated total present worth cost of $108 million, the cost of the fixed media process is two and one-half times the estimated present worth cost of the step feed process.

Table III.2.8.6-2 summarizes the costs for each alternative for additional facilities if the installed facilities fail to consistently meet the permit limit. Included in this table are the additional major cost items that are required. All the cost items listed in Table III.2.8.6-1 are included in the costs in Table III.2.8.6-2. Details of the costs are presented in Appendix E.

Table III.2.8.6-2: Present Worth Costs and Major Capital Cost Items For Denitrification Filters for Each Alternative*

Present Worth Costs	Step Feed	Floating Media	Fixed Media
Capital Cost, $Million ($M)	77	86	119
Annual Operation and Maintenance (O&M)Cost, $M	2.9	3.0	3.0
Present Worth of O&M Cost, $M (5.125% discount rate, 20 yrs.)	36	37	37
Total Present Worth Cost, $M	113	123	156
Additional Cost Items for Denitrification Filters			
Denitrification Filters on City Garage Site	x	x	x
Demolish City Garage	x	x	x
Finance New City Garage to Replace Demolished Garage	x	x	x
Denitrification Filter Influent Pumping System	x	x	
New Piping for Denitrification Filter Influent and Effluent Flows	x	x	x

* x = cost item is included in alternative

Since all alternatives require the same additional cost items for the denitrification filters, the Step Feed process is still the lowest cost alternative.

III.2.9 Results of Assessment

The alternatives were evaluated on both a qualitative and quantitative basis and included computer modeling and review of the IFAS free floating media pilot data.

The step feed alternative has more operational complexity and the solids loading rate to the final clarifiers is higher. However, it has greater flexibility in terms of ability to configure and re-configure the process in response to changes in wastewater characteristics and seasons. It is more difficult to retrofit the existing aeration basins for step feed than for the IFAS floating media alternative.

The IFAS floating alternative is significantly easier to operate than the step feed process and has an advantage in that it is relatively simple to retrofit the existing complete mix basins to the IFAS process. The ease and ability to retrofit the existing basins with this process is the single greatest advantage to the construction of a nitrogen removal process within the existing aeration tanks. Overall this will have at least some bearing on the amount of construction time and cost. However there is the offsetting cost for fine screening for this IFAS alternative.

The IFAS fixed media alternative has a distinct disadvantage in requiring new aeration tank volume to meet the 5 mg/L TN limit. This requirement results in higher costs and more difficult construction. This alternative also has less operational flexibility, and less reliability than the step feed and IFAS free floating media alternatives.

In Table III.2.9-1, each alternative is rated based on the evaluation criteria discussed in the assessment of alternatives. The rating points are totaled for each alternative to provide a quantitative comparison of the alternatives in which the highest rating is considered the best. The rating total for the IFAS free floating media alternative is slightly higher than the Step Feed process, while the IFAS fixed media alternative is rated much lower. The IFAS free floating media alternative might offer slightly better performance (approximately 0.5-1.0 mg/L lower effluent TN levels) than Step Feed based on modeling results, but both offer comparable capabilities in meeting current or future nitrogen limits and are similar in regard to reliability.

The advantages of the IFAS free floating alternative over the step feed alternative in terms of constructability are overshadowed by the step feed alternative's operational flexibility. However the IFAS free floating media has an ability to better maintain nitrification because it can hold nitrifiers on the media through winter under low temperature conditions and under high flows when washout of the nitrifiers could otherwise occur. The IFAS free floating media is operationally, much more simple to operate than the Step Feed process. Additionally it is thought that the IFAS process vendor will provide additional guarantees that the process will achieve a 5 mg/L TN effluent limit.