MAHANOY CITY WASTEWATER TREATMENT FACILITY
MAHANOY CITY, SCHUYLKILL COUNTY, PENNSYLVANIA

NPDES # PA0070041

WASTEWATER TREATMENT EVALUATION

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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WASTEWATER TECHNICAL ASSISTANCE PROGRAM

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Wastewater Treatment Evaluation:

Mahanoy City Sewer Authority (MCSA) owns and operates a sewage treatment plant (STP) in Mahanoy Township, adjacent to the municipality of Mahanoy City in Schuylkill County, Pennsylvania. The treatment plant employs two Schreiber process low-load, countercurrent extended aeration units having integrated secondary clarifiers. Design flow and organic loading are 1.38 MGD annual average daily flow (AADF) and 2,301 lb/day, respectively. The receiving stream is Little Mahanoy Creek, an AMD- impacted tributary of Mahanoy Creek in the Susquehanna River Basin.

The MCSA STP experienced a series of effluent limit violations that brought it to the attention of the Pennsylvania Department of Environmental Protection's (DEP) North East Regional Office. The violations were chiefly for disinfection system failures occurring during a facility upgrade and renovation, at which time half the treatment capacity was out of service for reconstruction. During this time, incomplete nitrification, combined with generally acidic influent waters, caused a suppression of chlorine disinfection, resulting in high fecal coliform counts.

MCSA staff contacted DEP's Technical Assistance program to provide on-site assistance and training in biological nutrient removal (BNR). DEP recommended that MCSA consider additional alkalinity in the form of magnesium hydroxide ($Mg(OH)_2$)to its treatment units. DEP also installed temporary instrumentation for optimizing nutrient reduction during the $Mg(OH)_2$ trials. Probes were installed in and ahead of the Schreiber units and at the effluent metering station, and monitoring began on August 4 and continued until October 14.

DEP analyzed operational data along with routine process monitoring results and provided potential options for implementing permanent adjustments to the treatment processes, including continued use of alkalinity supplementation, installation of additional process monitoring technology, and other recommendations.

Summary of Findings:

Generally, the facility was operating well during the late summer and early autumn. Addition of hydroxide alkalinity improved the performance of BNR by controlling acid formation and reducing the incidence of nitrite formation that had interfered with chlorine disinfection. Nitrification and denitrification appeared to be functioning optimally during the WTE.

Operational staff appeared to be motivated and well-versed in maintenance of the facility, but the basics of process monitoring, control, and of biological nutrient removal were relatively new to them. Ongoing cross-training is recommended, though, to assure multiplicity of skills and team depth. In particular, staff should become practiced in process monitoring tests required to maintain and optimize biological nutrient removal. Many of these tests were demonstrated during the evaluation, and there are ample sources for staff training available in response to licensees' continuing education requirements.

Recommendations:

The following recommendations are suggested for maintaining improved process control for nitrogen reduction at this facility:

1. Continue the alkalinity adjustment through the use of supplemental hydroxide alkalinity to the Schreiber treatment units. Where exclusive use of magnesium hydroxide may challenge the operating budget, a combination of alkalinity supplements such as sodium hydroxide for bulk control and magnesium hydroxide for polishing may be more cost-effective. The facility's engineer should evaluate this.
2. Install continuous monitoring probes for Oxidation/Reduction Potential to permit fine-tuning of the Schreiber oxic/anoxic cycling that is presently controlled exclusively through use of dissolved oxygen probes. Use of ORP probes will allow the operators to seek and maintain an optimized period of anoxic mixing, where denitrification occurs, without sacrificing the necessary oxidation of ammonium.
3. To maintain balanced alkalinity addition, installation of continually-monitoring pH probes in the Schreiber units is recommended. The operators should monitor mixed liquor pH frequently in order to maintain adequate alkalinity buffering, even using the pH probes to control the alkalinity feed system. Denitrification requires that mixed liquor pH remain above 7.0 s.u. and, ideally, at or above 7.5 s.u.
4. The operators should conduct more robust process monitoring tests, including regular analyses for mixed liquor alkalinity, and nitrogen forms such as ammonium, nitrite, and nitrate at various points throughout the process. A summary of recommended process monitoring tests and their frequencies is included as Attachment B.
5. Review of operational data suggested that sludge disposal measurement was deficient, including the use of suspect pump rates for sludge transfer to the reed beds, subsequently resulting in disparities in sludge accounting. It is suggested that a more robust solids inventory be maintained by monitoring the sludge wasting rates, solids concentrations of the digester, and more accurate measurement of pump rates.
6. Continue to pursue cross-training of facility staff in the operation and maintenance of the plant. This cross training should include not only facilities operation and maintenance, but also both laboratory and digitized recordkeeping.

Acknowledgements:

The WWTAP program thanks the Chief Operator, facility staff, and the Mahanoy City Sewer Authority for the opportunity to demonstrate BNR process optimization at the MCSA treatment facility.

Background and Discussion:

A schematic of the treatment process follows:

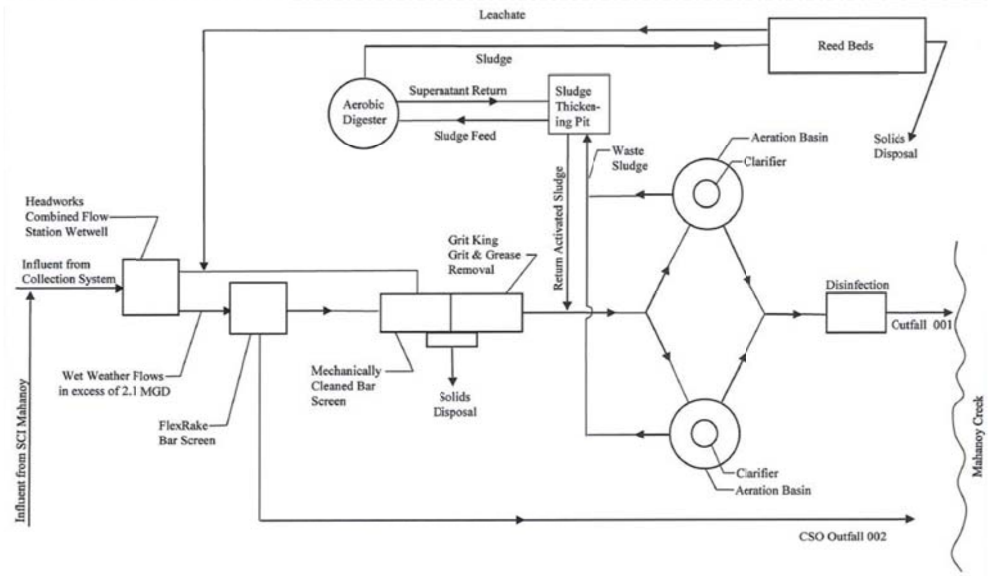


Photo: Schematic diagram of MCSA STP flows

Ancillary processes include the following:

- Stormwater bypass collection, screening, and outfall
- Raw wastewater lift pumps, fine-screening, and grit removal utilities
- Effluent disinfection system employing chlorine gas in 150-lb. cylinders, with associated chlorine contact tanks
- Service water pump and distribution system
- Influent and Effluent flow metering installations, with 24-hour composite samplers that are flow-proportioned
- Solids handling system consisting of
  - Solids holding tank having 30-day holding capacity
  - Reed Beds for dewatering and metabolic reduction of volatile solids
- Process Control Laboratory
- Emergency Generator
- Maintenance Garage and Workshop

During the WTE, a vendor-supplied magnesium hydroxide system was installed to provide supplemental hydroxide alkalinity to counteract acid formation during nitrification. The temporary system consists of four 220-gallon tote drums and an LMI metering pump. The plant operator anticipates that a permanent installation may include a single above-ground storage tank (AST) in this building, with appropriate enclosure, and that the chemical injection point may be altered when a planned fat, oil, and grease (FOG) removal utility is constructed within the next two years.

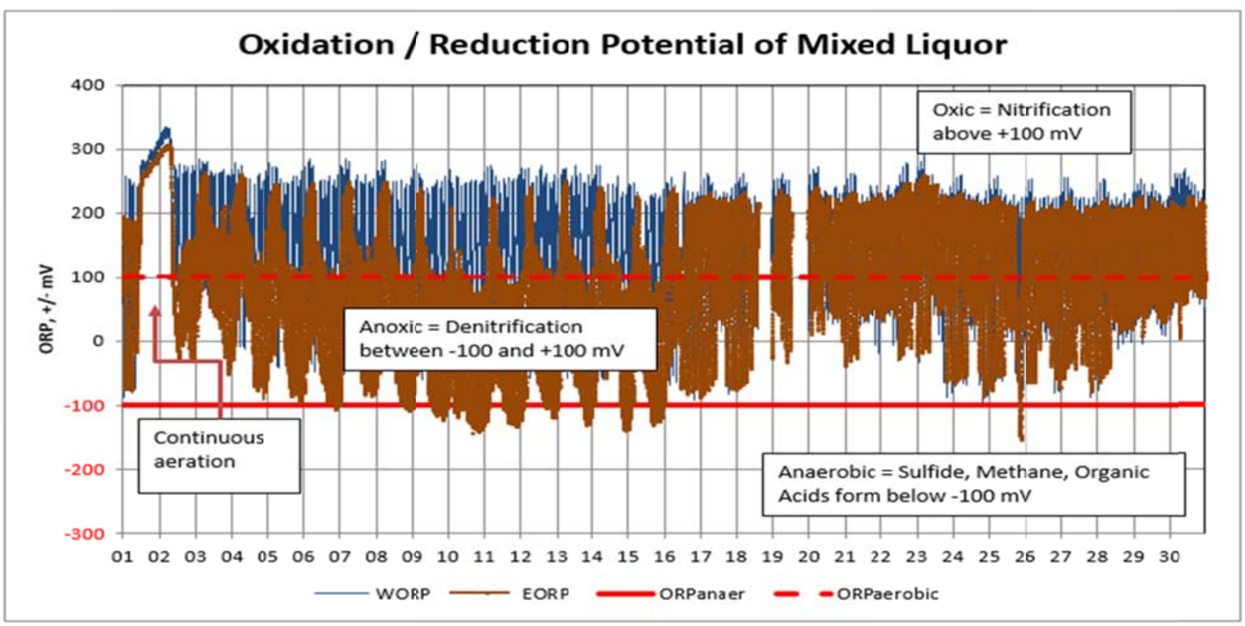
The FOG removal system would replace the currently listed Grit King system and have approximately the same foot print in the treatment schematic.

DEP's instrumentation chiefly focused on the Schreiber aeration units, where four probes each were installed. These included DO, pH/temperature, Oxidation/Reduction Potential, and Total Suspended Solids probes. A total organic carbon probe was installed in the influent channel to measure approximate BOD_5 concentration of the wastewater entering the Schreiber units. Also, probes for ammonium and nitrate were placed near the effluent outfall. Data was incorporated into workbooks for charting and analysis by DEP staff in Harrisburg.

In addition to the continuously-monitoring equipment, DEP staff also deployed a portable wastewater monitoring laboratory consisting chiefly of a solids centrifuge, settleometers, a microscope, and a spectrophotometer. DEP staff also instructed the chief operator in the daily use of this equipment for process monitoring and control purposes. Tests were performed twice per week during on-site activities.

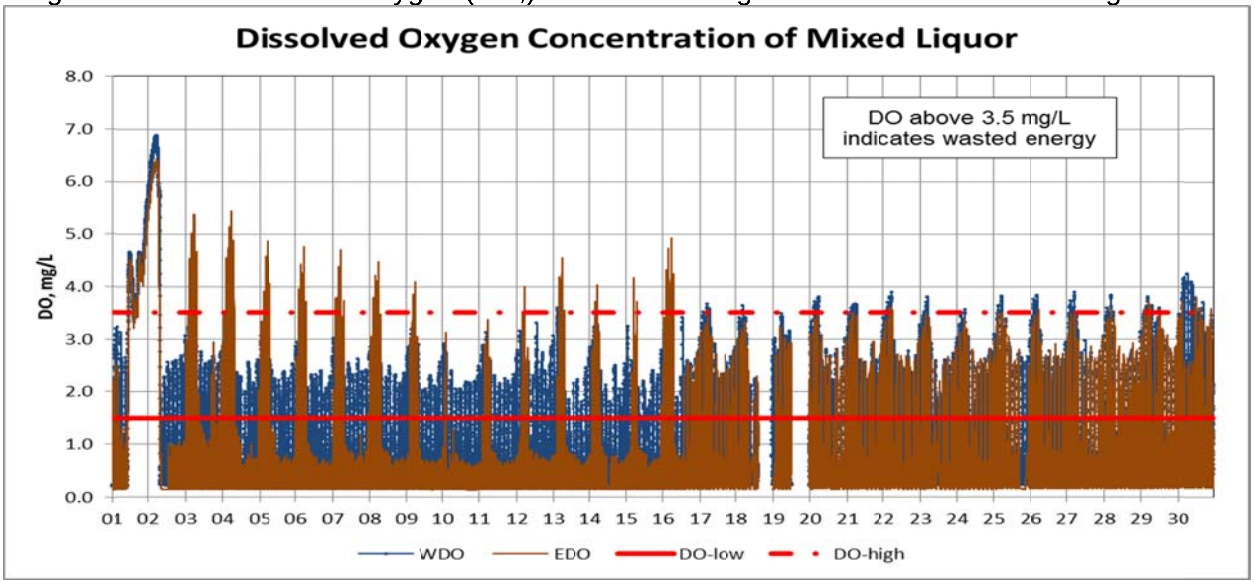
In addition to process monitoring, DEP provided instruction in basic electronic recordkeeping, in line with the state mandate for all wastewater treatment facilities to be submitting their discharge monitoring reports (DMR) electronically by the beginning of 2017. While plant staff were introduced to the new recordkeeping utility eDMR, licensing and permissions had not yet been received from DEP's central office before the end of field activities, so eDMR use remained pending as of the end of October 2016.

Facilities attempting to optimize biological nutrient removal (BNR) often find it very useful to monitor Oxidation/Reduction Potential (ORP) measurements of the mixed liquor. The defined operating range for nitrification is generally above + 100 millivolts (mV,) a relative collective, net-surface charge on the bacteria under aerobic conditions. Denitrification generally occurs during anoxic cycles, when ORP is between +100 and -100 mV. If ORP drops below -100 mV for long, anaerobic conditions occur, where aerobic bacteria begin to die and sulfides, methane, and various organic acids and intermediates are formed, all adverse for activated sludge treatment. The facility was operating well within the oxic/anoxic range during the evaluation.



Schreiber Units' MLSS oxidation/reduction potential, Sept.

After having upgraded the aeration system, the facility has operated well within the prescribed ranges for MLSS dissolved oxygen (DO,) where oxic range is between 1.5 and 3.5 mg/L:

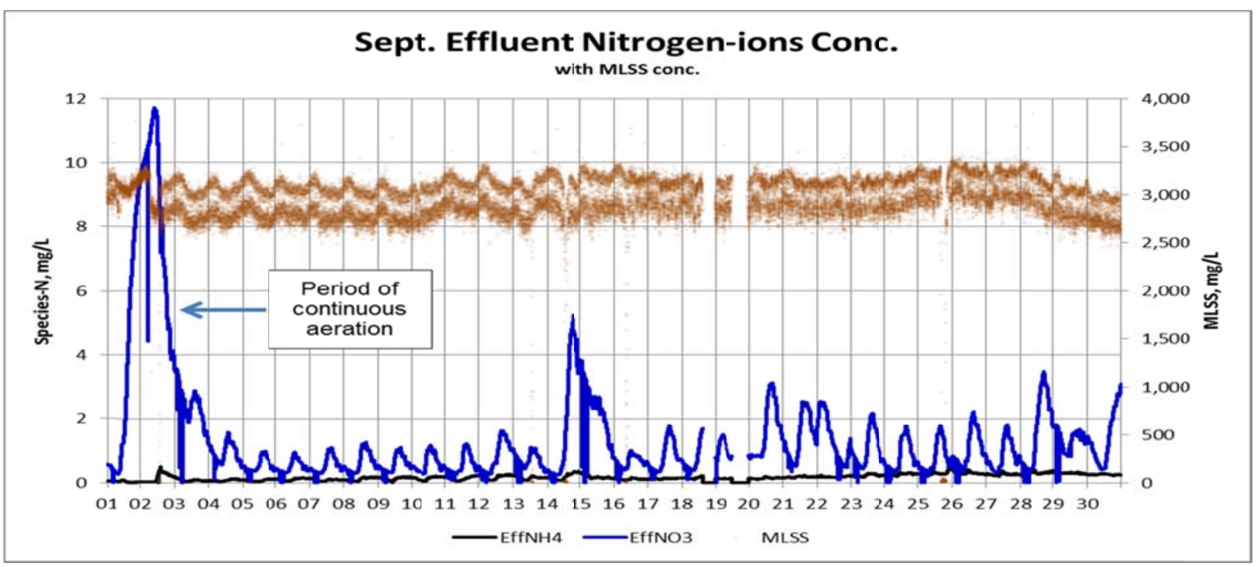


Schreiber unit dissolved oxygen concentrations, Sept: DO is already automatically controlled by MCSA.

Nitrification of ammonia wastes occurs under aerobic conditions.

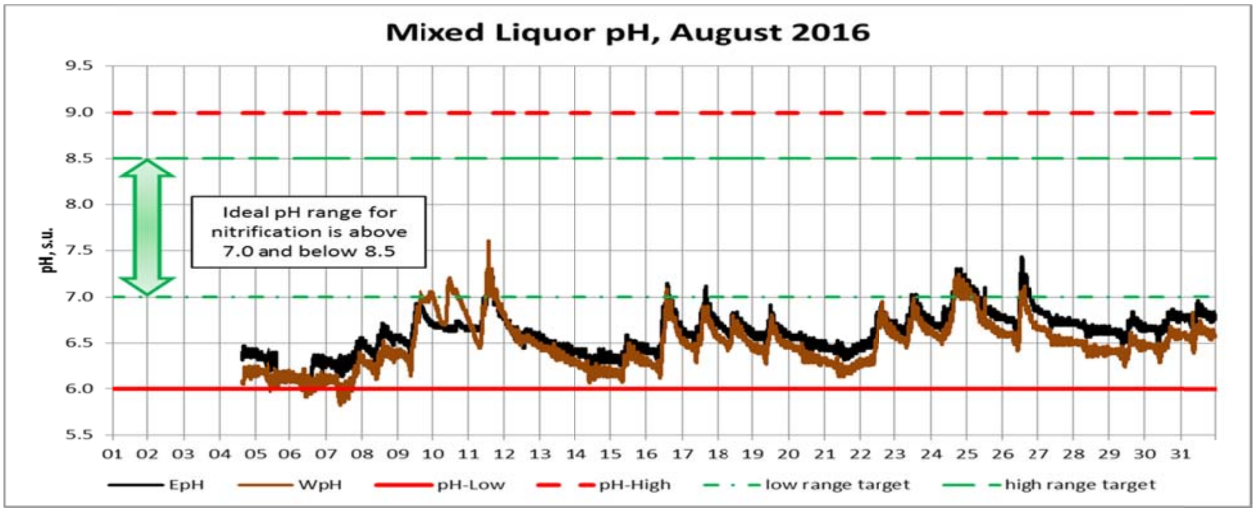
Generally, any DO over 3.5 mg/L is surplus and represents wasted energy. In order for anoxic conditions to be optimized, DO must approach 0 mg/L, after which ORP measurement becomes more useful in optimizing denitrification.

The chart, below, displays effluent ammonium and nitrate concentrations along with Schreiber unit mixed liquor suspended solids (MLSS.) Generally, nitrate concentrations were reduced as pH stabilized through alkalinity addition, as observed in the pH charts following.

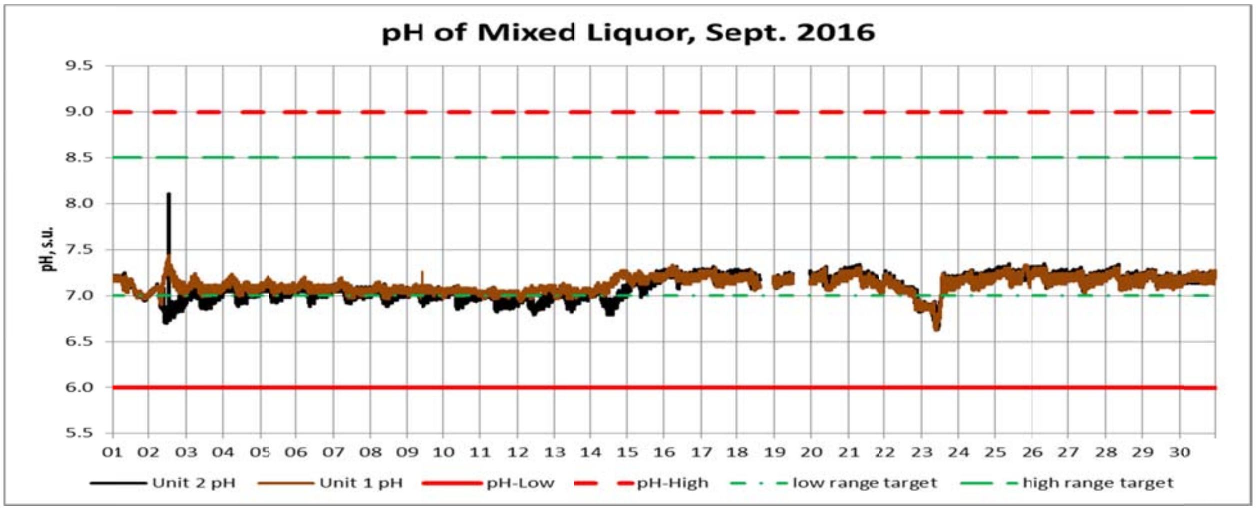


Effluent nitrogen species

The charts following show the mixed liquor pH measured during August and September. MLSS pH became stable with the addition of Mg(OH)2 alkalinity, reducing the inhibitory effects of acid produced by nitrifying bacteria during the oxic periods, allowing denitrification to be optimized.



Mixed Liquor pH in August, prior to and at the beginning of $Mg(OH)_2$ addition



Mixed Liquor pH in September, after adjusting $Mg(OH)_2$ feed rate

The facility noted that the annual cost for $Mg(OH)_2$ addition is equivalent to the costs of a full-time employee. Alkalinity dosing is determined by calculating the influent ammonia and/or organic-nitrogen (TKN) loading. At treatment facilities over 1 MGD in volume, use of $Mg(OH)_2$ to add hydroxide alkalinity may become expensive. Other chemical treatments are available at lower cost but with greater difficulty in handling and delivery. For example, caustic soda (soda ash, sodium hydroxide) is less expensive than $Mg(OH)_2$, but it is dangerous to work with and delivers half the hydroxide ion of $Mg(OH)_2$. It may be possible for the facility's engineer to evaluate other chemicals, or a hybrid combination of chemicals, to produce hydroxide alkalinity in more cost effective manner; however, the value of safety in handling and storage should be considered.

Attachment A—Process Monitoring Instrumentation

Recommended Process Monitoring Instrumentation

In October 2016, the facility's superintendent and its consulting engineer requested that DEP provide a cost approximation for equipment used during the field study, with the intent to apply to seek funding for the addition of similar equipment at the MCSA facility. The following information was provided:

Mahanoy City STP						
Vendor Equipment List used in field deployment:						
Probes and SCADA Equipment by Hach		***Order Part Number***	***Cost each***	***Qty.***	***Sub-total***	
1	LDO-2 Dissolved Oxygen Probe, 1" MNPT, SS	9020000	$ 1,917	2	$ 3,834	
2	pHD sc In-line pH & Temperature Probe, Viton	DPD-1P1	$ 1,018	2	$ 2,036	
3	pHD sc, Differential ORP Digital Sensor, PEEK Body Material, Co	DRD1P5	$ 1,086	2	$ 2,172	
4	Solitax sc Total Suspended Solids Probe	LXV423.99.00100	$ 4,539	2	$ 9,078	
5	UVAS sc Organic Molecule Probe	LXV418.99.20002	$ 18,359	1	$ 18,359	
6	Hach Nitratax NO3 Probe	LXV417.99.20002	$ 17,565	1	$ 17,565	optional
7	AISE (Ammonium) Probe	LXV440.99.10002	$ 7,428	1	$ 7,428	optional
8	SC1000 Base Unit, 6-input, wRTU, MODBUS, Relay, 4-20 input &	LXV400.99.5B532	$ 2,638	2	$ 5,276	check specs for hardwiring to exstg. SCADA
9	SC1000 Universal Display Controller	LXV402.99.02002	$ 3,303	1	$ 3,303	
10	eWON WiFi Digital Router	2600-0158-001	$ 1,552	1	$ 1,552	not needed if hardwired to SCADA system
11	Power supply for eWON Digital Router	9072600	$ 64	1	$ 64	not needed if hardwired to SCADA system
12	aa SC1000 MODBUS TCP/IP LICENSE KIT	LZY598	$ 854	1	$ 854	not needed if hardwired to SCADA system
13	Stainless Steel pole mount kit for UVAS	LZY714.99.53520	$ 499	1	$ 499	
14	si PROBE ADAPTER ELBOW 1 1/2FNPT	AHA034NPT	$ 131	2	$ 262	for TSS probes!
15	PVC rail mount kit for ISE sensors	6184900	$ 436	1	$ 436	AISE component
16	Automatic air cleaning compressor, 115 V AC	6860003.99.0001	$ 1,700	1	$ 1,700	AISE component
17	Cleaning system for AISE probe	LZY706	$ 289	1	$ 289	AISE component
18	Cartrical sensor cartridge for AN-ISE sc	LZY694	$ 989	2	$ 1,978	2 per year!
19	UVAS Tankside Mounting System, SS	LZY714.99.53520	$ 471	1	$ 471	for BOD probe
Laboratory Equipment:						
a	OMAX 40X-2500X Full Size Lab Digital Trinocular Compound LED Micr	CS-M837ZL-C140U	$ 560	1	$ 560	see note on part number for Amazon.com
b	Raven Process Centrifuge (110 vac) w/ 6 ea. 19-mm TWC Tubes	F-10300	$ 1,094	1	$ 1,094	
c	Raven Centrifuge tubes, graduated, 19-mm, poly, box of 12	B-10101-19	$ 81	1	$ 81	
d	Hach HQ40d Handheld Probe Module	HQ40D53000000	$ 1,077	1	$ 1,077	
e	Hach LBOD Probe w/lab kit	LBOD10130	$ 1,003	1	$ 1,003	
f	Hach Phosphorus, Orthophosphate (Reactive) Test Kit, Model PO-19A	224801	$ 138	1	$ 138	alternative to DREL-1900
g	Hach Nitrate Test Kit, Model NI-11	146803	$ 88	1	$ 88	alternative to DREL-1900
				Grand total:	$ 81,196	

Additional annual costs are to be incurred in providing for regular service and maintenance of all monitoring probes.

ITEM DESCRIPTIONS	Service Cost
NITRATAX plus sc Sensor, 2mm path length	$ 868.79
UVAS sc Organic Molecule Probe	$ 868.79
Solitax sc Total Suspended Solids Probe	$ 445.79
Dissolved Oxygen Probe	$ 200.00
Solitax sc Total Suspended Solids Probe	$ 445.79
sc1000 Probe Module, 6 sensors, 4mAOUT, 4mA/digitIN, 4 relays, Modbus (RS485)	$ 313.00
Digital pH & Oxidation / Reduction Probes	$ 220.00

DEP noted that multiple manufacturers exist for most of these items and that some of the probes listed were optional. There are low-cost laboratory test kits that would provide similar information at much less cost, such as substituting COD testing for the use of an organic molecule probe (UVAS.) A laboratory centrifuge for rapid suspended solids testing would preclude the need for TSS probes, in that the centrifuge test could be performed more often than gravimetric testing at only 15-minutes per test and provide sufficient information. Likewise, the ammonium and nitrate probes are less necessary, as colorimetric and strip tests are available at significantly lower cost. Thus, the minimum recommendation in this report is for installing pH and ORP probes into each Schreiber unit to monitor effectiveness of alkalinity and optimal denitrification ranges, respectively.

Attachment B—Recommended Process Control Tests, Observations, Calculations

PROCESS CONTROL TESTS FOR DOMESTIC WASTEWATER TREATMENT FACILITIES

Activated Sludge Facility: Conventional, Complete Mix, Step Feed, or Extended Air
Greater than 1.0 to 5.0 MGD

SAMPLE PARAMETER	SAMPLE LOCATION	SAMPLE TYPE	DAILY	2/WEEK	WEEKLY
Raw Influent					
BOD_5 & TSS	Influent	Composite		X	
COD	Influent	Composite			X
pH	Influent	Grab		X	
Flow	Influent	Totalizer	X		
Primary Clarifier*					
BOD_5, COD, and TSS	Effluent	Composite		X	
pH	Effluent	Grab		X	
NH_3-N	Effluent	Composite		X	
Flow	Effluent	Totalizer	X		
* Separate monitoring for raw influent and primary effluent location is only necessary when flow equalization or other recycled streams would cause volume and/or quality to differ.					
Aeration Basin					
DO & temperature	In situ	Grab	X		
Return sludge TSS	RAS line	Composite		X	
RS centrifuge solids	RAS line	Composite	X		
RS dissolved oxygen	RAS line	Grab	X		
Return sludge flow	RAS line	Totalizer	X		
Waste sludge flow	WAS line	Totalizer	X		
Mixed liquor TSS/VSS	Effluent	Composite		X	
MLSS centrifuge solids	Effluent	Composite	X		
pH	Effluent	Grab		X	
Settleability (SV30)	Effluent	Grab	X		
Microscopic examination	Effluent	Grab			X
Computation of SVI, F/M, sludge age, and/or MCRT	—	—			X
Secondary Clarifier					
Dissolved oxygen	Effluent	Grab	X		
Sludge blanket depth	As appropriate	—	X		
Final Effluent					
Parameters, sample types, and frequencies as required by permits.					

Table M-1: Suggested sampling frequencies

Discussion of Process Monitoring and Control:

The table reproduced above lists suggested sampling frequencies for facilities of capacity > 1.0 MGD and < 5.0 MGD. This represents the minimum monitoring requirements; however, experience suggests that process monitoring tests be performed more frequently when a facility is experiencing any changes. These changes include any process changes made by the operators and any changes due to unavoidable circumstances, such as slug loading or equipment service interruptions. Generally, the higher the level of treatment, the more process control testing is necessary. For example, denitrification operations require additional process monitoring when compared to nitrification operations.

Ideally, centrifuge solids tests are done daily and are backed up with gravimetric solids tests at least twice per per week in order to maintain centrifuge calibration (Weight-to-Concentration Ratio, or WCR.) Microscopy, Settleability, and water chemistry should be done on the mixed liquor at least twice per week until the operators have reasonable understanding of a 4-season set of reference data to which they may refer in future years. Whenever process or treatment methods change, the test data set would need to be reproduced. Also, whenever the facility experiences plant upset conditions more frequent process-monitoring and control testing should be performed by the operators, until conditions stabilize.

Process Monitoring testing is often not the same as those performed by contract laboratories in that approved test methods are not utilized. Compliance testing refers to those analyses used by certified laboratories for reporting parameters required by the NPDES permit. Over the years, many small treatment facilities began to contract compliance testing to certified environmental laboratories. This eased the burden on operators, and it saved the facility owner the cost of maintaining certification of its own laboratory. However, over time, many facilities ceased to perform regular process monitoring tests, as well. It is important for operators to know the condition of their facilities, the sludge solids inventory, and the qualities of the treatment solids (i.e., quantity and quality of “bugs”) to effectively optimize operations.

Thus DEP’s WWTAP has adopted the process monitoring tests recommended by US-EPA and the professional trade organization, Water Environment Federation (WEF.) These tests include the following:

Solids Inventory:

- Centrifuge solids test: percent volume/volume measurement of activated sludge solids for activated sludge-type plants: Calculations stemming from this data include solids inventory (expressed as “sludge units” (SLU).)
- Clarifier blanket level: a core-sampling of the clarifier contents provides a proportional quantity of mixed liquor and supernatant that can be used for developing awareness of how much mixed liquor is detained in the effluent clarifier, representing part of the overall sludge inventory.
- Settleometry test: 30- and 60- minute activated sludge settling rates in wide half-gallon or 1-liter, calibrated vessels: Settled sludge volume (SSV) is expressed in standard 30-minute intervals and used to calculate Settled Sludge Concentration (SSC) which is a qualitative measure of how well the activated sludge settles in the clarifier, mimicking clarifier performance in terms of supernatant quality as well.
- Oxygen Uptake Rate (a.k.a. Soluble Oxygen Uptake Rate): By measuring the rate of dissolved oxygen depletion in a sample of mixed liquor, one may demonstrate the relative effect of BOD loading on the biomass, how quickly this material will be metabolized by the activated sludge organisms. Expressed in “milligrams Oxygen per hour,” when mixed liquor volatile suspended solids concentration is known or can be extrapolated, then one may determine the actual Respiration Rate, in mg. Oxygen per hour per gram of activated sludge. OUR and RR are also useful for comparing the relative health of the biomass under toxic conditions, should there be undesirable contaminants in the raw wastewater, or anoxic conditions, should the aeration be insufficient to treat the incoming waste load using the available amount of oxygen.

- Raw Wastewater and Effluent Chemical Oxygen Demand (COD): an analog of the 5-day Biochemical Oxygen Demand test, COD can be determined in about three hours and give operators a quick assessment of relative strength of wastewater and/or the amount of material remaining in treated effluent, thereby providing an analog of treatment efficiency.
- Nutrient Tests: A portable wastewater laboratory provided during the WTE consists of materials for conducting various colorimetric analyses for nutrients such as ammonia-nitrogen, nitrite, nitrate, Kjeldahl nitrogen, phosphorus, etc. to determine whether the facility is removing or treating nutrients.
- Various other tests included in the portable wastewater laboratory include alkalinity testing (the buffering capacity of the mixed liquor or the clarified supernatant,) chlorides, sulfides, halogens such as Total Residual Chlorine and Free Chlorine, and metals including aluminum and iron, known contaminants to downstream aquatic life.

The objective of all this testing is to develop a unique profile for the facility useful in developing operations trends, showing conditions that become predictive of how the facility responds to various beneficial or adverse conditions that could affect effluent quality and treatment efficiency. Once sufficient data exists, operators should develop a cogent understanding of how the facility responds to process adjustments and what they must do to maintain it in good condition.

Typically, operators should determine an overall treatment strategy for their facility, using standard industry calculations for:

- Food to Mass Ratio (F/M)
- Mean Cell Residence Time (MCRT)
- Sludge Age or Dynamic Sludge Age

These values can be determined using the equipment described above. These calculations provide set-points unique to the facility that can be adjusted either through changes in sludge wasting rates or aeration capacity, assuming that the concentration of waste in the wastewater is a variable that operators cannot control.

During the WTE, DEP staff and the plant operator reviewed the original Schreiber Operations and Maintenance Manual for the Mahanoy City facility. The Manual recommended that F/M serve as the basis of overall process management. Frequent laboratory testing demonstrated that MCRT and West Sludge Age could not be reliably used at this facility.