LG&E/KU – Mill Creek Station

Phase II Air Quality Control Study

Air Quality Control Validation Report

March 4, 2011
Revision D – Issued For Project Use

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Acronym List

AHJ	Authority Having Jurisdiction
AQC	Air Quality Control
As	Arsenic
B&W	Babcock & Wilcox
Be	Beryllium
CAIR	Clean Air Interstate Rule
CATR	Clean Air Transport Rule
Cd	Cadmium
Co	Cobalt
Cr	Chromium
CS-ESP	Cold-side Electrostatic Precipitator
DCS	Distributed Control System
DOE	Department of Energy
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ESP	Electrostatic Precipitator
FRP	Fiberglass-Reinforced Plastic
HCl	Hydrogen Chloride
Hg	Mercury
ID	Induced Draft
Inw	Inch of Water
LNB	Low NO_x Burners
LV	Low Voltage
MACT	Maximum Achievable Control Technology
MBtu	Million British Thermal Unit
MCC	Motor Control Center
Mn	Manganese
MSW	Municipal Solid Waste
MV	Medium Voltage
MWC	Medical Waste Combustors
NAAQS	National Ambient Air Quality Standard
NFPA	National Fire Protection Association
Ni	Nickel
NID	Novel Innovative Desulfurization
NN	Neural Network

NO_x	Nitrogen Oxides
OFA	Overfire Air
PAC	Powdered Activated Carbon
Pb	Lead
PJFF	Pulse Jet Fabric Filter
PM	Particulate Matter
RGFF	Reverse Gas Fabric Filters
SAM	Sulfuric Acid Mist
Sb	Antimony
SBS	Sodium Bisulfite
SCA	Specific Collection Area
SCR	Selective Catalytic Reduction
Se	Selenium
SO_2	Sulfur Dioxide
tph	Tons per Hour
TR	Transformer/Rectifier
WFGD	Wet Flue Gas Desulfurization

1.0 Introduction

Following the submittal of the Phase I report on July 8, 2010, Black & Veatch met with LG&E/KU on August 5-6, 2010 and conducted a technology option review to further define facility technology options based on the Phase I report. The purpose of this Phase II air quality control (AQC) validation study is to build upon the previous fleet-wide, high-level air quality technology review and cost assessment conducted for six LG&E/KU facilities (Phase I) in order to develop a facility-specific project definition consisting of a conceptual design and a budgetary cost estimate for selected AQC technologies (Phase II) for the Mill Creek Generating Station. The following AQC technology options resulted from the August meeting and have been assessed in this report:

- NID or PJFF with sorbent (trona/lime/SBS [sodium bisulfite]) injection on Units 1-4.
- SCR on Units 1 and/or 2.
- Refurbishing or replacing WFGD on Units 1, 2 and 4, including using Unit 4's WFGD for Unit 3.
- New WFGD on Unit 4.
- Powdered activated carbon (PAC) injection on Units 1-4.
- Feasibility of neural network (NN) on Units 1-4.
- Feasibility of cold-side electrostatic precipitators (CS-ESPs) for pre-filtering on Units 1 and 2.

This validation study confirms the feasibility of installing the aforementioned AQC equipment at Mill Creek, and presents the supporting considerations, arrangements, and preliminary validating analyses of the AQC equipment that will be built upon in the next step of this project to complete the conceptual design and budgetary cost estimate.

2.0 Facility Description

2.1 Mill Creek - Units 1, 2, 3, and 4

The Mill Creek Station is located in southwestern Jefferson County, approximately 10.5 miles southwest of the city of Louisville, Kentucky, on a 509 acre site. Mill Creek Station includes four coal fired electric generating units with a gross total generating capacity of 1,608 MW. Mill Creek Station Unit 1 was placed in service in 1972, Mill Creek Station Unit 2 was placed in service in 1974, and Mill Creek Station Units 3 and 4 were each placed in service at 4 year intervals afterward in 1978 and 1982, respectively.

All four boilers fire high sulfur bituminous coal (i.e., high sulfur western Kentucky bituminous coal from Illinois Basin, natural gas for startup). Each Mill Creek Station unit includes one GE reheat tandem compound, double-flow turbine with a condenser and hydrogen-cooled generator. Units 1 and 2 each consist of one Combustion Engineering subcritical, balanced draft boiler and have a gross capacity of 330 MW each. Units 1 and 2 are equipped with LNBs and OFA for NO_x control, a CS-ESP for PM control, and a WFGD for SO_2 and HCl (hydrogen chloride) control. Units 3 and 4 each consist of one Babcock & Wilcox (B&W) balanced draft, Carolina type radiant boiler and have a gross capacity of 423 MW and 525 MW, respectively. Each is equipped with LNBs and SCR for NO_x control; a CS-ESP for PM control and a WFGD for SO_2 and HCl control.

Gypsum, a scrubber by-product, produced at Mill Creek is either stored in the on-site landfill or sold for use in manufacture of wall board for the home construction industry. Fly ash is either stored in the on-site landfill or sold for beneficial reuse to the concrete industry. Bottom ash is sluiced to on-site storage ponds. Initially, all four units were cooled using water from the nearby Ohio River; however, Units 2, 3, and 4 were retrofitted with mechanical draft cooling towers. Plant water is supplied by the Ohio River, well water and city water.

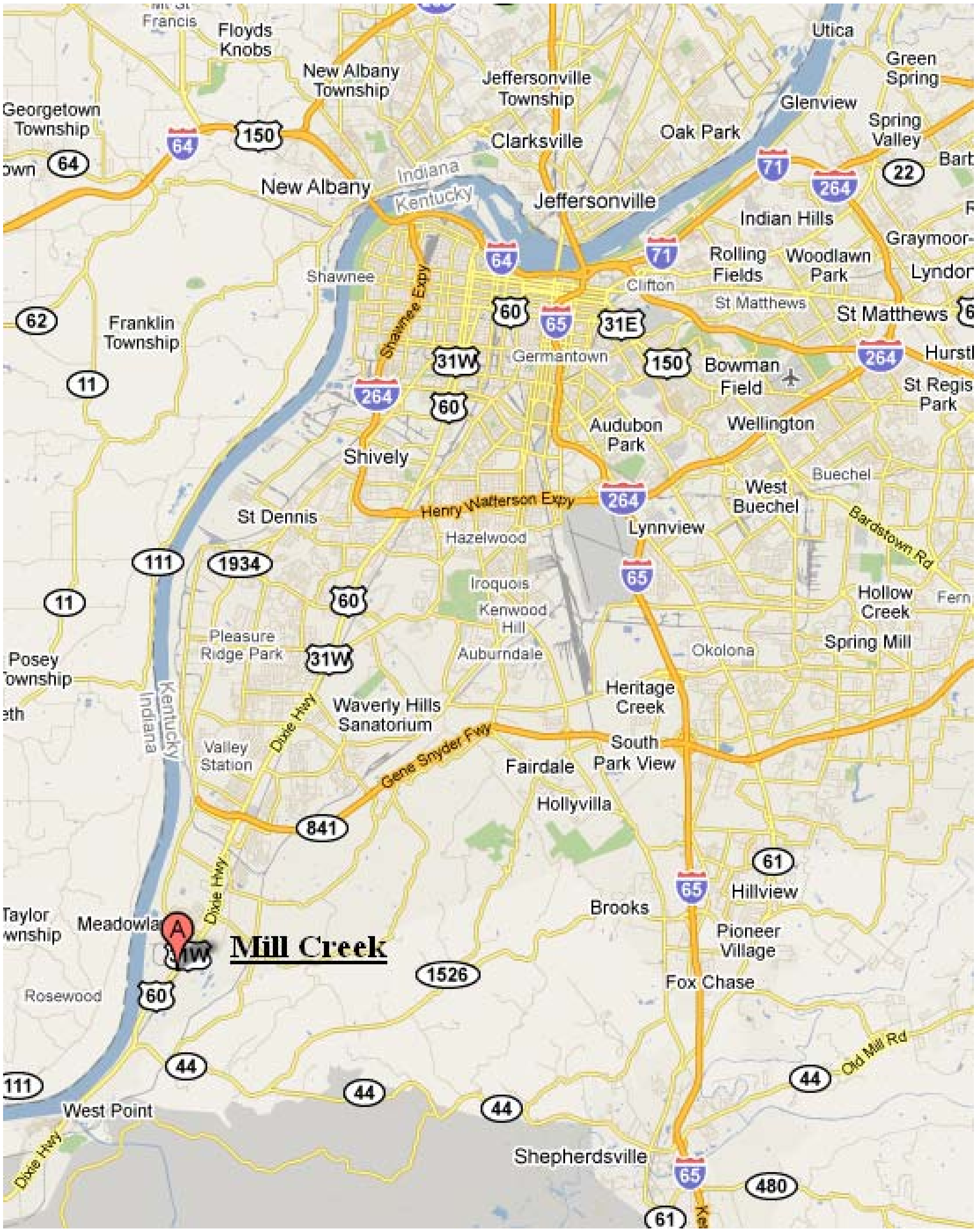
Figures 2-1 and 2-2 illustrate the plant location and Table 2-1 summarizes the plant's existing facilities.

NORTH

SOUTH

Figure 2-1. Mill Creek Power Plant Site

NORTH



SOUTH

Figure 2-2. Mill Creek and Surrounding Area Map

Table 2-1. Existing Mill Creek Plant Facilities	
• Existing On Site Generation Units:	• Unit 1 - 330 gross MW (in-service date 1972) • Unit 2 - 330 gross MW (in-service date 1974) • Unit 3 - 423 gross MW (in-service date 1978) • Unit 4 - 525 gross MW (in-service date 1982)
• Existing AQC Equipment:	• Unit 1 - Low NO_x Burners (LNBs), Overfire Air System (OFA), CS-ESP, Wet Flue Gas Desulfurization (WFGD) • Unit 2 - LNBs, OFA, CS-ESP, WFGD • Unit 3 - LNBs, Selective Catalytic Reduction (SCR), CS-ESP, WFGD • Unit 4 - LNBs, SCR, CS-ESP, WFGD

3.0 Emission Target Basis

LG&E/KU provided a matrix of estimated requirements under current and future environmental regulations, as well as a summary implementation schedule of regulatory programs. Table 3-1 summarizes the future pollution emission targets provided by LG&E/KU for each unit.

The current regulatory drivers include the NO_2 and SO_2 National Ambient Air Quality Standard (NAAQS). On January 22, 2010, the Environmental Protection Agency (EPA) announced a new 1-hour NO_2 NAAQS of 100 ppb. The final rule for the new hourly NAAQS was published in the Federal Register on February 9, 2010, and the standard became effective on April 12, 2010. Likewise, on June 2, 2010, EPA strengthened the primary SO_2 NAAQS. EPA established a new 1-hour standard at a level of 75 ppb and revoked the existing 24-hour and annual standards.

The potential impact of future regulations is the primary driver for both the timing and extent of environmental controls planned at the LG&E/KU plants. Among the regulatory drivers are the Utility Maximum Achievable Control Technology (MACT), and the Clean Air Transport Rule (CATR) -- Clean Air Interstate Rule (CAIR) replacement to be proposed by the United States EPA by spring 2011 and summer 2011, respectively.

From this information, LG&E/KU developed specific pollutant emission limit targets with the intent that the limits would be applied to each unit individually to assess current compliance and the potential for additional AQC equipment. These regulatory drivers and their associated emission levels serve as the primary basis used by Black & Veatch to develop unit-by-unit AQC technology recommendations. For the purposes of this study, compliance options beyond the addition of new AQC technology (such as fuel switching, shutdown of existing emission units, development of new power generation, and emissions averaging scenarios) were not considered.

Table 3-1. Primary Design Emission Targets

Pollutant	Unit 1	Unit 2	Unit 3	Unit 4
NO_x	0.139[b] lb/MBtu	0.139[b] lb/MBtu	N/A[a]	N/A[a]
SO_2	N/A[a]	N/A[a]	N/A[a]	98% removal
Sulfuric Acid Mist (SAM)	N/A[a]	N/A[a]	64.3 lb/hr	76.5 lb/hr
Mercury (Hg)	90% control or 0.012 lb/GWh	90% control or 0.012 lb/GWh	90% control or 0.012 lb/GWh	90% control or 0.012 lb/GWh
HCl	0.002 lb/MBtu	0.002 lb/MBtu	0.002 lb/MBtu	0.002 lb/MBtu
Particulate Matter (PM)[c],[d]	0.03[b] lb/MBtu	0.03[b] lb/MBtu	0.03[b] lb/MBtu	0.03[b] lb/MBtu
Arsenic (As) [e]	0.5×10^{-5} lb/MBtu	0.5×10^{-5} lb/MBtu	0.5×10^{-5} lb/MBtu	0.5×10^{-5} lb/MBtu
CO	0.10 lb/MBtu	0.10 lb/MBtu	0.10 lb/MBtu	0.10 Lb/MBtu
Dioxin/Furan	15×10^{-18} lb/MBtu	15×10^{-18} lb/MBtu	15×10^{-18} lb/MBtu	15×10^{-18} lb/MBtu

Data from Mill Creek kickoff meeting of September 15, 2010 (Gary Revlett handouts and meeting notes) unless noted otherwise.
[a]Not applicable for this Phase II study.
[b]Emission rate target is higher than what can typically be achieved with chosen technology; a lower emission target may be possible.
[c]Particulate matter control limits for $PM_{2.5}$ or $PM_{condensable}$ have not been determined for this project.
[d]Particulate matter assumed to be the surrogate for emissions of certain non-mercury metallic HAP (i.e., antimony (Sb), beryllium (Be), cadmium (Cd), cobalt (Co), lead (Pb), manganese (Mn), and nickel (Ni)).
[e]Arsenic assumed to be the surrogate for non-mercury metallic HAP (i.e., arsenic (As), chromium (Cr), and selenium (Se)).

4.0 Site Visit Summary

The following section describes the existing site conditions and site visit observations for the Mill Creek Generating Station.

4.1 Site Visit Observations and AQC

The following observations are from the September 14-16, 2010 site visit and summarize the site and equipment constraints based on the AQC technology refinement meeting held on August 5-6, 2010. The following excerpts are from the September 24, 2010, site visit meeting memo that focused specifically on installing the AQC equipment resulting from the aforementioned August meeting.

- If the new Unit 4 WFGD and stack require the relocation of the ammonia storage area, it may be possible to consolidate it with the ammonia storage requirements for the new Unit 1 and 2 SCRs.
- It may be possible to reuse Unit 4's fans on Unit 3 should the existing fans become superfluous in the new Unit 4 arrangement. It then may be possible to reuse the Unit 3 fans on Unit 1 and/or Unit 2.
- Mill Creek confirmed there is no "sacred ground" around the existing units, areas reserved for other uses and unavailable for use in the AQC upgrade. B&V requested if any balance-of-plant upgrades are currently under consideration that should be taken into account in the AQC work, beyond the plans for an additional ball mill at the limestone prep building.
- Unit 4 NID or PJFF likely to be required to be installed above the Unit 4 scrubber electrical building.
- Unit 3 would be tied into the current Unit 4 scrubber after the new Unit 4 WFGD is built. The large capacity of the Unit 4 scrubber as compared to the Unit 3 unit would allow SO_2 reductions on Unit 3. The current Unit 3 WFGD, with the below grade reaction tanks and pumps provide limited opportunity for upgrading the performance of the units and presents maintenance issues. The old Unit 3 WFGD would be torn down to allow new AQC equipment to be potentially located in that area.
- Unit 3 and 4 structural steel was generally in good shape for lower areas that could be inspected. Relatively isolated examples of steel corrosion, most likely due to exposure to flue gas, were noted in the superstructures at the scrubbers. Higher areas of Unit 3 and 4 could not be assessed due to the large flue gas leaks in the duct that limited access for personal safety reasons.

- Duct configuration will be complicated, but appears possible, and will depend on the specific fan arrangement and if new ID fans or booster fans will be used.
- The potential for locating the Unit 4 PJFF/NID unit and new WFGD, plus a new chimney, to the south of Unit 4 was considered as a possibility. The original location for the new WFGD and chimney was in the area of the demolished thickener south of the limestone prep building. This location, however, involved crossing the limestone conveyor with relatively high ductwork, plus moving both an overhead Unit 3 and Unit 4 345kV T-line and the ammonia tanks and electrical building to provide necessary working space for new construction.
- Alternately, it was determined that there is likely sufficient space for the new Unit 4 AQC train directly south of Unit 4, running more or less straight east to west with the new chimney located opposite of the Unit 4 turbine building. This arrangement, if it fits, has the advantage of relatively short ductwork runs, no impact to the overhead T-line, and no impact to the existing ammonia tank farm. It would, however, require relocation of the existing annex building and lab, plus limit construction access to one side of the train. This arrangement would serve as first choice for Unit 4, with the thickener area location used as a fall-back alternate. Should either of the above arrangements fit, it appeared that it would be advantageous to upgrade the existing Unit 4 WFGD in place and reuse it for Unit 3. The flue gas from Unit 3 would be rerouted to the Unit 4 scrubber in the short term (Phase I) and the Unit 3 scrubber demolished. A new Unit 3 PJFF/NID unit could be built in its place and tied into the Unit 3 ductwork as Phase II of a two phase construction sequence on Unit 3.
- Both Unit 1 and Unit 2 offer significant challenges for the addition of an SCR as an immediate and priority modification. The existing ESP at both units is located within a few feet of the boiler structure, leaving insufficient room to route ductwork to a new SCR overhead of the ESP. The ESP would have to be demolished or extensively modified before the SCR could be constructed, resulting in either an extended outage while the ESP is moved or reconstructed or the installation of a separate new ESP in another location prior to installation of the SCR. In addition, area available for new structures for either Units 1 or 2 is very limited, by the narrow alleyway between Units 1 and 3 for Unit 1 and by the new RO facility

north of the power block at Unit 2. No obvious arrangement for the AQC upgrades at Units 1 and 2 were immediately noted, and required additional investigation.

- The structural steel at the existing Unit 1 and 2 scrubbers is in poor condition. Severe corrosion and loss of structural mass was noted in a significant number of areas at Units 1 and 2. The most severe damage noted was in lighter components, such as platform and grating, but instances of chemical attack on the major structural steel members were also noted on Units 1 and 2.
- New AQC will likely restrict vehicle and maintenance access in some areas of the facility.
- The existing Unit 4 AQC equipment (i.e., ESP and WFGD) are powered by the Unit 4 auxiliary power supply. Should the Unit 4 WFGD be reused for Unit 3, an alternate source of auxiliary power for the refurbished equipment must be included. Otherwise, an outage on Unit 4 would result in the loss of AQC for Unit 3.
- No auxiliary power supply greater than 4,160V is currently available in the immediate plant area. However, there are spare cubicles which might be able to be modified to accept feeder breakers as potential sources of medium voltage power for new loads such as fans in the AQC upgrade.

5.0 Selected Air Quality Control Technology

The following sections present a general description of the AQC technologies considered for Mill Creek, as well as a unit by unit discussion of the key attributes of the technologies and special considerations for their application and arrangement at the affected units. Table 5-1 presents the selected AQC technologies that were considered in the validation process.

Table 5-1. AQC Technologies

	Unit 1	**Unit 2**	**Unit 3**	**Unit 4**
NO_x Control	New SCR	New SCR	Existing SCR	Existing SCR
SO_2 Control	Refurbish existing WFGD	Refurbish existing WFGD	Refurbish and reuse Unit 4 WFGD	New WFGD
PM Control	New NID or New PJFF	New NID or New PJFF	New NID or New PJFF	New NID or New PJFF
HCl Control	New NID or refurbished WFGD	New NID or refurbished WFGD	New NID or refurbished WFGD	New NID or New WFGD
CO Control	New NN	New NN	New NN	New NN
SO_3 Control	New NID or New PJFF with Sorbent Injection	New NID or New PJFF with Sorbent Injection	New NID or New PJFF with Sorbent Injection	New NID or New PJFF with Sorbent Injection
Hg Control	New PAC Injection	New PAC Injection	New PAC Injection	New PAC Injection
Dioxin/Furan Control	New PAC Injection	New PAC Injection	New PAC Injection	New PAC Injection
Fly Ash Sales	New CS-ESP (Optional)	New CS-ESP	Existing CS-ESP	Existing CS-ESP

5.1 Technology Descriptions

The following sections provide a brief general description of the proposed AQC technologies.

5.1.1 Selective Catalytic Reduction System

In an SCR system, ammonia is injected into the flue gas stream just upstream of a catalytic reactor. The ammonia molecules in the presence of the catalyst dissociate a significant portion of the NO_x into nitrogen and water.

The aqueous ammonia is received and stored as a liquid. The ammonia is vaporized and subsequently injected into the flue gas by compressed air or steam as a carrier. Injection of the ammonia must occur at temperatures above 600° F to avoid chemical reactions that are significant and operationally harmful. Catalyst and other considerations limit the maximum SCR system operating temperature to 840° F. Therefore, the system is typically located between the economizer outlet and the air heater inlet. The SCR catalyst is housed in a reactor vessel, which is separate from the boiler. The conventional SCR catalysts are either homogeneous ceramic or metal substrate coated. The catalyst composition is vanadium-based, with titanium included to disperse the vanadium catalyst and tungsten added to minimize adverse SO_2 and SO_3 oxidation reactions. An economizer bypass may be required to maintain the reactor temperature during low load operation. This will reduce boiler efficiency at lower loads.

The SCR process is a complex system. The SCR requires precise NO_x-to-ammonia distribution in the presence of the active catalyst site to achieve current BACT levels. In the past, removal efficiencies were the measure of catalyst systems because of extremely high inlet NO_x levels. Current technology SCR systems do not use removal efficiency as a primary metric because the current generation of LNB/OFA systems limits the amount of NO_x available for removal. Essentially, as NO_x is removed through the initial layers of catalyst, the remaining layers have difficulty sustaining the reaction.

A number of alkali metals and trace elements (especially arsenic) poison the catalyst, significantly affecting reactivity and life. Other elements such as sodium, potassium, and zinc can also poison the catalyst by neutralizing the active catalyst sites. Poisoning of the catalyst does not occur instantaneously, but is a continual steady process that occurs over the life of the catalyst. As the catalyst becomes deactivated, ammonia slip emissions increase, approaching design values. As a result, catalyst in a SCR system is consumable, requiring periodic replacement at a frequency dependent on the level of catalyst poisoning. However, effective catalyst management plans can be implemented that significantly reduce catalyst replacement requirements.

There are two SCR system configurations that can be considered for application on pulverized coal boilers: high dust and tail end. A high dust application locates the SCR system before the particulate collection equipment, typically between the economizer outlet and the air heater inlet. A tail end application locates the catalyst downstream of the particulate and FGD control equipment.

The high dust application requires the SCR system to be located between the economizer outlet and the air heater inlet in order to achieve the required optimum SCR operating temperature of approximately 600° to 800° F. This system is subject to high levels of trace elements and other flue gas constituents that poison the catalyst, as previously noted. The tail end application of SCR would locate the catalyst downstream of the particulate control and FGD equipment. Less catalyst volume is needed for the tail end application, since the majority of the particulate and SO_2 (including the trace elements that poison the catalyst) have been removed. However, a major disadvantage of this alternative is a requirement for a gas-to-gas reheater and supplemental fuel firing to achieve sufficient flue gas operating temperatures downstream of the FGD operating at approximately 125° F. The required gas-to-gas reheater and supplemental firing necessary to raise the flue gas to the sufficient operating temperature are costly. The higher front end capital costs and annual operating cost for the tail end systems present higher overall costs compared to the high dust SCR option with no established emissions control efficiency advantage. Figure 5-1 shows a schematic diagram of SCR.

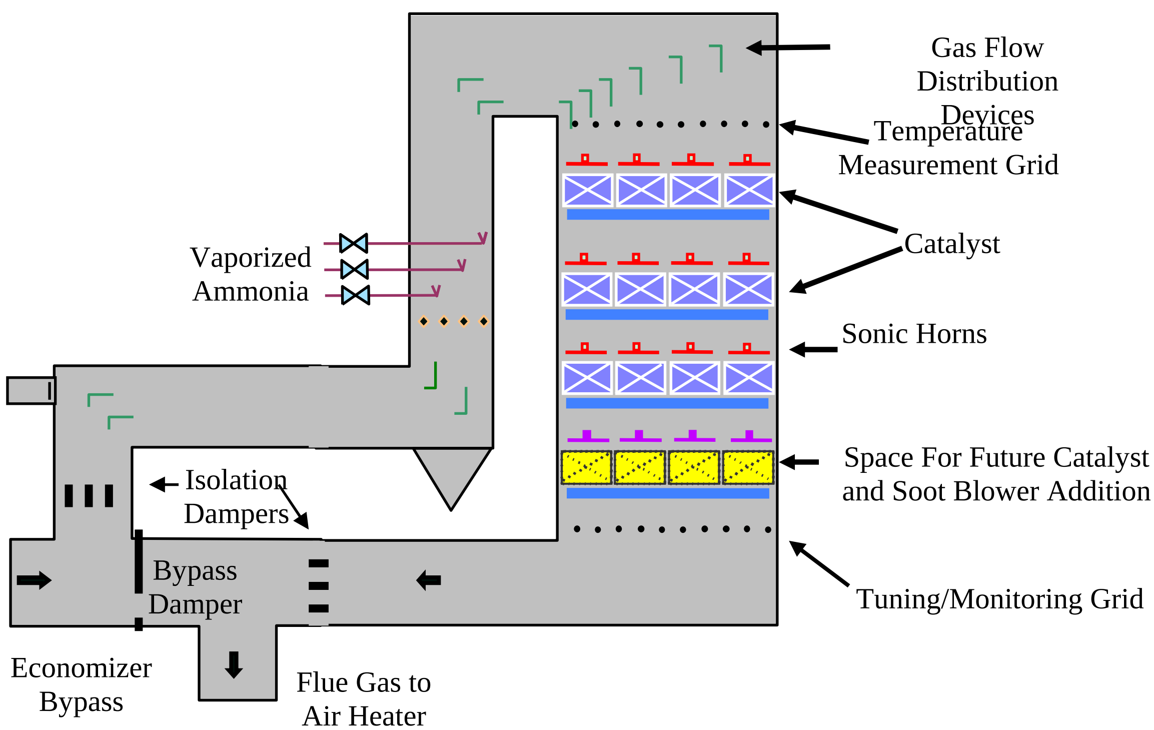


Figure 5-1. Schematic Diagram of a Typical SCR Reactor

5.1.2 Wet Flue Gas Desulfurization System

Wet limestone-based FGD processes are frequently applied to pulverized coal fired boilers that burns medium-to-high sulfur eastern coals. All of the FGD systems installed in response to Phase I of the 1990 CAA were based on a WFGD system using either lime or limestone as the reagent. Typically, the WFGD processes on a pulverized coal facility are characterized by high efficiency (> 98 percent) and high reagent utilization (95 to 97 percent) when combined with a high sulfur fuel. The ability to realize high removal efficiencies on higher sulfur fuels is a major difference between wet scrubbers and semi-dry/dry FGD processes. It is well known that SO_2 removal efficiencies for WFGD systems are generally higher for high sulfur coal applications than for low sulfur coal applications, for the fundamental physical reason that the chemical reactions that remove SO_2 are faster if the inlet SO_2 concentration is higher. The absolute emissions level becomes a limiting factor due to a reduction in the chemical driving forces of the reactions that are occurring. Thus, the calculated removal efficiency of the various types of WFGDs declines as the fuel sulfur content decreases; this is the case for low sulfur western and PRB coals.

In a WFGD system, the absorber module is located downstream of the induced draft (ID) fans (or booster ID fans, if required). Flue gas enters the module and is contacted with a slurry containing reagent and byproduct solids. The SO_2 is absorbed into the slurry and reacts with the calcium to form $CaSO_3{\bullet}1/2H_2O$ and $CaSO_4{\bullet}2H_2O$. SO_2 reacts with limestone reagent through the following overall reactions:

$$SO_2 + CaCO_3 + ½H_2O \rightarrow CaSO_3{\bullet}½H_2O + CO_2$$

$$SO_2 + CaCO_3 + 2H_2O + ½O_2 \rightarrow CaSO_4{\bullet}2H_2O + CO_2$$

The flue gas leaving the absorber will be saturated with water, and the stack will have a visible moisture plume. Because of the chlorides present in the mist carry-over from the absorber and the pools of low pH condensate that can develop, the conditions downstream of the absorber are highly corrosive to most materials of construction. Highly corrosion-resistant materials are required for the downstream ductwork and the flue stack. Careful design of the stack is needed to prevent the “rainout” from condensation that occurs in the downstream ductwork and stack. These factors contribute to the relatively high capital costs of the WFGD SO_2 control alternative.

The reaction products are typically dewatered by a combination of hydrocyclones and vacuum filters. The resulting filter cake is suitable for landfill disposal. In early lime- and limestone-based FGD processes, the byproduct solids were primarily calcium sulfite hemihydrate ($CaSO_3 \bullet 1/2H_2O$), and the byproduct solids were mixed with fly ash (stabilization) or fly ash and lime (fixation) to produce a physically stable material (Figure 5-2). In the current generation of WFGD systems, air is bubbled through the reaction tank (or in some cases, a separate vessel) to practically convert all of the $CaSO_3 \bullet 1/2H_2O$ into calcium sulfate dihydrate ($CaSO_4 \bullet 2H_2O$), which is commonly known as gypsum. This step is termed "forced oxidation" and has been applied to both lime- and limestone-based FGD processes. Compared to calcium sulfite hemihydrate, gypsum has much superior dewatering and physical properties, and forced oxidized FGD systems tend to have few internal scaling problems in the absorber and mist eliminators. Dewatered gypsum can be landfilled without stabilization or fixation. Many FGD systems in the United States are using the forced-oxidation process to produce a commercial grade of gypsum that can be used in the production of portland cement or wallboard. Marketing of the gypsum can eliminate or greatly reduce the need to landfill FGD byproducts.

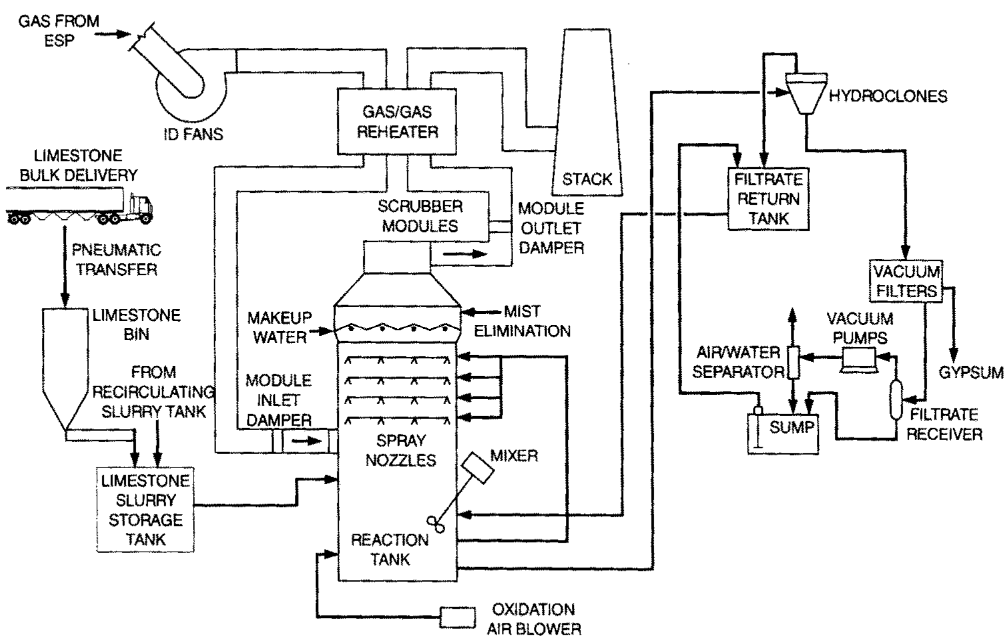


Figure 5-2. Process Flow Diagram of FGD Process

The absorber vessels are fabricated from corrosion-resistant materials such as epoxy/vinyl ester-lined carbon steel, rubber-lined carbon steel, stainless steel, or fiberglass. The absorbers handle large volumes of abrasive slurries. The byproduct dewatering equipment is also relatively complex and expensive. These factors result in relatively higher initial capital costs. WFGD processes are also characterized by higher raw water usage than semi-dry FGD systems. This can be a significant disadvantage or even a fatal flaw in areas where raw water availability is in short supply.

A countercurrent spray tower has become one of the most widely used absorber types in wet limestone-based FGD service (Figure 5-3). Flue gas enters at the bottom of the absorber and flows upward. Slurry with 10 to 15 percent solids is sprayed downward from higher elevations in the absorber and is collected in a reaction tank at its base. The SO_2 in the flue gas is transferred from the flue gas to the recycle slurry. The hot flue gas is also cooled and saturated with water. Recycled slurry is pumped continuously from the reaction tank to the slurry spray headers. Each header has numerous individual spray nozzles that break the slurry flow into small droplets and distribute them evenly across the cross section of the absorber. Prior to leaving the absorber, the treated flue gas passes through a two-stage, chevron-type mist eliminator that removes entrained slurry droplets from the gas. The mist eliminator is periodically washed to keep it free of solids.

In the reaction tank, the SO_2 absorbed from the flue gas reacts with soluble calcium ions in the recycle slurry to form insoluble calcium sulfite and calcium sulfate solids. In forced-oxidization processes, air is bubbled through the slurry to convert all of the solids to calcium sulfate dihydrate (gypsum). A lime or limestone reagent slurry is added to the reaction tank to replace the calcium consumed.

To control the solids content of the recycle slurry, a portion of the slurry is discharged from the reaction tank to the byproduct dewatering equipment. Depending on the ultimate disposal of the byproduct solids, the dewatering equipment may include settling ponds, thickeners, hydrocyclones, vacuum filters, and centrifuges. The liquid that is separated from the byproduct solids slurry is stored in the reclaim water tank. Water in the reclaim water tank is returned to the absorber reaction tank as makeup water and used to prepare the reagent slurry.

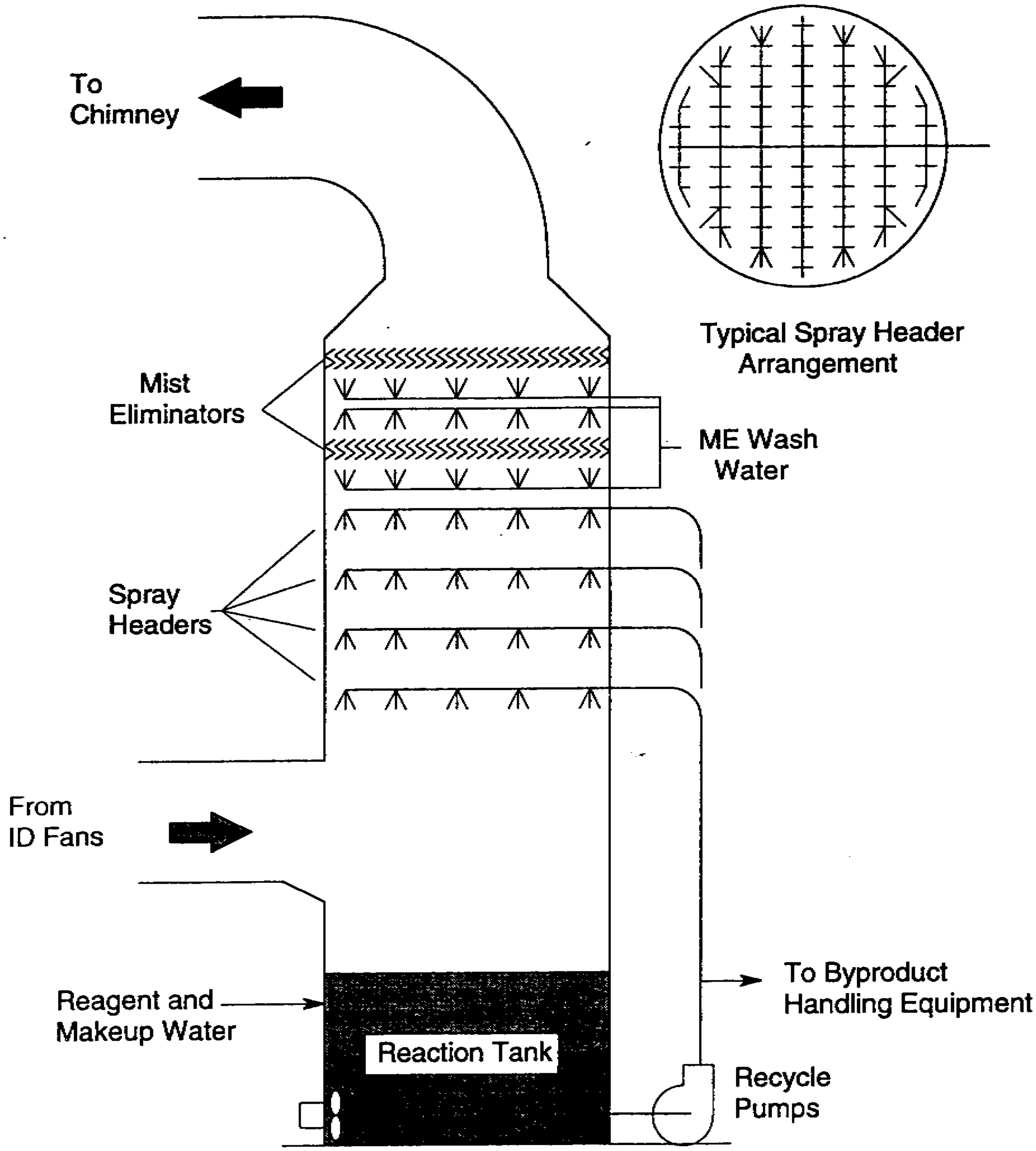


Figure 5-3. Countercurrent Spray Tower FGD Process

5.1.3 Dry Electrostatic Precipitator

Electrostatic precipitators (ESPs) are the most widely installed utility PM removal technology. ESPs use transformer/rectifiers (TRs) to energize “discharge electrodes” and to produce a high voltage, direct current electrical field between the discharge electrodes and the grounded collecting plates. PM entering the electrical field acquires a negative charge and migrates to the grounded collecting plates. This migration can be expressed in engineering terms as an empirically determined effective migration velocity, but takes place in a turbulent flow regime with the particulate entrained within the turbulent gas patterns. Thus, the charged particles are actually captured when the combined effect of electrical attraction and gas flow patterns moves the PM close enough for it to attach to the collecting surfaces. A layer of collected particles forms on the collecting plates and is removed periodically by mechanically impacting or “rapping” the plates. The collected particulate matter drops into hoppers below the precipitator and is removed by the ash handling system. Some particulate is also re-entrained and either collected in subsequent electrical fields or emitted from the ESP. A graphic showing the sections of an ESP is shown on Figure 5-4.

The required particulate removal efficiency, the expected electrical resistivity of the fly ash to be collected, and the expected electrical characteristics of the energization system determine the physical size of an ESP. Many parameters determine the ESP’s capability for particulate collection including the following major items:

- The first parameter is the Specific Collection Area (SCA). ESP size is often measured in terms of SCA. SCA is defined as the total collecting area in square feet (ft^2) divided by the volumetric flue gas flow rate (1,000’s of actual cubic feet per minute [acfm]).
- The treatment time of the flue gas within the electric collection fields of the ESP is an important aspect of particulate collection. High efficiency ESPs typically have treatment times between 7 and 20 seconds. Treatment time is becoming a major design parameter as lower particulate emissions are being mandated.
- Flue gas velocity, which is the speed at which the flue gas moves through the ESP, is important in the design and sizing of an ESP. Design gas velocities that range between 3 to 4 fps are common. The aspect ratio of the treatment length to the collection plate height is also important in the design and sizing of the ESP. As the aspect ratio increases, the re-entrainment losses from the ESP are minimized. Many existing ESPs have aspect ratios of approximately 0.8 to 1.2; newer ESPs, especially those meeting new particulate emission limits, have aspect ratios of approximately 1.2 to 2.0.

- The gas distribution for optimum particulate removal requires a uniform gas velocity throughout the entire ESP treatment volume, with minimal gas bypass around the discharge electrodes or collecting plates. If flue gas distribution is uneven, the particulate removal efficiency will decrease, and re-entrainment losses will increase in high velocity areas and reduce overall collection efficiency.
- Fly ash resistivity is a measure of how easily the ash or particulate acquires an electric charge. Typical coal fly ash resistivity values range from 1 x 10^8 ohm-cm to 1 x 10^{14} ohm-cm. The ideal resistivity range for electrostatic precipitation of fly ash is 5 x 10^9 to 5 x 10^{10} ohm-cm. Operating resistivity varies with flue gas moisture, SO_3 concentration, temperature, and ash chemical composition. As a result of fly ash resistivity being sensitive to these constituents, ESPs can be affected greatly by changes in fuel or operating conditions.

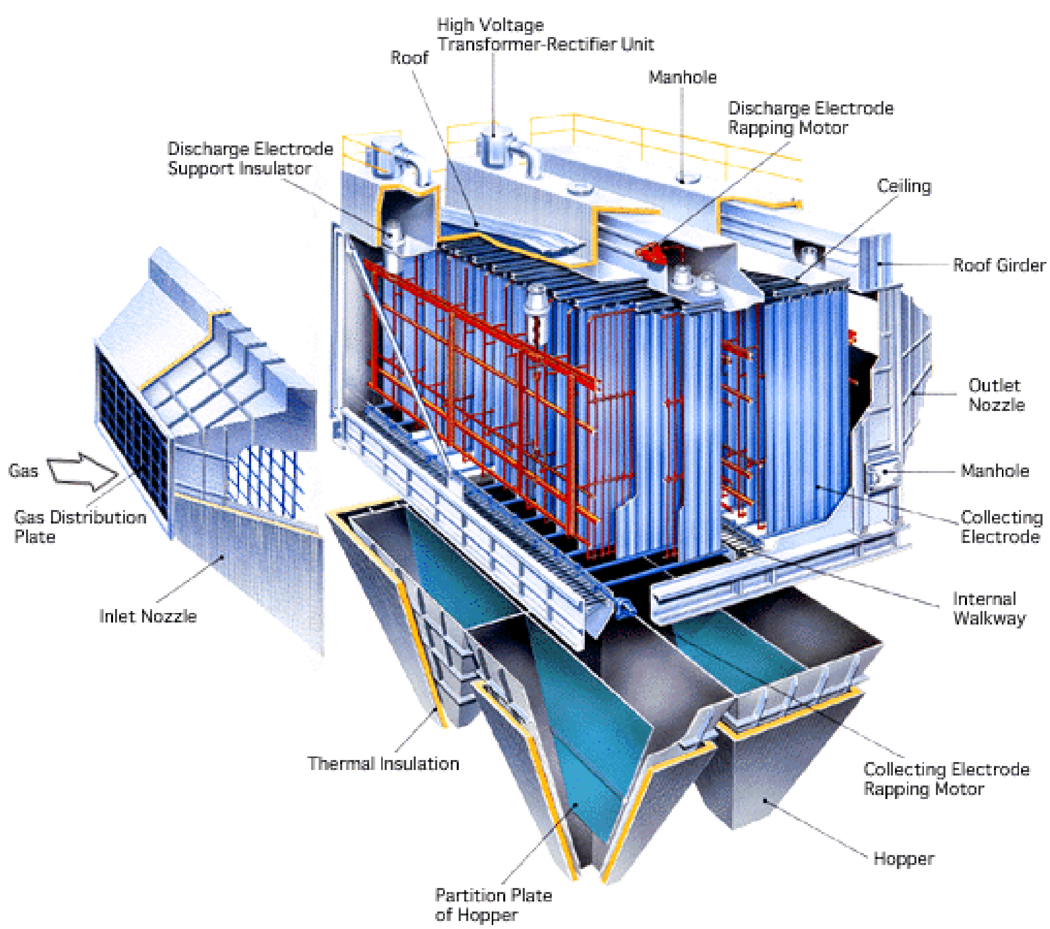


Figure 5-4. Electrostatic Precipitator System (MHI)

5.1.4 Pulse Jet Fabric Filter

Pulse jet fabric filters (PJFFs) have been used for over 20 years on existing and new coal fired boilers and are media filters through which flue gas passes to remove the particulate. The success of FFs is predominately due to their ability to economically meet the low particulate emission limits for a wide range of particulate operations and fuel characteristics. Proper application of the PJFF technology can result in clear stacks (generally less than 5 percent opacity) for a full range of operations. In addition, the PJFF is relatively insensitive to ash loadings and various ash types, offering superb coal flexibility.

FFs are the current technology of choice when low outlet particulate emissions or Hg reduction is required for coal fired applications. FFs collect particle sizes ranging from submicron to 100 microns in diameter at high removal efficiencies. Provisions can be made for future addition of activated carbon injection to enhance gas phase elemental Hg removal from coal fired plants. Some types of fly ash filter cakes will also absorb some elemental Hg.

FFs are generally categorized by type of cleaning. The two predominant cleaning methods for utility applications are reverse gas and pulsejet. Initially, utility experience in the United States was almost exclusively with Reverse Gas Fabric Filters (RGFF). Although they are a very reliable and effective emissions control technology, RGFFs have a relatively large footprint, which is particularly difficult for implementations. PJFFs can be operated at higher flue gas velocities and, as a result, have a smaller footprint. The PJFF usually has a lower capital cost than a RGFF and matches the performance and reliability of a RGFF. As a result, only PJFFs will be considered further.

Cloth filter media is typically sewn into cylindrical tubes called bags. Each PJFF may contain thousands of these filter bags. The filter unit is typically divided into compartments that allow on-line maintenance or bag replacement after a compartment is isolated. The number of compartments is determined by maximum economic compartment size, total gas volume rate, air-to-cloth ratio, and cleaning system design. Extra compartments for maintenance or off-line cleaning not only increase cost, but also increase reliability. Each compartment includes at least one hopper for temporary storage of the collected fly ash. A cutaway view of a PJFF compartment is illustrated on Figure 5-5.

Fabric bags vary in composition, length, and cross section (diameter or shape). Bag selection characteristics vary with cleaning technology, emissions limits, flue gas and ash characteristics, desired bag life, capital cost, air-to-cloth ratio, and pressure differential. Fabric bags are typically guaranteed for 3 years but frequently last 5 years or more.

In PJFFs, the flue gas typically enters the compartment hopper and passes from the outside of the bag to the inside, depositing particulate on the outside of the bag. To prevent the collapse of the bag, a metal cage is installed on the inside of the bag. The flue gas passes up through the center of the bag into the outlet plenum. The bags and cages are suspended from a tubesheet.

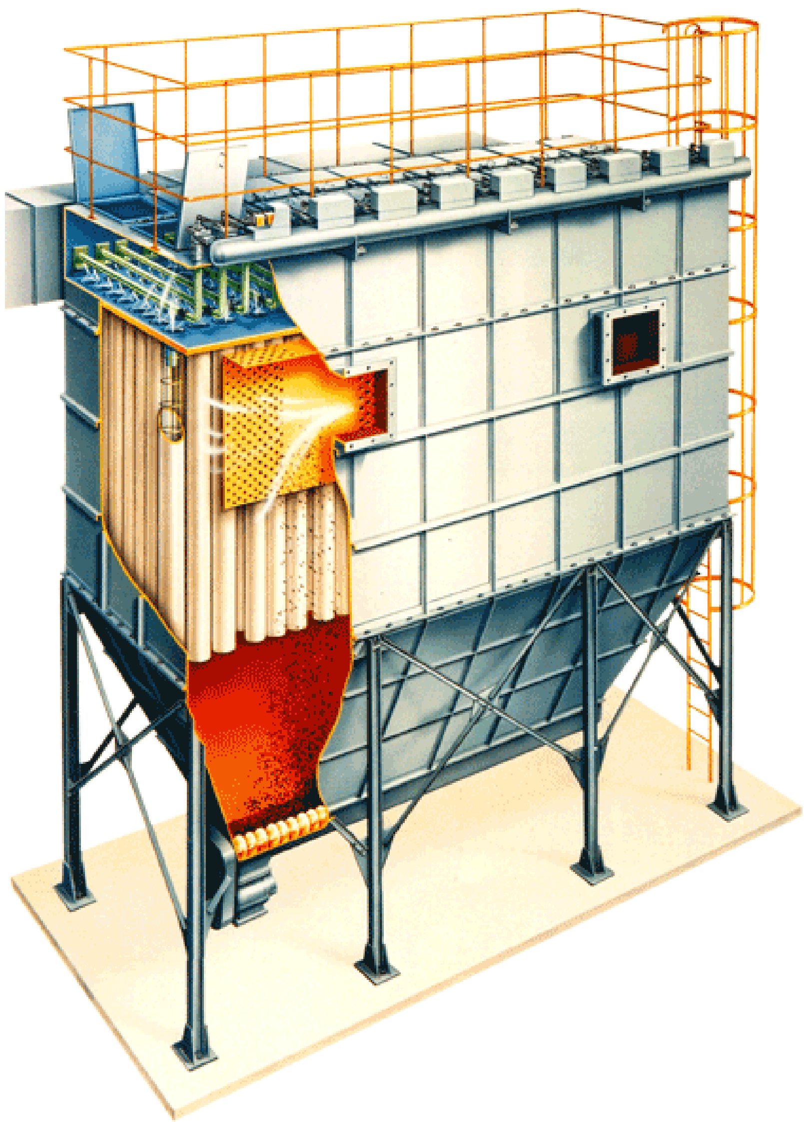


Figure 5-5. Pulse Jet Fabric Filter Compartment

Cleaning is performed by initiating a downward pulse of air into the top of the bag. The pulse causes a ripple effect along the length of the bag. This dislodges the dust cake from the bag surface, and the dust falls into the hopper. This cleaning may occur with the compartment on line or off-line. Care must be taken during design to ensure that the upward velocity between bags is minimized so that particulate is not re-entrained during the cleaning process.

The PJFF cleans bags in sequential, usually staggered, rows. During on-line cleaning, part of the dust cake from the row that is being cleaned may be captured by the adjacent rows. Despite this apparent shortcoming, PJFFs have successfully implemented on-line cleaning on many large units.

The PJFF bags are typically made of felted materials that do not rely as heavily on the dust cake's filtering capability as woven fiberglass bags do. This allows the PJFF bags to be cleaned more vigorously. The felted materials also allow the PJFF to operate at a much higher cloth velocity, which significantly reduces the size of the unit and the space required for installation.

5.1.5 Powdered Activated Carbon Injection

With reported Hg removals of more than 90 percent for bituminous coal applications, PAC injection is an effective and mature technology in the control of Hg in Municipal Solid Waste (MSW) and Medical Waste Combustors (MWC). Its potential effectiveness on a wide range of coal fired power plant applications is gaining acceptance based on recent pilot and slipstream testing activities sponsored by the Department of Energy (DOE), EPA, Electric Power Research Institute (EPRI), and various research organizations and power generators. However, recent pilot scale test results indicate that the level of Hg control achieved with a PAC injection system is impacted by variables such as the type of fuel, the speciation of Hg in the fuel, operating temperature, fly ash properties, flue gas chloride content, and the mechanical collection device used in the removal of Hg.

PAC injection typically involves the use of a lignite based carbon compound that is injected into the flue gas upstream of a particulate control device as illustrated on Figure 5-6. Elemental and oxidized forms of Hg are adsorbed into the carbon and are collected with the fly ash in the particulate control device.

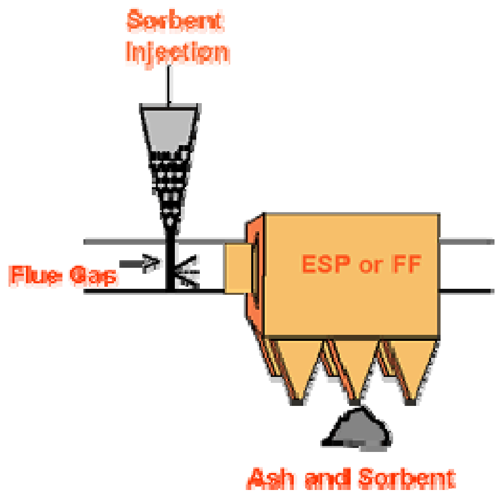


Figure 5-6. Activated Carbon Injection System

PAC injection is generally added upstream of either PJFFs or ESPs. For ESPs, the Hg species in the flue gas are removed as they pass through a dust cake of unreacted carbon products on the surface of the collecting plates. Additionally, a significantly higher carbon injection rate is required for PAC injection upstream of an ESP than is required for PAC injection upstream of a high air-to-cloth ratio PJFF or a PJFF that is located downstream of a SDA FGD system. Literature indicates that PAC injection upstream of a CS-ESP can reduce Hg emissions up to 60 percent for units that burn a sub-bituminous or lignite coal, and up to 80 percent for units that burn a bituminous coal. The addition of activated carbon does not directly affect the function of the ash handling system. The additional activated carbon in the fly ash does, however, affect the quality of the ash that is produced. For units that currently sell fly ash, this will negatively impact their continued ability to sell the ash.

Since the sale of fly ash depends on the carbon content of the ash, increasing the amount of carbon in the ash also makes it unsuitable for sale. To maintain the ash quality required for sale, the ash must either be removed upstream of the PAC injection system or the activated carbon should be injected into the flue gas so that it is not mixed with all the collected fly ash or is mixed with only a small portion of the total fly ash that is collected in the particulate control device. This can be accomplished by using a high air-to-cloth ratio PJFF downstream of CS-ESP.

Numerous testing efforts and studies have shown that most of the Hg resulting from the combustion of coal leaves the boiler in the form of elemental Hg, and that the level of chlorine in the coal has a major impact on the efficiency of Hg removal with PAC injection and the particulate removal system. Low chlorine coals, such as sub-bituminous and lignite coals, typically demonstrate relatively low Hg removal efficiency. Sub-bituminous and lignite coals produce very low levels (approximately 100 parts per million [ppm]) of HCl during combustion and; therefore, normal PAC injection would be anticipated to achieve very low elemental Hg removal.

The removal efficiency that is attained by halogenated PAC injection can be significantly increased by the use of PAC that has been pretreated with halogens, such as iodine or bromine. Recent testing results indicate that halogenated PAC injection upstream of a CS-ESP can reduce Hg emissions up to 80 percent for units that burn a sub-bituminous or lignite coal and up to 90 percent for units that burn a bituminous coal. Pretreated PAC is more expensive than untreated PAC: (approximately $5.00/lb of iodine, $1.00/lb of bromine, and $0.50/lb of PAC). However, less pretreated PAC is required to achieve significant removals, if such removal rates are dictated by more stringent Hg control regulations.

PAC can also be injected upstream of a PJFF located downstream of a semi-dry lime FGD. When a semi-dry lime FGD and a PJFF is injected with PAC upstream of the FGD, the activated carbon absorbs most of the oxidized Hg. This is a result of the additional residence time in the FGD and will basically allow greater contact between the Hg particles and the activated carbon. Because of the accumulated solids cake on the bags, the activated carbon is given another opportunity to interact with the Hg prior to disposal or recycle. Since the ash and reagent collected in the PJFF are already contaminated, the additional carbon collected in the PJFF will not affect ash sales or disposal. Recent literature indicates that PAC injection upstream of a semi-dry FGD and PJFF can reduce Hg emissions by 60 to 80 percent.

Halogenated PAC injection upstream of a semi-dry lime FGD and PJFF is basically similar in design to standard PAC, as described previously. Halogenated PAC includes halogens such as bromine or iodine. Literature indicates that halogenated sorbents require significantly lower injection rates (in some cases the difference is as much as a factor of 3) upstream of a semi-dry lime FGD and PJFF combination, as compared to an ESP, and can reduce Hg emissions of up to 95 percent.

5.1.6 Sorbent Injection

Injection of finely divided alkalis into the flue gas has been demonstrated for the removal of SO_3 from flue gases. Most commercial experience is from units firing high sulfur oil where trace metals, mainly vanadium, increase SO_2 oxidation. Magnesium-based compounds have been used successfully for decades to capture SO_3 in oil fired units. As coal fired units burning high sulfur bituminous coals have been retrofitted with SCR systems, interest in the injection of alkali compounds directly into the flue gas duct of a unit has increased. Sorbents such as SBS, trona, and hydrated lime have recently been used on large coal fired units, with reported results showing the achievement of high control efficiencies of SO_3 in high sulfur applications.

5.1.7 CO Reduction Technologies

Control of CO is divided into two basic categories, good combustion controls and neural networks.

5.1.7.1 Good Combustion Controls. As products of incomplete combustion, CO and VOC emissions are very effectively controlled by ensuring the complete and efficient combustion of the fuel in the boiler (i.e., good combustion controls). Typically, measures taken to minimize the formation of NO_x during combustion inhibit complete combustion, which increases the emissions of CO and VOC. High combustion temperatures, adequate excess air, and good air/fuel mixing during combustion minimize CO and VOC emissions. These parameters also increase NO_x generation, in accordance with the conflicting goals of optimum combustion to limit CO and VOC, but lower combustion temperatures to limit NO_x. The products of incomplete combustion are substantially different and often less pronounced when the unit is firing high sulfur bituminous coals, which is the rationale for the slightly higher BACT emissions limits found on units permitted to burn low sulfur PRB subbituminous coals. In addition, depending on the manufacturer, good combustion controls vary in terms of meeting CO emissions limits. Good combustion controls are an option to aid in reduction of CO but are assumed to currently be optimized. No further study of this option was considered in this report.

5.1.7.2 Neural Networks. Neural networks utilize a DCS based computer system that obtains plant data such as load, firing rate, burner position, air flow, CO emissions, etc. The computer system analyzes the impact of various combustion parameters on CO emissions. The system then provides feedback to the control system to improve operation for lower CO emissions. With this combustion system performance monitoring equipment in place, it is expected that sufficient information would be available to maintain the performance of each burner at optimum conditions to enable operations personnel to maintain the most economical balance of peak fuel efficiency and emissions of NO_x, and CO. In addition to burner performance these monitoring systems also allow continuous indication of pulverizer, classifier and fuel delivery system performance to provide early indication of impending component failures or maintenance requirements. This system is also used to improve heat rate and often provides operational cost savings along with CO control. It is commercially proven and has demonstrated CO reductions. However, CO emission reductions due to installation of NN vary from unit to unit based on each unit's specific equipment configuration and operation.

At this point, there are no proven and feasible post combustion AQC technologies for the control of CO emissions from coal-fired boilers of this size. DCS based computer furnace combustion monitoring systems, such as neural networks, may help reduce CO emissions by improving plant heat rate and optimizing the various combustion parameters responsible for the formation of CO. Improvising the coal mills and coal feed injection/air management and or burner modifications including the detuning of any existing NO_x combustion controls devices will help reduce the CO in combustion or pre-combustion stage. There are no arrangement fatal flaws or constraints associated with the installation of a NN at Mill Creek, although it cannot be validated at this point whether or not a NN can achieve the required CO target emission rate.

5.1.8 Novel Innovative Desulfurization

The Novel Innovative Desulfurization (NID) technology was developed by Alstom in late 1980's and had numerous pilot plant demonstrations in US and Sweden. The first commercial installation of the NID technology was completed in 1996 at Elektrownia Power's Laziska Power Plant in Poland on 2 x 125 MW PC boilers. The first commercial installation of the NID technology in the US was completed in 2004 at Reliant Energy's Seward Station Units 1 & 2 on 2 x 285 MW CFB units. In the United States, the NID technology has been installed and operated at:

- Reliant Energy – Seward Station Units 1 & 2 (2 x 285 MW CFB units commercial operation – 2004).
- Eastern Kentucky Power Cooperative – Gilbert Unit 3 (300 MW CFB unit commercial operation – 2004).
- Eastern Kentucky Power Cooperative – Spurlock Unit 4 (300 MW CFB unit commercial operation – 2008).

It is important to note that all of the US installations have been completed on CFB type boilers where the NID system is only used as a polishing type scrubber where the initial SO_2 removal occurs in the CFB. Some of the current ongoing NID installations occurring in the US include PC boilers where the NID system will be the only SO_2 control. The ongoing NID installations are at:

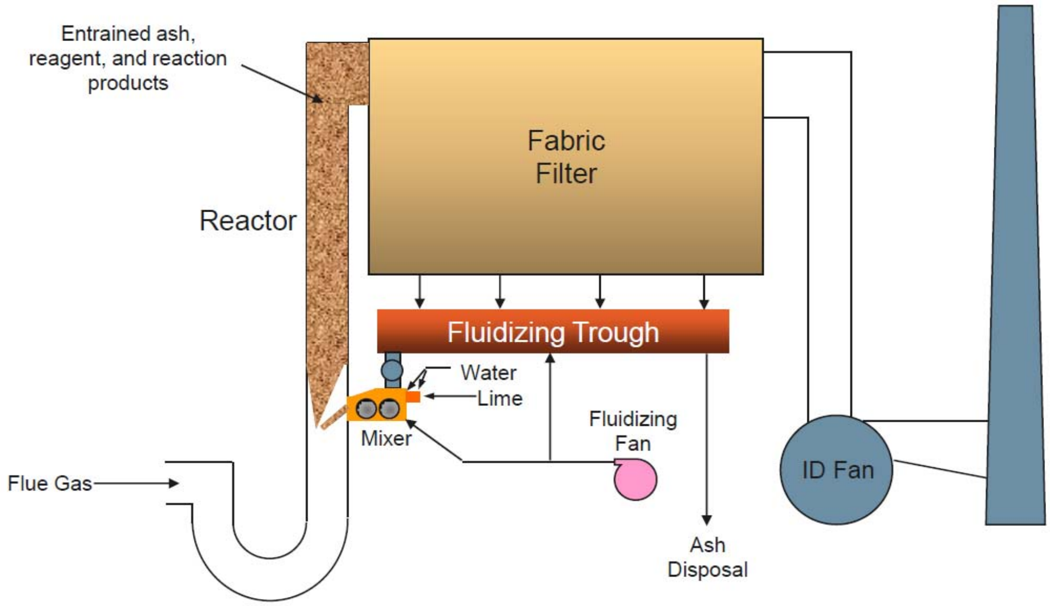
- Dominion/Kiewit – Brayton Point Unit 3 (630 MW PC units – potential start-up – February 2014).
- NRG – Indian River Unit 4 (440 MW PC units – potential start-up – Spring 2011).

In the NID system, the flue gas enters through a J-shaped reactor duct, as shown on Figure 5-7. An individual reactor duct can handle 50 to 90 MW of flue gas. Depending on the size of the boiler unit, there are multiple reactor ducts in the NID system. Each reactor duct is integrated with the compartment of PJFF. Conceptual proposal data received from Alstom indicates that a NID system for Boswell 4 would use a 10 reactor duct-PJFF compartment assembly. PM and SO_2 emission limits can be achieved with at least one reactor-PJFF compartment out of service. The ten-train system, with each train consisting of a NID reactor and a PJFF compartment, is required because of the size limitations of this technology.

Fresh lime and recirculating fly ash collected on the fluidized trough from a PJFF compartment is fed to corresponding mixer/hydrator dedicated to that compartment. The fresh lime is hydrated with water and mixed with the recirculating solids and water in a mixer-hydrator assembly. Figure 5-8 represents the mixer-hydrator assembly provided by Alstom. The mixed lime and recirculation solids are then fed from the mixer/hydrator into the NID reactor by gravity.

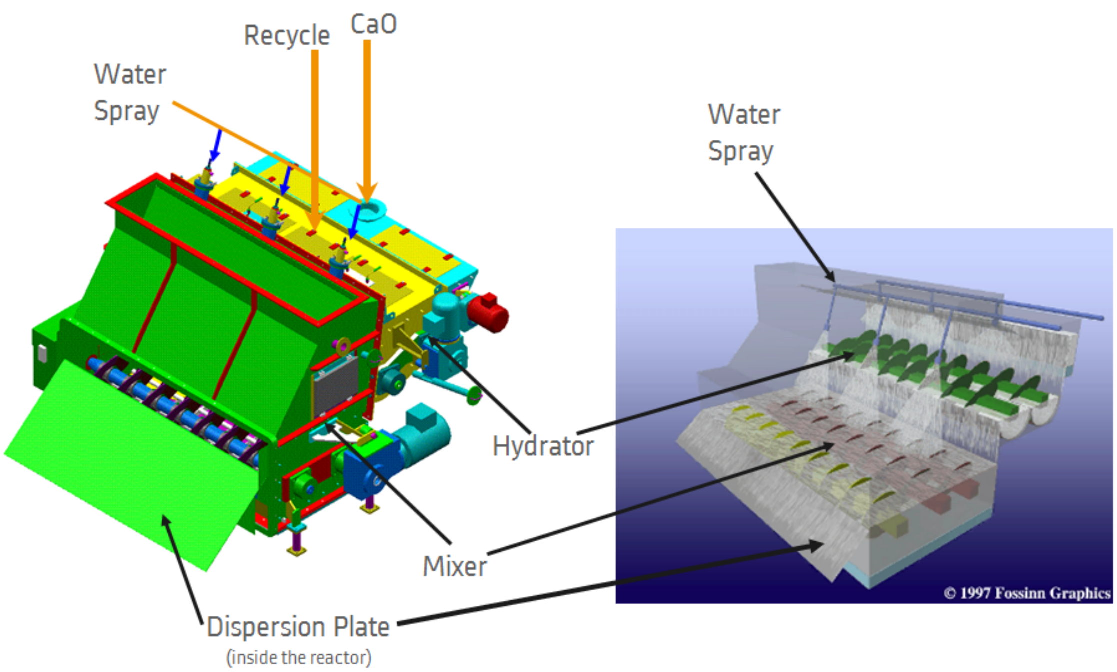
The amount of water added in the mixer-hydrator assembly depends on the temperature difference between the inlet and outlet flue gas (measured at NID inlet ductwork and outlet ductwork). The amount of SO_2 removal can be increased by adding additional fresh lime and by maintaining lower outlet flue gas temperature or high relative humidity.

The hot inlet flue gas is mixed with the moist mixture of fresh lime and recirculating ash and co-currently moves up the reactor duct. In this process, the flue gas is cooled and humidified while the mixture of fresh lime and recirculating solids is dried. The material is sufficiently dry before entering the PJFF. Majority of the acid gases and SO_2 up to 80 percent is removed in the reactor duct. The captured solids held on the bags in the respective PJFF compartment provide additional SO_2 capture.



(Courtesy: Alstom Power)

Figure 5-7. NID System



(Courtesy: Alstom Power)

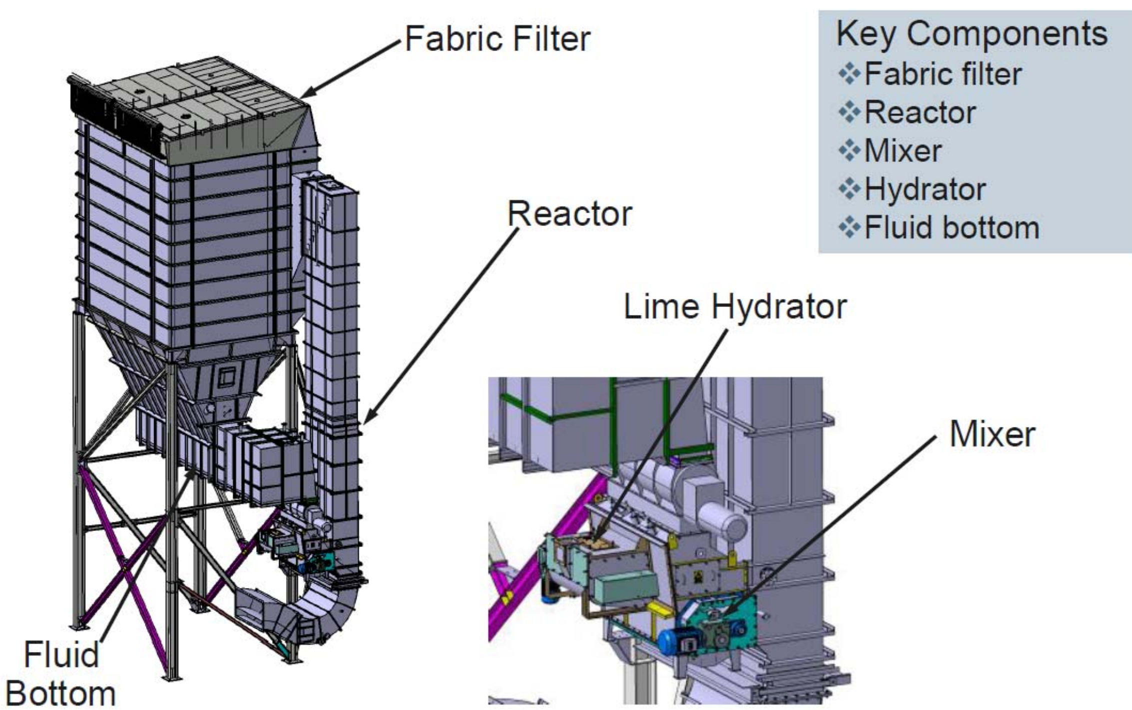
Figure 5-8. Mixer-Hydrator Assembly

Ash and byproduct solids removed form the compartment is collected in the fluidizing trough which is supplied with fluidizing air to prevent solids settlement and allow gravity flow to the mixer.

The NID system has the following major components:

- J-shaped reactor duct with inlet damper, venture, and outlet transition.
- Common lime silo with pneumatic conveyors.
- Lime day-bin for reactor pair with respective feeder.
- Hydrator and mixer assembly for each reactor.
- Fluidizing trough for each PJFF compartment.
- PJFF with outlet damper from each compartment.
- Inlet and outlet plenum with transition sections.
- Bypass provisions from inlet plenum to outlet plenum.

Figure 5-9 represents the various components of the NID system.



(Courtesy: Alstom Power)

Figure 5-9. NID Key Components

B&V has past experience with industrial units where NID system has been installed. Following is the summary of operational issues that B&V would anticipate for a NID system as identified by Alstom, other written sources and B&V's own experience:

- NID requires higher maintenance due to potential plugging of the mixer or water nozzles of the hydrator-mixer assembly. The wet/dry interfaces along with the chemical reaction that take place in the mixer when water is directly mixed with lime and recirculating ash in the mixer can lead to plugging in the mixer. On the similar application that B&V worked with, the frequency of cleaning the hydrator-mixer assembly led to the bolts on the mixer access panel being stripped within 6 months.
- The water nozzles on all the hydrator-mixer assembly require cleaning once a day. Alstom reports that 1 nozzle/mixer/day is required to be cleaned. The nozzles have quick disconnects and only weigh around 2 pounds, so operators can accomplish the cleaning manually by hand with no special equipment necessary. The daily cleaning cycle will require implementation of a specific routine and recording process so that the operator will know which nozzles require cleaning.
- The NID is provided with just one spare reactor module. Multiple failures which includes but is not limited to plugging of more than one reactor module or mixer could lead to load limiting of the unit.
- The low approach temperature may lead to cold spot and corrosion and would need to be investigated during detailed evaluation.
- During start-up of the NID system on one of the industrial units in France, reports indicate that the sealing of the fluidizing trough was not properly completed, which resulted in a rupture of the binding on the overlapping cloth.

The NID system does present some concern with regard to the specific application and the available experience with the mixer/hydration units. The NID systems currently installed in the U.S. operate on circulating fluid bed boilers, a boiler type where the large majority of the SO_2 is removed in the boiler. None of the current US NID applications have the hydration system included with the solids/water mixer, as would be required for Mill Creek units. These mixers are the area of most concern with this technology due to the number of mixers required and potential operability of these mixers for which additional information is unavailable. The mixer/hydration unit seems to be the weakest point of this technology, since it is really the only moving part and is not in wide use. Being unable to confirm the operability of these systems does present a significant uncertainty.

5.2 Unit by Unit Summary of AQC Selection

The following AQC control technologies comprise the selected technologies to control unit pollutant emissions to the targeted emission levels. As summarized on the following pages, the selected technologies are based on the known technology limitations, future expanding capability, arrangement or site fatal flaws, constructability challenges, unit off-line schedule requirements or site-specific considerations developed or understood during the AQC Technology Screening Workshop conducted on August 5-6, 2010, as well as information provided by LG&E/KU.

5.2.1 Mill Creek Units 1 and 2

Table 5-2 identifies the selected AQC technologies for Units 1 and 2. The key attributes of the technologies and special considerations for their application and arrangements are presented in a bulleted format for each technology.

Table 5-2. Units 1 and 2 – AQC Selection

AQC Equipment	Pollutant
New SCR	NO_x
Upgrade Existing WFGD	SO_2, HCl
New PAC Injection	Hg, Dioxin/Furan
New stand-alone full size PJFF (option)	PM
New Trona/Lime/SBS Injection (option)	SO_3
New NID System which includes a PJFF (option)	SO_3, HCl, PM
New CS-ESP for fly ash sales	Fly ash

New SCR

- SCR can consistently achieve NO_x emissions of lower than 0.11 lb/MBtu on a continuous basis. Therefore, SCR is the most feasible and expandable control technology considered for NO_x reduction including future NO_x reduction requirements.
- The SCR will increase pressure drop of the system, so the draft system needs to be investigated and new ID fans will be required. Additional auxiliary power requirement will need to be considered for new ID fans.

- Ammonia consumption increases with the addition of SCR. Detailed investigation or study will be required to confirm if a new ammonia storage facility is required or if the existing ammonia storage facility can be upgraded for accommodating Units 1 and 2 ammonia supply.
- Require SO_3 mitigation system like alkali injection and PJFF or dry scrubbing technology like NID.
- Existing air heater will be retained. Air heater basket modifications for acid resistance may be necessary after the installation of SCR.
- A new SCR can be located downstream of the existing economizer and upstream of the existing air heater for Units 1 and 2. Existing CS-ESP for each unit will be demolished and SCR will be installed in same physical location as existing CS-ESP of respective units.
- The SCR will be constructed after installing and operating the new CS-ESP of respective units (where a new CS-ESP is possible).

Upgrading Existing WFGD System

- Upgrade the existing WFGD system to consistently achieve SO_2 emissions of 0.25 lb/MBtu on a continuous basis when burning high sulfur content coals. Upgrading the existing WFGD with additional spray levels and/or flue gas contact rings/trays and flue gas flow modifications is the most feasible control technology considered for SO_2 reduction.
- Upgrading the existing WFGD system can consistently achieve HCl emissions of less than 0.002 lb/MBtu on a continuous basis.
- Existing wet stack will be re-used.
- Impact on existing wastewater treatment system will be checked and verified.
- The amount of limestone required and byproduct produced may by increased by approximately 5 percent.
- Existing scrubber refurbishment can be accomplished ahead of time during regular plant maintenance outages.

New PAC Injection

- A PJFF or NID is recommended in conjunction with PAC injection.
- PAC to be injected downstream of the air heater but upstream of new PJFF or NID.
- PAC Injection can meet the new Hg compliance limit of 1 x 10^{-6} lb/MBtu or lower on a continuous basis and new dioxin/furan compliance limit of 15 x 10^{-18} lb/MBtu or lower on a continuous basis and hence is the most feasible control technology.
- Dioxin and Furan removal will be a co-benefit with targeted mercury emissions removal and additional PAC consumption beyond mercury removal will be required.
- The use of PAC system will slightly increase the truck traffic at the plant.

New PJFF (Option)

- A PJFF can consistently achieve PM emissions of less than 0.03 lb/MBtu on a continuous basis and has the capability to expand in order to meet PM emissions lower than 0.03 lb/MBtu. Hence, a PJFF is the most feasible and expandable control technology considered for PM reduction, including future requirements.
- PJFF offers more direct benefits or co-benefits of removing future multi-pollutants like mercury and sulfuric acid using some form of injection upstream.
- The PJFF will increase pressure drop of the system. As such, the draft system needs to be investigated and new ID fans will be required. Additional auxiliary power requirement will need to be considered for new ID fans
- A new ash handling system will be required to collect ash from PJFF hoppers.
- Additional maintenance will be required for replacing bags and cages.
- For Units 1 and 2, the PJFF can be located downstream of the existing air heater and upstream of the new ID fans and can possibly be installed at three different locations as suggested in the high level layout drawings as shown in Appendix A.
- **Arrangement A**--The PJFF for Unit 1 on this option will be located on the south side of the existing chimney of Units 1 and 2 and west side of the Unit 1 scrubber module. The PJFF will be elevated above the existing electrical equipment building, new ash handling equipment and existing

Unit RATS. This arrangement cuts off access for materials and construction for the new Unit 1 SCR. It also cuts off access for a crane to maintain the new Unit 1 SCR. The CS-ESP for Unit 1 cannot be constructed with this arrangement thereby increasing the ash land-filling capacity requirements of the plant. The PJFF for Unit 2 on this option will be located on the North side of Unit 2 in the area of the existing auxiliary boiler building for Units 1 & 2, which will be demolished. The PJFF will be elevated and installed over the new Unit 2 CS-ESP. The existing over-head Unit 1 and Unit 2 transmission lines will be relocated to eliminate interference. Above and under ground utilities will be investigated, evaluated, and, if necessary, relocated.

- **Arrangement B**--The PJFF for Unit 1 on this option will be located between Unit 1 and Unit 2 scrubber modules. The PJFF will be elevated above the existing SDRS service building. However, the space between the two scrubber modules is very tight and there will be significant construction constraints to install the PJFF at this location. The CS-ESP for Unit 1 cannot be constructed with this arrangement thereby increasing the ash land-filling liability of the plant. The PJFF for Unit 2 on this option will be located on the north side of Unit 2 scrubber modules. The PJFF in this location need not be elevated. The existing over-head transmission lines will be relocated. Above and under ground utilities will be investigated, evaluated, and, if necessary, relocated.
- **Arrangement C**--The PJFF for Unit 1 on this option will be located on the north side of the existing Unit 2 scrubber. The PJFF will be elevated and installed over the new Unit 1 CS-ESP, allowing collection of Unit 1 fly ash for possible beneficial re-use, reducing landfill requirements. The biggest drawback with this arrangement is the long and complicated runs of ductwork which have the potential to overload the duct and structure with ash. The PJFF for Unit 2 on this option will be located on the north side of Unit 2 adjacent to and west of the Unit 1 PJFF. The existing auxiliary boiler building for Units 1 & 2 will be demolished to make room. The PJFF will be elevated and installed over the new Unit 2 CS-ESP. The existing over-head transmission lines will be relocated. Above and under ground utilities will be investigated, evaluated, and, if necessary, relocated.

New SO_3 Control System (Reagent Injection) (Option)

A reagent injection system that injects Trona, Lime or SBS into the flue gas to remove SO_3 would be necessary if a NID system is not included.

- A PJFF is recommended in conjunction with a reagent injection system.
- Trona/Lime would be injected downstream of the air heater but upstream of new PJFF. SBS would be injected upstream of the air heater.
- Reagent injection can reduce the sulfuric acid emissions on a continuous basis and mitigate the visible blue plume formation from the chimney which is often associated when burning high sulfur coal.
- The use of sorbent system will slightly increase the truck traffic at the plant.

New NID (Option)

- The NID, which includes a PJFF, offers more direct benefits or co-benefits as follows:
  - Mercury removal using some form of injection upstream.
  - Sulfuric acid emissions reduction and visible blue plume elimination.
  - HCl emissions reduction of less than 0.002 lb/MBtu on a continuous basis.
  - PM emissions reduction of less than 0.03 lb/MBtu on a continuous basis.
  - Reduce wastewater stream generated by WFGD using NID.
- The NID will increase pressure drop of the system, so the draft system needs to be investigated and new ID or booster fans may be required. Additional auxiliary power requirement will need to be considered for new ID/booster fans.
- A new ash handling system will be required to collect ash from the associated PJFF hoppers of the NID.
- Additional maintenance will be required for replacing bags and cages.
- Additional reagent (lime) handling system will be required. This will include lime storage silo, lime day bins and associated equipment.
- There will be additional water requirements for cooling the flue gas to 90° F above saturation point.
- Additional maintenance will be required every day to clean water nozzle in the mixer-hydrator assembly of each NID reactor.
- The use of lime reagent will slightly increase the truck traffic of the plant.

- For Units 1 & 2, the NID can be located downstream of the existing air heater and upstream of the new ID fans analogous to the three different alternate locations proposed for the PJFF, as suggested in the conceptual sketches as shown in Appendix A.
- **Arrangement A**--The NID for Unit 1 on this option will be located on the south side of the existing chimney of Units 1 and 2 and the Unit 1 scrubber module. The NID will be elevated similar to the arrangement described for the PJFF arrangement previously described. All concerns noted regarding the PJFF installation in this area are also applicable to installation of a NID in this location.
- **Arrangement B**--The NID for Unit 1 on this option will be located on the between Unit 1 and Unit 2 scrubber modules. The NID will be elevated above the existing SDRS service building similar to the arrangement described for the PJFF arrangement previously described. All concerns noted regarding the PJFF installation in this area are also applicable to installation of a NID in this location.
- **Arrangement C**--The NID for Unit 1 on this option will be located on the north side of the existing Unit 2 scrubber. The NID will be elevated and installed over the new Unit 1 CS-ESP. All concerns noted regarding the PJFF installation in this area are also applicable to installation of a NID in this location.

New CS-ESP

- Where it can be installed, a new CS-ESP will be used as a pre-filter to remove 80 to 85 percent fly ash that can be sold to the cement plant to lower the ash land filling liability.
- A new ash handling system will be required to collect ash from CS-ESP hoppers.
- Due to lack of available space, a new CS-ESP for Unit 1 can only be accommodated in the Arrangement C layout as described above, while a new CS-ESP for Unit 2 can be installed in Arrangements A, B, or C. The CS-ESP will be located downstream of the existing air heater and upstream of the new PJFF or NID at each unit.

5.2.2 Mill Creek Units 3 and 4

Table 5-3 identifies the selected AQC technologies for Units 3 and 4. The key attributes of the technologies and special considerations for their application and arrangements are presented in a bulleted format for each technology.

Table 5-3. Units 3 and 4 – AQC Technology Selection

AQC Equipment	Pollutant
Upgrade Unit 4 existing WFGD System and reuse it for Unit 3. New state-of-art WFGD system for Unit 4.	SO_2, HCl
New PAC Injection	Hg, Dioxin/Furan
New stand-alone full size PJFF (option)	PM
New Trona/Lime/SBS Injection (option)	SO_3
New NID System which includes a PJFF (option)	SO_3, HCl, PM

Upgrade Unit 4 Existing WFGD and Reuse as Unit 3 WFGD, Including Wet Stack

- Upgrading Unit 4 existing WFGD system to reuse for Unit 3 can consistently achieve SO_2 emissions of 0.25 lb/MBtu on a continuous basis when burning high sulfur content coals. The existing Unit 4 WFGD system is bigger in size and currently performs better than Unit 3 WFGD system. Therefore, upgrading the existing Unit 4 WFGD with additional spray levels and/or flue gas contact rings/trays and flue gas flow modifications is the most feasible control technology considered for SO_2 reduction.
- Upgrading the Unit 4 existing WFGD system for Unit 3 can consistently achieve HCl emissions of less than 0.002 lb/MBtu on a continuous basis.
- Existing Unit 4 wet stack will be re-used and Unit 3 current wet stack will be abandoned in place.
- Existing Unit 3 WFGD modules will be demolished to make room for Unit 3 NID/PJFF system.
- The amount of limestone required and byproduct produced may by increased by approximately 5 percent.
- Existing scrubber refurbishment can be accomplished ahead of time during regular plant maintenance outages.
- Existing Unit 4 WFGD will be tied-in to Unit 3 after installation of new AQC train for Unit 4.

New WFGD System for Unit 4

- WFGD can consistently achieve SO_2 emissions of 0.25 lb/MBtu on a continuous basis and has a capability to expand to meet the SO_2 emissions even lower than 0.25 lb/MBtu when burning high sulfur content coals. WFGD is the most feasible and expandable control technology considered for SO_2 reduction, including future requirements.
- WFGD can consistently achieve HCl emissions of less than 0.002 lb/MBtu on a continuous basis.
- Existing Unit 4 WFGD modules will be reused by Unit 3.
- Existing wet stack will be re-used by Unit 3.
- New wet stack will be required for Unit 4.
- The amount of limestone required and byproduct produced may by increased by approximately 5 percent.
- A new absorber slurry holding tank will be required.
- A new additional ball-mill may be required for limestone requirements.
- The WFGD will increase pressure drop of the system, so the draft system needs to be investigated and new ID or booster fans may be required. Additional auxiliary power requirement will need to be considered for new ID/booster fans.
- A new WFGD system can be located downstream of the new booster fans and upstream of the new chimney. The WFGD can possibly be installed at two alternate locations as suggested in the conceptual sketches as shown in Appendix A.
- **Arrangement A**--The WFGD absorber will be installed south of the reagent preparation building and northeast side of the cooling tower. The abandoned Unit 4 thickener will be demolished and new WFGD absorber module for Unit 4 will be installed in that area. The ammonia storage area and overhead transmission lines will be relocated. The ductwork serving the WFGD absorber in this arrangements must accommodate the existing limestone conveyor and pipe rack in the area. This location is in close proximity with the cooling tower which may cause icing concerns on the AQC equipment. Above and below ground utilities will be investigated, evaluated, and, if necessary, relocated.

- **Arrangement B**--The WFGD absorber will be installed on the west side of the reagent preparation building and south side of Unit 4 boiler. The existing annex building, lab building and old auxiliary boiler building for Unit 4 will be demolished or relocated and new WFGD absorber module for Unit 4 will be installed in that location. Above and below ground utilities will be investigated, evaluated, and, if necessary, relocated.

New PAC Injection

- A PJFF or NID is recommended in conjunction with PAC injection.
- PAC to be injected downstream of the existing CS-ESP but upstream of existing ID fans.
- PAC injection can meet the new Hg compliance limit of 1×10^{-6} lb/MBtu or lower on a continuous basis and new dioxin/furan compliance limit of 15×10^{-18} lb/MBtu or lower on a continuous basis and hence is the most feasible control technology.
- Dioxin and Furan removal will be a co-benefit with targeted Hg emissions removal, and additional PAC consumption beyond Hg removal will be required.
- The use of PAC system will slightly increase the truck traffic at the plant.

New PJFF (Option)

- A PJFF can consistently achieve PM emissions of less than 0.03 lb/MBtu on a continuous basis and has a capability to expand to meet the PM emissions lower than 0.03 lb/MBtu. Hence a PJFF is the most feasible and expandable control technology considered for PM reduction including future requirements.
- PJFF offers more direct benefits or co-benefits of removing future multi-pollutants like mercury and sulfuric acid using some form of injection upstream.
- A new PJFF can be located downstream of the existing ID fans and upstream of the new booster fans.
- The PJFF will increase pressure drop of the system, so the draft system needs to be investigated and new ID or booster fans may be required. Additional auxiliary power requirement will need to be considered for new ID/booster fans.
- A new ash handling system will be required to collect ash from PJFF hoppers.

- Additional maintenance will be required for replacing bags and cages.
- Existing WFGD modules of Unit 3 will be demolished and PJFF for Unit 3 will be installed in that location.
- For Unit 4, the PJFF can possibly be installed at two alternate locations as suggested in the high level layout drawings as shown in Appendix A.
- **Arrangement A**--The PJFF for this option will be located on the south side of the existing reagent preparation building in the area of the abandoned Unit 4 thickener, which will be demolished. Concerns noted regarding the ammonia storage area, overhead transmission lines, limestone conveyor, and pipe racks in the discussion for the WFGD Arrangement A also apply to this arrangement for the PJFF.
- **Arrangement B**--The PJFF for this option will be located south side of the existing Unit 4 ESP and west of the existing reagent preparation building. The PJFF will be installed over the existing switchgear building for Unit 4 (which will be modified as required to allow it to serve Unit 3.

New SO_3 Control System (Reagent Injection) (Option)

A reagent injection system that injects Trona, Lime or SBS into the flue gas to remove SO_3 would be necessary if a NID system is not included.

- A PJFF is recommended in conjunction with new reagent injection system.
- Trona/Lime/SBS to be injected downstream of the ID fans but upstream of new PJFF.
- Reagent injection can reduce the sulfuric acid emissions on a continuous basis and mitigate the visible blue plume formation from the chimney which is often associated when burning high sulfur coal.
- The use of sorbent will slightly increase the truck traffic at the plant.

New NID (Option)

- The NID, which includes a PJFF, offers more direct benefits or co-benefits as follows:
  - Mercury removal using some form of injection upstream.
  - Sulfuric acid emissions reduction and visible blue plume elimination.
  - HCl emissions reduction of less than 0.002 lb/MBtu on a continuous basis.

  - PM emissions reduction of less than 0.03 lb/MBtu on a continuous basis.
  - Reduce wastewater stream generated by WFGD using NID.
- The NID will increase pressure drop of the system, so the draft system needs to be investigated and new ID or booster fans may be required. Additional auxiliary power requirement will need to be considered for new ID/booster fans.
- A new ash handling system will be required to collect ash from the associated PJFF hoppers of the NID.
- Additional maintenance will be required for replacing bags and cages.
- Additional reagent (lime) handling system will be required. This will include lime storage silo, lime day bins and associated equipment.
- There will be additional water requirements for cooling the flue gas to 90° F above saturation point.
- Additional maintenance will be required every day to clean water nozzle in the mixer-hydrator assembly of each NID reactor.
- The use of lime reagent will slightly increase the truck traffic at the plant.
- Existing WFGD modules of Unit 3 will be demolished and NID for Unit 3 will be installed in that location.
- For Unit 4, a new NID with new PJFF can be located downstream of the existing ID fans and upstream of the new booster fans. The NID can possibly be installed at two alternate locations as suggested in the high level layout drawings as shown in Appendix A.
- **Arrangement A**--The NID for this option will be located on the south side of the existing reagent preparation building, analogous to the location of the PJFF in Arrangement A described above. Concerns described for the PJFF in Arrangement A also apply to the PJFF in this location.
- **Arrangement B**--The NID for this option will be located south of the existing Unit 4 ESP and west of the existing reagent preparation building, analogous to the location of the PJFF in Arrangement B described above. Concerns described for the PJFF in Arrangement B also apply to the PJFF in this location.

6.0 Validation Analyses

The following sections describe the analyses of various balance of plant systems necessary to validate the selected AQC equipment.

6.1 Draft System Analysis

A preliminary analysis of the flue gas draft systems and fans was completed to determine if modifications or replacements of the existing draft fans will be required. This is due to the installation of additional draft system equipment to control certain flue gas emissions. For Unit 1 the modifications and additions to the draft system being considered include a new SCR system, new PJFF or NID system, and the refurbishment and upgrading of the existing WFGD system. In addition, the Unit 1 ESP is expected to be demolished to make room for the new SCR system. The Unit 1 ESP may or may not be replaced depending on the final arrangement chosen. For the purpose of this analysis, it was assumed the existing Unit 1 ESP will not be replaced. Unit 2 would be similar to Unit 1 except that a new ESP would replace the demolished ESP at a different site location to retain ash for salability. Added to Unit 3 would be a new PJFF or NID system and new ductwork to utilize the Unit 4 WFGD system. The Unit 3 WFGD system would be abandoned. Unit 4 would have a new PJFF or NID system and a new WFGD system. In all cases for this analysis, it was assumed the NID system will be installed. This will be confirmed and revised if necessary during conceptual design based on the arrangement selected. For more detail on the AQC equipment modifications, additions, etc. for each Mill Creek unit refer to Section 5.0.

For the sizing of any new fans for the Mill Creek site, the standard Black & Veatch fan sizing philosophy for developing Test Block conditions as additional margin on MCR conditions is recommended. This philosophy includes the application of the following items to the required MCR conditions for new or modified fans:

- 10 percent margin on flue gas flow exiting the boiler.
- 50 percent margin on leakages throughout the draft system.
- 50 percent margin on air heater differential pressure.
- 25° F temperature increase at the fan inlet.
- Adjustments of draft system pressure drops to correspond with increased Test Block flow rates.
- 1.0 inch of water (inw) control allowance.

The application of these items typically results in flow margins in the range of 20 to 30 percent and pressure margins in the range of 35 to 45 percent.

Additionally, following the preliminary analyses of the Mill Creek draft systems, there is also a discussion on draft system transient design pressure requirements per NFPA 85.

6.1.1 Unit 1

Both an SCR system and a NID system are expected to be installed on Unit 1 as shown in Figure 6-1. Due to this additional equipment, the overall draft fan and drive system horsepower demand at MCR is expected to be higher than the combined 5,500 horsepower that each of the existing ID and booster fan combinations can deliver. This includes the consideration of removing and not replacing the ESP. In addition, since the existing ESP is expected to be demolished, the ID fans will likely move to a different location allowing them to be downstream of the NID system. The continued use of the existing ID and booster fans, if upgraded, downstream of the NID system would require additional ductwork on an already space limited portion of the Mill Creek site. With the likely relocation of the ID fans and increase in overall draft fan horsepower, or capacity, it is expected that the existing Unit 1 ID and booster fans will be replaced with a single set of new ID fans.

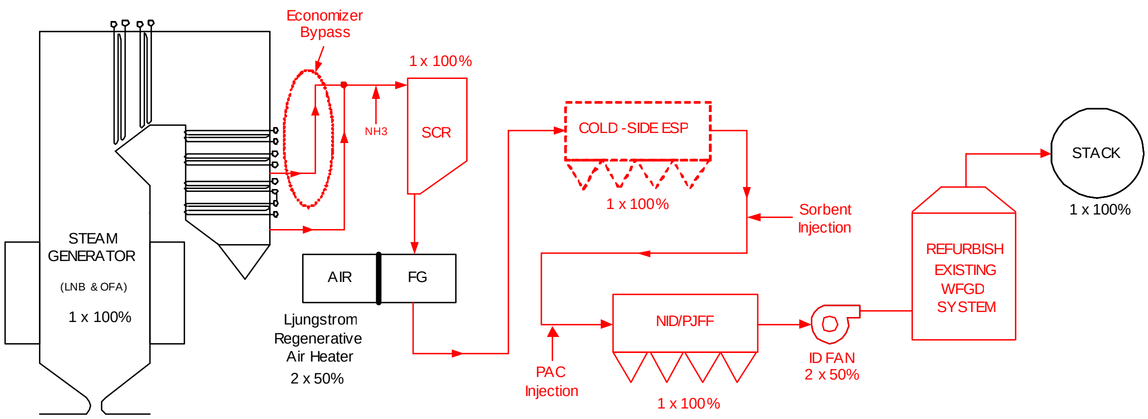


Figure 6-1. Unit 1 Future Draft System

Future Draft System Characteristics

The major performance characteristics of the Unit 1 future draft system at MCR are as follows in Table 6-1. Note that the items in bold in Table 6-1 are components in the draft system that are new or have been modified for the AQC upgrade.

Table 6-1. Unit 1 Future Draft System Characteristics at MCR	
SCR system leakage	**2%**
Air heater leakage	10% (estimated)
ESP leakage	**(demolished)**
NID system leakage	**3%**
Flue gas temperatures	
Boiler outlet	760° F
SCR outlet	**760° F**
Air heater outlet	375° F
ESP outlet	**(demolished)**
NID outlet	**213° F**
New ID fan outlet	**236° F**
Booster fan outlet	**(not replaced)**
WFGD outlet	~132° F
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	4.5 inw
SCR	**10.0 inw**
Air heater	5.0 inw
ESP	**(demolished)**
NID	**14.0 inw**
NID outlet to ID fan inlet	**(included in NID)**
WFGD	**12.0 inw (refurbished & upgraded)**
Stack	1.0 inw

Based on the layout of the future draft system in Figure 6-1 and the future draft system characteristics in Table 6-1, the estimated performance requirements of the new ID fans at MCR are shown in Table 6-2. Also in Table 6-2 are the recommended Test Block conditions developed using the recommended Black & Veatch fan sizing philosophy previously outlined in this section. Note the flow and pressure margins of 26 and 39 percent, respectively.

Table 6-2. Unit 1 New ID Fan
MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	------	900
Inlet Temperature (°F)	213	238
Inlet Density (lb/ft^3)	0.0530	0.0494
Flow per Fan (acfm) *	576,000	728,000
Inlet Pressure (inwg)	-34.0	-46.4
Outlet Pressure (inwg)	13.0	19.1
Static Pressure Rise (inw)	47.0	65.5
Shaft Power Required (HP) **	5,100	8,800
Efficiency (percent) **	85	85
Number of Fans	2	2
Flow Margin (percent)	---------	26
Pressure Margin (percent)	---------	39

*Per fan basis with both fans in operation.
**Estimated – assumes variable speed operation.

6.1.2 Unit 2

Both an SCR system and a NID system are expected to be installed on Unit 2 as shown in Figure 6-2. Due to this additional equipment, the overall draft fan and drive system horsepower demand at MCR is expected to be higher than the combined 5,500 horsepower that each of the existing ID and booster fan combinations can deliver. In addition, since the existing ESP is expected to be relocated, the ID fans will likely be relocated as well allowing them to be downstream of the NID system. The continued use of the existing ID and booster fans, if upgraded, downstream of the NID system would require additional ductwork on an already space limited portion of the Mill Creek site . With the likely relocation of the ID fans and increase in overall draft fan horsepower, or capacity, it is expected that the existing Unit 2 ID and booster fans will be replaced with a single set of new ID fans.

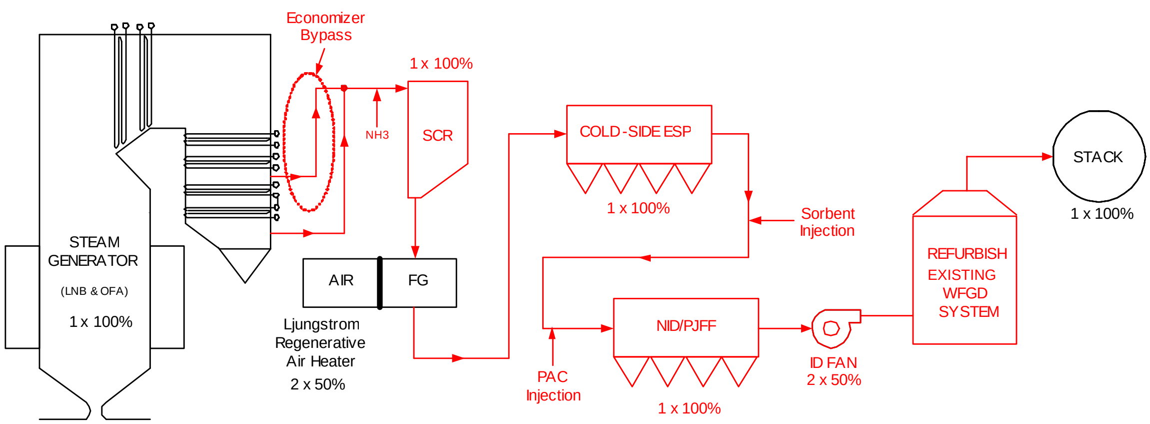


Figure 6-2. Unit 2 Future Draft System

Future Draft System Characteristics

The major performance characteristics of the Unit 2 future draft system at MCR are as follows in Table 6-3. Note that the items in bold in Table 6-3 are components in the draft system that are new or have been modified for the AQC upgrade.

Table 6-3. Unit 2 Future Draft System Characteristics at MCR

SCR system leakage	**2%**
Air heater leakage	10% (estimated)
New ESP leakage	**3%**
NID system leakage	**3%**
Flue gas temperatures	
Boiler outlet	760° F
SCR outlet	**760° F**
Air heater outlet	375° F
ESP outlet	375° F
NID outlet	**212° F**
New ID fan outlet	**238° F**
Booster fan outlet	**(not replaced)**
WFGD outlet	~130° F
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	4.5 inw
SCR	**10.0 inw**
Air heater	5.0 inw
New ESP	**5.0 inw**
NID	**14.0 inw**
NID outlet to ID fan inlet	**(included in NID)**
WFGD	**12.0 inw (refurbished & upgraded)**
Stack	1.0 inw

Based on the layout of the future draft system in Figure 6-2 and the future draft system characteristics in Table 6-3, the estimated performance requirements of the new ID fans at MCR are shown in Table 6-4. Also in Table 6-4 are the recommended Test Block conditions developed using the recommended Black & Veatch fan sizing philosophy previously outlined in this section. Note the flow and pressure margins of 29 and 40 percent, respectively.

Table 6-4. Unit 2 New ID Fan
MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	900	900
Inlet Temperature (°F)	212	237
Inlet Density (lb/ft^3)	0.0523	0.0485
Flow per Fan (acfm) *	616,000	794,000
Inlet Pressure (inwg)	-39.0	-53.2
Outlet Pressure (inwg)	13.0	19.5
Static Pressure Rise (inw)	52.0	72.7
Shaft Power Required (HP) **	6,000	10,700
Efficiency (percent)**	85	85
Number of Fans	2	2
Flow Margin (percent)	---------	29
Pressure Margin (percent)	---------	40

*Per fan basis with both fans in operation.
**Estimated – assumes variable speed operation.

6.1.3 Unit 3

A NID system and the use of the Unit 4 WFGD system are expected to be the new AQC additions for Unit 3 as shown in Figure 6-3. To compensate for the additional draft loss of the NID system and the additional ductwork and upgrades for the Unit 4 WFGD, Black & Veatch's initial approach is to install a set of new booster fans. Booster fans would allow the NID system with its integral PJFF to be under negative draft pressures without constructing additional ductwork to reuse the existing ID fans. The installation of PJFFs in draft system sections under positive pressures is not recommended. However, further analyses will be performed during conceptual design to determine the possibility and practicality of reusing the existing ID fans.

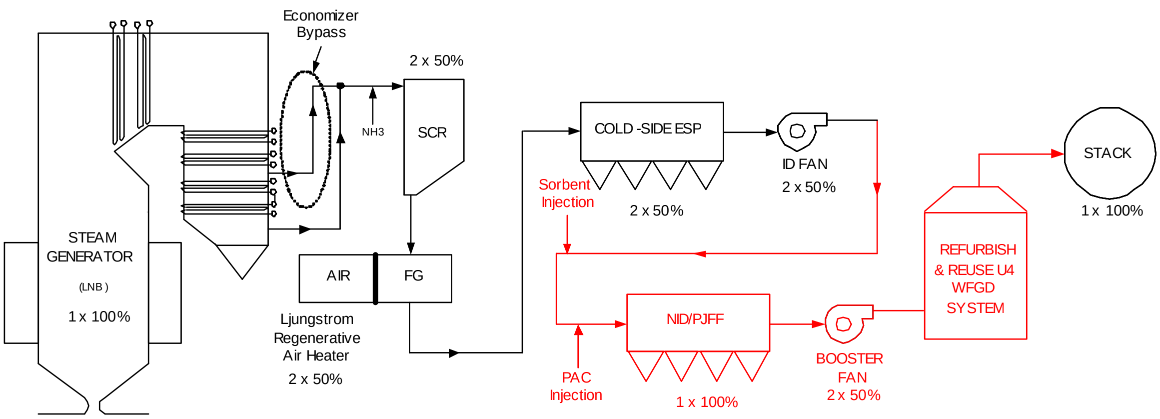


Figure 6-3. Unit 3 Future Draft System

Future Draft System Characteristics

The major performance characteristics of the Unit 3 future draft system at MCR are as follows in Table 6-5. Note that the items in bold in Table 6-5 are components in the draft system that are new or have been modified for the AQC upgrade.

Table 6-5. Unit 3 Future Draft System Characteristics at MCR

SCR system leakage	2% (estimated)
Air heater leakage	10% (estimated)
ESP leakage	5% (estimated)
NID system leakage	**3%**
Flue gas temperatures	
Boiler outlet	690° F
SCR outlet	690° F
Air heater outlet	330° F
ESP outlet	330° F
ID fan outlet	343° F (calculated)
NID outlet	**212° F (calculated)**
New booster fan outlet	**223° F (calculated)**
WFGD outlet	~130° F (calculated)
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	4.5 inw
SCR	8.0 inw
Air heater	5.0 inw
ESP	5.0 inw
NID	**14.0 inw**
Unit 4 WFGD	**12.0 inw (refurbished & upgraded)**
Unit 4 Stack	**1.0 inw**

Based on the layout of the future draft system in Figure 6-3 and the future draft system characteristics in Table 6-5, the estimated performance requirements of the new booster fans at MCR are shown in Table 6-6. Also in Table 6-6 are the recommended Test Block conditions developed using the Black & Veatch fan sizing philosophy previously outlined in this section. Note the flow and pressure margins of 27 and 43 percent, respectively.

Table 6-6. Unit 3 New Booster Fan MCR and Recommended Test Block Conditions

	MCR	**Test Block**
Fan Speed (rpm), maximum	900	900
Inlet Temperature (°F)	212	237
Inlet Density (lb/ft^3)	0.0562	0.0535
Flow per Fan (acfm) *	744,000	941,000
Inlet Pressure (inwg)	-14.0	-18.9
Outlet Pressure (inwg)	13.0	19.9
Static Pressure Rise (inw)	27.0	38.7
Shaft Power Required (HP) **	3,800	6,800
Efficiency (percent)**	85	85
Number of Fans	2	2
Flow Margin (percent)	---------	27
Pressure Margin (percent)	---------	43

*Per fan basis with both fans in operation.
**Estimated – assumes variable speed operation.

6.1.4 Unit 4

A NID system and a new WFGD system are expected to be the new AQC additions for Unit 4 as shown in Figure 6-4. To compensate for the additional draft loss of the NID system and new WFGD, Black & Veatch's initial approach is to install a set of new booster fans. Booster fans would allow the NID system with its integral PJFF to be under negative draft pressures without constructing additional ductwork to reuse the existing ID fans. The installation of PJFFs in draft system sections under positive pressures is not recommended. However, further analyses will be performed during conceptual design to determine the possibility and practicality of reusing the existing ID fans.

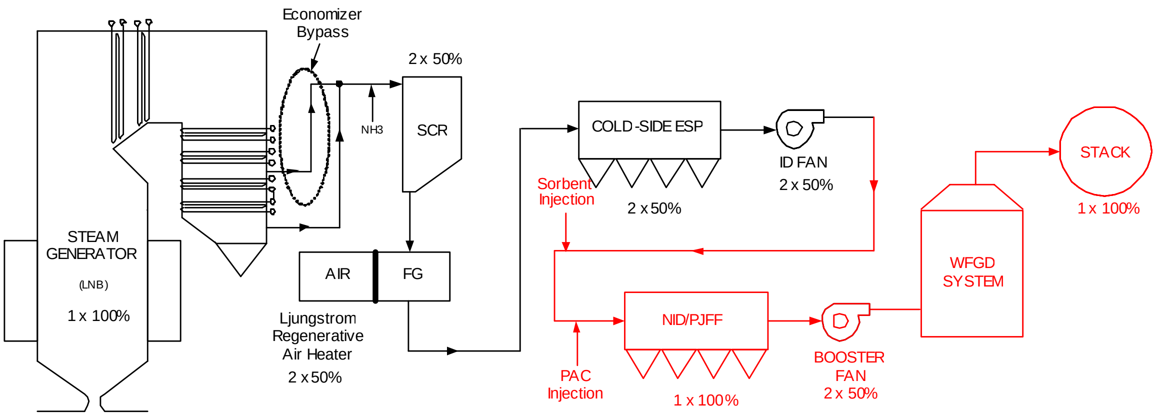


Figure 6-4. Unit 4 Future Draft System

Future Draft System Characteristics

The major performance characteristics of the Unit 4 future draft system at MCR are as follows in Table 6-7. Note that the items in bold in Table 6-7 are components in the draft system that are new or have been modified for the AQC upgrade.

Table 6-7. Unit 4 Future Draft System Characteristics at MCR

SCR system leakage	2% (estimated)
Air heater leakage	10% (estimated)
ESP leakage	5% (estimated)
NID system leakage	**3%**
Flue gas temperatures	
Boiler outlet	640° F
SCR outlet	640° F
Air heater outlet	330° F
ESP outlet	330° F
ID fan outlet	343° F (calculated)
NID outlet	**212° F (calculated)**
New booster fan outlet	**223° F (calculated)**
WFGD outlet	~130° F (calculated)
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	4.5 inw
SCR	8.0 inw
Air heater	5.0 inw
ESP	5.0 inw
NID	**14.0 inw**
New WFGD	**10.0 inw (refurbished & upgraded)**
New Stack	**1.0 inw**

Based on the layout of the future draft system in Figure 6-4 and the future draft system characteristics in Table 6-7, the estimated performance requirements of the new booster fans at MCR are shown in Table 6-8. Also in Table 6-8 are the recommended Test Block conditions developed using the Black & Veatch fan sizing philosophy previously outlined in this section. Note the flow and pressure margins of 27 and 43 percent, respectively.

Table 6-8. Unit 4 New Booster Fan MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	900	900
Inlet Temperature (°F)	212	237
Inlet Density (lb/ft^3)	0.0562	0.0535
Flow per Fan (acfm) *	905,000	1,145,000
Inlet Pressure (inwg)	-14.0	-18.9
Outlet Pressure (inwg)	11.0	17.0
Static Pressure Rise (inw)	25.0	35.8
Shaft Power Required (HP) **	4,200	7,600
Efficiency (percent) **	85	85
Number of Fans	2	2
Flow Margin (percent)	---------	27
Pressure Margin (percent)	---------	43

*Per fan basis with both fans in operation.
**Estimated – assumes variable speed operation.

6.1.5 Draft System Transient Design Pressures

The AQC equipment additions and changes to all of the Mill Creek units will likely be considered major alterations or extensions to the existing facilities per the National Fire Protection Association (NFPA) 85 code - Section 1.3 (2007 Edition). Furthermore, Section 6.5 of NFPA 85, in this instance, would imply that the existing furnace, or boiler, be designed for transient pressures of ± 35 inwg at a minimum. Black & Veatch is in the process of receiving and reviewing documentation confirming the boiler transient design pressures for each Mill Creek unit. Once all documentation is received and processed, Black & Veatch will have a better understanding of which boilers, if any, may require stiffening.

The code however acknowledges that an exception could be taken if the expense for modifying the existing boiler framing system would be disproportionate to the amount of increased protection as long as a reasonable degree of safety can be provided. The "burden" for proving to the authority having jurisdiction (AHJ) whether a reasonable degree of safety can be provided would fall to the User or their Engineer. In Section 1.4.3 NFPA 85 permits the AHJ to deviate from these requirements if deemed impractical to upgrade the existing facility to meet the latest code requirements and provided that a reasonable degree of safety can be provided without upgrading to the full extent of the code.

With the addition of the proposed Mill Creek AQC equipment for this study, this may be an instance where consideration should be given for deviating from these requirements. The basis for this line of reasoning is supported by the explanatory language in the Annex material. Section A.1.4 of NFPA 85 states that:

> "Users of equipment covered by this code should adopt those features that they consider applicable and practicable for existing installations. Physical limitations could cause disproportionate effort or expense with little increase in protection. In such cases, the authority having jurisdiction should be satisfied that reasonable protection is provided.
>
> In existing units, any condition that represents a serious combustion system hazard should be mitigated by application of appropriate safeguards."

The design process of the recently installed Units 3 and 4 SCR systems would have required an analysis of the boiler transient design pressures as previously discussed, and possibly boiler stiffening. Since the Units 3 and 4 SCR systems are in place, it is expected that the SCR systems for Units 1 and 2, as well as other Mill Creek AQC upgrades, could be installed without the addition of cost prohibitive boiler stiffening.

Black & Veatch is also in the process of receiving documentation stating the existing draft system (ductwork and AQC equipment) transient design pressures for Mill Creek. Black & Veatch will have a better understanding of which draft system sections may require stiffening once all of the documentation is received. If stiffening is required, though, it is not expected to be of the cost prohibitive nature of boiler stiffening.

Each new piece of AQC equipment, and its associated new ductwork, being considered for the Mill Creek units between the boiler outlet and the ID fan inlet will be required to meet the NFPA 85 ± 35 inwg requirement per Section 6.5 of NFPA 85. It should be implied that ID fans, in this code, include booster fans. Due to this requirement calculated transient design pressures below ± 35 inwg are disregarded and the ± 35 inwg is used as the design transient pressure for that draft system component or section of ductwork. For calculated transient design pressures over ± 35 inwg the calculated pressure is used. Sections of the Mill Creek draft systems that would likely be exposed to pressures beyond the ± 35 inwg minimum are the new NID (or PJFF) systems and ID fan inlet ductwork on Units 1 and 2. This may apply to other sections of the Mill Creek draft systems as well.

The Black & Veatch philosophy for calculating the minimum required transient design pressures is based on the draft system being designed to 66 percent of its yield stress for maximum continuous (fan Test Block at ambient conditions) operating pressures and 95 percent for short durations, or transient conditions. This results in a 44 percent increase in the allowable stress throughout the draft system for short durations without resulting in permanent deformation or buckling of any structural components. For example, if a section of ductwork is expected to be exposed to negative draft pressures of -30 inwg when the ID fans are operating at Test Block conditions under ambient conditions, the calculated negative transient design pressure would be 44 percent higher or -43.2 inwg. The positive transient design pressure would still be +35 inwg.

6.2 Auxiliary Electrical System Analysis

The existing Mill Creek auxiliary power systems includes outdoor 13.8 kV switchgear in a main-tie-main bus configuration fed at each end by one of two 345/138/13.8 kV Auto transformers. The outdoor 13.8 kV switchgear provides startup/backup power for each unit and the station auxiliary electrical systems. The outdoor 13.8 kV switchgear bus A feeds 13.8/4.16 kV reserve auxiliary transformer A and U1/U2 scrubber transformer A, and bus B feeds 13.8/4.16 kV reserve auxiliary transformer B and U1/U2 scrubber transformer B. Each 13.8 kV switchgear bus has a spare circuit breaker position for future use. Each 13.8/4.16 kV transformer has three windings. The two reserve auxiliary transformers are connected in an "A" or "B" fashion to each of the units' 4.16 kV auxiliary electrical alternate/back-up incoming circuit breakers for startup and backup power. In addition, the two reserve auxiliary transformers feed the 4.16 kV station feeder switchgear which is arranged in a main-tie-main bus configuration.

Units 1 and 2 auxiliary electrical system 4.16 kV switchgear buses are fed from their own respective one three-winding main auxiliary transformer that is powered from their respective generator leads. Units 3 and 4 auxiliary electrical system 4.16 kV switchgear buses are fed from their own respective two three-winding main auxiliary transformers that are powered from their respective generator leads. All units have four auxiliary electrical system 4.16 kV switchgear buses. Units 3 and 4 each have their own respective 4.16 kV scrubber switchgear in a main-tie-main bus configuration that are fed from their respective unit auxiliary electrical system 4.16 kV switchgear buses. Unit 1 and 2 4.16 kV scrubber switchgear buses are fed from the U1/U2scrubber transformers A and B described above.

The WFGD (Unit 4 only) and PJFF, or NID technology options will require the addition of new booster or new ID fans. The existing main auxiliary transformers, reserve auxiliary transformers, and 4.16 kV switchgear buses were determined to have insufficient spare capacity, short circuit rating, and voltages to power the AQC options that include new technology and booster/ ID fan electrical loads.

Based on using variable frequency drives for the ID and booster fans, Units 1, 2, and 3 will require one new two-winding 22 kV – 4.16 kV AQC main auxiliary transformer (MAT) that will be fed from their respective generator leads. Based on using variable frequency drives for the booster fans, Unit 4 will require one new three-winding 22 kV – 4.16 kV – 4.16 kV AQC MAT that will be fed from the Unit 4 generator leads. The secondary windings will power the new AQC 4.16 kV switchgear buses for the fans and other various AQC loads. The alternate/backup power for new AQC 4.16 kV switchgear buses will be fed from new AQC 4.16 kV reserve switchgear and two new AQC 13.8 kV – 4.16 kV two winding reserve auxiliary transformers (RATs) fed from the two spare breaker positions in the existing outdoor 13.8 kV switchgear described above. The new main and reserve auxiliary transformers will be sized such that one of the two transformers feeding the buses could be taken out of service, with the other transformer supplying the entire load. However, Unit 4 will require both AQC RATs to be in service if the Unit 4 MAT is taken out of service. Also, Unit 3 in the final arrangement will use the Unit 4 scrubber and auxiliary systems. The power feeds will need to be switched over from Unit 4 to Unit 3 during conversion in order to maintain power to the scrubber system while Unit 4 is off-line. Further electrical studies (short-circuit, motor starting, etc.) will be performed during detailed design to determine the final transformer impedance and MVA ratings.

The recommended location of the two new AQC reserve auxiliary transformers that will be connected to the existing outdoor 13.8 kV switchgear will be in close proximity to the tie-in points on the east side of the units. The recommended locations of each of the four new AQC main auxiliary transformers will be in close proximity to each of their respective generator leads. Cable bus will be routed during detailed design from the secondary windings of these auxiliary transformers to the new AQC electrical buildings. The new electrical AQC buildings would be located in the vicinity of the PJFF or NID equipment as shown in the conceptual sketches in Appendix A. The buildings will contain the new medium voltage (MV) and low voltage (LV) switchgear, motor control centers (MCCs), and distributed control system (DCS) cabinets. A DC and UPS system will also be included in the electrical buildings to provide control power to the switchgear and DCS system. Motor control centers and DCS I/O cabinets may be installed in a small electrical building adjacent to remote AQC equipment to minimize cable lengths for the equipment in this area.

6.3 Water/Wastewater Systems Analysis

The Mill Creek water supply comes from three water sources: the Ohio River, Well Water, and City Water. The Ohio River supplies water to the Mill Creek station service water system. The service water system supplies cooling water for Unit 1, makeup water for Unit 2, 3, and 4 cooling towers, sluice water for the fly ash and bottom ash systems for all four units, and water to other miscellaneous users at the plant. Well water and city water supplies water to the cycle makeup treatment system which supplies demineralized water for makeup to the steam cycle and closed cycle cooling water systems, and other miscellaneous users for all four units. The Mill Creek wastewater system is made up of a number of ponds which eventually discharge to the Ohio River. Some of the wastewater is recycled for specific plants systems. The makeup water source for the existing WFGDs for Units 1, 2, 3 and 4 is from the Clearwell Pond. The Clearwell Pond collects water from Units 3 and 4 cooling tower blowdowns and receives a slightly greater amount of make-up water from the service water system. Wastewater from the existing WFGDs discharges to the Rim Ditch, which runs north along part of the Ash Pond. Suspended solids in the wastewater settle out in the ditch and are removed and hauled to the landfill. From the Rim Ditch, the WFGD wastewater flows into the Ash Pond. Wastewater in these ponds discharges to the Ohio River through permitted discharge points.

The current water source for the WFGDs will be used for the upgraded, existing WFGDs, which include Unit 1 scrubber, Unit 2 scrubber and Unit 4 scrubber which will be functioning as the new Unit 3 scrubber. The new Unit 4 scrubber will also be supplied by the Clearwell Pond with the tie-in location to be determined during conceptual design. Upgrading the WFGDs and adding the new WFGD will result in changes of FGD makeup water quantity and wastewater discharge quality and quantity. However, these changes are minor and expected to be within the limits of the existing system and will be investigated further during conceptual design.

Additionally, if the NID option is selected, a source for NID makeup water will be required. Potential NID makeup water sources are FGD wastewater, water from the Clearwell Pond, service water, or the combination of the 3 water sources. The quality of water required for NID makeup water will be determined during conceptual design and the water quality of the potential sources will be evaluated. If the FGD wastewater is acceptable for NID makeup water, using the NID system will reduce the quantity of wastewater that flows to the pond system.

6.4 AQC Mass Balance Analysis

Upgrading the existing WFGD system for Mill Creek Units 1 and 2 will result in an increase in SO_2 removal efficiency from 92 to 96 percent. Upgrading the existing Unit 4 WFGD system and reusing it for Unit 3 will result in an increase in SO_2 removal efficiency from 86 to 96 percent. A new state of the art WFGD system on Unit 4 will result in an increase in SO_2 removal efficiency from 92 to 98 percent. The increase in the amount of SO_2 removed by WFGD system from the Mill Creek plants may potentially impact the reagent preparation and byproduct handling system.

Addition of NID or PJFF will increase the amount of ash removed from the Mill Creek units.

- **WFGD Byproduct Handling**--There will be a potential increase in the amount of byproduct produced by the WFGD because of the high amount of sulfur removal from the coal. Impact on existing byproduct handling system will be checked and verified during conceptual design.. Is is estimated that there will be an approximately 5 percent increase in WFGD byproduct formation at Mill Creek Station

- **Ash Handling**--Additional new ash handling system will be required for NID or PJFF. Additional ash handling equipment may include but is not limited to pipes, blowers, valves, etc.

6.5 Reagent Impact/Cost Analysis

- **WFGD Reagent Preparation System**--There will be an approximately 5 percent increase in WFGD reagent requirements at Mill Creek Station. LG&E/KU are currently planning to add a third ball mill to process limestone into reagent. This increase in processing capacity is expected to be more than enough to allow the necessary increased production of reagent for the wet scrubbers.
- **Anhydrous Ammonia System--**There will be an increase in the amount of ammonia required if SCR systems are implemented on Unit 1 and Unit 2. Additional equipment required for anhydrous ammonia system may include but is not limited to ammonia storage tank, ammonia feed pumps, dilution air blowers, vaporizers, pipes, valves, instrumentation and control equipments etc. There will be approximately total of 530 lb/hr of more anhydrous ammonia required for Mill Creek Units 1 and 2.
- **NID Reagent Preparation System**--A new reagent (lime) handling and preparation system will be required for NID. Additional equipment required for reagent handling system for NID may include but is not limited to lime storage silo, lime day bins, air slides, blowers, pipes, valves, instrumentation and control equipments etc. There will be approximately total of 10,650 lb/hr of lime required for Mill Creek Station.
- **PAC Injection System**--A new PAC injection system will be required for mercury and dioxin/furan control. Additional equipment required for PAC injection system may include but is not limited to PAC storage silo, PAC injection lances, blowers, pipes, valves, instrumentation and control equipments etc. There will be approximately total of 3,800 lb/hr of PAC required for Mill Creek Station.
- **Trona/Lime/SBS Injection System**-- A new sorbent (trona/lime/SBS) injection system will be required for SO_3 control. Additional equipment required for sorbent injection system may include but is not limited to sorbent storage silo, injection lances, blowers, pipes, valves, instrumentation and control equipments etc. There will be approximately total of 6,620 lb/hr of sorbent (trona) required for Mill Creek Station.

6.6 Performance of Refurbished Existing Scrubbers

(Later: Pending third party evaluation.)

6.7 Chimney Analysis

Based on the recommendations made in Section 5.2, analysis of the chimneys at Mill Creek Station is based on the following scenarios:

- Unit 1 and Unit 2 – reuse the existing common chimney shell housing two independent flues.
- Unit 3 – use the existing Unit 4 chimney to discharge treated exhaust gases from Unit 3.
- Unit 4 – construct a new "wet" chimney to be located south of Unit 4 to discharge treated exhaust gases from Unit 4.

6.7.1 Unit 1 and Unit 2 Chimney

The existing Unit 1 / Unit 2 chimney consists of a common reinforced concrete shell supporting two independent and dedicated exhaust flues, one per unit, constructed of carbon steel lined with nickel alloy C-276 (UNS N10276). The flues extend to 600 feet above surrounding grade and the shell is penetrated by two breeching openings, one for the exhaust duct from each unit's WFGD scrubbers.

The alloy flue liner is necessary due to the extremely corrosive conditions downstream of a wet flue gas scrubber. No physical inspection was completed as part of this study, but the alloy is an accepted and common liner material for this type of application and LG&E/KU have not indicated there is any reason to suspect problems with continuing to direct Unit 1 and Unit 2 exhaust gas the existing chimney.

The recommendations proposed in this study would result in negligible changes in the temperature, chemical aggressiveness, and total volume flow of the exhaust gases reaching the existing chimney. Moreover, no significant changes are proposed in the ductwork downstream of the existing wet scrubbers at Units 1 and 2, resulting in no expected change in the loads imposed on the chimney shell or the breeching penetrating the shell. Based on the above evaluation, it is recommended that the existing common Unit 1 / Unit 2 chimney be used as is when the respective AQC systems are upgraded.

It should be noted that chimney flue diameters and discharge elevations would remain unchanged. However, the affects of the new equipment will need to be included in the air permitting process.

6.7.2 Unit 3 Chimney

As part of the AQC upgrade recommended for Unit 3, exhaust from Unit 3 will be diverted to the existing Unit 4 wet scrubber and, via the existing exhaust ductwork from the scrubber, to the existing Unit 4 chimney. The existing Unit 3 chimney would be bypassed and abandoned in place. The Unit 4 chimney consists of a reinforced concrete shell supporting a single 19'-6" inside diameter exhaust flue constructed of carbon steel with a nickel alloy C-276 lining. The flue extends to 600 feet above surrounding grade and the shell is penetrated by a single breeching opening for the combined exhaust from both "trains" of the Unit 4 WFGD.

As with the Unit 1 / Unit 2 chimney, the alloy flue liner was provided to withstand the extremely corrosive conditions downstream of the wet scrubber. Alloy C-276 is an accepted and common liner material for the conditions expected in this application and, although no physical inspection was completed as part of this study, LG&E/KU have not indicated there is any reason to suspect problems with the condition of the existing chimney.

Because the Unit 4 chimney was designed for a unit larger than Unit 3, the inside diameter of the flue is larger than that in the to-be-abandoned Unit 3 chimney. The larger diameter flue will result in lower discharge velocities, assuming maximum Unit 3 flow remains relatively constant. The design expected exhaust gas flow reaching the Unit 4 chimney from Unit 3 is 1,347,348 ACFM. Based on the 19'-6" diameter of the flue, the average maximum velocity through the flue will be approximately 75 ft/sec.

The critical velocity for a liner material is a balance between sufficient velocity to ensure adequate dispersion as the gas is discharged from the top and a maximum velocity that prevents "stripping" of acidic condensate droplets from the liner surface and their carryover into the gas being discharged from the chimney. Relatively smooth liner surfaces like that of the alloy liner are less prone to being stripped of condensate by the gas stream than are rougher-surfaced brick and mortar liners. Thus higher velocities are normally allowed where smooth-surfaced liners are installed. There is no regulated or code-required range of velocities for exhaust gas in a chimney flue, but industry sources recommend the maximum gas velocity in a C-276 material-lined flue at 65 to 70 ft/sec. The calculated velocity of Unit 3 exhaust gas through the Unit 4 flue thus slightly exceeds the industry recommendations. However, this calculated velocity is less than that currently experienced through the existing smaller diameter Unit 3 chimney. Diverting the Unit 3 exhaust to the Unit 4 chimney would be expected to slightly lessen the potential of acid carryover, if any, from the Unit 3 chimney under current conditions.

The Unit 4 chimney should be fully acceptable as a discharge point for Unit 3 exhaust as recommended. Liner materials are appropriate for the conditions expected, maximum velocities are near optimum to prevent acid carryover, yet the exit velocity is only slightly reduced from that in the existing Unit 3 chimney. Due to changing the Unit 3 chimney to exhaust through the existing Unit 4 chimney, the affects of the new stack will need to be included in the air permitting process.

6.7.3 Unit 4 Chimney

Due to the recommended reuse of the existing Unit 4 chimney for Unit 3 and the prohibitive lengths of ductwork required to reuse any existing chimney, a new chimney will be required for Unit 4. The new chimney, similar to that of the other three units will be located downstream of a WFGD system and thus subject to extremely corrosive conditions. A "wet" chimney is required, usually consisting of a reinforced concrete shell protecting and supporting a chemically-resistant flue actually carrying the exhaust stream.

Several materials are suitable for use as a liner material in a wet chimney, each with their own advantages and disadvantages. Flues constructed of fire brick and acid-resistant mortar were the norm for many years. However, because of its relatively rough interior surface (increasing potential of carryover), high labor cost to construct, low seismic resistance, and high repair and maintenance record, brick and mortar flues are seldom specified any longer in the United States. Use of this type of flue for Mill Creek Unit 4 is not recommended.

Resin-lined carbon steel and borosilicate block-lined carbon steel are also suitable for the expected environment. However, the relatively low longevity and high repair costs of the resin liner make it a poor choice for a large chimney subject to constant operation. The borosilicate block (often known as Pennguard block after a primary manufacturer) is, similar to acid brick and mortar, relatively expensive to install and is somewhat brittle and susceptible to erosion and damage. For that reason, borosilicate block is used more often as a re-liner for existing chimneys than as the original liner material for a new chimney in the U.S. Neither resin nor borosilicate block liners are recommended for Mill Creek Unit 4.

The two liner materials used most often in the United States for large wet chimneys in that last 15 to 20 years are fiberglass-reinforced plastic (FRP) and C-276 alloy, either as a full-thickness flue material or as a cladding on carbon steel (known as "wallpapering"). The FRP liner material consists of fiberglass strands combined with a high temperature, flame retardant resin that is generally immune to the corrosive conditions in the flue gas. It has an excellent operating record in the U.S. and, usually prefabricated in sections onsite, is relatively quick to install and less expensive than other materials. One significant concern with FRP is its flammability. The fire-retardant resins will burn under the right conditions, although a "FR" FRP liner material has been developed with additional chemicals mixed with the resins to improve the fire rating on the finished liner. Moreover, a fire upstream of FRP liners could cause serious over-temperature damage to the lining. A flue gas quench system is mandatory to protect the liner from high flue temperatures. Some owners do not specify FRP liners due to requirements by their insurance carriers because of fire and high heat concerns.

Alloy C-276 also has an excellent service record as a liner material over the last 20 years. It is highly resistant to the corrosive environment, has superior internal strength, is non-combustible, and is relatively easy to install. However, the nickel alloy material is expensive, and its price volatility over the last 10 years has been extreme, making it an uncertain choice on which to budget large construction projects. To minimize the material costs, a flue of solid C-276 material is often rejected in favor of a carbon steel flue with a thin lining of C-276 material welded to the interior. This "wallpapered" flue is still, depending on market conditions, usually more expensive than an FRP flue and is substantially more dependent on the quality of installation than a solid C-276 flue. Failures of the welds attaching the thin wallpaper to the carbon steel flue result in leaks and exposure of the underlying carbon steel to the corrosive environment in the chimney.

Both FRP and C-276 materials are relatively smooth and have similar critical velocities. Maximum industry-recommended critical velocity of exhaust flow through a C-276-lined flue is 70 ft/sec; for FRP, 65 ft/sec. For an estimated design exhaust flow of 1,885,224 acfm, the recommended flue diameter for a C-276 flue is 23.9 ft; for an FRP flue, 24.8 ft. Based on the existing Unit 4 chimney, a flue discharge height of 600 feet above grade is assumed acceptable.

Although all three chimneys existing at Mill Creek have flues lined with C-276 material, the expected lower cost of the FRP liner makes it the recommended choice, assuming Owner requirements do not dictate otherwise. The new chimney for Ghent Station Unit 4 contains an FRP liner and it is thus assumed LG&E/KU has no inherent objection to FRP liners. The estimate that will be completed during conceptual engineering will include the cost of a reinforced concrete chimney with a single 25-foot diameter FRP liner with a discharge elevation 600 feet above grade.

A new Unit 4 chimney will built be to support the new Unit 4 equipment. The affects of the new stack will need to be included in the air permitting process.

6.8 Constructability Analysis

"Brown-field" construction of major new equipment on an existing site often presents significant challenges in construction due to congestion, obstructions, and the need to keep existing units on line during construction. Accordingly, a high level constructability analysis was completed as part of this study in order to identify and evaluate potential concerns in the arrangements presented. A total of three general arrangement options were considered for Units 1 and 2, both NID and PJFF versions, and two general arrangement options for Units 3 and 4, both NID and PJFF versions. A total of ten arrangement conceptual sketches are attached to this study in Appendix A, each showing two of the units. Following are a generalized discussion of the sequence and concerns identified at the two pairs of units for the various arrangements considered.

6.8.1 Unit 1 Arrangement

As part of Phase I of the project, the major equipment was proposed to be located in the "alley" between Unit 1 and Unit 3. This arrangement for Unit 1 was investigated further and is detailed on Unit 1 / Unit 2 NID Arrangement Sketch A and Unit 1 / Unit 2 PJFF Arrangement Sketch A, attached. This arrangement, as can be seen in the sketches, is extremely congested and would be difficult to erect. The lack of available space prevents inclusion of a replacement ESP at Unit 1 and requires construction of the NID/PJFF to be elevated to clear the scrubber vessel, as well as require construction above the existing reserve aux transformers. Moreover, the location of the NID/PJFF cuts off access for materials and construction for the new Unit 1 SCR and access for a crane to maintain the new SCR. From an operations standpoint, access to Unit 1, the existing Administration Building, and the existing Unit RATs from the east would be lost or seriously restricted. Installation of new Unit RATs in a different location may be necessary.

Due to problems presented with the Sketch A arrangement, a second potential arrangement for Unit 1 was investigated. Unit 1 / Unit 2 NID Arrangement Sketch B and Unit 1 / Unit 2 PJFF Arrangement Sketch B detail the second Unit 1 arrangement considered. The NID/PJFF is located on a new superstructure installed spanning the existing SDRS Service Building. New ID fans are located downstream of the NID/PJFF and gas flow is then reestablished into the existing scrubber inlets and thence out the existing chimney. The lack of available space for this arrangement also precludes installation of a replacement ESP for Unit 1. A substantial new foundation and superstructure must be constructed to span the SDRS Building (and adjoining road for the NID option), but access to the Unit 1 powerblock and construction access for the new SCR is maintained.

Should a new replacement ESP be mandatory for Unit 1, a third arrangement was considered as detailed on Unit 1 / Unit 2 NID Arrangement Sketch C and Unit 1 / Unit 2 PJFF Arrangement Sketch C. New construction for both Units 1 and 2 would be located north of the Unit 2 scrubber area east of the Water Treatment Building. This arrangement has the advantage of being relatively crane accessible and, to a great extent, more accessible for construction. However, the ductwork required for Unit 1 in this arrangement is extreme, with the resultant expense, complexity of foundations and support structures, and increased elevation of the ductwork to avoid restricting access to existing facilities. Due to Unit 2 construction being located in the same area, the new ESP/PJFF would have to be constructed on top of the new ESP, increasing the elevation of the installation as well as the complexity of construction.

All three Unit 1 arrangements considered include a new SCR located in place of the existing ESP, requiring the ESP to be demolished. To minimize unit outage, the NID/PJFF and replacement ESP, where one is planned, must be installed first and tied into the system before demolition of the existing ESP can begin. In all three arrangements, both sets of existing ID and booster fans are bypassed and the new ID fans provide the motive force for the gas flow through the system.

Although the three arrangements considered differ in detail, the same general sequence of construction applies to each. The expected sequence of construction (and estimated timeframe) for installation for the three Unit 1 arrangements is as follows and as noted:

- Construct new foundations and any supporting superstructure for the NID/PJFF and ductwork up to tie-in points. This would also include installing major portions of the new ESP for Arrangement C (8 months, non-outage).
- Install new NID/PJFF and ancillary systems, plus ductwork to tie-in points. Complete installation of new ESP for Arrangement C (*24 months, non-outage)*.
- Demo existing ESP (*8 weeks, outage)*.
- Install by-pass toggle ductwork to air heater (*8 weeks, concurrent with ESP demo outage)*.
- Complete tie-in of ductwork to new fans and existing scrubber *(8 weeks, concurrent with ESP demo outage)*.
- Start-up new NID/PJFF system (and ESP for Arrangement C) (*10 weeks)*.
- Construct new SCR (*18 months, non-outage)*.
- Tie-in SCR (*8 weeks, outage)*.

- Start-up new SCR (*10 weeks)*.
- Existing Scrubber refurbishment is to be completed ahead of time during regular plant maintenance outages.

Demolition of the existing ESP and construction of a new SCR in its place will require cranes with substantial reach, especially for Arrangement A. Open areas were left in Arrangements B and C to allow placement of cranes south of the Unit 1 scrubber and between the existing Unit RATs and the boiler building for work at Unit 1. All three arrangements require the NID/PJFF to be installed above other new or existing equipment, resulting in substantial work at heights and the resulting complications and inefficiencies. Installation of foundations will be problematic due to the existing congestion (somewhat less for Arrangement C) and the need to maintain unit operation to the extent practical. Micropiles may be required for many of the foundations in the interior area near the chimney. In addition, the following issues will have to be addressed in detail to support construction at Unit 1.

- Above and below ground utility interferences and relocations may be necessary.
- Ground and soil stability for setting cranes and heavy haul traffic must be confirmed.
- The potential and magnitude of existing equipment relocations needed to support access, crane setting, construction traffic flow, construction operations activities, and placement of new AQC equipment and ancillary equipment must be investigated.
- Conflicts with existing plant operations must be evaluated and minimized. Isolation of the work area from operating areas must be considered if practical, while still allowing maintenance access to existing equipment.
- Existing plant traffic patterns will be interrupted and must be rerouted. Existing roads must be reestablished or possibly modified upon completion of construction.
- Demolition will be selective dismantling operations in order to work around existing equipment and ancillaries.
- For Arrangement C, the existing overhead Unit 1 and Unit 2 transmission line north of Unit 2 must be relocated.
- Elevating the NID/PJFF and ductwork above the new or existing equipment or structures will require a substantial new foundation and superstructure.

- Relatively extensive new work and rework will be required within the envelope of the existing boiler and ESP structures, requiring extensive evaluation of the existing structure and careful implementation of new work.

6.8.2 Unit 2 Arrangement

In all three alternate arrangements considered for Unit 2, the major portion of new construction is located to the north of the existing Unit 2 scrubber area and east of the existing Water Treatment Building. Phase I of the project proposed the ESP and NID/PJFF be stacked in this area, as detailed on Unit 1 / Unit 2 NID Arrangement Sketch A and Unit 1 / Unit 2 PJFF Arrangement Sketch A, attached. This arrangement makes good use of available space, but requires substantial portions of the work to be elevated, with the resulting complications to construction and access.

A second potential arrangement for Unit 2 allowing more construction at grade was investigated. Unit 1 / Unit 2 NID Arrangement Sketch B and Unit 1 / Unit 2 PJFF Arrangement Sketch B detail the second Unit 2 arrangement considered. The NID/PJFF is located separate from and downstream of the new ESP. New ID fans are located downstream of the NID/PJFF and gas flow is then reestablished into the existing scrubber inlets and thence out the existing chimney. The larger footprint required results in some construction extending over the sharp slope northeast of Unit 2, requiring substantial fill work and establishment of a new plant road system in the area.

A third arrangement was dictated by the location of Unit 1 construction in the same area as detailed on Unit 1 / Unit 2 NID Arrangement Sketch C and Unit 1 / Unit 2 PJFF Arrangement Sketch C. This arrangement for Unit 2 is essentially the same as Arrangement A with the added complexity of routing duct through to Unit 1. This arrangement requires both the additional elevation and construction complexity of Arrangement A and the added fill work of Arrangement B. But it does have the advantage of being relatively crane accessible and, to a great extent, more accessible for construction.

As with Unit 1, all three Unit 2 arrangements include a new SCR located in place of the existing ESP, requiring the ESP to be demolished. To minimize unit outage, the NID/PJFF and replacement ESP must be installed first and tied into the system before demolition of the existing ESP can begin. In all three arrangements, both sets of existing ID and booster fans at Unit 2 are bypassed and the new fans provide the motive force for the gas flow through the system.

Although the three arrangements considered differ in detail, the same general sequence of construction applies to each. The expected sequence of construction (and estimated timeframe) for installation for the three Unit 2 arrangements is as follows and as noted:

- Construct new ESP and NID/PJFF with ductwork up to tie-in points at air heater and refurbished existing scrubber, plus ancillary systems required for operation (*24 months, non-outage)*.
- Demo existing ESP (*8 weeks, outage)*.
- Install tie-ins to air heater and scrubber (*8 weeks, concurrent with ESP demo outage)*.
- Start-up new ESP and NID (*10 weeks)*.
- Construct new SCR (18 months, non-outage).
- Tie-in new SCR (*8 weeks, outage)*.
- Start-up new SCR (*10 weeks)*.
- Existing scrubber refurbishment is to be accomplished ahead of time during plant maintenance outages.

An open area was left in the arrangement to allow placement of a large crane east of the Water Treatment Building for work at Unit 2. As at Unit 1, installation of foundations will be problematic due to the existing congestion and the continued operation of existing equipment. Micropiles may be required in congested areas, although the major construction area north of the Unit 2 scrubber appears relatively clear. In addition, the following issues will have to be addressed in detail to support construction at Unit 2.

- Above and below ground utility interferences and relocations may be necessary.
- Ground and soil stability for setting cranes and heavy haul traffic must be confirmed.
- A significant grade elevation change exists at northeast corner of the proposed area, which may require additional fill or may complicate access.
- The existing Water Treatment Building and an adjacent pipe rack will complicate crane access to Unit 2.
- The path to the existing warehouse receiving dock lies directly in the main construction area, requiring its early relocation to minimize impact on operations.
- Other conflicts with existing plant operations must be evaluated and minimized. Isolation of the work area from operating areas must be considered if practical, while still allowing maintenance access to existing equipment.

- Existing plant traffic patterns will be interrupted and must be rerouted. Existing roads must be reestablished or possibly modified upon completion on construction.
- Demolition will be selective dismantling operations in order to work around existing equipment and ancillaries.
- The existing overhead Unit 1 and Unit 2 transmission line located north of Unit 2 must be relocated.
- Relatively extensive new work and rework will be required within the envelope of the existing boiler and ESP structures, requiring extensive evaluation of the existing structure and careful implementation of new work.

6.8.3 Units 3 and 4 Arrangement

The modifications proposed at Units 3 and 4 are interdependent in that the Unit 4 scrubber and chimney will be reused in the modified Unit 3. Accordingly construction of these two units will be considered together. Unit 4 will be the first of the two units to be modified and will be addressed first. Since the Unit 4 scrubber and chimney will be dedicated to Unit 3, a new wet scrubber and chimney will be constructed downstream of the NID/PJFF, with the addition of booster fans to supplement the existing Unit 4 ID fans. Ductwork feeding the downstream Unit 4 AQC train will be located in the area currently occupied by Unit 4 duct to the scrubber and bypass duct to the chimney.

Phase I work identified a location for the new Unit 4 construction in the area of the existing foundation for the demolished thickener south of the Reagent Prep building. This arrangement, as detailed on Unit 3 / Unit 4 NID Arrangement Sketch A and Unit 3 / Unit 4 PJFF Arrangement Sketch A, allows construction access from the main plant road and relatively easy operational access to the equipment. However, ductwork lengths are significant for this arrangement, plus ductwork must be routed above the existing limestone conveyor and ash pipe rack. In addition, the thickener foundation must be demolished and the existing ammonia storage area relocated. An overhead T-line is routed directly through the area and would also likely have to be relocated to allow safe construction. Finally, the relatively close location of the Unit 4 cooling tower may cause icing problems on the new AQC equipment and this would have to be considered.

An alternate arrangement was then investigated for Unit 4 as detailed on Unit 3 / Unit 4 NID Arrangement Sketch B and Unit 3 / Unit 4 PJFF Arrangement Sketch B, attached. Instead of continuing to the south, the AQC train is turned along an east-west axis south of Unit 4, with new equipment located between the limestone storage area and Unit 4. The NID/PJFF will be elevated and located above the existing Unit 4 AQC

Switchgear Building, whose contents will be modified for reuse on Unit 3. Ash handling equipment and new electrical equipment for Unit 4 will be located in the remaining area under the NID/PJFF. This arrangement will require the existing Annex Building, Sample Lab, and old Aux Boiler Building to be demolished or relocated. This arrangement is also somewhat more congested than the Sketch A arrangement and equipment arrangement must be carefully coordinated to maintain access to the Unit 4 Boiler and Turbine Buildings and minimize impact to the limestone storage pile.

Construction of Unit 3 will be completed in two parts to minimize outages. Once Unit 4 modifications are complete and the unit is on line, new ductwork will be extended from the existing Unit 3 ID fans to the Unit 4 scrubber inlets. The new duct will be routed beneath the Unit 4 duct, turn, and rise at a diagonal to the existing scrubber inlet duct. Unit 3 will then be put back into operation using the Unit 4 scrubber and chimney. The existing Unit 3 scrubber, now bypassed, will then be demolished and the area cleared for a new NID/PJFF and two additional booster fans, plus tie-in ductwork. Once new construction is complete, tie-ins will be made to bring the new NID/PJFF into service. The NID/PJFF will be elevated to span across the existing road and allow ash handling equipment to be located beneath in the footprint of the demolished Unit 3 scrubber.

The expected sequence of construction (and estimated timeframe) for installation for the Unit 3 and Unit 4 construction is as follows:

- Demo and/or relocate existing structures in the way of new construction (duration to be determined based on arrangement selected, non-outage).
- Construct Unit 4 AQC Train, starting at the new chimney and proceeding upstream (*36 months, non-outage)*.
- Tie-in Unit 4 to new AQC Train (*8 weeks, outage)*.
- Start-up Unit 4 (*12 weeks)*.
- Recondition Existing Unit 4 Scrubber for use by Unit 3 and switch power source for “old” Unit 4 AQC to Unit 3 (*TBD - by others, non-outage)*.
- Install new duct from Unit 4 scrubber inlet to tie-in points at Unit 3 ID fans *(8 weeks, concurrent with scrubber reconditioning)*.
- Tie-in Unit 3 to reconditioned Unit 4 scrubber (*8 weeks, outage)*.
- Start-up Unit 3 *(8 weeks)*.
- Demo Unit 3 Scrubber and all areas needed to facilitate new NID/PJFF and all ancillary equipment (*6 weeks, non-outage)*.
- Reclaim area demolished and make ready for NID/PJFF construction (*12 weeks, non-outage)*.

- Erect Unit 3 NID/PJFF *(16 months, non-outage)*.
- Make final tie-in to Unit 3 NID/PJFF (*6 weeks, outage)*.
- Start-up Unit 3 (*10 weeks)*.

Crane access for construction of Unit 3 and Unit 4 appears relatively good for either arrangement, although access for both units in Arrangement B will be limited to a great extent to one side. Extensive coordination of the installation of new ductwork in the area between the existing ID fans and the existing scrubbers will be required to minimize outage. Demolition of the existing Unit 3 scrubber, especially the foundation and underground portion, will be extensive and consideration should be given to abandoning and backfilling the existing substructure to the extent practical. Reuse of existing ductwork support steel and foundations should also be considered as practical. Access for piling appears acceptable except under existing ductwork, where micropiles may be required. In addition, the following issues will have to be addressed in detail to support construction at Units 3 and 4.

- Traffic patterns for north/south road must be adjusted to accommodate construction traffic and cranes, primarily for Unit 3.
- The existing thickener foundation, overhead Unit 3 and unit 4 transmission line , and Ammonia Storage Building (Arrangement A) or Annex Building, Sample Lab, and old Aux Boiler Building (Arrangement B) must be demolished or relocated.
- Above and below ground utility interferences and relocations may be necessary.
- Ground and soil stability for setting cranes and heavy haul traffic must be confirmed.
- A retaining wall, either temporary or permanent, will likely be required at the north side of the limestone pile to maximize construction access along the south side of Unit 4 (Arrangement B only).
- Conflicts with existing plant operations must be evaluated and minimized. Isolation of the work area from operating areas must be considered if practical, while still allowing maintenance access to existing equipment.
- Demolition will be selective dismantling operations in order to work around existing equipment and ancillaries.
- The condition of existing ductwork support steel must be evaluated if it can be reused for new ductwork.
- Ductwork and ancillary layout will be extensive and must take existing operating units into consideration.

- Maintain operating access to Unit 4 Turbine Building.
- Maintain operating access to Unit 4 Boiler Building.

6.9 Truck/Rail Traffic Analysis

The modifications proposed for the four Mill Creek units will result in additional bulk material required to support the AQC processes. These materials will be delivered from offsite on a regular basis and stored onsite for use. Preliminary estimates of the rate of use of sorbents or reagents required in the proposed AQC processes by unit are listed in Table 6-9. Additional delivery traffic for the site as a whole will be addressed accordingly.

Table 6-9. Sorbents and Reagents Consumption Rates (tph)

Material	Unit 1	Unit 2	Unit 3	Unit 4	Station Total
PAC	0.39	0.41	0.49	0.60	1.89
Sorbent (Trona) (Note 1)	0.96	0.99	1.26	1.53	4.74
Pebble or powdered lime (Note 1)	1.48	1.55	2.01	2.47	7.51
Anhydrous ammonia	0.132	0.133	Note 2	Note 2	0.265 addn'l

tph - tons per hour.

Notes:
1. Sorbent (Trona) is not required if the NID particulate removal technology is specified. Lime is not required if the PJFF technology is specified.
2. Current rate of consumption of anhydrous ammonia at Units 3 and 4 will remain essentially unchanged.

Although a rail spur and delivery loop exist at Mill Creek Station, the onsite rail system is used exclusively for coal deliveries. Due to the variable schedules in coal train arrival and the relatively extended periods required to unload a unit train, using the existing rail system for periodic delivery of other bulk materials would be problematic at best. Similarly, limestone is delivered to the site via a dedicated barge unloading system that would be difficult to coordinate with delivery of other materials. Accordingly, delivery of bulk sorbents and reagents for the proposed AQC systems, other than limestone, will be assumed to be via truck on existing roads.

Dry bulk material, such as PAC, sorbent (trona), and pebble or powdered lime, is normally delivered in fully-enclosed bulk delivery trucks and offloaded using a pneumatic transfer system integral to the truck. A standard over-the-road trailer truck size for these materials is nominally 20 tons per load. Anhydrous ammonia is usually transported in a pressurized tank truck with a nominal capacity of 10,000 gallons. Based on the consumption rates in the Table 6-9 above and the nominal truck sizes, the additional truck deliveries to the Mill Creek site can be summarized as follows.

- PAC 16 loads per week
- Sorbent (Trona) 40 loads per week (PJFF only)
- Lime 63 loads per week (NID only)
- Anhydrous ammonia 2 loads per week additional

Noting that sorbent (trona) and lime deliveries are mutually exclusive depending on the particulate removal technology used, the total additional truck deliveries estimated to provide sorbents or reagents is approximately 58 loads per week for PJFF and 81 loads per week for NID. Assuming delivery operations are limited to five days a week and an 8-hour day, the maximum additional truck deliveries to site would be approximately 16 per day or 2 per hour over and above the current deliveries being made. Existing roads onsite should be able to accommodate the additional deliveries. A tank or silo is often provided for each material at each unit to minimize the size and length of distribution systems. However, where practical, consideration should be given to consolidated tanks or silos located so as to serve more than one unit, in order to minimize unloading time and extended truck travel onsite.

The upgrading of the existing FGD scrubbers will increase consumption of limestone reagent as well as produce additional gypsum byproduct. On a station-wide basis, approximately 5 percent additional limestone will be required for the desulphurization process, or an estimated total of 83 tph. Since all limestone is currently delivered via barge and offloaded into the limestone pile and reagent preparation building via dedicated conveyor, both deliveries and the unloading process will require an increase of approximately 5 percent over current operating rate or operating time to maintain needed supply to the process. LG&E/KU are currently planning to add a third ball mill to process limestone into reagent. This one third increase in processing capacity is expected to be more than enough to allow the necessary increased production of reagent for the wet scrubbers.

Gypsum production from the four units will also increase approximately 5 percent above current production, or an estimated 153 tph (wet basis) station-wide. This material is transferred to the dewatering/ash handling area for disposal. It is believed that the existing transfer system is adequate for the incremental increase in gypsum production.

The added particulate removal system at each unit, whether ultimately a NID or a PJFF, will capture additional particulate that will need to be landfilled. The PAC and trona (PJFF) or PAC and lime (NID) injected into the system upstream will ultimately be removed by the particulate removal equipment. In addition, more fly ash will be removed by the new PJFF or NID at Units 3 and 4 than is currently collected in the ESPs. The total expected additional particulate, including additional fly ash as well as the injected material, removed from the exhaust streams of the four units is estimated at 18,920 lb/hr, worst case, or approximately 227 tons per day of operation of all four units. This increased volume will require additional operating time for the existing (and augmented) ash transfer systems to deliver the ash to the ash handling area. Current ash disposal activities will have to increase accordingly.

7.0 Conclusion

This Air Quality Control Validation Report confirms the feasibility of installing certain AQC equipment at Mill Creek Station and presents the supporting considerations, arrangements, and preliminary validating analyses of the AQC equipment that will be built upon in the next steps of the project to complete the conceptual design and budgetary cost estimate.

After review of the presented information and further discussions, LG&E/KU has directed B&V to proceed to the conceptual design and budgetary cost estimate steps based on the following arrangements and summarized in Table 7-1.

Unit 1 shall include a new SCR, new sorbent injection system, new PAC injection system, new PJFF, new ID fans, refurbished scrubber and will utilize the existing common Unit 1/Unit 2 chimney. The project will include demolition of the existing CS-ESP as required for installation of the new SCR and shall not include installation of a new CS-ESP. A neural network shall also be included. Unit 1 PJFF Arrangement B with the new SCR located in the area currently occupied by the existing CS-ESP and with the new PJFF located above the existing Unit 1 and Unit 2 SDRS pump/electrical building is to be utilized. Cost associated with installation of the SCR shall be easily identifiable and separated for further consideration based on final regulations.

Unit 2 shall include a new SCR, new sorbent injection system, new PAC injection system, new PJFF, new ID fans, refurbished scrubber and will utilize the existing common Unit 1/Unit 2 chimney. The project will include demolition of the existing CS-ESP as required for installation of the new SCR and shall not include installation of a new CS-ESP. A neural network shall also be included. Unit 2 PJFF Arrangement C with the new SCR located in the area currently occupied by the existing CS-ESP and with the new PJFF located to the North of existing Unit 2 is to be utilized excluding the installation of a new CS-ESP. Cost associated with installation of the SCR shall be easily identifiable and separated for further consideration based on final regulations.

B&V developed Arrangement D to show the combination of Arrangements B and C for Units 1 and 2. Refer to Appendix A for Arrangement D.

Unit 3 shall include the existing SCR, existing CS-ESP, existing ID fans, new sorbent injection system, new PAC injection system, new PJFF, new booster fans. Also included will be the refurbishment of the existing Unit 4 scrubber for use on Unit 3 and will utilize the existing Unit 4 chimney. The project will include demolition of the existing Unit 3 scrubber as required for installation of the new PJFF. A neural network shall also be included. Unit 3 PJFF Arrangement A/B with the new PJFF located in the area currently occupied by the existing Unit 3 scrubber with ductwork extended to the existing Unit 4 scrubber is to be utilized.

Unit 4 shall include the existing SCR, existing CS-ESP, existing ID fans, new sorbent injection system, new PAC injection system, new PJFF, new booster fans, new WFGD, and new chimney. A neural network shall also be included. Both arrangements are to be included in the conceptual design and budgetary cost estimate steps: Unit 4 PJFF Arrangement A oriented north-south and Unit 4 PJFF Arrangement B oriented east-west.

Table 7-1. AQC Technologies

	Unit 1	**Unit 2**	**Unit 3**	**Unit 4**
NO_x Control	New SCR	New SCR	Existing SCR	Existing SCR
SO_2 Control	Refurbish existing WFGD	Refurbish existing WFGD	Refurbish and reuse Unit 4 WFGD	New WFGD
PM Control	New PJFF	New PJFF	New PJFF	New PJFF
HCl Control	Refurbish existing WFGD	Refurbish existing WFGD	Refurbish and reuse Unit 4 WFGD	New WFGD
CO Control	New NN	New NN	New NN	New NN
SO_3 Control	New PJFF with Sorbent Injection	New PJFF with Sorbent Injection	New PJFF with Sorbent Injection	New PJFF with Sorbent Injection
Hg Control	New PAC Injection	New PAC Injection	New PAC Injection	New PAC Injection
Dioxin/Furan Control	New PAC Injection	New PAC Injection	New PAC Injection	New PAC Injection
Fly Ash Sales	None	None	Existing CS-ESP	Existing CS-ESP

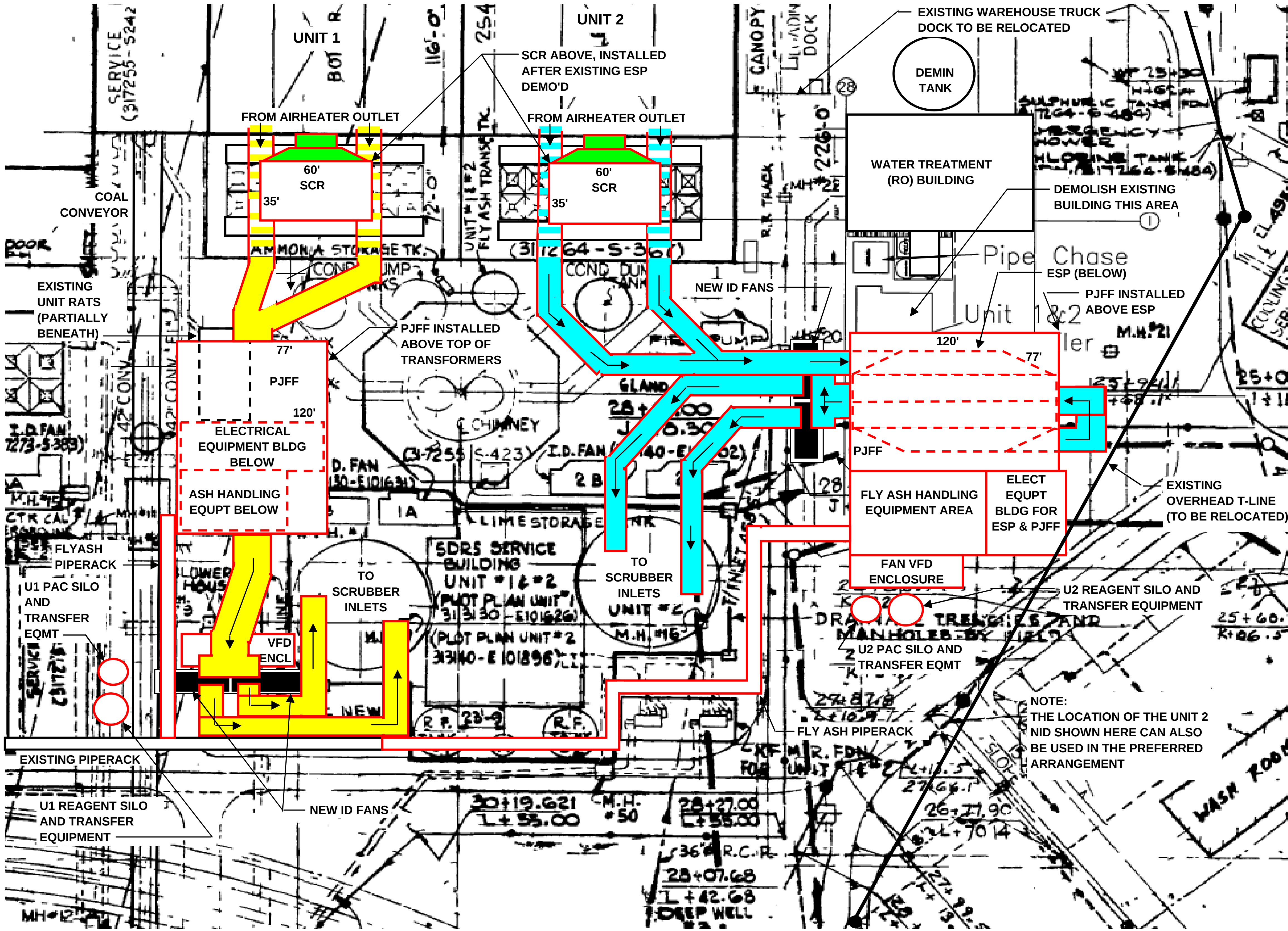
Additionally, the following items shall also be considered in the next step of the project.

- Relocation of the overhead transmission lines that serve Units 1 and 2 on the north end of the plant and that serve Units 3 and 4 on the south end of the plant should be avoided if possible. Weekend outages of the lines are possible if scheduled in advance. Lines can not be relocated underground.
- For Unit 4 Arrangement A, demolition and removal of the entire thickener foundation and tunnels may not be necessary.
- Unit 4 Arrangement B shall include provision for access and lifting means for replacement of conveyor belts on the tripper floor.
- Replacement of the existing Unit 4 scrubber to chimney ductwork is required due to corrosion and should be accounted for in this project.
- Isolation dampers shall be provided on all new fans.

- Unit 4 Arrangement B should consider locating the slurry storage tank inside the chimney shell below the liner to increase access.
- Unit 4 Arrangement B should included extension of the south FD fan monorail and modifications to the SCR tower.
- Locations for the relocation of Unit 3/4 ammonia storage system, annex building, laboratory and old unit 4 aux boiler building/warehouse to be recommended by LG&E/KU.

Appendix A
Conceptual Sketches

Unit 1 and 2
Pulse Jet Fabric Filter Alternatives (A, B, C, and D)



UNIT 1 / UNIT 2
PJFF ARRANGEMENT A
CONCEPTUAL SKETCH
USING ESP, PJFF, SCR & NEW ID FANS AT UNIT 2, AND PJFF & SCR AT UNIT 1, NO NEW ESP

U2 DUCT TO ESP & NID
11' & 16' SQ ASSUMED

U1 DUCT TO NID
11' & 16' SQ ASSUMED

U1/U2 DUCT TO/FROM SCR
10' X 40' (AVG) ASSUMED

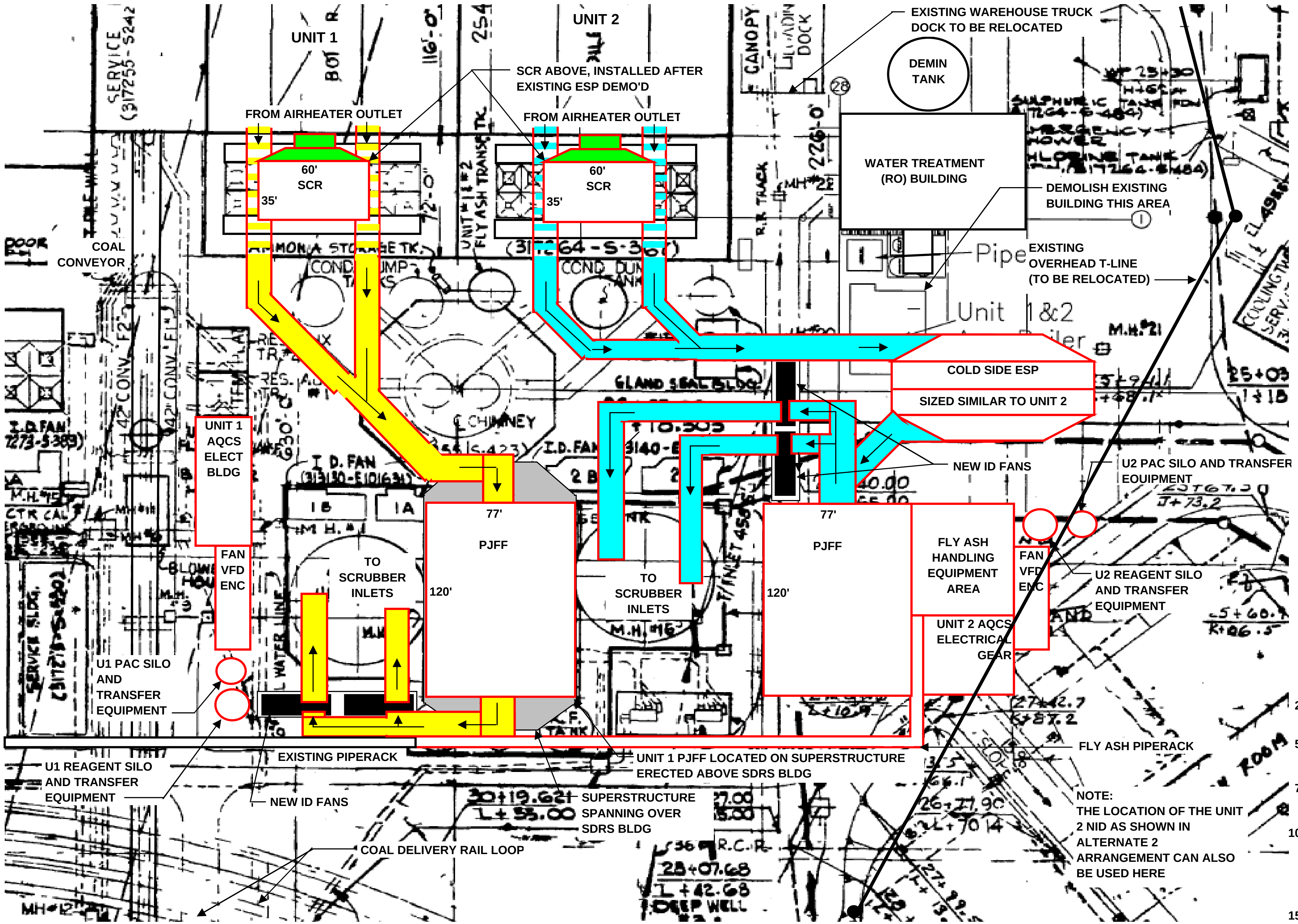
0 75 100 150

0 25 50 75 100 150

APPROX SCALE

N

MILL CREEK 1 & 2



UNIT 1 / UNIT 2
PJFF ARRANGEMENT B
CONCEPTUAL SKETCH
USING ESP, PJFF, SCR & NEW ID FANS AT UNIT 2, AND PJFF & SCR AT UNIT 1, NO NEW ESP

U2 DUCT TO ESP & NID
11' & 16' SQ ASSUMED

U1 DUCT TO NID
11' & 16' SQ ASSUMED

U1/U2 DUCT TO/FROM SCR
10' X 40' (AVG) ASSUMED

0 75 100 150

0 25 50 75 100 150

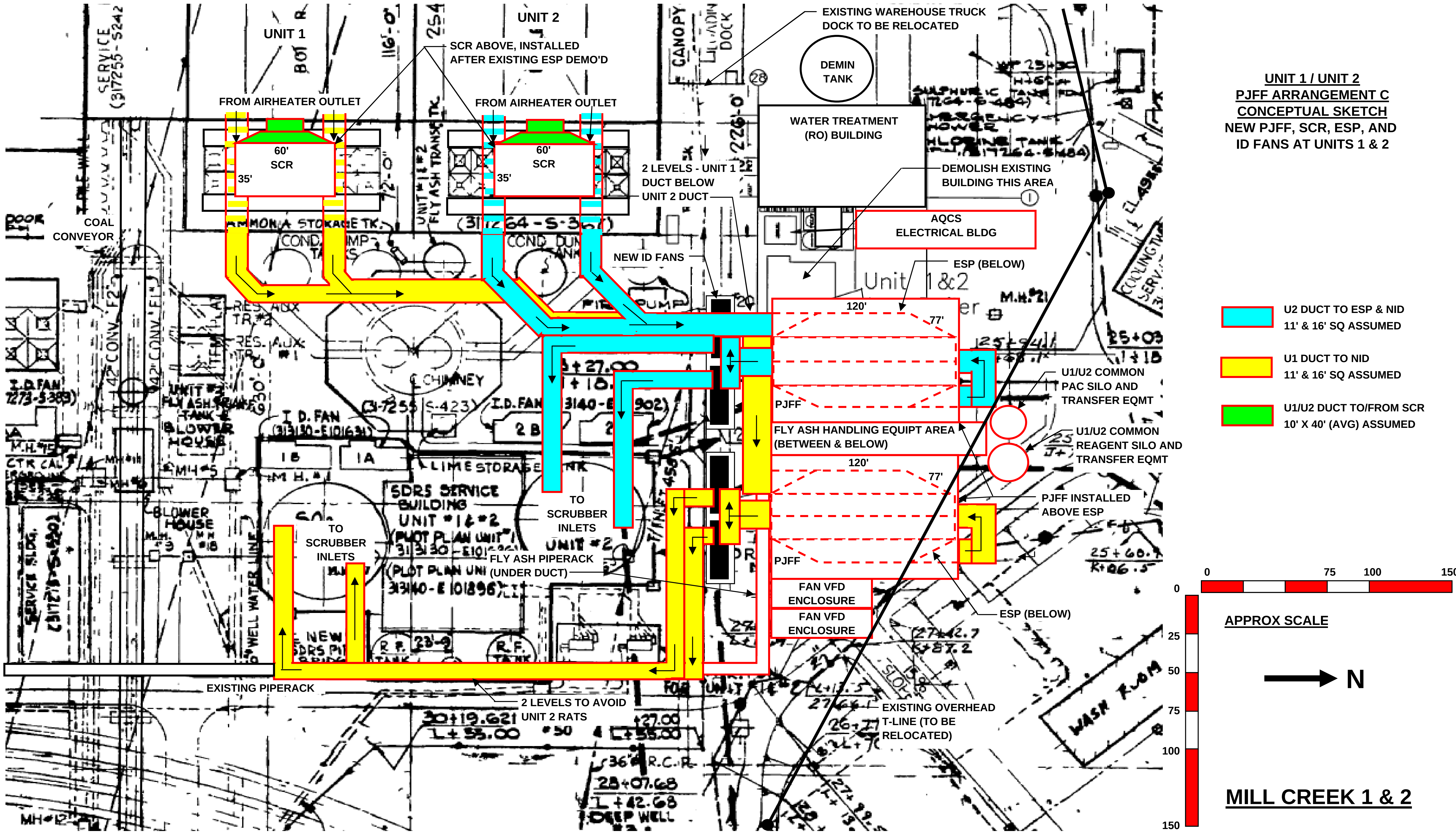
APPROX SCALE

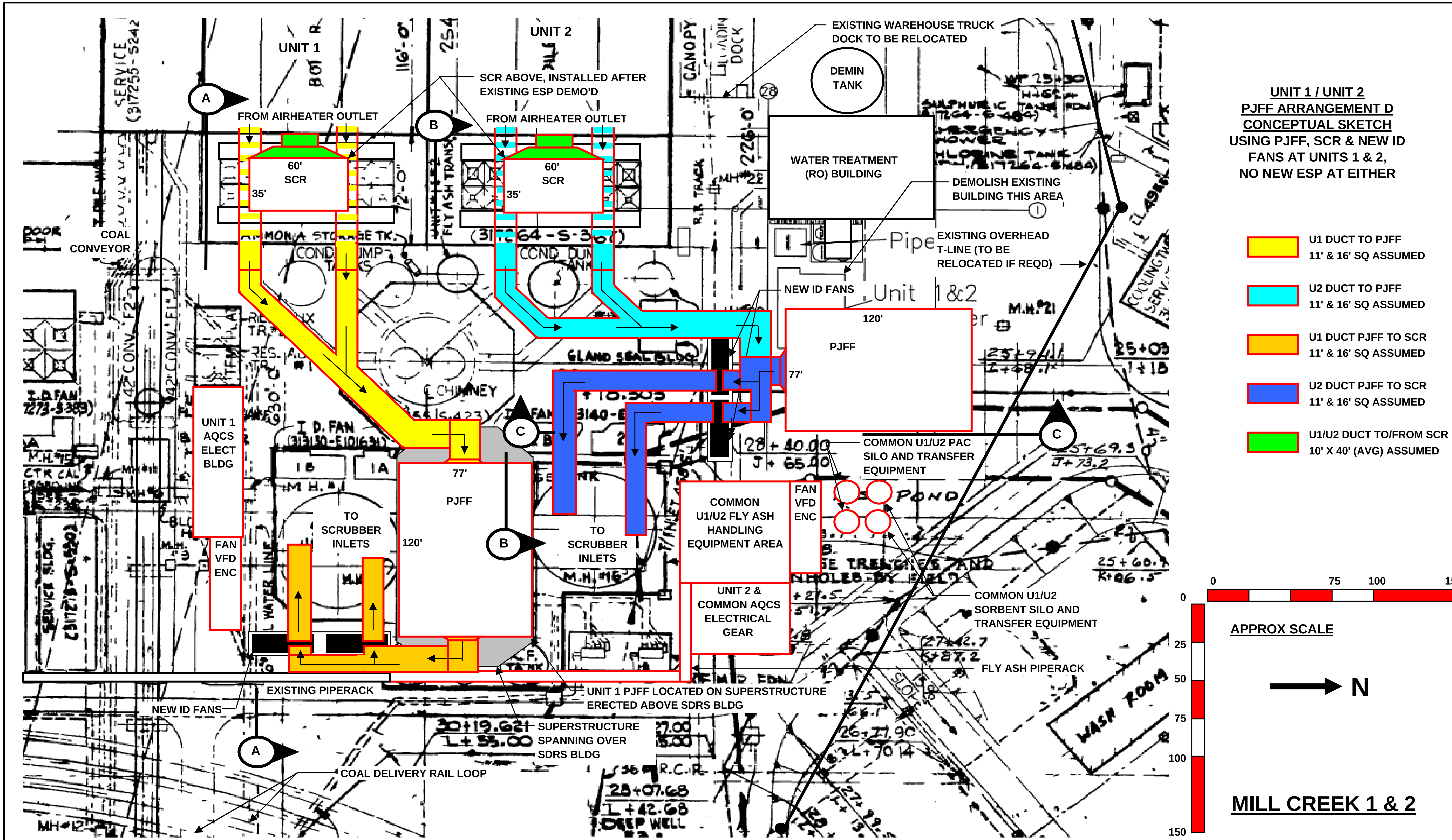
N

MILL CREEK 1 & 2

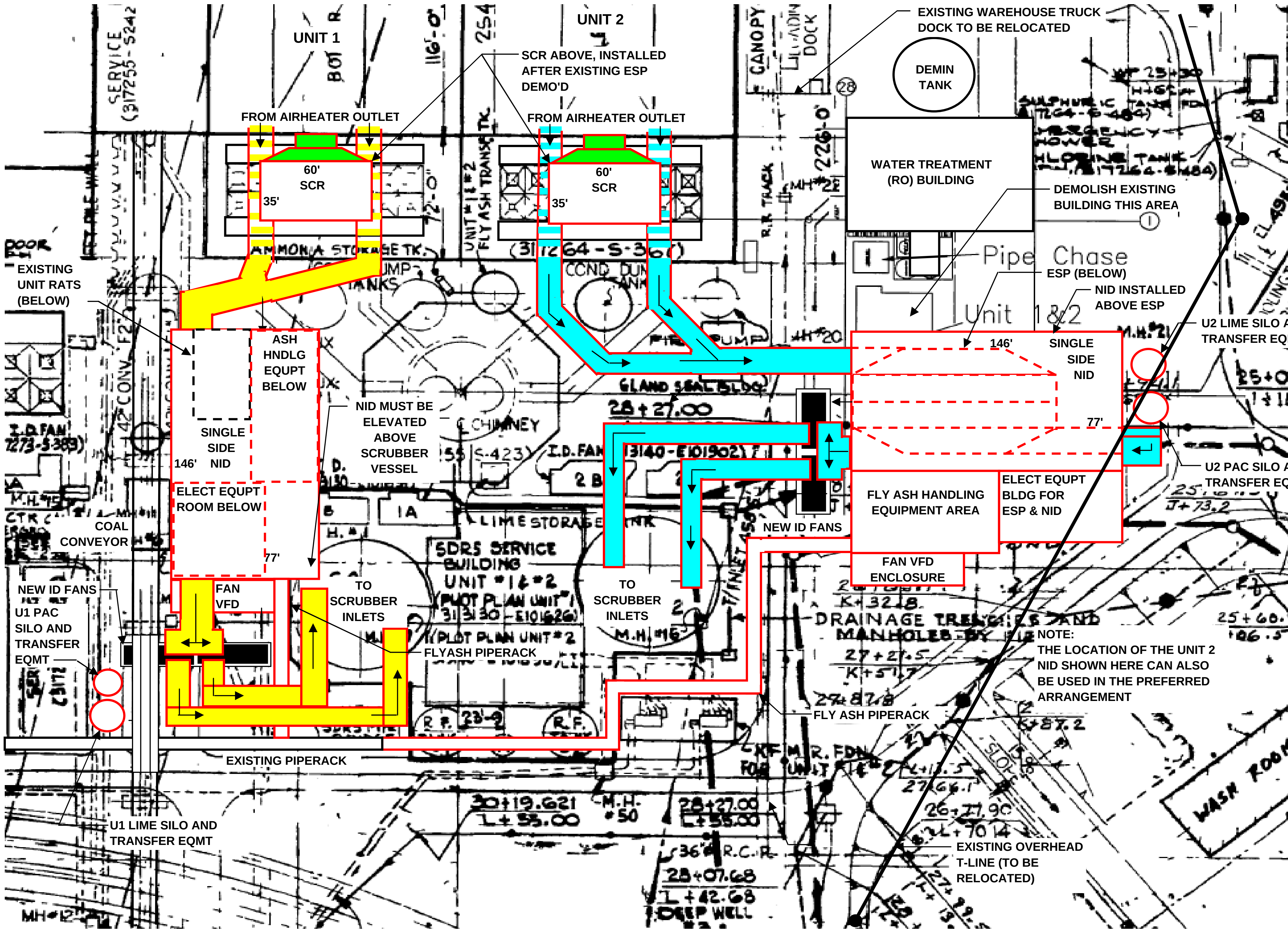
UNIT 1 / UNIT 2 PJFF ARRANGEMENT C CONCEPTUAL SKETCH

NEW PJFF, SCR, ESP, AND ID FANS AT UNITS 1 & 2




UNIT 1 / UNIT 2
PJFF ARRANGEMENT D
CONCEPTUAL SKETCH
USING PJFF, SCR & NEW ID
FANS AT UNITS 1 & 2,
NO NEW ESP AT EITHER
U1 DUCT TO PJFF
11' & 16' SQ ASSUMED
U2 DUCT TO PJFF
11' & 16' SQ ASSUMED
U1 DUCT PJFF TO SCR
11' & 16' SQ ASSUMED
U2 DUCT PJFF TO SCR
11' & 16' SQ ASSUMED
U1/U2 DUCT TO/FROM SCR
10' X 40' (AVG) ASSUMED
APPROX SCALE
0
75
100
150
25
50
N
MILL CREEK 1 & 2
UNIT 1
UNIT 2
EXISTING WAREHOUSE TRUCK
DOCK TO BE RELOCATED
DEMIN
TANK
SCR ABOVE, INSTALLED AFTER
EXISTING ESP DEMO'D
FROM AIRHEATER OUTLET
FROM AIRHEATER OUTLET
60'
SCR
35'
60'
SCR
35'
WATER TREATMENT
(RO) BUILDING
DEMOLISH EXISTING
BUILDING THIS AREA
EXISTING OVERHEAD
T-LINE (TO BE
RELOCATED IF REQD)
NEW ID FANS
120'
PJFF
77'
COAL
CONVEYOR
UNIT 1
AQCS
ELECT
BLDG
FAN
VFD
ENC
TO
SCRUBBER
INLETS
77'
PJFF
120'
TO
SCRUBBER
INLETS
COMMON U1/U2 PAC
SILO AND TRANSFER
EQUIPMENT
COMMON
U1/U2 FLY ASH
HANDLING
EQUIPMENT AREA
FAN
VFD
ENC
UNIT 2 &
COMMON AQCS
ELECTRICAL
GEAR
COMMON U1/U2
SORBENT SILO AND
TRANSFER EQUIPMENT
FLY ASH PIPERACK
EXISTING PIPERACK
NEW ID FANS
UNIT 1 PJFF LOCATED ON SUPERSTRUCTURE
ERECTED ABOVE SDRS BLDG
SUPERSTRUCTURE
SPANNING OVER
SDRS BLDG
COAL DELIVERY RAIL LOOP
A
B
C
C
B
A

Unit 1 and 2
Novel Innovative Desulfurization System Alternatives
(A, B, and C)



UNIT 1 / UNIT 2
NID ARRANGEMENT A
CONCEPTUAL SKETCH
USING ESP, NID, SCR & NEW ID FANS AT UNIT 2, AND NID & SCR AT UNIT 1, NO NEW ESP

(cyan)	U2 DUCT TO ESP & NID 11' & 16' SQ ASSUMED
(yellow)	U1 DUCT TO NID 11' & 16' SQ ASSUMED
(green)	U1/U2 DUCT TO/FROM SCR 10' X 40' (AVG) ASSUMED

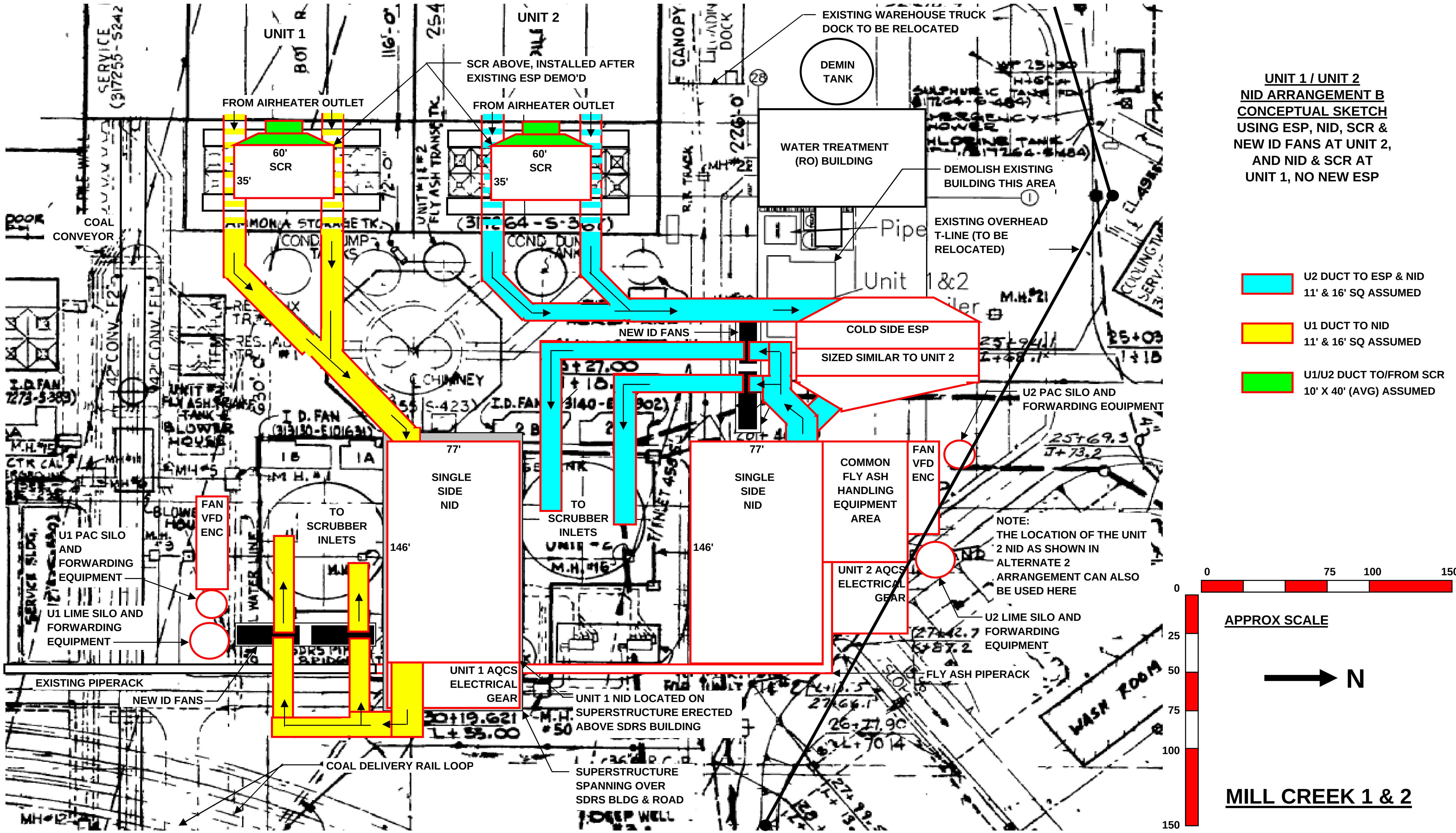
0 75 100 150

0 25 50 75 100 150

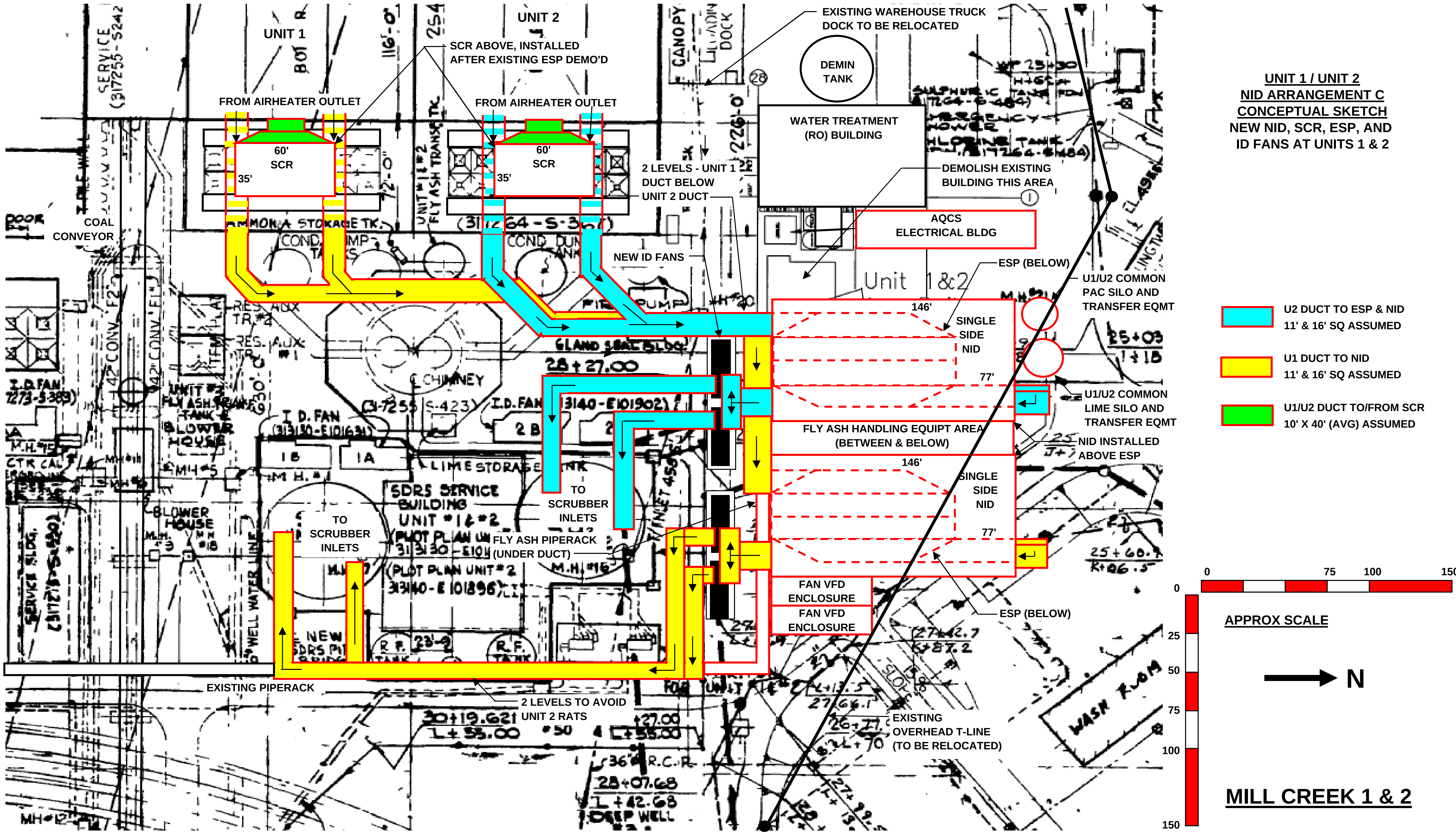
APPROX SCALE

N

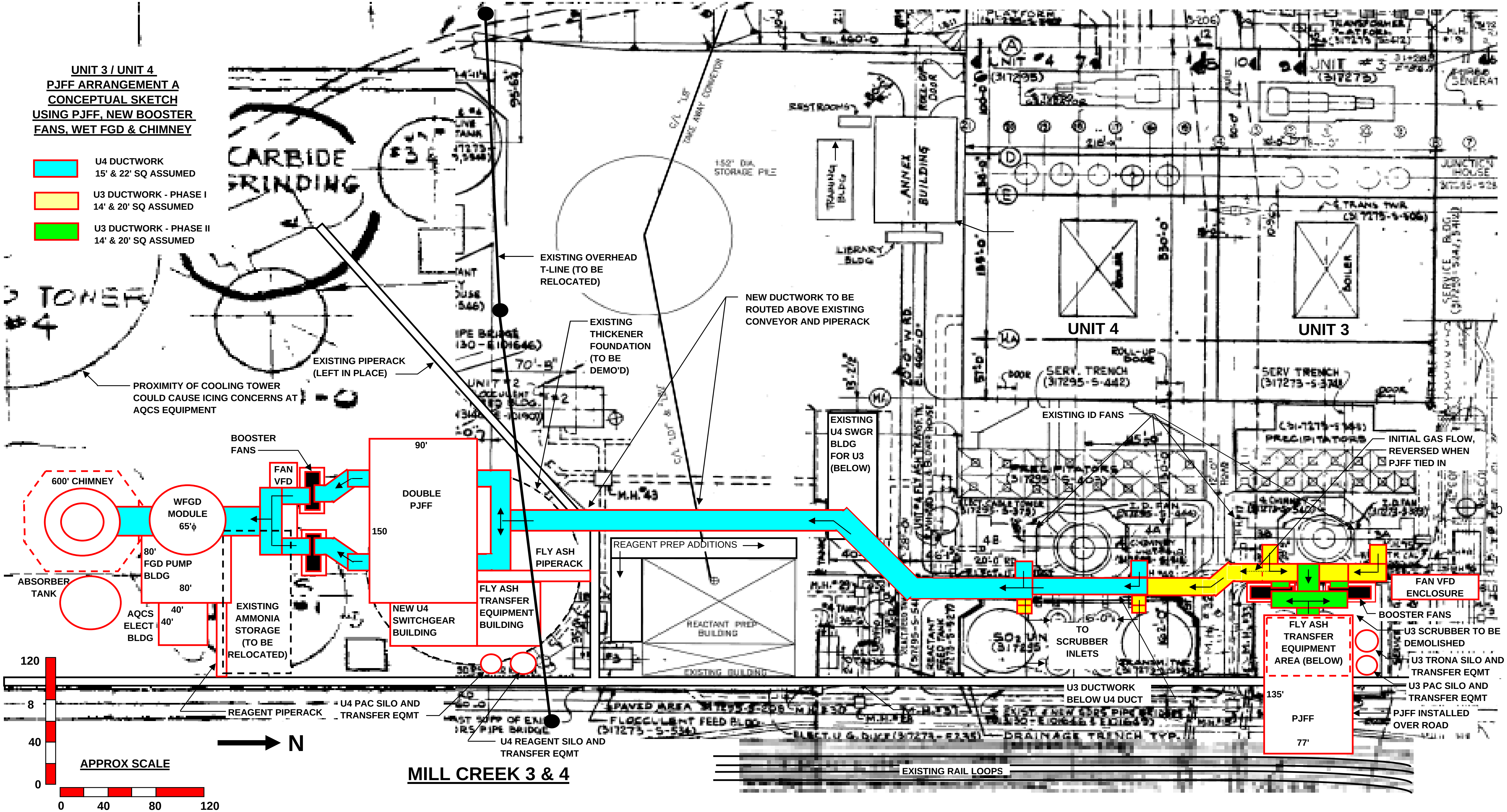
MILL CREEK 1 & 2



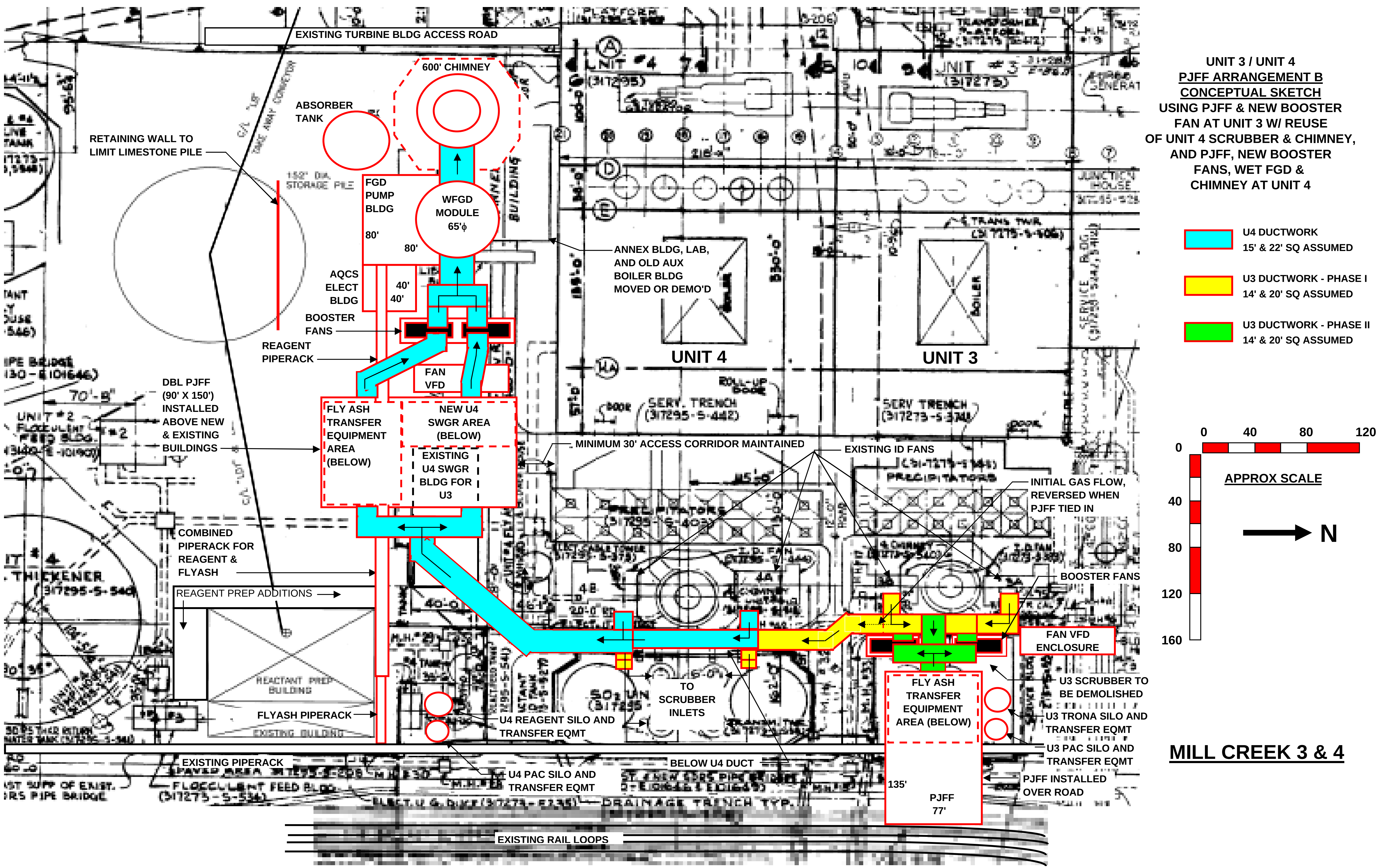
UNIT 1 / UNIT 2
NID ARRANGEMENT B
CONCEPTUAL SKETCH
USING ESP, NID, SCR & NEW ID FANS AT UNIT 2, AND NID & SCR AT UNIT 1, NO NEW ESP
U2 DUCT TO ESP & NID
11' & 16' SQ ASSUMED
U1 DUCT TO NID
11' & 16' SQ ASSUMED
U1/U2 DUCT TO/FROM SCR
10' X 40' (AVG) ASSUMED
UNIT 1
UNIT 2
SCR ABOVE, INSTALLED AFTER EXISTING ESP DEMO'D
FROM AIRHEATER OUTLET
FROM AIRHEATER OUTLET
60'
SCR
35'
60'
SCR
35'
EXISTING WAREHOUSE TRUCK DOCK TO BE RELOCATED
DEMIN TANK
WATER TREATMENT (RO) BUILDING
DEMOLISH EXISTING BUILDING THIS AREA
EXISTING OVERHEAD T-LINE (TO BE RELOCATED)
COAL CONVEYOR
NEW ID FANS
COLD SIDE ESP
SIZED SIMILAR TO UNIT 2
U2 PAC SILO AND FORWARDING EQUIPMENT
77'
SINGLE SIDE NID
146'
77'
SINGLE SIDE NID
146'
COMMON FLY ASH HANDLING EQUIPMENT AREA
FAN VFD ENC
FAN VFD ENC
TO SCRUBBER INLETS
TO SCRUBBER INLETS
U1 PAC SILO AND FORWARDING EQUIPMENT
U1 LIME SILO AND FORWARDING EQUIPMENT
UNIT 2 AQCS ELECTRICAL GEAR
NOTE:
THE LOCATION OF THE UNIT 2 NID AS SHOWN IN ALTERNATE 2 ARRANGEMENT CAN ALSO BE USED HERE
U2 LIME SILO AND FORWARDING EQUIPMENT
FLY ASH PIPERACK
EXISTING PIPERACK
NEW ID FANS
UNIT 1 AQCS ELECTRICAL GEAR
UNIT 1 NID LOCATED ON SUPERSTRUCTURE ERECTED ABOVE SDRS BUILDING
SUPERSTRUCTURE SPANNING OVER SDRS BLDG & ROAD
COAL DELIVERY RAIL LOOP
0
75
100
150
0
25
50
75
100
150
APPROX SCALE
N
MILL CREEK 1 & 2


UNIT 1 / UNIT 2
NID ARRANGEMENT C
CONCEPTUAL SKETCH
NEW NID, SCR, ESP, AND
ID FANS AT UNITS 1 & 2
UNIT 1
UNIT 2
SCR ABOVE, INSTALLED
AFTER EXISTING ESP DEMO'D
FROM AIRHEATER OUTLET
FROM AIRHEATER OUTLET
60'
SCR
35'
60'
SCR
35'
EXISTING WAREHOUSE TRUCK
DOCK TO BE RELOCATED
DEMIN
TANK
WATER TREATMENT
(RO) BUILDING
2 LEVELS - UNIT 1
DUCT BELOW
UNIT 2 DUCT
DEMOLISH EXISTING
BUILDING THIS AREA
AQCS
ELECTRICAL BLDG
COAL
CONVEYOR
NEW ID FANS
ESP (BELOW)
U1/U2 COMMON
PAC SILO AND
TRANSFER EQMT
146'
SINGLE
SIDE
NID
77'
U1/U2 COMMON
LIME SILO AND
TRANSFER EQMT
FLY ASH HANDLING EQUIPT AREA
(BETWEEN & BELOW)
NID INSTALLED
ABOVE ESP
146'
SINGLE
SIDE
NID
77'
TO
SCRUBBER
INLETS
TO
SCRUBBER
INLETS
FLY ASH PIPERACK
(UNDER DUCT)
FAN VFD
ENCLOSURE
FAN VFD
ENCLOSURE
ESP (BELOW)
EXISTING PIPERACK
2 LEVELS TO AVOID
UNIT 2 RATS
EXISTING
OVERHEAD T-LINE
(TO BE RELOCATED)
U2 DUCT TO ESP & NID
11' & 16' SQ ASSUMED
U1 DUCT TO NID
11' & 16' SQ ASSUMED
U1/U2 DUCT TO/FROM SCR
10' X 40' (AVG) ASSUMED
0
75
100
150
0
25
50
75
100
150
APPROX SCALE
N
MILL CREEK 1 & 2

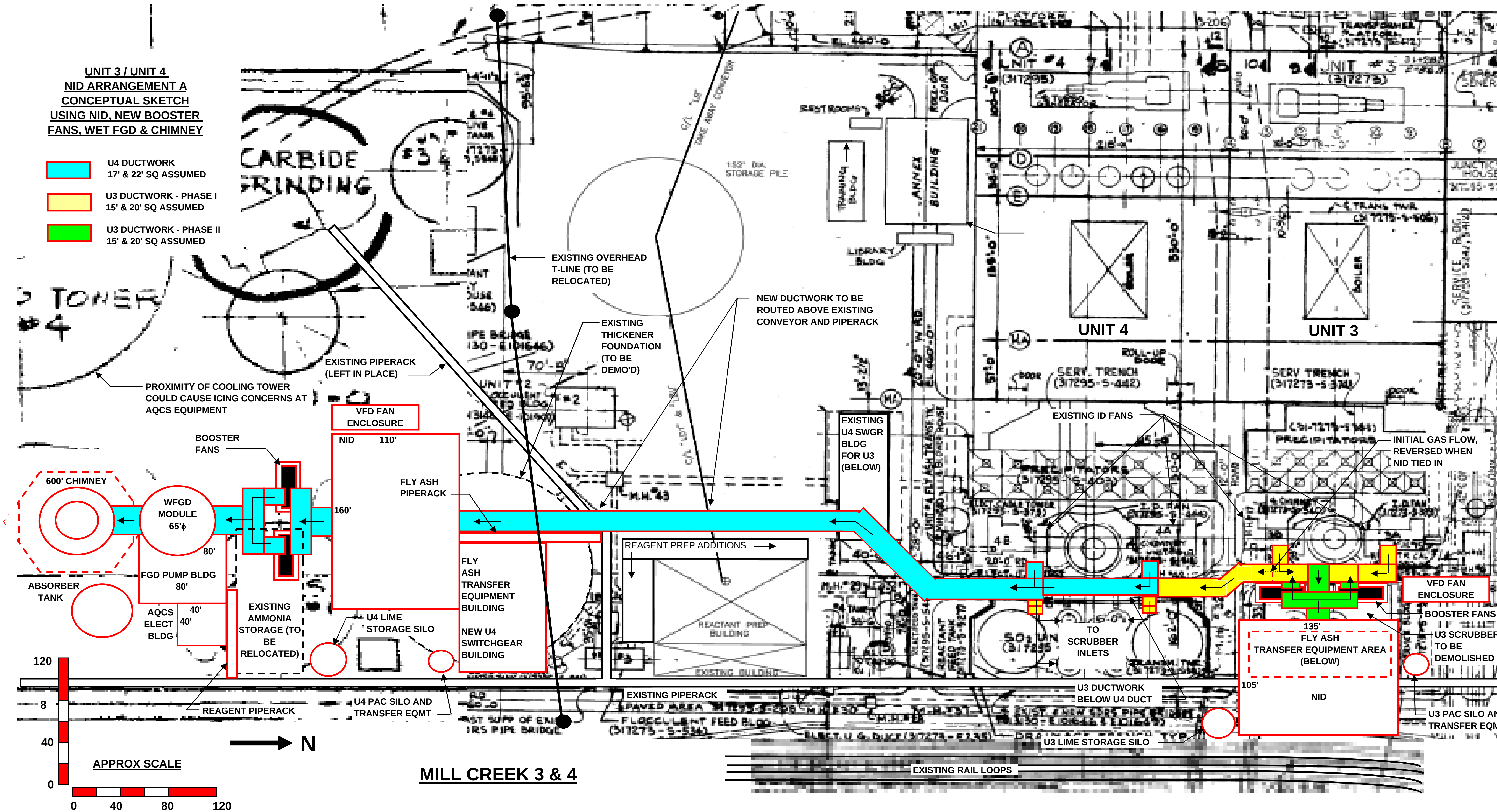
Unit 3 and 4
Pulse Jet Fabric Filter Alternatives (A and B)



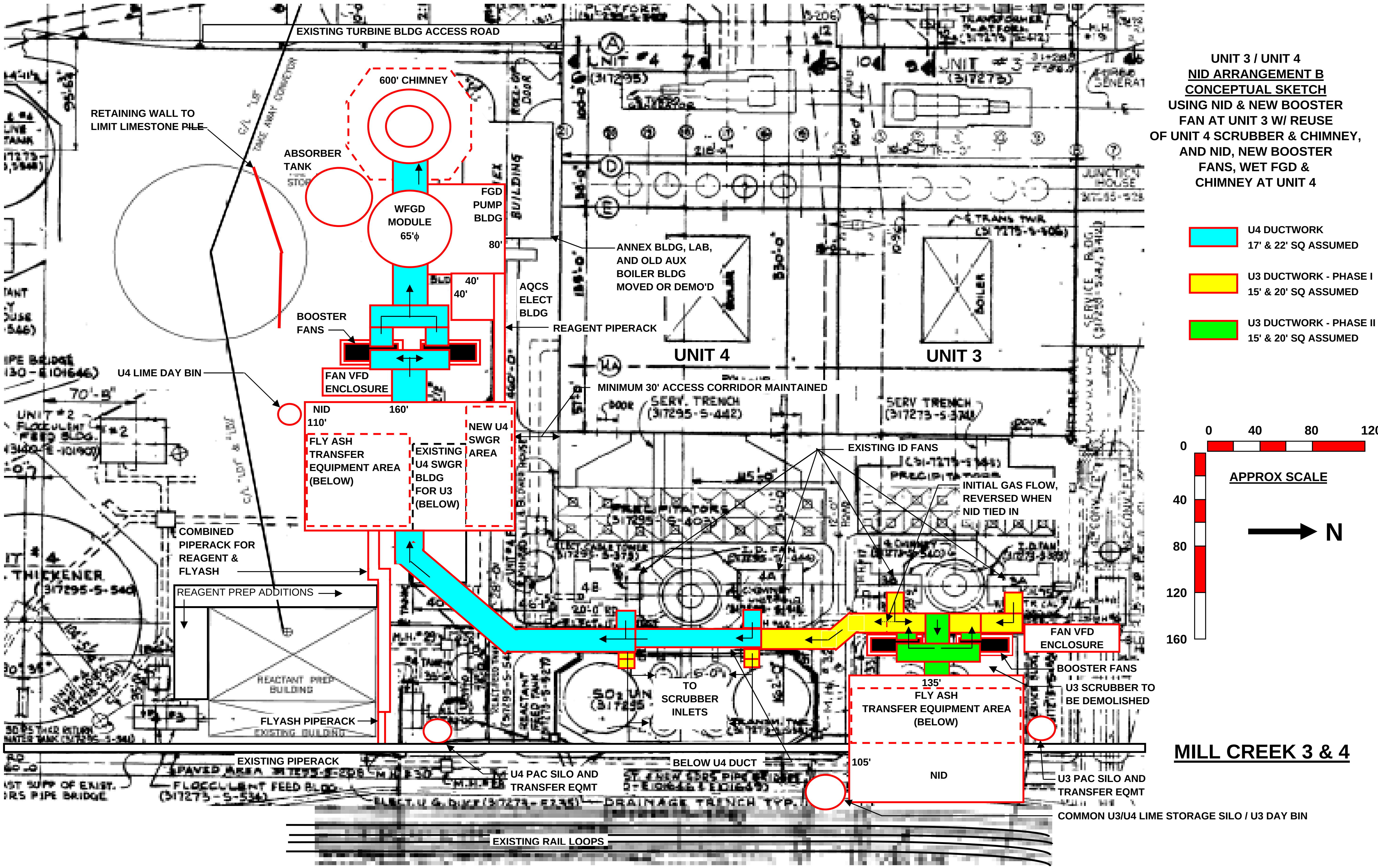
UNIT 3 / UNIT 4
PJFF ARRANGEMENT A
CONCEPTUAL SKETCH
USING PJFF, NEW BOOSTER
FANS, WET FGD & CHIMNEY
U4 DUCTWORK
15' & 22' SQ ASSUMED
U3 DUCTWORK - PHASE I
14' & 20' SQ ASSUMED
U3 DUCTWORK - PHASE II
14' & 20' SQ ASSUMED
CARBIDE
GRINDING
EXISTING OVERHEAD
T-LINE (TO BE
RELOCATED)
NEW DUCTWORK TO BE
ROUTED ABOVE EXISTING
CONVEYOR AND PIPERACK
EXISTING
THICKENER
FOUNDATION
(TO BE
DEMO'D)
EXISTING PIPERACK
(LEFT IN PLACE)
PROXIMITY OF COOLING TOWER
COULD CAUSE ICING CONCERNS AT
AQCS EQUIPMENT
UNIT 4
UNIT 3
EXISTING
U4 SWGR
BLDG
FOR U3
(BELOW)
EXISTING ID FANS
INITIAL GAS FLOW,
REVERSED WHEN
PJFF TIED IN
BOOSTER
FANS
FAN
VFD
90'
DOUBLE
PJFF
150
600' CHIMNEY
WFGD
MODULE
65'ϕ
80'
FGD PUMP
BLDG
80'
ABSORBER
TANK
AQCS
ELECT
BLDG
40'
40'
EXISTING
AMMONIA
STORAGE
(TO BE
RELOCATED)
NEW U4
SWITCHGEAR
BUILDING
FLY ASH
PIPERACK
FLY ASH
TRANSFER
EQUIPMENT
BUILDING
REAGENT PREP ADDITIONS
TO
SCRUBBER
INLETS
FAN VFD
ENCLOSURE
BOOSTER FANS
FLY ASH
TRANSFER
EQUIPMENT
AREA (BELOW)
U3 SCRUBBER TO BE
DEMOLISHED
U3 TRONA SILO AND
TRANSFER EQMT
U3 PAC SILO AND
TRANSFER EQMT
PJFF INSTALLED
OVER ROAD
135'
PJFF
77'
U3 DUCTWORK
BELOW U4 DUCT
REAGENT PIPERACK
U4 PAC SILO AND
TRANSFER EQMT
U4 REAGENT SILO AND
TRANSFER EQMT
EXISTING RAIL LOOPS
120
8
40
0
APPROX SCALE
0
40
80
120
N
MILL CREEK 3 & 4


EXISTING TURBINE BLDG ACCESS ROAD
600' CHIMNEY
ABSORBER TANK
RETAINING WALL TO LIMIT LIMESTONE PILE
FGD PUMP BLDG
80'
80'
WFGD MODULE 65'ϕ
AQCS ELECT BLDG
40'
40'
BOOSTER FANS
REAGENT PIPERACK
FAN VFD
DBL PJFF (90' X 150') INSTALLED ABOVE NEW & EXISTING BUILDINGS
FLY ASH TRANSFER EQUIPMENT AREA (BELOW)
NEW U4 SWGR AREA (BELOW)
EXISTING U4 SWGR BLDG FOR U3
COMBINED PIPERACK FOR REAGENT & FLYASH
REAGENT PREP ADDITIONS
FLYASH PIPERACK
ANNEX BLDG, LAB, AND OLD AUX BOILER BLDG MOVED OR DEMO'D
UNIT 4
UNIT 3
MINIMUM 30' ACCESS CORRIDOR MAINTAINED
EXISTING ID FANS
INITIAL GAS FLOW, REVERSED WHEN PJFF TIED IN
BOOSTER FANS
FAN VFD ENCLOSURE
TO SCRUBBER INLETS
U4 REAGENT SILO AND TRANSFER EQMT
U4 PAC SILO AND TRANSFER EQMT
EXISTING PIPERACK
BELOW U4 DUCT
FLY ASH TRANSFER EQUIPMENT AREA (BELOW)
135'
PJFF 77'
U3 SCRUBBER TO BE DEMOLISHED
U3 TRONA SILO AND TRANSFER EQMT
U3 PAC SILO AND TRANSFER EQMT
PJFF INSTALLED OVER ROAD
EXISTING RAIL LOOPS
UNIT 3 / UNIT 4
PJFF ARRANGEMENT B
CONCEPTUAL SKETCH
USING PJFF & NEW BOOSTER FAN AT UNIT 3 W/ REUSE OF UNIT 4 SCRUBBER & CHIMNEY, AND PJFF, NEW BOOSTER FANS, WET FGD & CHIMNEY AT UNIT 4
U4 DUCTWORK 15' & 22' SQ ASSUMED
U3 DUCTWORK - PHASE I 14' & 20' SQ ASSUMED
U3 DUCTWORK - PHASE II 14' & 20' SQ ASSUMED
0
40
80
120
0
40
80
120
160
APPROX SCALE
N
MILL CREEK 3 & 4

Unit 3 and 4
Novel Innovative Desulfurization System Alternatives (A and B)



UNIT 3 / UNIT 4
NID ARRANGEMENT A
CONCEPTUAL SKETCH
USING NID, NEW BOOSTER
FANS, WET FGD & CHIMNEY
U4 DUCTWORK
17' & 22' SQ ASSUMED
U3 DUCTWORK - PHASE I
15' & 20' SQ ASSUMED
U3 DUCTWORK - PHASE II
15' & 20' SQ ASSUMED
EXISTING OVERHEAD T-LINE (TO BE RELOCATED)
NEW DUCTWORK TO BE ROUTED ABOVE EXISTING CONVEYOR AND PIPERACK
EXISTING THICKENER FOUNDATION (TO BE DEMO'D)
EXISTING PIPERACK (LEFT IN PLACE)
PROXIMITY OF COOLING TOWER COULD CAUSE ICING CONCERNS AT AQCS EQUIPMENT
VFD FAN ENCLOSURE
BOOSTER FANS
NID
110'
600' CHIMNEY
WFGD MODULE
65'ϕ
160'
FLY ASH PIPERACK
80'
FGD PUMP BLDG
80'
ABSORBER TANK
AQCS ELECT BLDG
40'
40'
EXISTING AMMONIA STORAGE (TO BE RELOCATED)
U4 LIME STORAGE SILO
FLY ASH TRANSFER EQUIPMENT BUILDING
NEW U4 SWITCHGEAR BUILDING
REAGENT PREP ADDITIONS
EXISTING U4 SWGR BLDG FOR U3 (BELOW)
EXISTING ID FANS
INITIAL GAS FLOW, REVERSED WHEN NID TIED IN
UNIT 4
UNIT 3
VFD FAN ENCLOSURE
BOOSTER FANS
U3 SCRUBBER TO BE DEMOLISHED
135'
FLY ASH TRANSFER EQUIPMENT AREA (BELOW)
105'
NID
TO SCRUBBER INLETS
U3 PAC SILO AND TRANSFER EQMT
EXISTING PIPERACK
U3 DUCTWORK BELOW U4 DUCT
U3 LIME STORAGE SILO
EXISTING RAIL LOOPS
REAGENT PIPERACK
U4 PAC SILO AND TRANSFER EQMT
120
80
40
0
N
APPROX SCALE
0
40
80
120
MILL CREEK 3 & 4



UNIT 3 / UNIT 4
NID ARRANGEMENT B
CONCEPTUAL SKETCH
USING NID & NEW BOOSTER FAN AT UNIT 3 W/ REUSE OF UNIT 4 SCRUBBER & CHIMNEY, AND NID, NEW BOOSTER FANS, WET FGD & CHIMNEY AT UNIT 4

U4 DUCTWORK
17' & 22' SQ ASSUMED

U3 DUCTWORK - PHASE I
15' & 20' SQ ASSUMED

U3 DUCTWORK - PHASE II
15' & 20' SQ ASSUMED

MILL CREEK 3 & 4