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Title of Design: __Contaminated Stormwater Runoff Management__________________________

Design Challenge addressed: __Airport Environmental Interactions__________________________

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Contaminated Stormwater Runoff Management

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Executive Summary

Environmental issues in recent years have become a larger concern with more and more problems coming to the forefront of the news. Regulations from the EPA and other environmental agencies have become stricter and penalties for violating these regulations have increased. Airports have many environmental concerns; in particular, contaminated stormwater runoff is a problem at most all airports. Everyday operations at airports, such as the use of deicing chemicals during winter seasons, pollute stormwater runoff and can potentially cause a hazard to surrounding areas.

Several different methods of stormwater runoff management were analyzed in this study, including pumping the water to a publicly owned works treatment (POTW), biological degradation, and anaerobic degradation. Each potential solution was examined with regards to Federal Aviation Agency (FAA) regulations, financial impact, safety and feasibility.

Although each individual airport's situation is unique with regards to financial capabilities, surrounding land conditions, climate, and other factors, it was determined by the group that the best solution is an anaerobic baffled reactor (ABR). Pumping water to a POTW was found to be too costly, and not all public treatment works would accept the water because of the high levels of contamination. Biological degradation was considered too much of a hazard to departing and arriving planes. When considering anaerobic degradation, the FAA requires that any retention ponds at airports be emptied within 48 hours. ABRs comply with both the time constraints and removes up to 90% of chemicals. In addition, ABRs produce methane as a byproduct which could in turn be collected and used as a power source for the airport.

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Problem Statement and Background

Airports are often a major source of water contamination. Stormwater runoff from airports can often lead to problems when unfiltered water gets into nearby streams, creeks, and ponds. Stormwater can be contaminated by several common airport operations, including aircraft fuelling, de-icing, cleaning and maintenance. Chemicals and pollutants from these operations can have serious negative impacts. Another issue with stormwater runoff is the potential to attract various types of wildlife. Problems from wildlife near airports became a national topic in January of 2009 when US Airways Flight 1549 had to make an emergency landing in the Hudson River after a flock of geese got caught in both engines and disabled them. Any attraction to wildlife will decrease airport safety and can potentially have a negative economic impact as well.

Several different methods and processes are used at airports around the nation to manage stormwater runoff. Some techniques are more effective and less costly than others. However, water surrounding airports have been found to have contamination levels greater than that allowed by the Environmental Protection Agency (EPA). Levels of propylene glycol and ethylene glycol in particular exceed what is acceptable (EPA, 2000). Special treatment must be given to airport stormwater runoff to ensure maximum safety.

The FAA strongly recommends that any water retention system be designed so that water drains from this system within 48 hours and be dry between rains. Also there should be no settling ponds or artificial wet lands, and protected wetlands are permitted only if moving them is not an option. For periods longer than 48 hours, the water might become an attraction for hazardous wildlife. Retention ponds need to be located away from the Airport Operating Area (AOA), and, whenever possible, the water needs to be protected by physical barriers that are approved by the FAA (FAA, 2007). To prevent wildlife from becoming a danger, the FAA provides three different criteria to help keep them from coming within a certain radius. The criteria include:

> (1) flight patterns of piston-powered aircraft and turbine-powered aircraft, (2) the altitude at which most strikes happen (78 percent occur under 1,000 feet and 90 percent occur under 3,000 feet above ground level), and (3) National Transportation Safety Board (NTSB) recommendations (FAA, 2007).

However, according to the FAA, this radius should be five miles for all airports to protect the approach and take off of the planes. (Dolbeer, Wright, Weller, and Begier, 2009). Since 1990, the FAA has been keeping track of animal strikes and has released these findings in the Wildlife Mitigation Report.

According to the FAA there is an average of twenty reported animal strikes a day. During the nineteen years that were analyzed in the report, only nine reported strikes ended in fatalities. In those nine strikes, sixteen peoples died. Reports were also made for the accidents that ended in injuries. One hundred and sixty seven reported strikes resulted in 209 people injured (Dolbeer, Wright, Weller, & Begier, 2009). This is a very small percentage of casualties during a nineteen year period. However, these strikes also have a negative economic impact. The FAA estimates that there is a loss of $123 million per year. The FAA also estimates that only 20% of strikes are reported. If this is factored in, then there is a loss of $614 million per year. Considering that only 20% of strikes are reported, then the casualties would also increases five times. This, however, is probably not the case since accidents involving injuries are closely watched (Dolbeer, Wright, Weller, & Begier, 2009). In response to these issues, airports are taking another look at the way that wildlife interacts with the land around the airports and whenever possible, implementing ways to reduce wildlife attraction to the area.

In 1974 the Clean Water Act (CWA) was enacted by Congress. The CWA allows the Environmental Protection Agency (EPA) to set limits on the effluent that leaves a site and to require a National Pollutant Discharge Elimination System (NPDES) permit. NPDES allows the EPA to regulate industries that might introduce pollutants to the environment. In 2000 the EPA published a Preliminary Data Summary on Airports Deicing Operations. The study analyzed a technical profile of the industry, climatic influences and deicing/anti-icing agent- contaminated storm water generation and discharge, pollution prevention opportunities, wastewater collection, treatment, and disposal wastewater characterization. In addition, the document looked at the toxicity of deicing/anti-icing fluids. It and provided an environmental assessment of impacts related to airport deicing/anti-icing, and provided estimated numbers on the pollutant load removals and costs to manage wastewater affected by deicing operations. From this study, the EPA established that the biological oxygen demand (BOD) levels found in water surrounding airports are found to exceed the limits that are established by the EPA. This has led the EPA to be concerned with storm water runoff that is contaminated by the deicing/anti-icing agent and other contaminates from the airport. The EPA looked at five different airports and found in the water located by these airports showed levels of propylene glycol and ethylene glycol. Ethylene glycol and propylene glycol are the two most common deicing chemicals because they both have a freezing point lower than water. The BOD was also taken at all but one airport. These levels showed varied results in places (or times of the year). Some concentrations were considered lethal while in others there was not enough contaminate to be detected (EPA, 2000). When ethylene glycol and propylene glycol are added to the frozen water slush is formed, which is collected by the airports. Both of these are toxic when consumed by humans. The EPA says that when ingesting large amounts, three stages of health are affected: the central nervous system (CNS) depression, followed by cardiopulmonary effects, and later renal damage. The only consequences pointed out in a particular study of individuals exposed to low levels of ethylene glycol by inhalation for about a month were throat and upper respiratory tract irritation. EPA has not classified ethylene glycol for carcinogenicity (EPA, 2010). During the winter when airports are deicing or during a rainfall when residual amounts are released, there is a chance for both of these to enter the ecosystem. Due to the high cost of operating a waste water treatment plant or even containment system, the only water collected by EPA is mandated through NPDES permits.

Chicago O'Hare is one of only three airports worldwide that has a storm water retention system that collects up to 70% of the run off from the runways, taxiways and the deicing areas. The water is collected in two retention ponds that are then emptied at a controlled rate into the local publicly owned treatment works (POTW); one of the retention ponds is located in the middle of three of the runways, failing to meet the FAA standard previously discussed. The airport is charged an extra cost for any water that exceeds contamination level, which approaches around a million dollars a year (EPA, 2000).

Wastewaters contaminated with aircraft deicing fluid (ADF) have a relatively high oxygen demand which means biological treatment is usually the most efficient treatment method, both time and cost wise. Airports normally choose to discharge wastewater to POTW for treatment; however, this technique is not always possible. Not all POTW have the ability to treat airport wastewater or handle the high pollutant levels (EPA, 2000). Failure to meet pollutant levels as well as the high volume of water has led to high fees charged by the POTW. This extra cost has turned airports towards an on-site biological treatment process. On-site treatments have several advantages. First, they can be built to specifically handle contaminants from deicing (ethylene glycol and propylene glycol), jet fuel, and other common pollutants from airport operations. Second, airport specific treatment plants can be designed to handle both high-strength and diluted wastewaters, therefore being effective in both deicing season and the rest of the year (EPA, 2000).

Literature Review

When dealing with storm water runoff, airports can use the surrounding land, specific to each individual airport, as a tool to help manage pollutants. For example, Baltimore/Washington International Airport has installed facilities all throughout its airfield to take the first one-half inch of rainfall and temporarily store it in gravel-filled trenches built parallel to runways and taxiways. When the trenches overflow, excess water is directed to detention areas. The important issue here is to limit standing water as much as possible so as to not attract local wildlife near the airfield. Albany International Airport, as a substitute for disposing waste water from the on-site biological treatment system to the POTW, uses a spray irrigation operation throughout the airfield. The irrigation system covers about 40 acres and is more cost efficient. Because glycol is biodegradable this method is permitted by the EPA. The majority of the airports that the EPA studied used a waste water retention system where the water flowed into ponds that were then allowed to empty into the local POTW. Almost all of these airports use the fact that glycol is biodegradable to their advantage by creating swales, either natural or artificial, to allow deicing chemicals in storm water runoff to degrade naturally. One example is Duluth International Airport which sends some of its ADF-contaminated storm water to retention areas that allow the water to evaporate and infiltrate the ground for natural degradation. Natural degradation saves the airport time, money and other resources when dealing with wastewater treatment (EPA, 2000).

An effective method of ADF-contaminated water disposal is an anaerobic bioremediation system. These systems include runoff collection/storage with an anaerobic biological treatment center. These systems decrease oxygen demand levels adequately enough to allow disposal to a POTW while also eliminating additives from the runoff. Bioremediation systems also can take glycol and convert it to methane which can be used for heating, providing an additional economic advantage. Another benefit of this system is that because it is anaerobic, it can be held underground or in covered tanks. These measures will limit the attraction of nearby wildlife (EPA, 2010).

If additional drainage systems are not financially feasible, vacuum sweeper trucks can be a cost effective solution. The trucks usually range from $200,000 to $400,000. The trucks collect deicing fluids from the airfield as well as snow/slush from other parts of the airport. The fluids collected are sometimes able to be reused as well (EPA, 2010).

Problem Solving Approach

Proposed Solutions

An environmentally friendly and cost effective solution to having airport runoff go directly into the ground water turned out to be a challenge. A water treatment solution needed to be found. Research led to three main ideas. Table 1 outlines these ideas, which are pumping water to a POTW, Biological Degradation, and Anaerobic Degradation, and highlights the advantages and disadvantages of each proposed solution.

Table 1 - Proposed solutions for airport runoff treatment

Proposed Solutions			
Solution	Description	Advantages	Disadvantages
Pumping water to a POTW	Collect water and transport to local treatment plant	• Airport not responsible for treatment of water • Existing pipes connecting for sewer • No open water	• High cost- POTW will charge for the contaminated water and to upgrade sewer system • Not all water will get treated if the POTW gets overloaded by rain
Biological Degradation	Collect water in ponds, lagoons or artificial wetland	• Low Cost • Simple • Effective glycol is biodegradable	• Open water would attract hazardous wildlife
Anaerobic Degradation	Collect water in anaerobic reactors	• Most effective water treatment method • No open water • Low Cost	• Energy required to operate • Risk of Freezing • Biogas created

Through analyzing the proposed solutions, the three were narrowed down to one. Although an easy solution, pumping water to a POTW was eliminated because of the high cost that would be associated with its implementation. Biological Degradation was also eliminated because it includes open water areas, providing a potential wildlife attraction. This would prove hazardous to the safety of the planes. While Anaerobic Degradation is the only viable option remaining, it also makes the most sense. As previously mentioned in the problem statement, a major concern with onsite treatment is open water retention ponds, Anaerobic Degradation mitigates this issue by containing the stormwater runoff in a closed-in reactor. It can be maintained at a relatively lower cost than other options.

FAA Requirement

According to the FAA there should be no waste water treatment facilities within five miles of the airport because of the attraction that the open water would cause for hazardous wildlife. The FAA also requires that any retention ponds that are used for storm water runoff are emptied within 48 hours, and that the pond would not hold water between rain events. Although a traditional anaerobic reactor would take around 20 days for the removal of 90% of polyethylene glycol (Otal & Lebrato, 2003) this should not be an issue as the reactor will be covered. However, the long time spent in the reactor could lead to issues with the water becoming stagnated, possibly freezing in cold weather, or becoming a wildlife attraction if there were any holes to be found in the covering. Thus another option that drains within 48 hours is necessary.

Solution

An anaerobic baffled reactor (ABR) is another solution. An ABR can remove 89% of the chemical oxygen demand (COD) in 27 hours from ADF (Kennedy & Barriault, p.6, 2005). The amount of COD removed is representative of the amount of ethylene glycol that has disintegrated. By addressing both the time restraints imposed by the FAA and the goal of removing harmful chemicals from the water, an ABR is the most practical solution. An additional advantage of anaerobic degradation creates methane as a by produce which could be collected and used to generated power. Through the use of existing infrastructure this should be a cost effective solution. Currently ABRs are used in several different operations the leading uses being residential (septic tanks) and agricultural (mainly cow and pig farming). Other forms of anaerobic treatment can be found at municipal wastewater treatment plants in the sludge removal process. These uses of anaerobic treatment are for processing high-strength wastewater. However, research has shown that anaerobic treatment and ABR in particular are able to treat low-strength wastewater (Torabian, Abtahi & Momeni, 2010). Airports produce low-strength waste water so an ABR is a good reactor to have for an airport.

Conclusion

The initial issue set out to be addressed was the treatment of water not involved with the deicing anti-icing operation. An ADF would effectively manage this, as well as ensure safety for airborne planes and provide an additional benefit through the production of methane gas. By combining the ADF with the storm water runoff the airport would save money, generate energy, and maximize safety.

Safety Risk Assessment

When extreme winter conditions plague an airport, a deicing chemical generally made of glycol is applied to the airplane to prevent the harmful weather from damaging the plane and/or the takeoff and landing. Obviously, there will be some runoff that will land on the runway and when it rains or the snow melts, the water, now contaminated from its contact with glycol, runs off the runway and will come into contact with the surrounding terrain if not canaled to a proper treatment facility. Possible options for treatment include onsite retention and treatment, transfer to an offsite treatment plant, or a hybrid of both.

Phase 1: Describe the System

The system that we want to implement, an ABR, is comprised of three main parts. There is piping to move the stormwater runoff from the runway and aprons to the retention pond, the actual retention pond itself, and the effluent vents that emit methane gas as a byproduct.

Phase 2: Identify the Hazards

The three main causes that could result in system failure are equipment malfunction, wildlife habitat potentials, and external contamination. The piping system that transports the methane biogas offsite could leak or rupture, releasing the gas into the environment. This gas is highly flammable. Secondly, as the FAA points out in AC 150/5200-33B, "Existing on-airport detention ponds collect storm water, protect water quality, and control runoff. Because they slowly release water after storms, they create standing bodies of water that can attract hazardous wildlife." The surrounding wildlife is considered hazardous because, if they come into contact with a plane, they can create devastating damage to both the plane and animal. The most recent notable case occurred in March of 2009 when US Airways Flight 1549 lost both of its engines to bird incursions and was forced to do an emergency landing in the Hudson River. Aside from being hazardous to wildlife, the runoff, if not properly contained has the potential to contaminate surrounding ground water.

Phase 3: Determine the Risks

The major risk associated with wildlife incursions is damage to the plane, either the body or the engine. This damage could cause a crash, resulting in many injuries and/or death. A less severe consequence would be a more difficult flight for the pilot. A leaky retention pond would be a catastrophic event, because there is a possibility the contaminated water could come into contact with a ground water source. Similarly, if the transfer pipes to an offsite facility were to fail for any reason, contamination could again happen. Anaerobic degradation has a byproduct of biogas. If the biogas is not properly dealt with there is an increased risk of fires and explosions. Contaminated groundwater has the potential of being ingested, which could lead to ethylene glycol intoxication. "Intoxication by ethylene glycol causes severe metabolic acidosis which may lead to death if diagnosis is delayed and specific treatment is not initiated promptly." (Lovric, Granic, Cubrilo-Turek, Lalic, & Sertic, 2007) Obviously, this is a very serious risk.

Phase 4: Assess and Analyze the Risks

The possibility of fires and/or explosions is by far the most severe risk associated with this system. An explosion of any kind is devastating but this explosion would also happen around a lot of airplane fuel, which would serve as an even bigger catalyst. If the two were to come into contact, the entire airfield could be in danger. A leaky retention pond would be the second most important risk to prevent or mitigate. As mentioned before, ground water contamination could be fatal. However an explosion takes much less time to occur. There is little to no warning whereas ground water contamination could be tracked and treated if it were discovered. Finally, wildlife incursions need to be accounted for. When they do happen, incursions cost a lot of money to repair damages. However, few lives have been lost since monitoring started and in the case of the Hudson aircraft, no lives were lost. This risk poses the smallest hazard to human life and therefore is the least severe. Animal incursions have been tracked for nearly 20 years and only nine incursions have resulted in fatalities. This would make the risk of wildlife incursions highly improbable.

Phase 5: Treat the Risk

All three risks are dangerous and needed to be mitigated or monitored. The ABR covers the treated water therefore mitigating the potential of a wildlife habitat. The other two risks, both severe, can be easily monitored. Pressure gauges on the gas pipes will alert facility management to any leaks and can easily be capped to prevent any biogas seepage. Biochemical Oxygen Demand (BOD) levels can be monitored in any nearby streams or ground water wells to ensure no leaks are present in the tanks. Also, pressure gauges on the ABR tanks can help locate and remedy any leaks in the tanks.

Technical Aspects

In general an ABR has several baffles or columns that force the water to flow under and over in order for the water to leave. This process allows for solids to settle out while containments in the water are worked on by biological agents. During the digestion process there are biogases, such as methane, produced. The gasses need to be collected and properly disposed of, whether through burning or energy generation. The vertical baffles create a difference in the SRT (solid retention time) and the HDT (hydraulic detention times) which allows the water to be cleaned faster (Kennedy & Barriault 2007). The calculations that are performed on ABR's are done assuming each compartment is a CSTMR (continuous flow stirred tank membrane reactor) that is connected to the others in series. Figure 1 is an ABR that was used in a scale test at the University of Tehran and this figure has all the parts of the reactor labeled.

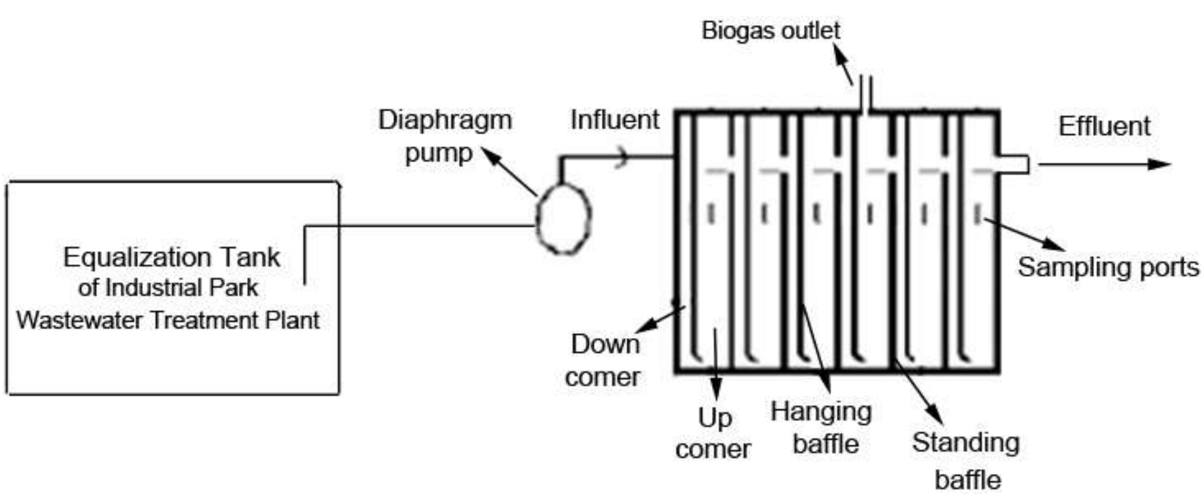

Figure 1- Scale anaerobic baffled reactor (add citation like you did in Figure 2)

Plot of the % COD removed vs. HDT

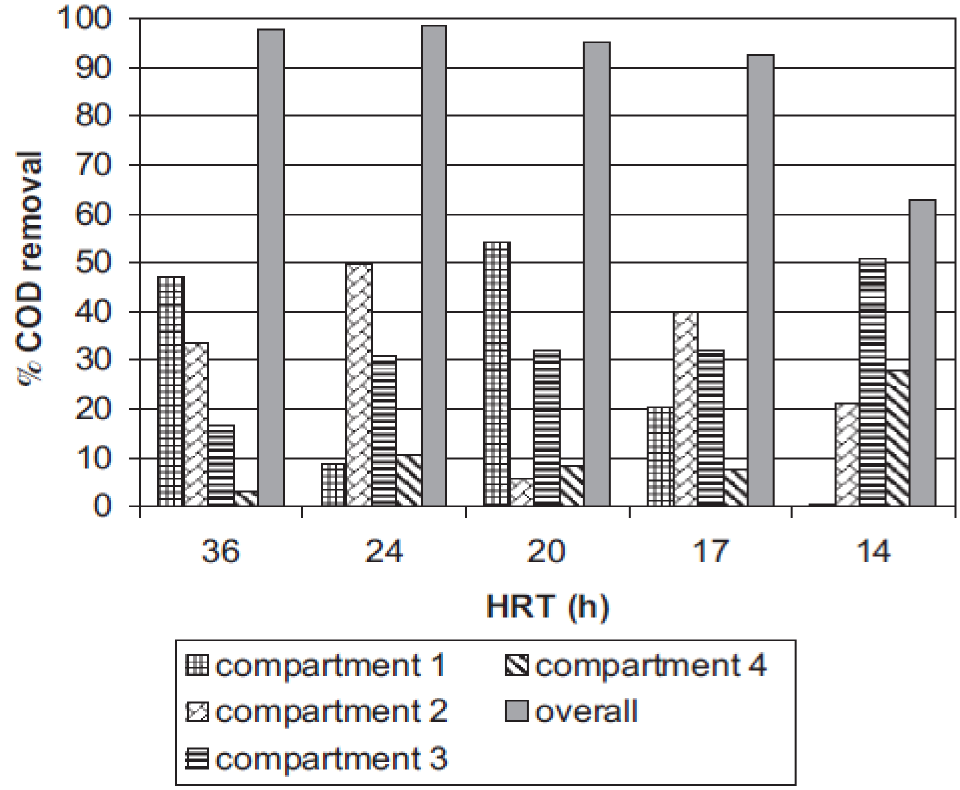

Figure 2- Plot of the % COD removed vs. HDT where HDT is in hours. (Kennedy & Barriault 2007)

Table 2- First order reactions rate coefficients for the ABR comparing different HDT and the ABR's with and without recycling (Kennedy & Barriault, 2007)

First Order Reaction Rate Coefficients

ABR	HRT (h)	k^* ($L \cdot g^{-1} \cdot d^{-1}$)
No recycle	39	2.1
	27	0.31
	20	0.048
With recycle	36	1.4
	24	2.9
	20	0.94
	17	0.59
	14	0.10

Note: ABR, anaerobic baffled reactor; HRT, hydraulic retention time; k^*, overall first order reaction rate coefficient.

As Table 2 and Figure 2 show the best results are achieved around the 24 hour mark. At that time the *k* value is the largest at 2.9 also the COD removal percent is well above 90% close to 100%. In this experiment the DAF was recycled trough the ABR to lower the COD (Kennedy & Barriault, 2007). The solution proposed here is to achieve the same results by mixing the runoff with the DAF. Timing is very important in ABR and if the HDT is to long the COD levels begin to rise again. As Figure 3 clearly shows, the amount of COD in each compartment is reduced, showing that the ABR is doing its job. There has been very little research done on how much biogas is produced in an anaerobic environment containing DAF. The existing research however, shows that there methane is present (Martin, Kennedy & Eskicioglu, 2009). Therefore for the biogas will not be considered for in this design, other than recognizing that the biogas needs to be collected.

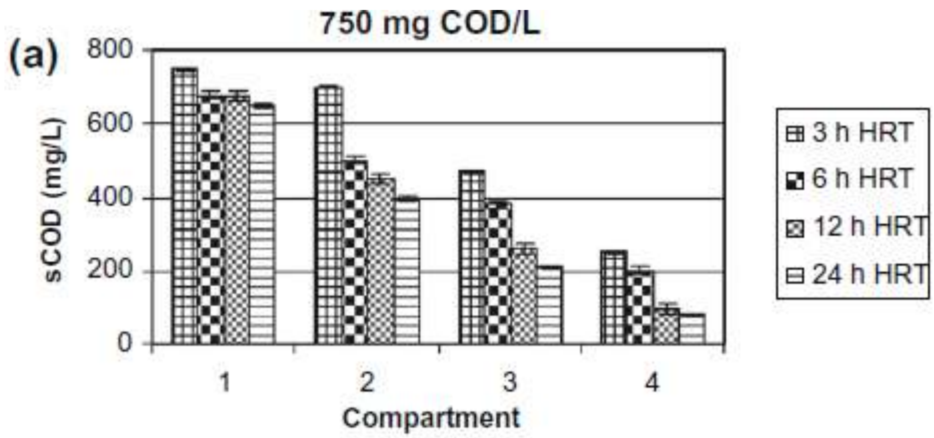

Figure 3 – COD (mg/L) vs. the four compartments of an Anaerobic Baffled Reactor, these are graphed for four different HRT's. The maximum amount of COD in the samples was 750 mg/L. (Martin, Kennedy & Eskicioglu, 2009)

The first step to design an ABR is to figure out the amount of water that needs to be accounted for can be determined if the area of land and location of the airport is known. Lambert airport in St. Louis Missouri was used as a test case, although the calculations could easily be changed for any airport. The area of Lambert that is within the protected fence is 2.8 square miles; this is the area that will be used for the design process. The total area of the airport is not needed because the rain that is not in the operating area will not have any contaminates in it; in practice this area could probably be cut down even more. To figure out the amount of rain fall Technical Paper 40 was used (Hershfield, 1961). To use TP40 several assumptions need to be made, first the design storm needs to be selected. The design storm that was selected for this design was a 2-hour rain event with a 25-year return period. Although it is possible to design for up to a 100-year storm this would greatly over estimate the amount of water that would likely be seen in an average year; lesser return periods could also be used however were not considered because these values would lead to the ABR being under designed. A 2-hour rainfall was chosen for the length of the storm.

For a 2-hour rain event and 25-year return period which will then have a 3.2 inches of precipitation, by Figure 4. Once that amount of precipitation is found then it needs to be adjusted for the area, this is a percent found in Figure 5, 99% for this problem. Thus the adjusted value is found by multiplying the precipitation by the percent of rainfall, giving a new precipitation (P) of 3.168 inches.

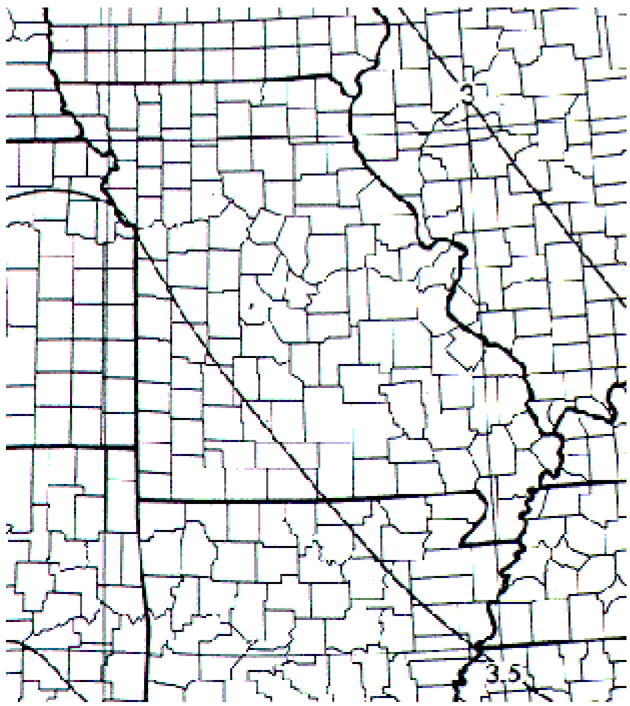

Figure 4 – TP40 chart for a 25-year and 2-hour rainfall, of the state of Missouri (Hershfield, 1961)

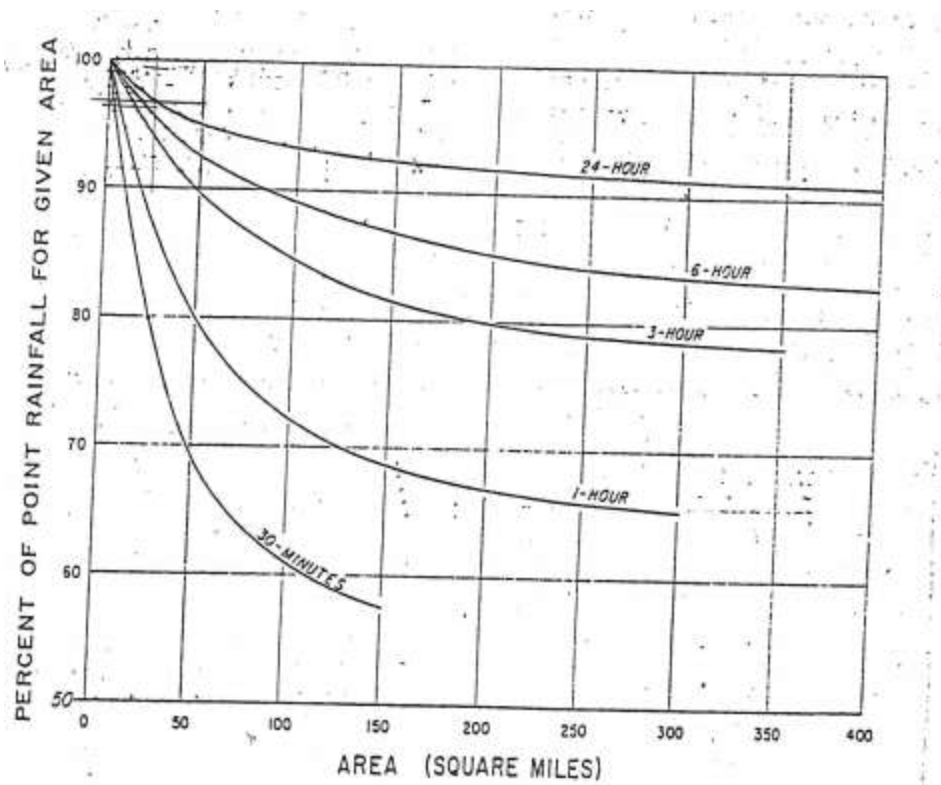

Figure 5 – TP40 document for the percent of rainfall per area (Hershfield, 1961)

Other assumptions that need to be made before the volume of runoff can be calculated are what types of ground covering (CN) there are and the percent of each. By looking at the runoff curve table Figure 6 the two types of land uses were selected, these are open spaces for the grass and paved parking lots for all the area's that are covered with concrete, the assumption was also made to include the buildings along with the runways and other paved areas. To find the open space CN value the type of soil also has to be determined, for this example soil group C was used. These assumptions lead to CN values of 98 for the paved areas and 74 for the open space. Having decided on CN values the percent of the land that each of these occupies is the next assumption that needs to be made. Looking at an aerial photo an educated guess of 70% paved and 30% grass made the assumption of land use. The two different CN values needed to be combined into one average CN, which turns out to be 90.8.

Land Use Description		Hydrologic Soil Group A	B	C	D
Cultivated land[1]					
Without conservation treatment		72	81	88	91
With conservation treatment		62	71	78	81
Pasture or range land					
Poor condition		68	79	86	89
Good condition		39	61	74	80
Meadow					
Good condition		30	58	71	78
Wood or forest land					
Thin stand, poor cover, no mulch		45	66	77	83
Good cover[2]		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.					
Good condition: grass cover on 75% or more of the area		39	61	74	80
Fair condition: grass cover on 50%–75% of the area		49	69	79	84
Commercial and business areas (85% impervious)		89	92	94	95
Industrial districts (72% impervious)		81	88	91	93
Residential[3]					
Average lot size	Average % impervious[4]				
1/8 ac or less	65	77	85	90	92
1/4 ac	38	61	75	83	87
1/3 ac	30	57	72	81	86
1/2 ac	25	54	70	80	85
1 ac	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.[5]		98	98	98	98
Streets and roads					
Paved with curbs and storm sewers[5]		98	98	98	98
Gravel		76	85	89	91
Dirt		72	82	87	89

[1]For a more detailed description of agricultural land use curve numbers, refer to *National Engineering Handbook*, Section 4, "Hydrology," Chapter 9, Aug. 1972.

[2]Good cover is protected from grazing, and litter and brush cover soil.

[3]Curve numbers are computed assuming that the runoff from the house and driveway is directed toward the street with a minimum of roof water directed to lawns where additional infiltration could occur.

[4]The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

[5]In some warmer climates of the country a curve number of 95 may be used.

Figure 6 – Runoff curve numbers for typical land use.(Bedient & Huber, 1988)

By assuming that the total grade change of the airport is the same as the maximum grade change of the airport is the same as the maximum allowed by the FAA for change on a runway, the grade was assessed to be 1.5%. The maximum drainage length was assumed to be 2 miles. From these assumptions a simple Hydrograph was constructed, Figure 7. The hydrograph shows how long into the rainfall starts that the peak discharge occurs, as well the maximum flow.

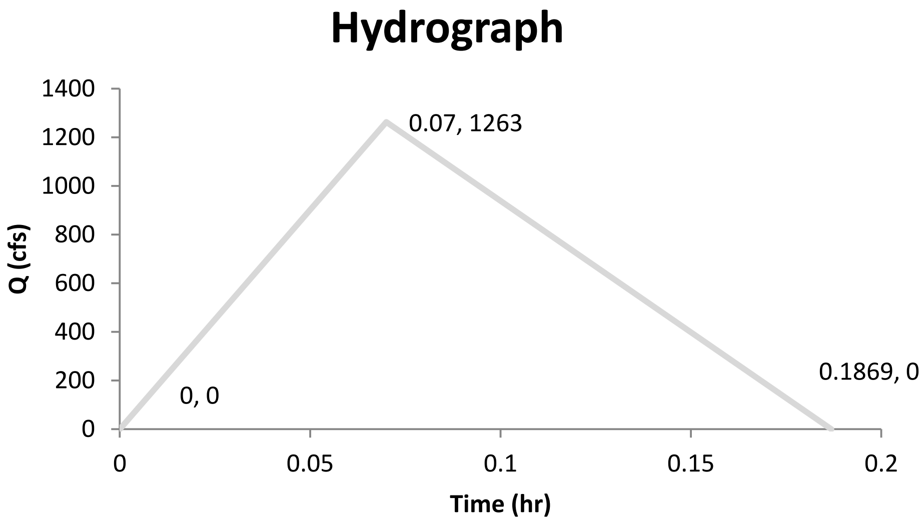

Figure 7 – Hydrograph for 2-hour rainfall, 25-year storm,

Relating the CN values to the precipitation was done using the equations (Bedient & Humer, 1988):

$$S = \frac{1000}{CN} - 10$$

$$Q = \frac{(P - .2S)^2}{P + .8S}$$

The direct runoff (Q) is then found to be 2.21 inches, based on the values of CN and P. Direct runoff is calculated for $1in^2$, when adjusted for the whole airport the volume of runoff amounts to 23829 cubic feet. The volume of runoff should be able to fit in one large retention pond.

The size of the reactor can now be found. Based on having the retention pond drain within 48 hours the ABR can operate in two different ways. The first way that the ABR can work is to have a total retention time of 48 hours; this would mean that from when the water enters the reactor to when it is discharged could not exceed 48 hours. Figure 3 shows how the concentration of COD reduces with the amount of time that the water in the system. The second option would be to get rid of the retention pond and have the first column of the ABR act as a retention pond. A small retention pond would still be good to have as a safety factor if more rain fell then the design allows for. Considering these two options the first option seems to be the best way to design the ABR. The design that is proposed here is for five columns. The retention time for each baffle is 9.6 hours and the total retention time is 48 hours, this allows for the COD levels to reduce significantly. Although the ideal retention time as discussed above is 24 hours this would double the size of the reactor. The total water that the ABR needs to be able to hold is the volume of water times the retention time; 23829 ft^3 times 2 days is 47658 ft^3. Therefore the size of the reactor can be found by knowing that one column needs to be able to hold one fifth of the total water or 9531.6 ft^3. Based on these numbers the proposed dimensions of the reactor are 30' x 32' x 55', the columns would each have a length of 11', a width of 30' and a height of 32' the top 2' would be used for a biogas collection system. There would be a need to have several pumps on the system, at the discharge and in each baffle. The pumps would sever to circulate the water when the flow is not significant enough. The pump at the end of the system would be connected to the beginning of the system and allow for the water to recirculate when there is not enough water or the water is very contaminated. There also needs to be a sludge removal system, for what settles out of the water.

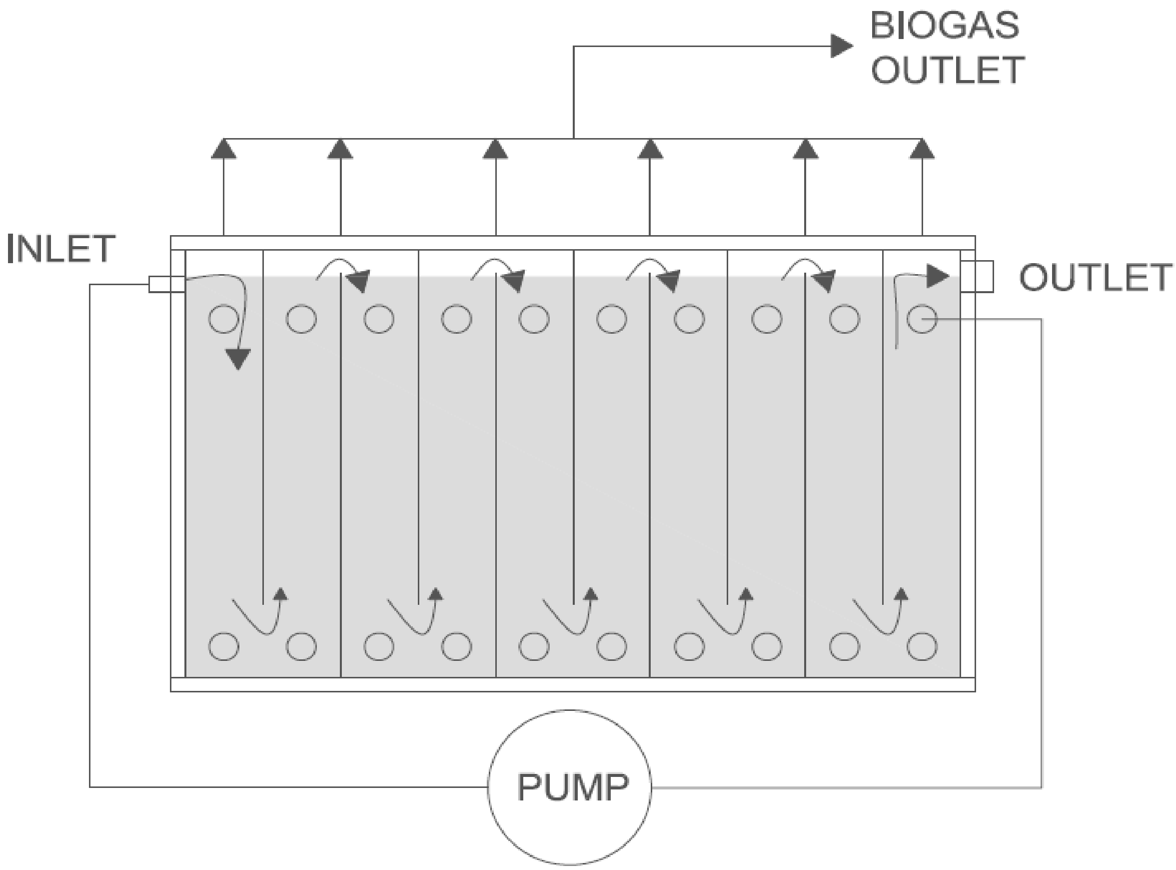

Figure 8 – Rendering of design

Industry Interactions

Greg Cecil, Chairman of the Columbia Regional Airport (COU) board, presented to the group the general airport procedures at COU and outlined the methods used at COU to treat stormwater runoff. The group asked Cecil what sort of problems COU has faced with their design in the past, as well as what regulations they have had to shape their design in order to abide by. The group was informed that smaller airports do not usually require an on-site treatment process because of the limited amount of deicing operations that are performed. At COU, the contaminated water is simply transported to the local POTW for treatment. It is acceptable for most small to mid-sized airports to follow a similar procedure, assuming the contamination levels do not exceed the requirements of their respective POTW.

David Sparkes from Kimley-Horn gave a presentation to the group on the design and construction of runway 19/27 at Memphis International Airport (MEM). Sparkes has been thoroughly involved with the design of the airfield at MEM and discussed the specific issues they have had dealing with stormwater runoff. The group asked David to share details and drawings of the designs MEM has implemented and what problems are still faced. The group proposed a couple of potential design solutions they had been considering. Sparkes discussed what would work well with these designs and what possible problems these designs could face, as well as the practicality of the designs.

Mark Williams is the Associate Vice President of HNTB Corporation. When the group asked what HNTB looks for most when designing a stormwater runoff plan, Mr. Williams went into great detail on how airports move contaminated water from the runways and aprons to the treatment plants. He used as a specific example Dallas-Fort Worth Airport (DFW). At DFW, there are channels that move water from the pavement to runoff drains. Once the water moves into these drains it reaches a junction. If the airport has used any deicing chemicals recently, this junction directs water into onsite retention ponds where it is treated. If no deicing chemicals have been necessary, the junction directs the water directly to a treatment plant.

Projected Impacts

The design solution presented here could be customized for any airport size. However this solution would be most suited for the approximately 200 U.S. airports that the EPA identified as using glycol based deicing practices (EPA, 2000, Section 14.1.1.2, Table 14-4). The solution was focused on aircraft safety as the ruling principle. While the goal of this design is to improve the quality of the water that enters the ecosystem the safety of the aircraft is always the number one concern. An ABR is the most effective type of reactor for an airport because of how quickly the water can be treated. Currently anaerobic reactors are used in several different operations around the country including waste water treatment plants, septic tanks and on farms. Existing ABRs would make the commercial design of the system easier to create; the design would just need to be customized to an airport.

In the case of the proposed solution the implementation of the design would be more difficult than the design. The infrastructure that the airport currently has in place for storm water drainage should lend itself to the installation of an ABR. Airports currently employ artificial retention ponds that are then drained within 48 hours into the local water supply. The proposed design would divert the water from the retention pond into the ABR for treatment. The ABR is a very good treatment for stromwater runoff, and combining this with the treatment of the deicing chemicals makes it an even more appealing solution. Most airports spend a large amount of money annually on deicing, over a million dollars in some cases, and then spend even more to treat the DAF, up to another million more (EPA, 2000). A large cost for treating DAF comes from fees that POTWs charge airports. An ABR is capable of removing 90% of the glycol that is in DAF; although this would not usually pass the effluent limits set forth by the EPA. In some cases, it might meet the POTW standards or would at least result in a large drop in the fines.

Anaerobic reactors have low capital costs and low annual costs. Currently, Albany International Airport uses anaerobic treatment (two fluidized bed biological reactors) for the DAF at the airport. The system was installed in 1998 for $3.2 million (EPA, 2000). While this is not the norm, and most airports use other methods, a push to be green could aid the switch to anaerobic treatment. This may not be the most popular move ever, as many airports do not currently have any stormwater mitigation programs in place. However, to entice airports to be more environmentally friendly, the FAA and the EPA could implement a system similar to the AgSTAR program that the EPA has in place for farmers (Lazarus & Rudstrom, 2007). The AgSTAR program has seen positive results in having dairy farmers install anaerobic treatment with biogas generators. Although more research is needed to determine how much biogas would be generated by airport runoff, a generator might be a very good way to help offset the cost. Each airport would need to perform a cost/benefit analysis to determine if the move to an anaerobic reactor makes financial sense. Several researchers, however, do state that anaerobic degradation is a cost effective solution (Abdullah et al., 2005; Liu, Tian & Chen, 2010; Saktaywin et al., 2005; Sato et al., 2006).

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Appendix B-University of Missouri Description for FAA Design Project

- Mizzou is both the state land grant and the research university and is the flagship university of the University of Missouri System
  - 11 Academic Departments in the College of Engineering
  - Mizzou is a member of the American Association of Universities, an association of 63 leading public and private research universities in the United States and Canada.
  - Mizzou is classified by the Carnegie Foundation at the highest level for doctorate-granting universities, i.e. research university, very high research activity.
- University of Missouri-Columbia (Mizzou) transportation engineering program
  - Five faculty members
  - ~Twenty graduate students (both Ph.D. and Masters)
  - Other related areas such as pavements/geotechnical, structures, GIS and project management
  - Programs associated with transportation research at Mizzou include the Truman School of Public Policy, Agricultural Economics, Statistics, Electrical Engineering, Industrial and Manufacturing Engineering, Computer Science, Library Sciences, Rural Sociology and School of Law.
- Airport Engineering Class
  - Professor: Dr. Carlos Sun – previously designed aircraft information systems as an employee of Airshow, Inc. (now Rockwell/Collllins)
  - Topics covered in class:
    - Airport Design AC150/5300-13
    - Airport Master Plans AC150/5070-6a
    - Airport Capacity AC150/5060-5
    - Airport Planning AC150/5090-3C
    - Airport Terminal Design AC150/5360-13
    - Airport Pavement Design and Evaluation AC150/5320-6d
    - Airport Certification AC150/5210-22
    - Runway Length AC5325-4A
    - Safety Management Systems AC150/5200-37
    - Safety Management Systems Manual

Appendix C– None University Partners

None

Appendix E for submissions for the FAA Design Competition for Universities

Jonathan Loos

The FAA Design Competition was a brand new experience to me. I've never had to come up with a brand new idea for something, research it, and propose it. I've done projects in class labs but nothing too innovative or as serious as our proposal. I've learned a lot about using a pragmatic approach, brainstorming, and producing professional proposals. Our team ran into problems mostly at the start. We decided we wanted to create a project for stormwater runoff management but didn't know exactly how to approach it, or what our exact solution would be. Of course, it's hard to make any progress with a project without a clear understanding of what you want to accomplish. Further brainstorming and a positive attitude helped overcome these challenges. When developing our hypothesis, we did a lot of research to find as many approaches to our problem as possible. We selected a few, and then finally settled on one remediation process to solve our identified issue. Mark Williams was the greatest help from an industry interaction standpoint. He seemed very eager to help us and was extremely helpful and a great resource when selecting the solution to our hypothesis.

Sara Goebel

I thought that the FAA design competition was a really interesting experience. The opportunity to pick a topic, almost any topic, that you found interesting and then seeing it through the initial proposition to the final proposal was a very great learning experience. I feel that the largest problem that our team ran into was a lack of communication between team members, and overcoming that was an ongoing issue. The project had somewhat of a bumpy start because we chose a topic that was interesting to us rather than one which we had an answer for already. This led to a whole lot of research on many different ways to contain stormwater runoff and I felt that this has given us a better understanding of our final solution and the reason that it was the best. Since we did not have a clear path at the start of the project, the industry interactions were possibly a bit on the weak side. This was because we did not understand our project, so how could we ask another for input? I believe that this project has helped in my ability to write a well-researched paper. It has also strengthened my ability to research and to then form my own opinion. This skill will help in many areas of my life, not only in the realm of academic or professionals life, but with my personal life as well.

John Fitzpatrick

The FAA Design Competition was a very meaningful experience. It provided an opportunity that I have not quite had in my life yet. It gave me a chance to look at situations in the real world and gave me insight into the problems faced in the actual airline industry. Certain challenges that our team faced were the fact that every airport is unique. It is difficult to say what the "best" solution is when every individual airport faces its own issues. To develop our hypothesis, our team analyzed several different case studies of airports and examined what worked well and what did not with their current stormwater runoff systems. Industry participation was meaningful; it provided a chance to get first hand insight into potential systems, and also it helped us to deterimine the feasibility of different solutions. This project definitely gave me skills and knowledge that will be helpful for entry into the workforce. It was an excellent hands-on experience, and was a good practice at writing papers for the industry.

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