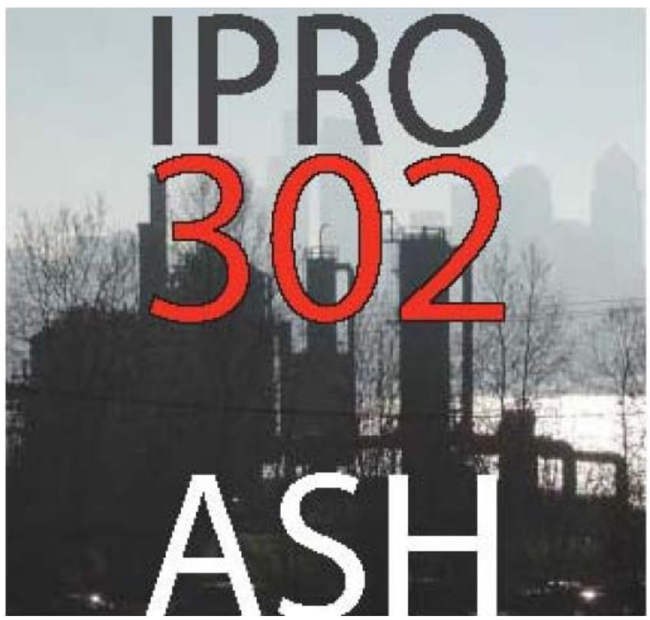
IPRO 302 - Final Report
Spring 2011

COAL COMBUSTION RESIDUALS (CCR) SOLUTIONS



"Improving the earth, one ash pond at a time."

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Sponsored by: Sargent & Lundy

I. Executive Summary

The goal of this IPRO project, sponsored by Sargent & Lundy, was to evaluate the impacts of eliminating an ash storage pond from a coal power plant. The use of coal to produce power is the most widely practiced form of energy production throughout the world. Bottom ash is created through the burning of coal, and it has to be cooled before it can be handled. With this being the case, many power plants use ash ponds to cool and store bottom ash. A number of recent events have led power companies across the nation to seek alternative bottom ash handling solutions. The EPA is currently considering the elimination of all ash ponds, as well as looking into whether or not they will deem bottom ash to be a hazardous waste material.

This IPRO project researched and analyzed the environmental, and cost impacts of closing an ash pond at an active power plant. After receiving assumptions from our sponsor, Sargent & Lundy, our team researched and analyzed the current status of regulations for coal combustion residuals, and wastewater. We also investigated the current, and alternative handling solutions for bottom ash, and made recommendations for the best alternatives for coal combustion residual disposal, reuse, and wastewater treatment and disposal. Finally, we analyzed the cost and environmental implications of closing an unlined ash pond at an active power plant.

II. Purpose and Objectives/Background

Bottom ash is produced in a dry bottom coal boiler, which is usually found in electric power plants that burn coal. The coal is ignited and the incombustible portion of this material, not collected in the flue as fly ash, is known as dry bottom ash. This dry bottom ash is heavier than fly ash, which is why it falls to the bottom. The ash then drops down to a water-filled hopper at the bottom of the boiler. The bottom ash/water mixture is then stored in an ash pond. A major concern with ash ponds is that contaminants from the bottom ash can leach into groundwater, and then into drinking water.

A steam power plant is used to convert the potential chemical energy of fuel into electrical energy. This process uses a boiler and a turbine that drives an electric generator. The boiler device is used for turning water into steam. There is a steam jet that issues from the spout, this in turn spins the highly engineered blades of the turbine and the generator. The generator consists of a bar magnet that spins inside a stationary coil or wire. The magnet directs the electricity to use and storage.

There is a belt conveyor that transports coal to a furnace, where it is burned on a traveling grate stoker. A bellow supplies air for combinations. A chimney, or stack, is used to remove the combustion gas, and a heater is used to heat the air from the bellows before it is blown into the furnace. During the process, it is imperative to maintain a consistent balance of heat for the coal; too hot, or too cool of an environment can be detrimental to the efficiency of the burning coal.

The technology involved is continually being adjusted to make the process ever more efficient. For example, two steel drums were added that connect to a number of steel tubes. These are arranged in the furnace so that the hot gases have to pass through the bank of tubes on their way out. A boiler feed pump is used to replenish the water from the steam that has been evaporated, and a feed water heater is used to heat the water before pumping it into the boiler.

On Monday December 22, 2008, the TVA Kingston Ash Spill occurred. This environmental disaster helped highlight the major issues with ash ponds. Coal fly and bottom ash slurry spread out when an ash dike burst in the Kingston Fossil Plant in Roane County, Tennessee. The TVA and EPA estimated that the spill spread out over 1.7 million cubic yards. They first projected that the spill would be cleaned up in six weeks. Later, however, the staff attorney for Southern Environmental Law Center, Chandra Taylor, said it would take months, possibly even years to clean the spill.

There are many ethical issues associated with ash ponds that we had to discuss and consider when starting this project. One of the main issues is that the storage of bottom ash can negatively affect the environment in the areas surrounding the power plant; this includes the use of valuable land for storage of the waste, and the difficulty of converting land back to usable property.(1) Other concerns also include the potential contamination of water sources, which could damage drinking water(1), and kill off aquatic life; which would destroy the fishing industry(2). Direct damage to land caused by ash spills, like that with the TVA disaster, could also lead to the destruction of vegetation and wildlife(1), and cause leakage into the groundwater; creating a wider affected area(1), arsenic-laced water(1), and increase other potentially hazardous metals in the environment(2), including Nickel, Selenium, Lead, Mercury, Copper, Zinc, Arsenic, Boron, and Manganese.

As of March 31, 2010, there were 101 sites deemed contaminated by deadly pollutants.(2) This leads to another issue that has to be taken into account, which is the safe handling issues related to being in contact with the byproduct; due to trace amounts of chemicals that can be found.(1) Hazardous residuals can cause loss of human life, due to contaminated water, genetic defects, or medical issues that arise due to toxins in the water; including but not limited to:(2) cancer, birth defects, memory loss, learning difficulties, loss of coordination, permanent damage to the central nervous system, etc. There is potential for widespread damage due to limited detection equipment in many locations.(1) Dangers arise from toxins and may be worse now than ever before, due to the increased regulation on particulate matter dealt with in the form of smoke or other types of air waste.(1)

The purpose of the IPRO 302 project, sponsored by Sargent & Lundy, is to evaluate the environmental and cost impacts of closing an ash pond at an active power plant; as well as to consider alternative beneficial uses for coal combustion residuals (CCR) and wastewater.

The objectives for this IPRO were to: investigate the current status of regulations for CCR and wastewater, find alternatives for disposing of ash, give a recommended alternative for disposal or reuse of the bottom ash, recommend alternative options for treatment and disposal of wastewater, and to find the cost impact of closing an existing unlined ash pond.

Sargent & Lundy is the sponsor for this IPRO project. They have "provided comprehensive consulting, engineering, design, and analysis for electric power generation and power delivery projects worldwide." Their organization is headquartered in Chicago's Loop. They have had past experience with sponsoring IPROs at IIT. They have provided the team with the essential background information, an open-ended problem, and they have provided guidance throughout the semester and will continue to provide guidance beyond, through their professional reviews of our reports and presentations.(3)

There are many costs associated with the process to change/eliminate ash ponds. Research costs money, often without immediate benefit. There are many occasions when businesses are reluctant to risk investing in research because of the potential money loss. Another business related cost is abiding by the ever changing governmental regulations surrounding the conveyance of CCRs. This may become time consuming and difficult to achieve. The existence of bottom ash storage ponds can also have societal and community costs. Since conveying CCRs from a coal power, to plant, to a storage area can negatively affect the water quality of the surrounding areas, the surrounding communities can be negatively affected.

III. Organization and Approach

To achieve the wide range of goals that our team identified, we first recognized the need to divide the group into four sub-teams. Each team was responsible for different areas of the project, which are complimentary to the main goal of this IPRO. Team members were placed in respective sub-teams in accordance with their strengths and interests.

The overall team co-leaders were Andrew Gardner, Joseph Sanchez, and Nicole Firnbach. These individuals set up an agenda for each class meeting and directed activities according to the developed plan. Sub-team leaders were chosen to improve communication and cohesiveness between the groups, the team leaders, and our two advisers.

The Regulations team did research on current and pending EPA regulations on coal combustion residuals (CCR). This team's tasks included research on pending provisions to CCR regulations, identifying the differences between the different types of hazardous materials classifications proposed for CCRs, research on the EPA's approved applications for reusable CCRs, and regulations concerning wastewater management and decontamination. The Regulations team also did research on patents for systems that were in the process, or being thought of, that would be used in place of an ash pond. The Regulations team also went on to help the other teams in their calculations and research during the last five weeks of the semester. The Regulations team members were Shana Burnett, who was the sub-team leader, Jennifer Agosto, and Chad Parker.

The Current Solutions CCR Management team was responsible for researching and identifying the various bottom ash handling systems that are currently in use. This team's tasks included identifying current bottom ash handling systems in use globally, researching the current methods for CCR reuse, identifying the benefits and costs of these systems, and giving an analysis of current ash pond use in the U.S. The Current Solutions CCR Management Team members were Graeme Port, who was the sub-team leader, Nicole Firnbach, and Andrew Gardner.

The CCR Management Alternatives team conducted an analysis of the various possible alternatives to bottom ash handling. This team's tasks include identifying proposed and implemented alternatives to bottom ash handling, giving an analysis of the viability of each alternative, with respect to our given assumptions, and giving an analysis of the relevant costs and benefits for each alternative. The CCR Management Alternatives team members were Joseph Sanchez, who was the sub-team leader, and Susan Rafalko.

The Wastewater Solutions team was responsible for researching methods for decontamination and removal of ash-pond water. Their duties included identifying current methods for wastewater removal and decontamination, researching potential methods for ash-pond wastewater removal that are currently implemented in other industries, and giving an analysis of the relevant costs associated with ash-pond closure, including wastewater removal and decontamination. The Wastewater Solutions team members were Sheena Enriquez, who was the sub-team leader, Daniel Kipp, and Robert Herman.

Each respective team did their research utilizing, the Internet, Galvin Library, scholarly articles, etc. The information that was gathered was shared within the groups, and then with the entire team as a whole in brief sessions at the beginning of class meetings. A Gantt chart was used to monitor the progress that was made by the team, and to keep track of where the group was going by pointing out when certain tasks were to be completed. Once all the groups had finished their research and analysis, and the group came to a consensus on a final recommendation, the remaining tasks were evenly divided amongst the group to finish the final project deliverables. This also included giving a presentation to the sponsor, Sargent & Lundy, at their downtown offices a week before IPRO day, on our final findings and recommendations.

There were also other roles in the group that existed to help the group as a whole in running the class sessions. Sheena was the minute taker, and was thus responsible for recording decisions made during meetings, including task assignments or any changes that were under consideration. Nicole was the agenda maker, and was responsible for creating an agenda for each class meeting, which provided structure to the meetings and offered a productive environment for the team to work. Dan was the time keeper, and was therefore responsible for keeping the group on track and focused during meetings, providing the team with adequate information or thoughts to foster effective brainstorming. Susan was the iGroups Moderator, and was responsible for organizing the team’s iGroups account, keeping it updated regularly, and contacting iGroups administrators to make the best use of this website.

IV. Analysis and Findings

At the beginning of the project, the four sub- teams were divided and did research on their respective topic using the tools that were available to them. It was important to attain the information and discuss the findings during class meetings, in order for everyone to know what was going on as a whole throughout the project. The team had to take into account the assumptions about the power plant that were given by the sponsor when we did the research and when we analyzed costs, etc. The assumptions were that it was an average coal power plant that was located in Illinois with the following specifications:

- 500 Mega Watts (MW) Power plant
- 200 tons/hr coal consumption
- 15 tons/hr bottom ash production
- 30 acre X 10’ deep ash pond
- 2000 gallons per minute (gpm) ash sluice water

It was important to find out the regulations that were being decided on by the EPA from the beginning, because it dictated which direction the team took in terms of choosing the appropriate alternatives and recommendations, etc. The research that was done showed that the EPA had proposed two new regulations regarding the handling of coal ash. The reason why the EPA decided on two options was to make sure they looked into several new ideas to receive intellectual and structural feedback, based on the best available data and the fullest extent of public input so that they can choose the best and most effective regulations. The two new proposals are classified under Subtitle C and Subtitle D. There are seven important differences between the two, the most important being the categorization of the waste. In Subtitle C, the waste would be categorized as hazardous and would have had adverse impact on recycling the ash, where as in Subtitle D, the waste would not be categorized as hazardous but the amount of new regulations then imposed would cause for a more expensive means of handling. Other important differences include the federally enforceable standards, the coal ash pond closures, national minimum standards, how to address contamination from old dumps, operating permits, and cradle to grave management. There are many more aspects to each subtitle, both having their disadvantages and advantages. The EPA has yet to decide what subtitle will be chosen, or when the decision must be made. As of September 21, 2010, the EPA had stated that they do not know exactly when a decision will be made, but they will be sure that when it is, they will have considered all the information so that the best decision is made.

It was also important for the team to explore what current bottom ash removal systems were currently in use; this included both wet and dry ash removal systems. We found data on a number of current systems, from a number of different power companies. These included, Delta Ducons (owned by Clyde Bergemann Power Group) - Aschon Wet System, United Conveyor Solutions two hydraulic systems - (1) Recirculation Wet System, and (2) Sluice System, and their mechanical system - Submerged Flight Conveyor, and Allen-Sherman-Hoff's Submerged Scraper Conveyor system (which is extremely similar to United Conveyor's Submerged Flight Conveyor System). In the end - due to the wide spread current use, the available information, and the fact that it requires an ash pond - we decided to recommend the Submerged Flight Conveyor system as the operational model for our starting, standard, power plant; that we would use to compare against our proposed dry ash handling system.

Our team also looked into how a power plant can't best get rid of their contaminated pond water. Ash pond water contains high concentrations of toxic metals. The need for wastewater disposal, and the risk of seepage, raises the fear of possible drinking water contamination. The team first looked into the Metfloc system, which is a heavy metal chemical removal system. However, we found that the chemical removal systems are not cost effective. Systems, like Metfloc, are systems that are permanently installed on-site. Once the pond is removed, the company would then be stuck with a system that they would no longer have any use for. We also considered extraction wells, but those pose the risk of long term seepage. In the end, we decided that the best option is to outsource this task to wastewater specialists. The price to have a company come in to remove the wastewater would be cheaper than installing a chemical system, and it also removes the problem of having useless equipment left over.

The team did a lot of research on the alternative bottom ash removal systems that were generally fairly new. It was recognized almost immediately that most of the alternative solutions were dry ash removal systems- none of them required the use of an ash pond or the use of water for that matter. A lot of different data from the companies themselves, third party studies, and other sources were found on the systems. The systems that were looked at in particular were the DRYCON system by the Clyde Bergemann Power Group, the Vibratory Ash Extractor system (VAX) by United Conveyor, and the Magaldi Ash Cooler system by Magaldi. Each system was unique and they were fairly new with only being in use by a select handful of power plants (primarily overseas), except for the Magaldi system which was in use for over ten years. The DRYCON system was the final choice chosen by the group due to the extensive data and information as well as third party study cases that were available. It was also the newest of the three systems and hence provided the newest technology that traditional “old” ash removal system using ash ponds and water.

In the process of our research we tried contacting many companies and power plants to get information, data or price quotes using our power plant’s specifications both through telephone calls or emails. Unfortunately, we did not get the information we were hoping to get. Most of our emails went unanswered and many of our phone calls that were answered were not useful as most companies would not answer or would avoid the questions. This did not deter our findings, but showed that attaining very specific information from companies was not as easy as we thought it would have been.

V. Conclusions and Recommendations

The team decided to follow a four phase approach to include all aspects and requirements for the final recommendation. The four phases were:

1. Convert to a dry ash handling system
2. Establish a ground water monitoring zone (GMZ)
3. Begin secure wastewater treatment and disposal
4. Cap ash pond using a geo-synthetic membrane cover.

The first phase involved converting the wet system to a dry ash handling system. It was decided that the current system in the power plant used a Submerged Scraper Conveyor System (SSC), which was widely available, used ash pond storage, and required water. This system would be converted to the DRYCON dry ash handling system which compared to the SSC, does not use water, increases the thermal energy by fifty percent, has more profitable ash quality, due to no ash saturation, and would meet future EPA regulations.

	DRYCON ($)	SSC ($)
Equipment Costs	1,400,000	850,000
Water Treatment	0	103,000
Crushing Equip.	42,700	42,700

Equipment Transportation	171,000	214,000
Total Investment	1,613,700	1,209,700

Figure 1. Investment Cost Comparison. Source: Clyde Bergman Materials Handling Ltd.

Figure 1 shows a comparison of the investment costs between the Drycon system and the Submerged Scraper Conveyor System (SSC). By looking at this, the SSC system is a cheaper by $404,000 in terms of an investment compared to the DRYCON system. However, when you look at Figure 2, you can see the annual operating costs between the two systems. The DRYCON system in this case is cheaper to operate by $75,800 in comparison to the SSC system. In only five years, the savings from operating costs would cover the investment difference for the DRYCON system. It should also be noted that the data costs are based on 800 MW boiler size.

	DRYCON ($)	SSC ($)
Energy Consumption($0.14/kWh)	38,000	68,500
Cooling Water ($0.03/m^3)	0	5,000
Ash Handling and Disposal	7,400	9,700
Service and Maintenance	24,000	62,000
Total Operating Costs	69,400	145,200

Figure 2. Annual Operating Cost Comparison. Source: Clyde Bergman Materials Handling Ltd.

Another perspective that has to be taken into account is the resale of the bottom ash. Bottom ash, when dry, can be resold and used in concrete, land-fill, and asphalt. With an SSC system, the bottom ash has to be dewatered before it can be resold. Whereas the DRYCON system decreases the saturation which then allows for it to be resold at a higher value. By reusing and reselling bottom ash, it redirects it from being just waste disposal in landfills and ash ponds, which decreases the impacts on human health and the environment. From a company's perspective it saves them money on bottom ash conveyance and disposal costs as well as generating revenue from selling the bottom ash.

The second phase involves establishing a ground water monitoring zone. This particular step is a critical aspect of a pond closure. Ground water monitoring zones would ensure that ash pond closures are within full EPA compliance and they would promote secure treatment and disposal of wastewater. Ground water monitoring zones would be required to manage on-site contamination of an ash pond. There would be monitoring wells would be drilled around the ash pond area, which could be monitored either on-site or off-site. However, before these monitoring zones could be implemented, the EPA would have to approve them.

The third phase would be to outsource ash pond wastewater treatment and disposal. The wastewater has to be treated before it could be disposed safely. All options were looked at including chemical solutions and extractions. Chemical removal systems were not very cost effective and extraction wells posed a risk of long term seepage. So after much research, analysis, and deliberation, it was decided that the best option to treat wastewater before it could be disposed of safely and properly would be to outsource the task to wastewater specialists. Charah was one of the wastewater disposal contractors that we found could do this task effectively. Although they are based in Kentucky they still serve Illinois power plants and are highly experienced with wastewater disposal and complete ash pond closures. The estimated cost for a complete wastewater removal and disposal would cost around $600,000. This proved to be the most cost effective and best option for this task.

The fourth and last step would be to cap the ash pond using a geo-synthetic membrane cover. Through our research, we saw that excavating an ash pond would cost approximately $200 million. This is a very expensive alternative in dealing with the ash pond. It was decided that the best option would be to cover the ash pond. Many options were looked at to cover the pond including compacted clay, layered earth caps and a geo-membrane. The capital costs for a plant with the specifications that we had would range between $7.5 - $13.7 million. The best option that we decided upon was the geo-synthetic membrane cover which is environmentally safe and readily available. Two feet of soil and vegetation would cover the membrane and it would allow for a natural ground flow due to the porous membrane. The estimated capital cost for the geo-synthetic membrane cover would be $11.2 million.

Our final recommendation is to follow the four phase outline which is to convert to dry ash handling system from a Submerged Scraper Conveyor system to a DRYCON system, establish a ground water monitoring zone once the EPA would approve it, outsource the wastewater treatment and disposal to a company like Charah, and to cap the ash pond using a geo-synthetic membrane cover. The overall cost to follow this recommendation is shown in Figure 3. The overall cost for closing an ash pond following our four phase outline, which does not include the operating costs, would be $13,566,000. Although the cost may seem high it is most cost effective option we have come up with, while also being environmentally conscious and ultimately following the EPA regulations.

Closure Activity	Cost ($)
DRYCON Investment	1,613,700
Ground water monitoring zone	151,600
Wastewater Treatment/Disposal	600,000
Geo-synthetic Membrane Cover	11,200,000
TOTAL CAPITAL COSTS	**13,566,000**

Figure 3. Total Cost of Ash Pond Closure Recommendation

Sources: Clyde Bergman Materials Handling Ltd, Ameren UE, Van Cleef Engineering Associates.

Throughout this IPRO, the team as a whole gained a lot knowledge on this particular subject with all the different areas that we researched. This group also learned many lessons that were work oriented that would help in our future careers. We learned and realized the benefits of project planning early in the entire process. We learned the benefits of team management and delegation as it made the work flow and ensure that everyone had their equal share of work as well as the importance of keeping a log of time spent working on a project and the content of said work. As always we learned that communication was highly important especially in a team setting. One of the biggest lessons that this team learned through its own struggles in the beginning was punctuality and respecting others' time.

As for our recommendation for future IPROs would be to do further research and explore patents and advanced technologies for bottom ash handling that offer even better options for companies both financially and environmentally. We also recommend that they do further research on wastewater management solutions in other industries and find the impacts of clean coal technology with the proposed solutions. These areas would provide a more in depth solution to the problem for the customer while also looking at the absolute newest technologies that are available or are in the process of becoming available that would help the companies and the environment.

VI. Acknowledgements & References

We would like to acknowledge Diane Martin and Ajay Jayaprakash of Sargent & Lundy for the time they gave to the project, and for providing our team with the relevant information that started the IPRO. We would also like to acknowledge our advisers, Dr. Myron Gottlieb and Dr. Don Tijunelis, for providing the team with helpful feedback and guidance throughout the semester, as well as for their constant patience.

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Appendix A: Team Information

Team Member	**Strengths**	**Knowledge/Skills to develop**	**Expectations For the Project**
Nicole Firnbach Major: 5th year Architecture Minor: Structural Engineering email: nfirnbac@iit.edu	Creative, motivated, organized, good listener, good moral values, can develop drawings and models to presentation quality.	Develop an understanding of the chemical engineering aspect of the problem, speech skills.	Develop an economic, efficient, and environmental use for bottom ash build up in electrical power plant facilities.
Jennifer Agosto Major: 4th year Business Minor: Architecture email: jen.a.agosto@gmail.com	Hard-working, sociable, dedicated, willingness to learn, respectful and strong moral values.	Develop all of my weaknesses, especially learn more about sustainability in the problem presented,	Develop an efficient way to get rid of, and handle, bottom ash to prevent future environmental disasters.
Shana Burnett Major: 4th year Business Administration email: shanaburnett248@gmail.com	Microsoft Office skills, work well with others, willingness to learn from others, great presentation skills.	I would like to gain a better understanding of the energy production process.	I expect us to come up with ideas, and to implement them, to remove ash ponds from coal power plants.
Sheena Enriquez Major: 5th year Architecture email: senrique@iit.edu	Organized, willingness to learn from others, productive, graphic presentation skills	Better understanding of the energy production process and its byproducts, time management skills.	Utilize group dynamic to come up with an innovative way to use ash from coal power plants.
Robert Herman Major: Electrical Engineering Major: Mathematics email: rherman1@iit.edu	Background in electrical engineering and mathematics, thinking logically, hard worker.	Develop better time management skills, and hopefully learn more about what’s involved with energy production	Find a better solution for the issues with bottom ash. Possibly to find more practical uses for it.

		and waste.	
Daniel Kipp major: 4th year Mathematics Major: Computer Science email: puzzler42@gmail.com	Most branches of math, Computer programming (java, c, lisp, c++, c#, python), problem solving, public speaking, relation to former coal power plant employees, analytical thinking.	Develop chemical engineering background knowledge.	Analyze potential solutions for bottom ash and waste water disposal, and recommend a solution that is as close to optimal as possible.
Chad Parker Major: Business Administration email: cparker7@iit.edu	Public speaking, Microsoft Office skills, work experience with power plants and personal relationships with current employees, creativity.	Help develop computer skills, Learn more about the industry.	Develop a better understanding of the industry, acquire some engineering knowledge while applying my business experience.
Graeme Port Major: 4th year Humanities Minors: Journalism, Political Science, Middle Eastern Studies email: gport@iit.edu	Writing, editing, communicating, work well as part of a team, motivated, organized.	Learn about the chemical engineering aspect of the problem.	Develop an environmental, economic, and efficient solution for bottom ash build up in electrical power plant facilities.
Susan Rafalko Major: 4th year Computer Engineering Email: srafalko@iit.edu	Hard worker, organized, good listener, dedicated, adept in Microsoft Office, work well in groups.	Develop a better understanding of bottom ash disposal. Improve my skills in giving a presentation or a speech.	Develop a plan that shows the impacts of closing an ash pond while also looking for alternative uses for bottom ash.
Joseph Sanchez Major: 4th year Business Administration Email: jsanch1@iit.edu	Very hard worker, strong writing and presentation skills, willingness to lead, full dedication to a project's success.	I would like to further strengthen my problem solving skills within a group. I would also like to gain a better understanding of project management within the energy industry.	Gain a strong understanding of the daily operations of power plants. Develop a report containing an outline of the most viable alternatives to bottom ash disposal, methods for systematically closing a plant's unlined ash pond, and a detailed analysis of the associated costs.
Andrew Gardner Major: 4th year Civil Engineering & Applied	Civil Engineering Major. Confident with math problems and	Develop team skills in regard to research and problem solving.	Develop realistic solutions to issues involving the disposal of

Mathematics (double major) Email: dan.gardner@my.wheaton.edu	engineering issues. Good at following directions, work very well under pressure. Good communicator, confident speaker, committed to conflict resolution.		fly and bottom ash in coal power plants. Provide cost-effective alternatives to current pond storage method.

Appendix B: Team Structure

TEAM CO-LEADERS
- Andrew Gardner
- Joseph Sanchez
- Nicole Firnbach

REGULATIONS SUB-TEAM:
- Shana Burnett (Sub-team leader)
- Chad Parker
- Jennifer Agosto

CURRENT BOTTOM ASH HANDLING SUB-TEAM:
- Graham Port (Sub-team leader)
- Nicole Firnbach
- Dan Gardner

WATER TREATMENT SOLUTIONS SUB-TEAM:
- Sheena Enriquez (Sub-team leader)
- Dan Kipp
- Robert Herman

ALTERNATIVE BOTTOM ASH HANDLING SUB-TEAM
- Joseph Sanchez (Sub-team leader)
- Susan Rafalko

Appendix C: Gantt Chart

CCR Solutions

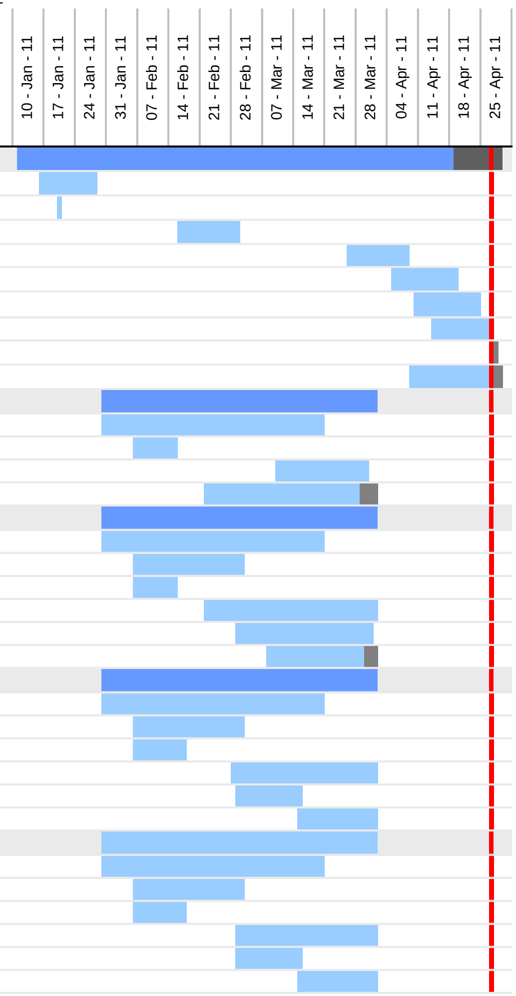
IPRO 302

Today's Date: 4/27/2011 Wednesday
(vertical red line)

Project Lead: Nicole Firnbach
Start Date: 1/11/2011 Tuesday

First Day of Week (Mon=2): 2

WBS	Tasks	Task Lead	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Days Remaining
1	**IPRO Deliverables**		1/11/11	4/29/11	109	90%	79	98	11
1.1	**Project Plan**		1/16/11	1/28/11	13	100%	10	13	0
1.2	Initial Meeting with Sargent & Lundy		1/20/11	1/20/11	1	100%	1	1	0
1.3	**Midterm Review Presentation**		2/16/11	3/01/11	14	100%	10	14	0
1.4	Ethics Deliverable		3/26/11	4/08/11	14	100%	10	14	0
1.5	**Presentation to Sargent & Lundy**		4/05/11	4/19/11	15	100%	11	15	0
1.6	IPRO Day Abstract, Brochure & Poster		4/10/11	4/24/11	15	100%	10	15	0
1.7	IPRO Day Presentation		4/14/11	4/27/11	14	100%	10	14	0
1.8	**IPRO Final Day Presentation**		4/28/11	4/28/11	1	75%	1	0	1
1.9	**IPRO Final Project Report**		4/09/11	4/29/11	21	90%	15	18	3
2	**Regulations**	Team R	1/30/11	4/01/11	62	100%	45	62	0
2.1	Research Current & Pending		1/30/11	3/20/11	50	100%	35	50	0
2.1.1	Mini Presentation		2/06/11	2/15/11	10	100%	7	10	0
2.1.2	Patents		3/10/11	3/30/11	21	100%	15	21	0
2.2	Analysis		2/22/11	4/01/11	39	90%	29	35	4
3	**Current Solutions**	Team C	1/30/11	4/01/11	62	100%	45	62	0
3.1	Identify & Research		1/30/11	3/20/11	50	100%	35	50	0
3.1.1	Contact Manufacturers/Companies		2/06/11	3/02/11	25	100%	18	25	0
3.1.2	Mini Presentation		2/06/11	2/15/11	10	100%	7	10	0
3.2	Analysis		2/22/11	4/01/11	39	100%	29	39	0
3.2.1	Benefits & Costs		3/01/11	3/31/11	31	100%	23	31	0
3.2.2	Ash Pond Use		3/08/11	4/01/11	25	90%	19	22	3
4	**Alternative Solutions**	Team A	1/30/11	4/01/11	62	100%	45	62	0
4.1	Identify & Research		1/30/11	3/20/11	50	100%	35	50	0
4.1.1	Contact Manufacturers/Companies		2/06/11	3/02/11	25	100%	18	25	0
4.1.2	Mini Presentation		2/06/11	2/17/11	12	100%	9	12	0
4.2	Analysis		2/28/11	4/01/11	33	100%	25	33	0
4.2.1	Benefits/Effectiveness		3/01/11	3/15/11	15	100%	11	15	0
4.2.2	Costs		3/15/11	4/01/11	18	100%	14	18	0
5	**Wastewater Solutions**	Team W	1/30/11	4/01/11	62	100%	45	62	0
5.1	Identify & Research		1/30/11	3/20/11	50	100%	35	50	0
5.1.1	Contact Manufacturers/Companies		2/06/11	3/02/11	25	100%	18	25	0
5.1.2	Mini Presentation		2/06/11	2/17/11	12	100%	9	12	0
5.2	Analysis		3/01/11	4/01/11	32	100%	24	32	0
5.2.1	Benefits & Costs		3/01/11	3/15/11	15	100%	11	15	0
5.2.2	Closure- Benefits & Costs		3/15/11	4/01/11	18	100%	14	18	0



Appendix D: Data Charts

The following are data graphs and charts that were used in analyzing the final recommendation.

2009 Different Uses for Bottom Ash	
Uses	Amount in short tons
Structural Fills/Embankments	2,944,354
Road Base/Sub-base	765,181
Blended Cement/Raw Feed for Clinker	720,828
Concrete/Concrete Products/Grout	555,996
Mining Applications	498,180
Miscellaneous/Other	467,192
Aggregate	452,066
Snow and Ice Control	207,250
Soild Modification/Stabilization	188,504
Flowable Fill	113,395
Blasting Grit/Roofing Granules	78,156
Waste Stabilization/Solidification	5,867
Agriculture	3,696
Total Bottom Ash Used	7,000,665
Total Bottom Ash Produced	16,600,000

Source: American Coal Association “ 2009 Coal Combustion Product (CCP) Production & Use Survey Report” Feb 8, 2011