Comments on the Draft Determination of Technology-Based Effluent Limits for the Flue Gas Desulfurization Wastewater at Merrimack Station in Bow, New Hampshire

Introduction

The Electric Power Research Institute (EPRI) is providing comments to Region 1 of the United States Environmental Protection Agency (EPA) on the draft permit for wastewater discharges for the Public Service of New Hampshire (PSNH) Merrimack Station.

EPRI was established in 1973 as an independent, nonprofit center for public interest energy and environmental research. EPRI brings together member organizations, the Institute's scientists and engineers, and other leading experts to work collaboratively on solutions to the challenges of electric power. These solutions span nearly every area of power generation, delivery, and use, including health, safety, and environment. EPRI has been active in characterizing flue gas desulfurization (FGD) wastewaters and evaluating treatment technologies since 2006. This work includes characterization of FGD wastewaters, evaluation of mercury and selenium chemistry in FGD wastewaters, and the evaluation of physical/chemical and biological wastewater treatment approaches.

Summary

EPRI reviewed the draft PSNH Merrimack permit and most of the supporting documents. We have focused our analyses and review on the physical/chemical and biological FGD wastewater treatment cost/benefit assessment portion of the permit. EPRI's comments can be summarized as follows:

1. EPA's estimated capital and operating costs for physical/chemical and biological FGD wastewater treatment are low relative to EPRI's estimates. EPRI estimates the total capital cost for physical/chemical treatment to be $18M, as compared to EPA's estimate of $4.9M. EPRI estimates the total capital cost for biological treatment to be $10.5M, as compared to EPA's estimate of $5M. As EPA's cost estimates do not provide detailed itemization of costs, EPRI was not able to identify the differences in our estimates. One possible explanation is that EPA's estimates incorporate primarily the direct equipment and installation costs, but may not incorporate all the indirect costs, e.g. engineering, construction, contingency, start-up and commissioning costs – which are significant and can represent about two-thirds of the total capital costs. Accordingly, EPRI requests additional details in regards to EPA's methodology and supporting information in order to properly evaluate EPA's estimate along with EPRI's estimate.

2. EPA's estimated benefits (i.e., removal calculations) for biological treatment are high relative to EPRI's estimates. EPRI estimated benefits using the dataset from EPA's sampling and analytical studies at two power plants employing physical/chemical plus biological treatment systems. While there are multiple approaches for calculating total pounds of pollutants removed, our estimates are consistently two orders of magnitude less than EPA's estimates for biological treatment. We evaluated numerous scenarios and are not able to develop a plausible explanation leading to the differences in the EPA and EPRI benefit estimates for biological treatment. Thus EPRI requests additional details in regards to EPA's methodology and supporting information.
3. EPRI has included a wastewater treatment benefit (i.e. removal) estimate employing toxic-weighted pounds equivalent (TWPE). This approach incorporates varying toxicity factors which provide a more realistic estimate of the true environmental benefits.

An overview of our comments is presented in this document, with supporting calculation details provided in the appendices A, B, and C.

Technical Comments

FGD Wastewater Treatment Cost Estimates

EPRI conducted a parallel analysis of the costs for physical/chemical treatment and biological wastewater treatment of FGD wastewater for PSNH Merrimack. This cost estimate for physical/chemical treatment is based on a generic cost tool developed by EPRI to help power plants understand the factors that impact costs; this cost tool provides a "Class Five" (+100%/-50%) cost estimate and does not take into account the site-specific conditions at Merrimack. The EPRI cost estimates are summarized in Tables 1 (physical/chemical) and 2 (biological). Additional supporting calculations are provided in Appendix A: FGD Wastewater Physical/Chemical Treatment Cost Estimating Summary and Appendix B: FGD Wastewater Biological Treatment Cost Estimating Summary.

As can be seen from the following tables, EPA's cost estimates for the Merrimack facility are significantly lower than EPRI's estimate for physical/chemical wastewater treatment. EPRI estimates the total capital cost to be $18M, as compared to EPA's estimate of $4.9M. Similarly, EPA's cost estimates are lower for the incremental biological wastewater treatment than EPRI's estimates.

A consideration in estimating the capital costs is the flow rate basis; specifically, whether the average flow rate or peak (maximum) flow rate is used. On Page 37 of the text and Footnote 23 of *Attachment E: Determination of Technology-Based Effluent Limits for the Flue Gas Desulfurization Wastewater at Merrimack Station in Bow, New Hampshire; EPA – Region 1 (9/23/2011)* (Attachment E), it appears that EPA developed cost estimates for equipment based on a flow rate of 50 gallons-per-minute (gpm) sizing. However, Page 37 of Attachment E states that the discharge flow may increase to 100,000 gallons per day (gpd) (approximately 70 gpm). Docket File #AR115 (e-mail on FGD purge rate at 70,000 gpd) states that the average flow rate is 70,000 gpd (50 gpm) and the design flow rate is 100,000 gpd. Wastewater treatment plants are generally designed for peak flow rates, which is the "worst case" or maximum flow rate—as compared with the average flow rate. Table 1 provides a comparison of the EPRI cost estimates based on 50 and 70 gpm flow rates. The difference in flow rates yields about a 10 percent increase in capital costs – which by itself does not account for the large differences between EPA's and EPRI's estimates. EPRI's evaluation of wastewater treatment cost for Merrimack was conducted based on peak design flow rate to represent typical design approach.

We are not able to determine the cause of the remaining cost estimate differences. EPA's cost estimates are based on an e-mail dated September 13, 2011, from Ron Jordan to EPA Region 1 (Docket #AR118); however, the e-mail does not provide the supporting calculations. One possible explanation is that EPA's estimates incorporate primarily the direct equipment and installation costs. EPRI's direct equipment and installation cost estimate was $4.2M (based on a 50 gpm flow rate), which is comparable to EPA's cost estimate of $4.9M. However, the total capital costs would also include all the indirect costs, e.g., engineering, construction, contingency, start-up and commissioning costs – which are significant. EPRI estimates that the indirect costs are about $13M for a treatment system based on a 70 gpm flow rate. EPRI requests that EPA confirm whether their cost estimates include all direct and indirect costs, and we also request additional information in regard to EPA's methodology and supporting information in order to properly evaluate EPA's cost estimate.

TABLE 1

Physical/Chemical Treatment Installed Equipment, Capital, Operations and Maintenance (O&M), and Annualized Costs

	EPA	EPRI	
	50 gpm	**50 gpm Average Flow**	**70 gpm Peak Flow**
Sub-total – Installed Equipment	NA	$4,200,000	$4,700,000
Capital Costs	$4,869,000	$16,000,000	$18,000,000
Annualized Capital Costs	$459,000	$1,500,000	$1,700,000
Annual O&M Costs (at 50 gpm)	$430,000	$1,000,000	$1,000,000
Total Annualized Costs	$889,000	$2,600,000	$2,800,000

Capital costs are annualized by assuming a lifetime of 20 years and 7 percent interest rate.

TABLE 2

Biological Treatment Installed Equipment, Capital, O&M, and Annualized Costs

	EPA	EPRI	
	50 gpm	**50 gpm Average Flow**	**70 gpm Peak Flow**
Sub-total - Installed Equipment	NA	$5,100,000	$6,100,000
Capital Costs	$4,954,000	$9,000,000	$10,500,000
Annualized Capital Costs	$468,000	$850,000	$990,000
Annual O&M Costs (at 50 gpm)	$297,000	$550,000	$550,000
Total Annualized Costs	$765,000	$1,400,000	$1,500,000

Capital costs are annualized by assuming a lifetime of 20 years and 7 percent interest rate.

Note that EPRI is currently developing cost estimation approaches for thermal zero liquid discharge (ZLD), and we are currently not able to provide technical comments on the Merrimack ZLD cost estimates.

Benefits/Removals

EPRI also evaluated the available data to estimate pollutant removals or benefits. EPRI used the EPA field sampling data from Duke Energy's Allen and Belews Creek stations (Eastern Research Group, 2011a and 2011b). These two facilities have treatment performance characterization data for a wastewater treatment system with both physical/chemical and biological treatment, which EPA concluded to be best available technology (BAT) for Merrimack. EPRI calculated benefits using both the total constituent concentration, as well as an estimated "settled" concentration for the untreated FGD wastewater. It appears that EPA estimated removal based on "settled" data (ERG 2009) assuming that most of the industry already uses settling ponds, although Merrimack does not have a settling pond. EPRI's analysis of removal benefits is summarized in Table 3; EPRI's estimate of physical/chemical removal on total constituents is greater than EPA's estimate by a factor of 2 to 3, while our estimate of physical/chemical removal from "settled" effluent are an order of magnitude less than EPA's estimate.

TABLE 3
Estimated Physical/Chemical Treatment Benefits/Removal (pounds per year)

	EPA	EPRI – TOTAL		EPRI – SETTLED	
		Belews Creek at 50 gpm*	Allen at 50 gpm*	Belews Creek at 50 gpm*	Allen at 50 gpm*
Physical Chemical Treatment	16,900	45,100	33,700	1,500	2,200

*Using Belews Creek/Allen data to estimate removals for Merrimack average flow rate of 50 gpm.

EPRI performed a similar analysis of removal benefits of biological treatment. We calculated the incremental removal of the biological system as well as the overall physical/chemical plus biological treatment removal (see Table 4). EPRI estimated the incremental biological removal of 3,900 pounds per year using the Belews Creek data and 2,100 pounds per year using the Allen data, which are both two orders of magnitude less than EPA's estimate (623,000 pounds per year). EPRI's calculation of the incremental biological removal using an estimated "settled" concentration for the untreated FGD wastewater are similar, and are 2 orders of magnitude less than EPA's estimate. Supporting information for EPRI's benefit/removal calculations is included in Appendix C: FGD Wastewater Treatment Benefits Analysis.

EPRI is not able to develop a plausible explanation of the significant differences between our estimates, thus we request the underlying data and methodology that EPA used to evaluate the benefits at Merrimack.

TABLE 4
Biological Treatment Benefits/Removal (pounds per year)

	EPA	EPRI – TOTAL		EPRI – SETTLED	
		Belews Creek at 50 gpm*	Allen at 50 gpm*	Belews Creek at 50 gpm*	Allen at 50 gpm*
Incremental removal by Biological Treatment	623,000	3,900	2,100	3,900	2,100
Overall removal by Physical/Chemical + Biological treatment	639,900	48,100	35,800	4,400	4,300

*Using Belews Creek/Allen data to estimate removals for Merrimack approach at 50 gpm.

Lastly, EPA's benefit estimate focuses on total pollutant loading, which estimates the benefit of 1 pound of mercury to be comparable to 1 pound of manganese. In EPA's *Technical Support Document for the Annual Review of Existing Effluent Guidelines and Identification of Potential New Point Source Categories* Steam Electric Effluent Guidelines Final Report (EPA, 2009), EPA discussed an analyses based on toxic-weighted pounds equivalent (TWPE) removed. EPRI also conducted an analysis of TWPE removed versus total pounds removed per year, as shown in Table 5. Supporting calculation data are included in Appendix C. The TWPE approach incorporates a measure of the potential environmental risk impacts into EPA's cost/benefit assessment.

TABLE 5

Physical/Chemical and Biological Treatment Benefits in Mass and TWPE

	EPA		EPRI – TOTAL				EPRI – SETTLED			
			Belews Creek		Allen		Belews Creek		Allen	
	Pounds per Year	TWPE per Year	Pounds per Year	TWPE per Year	Pounds per Year	TWPE per Year	Pounds per Year	TWPE per Year	Pounds per Year	TWPE per Year
Physical/Chemical Treatment	16,900	-- *	45,100	8,400	33,700	3,000	1,500	100	2,200	100
Incremental Biological Treatment	623,000	--	3,900	1,500	2,100	<100	3,900	1,500	2,100	<100
Overall Physical/Chemical + Biological Treatment	639,900	--	48,100	10,000	35,800	3,100	4,400	800	4,300	200

*EPA memorandum provided only total pounds per year removed, and did not provide either a TWPE nor specific constituent removal to estimate TWPE

The overall treatment benefits do not equal to the sum of the physical/chemical plus biological treatment due to some parameters having a calculated negative removal for either the physical/chemical or biological treatment system. In these instances (with the exception of ammonia), EPRI substituted “0”.

References

Attachment E: Determination of Technology-Based Effluent Limits for the Flue Gas Desulfurization Wastewater at Merrimack Station in Bow, New Hampshire; EPA – Region 1 (9/23/2011).

Docket #AR115: E-mails between Allen Palmer/NU and John King/EPA regarding 70,000 gpd and 100,000 gpd flow rates.

Docket #AR118: E-mail from Ronald Jordan about capital and O&M costs for physical/chemical, biological and ZLD; September 13, 2011.

Eastern Research Group, Inc. 2009. *Technology Option Loads Calculation Analysis for Steam Electric Detailed Study.* October 9.

Eastern Research Group, Inc. 2011a. *Sampling Episode Report, Duke Energy Carolinas' Allen Steam Station, Sampling Episode 6561*. December 13.

Eastern Research Group, Inc. 2011b. *Sampling Episode Report, Duke Energy Carolinas' Belews Creek Steam Station, Sampling Episode 6558*. December 13.

United States Environmental Protection Agency (EPA). 2009. *Technical Support Document for the Annual Review of Existing Effluent Guidelines and Identification of Potential New Point Source Categories*. EPA-821-R-09-007. Washington, DC. (October). EPA-HQ-OW-2008-0517-0515.

Appendices

- Appendix A: FGD Wastewater Physical/Chemical Treatment Cost Estimating Summary
- Appendix B: FGD Wastewater Biological Treatment Cost Estimating Summary
- Appendix C: FGD Wastewater Treatment Benefits Analysis

Appendix A: FGD Wastewater Physical/Chemical Treatment Cost Estimating Summary

Introduction

Appendix A provides supporting calculation details to how EPRI estimated the cost of FGD wastewater treatment employing a physical/chemical treatment approach. EPRI's cost estimates for the Public Service of New Hampshire (PSNH) Merrimack Station are based on the design flow rates of 50 (average) and 70 (peak) gallons per minute (gpm).

The following approach was used:

- Identified the flow and solids of the untreated FGD wastewater stream
- Identified the sub-systems of the physical/chemical FGD wastewater treatment plant (desaturation and solids removal by primary clarification, equalization, metals removal, effluent media filtration, solids dewatering, supporting equipment)
- Used the EPRI cost estimating tool to estimate the total installed equipment cost.
- Used the cost factors to estimate the total capital cost.

The cost estimating tool that EPRI used in providing our cost estimates for physical/chemical FGD wastewater treatment was checked using real-world data from power plants provided via UWAG to EPRI. The EPRI cost estimates corresponded well (+/- 30%) for the majority of plants evaluated. The precision of the comparison was lessened by the fact that the exact costs could not be provided to EPRI in order to maintain Confidential Business Information (CBI) status. However, the comparison was still able to show that the cost tool represented the cost for the majority of plants evaluated.

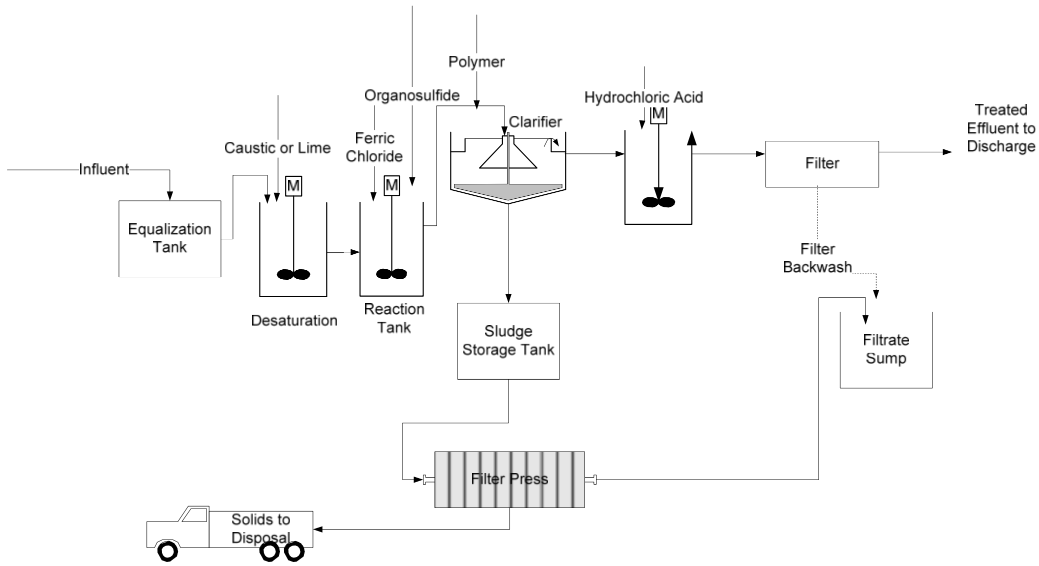
Flow Data Used in Calculation

EPRI estimated the Merrimack costs based on the following two flow rates: (1) the average flow rate of 50 gpm (70,000 gallons per day [gpd]) and (2) the peak flow rate of 70 gpm (100,000 gpd). The flows are based on *Attachment E: Determination of Technology-Based Effluent Limits for the Flue Gas Desulfurization Wastewater at Merrimack Station in Bow, New Hampshire*.

The design of treatment process units is driven primarily by the peak flow rates. If equipment were sized for the average flow rates, it would not be able to handle peak conditions. As capital costs are related primarily to flow rate, the design flow rate has a strong impact of the estimated cost. Conversely, annual operating costs were estimated using average flow rates.

Figure 1 shows a process flow diagram representing the physical/chemical wastewater treatment system for the Merrimack station that EPRI employed for cost estimating purposes. Note that the Merrimack facility will have a mercury-removal polishing adsorptive media. This is not a standard part of physical/chemical treatment and is not currently included in EPRI's estimate. It is not clear if the United States Environmental Protection Agency's (EPA's) estimate included this polishing step or EPA's cost was based only on a "standard" physical/chemical system, such as in Figure 1.

FIGURE 1
Process Flow Diagram



Costs

Physical/Chemical Cost Tool Outputs

The cost estimates for physical/chemical treatment are provided in Table 1.

TABLE 1
Physical/Chemical Treatment: Capital Cost Estimate Comparison Evaluating Average versus DesignFlow

Design Flow (gpm)	Solids in Influent to Treatment (%)	Physical/Chemical Cost	
		Capital ($MM)	O&M ($MM)
50	2.0	16	1.0
70	2.0	18	1.0*

Note: Cost estimate is based on two treatment trains each sized at 100 percent of peak flow, and assumes one clarifier (primary) per train.

*Average flow (50 gpm) is used to calculate operating and maintenance (O&M) costs. Peak flow is used to calculate capital costs.

Cost Assumptions

All cost estimates require consideration of many assumptions. The following are typical cost factors that were considered, and the assumptions made in the EPRI cost estimates. If these assumptions do not hold true, costs could differ significantly.

- System redundancy has a significant impact on capital cost. The system is assumed to be built with two treatment trains, each able to treat 100 percent of peak flow (termed “2 x 100”). A redundancy of 2 x 100 was assumed to ensure power generation operation will not be adversely affected. This is fairly common in the industry as many power plants realize that wastewater treatment system reliability and availability is critical to maintaining power plant operations. Merrimack’s current FGD wastewater treatment system was built with a 2 x 100 redundancy, according to discussion with PSNH.
- Solids loading can have a significant impact on capital costs. An influent solids concentration estimate of 2 percent was used to determine costs of solids dewatering based on discussion with PSNH.
- No impacts from weather were assumed in developing the wastewater treatment costs. However, some enclosure and heating of the wastewater treatment system may be necessary to avoid lines from freezing, and other weather related issues.
- Escalation is not included. Costs are from 2010 and would need to be escalated based on actual construction date.
- Piping from wastewater sources to the wastewater treatment plant (WWTP) and from the WWTP to the outfall is not included.
- Sales tax is not included; the project is assumed to be sales tax exempt.
- Dewatering for construction is not included.
- The site is balanced cut/fill.
- Temporary fencing is not required.
- Curbs and gutters are not required for roads or parking areas.
- Buried pipe depth is assumed to be 3.5 feet to the top of the pipe.
- Seeding of disturbed areas is required.
- No painting of galvanized steel, aluminum, stainless steel, or polyvinyl chloride (PVC) material is required.
- The number of operational shifts per day of the filter presses is based on the solids loading; it is assumed presses are run one shift per day.
- A 12-hour hydraulic retention time is assumed for equalization.
- Materials resistant to high chlorides up to 15,000 milligrams per liter (mg/L) were assumed to be needed for treatment equipment. Such materials are more expensive than materials that do not offer corrosion resistance. This was factored into the cost estimate.

Cost Estimate Approach

The costs presented are based on the total estimated capital costs, which by definition include everything that will be required to install the system. This typically includes the following elements:

- Direct costs—equipment, delivery, taxes, and installation costs
- Indirect costs—engineering, construction, contingency for undefined, escalation, permitting, startup, and commissioning costs

The American Association of Cost Engineers International (AACEI) Recommended Practice 18R-97 provides guidelines classifying cost estimates and their relative accuracy. The accuracy of the cost estimate is generally a function of the amount of engineering completed at the time of the estimate. Table 2 shows the class of total capital cost estimates, the relative accuracy, and the project definition percent complete for each estimate.

TABLE 2
Cost Estimating Guideline

Estimate Class	Level of Accuracy	Project Definition
5	+100%/-50%	0% to 2%
4	+50%/-30%	1% to 15%
3	+30%/-20%	10% to 40%
2	+20%/-15%	30% to 70%
1	+20%/-10%	50% to 100%

Source: Adapted from American Association of Cost Engineers International Recommended Practice 18R-97 (AACEI, 2005)

Total estimated capital cost and operation and maintenance (O&M) cost estimates and associated parametric cost graphs presented in Appendix A are considered Class 5 cost estimates. Class 5 cost estimates are defined as an order of magnitude estimate and are generally prepared based on limited information containing a wide estimated accuracy range of +100 and -50 percent (AACEI, 2005). These estimates were prepared to provide guidance in evaluation of each technologies. They are based solely on the information available at the time of the estimate, which is to assume “typical” power plant conditions. Actual final costs will depend on the actual labor and material costs, competitive market conditions, site conditions, final project scope, implementation schedule, and other variable factors.

Estimated operational costs include maintenance, labor, energy, cleaning, chemical, and residual disposal costs. Residuals are assumed to be non-hazardous and disposed in a non-hazardous waste landfill. Chemical cost estimates are based on typical dosage rates and will vary based on site-specific conditions. Maintenance cost estimates are based on 5 percent of total installed equipment costs for the facility.

The total capital and operating cost for a system is estimated by first building up the total installed equipment cost for the sub-systems, and then using system-wide cost factors (Table 3). The midpoint of the suggested range for each cost factor was used to estimate costs for this evaluation. The cost of the building to house the treatment equipment is part of the total installed cost for each of the sub-systems.

TABLE 3
Physical/Chemical Cost Estimate Factors

Additional Cost Items	Suggested Range		Value Used
Site Work	3%	5%	4%
Concrete	15%	20%	17.5%
Piping	6%	8%	7%
Miscellaneous Metals, Finishes	5%	15%	10%
Mechanical and Heating, Ventilation, and Air Conditioning (HVAC)	5%	10%	7.5%
Electrical	14%	30%	22%
Instrumentation and Control (I&C)	10%	20%	15%
Subcontractor Overhead and Profit	5%	15%	10%
General Contractor General Conditions	11%	14%	12.5%
Bonding and Insurance	2.7%	3%	2.85%
General Contractor Profit	14.1%	14.4%	14.25%
Miscellaneous Unidentified Cost	10%	30%	20%
Engineering (Design, Services during Construction [SDC], Startup, and Operator Training)	15%	25%	20%

Supporting Calculations Used to Develop Capital Cost Estimate

Physical/Chemical FGD Wastewater Treatment

The first step in the cost estimating tool includes estimating the capital cost of the equipment included in the treatment system. The subsystems assumed in Merrimack's FGD wastewater treatment system include the following:

- Desaturation and solids removal by primary clarification
- Equalization
- Metals removal
- Effluent media filtration
- Solids dewatering
- Supporting equipment

After the sub-total - installed equipment cost was estimated, the total estimated capital cost was estimated using system-wide cost factors as shown in Table 4.

Table 4 summarizes EPRI's calculations of total capital cost for the 70-gpm system.

TABLE 4
Summary of Estimated Physical/Chemical Treatment Costs

Cost Element*	Costs
Desaturation and solids removal primary clarification	$860,000
Equalization	$400,000
Secondary Clarification	$0**
Filtration	$380,000
Metals removal	$140,000
Solids dewatering	$1,850,000
Support Equipment	$1,090,000
Sub-total – Installed Equipment	**$4,720,000**
Site Work*	$189,000
Concrete*	$826,000
Piping*	$330,000
Miscellaneous Metals, Finishes*	$472,000
Mechanical, HVAC*	$354,000
Electrical*	$1,038,000
I&C*	$708,000
Sub-total – Subcontractor Direct Costs	*$8,640,000*
Subcontractor Overhead and Profit*	$864,000
Sub-total – Subcontractor Cost	*$9,500,000*
General Contractor General Conditions*	$1,190,000
Bonding and Insurance*	$271,000
Sub-total – Direct Costs	**$10,960,000**
General Contractor Profit*	$1,560,000
Sub-total	**$12,500,000**
Miscellaneous Unidentified Cost*	$2,500,000
Sub-total – Estimated Construction Cost	**$15,000,000**
Engineering (Design, SDC, Startup, and Operator Training)*	$3,000,000
Total Estimated Capital Cost	**$18,000,000**

* See Table 3 for factors used to estimate these additional cost items.
** The Merrimack system has only one clarifier per treatment train, so the secondary clarifier sub-system was set to zero.

Physical/Chemical Treatment Plant Sub-Systems

Table 5 presents the equipment and the design criteria for the different sub-systems used to estimate costs for Merrimack at a flow of 70 gpm. For each sub-system (desaturation and solids removal by primary clarification, equalization, metals removal, effluent media filtration, solids dewatering, and supporting equipment), a cost curve was developed as a function of a key variable affecting cost. The key variable is wastewater flow for most sub-systems, while daily solids load to the treatment system is the key variable for the solids dewatering sub-system. Examples are provided for the desaturation/primary clarification and solids dewatering sub-systems, which are the two more-capital-intensive sub-systems. The curves include the cost of the elements that make up the sub-systems (e.g., pumps, mixers, tanks). The curves were built by developing cost estimates for equipment at seven flows (25, 50, 100, 200, 400, 600, and 800 gpm).

For example, Figure 2, the desaturation/primary clarification subsystem, includes the following equipment: desaturation tank, desaturation tank mixer, primary clarifier, primary clarifier sludge pumps, and polymer blending system. The installed equipment costs for the desaturation/primary clarification sub-system include costs for equipment, foundation, building and installation.

Each cost curve was developed by sizing and then estimating cost of each element by obtaining quotes from equipment vendors, and estimating costs to install the equipment based on construction cost estimators' experience. An example of equipment sizing for the primary clarifier is summarized as follows:

- Primary clarifier design criteria set at 0.25 gpm per square foot (ft^2). Construction assumed to include clarifier drive mechanisms of carbon steel coated with Ceilcote, tank field-fabricated carbon steel with Ceilcote lining, picket fence floc mechanism, steep floors, high torque
- At 50 gpm = 16-foot-diameter clarifier
- Cost estimate obtained from equipment vendor for a 16-foot-diameter clarifier = $194,000
- Installation cost from engineering cost estimators = $14,000
- Total estimated cost of installed primary clarifier equipment = $208,000
- Total estimated cost of installed equipment for sub-system (primary clarifier, desaturation tank, desaturation tank mixer, primary clarifier waste pumps, polyblend system, building area for all but clarifier) = $390,000

In Figure 3, the solids dewatering sub-system, the curve was created based on solids loading (3,000, 10,000, 50,000, 100,000, 250,000, and 500,000 pounds per day). One shift of operation per day was assumed. The equipment includes the following: sludge holding tank, sludge holding tank mixer, filter press, filter press feed pumps, filter cloth wash water tank.

FIGURE 2
Capital Cost Estimate Curve for Desaturation and Primary Clarification Sub-System

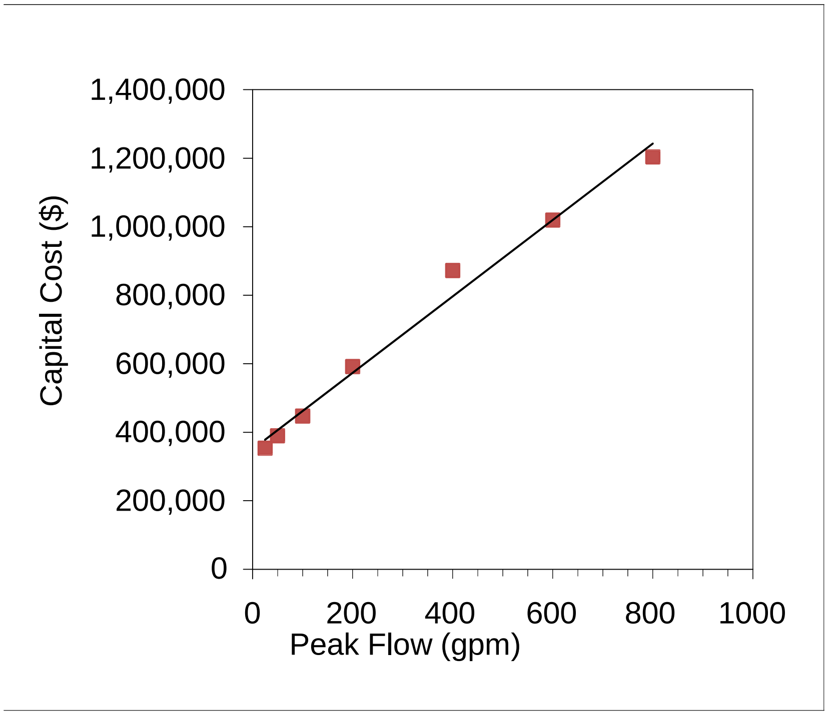


FIGURE 3
Capital Cost Estimate Curve for Solids Dewatering Sub-System

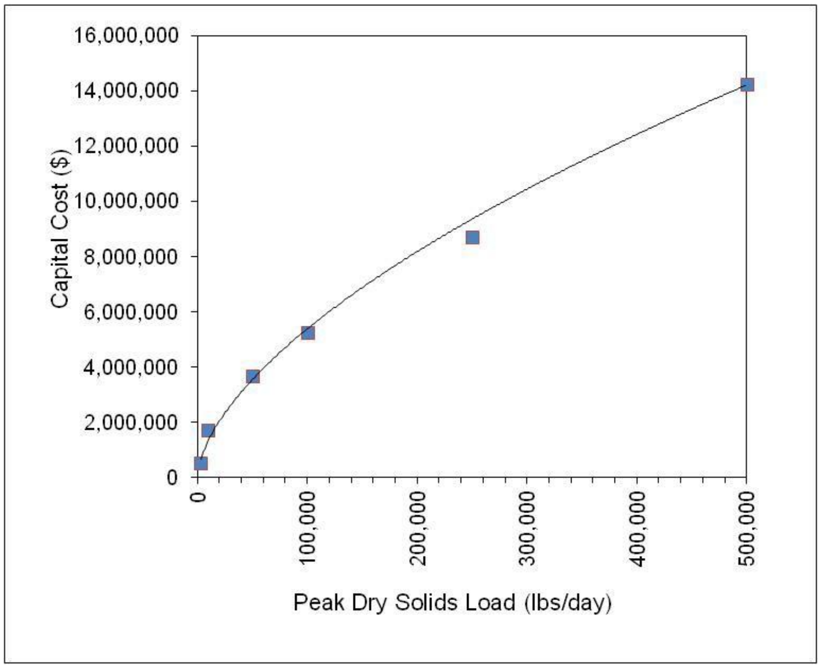


TABLE 5

Equipment List for 70 gpm Physical/Chemical Treatment

Sub-system	Cost Element	Design Criteria
Desaturation/Primary Clarifier	Desaturation Tank	40-minute hydraulic detention time (HDT)
	Desaturation Tank Mixer	0.001 horsepower (hp)/gallon
	Primary Clarifier	0.25 gpm/ft^2
	Primary Clarifier Waste Pumps	gpm (equal to ~50% of wastewater flow)
	Polybend System	10 Dose (parts per million [ppm] vol/vol)
	Building Area Requirement	$150 cost/ ft^2/ floor
EQ	Equalization Tank	12-hour HDT
	Equalization Tank Mixer	5 hp at 50 gpm, 7.5 hp at 100 gpm
Filter	Filter	2.5 gpm/ft^2
	Backwash Pumps for the Filter Backwash	15 gpm/ft^2
	Building Area Requirement	$150 cost/ ft^2/ floor
Metals Removal	Organosulfide Chemical Feed Pumps	Dose (30 ppm)
	Reactor Tank	20-minute HDT
	Reactor Tank Mixer	0.001 hp/gallon
Solids Dewatering	Sludge Holding Tank	24-hour HDT
	Sludge Holding Tank Mixer	0.0005 hp/gallon
	Filter Press Feed Pumps	gpm (equal to wastewater flow)
	Filter Press	Sludge production, 2 hours per cycle, press capacity
	Filter Cloth Wash Water Tank	1,500 gallons
	Building Area Requirement	$150 cost/ ft^2/ floor
Support Equipment	Lime Feed System Filter	15 days storage
	Effluent Sump Miscellaneous	20-minute HDT at filter backwash rate
	Waste Sump Pumps from	20-minute HDT at filter backwash rate
	Equalization Tank Flushing	gpm (equal to wastewater flow)
	Pumps	gpm (equal to wastewater flow)
	Seal Water Pumps	gpm (equal to 4% of wastewater flow)
	WWTP Effluent Pumps	gpm (equal to wastewater flow)
	pH Adjustment: Acid Feed Pump System	Dose (20 ppm)
	pH Adjustment: Caustic Feed Pump System	Dose (20 ppm)
	pH Adjustment: Caustic Storage	Truck load (7,000 gallons)
	pH Adjustment: Hydrogen Chloride (HCl) Storage	Truck load (7,000 gallons)
	Ferric Chloride Storage	Truck load (7,000 gallons)
	Sump Pumps	Flow (1/3 of the flow to backwash pumps)
	Building Area Requirement	$150 cost/ ft^2/ floor

Supporting Calculations to Develop O&M Cost Estimate

The estimated O&M costs are built up from five elements: labor, chemicals, waste transport and disposal, utilities (such as electrical power), and equipment maintenance. Estimated O&M costs are estimated based on average flow, since this will drive the amount of chemicals and utilities used and the waste generated. The average flow rate for the Merrimack FGD wastewater treatment system is 50 gpm, and average daily solids loading is 20,000 mg/L suspended solids to the wastewater treatment system.

Table 6 summarizes EPRI's calculations of O&M cost for the 50-gpm system. Key assumptions used in these calculations are also described. The largest line item is the labor costs to operate the wastewater treatment system. EPRI assumed one person on duty at all times (24 hr/day, 365 days), plus one person per shift 7 days/week to operate the dewatering presses. This is prudent, typical staffing level for a complex wastewater treatment system. Maintenance cost estimates are based on 5 percent of total installed equipment costs.

TABLE 6
Summary of Physical/Chemical Treatment O&M Costs

Cost Element	Costs	Assumptions
Chemicals	$130,000	Lime: $0.24/pound Ferric chloride (35%): $4.25/gallon Hydrochloric acid (93%): $1.79/gallon Caustic (25%): $1.68/gallon Polymer: $25/pound Organosulfide: $25/gallon
Electricity	$10,000	$0.02/kW-hr
Maintenance	$230,000	5% of total installed equipment cost
Labor	$520,000	$45/hour
Waste transport and disposal	$70,000	$14/ton disposed
Overall assumptions		Treatment system operates 85% of the time Average influent of 50 gpm and 20,000 mg/L suspended solids
Total Estimated O&M Cost	**$1,000,000**	

Appendix B: FGD Wastewater Biological Treatment Cost Estimating Summary

Introduction

Appendix B provides supporting calculation details to how EPRI estimated the cost of FGD wastewater treatment using a biological system for the PSNH Merrimack Station. EPRI's costs estimates are based on the flow rates of 50 (average flow rate) and 70 (peak flow rate) gallons per minute (gpm).

The following approach was used:

- Used vendor-developed cost curve for the General Electric (GE) Advanced Biological Metals Removal Process (ABMet®) system, taking into account the assumptions developed by the vendor to prepare the cost curve
- Used the values obtained from the cost curve, adding cost factors for plant tie-in/integration, permitting, insurance and bonding, and other factors that vendor has identified as not being included within their own estimate to create total estimated capital cost for ABMet® system
- Added costs for required pre-treatment of heat exchanger for cooling water prior to entering; heat exchanger is not part of typical FGD wastewater treatment plant (WWTP) so is added on to the incremental biological treatment cost; total estimated capital costs were calculated for pre-treatment

Biological Cost Estimate Assumptions

The cost estimate of FGD wastewater biological treatment was evaluated at 50 (average flow rate) and 70 (peak flow rate) gallons per minute (gpm). EPRI assumed that influent FGD solids are removed by physical/chemical treatment prior to entering the biological system such that influent total suspended solids (TSS) is less than 30 milligrams per liter (mg/L). Biological treatment is based on the commercially available ABMet® system supplied by GE, which has been used primarily for selenium removal at a few FGD systems. It is assumed that a heat exchanger will be required as pre-treatment to cool the physical/chemical treatment plant effluent to less than 100 degrees Fahrenheit (°F).

The treatment train for the ABMet® system consists of two-stage biological reactors and a nutrient feed system. The reactors are typically sized to provide 4 to 8 hours of hydraulic detention time. The bioreactor tanks are filled with granular activated carbon (GAC), which provides a growth medium for microbes. Microbial growth is supported by addition of nutrients and an additional substrate in the event that the feed water contains an insufficient food source for microbes.

The vendor-supplied cost curve was provided to EPRI in May 2010, and is not unique for the Merrimack system. In this cost curve, GE assumed that the influent feed to the ABMet® system met the following water quality characteristics:

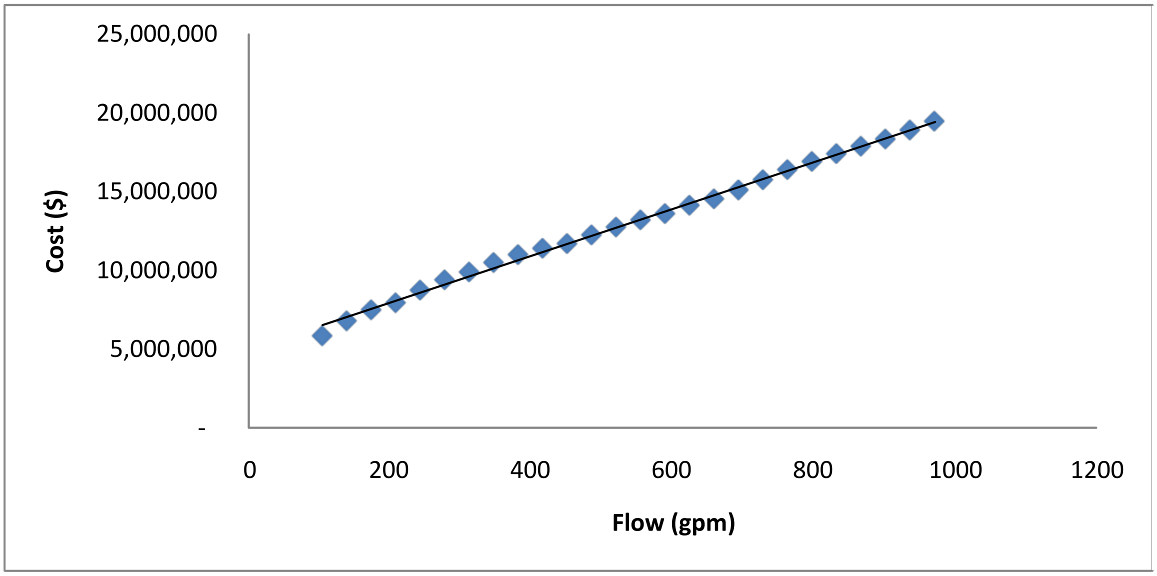
- Feed TSS <30 mg/L
- Feed chlorides 10,000 to 20,000 mg/L
- Feed temperature 50°F to 100°F
- Feed pH 6 to 7.5
- Feed nitrate-N <100 mg/L
- Feed total selenium <6 mg/L (oxidized forms [i.e., Se(VI) and Se(IV)], no reduced species [i.e., SeCN])

The following equipment is included within the ABMet® system provided by the vendor:

- All process pumps, valves, and instruments
- Process and instrument compressed air system, valves, and lines
- Nutrient system, storage tank, and pumping
- All process piping and supports within the ABMet® "island"
- Process equipment building with heating, ventilation, and air conditioning (HVAC) (concrete floor, block structure with steel roof)
- Concrete bioreactor tank walls and floor with epoxy-coated rebar and epoxy flake-glass coating
- Concrete backwash supply and backwash waste tank walls and floor with epoxy-coated rebar and epoxy flake-glass coating
- Concrete process and utility sump with pumps
- Support steel, access stairs, walkways, grating, and handrails

EPRI used the vendor-developed cost curve for the ABMet® system, taking into account the assumptions developed by the vendor to prepare the cost curve. The cost curve is based on the flow rate of the system. The information presented in the cost curve is based on typical installation specifications for the implementation of ABMet® technology into FGD wastewater applications for the removal of selenium and nitrate.

FIGURE 1
GE ABMet® Cost Curve (from May 2010)



EPRI then added cost factors for plant tie-in/integration, permitting, insurance and bonding, and other factors that vendor has identified as not being included within their own estimate to create total estimated capital cost for ABMet® system.

EPRI then added estimated costs for required pre-treatment of the cooling water entering the heat exchanger. The heat exchanger is not part of typical FGD wastewater treatment plant so it is added to the incremental biological treatment cost.

Backwash waste disposal/solids handling treatment equipment were not included in the estimate because it is assumed that a physical/chemical treatment plant will include this equipment and there will be enough capacity for the solids dewatering equipment to account for handling/dewatering of biological solids.

TABLE 1
GE ABMet® Equipment and Cost Factors

Additional Cost Items	Value Used
GE ABMet®	$6,000,000
Heat Exchanger	$80,000
Subtotal – Installed Equipment	**$6,100,000**
Piping	1%
Electrical	2%
Electrical Transmission Power Feed	$100,000
Electrical Building and Equipment	$170,000
Yard Improvements	1%
Sub-total Direct Costs	**$6,500,000**
Engineering	2%
Sub-total	**$6,700,000**
Tie-in Allowance	20%
Engineering for Tie-Ins**	15%
Contingency	30%
Sub-total - Estimated Construction Cost	**$10,200,000**
Engineering Services for ABMet***	5%
Total Estimated Capital Costs******	**$10,500,000**

* The price of the heat exchanger is based on titanium as the material of construction. Some applications may not require a heat exchanger to maintain the desired feed water temperature.
** The Engineering for Tie-Ins is calculated as 15% of the Tie-In Allowance.
***The Engineering Services for ABMet are calculated as 5% of the sub-total Direct Costs.
**** This assumes a physical/chemical system is already in place.

The following assumptions and factors are included within the total estimated capital costs of biological treatment:

- Engineering, commissioning, and project management labor
- Construction equipment, materials, and labor
- Integration into existing physical/chemical treatment plant
- Unionized contractor labor is assumed
- No special seismic criteria incorporated
- Costs based on executing project structure of consortium between GE and contractor with balance of plant engineering as a sub-contractor

- Costs assuming integration of ABMet® system into larger wastewater facility, following conventional physical/chemical treatment with ABMet® backwash waste recycled to conventional system for solids removal
- Labor for power plant staff to support this work not included within this estimate

Biological Treatment Cost Estimate

A summary of the incremental costs for addition of biological treatment are shown in Table 2. This cost is in addition to the physical/chemical treatment costs outlined in Appendix A.

TABLE 2
Biological Treatment: Cost Estimate Comparison Evaluating Average versus Design Flow

Flow (gpm)	Capital Cost ($MM)	O&M Cost ($MM/year)
50	9.0	0.55
70	10.5	0.55*

*Average flow (50 gpm) is used to calculate O&M Costs.

Supporting Calculations to Develop O&M Cost Estimate

The estimated O&M costs are built up from five elements: labor, chemicals, waste transport and disposal, utilities (such as electrical power), and equipment maintenance. Estimated O&M costs are based on average flow, since this will drive the amount of chemicals and utilities used and the waste generated.

Table 3 summarizes EPRI's calculations of O&M cost for the 50-gpm system. Key assumptions used in these calculations are also described. For the labor costs to operate the wastewater treatment system, EPRI assumed an additional operator per shift. Maintenance cost estimates are based on 5 percent of total installed equipment costs.

TABLE 6
Summary of O&M Cost Estimates: Biological Treatment

Cost Element	Costs	Assumptions
Chemicals	$3,000	Based on vendor quote
Electricity	$1,000	Based on vendor estimate of $0.022/1,000 gallons treated
Maintenance	$260,000	5% of total installed equipment cost
Labor	$280,000	One additional operator per shift. $45/hour
Waste transport and disposal	$1,000	$14/ton disposed
Overall assumptions		Treatment system operates 85% of the time Average influent of 50 gpm and 20,000 mg/L suspended solids
Total Estimated O&M Cost	**$550,000**	

Appendix C: FGD Wastewater Treatment Benefits Analysis

Introduction

Appendix C provides supporting calculation details to how EPRI estimated the benefits (i.e. removal) of physical/chemical and biological FGD wastewater treatment. EPRI's benefit estimates for the Merrimack Station are based on the average flow rate of 50 gallons per minute (gpm).

Calculation Methodology

For the purposes of this analysis, the benefits of treatment were defined as the amount of contaminants removed from wastewater. The contaminants removed were calculated both as total pounds removed and toxic-weighted pound equivalents (TWPE). TWPE factors are used by the United States Environmental Protection Agency (EPA) to express the relative toxicity of pollutants. Calculations use the concentration of contaminants in the water, wastewater flow, and toxic weighting factors (TWF). Data from the Duke Energy Belews Creek and Allen plants were used in the calculations. These sites are not necessarily representative of PSNH Merrimack's wastewater, or the entire industry. However, the Duke plants have similar treatment trains - physical/chemical treatment followed by biological treatment – which EPA determined to be best available technology (BAT) in the draft Merrimack permit. Also, the data from the Duke plants are likely the source of data that EPA used in their benefit calculations of FGD wastewater treatment.

Summary of Available Data

The data used in EPRI's evaluation is from *EPA's Sampling Episode Report Duke Energy Carolinas' Belews Creek Steam Station; Belews Creek, NC Sampling Episode 6558; December 2011 and the USEPA's Sampling Episode Report Duke Energy Carolinas' Allen Steam Station; Belmont, NC Sampling Episode 6561; December 2011.*

During June 2010, EPA and Eastern Research Group, Inc. (ERG) collected samples over 4-day period at Belews Creek and Allen. The sampling points for this episode were influent to the FGD wastewater treatment system (SP-1), influent to the bioreactor system (SP-2), and effluent from the bioreactor system (SP-3). Samples collected were analyzed for classical pollutants, total metals, and dissolved metals. EPRI used the 4-day average concentration in developing the benefit calculations for Merrimack. The average concentration was multiplied by the average flow rate at Merrimack (50 gallons per minute [gpm]) to estimate the mass in pounds per year at Merrimack, using the assumption that the Duke data will be representative of Merrimack's wastewater. The flow was conservatively assumed to be continuous (24 hours per day, 365 days per year). The mass was then multiplied by the TWF to calculate the TWPE.

When data were reported with a data qualifier flag of J, meaning the result was measured above the method detection limit (MDL), but less than the quantitation limit, the quantified data were used in EPRI's calculations. For the samples that were not detected, EPRI used half the method detection limit. All of the parameters that were analyzed by EPA were used in the

EPRI benefit calculations with the following exceptions: calcium, chloride, hexavalent chromium, sodium, sulfate, biological oxygen demand, total suspended solids, total dissolved solids, and total Kjeldahl nitrogen. These parameters were removed from the EPRI calculations to be consistent with the September 13, 2011 e-mail from Ron Jordan (Docket # AR118), which stated that these parameters were not used in EPA's estimate of contaminant removal. Chemical oxygen demand (COD) was also not included in this analysis. Total nitrogen was not analyzed by EPA and was not included in EPRI's removal analysis. As some nitrate/nitrite may be converted to ammonia, EPRI included nitrate/nitrite as well as ammonia to characterize the fate of nitrogen through the treatment systems.

To estimate the effluent concentrations from a settling pond, EPRI followed the assumptions made by EPA, which is the total settling pond effluent concentration was equal to the sum of the contribution from the solids present in the wastewater and the dissolved concentration present in the wastewater. Additionally, EPA assumed a TSS concentration of 30 mg/L at the effluent (ERG, 2009). The following equation was used to perform this calculation:

$$C_{Settling}\text{ (ug/L)} = C_{Dry}\text{ mg/Kg} \times 30\text{ mg/L} \times 0.000001\text{ Kg/mg} \times 1000\text{ ug/mg} + C_{Dissolved}\text{ (ug/L)}$$

Where:

$$C_{Dry}\text{ (mg/Kg)} = [\ C_{Total}\text{ (ug/L)} - C_{Dissolved}\text{ (ug/L)}\ ] \times 1000000\text{ mg/Kg}\ ] / [\ C_{TSS}\text{ (mg/L)} \times 1000\text{ ug/mg}\ ]$$

Calculated Benefit Estimates of Wastewater Treatment

For clarity, the following terms are used:

- Physical/Chemical removal: The amount removed via physical/chemical treatment
- Incremental Biological removal: The incremental amount removed across the biological treatment system
- Overall removal: The amount removed via the combination of physical/chemical treatment and biological treatment.
- Total: The data based on total constituent analyses. Total values were provided for untreated FGD wastewater, physical/chemical effluent, and biological effluent
- Settled: To estimate the effluent concentrations from a settling pond, EPRI followed the assumptions made by EPA, which is the total settling pond effluent concentration was equal to the sum of the contribution from the solids present in the wastewater and the dissolved concentration present in the wastewater. See a description of these calculations in the Summary of Available Data section above. The removal calculations compared the settled values with total values for physical/chemical effluent and biological effluent.

A summary of the estimated benefit calculations for Merrimack is presented in Table 1. Tables 2 & 3 present the 4-day average concentrations at Belews Creek and Allen. Tables 4 & 5 present EPRI's estimated benefits in the pounds per year removed for each element. Tables 6 and 7 present the TWPE per year removed for each element.

A more detailed evaluation is needed to understand which removals and increases are statistically significant and which are part of the natural variability that comes with sampling and analytical methods. For example, at Allen, the total and dissolved boron concentration slightly decreased through physical chemical treatment and then slightly increased after biological treatment. The total boron concentration at Allen increased from 58,000 mg/L in the physical/chemical effluent to 63,800 mg/L in the biological effluent. This increase alone accounted for a negative removal of nearly 1,300 pounds per year, however for the purposes of this estimate, EPRI substituted “0” for all negative removals, with the exception of ammonia – which may be produced as the nitrate is converted to other nitrogen species in the biological treatment system. Hence, the calculated removals in Table 1 do not include boron, magnesium, and all negative values of removal except the ammonia.

TABLE 1

Mass and TWPE Removal by Physical/Chemical and Biological Treatment of FGD Wastewater

	EPA		EPRI – TOTAL				EPRI – SETTLED			
			Belews Creek		Allen		Belews Creek		Allen	
	Pounds per Year	TWPE per Year	Pounds per Year	TWPE per Year	Pounds per Year	TWPE per Year	Pounds per Year	TWPE per Year	Pounds per Year	TWPE per Year
Physical/Chemical Treatment	16,900	NA	45,100	8,400	33,700	3,000	1,500	100	2,200	100
Incremental Biological	623,000	NA	3,900	1,500	2,100	< 100	3,900	1,500	2,100	<100
Overall	639,900	NA	48,100	10,000	35,800	3,100	4,400	800	4,300	200

* The overall treatment benefits do not equal to the sum of the physical/chemical plus biological treatment due to some parameters having a negative calculated removal (concentration increased in value) which EPRI substituted “0”.

TABLE 2
EPA Sampling and Analytical at Duke's Belews Creek, 4-Day Average Concentration

	Untreated FGD Scrubber Purge: TOTAL		Untreated FGD Scrubber Purge: DISSOLVED		Settling Pond Effluent: CALCULATED		Physical/Chemical System Effluent: TOTAL		Biological Effluent: TOTAL	
Analyte	**Concentration (ug/L)**	**Flag**	**Concentration (ug/L)**	**Flag**	**Concentration (ug/L)**	**Flag**	**Concentration (ug/L)**	**Flag**	**Concentration (ug/L)**	**Flag**
Aluminum	88,500		8	J, B, U, F	777		82	J, U	47	J, U
Antimony	9		2		2		2	J	0.4	U
Arsenic	235		3	<	5		2	J	2	J
Barium	1,230		663		668		393		380	
Beryllium	9		0.4	U, F	0.4		0.4	U	0.4	U
Cadmium	3	<	3	J	3		1	U	1	U
Chromium	253		5	<	7		19		2	U
Cobalt	57		23	<	24		1	U	1	U
Copper	155		3	<	4		1	J, U	0.5	U
Iron	102,000		16	U, F	903		30	J, U	150	<
Lead	125		0.4	U	1		0.4	U	0.4	U
Manganese	5,730		4,550		4,560		5	J	320	
Mercury	255		17	*	19		48		0.31	**
Molybdenum	45		23	J	23		20	J	2	J, U
Nickel	230		128		129		10		1	J, U
Nitrate/Nitrite	16,300		16,300		16,300		19,800		12	J, U, F
Selenium	6,580		665		716		1,230		16	
Silver	0.3	U	0.3	U	0.3		0.3	U	0.3	U
Thallium	4		4		4		1	J	0.2	U
Tin	15	J	7	J, F	7		3	J, U	2	U
Titanium	1,400		8	J, F	20		9	J	8	J
Vanadium	198		2	J, U	4		4	J	1	U
Zinc	300		34		36		7	<	2	U
Total Phosphorus	456	<	456	<	456		9	J, B	96	<
Ammonia as Nitrogen	650	<	650	<	650		1,010	<	4,460	
Boron	150,000		148,000		148,017		150,000		170,000	
Magnesium	743,000		695,000		695,417		753,000		785,000	

TABLE 3
EPA Sampling and Analytical at Duke's Allen, 4-Day Average Concentration

	Untreated FGD Scrubber Purge: TOTAL		Untreated FGD Scrubber Purge: DISSOLVED		Settling Pond Effluent: CALCULATED		Physical/Chemical System Effluent: TOTAL		Biological Effluent: TOTAL	
Analyte	**Concentration (ug/L)**	**Flag**	**Concentration (ug/L)**	**Flag**	**Concentration (ug/L)**	**Flag**	**Concentration (ug/L)**	**Flag**	**Concentratio n (ug/L)**	**Flag**
Aluminum	72,300		16	J, U	890		7	J, B, U	38	J, B
Antimony	11		3		3		2		0.4	U
Arsenic	135		9		10		2	J	1	J, U
Barium	888		368		374		223		214	
Beryllium	12		0.4	U	0.5		0.4	U	0.4	U
Cadmium	3	<	2	J	2		1	U	1	U
Chromium	133		2	U	3		2	U	2	U
Cobalt	61		19	<	20		1	U	1	U
Copper	160		11		13		11		0.5	U
Iron	67,800		16	U	836		29	J, B, U	128	<
Lead	101		0.4	U	2		1	J, U	0.4	U
Manganese	3,930		3,380		3,387		425		436	
Mercury	49		0.03		1		1		0.022	
Molybdenum	25	<	18	J	18		20	J	2	J, U
Nickel	188		80		82		8		1	J, U
Nitrate/Nitrite	18,300		18,300		18,300		13,300		70	<
Selenium	1,700		315		332		95		1	J
Silver	0.3	U	0.3	U	0.3		0.3	U	0.3	U
Thallium	3		1	J	1		1	J	0.2	U
Tin	9	J	2	U	2		2	U	2	U
Titanium	1,530		3	J	22		5	J	4	J
Vanadium	155		2	J, U	4		1	U	1	U
Zinc	278		37		40		7	J	8	<
Total Phosphorus	106	<	106	<	106		34	<	153	
Ammonia as	7,930		7,930		7,930		8,110		11,800	
Boron	74,000		72,300		72,321		58,000		63,800	
Magnesium	505,000		473,000		473,387		415,000		429,000	

< - Average results includes at least one value measured below the quantitation limit. (Calculation uses 1/2 the quantitation limit for values below the quantitation limit).

* - The 4-day average result includes an analytical result where the accuracy is questionable. If the questionable result was excluded from the calculated average, the 4-day average would be 131 ng/L.

** - The 4-day average result presented has been revised to exclude the Day 2 duplicate result because it is an erroneous result based on the Day 2 original sample result and the results from the other sampling days.

J - Result measured above the MDL, but less than the quantitation limit.

B - Analyte was found in the blank and sample.

F - MS and/or MDS not within laboratory control limits.

U - Result below the MDL.

TABLE 4

EPRI Estimated Benefit Calculation Using Duke's Belew Creek: Pounds Per Year Removed

	TOTAL			SETTLED		
Analyte	**Physical/ Chemical**	**Incremental Biological**	**Overall**	**Physical/ Chemical**	**Incremental Biological**	**Overall**
Aluminum	19,415	8	19,423	153	8	160
Antimony	2	0	2	0	0	0
Arsenic	51	0	51	1	0	1
Barium	184	3	187	60	3	63
Beryllium	2	-	2	0	-	0
Cadmium	0	-	0	0	-	0
Chromium	51	4	55	(3)	4	1
Cobalt	12	-	12	5	-	5
Copper	34	0	34	1	0	1
Iron	22,391	(26)	22,364	192	(26)	165
Lead	27	-	27	0	-	0
Manganese	1,257	(69)	1,188	1,000	(69)	931
Mercury	46	10	56	(6)	10	4
Molybdenum	6	4	10	1	4	5
Nickel	48	2	50	26	2	28
Nitrate/Nitrite	(769)	4,345	3,577	(769)	4,345	3,577
Selenium	1,175	267	1,441	(113)	267	154
Silver	-	-	-	-	-	-
Thallium	1	0	1	1	0	1
Tin	3	0	3	1	0	1
Titanium	305	0	306	2	0	3
Vanadium	43	1	43	0	1	1
Zinc	64	1	65	6	1	8
Total Phosphorus	98	(19)	79	98	(19)	79
Ammonia as	(79)	(758)	(837)	(79)	(758)	(837)
Boron	-	(4,392)	(4,392)	(435)	(4,392)	(4,827)
Magnesium	(2,196)	(7,027)	(9,222)	(12,644)	(7,027)	(19,670)

Note: all negative values were set to zero in summing total benefits (pounds per year removed and TWPE per year), except for ammonia.

TABLE 5
EPRI Estimated Benefit Calculation Using Duke's Allen: Pounds Per Year Removed

Analyte	TOTAL			SETTLED		
	Physical/ Chemical	Incremental Biological	Overall	Physical/ Chemical	Incremental Biological	Overall
Aluminum	15,874	(7)	15,867	194	(7)	187
Antimony	2	0	2	0	0	1
Arsenic	29	0	29	2	0	2
Barium	146	2	148	33	2	35
Beryllium	2	-	2	0	-	0
Cadmium	0	-	0	0	-	0
Chromium	29	-	29	0	-	0
Cobalt	13	-	13	4	-	4
Copper	33	2	35	0	2	3
Iron	14,881	(22)	14,859	177	(22)	155
Lead	22	0	22	0	0	0
Manganese	770	(2)	767	650	(2)	648
Mercury	11	0	11	(0)	0	0
Molybdenum	1	4	5	(0)	4	4
Nickel	40	2	41	16	2	18
Nitrate/Nitrite	1,098	2,905	4,003	1,098	2,905	4,003
Selenium	352	21	373	52	21	73
Silver	-	-	-	-	-	-
Thallium	0	0	1	0	0	0
Tin	1	-	1	0	-	0
Titanium	335	0	335	4	0	4
Vanadium	34	-	34	1	-	1
Zinc	60	(0)	59	7	(0)	7
Total Phosphorus	16	(26)	(10)	16	(26)	(10)
Ammonia as	(40)	(810)	(850)	(40)	(810)	(850)
Boron	3,513	(1,274)	2,240	3,145	(1,274)	1,871
Magnesium	19,762	(3,074)	16,688	12,821	(3,074)	9,746

Note: all negative values were set to zero in summing total benefits (pounds per year removed and TWPE per year), except for ammonia.

Table 6
EPRI Estimated Benefit Calculation Using Duke's Belew Creek: TWPE Per Year Removed

Analyte	TOTAL			SETTLED		
	Physical/ Chemical	Incremental Biological	Overall	Physical/ Chemical	Incremental Biological	Overall
Aluminum	1,256	1	1,256*	10	1	10*
Antimony	0	0	0	0	0	0
Arsenic	207	0	207	3	0	3
Barium	0	0	0	0	0	0
Beryllium	2	-	2	0	-	0
Cadmium	10	-	10	11	-	11
Chromium	4	0	4	(0)	0	0
Cobalt	1	-	1	1	-	1
Copper	22	0	22	0	0	0
Iron	125	(0)	125	1	(0)	1
Lead	61	-	61	1	-	1
Manganese	89	(5)	84	70	(5)	66
Mercury	5,334	1,216	6,550	(746)	1,216	470
Molybdenum	1	1	2	0	1	1
Nickel	5	0	5	3	0	3
Nitrate/Nitrite	(2)	14	11	(2)	14	11
Selenium	1,317	299	1,616	(126)	299	173
Silver	-	-	-	-	-	-
Thallium	1	0	1	1	0	1
Tin	1	0	1	0	0	0
Titanium	9	0	9	0	0	0
Vanadium	1	0	2	0	0	0
Zinc	3	0	3	0	0	0
Total Phosphorus	-	-	-	-	-	-
Ammonia as	(0)	(1)	(1)	(0)	(1)	(1)
Boron	-	(37)	(37)	(4)	(37)	(40)
Magnesium	(2)	(6)	(8)	(11)	(6)	(17)

*Rounding accounts for the slight inconsistency of the addition of the physical/chemical removal and biological removal with the overall removal.

Note: all negative values were set to zero in summing total benefits (pounds per year removed and TWPE per year), except for ammonia.

TABLE 7
EPRI Estimated Benefit Calculation Using Duke's Allen: TWPE Per Year Removed

	TOTAL			SETTLED		
Analyte	**Physical/Chemical**	**Incremental Biological**	**Overall**	**Physical/ Chemical**	**Incremental Biological**	**Overall**
Aluminum	1,027	(0)	1,026	13	(0)	12
Antimony	0	0	0	0	0	0
Arsenic	118	1	119	7	1	8
Barium	0	0	0	0	0	0
Beryllium	3	-	3	0	-	0
Cadmium	10	-	10	6	-	6
Chromium	2	-	2	0	-	0
Cobalt	2	-	2	0	-	0
Copper	21	1	22	0	1	2
Iron	83	(0)	83	1	(0)	1
Lead	49	0	49	0	0	1
Manganese	54	(0)	54	46	(0)	46
Mercury	1,239	26	1,265	(11)	26	16
Molybdenum	0	1	1	(0)	1	1
Nickel	4	0	4	2	0	2
Nitrate/Nitrite	4	9	13	4	9	13
Selenium	395	23	418	58	23	81
Silver	-	-	-	-	-	-
Thallium	0	0	1	0	0	0
Tin	0	-	0	0	-	0
Titanium	10	0	10	0	0	0
Vanadium	1	-	1	0	-	0
Zinc	3	(0)	3	0	(0)	0
Total Phosphorus	-	-	-	-	-	-
Ammonia as	(0)	(1)	(1)	(0)	(1)	(1)
Boron	29	(11)	19	26	(11)	16
Magnesium	17	(3)	14	11	(3)	8

Note: all negative values were set to zero in summing total benefits (pounds per year removed and TWPE per year), except for ammonia.