COVER PAGE

Title of Design: Pervious Concrete-based Airport Fuel Spill Control System

Design Challenge addressed: Airport Environmental Interactions

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Airport Environmental Interactions Challenge
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Executive Summary

Title: Pervious Concrete-based Airport Fuel Spill Control System

Team: Twenty-four undergraduate students - Department of Computer Science, Thomas J. Watson School of Engineering and Applied Science, Binghamton University – State University of New York.

Airport fuel spills are not a common occurrence, but still represent a serious concern. The current protocol for a fuel spill is labor intensive, prone to human error, and can cause significant delays in air traffic at airports. Depending on the size of the spill, the cleanup process can take anywhere from an hour to several days. The fuel spill may spread quickly enough that an attempt to surround the spill with containment booms could be unsuccessful, causing ground water, soil and surface water (streams, rivers, etc.), to be contaminated. Also, because of the fuel's high flammability, the lives of passengers, pilots, crew, and airport personnel are at risk.

Proposed herein is a system that will allow fuel spill containment to rely less on the human element, making the process far less dangerous, less error prone, less labor intensive, and much more environmentally sound. The proposed system consists of an airport apron surface constructed of pervious concrete. Each component of the proposed system is designed in 90‘ x 90‘ sections and may be repeated as needed to accommodate more fueling area. Each 90‘ section will have a v-shaped valley composed of two layers of concrete. The top layer of the valley consists of pervious concrete and the bottom layer (below the valley) consists of non-porous concrete. The valley funnels the spilled fuel into a collection tank. The drainage system consists of storm water valve and a fuel storage tank valve. The valve leading to the storm water drainage system will be opened upon a successful fueling operation. This will permit rainwater to drain into the surrounding soil. However, if a fuel spill occurs, the valve leading to a 2,000 gallon fuel storage tank will be opened to capture the spilled fuel.

This preemptive approach to capturing fuel, rather than concentrating on cleanup, will provide a safe and reliable method of handling fuel spills.

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I. Problem Statement and Background

i. The Dangers of Fuel Spills

The fueling of an aircraft is a stringent process that is carried out frequently and routinely at most airports. The primary concerns during fueling are safety, preventing a fuel spill, and preventing a fire.

Figure 1. Airport fuel spill [7]

Figure 2. Airport fuel spill fire [1]

Figure 3. Removal of contaminated soil [9]

Compared to the number of fueling operations that occur at thousands of airports, fuel spills are relatively rare. However, as can be seen in *Figure 1* and *Figure 2*, fuel spills can be extremely dangerous due to the volatility of the fuel and for subsequent environmental impacts. Fires can cause loss of life, loss of the aircraft, and loss of airport infrastructure. Even spills that do not lead to fire may require time consuming and expensive cleanup operations and can lead to extensive environmental damage as shown in *Figure 3*. Aviation fuel can trap marine mammals and birds that rest on the contaminated water surface; it can damage their skin and eliminate their mobility. Ingestion of these toxic substances can eat away at the internal organs of the consumers [11]. A 3.8 million gallon fuel spill in 1988 released more than 750,000 gallons of fuel into the Ohio River in Pennsylvania, and killed more than 10,000 fish and 2,000 birds. The state of Pennsylvania spent over $17 million to contain and eliminate the spilled fuel from the environment [12]. Not only do fuel spills present a risk of fire and environmental damage, they also can cause service delays and flight cancellations. For example, a recent fuel spill at the Miami International Airport caused more than 36 flights cancellation [14].

Prevention and improved handling of fuel spills has the potential to directly affect the FAA's goal of ―exceeding Federal Emergency Management Agency continuity readiness level by 5 percent" [13] as described in FAA Portfolio of Goals.

ii. Fuel Spills, FAA Goals, FAA Safety Procedures

The Portfolio of Goals outlines what the organization plans to achieve in the near future. One such goal is a reduction in the general aviation fatal accident rate [14]. Because fuel spills can lead to fatalities, then by reducing the danger of fuel spills, there is a potential to improve the general aviation fatality rate. The Safety Management System (SMS) is a tool the FAA uses to track and manage safety risks. It is used to create ways to plan and manage issues before they become major incidents. Improved methods of dealing with fuel spills could be added to the SMS in an effort to improve safety. [16]


Figure 4. Dead-man system [8]

To prevent fuel spills, the FAA has strict fueling guidelines for aircraft fueling. Failure to follow the procedures can lead to fuel spill accidents. Currently when aircrafts are about to be fueled, checks are made to ensure safety throughout the fueling process. Checks are used to see if all electrical systems are turned off and if the correct grade of fuel is being used. In addition to procedural checks, the FAA requires that all fueling personnel complete Fueling Safety Programs, also known as Fueling Supervisory Courses. Topics in these courses related to fueling include proper handling and storage of fuels and lubricants, oxygen, fuel flash points, situations requiring cessation of fueling procedures, safety awareness (location of fire extinguishers, use of emergency shutoffs, and communications for assistance), emergency procedures/notifications including spill control/containment and cleanup procedure. [13]

One of the safety procedures outlined in FAA Advisory Circular is the dead-man system. [17] As can be seen in *Figure 4*, the dead-man system is a commonly used protocol for dispensing fuel into an aircraft. This control can come in the form of a handle; touch sensor, pedal, or regular switch. It is generally built into the manual over-wing nozzle of the plane. [1] After the nozzle is locked into the aircraft and the operator depresses the handle, fuel begins to flow. [5] The primary purpose of the dead-man control is to halt fueling if the attendant should for any reason release the control.

iii. Containing and Cleaning Fuel Spills

The FAA has written a general containment procedure to follow in the case when a fuel spill does occur. The first step is for the emergency response team to insure the safety of the passengers and crew.

Figure 5. Yellow fuel-spill-containment boom [10]

Next, the response team place containment booms on the edges of the spill to prevent the spill from spreading any further (*Figure 5*). Once the spill is contained, the cleanup then begins. Air-driven diaphragm pumps may be used to pick up the spilled fuel and/or absorbent materials are placed on the spill to soak up the fuel (*Figure 6*). The absorbent materials are then disposed of in an environmentally responsible manner. After the initial cleanup procedure, the response team must inspect the surrounding area to determine if the spill reached soil or water, if so, the proper protocols such as soil removal or bio-remediation methods must be implemented immediately. [6].

Figure 6. Acid Neutralization of fuel [7]

Despite the preventative and contingency measures that are currently implemented at airports, fuel spills continue to occur due to human error, equipment failure or other factors. A speedy and efficient containment method is needed to reduce the danger, environmental risks, and financial risks of fuel spills. The solution proposed here is a system based on an apron constructed of pervious concrete and a fuel-spill-collection system to capture fuel spills immediately. With this system, spilled fuel does not pool on the apron and will not spread to the environment, eliminating most of the danger to human life, and eliminating all adverse environmental impacts. Additionally, the cleanup process is reduced to a simple flushing of the apron surface, which minimizes the downtime of the portion of the apron where the spill occurred.

II. Summary of Literature Review

To prepare the team for moving forward with a proposal involving a method to capture fuel spills at airports, a thorough literature review was conducted on related topics. The primary topics investigated fell into seven categories: FAA goals and plans, FAA guidelines related to fueling operations, current fuel spill cleanup and containment procedures, the impact of spilled fuel on the environment, pervious concrete and apron regulations, environmental benefits of pervious concrete, and FAA risk/safety assessment.

i. FAA Goals and Plans

In the FAA's 2009-2013 Flight Plan and Portfolio of Goals, the FAA defined a set of goals, which the FAA expects to be met within the next few years. When designing a better solution for fuel spill containment at airports, we made sure that our plan would help meet several of these goals.

One of the most important priorities of an airport is to ensure the safety of passengers. In the event of a fuel spill during aircraft fueling, the life of every passenger on an airplane becomes at risk. Any kind of spark can ignite the fuel spill, which can lead to the plane catching on fire. One of the objectives listed in the Portfolio of Goals is to ―reduce commercial air carrier fatalities" [13]. With the use of pervious concrete, fuel spills would immediately flow off the surface of the apron, which in turn would decrease the chance of a fire.

One of the main goals of our fuel spill plan is to prevent fuel from entering the water supply. When the fuel is drained through the pervious concrete, valves will be closed to prevent fuel from entering the soil, nearby streams, and groundwater, and the spilled fuel will be captured in an underground tank. Our plan will help the FAA ―address environmental issues" [18], as the introduction of unwanted chemicals into the water is dangerous not only for people but for all forms of life. Our plan will also help the FAA meet the goal to have ―no significant property damage to the uninvolved public" [18] because the system proposed here will prevent fuel from entering a community's water supply.

ii. FAA Guidelines Related To Fueling Operations

The FAA poses several guidelines related to fueling aircraft. These guidelines ensure the safety of fueling personnel as well as the safety of passengers and the environment. Fuel spills pose environmental hazards as well as public safety concerns. In order to avoid these risks the FAA guidelines must be strict and aim to prevent any possible scenario from occurring. Currently, the NFPA, National Fire Protection Agency, sets the standards for aircraft fuel servicing, as described in NFPA 407: Standard for Aircraft Fuel Servicing. [19]

Every few years the NFPA renews its guidelines, with 2007 being the latest renewal. The guidelines are set for fuel tank design as well as operations. The NFPA 407 guidelines range, for example, from the types of hose to be used to the location of radar equipment. Guidelines specific to fueling and fuel spills state that a ―dead-man" control is to be located on the valve that controls the flow of fuel to the aircraft [19]. This control is a switch that must be held by the fueling operator. Should the operator become incapacitated, the switch would release, signaling the fuel system to stop the flow of fuel [19]. The fuel control valve can be the hydrant pit valve, at the tank outlet on a tank vehicle, a separate valve on the tank vehicle, or on the hose nozzle for over wing service [19]. Aircraft fuel servicing vehicles must have two fire extinguishers, one mounted on each side of the vehicle [19]. Emergency fuel shutoff controls must be made available as well [19].

For fueling operations, only personnel trained in the safe operation of fuels and equipment, operation of emergency controls, and emergency procedures can be permitted to handle fuel [19]. In order to prevent a spill, fuel servicing equipment must comply to regulations and be maintained in safe operating conditions [19]. Leaking or malfunctioning equipment must be removed form service [19]. All hose is to be removed after the fueling of an aircraft [19]. Pumps must be used when filling from tanks with over a 5-gallon capacity [19]. While the airplane engine is operating, fueling is prohibited [19]. While lightning occurs in the near vicinity, fueling is to be suspended [19].

When a fuel spill occurs, the fuel servicing is to be stopped immediately by release of the dead-man control [19]. If a spill is to continue, the emergency shutoff valve is to be set [19]. The supervisor is to be notified immediately and operations cannot continue until the spill has been cleared and conditions are safe [19]. If a spill covers over 10 feet in any direction, has a surface area of over 50 feet squared, continues to flow, or is hazardous to persons or property, then the airport fire crew must be notified [19]. The spill is to then be investigated [19].

iii. Current Fuel Spill Cleanup and Containment Procedures

While many precautions are taken to make sure that fuel spills do not occur, the fact is that these spills do still happen, which is why it is just as important to understand the steps that are currently taken once fuel is spilled. The current procedures for fuel spill cleanup involve many processes that require careful monitoring. First, if it is possible, a response team should try to use tools to recover the fuel and transfer it into containers or empty tankers. Airports often use air-driven diaphragm pumps to pick up the spilled fuel [20]. Next, the fuel must be cleaned up quickly using materials that are absorbent and easily disposable. Clay absorbents are the most common material used by most airports to soak up spilled fuel. Another material, called ―Aqua-N-Cap" polymer [7], was recently developed and found to absorb spills more quickly and more effectively than the clay absorbents.

After the initial cleanup procedure, the response team must proceed with secondary containment. Secondary containment refers to the containment or capture of fuel that has spilled in order to prevent its release into the environment. Some tools used to achieve this are ―dikes, curbs, oil/water separators, drip pans, and collection systems. Additional examples may include remote secondary containment such as floating booms and flow diversions utilizing basins, sumps, ponds, etc." [21] Finally, the waste from the cleanup must be disposed as chemical waste and taken away by a licensed collector [7].

iv. Impact of spilled fuel on the environment

Jet fuel can cause substantial damage to the environment. Therefore, immediate action must be taken to ensure that spilled fuel is quickly contained. Fuel may spill into the surrounding soil, into both water bodies (such as rivers, lakes, etc.) and the groundwater. _Soil contaminants, such as jet fuel, can have significant deleterious consequences for the ecosystem. Radical soil chemistry changes can arise from the presence of many hazardous chemicals even at low concentrations of the contaminant species, e.g., alteration of metabolism of endemic microorganisms and arthropods resident in a soil environment.'[27] Water pollution caused by jet fuel spills can also have devastating effects on the ecosystem.

On February 12, 2011, 150 gallons of fuel spilled onto the apron at the Bradford County Airport in Towanda, Pennsylvania. The fuel flowed past the pavement and into the soil. In order to minimize environmental damage, the Pennsylvania Department of Environmental Protection ordered the removal of the contaminated soil [2].

On November 7, 2006, over 1 million liters of jet fuel spilled out of the OR Tambo International Airport and into the Blaauwpan Dam in South Africa. The spill caused massive damage to the ecosystem—polluting the water and contaminating over 5,000 cubic meters of soil. Environmental officials reported deaths of small animals and birds [22].

v. Pervious Concrete and Apron Regulations

Because our proposed solution to the fuel spill problem involves the use of pervious concrete, a review of the literature relating to pervious concrete was undertaken. Pervious concrete is a special kind of concrete that allows liquids to pass through it. Pervious concrete consists of specially formulated mixtures of Portland cement, uniform, open-graded coarse aggregate, and water [23]. Without the fine aggregate that is added to conventional cement, the resulting concrete is porous, allowing liquids to pass through the voids. Typically, pervious concrete is used as a substitute for conventional concrete for sustainable construction and storm water management.

Pervious concrete is a possible solution to fatality and damage caused by fuel spills, and there are both advantages and disadvantages to using it. Pervious concrete is desirable compared to metal grates, because the grates will cause the concrete surrounding it to crack and crumble. In addition, pervious concrete provides much more surface area for draining than strategically placed metal grates would.

Choosing the right recipe for the concrete is important; more air in the concrete means that it is more resistant to being weakened, but it also means that the mixture contains less water and holds a smaller peak load. Choosing the aggregate to cement ratio is important as well; more cement means stronger concrete, but slower drainage through the concrete [24].

vi. Environmental benefits of pervious concrete

According to The Concrete Network, normal concrete creates _an imbalance in the natural ecosystem and leads to a host of problems including erosion, flash floods, water table depletion, and pollution of rivers, lakes, and coastal waters as rainwater rushing across pavement surfaces picks up everything from oil and grease spills to deicing salts and chemical fertilizers [25].

Pervious concrete, however, has the _inherent durability and low life-cycle costs of a typical concrete pavement while retaining storm water runoff and replenishing local watershed systems. Instead of preventing infiltration of water into the soil, pervious pavement assists the process by capturing rainwater in a network of voids and allowing it to percolate into the underlying soil. In many cases, pervious concrete roadways and parking lots can double as water retention structures, reducing or eliminating the need for traditional storm water systems such as retention ponds and sewer tie-ins [25].

vii. FAA Risk/Safety Assessment

Safety, in the context of the Safety Management System (SMS), is defined as freedom from unacceptable risk and is therefore the principal consideration of all aviation activities and procedures [16]. For this reason, the FAA has set forth a detailed, five-phase protocol for Safety Risk Management (SRM). Current SRM protocol mandates that one must not only describe the system in which the risk lies, but identify, analyze, access, and mitigate any unacceptable risk present in the system as well.

Fuel spills, which pose a grave risk to humans, airports and the environment, are an unfortunate and inevitable reality that airports must be ready to combat. To mitigate risks associated with aircraft fueling, current FAA procedures mandate where aircraft fueling shall occur, require the use of a dead-man switch, and call for other precautionary measures. However, the guidelines leave much to be desired in providing information regarding the event of an actual fuel spill.

The SMS and SRM would both be utilized in reducing risks throughout the construction of an airport apron with pervious concrete. Aspects such as the weight capacity and permeability rates of pervious concrete must be considered [26].

III. Problem Solving Approach

Fuel spills at airports are a serious threat to life, aircraft, the environment, and airport infrastructure as can be seen in *Figure 1*, *Figure 2*, and *Figure 3*. Our team has proposed a fuel spill containment system that greatly reduces and in some instances even eliminates these threats. Michael Turek was recruited by Professor Ziegler as the project leader months before the team was formed to go over the challenges presented by the FAA Design Competition, and to start the planning for this project. Following a review of the Competition guidelines, it was decided to undertake the Airport Environmental Interactions challenge. Specifically, improving the containment and cleanup of fuel spills. Michael also met with Carl Beardsley, Commissioner of Aviation of the Greater Binghamton Airport, and Chad Nixon, Vice President of McFarland-Johnson, Inc. to discuss technical issues such as current airport guidelines for fueling a plane as well as guidelines for dealing with a fuel spill. Michael also visited the airport to learn firsthand how fueling is performed and to see the procedures involved when fuel spills occur. He also visited McFarland Johnson to meet the industry consultants who would be assisting the team. Several months later a team of 25 undergraduate students was formed and joined Michael on the project. Michael then split the team up into four smaller teams, the ―Design Team”, the ―Strategies and Ethics Team”, the ―Engineering and Graphics Team”, and the ―Risk Assessment and Research Team”. The ―Design Team” handled the technical design of the project, the ―Engineering and Graphics Team” narrowed down the problem. The ―Risk Assessment and Research Team” provided an overview of what was gleaned from the literature with a discussion of primary sources and their influence on the design. The ―Strategies and

Ethics Team" provided the approach to solving the problem. Joseph Macri was appointed as the Technical Leader of the project and he also led the ―Design Team." Joseph and Michael attended weekly meetings at McFarland-Johnson to discuss the project in more detail, as well as begin deeper research into the background of our problem and the technical aspects needed to achieve a solution. Each sub-team and the overall team met regularly and often to discuss the details and work together on the project.

Figure 7, Here is a photo showing Michael (right) at our pervious concrete test site

Figure 8, Michael (left) testing the pervious concrete with 11 gallons of water

The team proposed the idea of using pervious concrete as the primary material to capture fuel spills. An alternative of using metal grid drains to collect the fuel spill was discussed as well. After exploring the two possible choices, the team decided that the better of the two alternatives was the pervious concrete. Some advantages of the metal grid drains were that they would be easy to install into the apron, and their high strength. Some disadvantages included that the grid drains would cause some weak spots on the edges of the concrete where they would be installed. Due to this damage, grids can pop up and cause damage to aircraft passing over the metal drains on the apron. One advantage of pervious concrete is that it would reduce global warming effects because the sun would not bounce back off of it, and instead it would absorb the sun‘s energy. Another advantage is that there would be less pollution from rainfall run-off.

A test slab of pervious concrete is in place at Binghamton University and, was tested for porosity. As shown in *Figure 7* a grid of one-foot measurements was drawn on the surface of the concrete in order to measure the square footage per gallon required to capture a fuel spill. The test consisted of pouring 11 gallons of water as a test to represent the fuel as shown in *Figure 8*. The concrete took about 12 seconds to absorb the whole spill, and it required about 60 square feet showing that a fuel spill can be collected at the rate of about 1 gallon per second per 6 square feet of pervious concrete. This was proof that the team's overall premise of basing a spill control system on the use of pervious concrete was sound.

Figure 9, Commissioner Beardsley describing the layout of BGM

The team met regularly to discuss different ways that pervious concrete could be used to capture fuel spills. The entire team visited the Greater Binghamton Airport and met with Commissioner Beardsley as shown in *Figure 9*. At the airport, the team focused mainly where the planes are parked and fueled, and the process of how a plane is fueled, as shown in *Figure 10*. The fuel trucks were inspected as well, as shown in *Figure 11*, and the team learned about the protocols that are to be followed when fueling the planes.

Figure 10, The team and Commissioner Beardsley standing on the apron of BGM

Figure 11, Carl Beardsley showing the team how a fueling truck works

After visiting the airport, the class discussed the possibility of proposing individual fueling pits that were made of pervious concrete, and requiring planes to park on them when being fueled. After considering that the plane would need to be parked on the pervious concrete during the duration of the fueling process, the team then began to question how much weight the concrete would be able to withstand. The team also started to question how much the concrete would wear away. An interesting question was brought up about how the concrete would react during the winter. Since it is pervious, if traces of water that are left in the concrete started to freeze, would the concrete start to crack and become unusable. After many discussions and after much research, the team determined that the concrete could be mixed to a strength that can withstand the weight of planes, which is about 4000 pounds per square inch. The team also determined that pervious concrete is not more prone to freezing and cracking than traditional concrete.

The entire team was visited by Chad Nixon of McFarland Johnson, Inc. at Binghamton University, and he assisted the team by answering many questions as shown in *Figure 12*. Mr. Nixon described the technical aspects of the pervious concrete and shared his experiences with other airports. From his visit, we concluded that our original idea of having pads big enough to fit the planes would not be the best solution. The team then decided to use a large continuous area of the pervious concrete instead, as opposed to the idea of each plane having its own individual fueling spot of pervious concrete.

Figure 12, Chad Nixon at Binghamton University

After several weekly discussions, the team finally came up with what was decided to be the best approach to solving this problem. First, the size of the pervious concrete basins was determined. Then the team discussed how many fuel collection tanks should be used to capture spilled fuel. Then the team discussed how many valves the design should have in order to guide the fuel when it is passing from the concrete into the collection tank. The team decided that the design should have a system of pipes along with these valves underneath the concrete, so when rainwater could be diverted to an area for natural drainage back into the environment, and fuel would be directed into the containment tank. The valves will open or close depending on certain situations. When fueling occurs, the fuel tank valve will be open, and the storm water valve will close so the fuel will go into the collection tank if a fuel spill were to occur. When a plane is not being fueled, the storm water valve will be open, and the fuel valve will be closed to permit water to drain back into the environment.

IV. Technical Aspects Addressed

The proposal presented herein is to develop an automated fuel-spill containment system as an integral part of the construction of an airport apron. With this system, fuel spills are captured immediately, preventing fuel ponding on the apron, and eliminating any chance that fuel would enter the environment, terminal building, or any other undesirable location. The spilled fuel is collected in an underground tank for safe removal later. Cleanup is virtually non-existent, and delays on the apron are nearly eliminated.

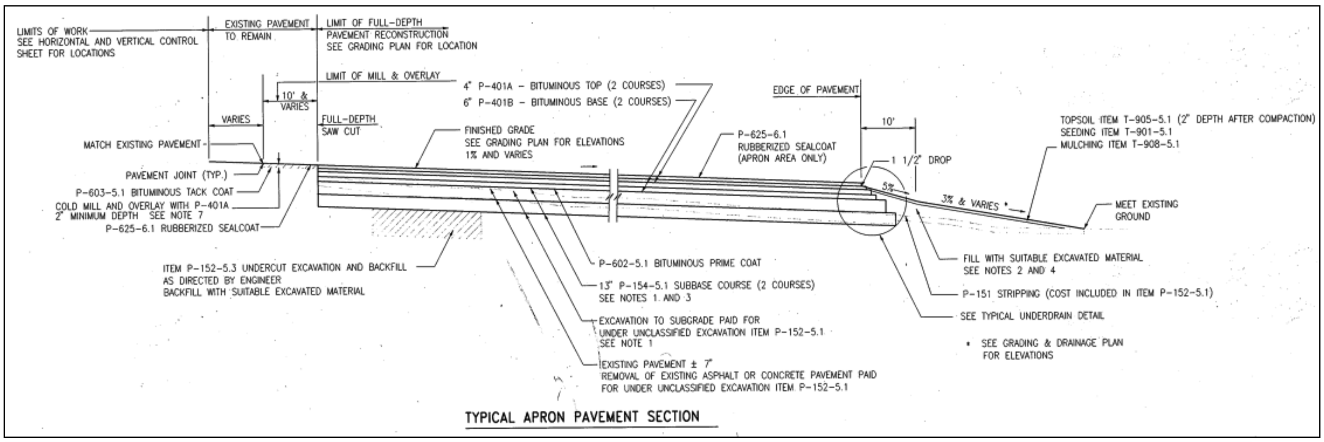

Figure 13, Detail of the concrete pavement. [28]

i. Background

As shown in the architectural drawing in Figure 13, the airport apron at the Greater Binghamton Airport, and at similar airports, typically consists of item P-152-5.3 undercut excavation and backfill as a base. Thirteen inches of P-154-5.1 sub base course is layered on top, followed by a course of P-602-5.1 bituminous prime coat. Six inches of P-401B bituminous base is then placed in 2 courses, followed by 4 inches of P-401A bituminous top placed in 2 courses. P-625-6.1 rubberized sealcoat is then placed as a final layer.

ii. Pervious Concrete

The primary design feature of the proposed fuel-spill containment system is the use of pervious concrete as the pavement product for airport aprons. Pervious concrete is a relatively new product that is currently being used as a way to permit rain and storm water to seep into the ground directly through the concrete, rather than creating runoff conditions that must be handled on the edges of concrete surfaces.

Figure 14, Pervious Concrete.

See *Figure 14* for reference. “This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other storm water management devices.” [29]

Another reason for the use of pervious concrete is to help the environment. Paved surfaces that do not allow the penetration of liquids could “create[s] an imbalance in the natural ecosystem and lead[s] to a host of problems including erosion, flash floods, water table depletion, and pollution of rivers, lakes, and coastal waters as rainwater rushing across pavement surfaces picks up everything from oil and grease spills to deicing salts and chemical fertilizers.” [25]

Pervious concrete is created by reducing the amount of sand in the sand, stone, cement, water mixture that makes up concrete. With reduced sand, the pervious concrete has a substantial void content. “Using sufficient paste to coat and bind the aggregate particles together creates a system of highly pervious, interconnected voids that drains quickly. Typically, between 15% and 25% voids are achieved in the hardened concrete, and flow rates for water through pervious concrete are typically around 480 in./hr. (0.34 cm/s, which is 5 gal/ft^2/ min or 200 L/m^2/min), although they can be much higher.” [29]

A/C Ratio	Water Content	Compaction Energy (kN-m/m^3)	Permeability (in/min)	Strength (psi)
4	0.372	0.013	215	1650
		0.033	125	2200
		0.066	65	2850
		0.099	60	3300
		0.132	55	3500
		0.165	30	4000
		0.198	20	4200
		0.264	15	4500
4.5	0.381	0.013	220	1450
		0.033	140	2000
		0.066	115	2300
		0.099	110	2500
		0.132	70	2700
		0.165	60	3000
		0.198	55	3200
		0.264	50	3550

Figure 15, Strength and permeability of pervious concrete. [24]

iii. Pervious Concrete and Fuel Spill Capture

The system proposed here, utilizes pervious concrete to drain spilled fuel through the concrete rather than permitting the fuel to pool on the surface of the apron. Spilled fuel runs through the pervious concrete, which is shaped (underground) in a manner that the fuel is funneled into an underground fuel collection tank. There are concerns that must be taken into account at the time and place of implementation. At the Greater Binghamton Airport, for example, one of the major problems with a drainage system is ice and snow buildup. In an 80-day experiment where various mixtures of pervious concrete were frozen and thawed once a day, the mixtures were still able to carry more than 95% of their original peak loads [29]. However, when the same mixtures were frozen/thawed five to six times per day they were barely able to maintain 50% of their original peak load [29]. It was noted that in this experiment, the percentages were off because of the concrete's draining property, but it shows that pervious concrete's peak load will decrease with freezing and thawing. To combat the freezing problem, experiments show that entrained air in the concrete paste makes it more resistant to peak load detriment. Unfortunately, putting air in the concrete mixture decreases the initial peak load as can be seen in *Figure 15*.

However, there are specific design considerations that can offset loss of strength in the concrete, including the use of cement with a higher strength than typical cement. Airport aprons are typically constructed of concrete that can withstands loads of up to 4000 pounds per square inch (psi) and research shows that pervious concrete can be constructed to withstand loads of up to 4000 psi as well, as shown in *Figure 15*.

iv. Technical Design Details

The automated fuel-spill containment system proposed here consists of four primary features, pervious and traditional concrete to capture a fuel spill, the piping system to channel the spilled fuel, a spilled fuel holding tank, and a valve system to open and close the system to capture spilled fuel or to drain rainwater.

a. Pervious and Traditional Concrete Apron

The primary component of the spill control system is concrete. Rather than an apron that is simply made of traditional concrete, the concrete in this system is divided into two layers. The top layer is

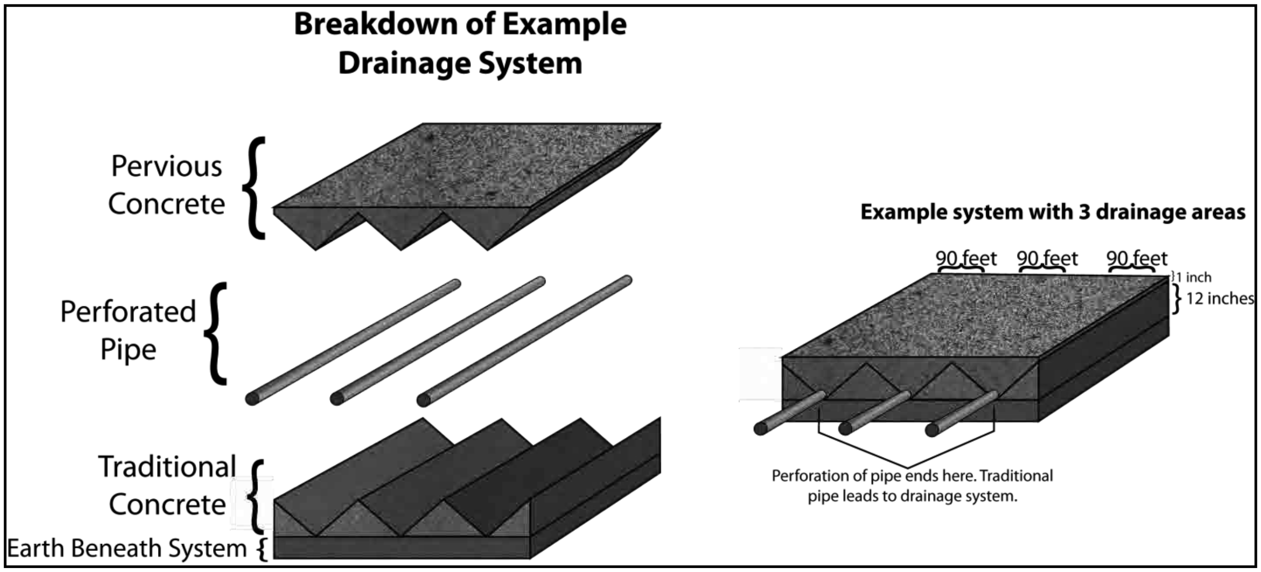

Figure 16, Breakdown of the system in a three dimensional view.

pervious concrete and the bottom layer is traditional concrete. The top layer of the apron (where fueling occurs) will have a 1-inch continuous layer of pervious concrete. As seen in *Figure 16* and

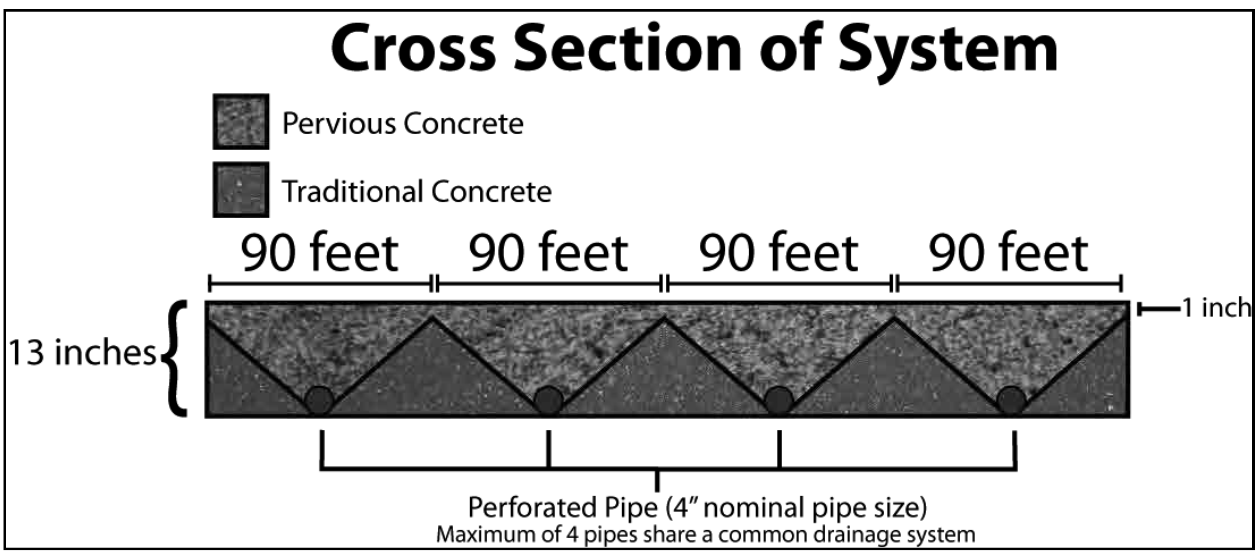

Figure 17, Cross section of the proposed system.

Figure 17, the apron will consist of a layer of 1" to 13" layer of pervious concrete (shaped like a V on top with a denser material consisting of traditional non-porous 1" – 13" concrete (also shaped like a V) on the bottom layer as shown in *Figure 16* and *Figure 17*.

The surface of the fueling area of the apron would be built in 90‘ widths and the length would be the length of the longest plane that would fuel at the airport. In order to support the largest plane at the Greater Binghamton Airport (BGM), the CRJ-200, each section would be 90‘ x 90‘. The pervious concrete will begin sloping 0.266 inches/foot after 1 inch deep allowing any fuel spilled on the surface to permeate and funnel to the bottom (13 inches down). At the bottom, there will be a perforated pipe, also seen in *Figure 16* and *Figure 17*. The purpose and specifications of the pipe is described below.

Heavy loads must be considered when making the concrete mixture, because less sand could mean weaker concrete. Less sand in the mixture allows for higher flow rates through the concrete, but a balance must be achieved to ensure structural integrity. However, pervious concrete can withstand loads of 4000 psi, as required for airport aprons. [24]

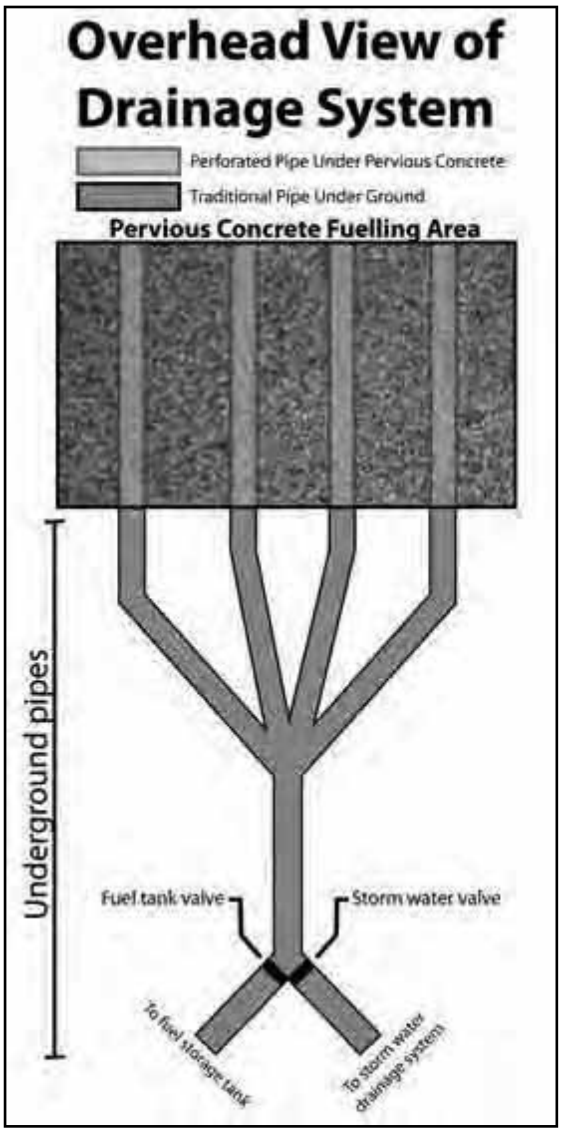

Figure 18, Overhead of System along with piping details.

b. Piping System

At the bottom (the low point of the pervious concrete), there will be a perforated pipe, also seen in *Figure 18* to collect any fuel or water that has entered into the pervious concrete. The perforated pipe that we propose is the SCH40/80 & DWV PVC Pipe perforated to AASHTO M278 from National Pipe & Plastics, Inc. Depending on the width of the apron used for fueling, up to four 90‘ sections of the collection system will have its perforated pipe connect to a single non-perforated pipeline to channel fuel or rainwater toward the fuel collection tank as can be seen in *Figure 18*.

As this pipe approaches the fuel collection tank, the pipe is split (using a Y pipe) into two paths, each blocked by a valve as shown in *Figure 18*. The purpose of the split pipe and valves is to channel spilled fuel into the holding tank, and to channel rainwater into an environmentally sound rainwater drainage system.

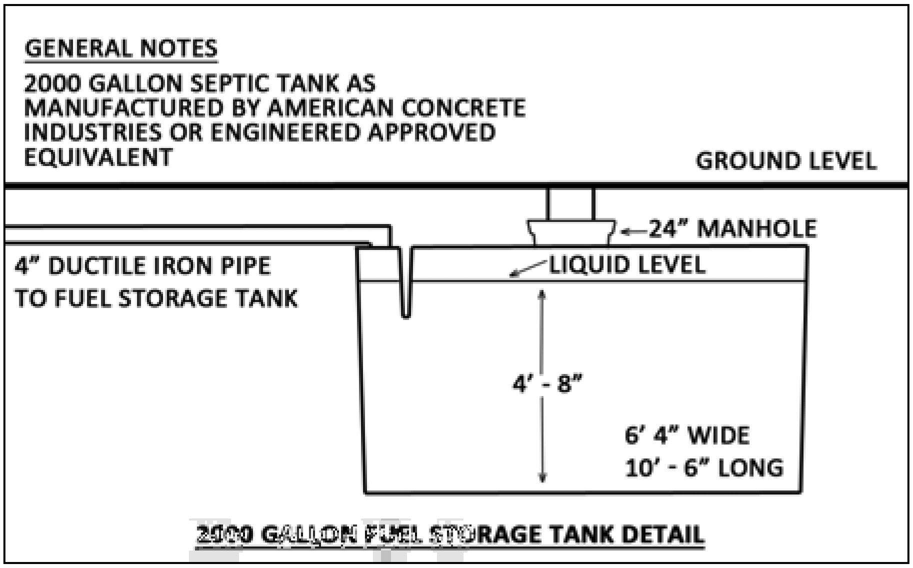

Figure 19, Fuel Storage Tank

c. Holding Tank

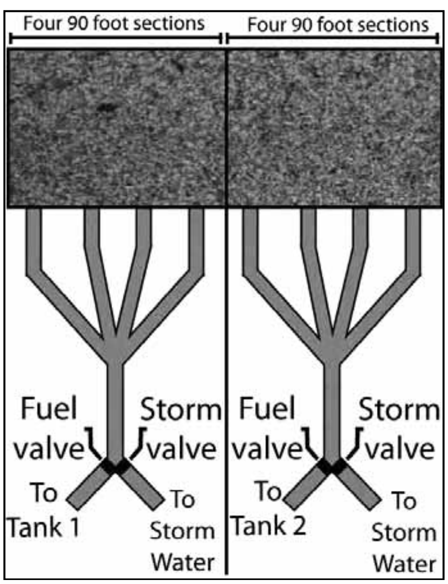

Figure 20, Example of the System for eight planes.

One of the pipes leading from the control valves will be connected to a 2,000-gallon holding tank, as manufactured by American Concrete Industries, item# 2062 [30]. There will be one holding tank, as shown in *Figure 19*, for every four 90‘ sections of the pervious concrete collection system. For instance, if the apron is designed for eight planes, there will be a section for each plane and two 2,000-gallon tanks, one for every four sections, as shown in *Figure 20*. The fuel storage tank will be located underground where the grass section of Greater Binghamton Airport is located. This is the section of grass past the north side of the apron. There will be solid ductile iron pipe going into the side of the tank, which is 4” in diameter. This pipe will be coming from the non-perforated pipe to transport the spilled fuel to the storage tank. The tank will be concrete with a 2,000-gallon capacity. The weight of the tank will be 16,200 lbs. There will be a manhole leading into the tank from the surface of the grass. This will serve the purpose of draining the tank once it becomes full with spilled fuel. The manhole will be 23.5” in diameter. There will be an 11” x 13” cleanout cover at each end of the tank. The concrete strength will be 4000 psi. *Figure 19* shows a model of the tank.

d. Valve System

In order to control whether the liquid from the drain pipe can enter the holding tank, there will be a valve system. Near where the primary non-perforated drainage pipe will enter the fuel spill holding tank, the pipe is split into two sections (via a Y pipe) and each leg of the Y will contain an off/on valve controlled by an operator on the surface. The valve for the water pipeline will remain open except during fueling. Before fueling starts, all valves will be closed. In the event of a fuel spill, the valve for the fuel pipe will be opened. The pipes will all have a pitch of 0.125 inches/foot to allow any liquid to flow properly.

v. Drainage for Rain Water

In the event of torrential rain during fueling, there is the question of whether or not the system will begin to back up since valves will be closed. During the design of the system, this problem was taken into account and the system provides enough volume to hold heavy rainfall without overflowing. The largest airplane at the BGM is the CRJ-200 ER, which has a maximum fuel load of 14,305 pounds [31]. Given the density of Jet A fuel is between 0.75 and 0.84 grams/ml at 15 degrees Celsius (59 degrees Fahrenheit), that means that the CRJ-200 ER can hold between 2,285.48939 and 2,040.61553 gallons [31]. According to Atlantic Aviation at BGM, a plane is fueled at about 100 gallons/minute, which means that it would take between 20.4061553 and 22.8548939 minutes to fuel. Assuming that rain fell at 1 inch per hour, a highly unlikely amount, 19,440 cubic inches of rainfall will accumulate over a 90‘ x 90‘ area per minute. The calculated volume of one section of pervious concrete is 8,164,800 cubic inches. The void content is 15% of that volume, which calculates to 1,224,720 cubic inches. Assuming an unlikely amount of 1 inch of rainfall per hour, it will take 63 minutes for a section of concrete to overflow, while the maximum time for fueling an empty CRJ 200 tank is less than 23 minutes.

vi. Technical Demonstration

In order to demonstrate the efficacy of our proposal, we followed standard industry practice for drainage and spill control. The general approach is to use a two percent grade towards the receiving drainage pipe [32]. Because soil erosion is not an issue, exceeding this grade would be ideal. Any fuel that settles in the interior of the concrete drainage body will need to be purged with water and possibly other fire control substances. Providing a steeper slope will guarantee that any residues will be less likely to collect after a spill. The viscosity of aircraft fuel is similar to water [33], so a simple high-volume wash would be sufficient to remove build-up.

Once fuel has reached the drainage pipe, the gradient should increase, as fuel should move quickly to avoid stagnancy in the concrete. When a fuel spill is detected, the solenoid-actuated valves will toggle to block fuel from escaping into the groundwater supply and open the receptacle leading to the fuel containment tank. These valves should be placed in proximity to one another, to limit the length of drain that needs to be flushed to ensure that fuel does not contaminate the runoff, which next traverses the pipe. In case of electronic failure, manual actuation of the valves is trivial by extending the manual valve controls to the surface. Once a spill is deemed contained on the surface and the flushing procedure is completed, the valves are again toggled, preventing fresh water from flowing into the fuel tank. This prevents both unnecessary cleanup costs and possible overflow of the containment area.

V. Safety and Risk Assessment

All changes to aviation related procedures, aircraft, or airport infrastructure require a thorough safety analysis. The FAA provides guidelines for assessing risk in its Safety Management System (SMS) Manual. The following components of the proposed system have been analyzed for risk according to the SMS Manual, including the durability of pervious concrete, the potential for containment system overflow, and the potential for fire due to jet fuel vapor. Weather related hazards include clogging risks due to snow or hail and reduced effectiveness of the system in adverse weather conditions. The FAA SMS Safety Manual provides risk classifications for analyzing procedures, construction, and other factors that could influence the safety of an airport [35]. The Hazardous Severity Classification Table is a table in the FAA Safety Manual and provides five classifications regarding a hazard‘s severity. These classifications are ―No Safety Effect", "Minor", ―Major", ―Hazardous", and ―Catastrophic".

Mix*	Compact. level**	Unit weight (lbs/ft3)	Void ratio (%)	Compressive strength (psi) 7-day	21-day	28-day	Split strength (psi)	Permeability (in./sec.)
No. 4-RG	Regular	117.5	25.3	2100	2385	2506	287	0.10
3/8-RG	Regular	116.9	28.8	1771	-	-	-	-
1/2-RG	Regular	112.9	38.8	1145	-	-	-	-
3/8-LS	Regular	104.1	33.6	1396	1663	1722	205	0.57
No. 4-RG-S7	Regular	127.7	18.3	3299	3380	3661	429	0.04
No. 4-RG-L10	Regular	138.2	12.9	3142	-	-	-	-
No. 4-RG-L5	Regular	120.3	26.0	1307	-	-	-	-
No. 4-RG-S7-L10	Regular	126.8	19.0	2969	3313	3349	453	0.07
No. 4-RG-S7-L10	Low	123.0	23.2	1737	1848	1960	197	0.26
No. 4-RG-S7-L15	Regular	132.2	14.1	2735	-	-	-	0.02
3/8-RG-S7	Low	121.6	22.5	2725	2735	2830	301	0.13
3/8-RG-S7	Regular	130.9	20.5	3262	-	-	-	0.19
3/8-RG-SF5	Regular	111.6	33.0	1347	-	-	-	-
3/8-RG-S7-L10	Regular	127.3	20.2	2641	-	2924	-	0.09
1/2-RG-SF5	Regular	110.5	33.6	1313	-	-	-	-
3/8-LS-S7	Low	107.8	33.2	1504	2024	2096	203	0.59
3/8-LS-S7	Regular	119.8	23.0	3229	-	-	-	0.09
3/8-LS-SF5	Regular	98.6	41.8	784	-	-	-	-
3/8-LS-S7-L10	Low	111.3	28.8	1796	1870	2045	201	0.25
3/8-LS-S7-L10	Regular	117.4	25.7	2483	-	-	-	0.19
3/8-PG	Regular	138.9	11.2	4027	-	-	-	0.004
No. 4-PG	Low	125.2	20.9	2526	2963	3113	249	0.13
No. 4-PG	Regular	125.3	22.6	2773	-	-	-	0.13
No. 4-PG-L10	Low	122.9	22.9	2099	2426	2452	231	0.28

*Mix Names: N-X-YJ
N = is the aggregate size which indicate the size of the sieve on which 100% of the aggregate is retained on
X = RG for River Gravel, LS for Limestone, PG for Pea Gravel
Y: S for Sand with J%, L for Latex with L%, SF for Silica Fume with M%
**Regular compaction indicates using a vibrating table with 0.005 inch amplitude and Low compaction indicate using a vibrating table with 0.0034 inch amplitude

Figure 21, Engineering properties of pervious concrete mixes. [33]

i. Durability of Pervious Concrete

It is necessary to keep in mind the inherent strength limitations of pervious concrete. Studies suggest that the addition of sand to a pervious concrete mixture increases its compressive strength but decreases its permeability. The proper combination of aggregate to sand to concrete must be attained to ensure maximum strength properties that still satisfy drainage requirements. The team has determined that this is not a problem, but it is a design feature that must be carefully considered.

The severity of the possible hazards due to the limitations of the durability of pervious concrete would be classified as minimal (5) on the Hazard Severity Classification table (Table 3.3 of the SMS Manual).

ii. Pervious Concrete Clogging Risk

The only real maintenance requirement of pervious concrete is a periodic de-clogging of the surface. There are two prevalent methods for effective de-clogging: power-washing and vacuum sweeping [34]. In this application of pervious concrete, where dislodged materials may adversely affect the environment, it is recommended that vacuum sweeping is performed when the permeability is noticeably affected. It is impossible to avoid the necessity of laying down sand in snowy climates. In order to avoid undue clogging, larger-grained sand should be used.

The severity of the possible hazards due to the limitations of the durability of pervious concrete would be classified as minimal (5) on the Hazard Severity Classification table (Table 3.3 of the SMS Manual) so long as the surface is properly maintained [35].

iii. Potential for Containment System Overflow

The extreme example where an airport employee does not notice a spill must be considered. The fuel capture basin is only able to contain a limited amount of liquid before it overflows. The basins are devised in such a way that each basin has a 1-inch lip of pervious concrete connecting it to other basins. Each basin is 90 feet wide and 90 feet long, 1 foot deep. Every 4 basins are connected together at the top with a 1” pervious layer of concrete and there is one 2,000-gallon tank connected for every 4 basins to hold spilled fuel once it passes through the pervious concrete. Carl Beardsley reported that a 500-gallon spill at Greater Binghamton Airport would be a very rare occurrence and would be considered a very large spill, so we have proposed a 2,000 gallon tank to safely assure that all spills can be safely captured. Each basin has a volume of 8,164,800 cubic inches as per the technical aspects addressed. Then, combined, ignoring the 1-inch lip, the 4 basins will have a volume of 32,659,200 cubic inches. Pervious concrete has a void content between 15- 25% [34]. Taking 15% of 32,659,200 cubic inches will yield 4,898,880 cubic inches. If a 1,000-gallon spill were to occur, it would require a containment capacity of 231,000 cubic inches. This would easily be contained in the 4,898,880 cubic inches of void space shared by the group of four basins. If an employee is unable to turn on the drainage system right away, the pervious concrete can easily contain this spill until it is properly flushed. This means the ―human element", which the Introduction to Safety Management Systems for Airport Operators identifies as a hazard, is a non issue since the system is able to accommodate much more fuel than would typically spill [35].

iv. Reduced Effectiveness of Pervious Concrete in Adverse Weather

Due to the porosity of pervious concrete, the effect of adverse weather conditions, such as freeze-thaw, has generated some concern. This is especially true in areas of hard wet freezes, areas where the ground stays frozen due to a long continuous period of average daily temperatures that are below freezing [36]. In areas such as these, it is important to ensure that there is a consistent porosity throughout the concrete structure so that damage from freeze-thaw can be prevented [37]. If there is not a consistent porosity then it is possible that cement paste and smaller aggregate can settle to the bottom during consolidation and seal off the concrete pores [37]. Surface water could potentially be trapped in pavement voids, where it can freeze, expand and break apart the pavement [37]. However, this can be avoided by considering certain design factors, such as permeability, degree of saturation, amount of freezable water, rate of freezing, and average maximum distance from any point in the paste to a free surface where ice can safely form [37]. To prevent pervious concrete from becoming saturated, the National Ready Mixed

Concrete Association (NRMCA) recommends an under-drain to drain the aggregate base, which is included in our design via a perforated pipe collection system leading to a fuel containment tank. [37].

With adverse weather conditions also comes an increased potential for clogging the pervious concrete. Clogging occurs because of fine particles that are deposited on the surface of the concrete from vehicles and the atmosphere, and will increase with age and use [37]. This does not cause the concrete to be impervious though, but instead only decreases the infiltration rate [37]. To decrease clogging, and therefore increase permeability, performing a vacuum sweep will help [37]. In cold climates, during time of snow and ice, sand should not be applied but plowing can be performed as with any other concrete. The performance of pervious concrete has been found to be good in cold climates since the rapid drainage of the surface reduces the occurrence of freezing puddles and black ice [37]. However, snow piles should not be left to melt on the pervious concrete because it will cause the concrete to receive a high sediment concentration, which will speed up clogging [37]. The severity of the possible hazards due to the limitations of the durability of pervious concrete in adverse weather conditions would be classified as minimal (5) on the Hazard Severity Classification table (Table 3.3 of the SMS Manual) so long as the surface is properly maintained [35].

v. Potential for Fire Due to Jet Fuel Vapor

Even after a fuel spill has occurred, and most of the fuel has been captured using the pervious concrete, there is a still a danger present [38]. Due to the fact that jet fuel is volatile, the jet fuel that remains inside the pervious concrete will vaporize, and extremely flammable vapor will still be present a short time after the fuel spill [38]. This is enough time for a potential fire, and the source of ignition must be equal or above the flash point of the jet fuel. The flash point is the lowest temperature at which the vapors above a flammable liquid will ignite on the application of an ignition source [38]. The jet fuel used across the United States is ‗Jet A', this fuel is Kerosene-type fuel, which means that it is a lot less volatile than non Kerosene-type fuel. The minimum flash point of this fuel is 38°C (100°F) compared with 0°C

(32°F) of the former. Therefore the risk of fire occurring has been reduced because of the higher flash point, although the threat is ever-present. The pervious concrete will take in a very large majority of the fuel spill, and the residue will be sprayed away. The possible hazard severity as described in the FAA Safety Management System Manual would be classified as ‗No Safety Effect' for when jet fuel vapor is present. (Table 4.2 - Severity Definitions) [35]. This, coupled with the safety procedures that are already in place, ensures that the risk is minimized to the full extent.

In summary, upon an analysis of the five most critical factors of this design in terms of safety and risk, the Risk Assessment sub-team has determined that the overall risk of the system is classified as minimal.

VI. Interactions with Airport Operators

To obtain expert advice regarding the project, the team interacted with various aviation industry professionals. These professionals helped the team solve issues with the project and helped shape the design. A large part of the team's industry collaboration was with Chad Nixon, Vice President of McFarland Johnson, Inc., and Carl Beardsley, Commissioner of Aviation for the Greater Binghamton Airport (BGM). *Figure 22* lists the industry professionals the team contacted throughout the project.

Name	Title	Employer
Carl Beardsley	Commissioner of Aviation	Greater Binghamton Airport
Chad Nixon	Vice President	McFarland Johnson
Dr. Stewart Schreckengast	Visiting Associate Professor	Purdue University
Dave Smith	Planner, Aviation Division	Sea-Tac International Airport

Figure 22. Experts consulted throughout the project

The Greater Binghamton Airport was used as the model to learn about fuel spills at airports. As can be seen in *Figure 23*, the team worked with Commissioner of Aviation Carl Beardsley, who helped in the preliminary planning stages.

Initially, the team sought to understand the current protocols and regulations governing fuel spills. The team learned of other drainage systems currently in place at the airport, particularly for draining glycol during aircraft deicing. At the airport, the team viewed current schematics for the apron and began to discuss different possible configurations for the layout of the pervious concrete pads and different configurations for the tank and pipes. Commissioner Beardsley assisted as the team sought to more fully understand the hazardous effects of fuel spills on the airport, and to what scale of spills had occurred previously. After some deliberation, the team studied the apron on-site at BGM to get a preliminary estimate on the size of the concrete pad. The team also took note of the icy conditions on the apron as seen in *Figure 24*, due to the lack of the use of salt. The team learned that salt cannot be used at airports because of its corrosive properties on the planes.

Figure 23. Commissioner of Aviation Carl Beardsley explaining an airport schematic to the team

Figure 24. The team discussing the icy conditions with Commissioner Beardsley

At BGM, the team also studied the fueling process. The team observed a fueling truck (*Figure 25*), along with all of its controls, hoses, and ladders, to better understand how fueling actually happens. The team also noted the position of the gas tanks on a typical regional jet (*Figure 26*), which is on the upper side of either wing.

One of the team's contacts was Dave Smith, a planner with the Port of Seattle's Aviation Division at Sea-Tac International Airport. Mr. Smith and his associates provided the team with information regarding pervious concrete. Smith said that a benefit of an impervious surface is that a fuel spill on top of it can be easily identified, tracked, and cleaned. However, a porous surface, without an impervious surface underneath it, would allow the fuel to seep down into the ground. The system proposed herein addresses this obvious issue by utilizing an impervious surface underneath the porous surface, which will force the fuel to a tank. The pervious concrete would have to be washed down with high pressure water to keep the spilled fuel out of the concrete after a spill. Finally, Mr. Smith noted that the concrete might not be strong enough to hold a large plane. This was of course a concern for the team which was later addressed. These were simply ideas to think about, and when the team consulted with Chad Nixon, they asked him for possible solutions to these problems.

Figure 25. A fueling truck at Greater Binghamton Airport

Figure 26. Commissioner Beardsley showing the location of a gas tank on a typical regional jet

Another contact was Dr. Stewart Schreckengast, Visiting Associate Professor in the Aviation Technology Department of Purdue University where he conducts aviation safety and security research. Dr. Schreckengast gave the team some situations to think about. First, the biggest danger with a fuel spill is not the liquid, but the vapors. Trapping the vapors in concrete on a hot day could be dangerous, as it could potentially explode. Also, the concrete would only be effective during dry periods where rain or snow would not be a concern, which would ensure that only fuel would be captured. A possible solution to deal with the vapors, Dr. Schreckengast suggested, would be to have a ventilation system in the concrete where the fuel and vapors can be sucked into a flameproof containment system; a solution which can be easily implemented within our system. The team used the comments made by Dr. Schreckengast to guide our design and avoid the problems he outlined.

In our meeting with Chad Nixon, Vice President of McFarland Johnson (*Figure 27*), many questions that the team had were answered. In the session, the team, along with Nixon, agreed that a large continuous rectangle of pervious concrete was the desired design instead of patchworks beneath each fueling area.

Figure 27. Chad Nixon works with the student team on-site at Binghamton University

Mr. Nixon suggested that metal reinforcement should be included in the pervious concrete design to strengthen its integrity. The group discussed possible solutions to prevent ice from clogging the pervious concrete, and ultimately determined that icing is not typically a problem. Nixon explained the difference between BGM and other airports. The way that one airport operates can be entirely different from another. The size of an airport can also change the way it is run. Some airports, in order to maximize efficiency, will fuel and de-ice in the same area. The team learned that at BGM, de-icing is performed in a separate area than that used for passenger loading and fueling.

In summary, the interactions with industry experts assured the team that the design being proposed, while using BGM as its model, can be applicable (with minor changes) to other airports regardless of size or climate.

VII. Projected Impacts of Design

i. FAA Goals

There are four primary objectives of the FAA Portfolio of Goals.

1. Increased Safety – Achieve the lowest possible accident rate and constantly improve safety.
2. Greater Capacity – Work with local governments and airspace users to provide increased capacity and better operational performance in the United States airspace system that reduces congestion and meets projected demand in an environmentally sound manner.
3. International Leadership – Increase the safety and capacity of the global civil aerospace system in an environmentally sound manner.
4. Organizational Excellence – Ensure the success of the FAA's mission through stronger leadership, a better-trained and safer workforce, enhanced cost-control measures, and improved decision-making based on reliable data [13].

The project proposed herein supports each of these goals.

Increased safety – Fuel spills are extremely dangerous to airline personnel, passengers, and the local environment. Fumes and potential of fire endanger human life, equipment, and airport infrastructure. The current fuel containment and cleanup methods require manual intervention from personnel and leaves fuel in close vicinity of passengers that may have already boarded the affected aircraft. The pervious concrete system proposed here would allow fuel to drain immediately away from the passengers and no first responders will come into direct contact with any flammable substances. The efficient containment of the spilled fuel prevents the disastrous release of contaminants into the surrounding soil, surface water, and groundwater. This process would be a valuable addition to the FAA's Safety Management System [18] by allowing a reliable and data based approach to fuel containment

Greater Capacity – To avoid excessive delays and congestion, it is important that fueling is able to occur at the same time as other necessary flight operations. This becomes increasingly dangerous, as a fuel spill in these conditions would be extremely difficult to control. The high number of support personnel and taxiing aircraft could inhibit the timely response of emergency vehicles. A pervious concrete spill control system would immediately capture the spill, minimizing the risk to personnel and property, while still permitting operations to meet the hard deadlines required for efficient and on-time flights.

International Leadership – Technology is an incremental process. By being the first to adopt an effective and environmentally sound fuel spill control system, the US could stand as the model for other nations aspiring to conduct conscientious airport operations. By providing assistance to airports in other countries, the FAA could satisfy its requirements for nations using NextGen Technologies [18]. The drive to new and innovative designs would reflect positively on the FAA and prove its organizational flexibility.

Organizational Excellence – Passenger safety, worker safety, environmental concerns and cost-control are very important issues to consider. The difficulty is that fuel spills inhibit the effectiveness of these. Cleaning up fuel is inherently dangerous, expensive, and time consuming. By automating, fuel spill control risk to worker health, worker safety, and the environment becomes minimal during a fueling accident. Cost-control is also strengthened, as there is no longer a need for expensive decontamination protocols and public relation issues. Many consumers place a high premium on environmental consciousness and proving commitment to this end would be beneficial. Through a one-time expenditure for the construction of the pervious concrete system, the cost of future spills is amortized, and possibly eliminated.

ii. Commercial Potential

This project has high commercial potential. The project we have designed has potential to positively affect the environment by making fuel spills easier to handle. Not only will our proposed solution bring ease to the cleanup of fuel spills; it will also greatly help the environment.

With the installation of the proposed system, cleaning up a fuel spill simply requires opening a valve to release the fuel from the pervious concrete basin into a holding tank for later disposal. For maximum safety, water could be used to flush the fuel completely through the pervious concrete, a simple process that can be accomplished in just a few minutes. This is certainly a much safer and simpler procedure than current methods of dealing with fuel spills. The safety factors and ease of the new system has the potential to provide commercial benefit to all airports.

With the installation of our proposed solution, there are also great environmental benefits. The fuel will be collected immediately eliminating surface pooling of fuel and all environmental risks. Going ‗green' is currently a popular business expenditure and this proposal is certainly follows a ‗green' initiative.

iii. Processes for Implementation

Common steps must be taken when planning to install this proposed pervious concrete fuel spill system. These include deciding the number of pads, the number of collection tanks, and their placement.

The first common step for installing any implementations of this pervious concrete-based fuel spill control system is to excavate the area that will house the pervious concrete. The dimensions of this excavation will have to be large enough to satisfy the dimensions of the pervious concrete system as can be seen in *Figure 16*.

If an airport is installing a new fuelling area, rather than modifying an existing one, impervious concrete must be laid in the shape shown in *Figure 16* and *Figure 17*. These ridges of impervious, traditional, concrete will serve to house lengths of perforated pipe. Preparing an airport whose fueling area is already paved will require an initial set of steps that would not be necessary if the area was built from scratch. This simply means that the existing pavement must be cut out where the pervious pads are to be installed. After this has been finished, the remainder of the process is exactly the same for an airport that is installing this solution to a new fueling area.

Once this basic layout of the pad has been dug and the impervious layer has been set, the perforated pipes and pervious concrete must be installed. Perforated PVC pipe will be placed where the center of each v-shaped valley so that it can be embedded in the pervious concrete layer. The pervious section of concrete can then be poured on top of the impervious ridges of concrete, taking every precaution not to plug any of the pipes with any concrete. Covering the perforations with a degradable material that dissolves after the concrete hardens will preserve them. An example of the slab can be seen in an exploded view in *Figure 16*.

The next step is to install the pipes that will lead to the tanks. These non-perforated pipes will connect the perforated pipes that lie below the pervious concrete.

The work involved in implementing this proposal is minimal when considering the amount of work that must be done to construct a non-pervious apron. Essentially the additional work is to separate the pervious concrete from the traditional concrete, to install the pipes that run to the fuel holding tank, and installation of the holding tank. From this standpoint, it can be seen that any apron replacement project could implement this fuel capturing system with very little extra monetary investment.

iv. Affordability and Utility

This project will help increase affordability and utility. After installation of the proposed system, dealing with future fuel spills will be both less costly, and less dangerous. The system will also minimize delays on the apron for cleanup. The system does not require additional personnel to operate, and virtually eliminates most cleanup personnel costs. The design uses gravity to pull the fuel spill away from the plane and towards perforated pipes for drainage. This will eliminate costs in treating the environment after the fuel spill, and because of its automated nature the design will also lower costs of cleanup personnel. When dealt with improperly, fuel spills can start huge fires that can result in injury, death, loss of the aircraft, and damages to airport infrastructure. In addition to providing a better fuel containment system, the system creates a ―green” method of dealing with rainwater, by permitting rainwater to enter the pervious concrete rather than creating the problems associated with pavement runoff.

	Labor Hours	Material Cost	Labor Cost	Equipment Cost	Total Cost	Total Cost with Overhead and Profi
15" Thick Concrete Pavement(Sq. Yard)	0.029	54.5	1	0.99	56.49	62.5
7" Thick Concrete Pavement(Sq. Yard)	0.015	25.5	0.52	0.52	26.54	29.5
Perforated PVC, 4" diameter(Linear Foot)	0.153	0.99	4.87	0.91	6.77	9.65
Ductile Iron Pipe, 4" Diameter(Linear Foot)	0.2	14.6	7.5	3.06	25.16	31
Butterfly Valve, 4" diameter(Each)	4	885	131	47.5	1063.5	1225
2,000 gallon concrete tank	5.6	1926	196	26	2148	2362.8
	All Units except for Labor Hours are in US Dollars					

Figure 28, Pricing information used to calculate the cost of the system [39]

The estimated cost of implementing a fuel capture system as proposed here can be determined from the following cost estimates as shown in *Figure 28*.

The concrete will be 13" thick. Each 90'x90' section of concrete will contain 1,166,400 square inches, or 900 square yards.

Don Harris, Senior Project Engineer of McFarland Johnson, has stated that the cost of implementing V shape cuts will slightly increase the cost of labor. Assuming the bottom layer of concrete will require approximately double the labor hours, due to the V shaped cuts, 52 cents will be added to each square yard. This brings the total per square yard to $30.02. We obtain the cost of the first layer of a 90' x 90' section by multiplying the square yardage to the unit cost, which is $27,018. The next top layer will be of pervious concrete. Don Harris stated that pervious concrete will cost approximately 1.5 times the cost of regular concrete due to increased production cost due to infrequency of use. Multiplying the unit cost of a 7" layer by a factor of 1.5, we obtain $44.25 per square yard. Multiplying the adjusted unit cost to the square yardage we obtain $39,825 per 90' x 90' section. This brings the total of one 90' x 90' section, obtained from the sum of the two separate layer costs, to $66,843.

Cost of perforated piping will be determined by the pipe length (90') and price per foot ($9.65). This brings cost of perforated pipe to $868.5.

Total cost of a 90'x90' section will be the cost of concrete in addition to cost of perforated piping. This brings the total to $67,711.50.

Additional costs are incurred from the fuel tank and piping leading from the fuel collection system. Every four 90‘ x 90' sections will connect to a 2,000-gallon concrete fuel containment tank and a water drainage system. When factoring in labor and equipment to the initial cost of $1,928.00 [40], the final cost of tank will be approximately $2,362.80. Total pipe length is determined by distance from the apron to the water drainage system. At Greater Binghamton Airport, according to Don Harris, this is approximately 320 feet. Therefore, for every four 90'x90' sections pipe length will be 320' plus additional connecting pipe, which can be estimated as a total of 360'. Therefore, additional pipe cost will be approximately $11,160. This brings the total cost for every four sections of 90'x 90' pavement to $284,368.80 plus two valves costing $1,225 each for a total cost of $286,818 per every four 90' x 90' sections, or 90' x 360' (32,400 square feet) area of apron.

Comparing this to the estimated typical apron cost at Greater Binghamton Airport of $225,000 for an area of 32,400 square feet, the fuel spill containment system proposed here adds an additional cost of $61,818 (286,818 - 225,000) or $1.91 per square foot and will pay for itself by eliminating clean-up expenses and flight delays during cleanup operations of the apron.

These figures represent a cost that is very reasonable considering the potential lifesaving benefit of the fuel capture system. Additionally, this system has the potential to eliminate all adverse environmental impacts of a fuel spill. Cleanup of the apron after a spill is minimal compared to current cleanup procedures that close an apron for extended periods of time. The chance of a fire following a fuel spill is greatly reduced. For an added cost of just $1.91 per square foot, the fuel spill containment system proposed here is well worth the investment.

Ongoing maintenance costs are minimal and no greater than a traditional concrete apron. Periodic cleaning to avoid clogging is necessary, but is not more labor intensive than the periodic cleaning of traditional non-porous concrete. Maintenance following a fuel spill is negligible compared to the costs, and delays associated with spills on non-porous surfaces. The life of permeable concrete is similar to that of traditional concrete and is not a factor.

VIII. Summary and Conclusion

Providing a fast, safe, cost efficient method of controlling airport fuel spills is an important priority of airports. Fuel spills are a hazard that can claim lives, destroy aircraft, damage airport infrastructure, and devastate the environment if not properly contained. Fuel spills that reach into the environment can cause long-term damage to humans, plants, and wildlife. In addition, fuel spills can be major fire hazards. Aviation fuel is highly volatile, which means it evaporates and produces vapors quickly. Fuel vapors are easily ignitable and explosive. This puts human lives, aircrafts, and airport infrastructure at risk.

Currently there are safety procedures that guide technicians to fuel aircrafts properly and minimize the chance of a fuel spill. Once a fuel spill occurs, however, it is the responsibility of the response team to assure the safety of the humans on or near the aircraft and to contain and properly dispose of the hazardous waste.

Working with industry professionals from McFarland Johnson, Inc., and the Commissioner of Aviation at the Greater Binghamton Airport (BGM), the team has a created a solution to immediately contain fuel spills, which minimizes the danger and cleanup associated with a spill. The proposed system utilizes pervious concrete in aircraft fueling areas, which allows liquids to flow through the concrete surface of the fueling area into a containment system, preventing the fuel from pooling, which creates an extremely dangerous fire hazard, and spreading to the environment. While extremely efficient in capturing a fuel spill, pervious concrete is only part of the solution. Underneath this layer of pervious concrete is the actual fuel containment system. The proposed containment system consists of triangular basins spanning the length of the apron, wherever fueling occurs. At the bottom of the basin is a semi-perforated pipe used to capture the fuel as it flows through the pervious concrete. This pipe leads directly to a 2,000-gallon tank reserved specifically for the containment of aircraft fuel.

In summary the fuel spill control system proposed here can provide a solution to the FAA environmental goal of improving methods for containment and cleanup of fuel spills, and could in fact save lives.

Appendix A: Contact Information

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Appendix B: Description of Binghamton University

Binghamton University is one of the 64 campuses and one of 4 university centers that make up the State University of New York. Located in upstate New York, Binghamton is proud to be ranked among the elite public universities in the nation for academics [41]. In a little over 60 years, Binghamton University has built a reputation as a world-class institution that combines a broadly interdisciplinary education with one of the most vibrant research programs in the nation [41].

Figure 29, Binghamton University [42]

Binghamton consistently ranks high among top publications that assist students and employers with determining the quality and value of a college education. *Kiplinger's Personal Finance* has ranked Binghamton University as the “number-one spot for out-of-state value” three years in a row, and sixth for overall best value [43]. *U.S. News & World Report* has ranked Binghamton University among the nation's elite universities for 13 years in a row [44], while *The Princeton Review* names it #6 in best-value for public universities based on academics, cost of attendance, and financial aid [45].

The 14,713 students that attend Binghamton University represent a variety of backgrounds. Students come from all 50 states and from 100 countries. Students of color represent 33.3% of the demographic, and 10% of students are of international standing. Students from the top 25% of their high school class are represented by 85% of the demographic. The average SAT score range is 1190-1340 [41].

Binghamton offers more than 80 majors for undergraduate students and more than 30 majors for graduate students. Binghamton employs close to 600 full-time faculty members, 93 percent of whom have PhDs or equivalents in their fields. The university received more than $44 million in outside research grants in fiscal year 2009-2010 [46].

Binghamton University is a part of the State University of New York (SUNY) system, and consists of six colleges: Harpur College of Arts and Sciences, Thomas J. Watson School of Engineering and Applied Science, Decker School of Nursing, College of Community and Public Affairs, the School of Management, and the School of Education. The Binghamton campus consists of a variety of residential colleges, including Dickinson Community, Hinman College, Newing College, College-in-the-Woods, Mountainview College, Susquehanna Community, and Hillside Community.

Appendix C: Description of Non-university Partners

McFarland Johnson, Inc. (MJ-Inc) is the team"s primary industry partner in the FAA competition. MJ-Inc, founded in 1946, is an employee-owned engineering firm headquartered in Binghamton, NY, with additional offices in Concord, NH, Canandaigua, NY, Putnam, CT, Saratoga Springs, NY, Hallstead, PA, South Burlington, VT, and Boston, MA. MJ-Inc is a leader in infrastructure planning as well as design and construction management [44], and the firm has been recognized with two Engineering Excellence awards from the American Council of Engineering Companies (ACEC) of New Hampshire, and one from ACEC of Vermont [54]. Recent projects include the LEED (Leadership in Energy and Environmental Design) certified Binghamton Intermodal Transit Terminal, as well as a major infrastructure upgrade for the Greater Binghamton Airport, and the ACEC-NH award-winning White Park Restoration Project in Concord, NH, which took full advantage of porous pavement for its environmental benefits [45] [46] [47].

Chad Nixon is Vice President and Business Development Officer at McFarland Johnson, and specializes in aviation planning projects. Mr. Nixon has also served in the US Navy as an air traffic controller, airport operations manager as well as aviation planner [53]. Nixon has had a strong relationship with Binghamton University, and this is also his third year advising for the Design Competition team.

The Greater Binghamton Airport (BGM) is the team"s primary airport partner on the FAA competition project. BGM is a regional airport in Johnson City, NY, eight miles to the north of the city of Binghamton, and serves both the Greater Binghamton Area and many of the regions surrounding it. BGM is a mid-sized airport, covering a total of 1,199 acres, and it has two runways. BGM offers direct daily flights to Detroit, Washington/Dulles, and Philadelphia [48]. BGM's airfield is named in memory of Binghamton resident Edwin A. Link, the inventor of the Link Trainer, the first aircraft instrument simulator. There is an original Link Trainer on display in the terminal building. [49].

BGM is overseen by Broome County Commissioner of Aviation Carl Beardsley. Beardsley has led the airport through a large increase in passenger traffic [50], and has worked with New York State and US legislators to secure funding for the continued development, maintenance, and expansion of BGM, including the addition of more regularly scheduled airline routes [51] [52]. This is Mr. Beardsley‟s third year assisting the Binghamton University FAA Design Competition team.

The team was also assisted by several consultants in the field of aviation. Dr. Stewart Schreckengast is a Visiting Associate Professor in the Aviation Technology Department of Purdue University where he conducts aviation safety and security research. Prior to joining Purdue in 2008, Dr. Schreckengast worked in the Office of the Secretary General of the International Civil Aviation Organization (ICAO), in the Implementation Support and Development Branch. Dr. Schreckengast provided technical support, training and assistance to ICAO member States in the implementation of ICAO Standards and Recommended Practices (SARPs). Specific areas of interest included Aerodromes, Accident Investigation, and Flight Operations oversight. He is an ICAO Safety Management System (SMS) Instructor and graduate of the ICAO Safety Oversight Assessment Training Program. He was also the Membership Chairman for the Montreal Branch of the Royal Aeronautical Society and coordinated numerous lectures and Branch events.

Dave Smith is a planner with the Port of Seattle‟s Aviation Division at Sea-Tac International Airport. With 24 years of airport experience, Dave provides technical support on a wide range of airfield and airspace planning efforts, including: airfield/airspace capacity and delay, demand forecasts and projections, and land use issues related to Runway Protection Zones. Mr. Smith also manages the Airport Layout Plan and Airport Overlays, and provides on-going coordination with the FAA's Airport District Office and with the Puget Sound Regional Council's aviation section. Dave began his career in the Airports Group with Transport Canada in 1983 as a Project Development Manager and subsequently moved to be an Aviation Specialist with the Capital District Regional Planning Commission in Upstate New York. Smith‟s other experience includes working for Bristol Aerospace and Pacific Western Airlines (aka Canadian). Dave Smith is a U.S. Certified Pilot, and he has a B.S. in Business/Aviation Administration from the University of North Dakota.

Appendix E: Evaluation of Educational Experience Provided by the Project

<u>Student Evaluation</u>

1. Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?

One of the greatest complaints of employers is that graduates do not have enough real-world experience, or overemphasize what little real world experience they have had [57]. In today‟s world, it is imperative for college graduates to face real-world problems that require them to brainstorm outside their domain and work as a team if they are to be successful. Unfortunately, many students lack these skills and are not ready to face the problems today‟s increasingly complex world presents.

Programs such as the FAA Design Competition give students the experience they need for the workforce and higher-level research. It provided our class, a talented group of aspiring computer scientists, with a means to develop the brainstorming, teamwork, and problem-solving skills today‟s problems require. Furthermore, the competition gave our class the opportunity to work with industry leaders, Chad Nixon and Carl Beardsley, and develop a system that significantly reduces the chances of a fuel spill that would otherwise endanger humans, airport infrastructure, and the environment.

2. What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?

Throughout the project, our team encountered several challenges. With no budget, and little experience at hand, it was very challenging to develop a system that can handle fuel spills on a large magnitude. We overcame the problems by testing our proposal on a smaller scale, and referring to Chad Nixon, Carl Beardsley, and the resources provided on the FAA competition website as necessary.

The biggest problem was developing and refining an effective solution to the fuel spill problem. After hypothesizing about how to take advantage of the properties of pervious concrete, the class experimented with a small plot of pervious concrete on campus. This was done to determine pervious concrete"s ability to collect water, which has a viscosity very similar to that of aircraft fuel. The results were very promising; the class brainstormed for several weeks as to how to use pervious concrete and refined the idea into a proposal.

3. Describe the process you or your team used for developing your hypothesis.

The class first considered how fuel spills are currently contained and considered the problems with the current system. Fuel spills are occurring nationwide on a regular basis, oftentimes on an extremely dangerous scale. Thus, the team thought the best way to approach the problem was to develop a more effective way to capture the fuel when it does spill, as the current procedure of attempting to contain the spill is slow, ineffective, dangerous, and costly.

After reviewing all possible considerations as to how to capture the fuel, the class chose pervious concrete as it was environmentally friendly, and is increasingly used in real-world applications to drain water off roadways and other surfaces. We experimented and researched into how we could use the pervious concrete for our project and eventually developed the proposal after many stages of refinement and consideration of the feedback received from industry leaders.

4. Was participation by industry in the project appropriate, meaningful and useful? Why or why not?

Working with industry professionals enabled our class to not only brainstorm a solution for fuel spills, but also to write a detailed proposal for the Federal Aviation Administration as well. Without the expertise of Chad Nixon and Carl Beardsley, completion of the project would have been much more difficult due to class"s unfamiliarity with the problem at hand. Moreover, without Mr. Nixon or Commissioner Beardsley, the class would have never had the chance to have an engineering firm provide feedback or visit the airport and see first-hand how and where the aircraft are fueled. Both were crucial to the success of our design and allowed us to avoid any potential problems well in advance.

5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?

The countless opportunities provided by the project will allow everyone who participated to be much more effective in the workforce. Having the opportunity to work first-hand with industry leaders, brainstorming a solution to a life-threatening problem, and putting the solution into a formal proposal for the Federal Aviation Administration gave the entire team the experience they need to understand, brainstorm, and solve real-world problems. The opportunities to converse, discuss, and refine a potential solution to a large-scale problem with industry leaders was in and of itself something few college students will have upon entry to the workforce, let alone all the other experiences and skills gained throughout the course of this project.

<u>Faculty Evaluation</u>

l. Describe the value of the educational experience for your student(s) participating in this Competition submission.

Real world experience can never be gained by sitting in a classroom. Several of my students participating in this competition have never even been on a plane; most have never consulted with experienced professionals, nor ever had to solve a technical problem that did not come out of a textbook. Certainly none of them ever experienced the once-in-a-lifetime experience of examining behind-the-scenes technical operations at an airport. They have never had to perform real research on a topic they began knowing nothing about, they have rarely worked in teams, and they have never had to collaborate with so many individuals. When they can learn and experience all of those lifelong skills by working on this project, then they truly have had an educational experience that is simply immeasurable in value.

2. Was the learning experience appropriate to the course level or context in which the competition was undertaken?

When I describe the project that my students worked on for the FAA competition, people are quite surprised that the primary goal of the project is to make my students better communicators. The competition was undertaken as a class project in a required senior level undergraduate course titled Professional Communication and Ethics. The course is intended to bridge academe and professional practice within the themes of communication and ethical decision making. The students in this project are stretched far beyond their comfort zone, but the learning experience presented by the FAA competition is exactly what should be expected of all students as they approach graduation.

3. What challenges did the students face and overcome?

There were four primary challenges that the students needed to overcome. First, the students are all undergraduate Computer Science seniors with no experience relating to air travel, airports, aviation, etc. However, they are experienced at problem solving, research, and communication, which are the foundations of the competition. Their lack of experience relating to the aviation industry took them far from their comfort zone and that was quite a challenge for them.

The second challenge was that of communication. The student team consisted of over 20 students, far too many for such a project. However, as the students learned, sometimes you have to seize the moment when opportunity arises, and the FAA competition was such a moment. As I tried to explain to the students, you do not always get to work on the ideal team, the perfect team size, or the perfect project; the idea is to learn and adapt as you go. They will realize later that the technical and communication challenges they faced on the FAA project prepared them well for the future.

The third challenge was that of motivation, and the methods to deal with the students who fall into the category of the *weakest links*. Some students are content to just *get by*, while others are striving for perfection. The challenge is how to deal fairly with the two extremes, especially in a competitive situation, where the weakest links can bring down the entire team. As a professor, I constantly face the reality that students rise or fall to their own motivations. However, for this competition, my role as professor turned into more of the role of a coach. I refused to allow the unmotivated students to bring down the rest of the team to their level, which required several very uncomfortable discussions with various individual students and teams during the project. There were times when I am sure that some of the students were not happy that I was making them rise to their true abilities. In the end, I hope they have learned the true meaning of teamwork and responsibility, and to take pride in their work.

The fourth challenge is getting all students on the team to understand the value of the FAA project. I do not think that all of the students grasp how real this is and how this competition will prepare them for the realities that will face them once they leave college. I try to follow the saying, "*keep talking, they'll listen*", but I wish they knew how valuable this experience is for them, right from the start.

4. Would you use this Competition as an educational vehicle in the future? Why or why not?

I am already making plans to enter my students in the competition next year. This has been a fabulous experience for not only the students, but also our aviation partners who assisted us in the competition, our local community, the university, and of course for me. I have reviewed and analyzed every action and decision throughout the competition with the goal of making the experience for my students even better the next time around.

5. Are there changes to the Competition that you would suggest for future years?

The FAA competition is by far the best-organized competition I have seen in my 33 years in higher education. Because my students are computer scientists, this competition was quite a stretch for them. However, the educational value and experiences presented by participating in the competition is simply unmatched anywhere else, so I am willing to go the extra effort to bring my students up to speed, just to be able to participate.

Because my students have submitted six proposals to the FAA competition in the last three years, I worry that fresh ideas regarding the topics listed in the competition guidelines may get more difficult for those of us who are regular competitors in the competition. I do not want my students to work on any projects that have been submitted to the FAA competition in the past, because I feel it will be too easy for them to use existing information rather than starting from scratch. I also do not want it to appear that we were copying ideas that had already been presented at some earlier time. I am not sure what can be done by the FAA to avoid this situation, but if the list of topics was expanded, that may help.

Regardless of any changes in the list of topics, I am looking forward to having my students compete again next year.

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Appendix G: Photo Gallery

Figure 30, Consulting with industry professionals at the Greater Binghamton Airport (BGM).

Figure 31, Students measuring the effectiveness of pervious concrete.

Figure 32, Students with Industry professionals at the Greater Binghamton Airport (BGM) examining a runway.

Figure 33, Industry professionals work with students at Binghamton University

Appendix H: Ethical Considerations

When jet fuel is spilled and it is not contained properly, it can have many negative effects on the environment. Grade A jet fuel is considered a light oil, so it will evaporate quickly, and it is highly volatile. It is also considered a highly toxic type of oil that can have environmentally devastating effects on both animals and aquatic plants [57].

Jet fuel can have many effects on humans, and when a water supply is contaminated. Jet fuel can cause reproductive and developmental problems, as well as acute toxicity, neurotoxicity, and cancer [56]. If the fuel comes anywhere near water that is used for human consumption, the water is rendered unusable, which happened at the Kirtland Air Force Base in 2010 [56]. Fish and marine plants can also be at extreme risk when there is a jet fuel spill. Fuel spills may harm fish by causing an enlarged liver, growth reduction, heart problems or respiration rate changes, as well as reproductive difficulties [56]. Fish eggs can also be damaged which in turn can jeopardize their chances of survival in the future. Marine plants have various reactions to the spill, with some experiencing some growth difficulties and others dying [56].

There also can be an effect on birds and mammals if they come into contact with the fuel. Physical contact can destroy the insulation of fur and feathers causing them to die of hypothermia [57]. If they come into contact with enough of the fuel, they can lose their ability to fly and cause drowning. In effort to clean themselves, birds and sea otters can ingest or inhale the fuel [57]. This can often result in lung, liver and kidney damage [57]. Fuel ingestion has also been shown to cause a suppression of the immune system, organ damage, skin irritation and some behavioral changes that affect ability to find food or avoid predators [57].

With the use of the fuel spill containment system proposed here, these environmental issues can potentially be minimized or eliminated. An additional advantage of the proposed system is its use of pervious concrete as the basis of the design. Pervious concrete is environmentally superior to conventional concrete in that it helps lower the risk of global warming because the heat from the sunlight is absorbed rather than bouncing back into the atmosphere. An obvious advantage is that the fuel will be contained so it will not have the potential to contaminate soil, surface water or ground water.

Appendix I: Biographies

Alexander Black

Alexander Black is a senior at Binghamton University and is expected to graduate with a Bachelor's of Science in Computer Science in May 2011. He spends most of his time at his job as Newsroom Technology Manager for Pipe Dream, a university newspaper ranked in the top 20 by the Princeton Review. Alexander is also the Webmaster for 31BondStreet.com and recently interned for the law firm, Hinman, Howard & Kattell, and LLC. While he has many interests, only one occupies his free time of late: the immensely popular computer game, Team Fortress 2.

Jonathan Ellenbogen

Jonathan Ellenbogen is currently a senior pursuing a Bachelor's degree in Computer Science at Binghamton University. He is currently employed at Apple Inc. where he works as a software engineer for the iTunes Storefront team. He deals primarily with Java, JavaScript and HTML creating many new frontend features of the iTunes store. He is also Co-Founder and Owner of Hoolip.com, a T-shirt company he and his partner started in the summer of 2010. He has used his skills to network many of the business relations needed to start a company and thrive in today's working world.

Jesse Elwell

Jesse Elwell is currently working on a BS in Computer Science at Binghamton University. Once the BS has been completed Jesse plans to attend Binghamton University to achieve a PhD also in Computer Science, his research interests include computer security and computer architecture. During the summer of 2010, Jesse was selected to participate in Binghamton University's Research Experience for Undergraduates and has been researching at least part time since then.

Laura Flower

Laura Flower is a senior from Albany, New York, majoring in computer science at BU. She plans to graduate in May 2011 and is still determining what area of computer science she would like to go into after graduation. Her interests include baking and traveling.

Leah Haas

Leah Haas will be graduating in May 2011 with a B.S. in Computer Science and a Minor in Mathematics. Previously, Leah has completed an internship at BAE Systems in Johnson City, NY during Summer 2009, and an internship at Lockheed Martin in Gaithersburg, MD during Summer 2010. Leah plans on attending graduate school next fall with a research focus in Data Mining. She is also a Peer Advisor at Binghamton University's Watson Undergraduate Advising as well as a member of the university's club Field Hockey team.

Phillip Hewitt

Phillip Hewitt is a senior at Binghamton University and currently in the last semester before he graduates in May. His first two years of college were spent at Broome Community College in their Computer Science department. In the fall of 2008 he transferred out of their program, and into the Watson School of Engineering, however he transferred out before receiving an associate degree. He is currently interning at the Student Athletic Success Center, helping out with their computers and handling any problems that surface. He hopes that when he graduates he will find a good job in the Binghamton area to be close to his family.

James Hill

James Hill is currently pursuing bachelor degrees in Electrical Engineering and Computer Science. He has experience as an intern from Good Technology with expertise in Web Programming and Digital Signals Processing. James is a member of the Electrical and Computer Engineering Honor Society Eta Kappa Nu. His personal interests include Juggling, Unicycling and playing Video games.

Edward Kaplan

Edward Kaplan is a Computer Science and Mathematics major at Binghamton University. He is currently a research assistant for the OSNET laboratory working under Kartik Gopalan. He is also the Webmaster for WHRW Binghamton and hosts the program "Throw Out Your Radio," now in its third year.

Jonathan Lam

Jonathan Lam was born and raised in Brooklyn, NY. He is a senior at Binghamton University and is expected to graduate in May 2011. He is currently double majoring in Computer Science and Economics. His varied academic interests include game theory, computer architecture, and the intersection between economics and computer science. Jonathan's hobbies include programming, bowling, and snowboarding.

Justin Li

Justin Li is born in China and raised in the United States. Currently working on is BS in Computer Science at Binghamton University; he likes politics and history and is also the Captain of the University Ultimate team. In his spare time, he enjoys the thrill that only Internet gaming can provide.

Joseph Macri

Joseph Macri is a Binghamton University student expected to graduate in may 2011. He is a Yonkers, NY native with a background in Computer Science. He currently works as a technical leader for his CS 495 class, which aims to design a fuel capture system for the FAA national level competition. As technical leader he works closely with McFarland Johnson, an engineering firm, in Binghamton, NY. As an intern he performs research as to the technical details of the project, as well as brainstorming ideas. He hopes to pursue a sustainable career in Computer Science to work on projects that aim to help current technological issues, which remain unsolved.

Dan McFadden

Dan McFadden is a senior Computer Science major. He had previously spent a year at the University of Maryland in pursuit of an English degree. His interests include Neural Networks, Data Mining, Quantum Computing, and Nascar.

Alen Muminovic

Alen Muminovic is a senior Computer Science major attending Binghamton University. He will receive his BS in Computer Science in May 2011. His interests in the field are in information systems architecture. He is a member of Upsilon Pi Epsilon. He is currently a Securities Lending Technology Analyst for Goldman Sachs & Co. in New York, New York.

Jon Perovich

Jon Perovich is a senior pursuing a BS in computer science at BU. He is currently a residential computer consultant for one of the dormitories on campus. His interests include skiing, programming, and playing tennis.

Joseph Sangiorgio

Joseph Sangiorgio is currently a senior computer science major pursuing a BS degree at Binghamton University. He has interned at the SUNY ATTAIN lab in downtown Binghamton, where he taught a semester-long class to the community regarding the essentials of computing. He has also had work experience at the Port Authority of New York and New Jersey, where he used his expertise to help create a web-based application that queried an external database. He has been both President and Vice President of Theta Tau Professional Engineering Fraternity. His primary research interests include cloud computing, as well as android application development.

Joseph Schechter

Joseph Schechter will be receiving a BA degree in Mathematics and a BS degree in Computer Science from the State University of New York at Binghamton. His interests include statistics, computer security, multimedia, and computer architecture. Joseph will be graduating from Binghamton in the fall of 2011.

Jared Schmitz

Jared Schmitz is working towards a BS in computer science from Binghamton University. He is currently employed as a research assistant for Binghamton University in the area of secure computer architecture. His interests include optimizing compilers, benchmarking, grid computing, systems programming, and secure virtualization. He is a member of the Association for Computing Machinery.

Daniel Scott

Daniel Scott attained the BTEC National Diploma in Business Management in 2009 after completing two years of study at Accrington and Rossendale College in Lancashire, England. The degree he is currently undertaking is a BSc Hons in Computer Science. Right now he is in his second year of university studying at Binghamton University in New York, USA. He is on a study abroad exchange program, with his home university being Lancaster University in Lancashire, England. He will return to Lancaster University to complete his third year of undergraduate study in Fall 2011. His previous jobs have included direct sales, telesales (including cold calling) and being a waiter. He is a member of the IET.

Tyler Stachecki

Tyler Stachecki is a three-year computer science major at Binghamton University. He serves as the university's chapter president of the Upsilon Pi Epsilon (UPE) and chapter treasurer for the Association for Computer Machinery (ACM). After graduation, he will begin pursuing a PhD in computer science with a concentration in distributed computing. His interests include competitive long-distance running, snowshoeing, and systems-level programming.

Michael Turek

Michael Turek is a senior at Binghamton University and the project leader of this project. He is graduating in May with a Bachelor of Science degree in Computer Science. He plans to continue his education and earn a masters degree in the field of Computer Science. In the past, he has been honored with the Lockheed Martin Scholarship for Excellence in Computer Science, Watson School of Engineering Dean's List, Hofstra Distinguished Academics Scholarship, and acceptance into Sigma Alpha Lambda National Honor Society.

Jason Wasserzug

Jason Wasserzug is currently a senior at BU. He will be continuing his education with BU in the fall of 2011 to obtain his masters in computer science. This summer, he will be working with Knolls Atomic Power Laboratory as an intern in the IT department. Jason has many interests, including: computers, competitive video games, sports, television and playing the piano.

Wilfred Wong

Wilfred Wong is a candidate for a BS degree in Computer Science from Binghamton University. He is currently a server-side developer at Interos LLC. located in Downtown Binghamton and has previously worked as an application and server-side developer for Behance LLC. in lower Manhattan. Wilfred is a recipient of the second prize in the Intel International Science and Engineering Fair (ISEF) in 2006 for his project, *Polycaprolactone-Chitosan Nanocomposite Biomaterials for Wound Healing and Tissue Engineering*, and has a minor planet named his honor for his research.

Paul Yi

Paul Yi is currently pursuing a Bachelor's degree in Computer Science at Binghamton University. He is the publicity chair of Asian Outlook, a student run organization in Binghamton University. His outside interests include drawing and writing.

Baote Zheng

Baote Zheng is pursuing dual degrees in both Computer Science and Global Business Management at Binghamton University, New York. He has experience in software and application development in multiple languages including C, C++ and Java. His interests include web design, graphic design, basketball and video games. He is also a member of Alpha Kappa Psi, a professional business fraternity, and UPE.

Appendix J: Milestones

Milestone 1: The project leader, Michael Turek, met with Professor Ziegler and discussed possible design proposals to compete in the Federal Aviation Administration (FAA) Design Competition. The "Airport Environmental Interactions" challenge was chosen as the category the team would work on in the competition.

Milestone 2: Michael Turek met with Professor Ziegler and decided to solve the problem where if, while fueling a plane, a malfunction or error occurs, and the fuel begins to spill. The proposed solution would be to use Michael concrete in the fueling area in order to capture the fuel spills.

Milestone 3: Michael and Professor Ziegler performed an experiment with Michael concrete and measured how fast the concrete absorbs water. Here are the results:

11 gallons spilled

12 seconds to capture the entire spill

60 square feet required to contain the spill

Milestone 4: Michael met with the Vice President of McFarland Johnson, Chad Nixon, and the Commissioner of Aviation at the Greater Binghamton Airport, Carl Beardsley. Michael took a tour of the fueling areas of the apron and the emergency services facility, and discussed our planned proposals. Michael, Mr. Nixon, and Mr. Beardsley decided that a sloped surface of solid concrete underneath the Michael concrete would be able to direct a spill towards a pipe that would lead the spilled fuel into a tank. The tank would hold onto the fuel, keeping it away from the soil and water in the ground.

Milestone 5: Michael and Professor Ziegler decided how to break everyone into teams and that there should be a short presentation when the entire team meets for the first time to explain the intended proposal.

Milestone 6: The entire team met for the first time. Professor Ziegler and Michael explained the problem we are attempting to solve and possible solutions. The responsibilities of each team were also discussed.

Milestone 7: The class was split into teams, and then all the sections of the document were explained to the teams. The distribution of work between the teams was also explained, and then the teams began to work on their literature reviews.

Milestone 8: The class visited the Greater Binghamton Airport. Commissioner Beardsley talked with the team about the layout of the airport and possible places for Michael concrete. The team inspected the area outside of the terminal, where the planes park, where the fueling trucks are parked, and where the planes are fueled.

Milestone 9: The team revised the ideas for placing the concrete. The way that the planes are parked and fueled would mean that putting circles of concrete for the area of fueling is no longer the best idea. The team continued to come up with more ideas given the new information about the layout of the Greater Binghamton Airport.

Milestone 10: Chad Nixon of McFarland Johnson visits the team at Binghamton University. Mr. Nixon discussed the technical aspects of the pervious concrete and his experience with airports. The team re-revised the plans for how to place the concrete and how the implementation plan could be refined. The team inspected a test slab of pervious concrete at Binghamton University.

Milestone 11: The team decided on the configuration of the concrete including a „W‟-shape for the intersection of pervious concrete with non-pervious concrete

Milestone 12: The team decided to design the fuel spill area in 90‟x 90‟ sections rectangular sections with „W‟-shaped sloped bottoms.

Milestone 13: The team decided to use one fuel collection tank for every four 90‟ sections.

Milestone 14: The team finalized the layout design for where valves, concrete, and tanks would be placed in order to best collect the spilled fuel.

Milestone 15: The team created engineering drawings of the system

Milestone 16: The team completed the FAA competition written entry