Project Deliverable [G]: Prototype II and Customer Feedback

GNG1103[F]: Engineering Design

Professor: Rubina Lakhani

Team 5:

Amenah Waheed (300018138)

Thomas Baycroft (300157691)

Krishna Patel (300171101)

Jonathan Rivington (300164793)

Lucy McKenzie (300120299)

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Introduction:

For Project deliverable G Team 5 will create a second prototype that will build on the feedback and knowledge gained following the making of prototype one. The second prototype will be higher fidelity than the first as we will build onto the design by showing the drainage system. The materials used for building this prototype will be purchased using the allocated $100. Another prototype will be made using Onshape. The team will conduct analytical experiments to ensure that the design is capable of meeting the clients needs. This report will begin by setting objectives to determine what Team 5 would like to accomplish from the second prototype. The team will then set forth testing objectives and stopping criteria that will aid the testing into achieving the desired results. In order for the team to take full advantage of each prototyping step, we will review the results from the past prototype and then justify and give reasons for the development from the last prototype to the current one. The development from the past prototype will also incorporate the clients feedback from the client meeting. Pictures and screenshots will be included at the end of the report showing the second prototype. The final part of this report will show the teams progress in Wrike.

Outline Prototyping Test Plan:

Initial tests (Table 3 of Appendix belonging on PD-F report) consisted of verification of basic aspects of the components of the system. For example, strength and basic functionality. In this project deliverable report, we will analyze analytical limitations of our constructed device and discuss methods and implementation that could take place in order to further optimize the functionality of our device (Reference Appendix A. Table 6). Analytical models and representations allow us to determine how the device will be able to function once implemented. This helps us determine if the device is feasible and makes numerical and physical sense. From this point on, prototypes, sketches and analytical models will include greater details and fixed dimensions and measurements. Prototype 2 is the first partially functional prototype fabricated for our device. As there are two different components that can be prototyped, the regular transporting panel with a simple central pipe as well as a T-sectioned panel that serves as the drainage system outputting the liquid precipitate into the sewer systems; we have decided to prototype a hybrid of the two to demonstrate both types of panels. This will allow us to test more elements of the device as well as be able to demonstrate more aspects of our prototype. This model serves as a basis for the upcoming prototypes and testing objectives, therefore the tests done with this prototype are research-based, analytical or experimental. These experiments tested for the sustainability of this device.

Description of Prototyping Objectives:

For this second prototype the team is going to continue to develop the design and build on what was learned from the first prototype. The main objective of the first prototype was to determine the assembly system and connecting system of the snow melting panels. What we were able to learn from that prototype is that the dimensions of the panels need to be kept to a height that makes stepping onto the panel safe and easy to do. We also learned that the connectors should be placed at the ends of the panels and closer to the corners to not get in the way of the drainage system. The OnShape model gave the team a good understanding of what the system should look like fully assembled and where each subsystem should be placed in order to not affect the other subsystems. This in-tales making sure the drainage system doesn't get in the way of the heating wires and also the connectors. To take the second prototype design to the next level the team will create both a physical model and a model using OnShape with the purpose of building a prototype that shows the design of the drainage system.

For this prototype there will be a few objectives that the team would like to accomplish. One of the objectives is to create a physical model of the previously designed drainage system and test its ability to funnel water from the top surface of the panel, down into the gutter and then out to the sewer. As mentioned in the introduction, the team will be creating the last two prototypes out of the $100 in allocated funds, the materials used to create this prototype will be the same materials used to create the final prototype. Therefore, it is expected that this prototype is held to a higher standard than that of the first. The second objective is to fully incorporate the out shell of the panel with the drainage system itself. This will mean connecting the piping from the drainage system with the body of the panel and doing so in a way that prevents any possible leaks or access from unwanted materials. The final objective for this prototype is to gain knowledge on the proportions of each subsystem and to see how much space is needed for the drainage system and further, how much space is going to be available of the heating systems wires. Although it has been already determined during the design, we would like to verify the proportions in this prototype to allow for the next prototype to easily include all three subsystems.

Testing Objectives & Stopping Criteria:

The initial testing objectives for the second phase of prototyping, presented in the PD-F, have been modified and extended to allow for more analytical data to be observed, regarding the functionality of the system. For the second phase of prototyping, the materials for the drainage subsystem were purchased and assembled. There were five main testing objectives for the drainage system, as well as a few recommendations for the third phase of prototyping.

The first testing objective measured the rate the water entered the system. This parameter was tested by pouring a measured amount of water (approximately 1 cup/0.2366 L), onto the grated surface and recording the time taken for the water to drain. The amount of water used should be measured before and after to ensure all the water is passing directly through the grated surface, no water remains on the surface. This test will be repeated, increasing the amount of water that is poured over the system. Three trials per each increase in water should be recorded. The stopping criteria for this test will be when the water begins to pool and spill over the sides of the system. This is an important parameter as the water needs to be able to drain at a sufficient rate, to prevent the pooling of water or snow from moving over the sides of the mat. This would create a potential slipping hazard and require another form of ice removal if the system were to fail (the temperature were to drop below the freezing point). This test is performed under the assumption that the temperature of the grated piece is the same as the water draining through, due to the heat transfer between the surface material and the liquid state of the water (undergone a phase change).

The second testing objective measured the rate of the water leaving the system. This parameter was tested by pouring a measured amount of water (approximately 1 cup/0.2366 L), into the internal piping system and recording the time taken for the water to travel through the pipe. The amount of water used for this test should be measured before and after. This test will be repeated, increasing the amount of water that is poured into the piping system. Three trials per each increase in water should be recorded. The stopping criteria for this test will be when the pouring rate of the water into the pipe exceeds the drainage rate of the water out of the pipe. This is an important parameter as the water needs to be able to drain out of the system at a sufficient rate, to determine the maximum drainage rate at this specific pipe diameter. This test is performed under the assumption that the temperature of the pipe and the water are the same, due to the heat transfer between the surface material and the liquid state of the water.

The third testing objective measured the functioning rate of the system at varying temperatures. This parameter was tested by pouring a measured amount of water (approximately 1 cup/0.2366 L), over the overall system, recording the time taken for water to drain throughout the overall system at different temperatures. The amount of water used should be measured before and after. This test will be repeated, decreasing the surrounding temperature of the system by testing the system under the following conditions: at room temperature, placing the system in an ice bath, and placing the system in a deep freezer. Three trials per temperature should be recorded to provide an accurate reading. The stopping criteria for this test will be when the water freezes within the system. This will determine the minimum temperature at which the system is able to function. This is an important limitation to the system to determine before use of the application in winter seasons with very low-temperature conditions. This test is performed under the assumption that each subsystem is fully functional in all testing conditions.

The fourth testing objective measured the volumetric flow rate of the system. This parameter was tested by comparing analytical data from previous wet and cold seasons, the average amount of precipitation and snowfall, to the volumetric flow rate the system is able to outsource. To complete this comparison, researched data and the volumetric flow rate can be determined manually and mathematically, reference Appendix A. Table 6. The requirement of two methods to determine the system flow rate is important, to reduce instrumental and analytical errors, as well as to allow for limitations of the system to be clear (maximum amount of liquid present). The stopping criteria for this test will be when the system is able to match the statistics researched. If the system does not meet the requirements, the different parameters of the drainage system must be manipulated until the system is able to withstand such weather conditions. This is an important limitation to the system to determine before use of the application, as one of the systems requirements is to successfully and safely remove melted ice and snow. This test is performed under the assumption that the overall system is fully functional, and the research gathered is accurate and based on the current living conditions in the city of Ottawa (as this test is primarily researched based).

The fifth testing objective measured the maximum capacity of the piping system. This parameter was tested by researching the restrictions and limitations of each component of the drainage system and recording the temperature and pressure of the drainage subsystem. This will be completed by comparing the analytical data from the manufacture and attached temperature and pressure sensors throughout the system, reference Appendix A, Table 6. Pressure and temperature are two variables that will impact the functionality of the drainage system. The stopping criteria for this test will be when the temperature or pressure of the system is within the acceptable range that will not cause damage to the internal components of the system. If the system does not meet the requirements listed, the different parameters of the drainage system must be manipulated until the system is able to withstand such conditions. This is an important limitation to the system to determine before use of application because if one of the components exceeds one of the limitations (either temperature or pressure), the drainage system could leak causing internal damage to the electrical wire, hardware within the system and wasted heat energy. This test is performed under the assumption that the overall system is fully functional, and the research gathered is accurate. This test is also under the assumption that the temperature and pressure sensors will provide an accurate reading of the different segments of the overall system.

In the next phase of prototyping, the electrical subsystem will be installed, as well as the final modifications to the overall project. Based on the client feedback from the third client meet, the following criteria were highlighted as areas for our project to improve: the dissipation of current from each connector, the ideal curvature for the anti tripping and additional ramp-like structure to allow for easy access onto the platform, as well as the typical lifespan for the surface materials. These criteria are further expanded in Appendix A. Table 6.

Justifications & Reasoning for this Prototype:

This prototype was created to help develop on the first prototype which focused on assembly. Once the previous prototype showed that the assembly method was feasible, we could focus our analysis on more specific parts and in this case the drainage system. This was important to do first because the drainage system acts as the base for the rest of the sub assemblies and therefore needs to be perfected before anything else can continue. Due to the small scale of manufacturing this box it was important to get this done with the materials available on the market currently because if something is not available it may alter the design. Now that there is a base for the project and it was tested empirically and deemed acceptable the following prototypes will be easy to implement. Those are the reasons this style of model was chosen for this prototype.

Client Feedback:

From Client Meet 3 that was held on 03/10/2021 was a very informative lecture where the client was able to ask questions and express any concerns. We learnt, through discussion, that our prototype has met all the required needs that the client, Jonathan Rousseau, expressed. Overall, the interaction with the client was able to bring light to any misconceptions and blurry details that needed to be addressed. As for the presentation, we learnt that more preparation would be required for the presentation on Design Day (04/08/2021). We must organise our roles and make sure that all the explanation we are doing is essential and clear. This allows us to elebrote on our visual presentation while outputting all necessary information for the optimal understanding of the concepts of our device. The pictures were good; but next time we will include more explanation in reference to them.

Overall, the presentation was informative and served as a great check-in with our client. We were able to ask some simple questions as well as initiate a good discussion. This discussion helped us determine what concepts we should be elaborating on in our presentation on Design Day. In conclusion, the presentation taught us what should be included and extended from our final presentation on Design Day.

Prototyping:

Physical Prototype:

To create the physical prototype the materials chosen from the bill of materials were used and common tools such as a drill with a 7/8ths bit and a hand saw were used to fabricate it. The first thing to be done was to cut the ABS pipe in half to fit the box and then drill a hole halfway through the length of it to put the drainage tube. There was a second hole of the same size made in the box to allow it to drain outside. Finally all the pipes were glued in place and the other half of the ABS pipe was inverted to give the gutter stability and the required height to be flush with the top of the box. This structure will make the box more stable and allow more force to be put on the surface without crushing it. The images in appendix b table 3 represent the final outcome after constructing the system. Reference Appendix B. Table 7.

OnShape Prototype:

The OnShape Design (CAD) was significantly modified to allow for a better representation of the overall design of the two subsystems that have been prototyped; the assembly and the drainage system. This model was based on the materials listed in the BOM, including proper dimensioning and selection of such materials. This model will be further modified throughout the third and final phase of prototyping. Reference Appendix C. Table 8.

Analytical Models and Analysis of Data:

The drainage system of the heated mat is meant to carry hydraulic load; specifically, the drainage system transfers the melted snow and ice on top of the mat, through the drainage pipes in the chain of panels, into the final panel. Each panel has a sloped black pipe which carries the main load and encourages the melted snow/ice to flow into the next panel. In addition, the final panel also contains a perpendicular sloped white pipe which leads the melted flow away into a hose, where the water flows into the sewers via manholes.

This prototype contains the design of the final panel, as it contains the most complex subsystem in comparison to the 'internal' or chain panels. To determine the efficacy of the drainage system, two different hydraulic conditions will need to be tested. These conditions will be outlined after some initial analysis of water flow in the system.

General Analysis of Water Flow in the Drainage System

As the final prototype of the heated mat has not yet been constructed, the overall mat and its functionality cannot be determined. Therefore, the snowmelt rate of the mat is unknown, and for the sake of this analysis, must be estimated using previous data. From benchmarking in previous deliverables, the typical snowmelt rate of the mat is 2 in/hr, which will be used in the calculations.

Converting the typical snowmelt rate units into mm/min:

$2\ in/hr\ *\ 25.4\ mm/in\ *\ 1\ hr/60\ min\ =$ 0.85 mm/min

Therefore, the drainage system needs to accommodate at a melt rate of at least 0.85 mm/min of flow.

Before any analysis can be done, parameters affecting flow velocity must be established.

As the water will not flow in a pressurized pipe, the flow will be classified as open channel flow. Due to open channel flow, the pressure on the water will be atmospheric, and can be considered 0 Pa. The initial velocity of the flow is also 0 m/s. Minor head loss across the black and white pipes will be ignored as it is negligible; frictional head loss will be considered as it may not be a very low value.

The preliminary analysis will be done using the Bernoulli Equation, from the beginning of the pipes (point A) to the end of the pipes (point B):

Bernoulli Equation for preliminary analysis

$$\frac{P_A}{\rho g} + \frac{v_A^2}{2g} + z_A = \frac{P_B}{\rho g} + \frac{v_B^2}{2g} + z_B + h_{A-B}$$

Where: P is the pressure in the pipe;
V is the velocity in the pipe;
Z is the elevation of the point in the pipe;
h is the head loss in the pipe due to friction

By accounting for the aforementioned assumptions,

$$z_A - z_B = \frac{v_B^2}{2g} + \frac{fL}{D} * \frac{v_B^2}{2g}$$

where: f = friction factor of the pipe, depending on its material;
L = length of pipe
D = diameter of pipe

These three factors are dependent on the pipe, and do not vary regardless of flow.

Therefore, to affect the velocity of flow in the pipe, the main parameter is the elevation between the start (point A) and end (point B) of the pipe. In other words, the velocity of the pipe is impacted significantly by the slope of the pipe. In conclusion, if the current pipe slope in the prototype, 4:1 (black pipe) and 2:1 (white pipe), is not significant enough to properly lead the flow down the pipe, steeper slopes will be required to meet the criteria.

The properties of each pipe are also considered in the following table. The area of half of the black pipe will be considered as it is cut in half in the prototype. The pipe properties will be converted from in to mm using the conversion: 1 in = 25.4 mm. Area is calculated as (pi*diamater^2)/4.

Table 1: Measured pipe properties

Pipe	Length		Diameter		Cross-sectional Area	
	(in)	(mm)	(in)	(mm)	(in2)	(mm2)
Black	12	304.8	3	76.2	7.07	2280.18
White	17	431.8	3/4	19.05	0.44	285.02

Additionally, the surface area of the mat is 12 in x 15 in, which will be used to analyze typical flow rates of the snow to be melted on top of the mat, as follows, using the continuity equation, Q=vA.

Typical flow rates experienced by the mat, with respect to its surface area:

Area of mat = 12 in x 15 in = 304.8 mm x 381 mm = 116,128.8 mm^2.
v=0.85 mm/min (melt rate)

Therefore, the typical flow rate experienced by one panel of the mat is:
Q = (0.85 mm/min) (116128.8 mm^2) = 98,709.48 mm^3/min.

However, to determine the velocity of flow required in the mat, the velocity in the black pipe needs to be considered as it carries the load of the melted water:

v=Q/A (pipe) = 98709.58 mm^3/min / 2280.18 mm^2 = **43.29 mm/min.**

Therefore, the system needs to accommodate at least a flow velocity of 43.29 mm/min (for a droplet) in the drainage system. If the velocity is lower than this value, steeper slopes must be considered to meet the flow demand.

Condition 1: Typical Snowmelt

The first condition models typical snowmelt conditions, where snow melts in droplet form, then flows through the black and white pipes, to lead into the sewer. It is important to note that the snow/ice on top of the mat does not melt all at once, thus a low volume of water must be considered to simulate the given condition in the drainage system. In this model, the flow of one drop of water through the system will be analyzed. These results will then be extrapolated to infer the flow of actual snowmelt from the heated mat.

The following assumption will be used for the analysis: 1 droplet of water = 1 mL in volume.

The following two tables highlight the time it takes for one droplet of water to travel through the white and black pipes, respectively. For 'internal' panels, only the black pipe is considered for the analysis. Flow velocity vs time graphs will also be constructed to show a visual model of the tables, and may allow for extrapolation of the trend, as needed, to determine additional flow rates for a droplet of water.

Note that in terms of collection, the entire water droplet was collected (100%) from start to finish of both the black and the white pipes.

Table 2: Time taken for one droplet of water to travel through the white drainage pipe

Trial #	Volume of water, V, (L)	Time taken for water to flow through the white pipe, t		Flow rate, Q, (L/min)	Flow velocity of droplet, v, (mm/min)
		(s)	(min)		
1	0.001	2.5	0.042	0.024	84.21
2	0.001	3.1	0.052	0.019	66.67
3	0.001	2.2	0.037	0.027	94.73

Sample calculation for calculating flow rate, Trial 1:

Q=V/t = 0.001 L/2.5 s * 60s/min= 0.024 L/min

Note: trial 2 may be an outlier, so consider only trials 1 and 3. Trial 2 may have had issue with the timer.

Sample calculation for calculating flow velocity of the droplet, Trial 1, using continuity equation, Q = vA:

Q=vA
Where A is the area of the pipe (white); v is the flow velocity (mm/min) ; Q is the flow rate (L/min)
v=Q/A = $(0.024 L/min \ * \ m^3/1000L \ * \ (1000mm/m)^3) \ / \ 285.02\ mm^2 \ = \ 84.21\ mm/min$

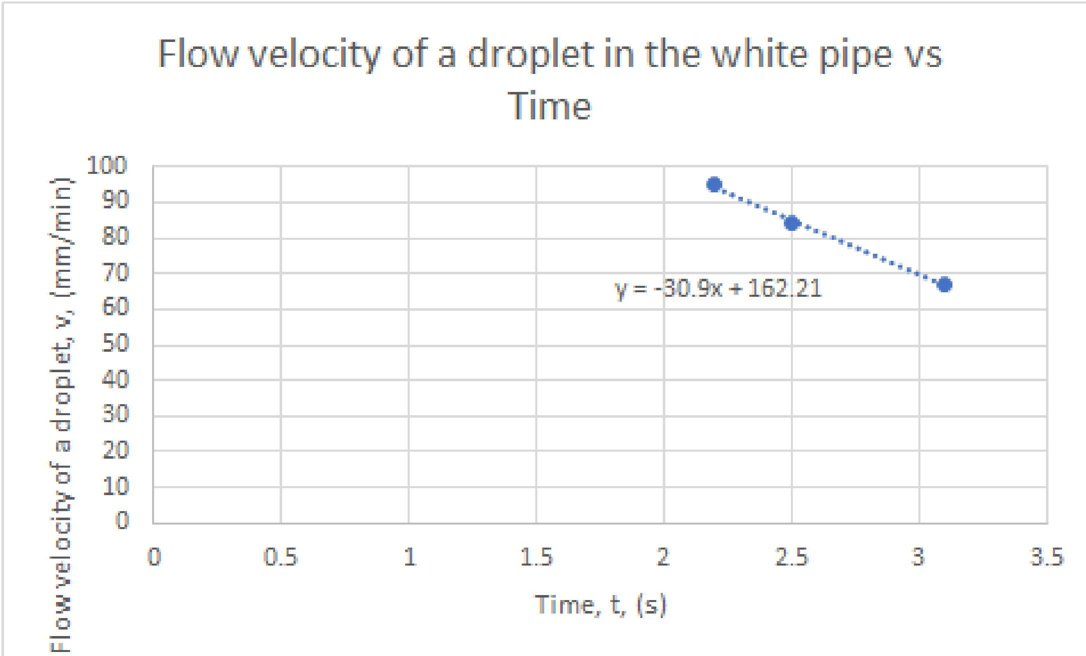


Figure 1: Flow velocity of a droplet in the white pipe vs. time

Table 3: Time taken for one droplet of water to travel through the black drainage pipe (4:1 slope)

Trial #	Volume of water, V, (L)	Time taken for water to flow through the black pipe, t		Flow rate, Q, (L/min)	Flow velocity of droplet, v, (mm/min)
		(s)	(min)		
1	0.001	1.7	0.028	0.035	15.35
2	0.001	1.9	0.032	0.032	14.03
3	0.001	1.6	0.027	0.038	16.67

The same sample calculations from Table 2 apply for Table 3. Note that the time taken for the droplet to flow through the black pipe is less than the white pipe, as the length of the black pipe is smaller than the white pipe.

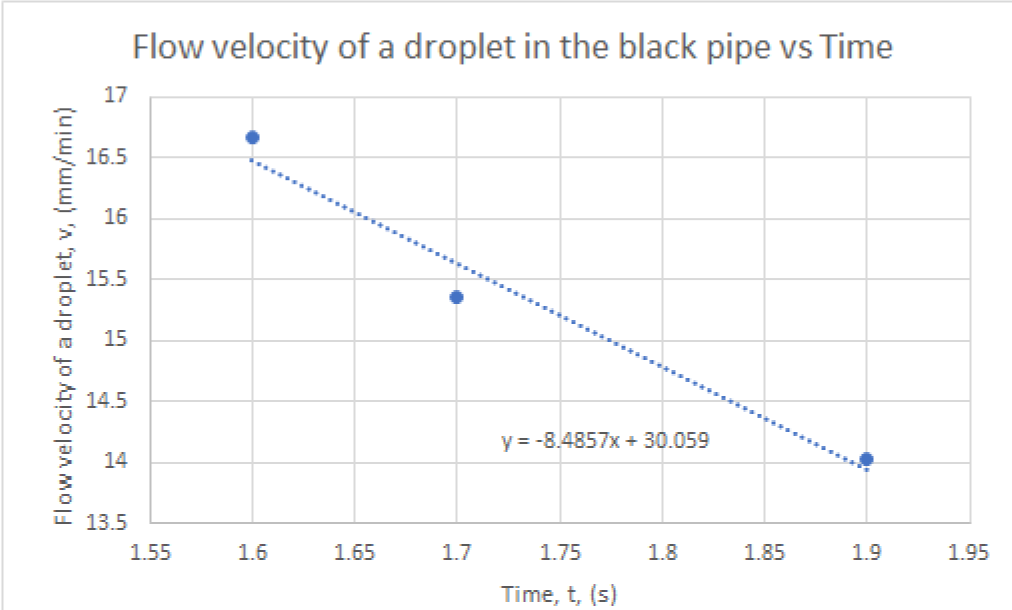


Figure 2: Flow velocity of a droplet in the black pipe vs. time (4:1 slope)

Therefore, after analyzing the velocities of all trials, in the white pipe, all velocities are greater than the minimum flow velocity of 43.29 mm/min. This means that the 2:1 slope of the white pipe is adequate for the drainage purposes. However, as per Table 3, the black pipe has lower velocities than the minimum; this means that the 4:1 slope is not adequate to accommodate the flow rate of the snowmelt from the mat. Therefore, in another trial, a steeper slope, 2:1 will be considered.

Table 4: Time taken for one droplet of water to travel through the black drainage pipe (2:1 slope)

Trial #	Volume of water, V, (L)	Time taken for water to flow through the black pipe, t		Flow rate, Q, (L/min)	Flow velocity of droplet, v, (mm/min)
		(s)	(min)		
1	0.001	0.53	0.0088	0.11	49.65
2	0.001	0.58	0.0097	0.10	45.37
3	0.001	0.6	0.01	0.1	43.85

The same sample calculations from Table 2 apply for Table 4.

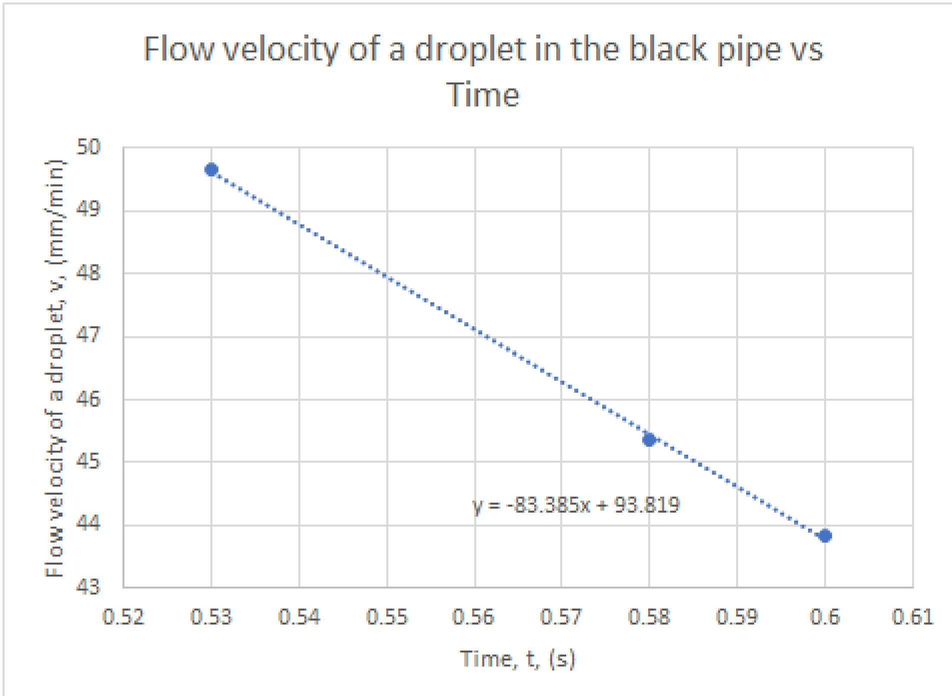


Figure 3: Flow velocity of a droplet in the black pipe vs. time (2:1 slope)

As shown, using the new slope, 2:1, instead of 4:1, it can be seen that all resultant velocities in the black pipe are greater than the minimum 43.29 mm/min. This means that the black pipe can now also support the given flow rate of the panel of the mat.

The high velocities in the pipes ensure that there is no buildup of water in the drainage system, and the prototype has effectively met its testing and stopping criteria/objectives. This analysis also proves that the elevations between points A and B (start and end) of the pipes are sufficient to convey the flow of water at a highly functional velocity. Additionally, it is safe to say that the slopes of the pipes in the prototype can be slightly less steep and more subtle if needed, to accommodate the natural slopes of the sidewalks, which will still allow for sufficient drainage in the panels. This is a conservative conclusion as the flow velocities are much higher than the minimum required velocity, as explained previously. Therefore, through the Bernoulli equation, it can be said that the slopes of the pipes (zA-zB) allow the drainage system to work effectively, meanwhile the high velocities in the trials allow for potential flattening of slopes, as well as frictional head loss to be accounted for, to display little effect to the drainage of the water.

In terms of the graphs, the lines of best fit show that the relationship between flow velocity of a droplet vs. time is linear (higher velocities take less time in the system, and vice versa), and that various velocities of snowmelt can be easily extrapolated for this drainage system, using the equations of the lines, shown on the graphs.

Condition 2: Heavy precipitation events

The second condition to be modeled, is heavy precipitation events. From observation, it is typical for heavy precipitation events in the winter to only include blizzards. However, as the heated mat will also be used in future years, climate change conditions must also be accounted for. Due to climate change, heavier, more frequent, and increasingly unpredictable precipitation and rain events may occur in years to come. Therefore, with increased precipitation events, potential flooding is also a common and important issue to consider. Flooding may occur due to decreased infiltration of rain into the soil due to urbanization and the use of impervious materials (asphalt and some concrete) on roads and sidewalks, thus resulting in more water on the surface of the roads and sidewalks. Blizzards will also cause a greater level of snowmelt, resulting in greater load on the mat's drainage system.

Thus, to model heavy flow, a large quantity of water will be passed through the drainage system, from which the hydraulics of the system will be analyzed.

The Bernoulli equation parameters will also be evaluated and/or confirmed, by determining if the prototype slopes of the pipes (zA-zB) are sufficient enough to convey the flow; the head loss will have little to no effect on the higher flows as it did not have any significant impact on the droplet of water.

All sample calculations for the tables in 'Condition 1' apply for the following tables as well.

Table 5: Heavy flow of water through the Drainage System as a whole

Trial #	Volume of Water (L)	Time taken for water to flow through the drainage system		Calculated Flow Rate (L/min)	Estimation of type of flow	Volume of water collected from white pipe (L)	Percentage of water collected from white pipe, from total flow (%)
		(s)	(min)				
1a)	4	17.6	0.29	13.7	Medium/ typical	3.40	85
1b)	4	18	0.30	13.3	Medium/ typical	3.43	86
1c)	4	19.4	0.32	12.5	Medium/ typical	3.38	85
2	4	10	0.17	23.5	Fast	3.41	85
3	4	24.5	0.41	9.8	Slow	3.40	85
Average flow collected from white pipe:						3.4 L	85%

Fast flow was achieved by aggressively dumping 4 L of water into the system; slow flow was achieved by pouring a thin slow stream into the system. Caution was taken to prevent sources of error through spillage and/or splashing. Flow velocities were not able to be calculated as the water was run through the system as a whole (with two different pipes - white and black).

From the table, it can be seen that approximately 85% of the flow was collected and drained by flowing water through the entire system. This shows that there was some percentage of flow which remained in the end of the black pipe, specifically in the last 263 mm of the pipe, which will be carried forward into another panel. In the last panel, the 263 mm of the pipe will collect stagnant water which may cause issues with bacteria, odours, etc in the panel. Therefore, after the initial prototype and analysis, it was concluded that a block would be put at the end of the white pipe (263 mm in from the end of the black pipe), to encourage complete drainage of the system and to prevent issues arisen from stagnant water collected in the main black drainage pipe. In the second iteration of the prototype, to improve, the block was implemented as explained previously. Therefore, through this analysis and these strategies, it is apparent that the drainage system is well equipped to handle both snowmelt and heavy precipitation flows.

Wrike Link:

https://www.wrike.com/open.htm?id=626625016

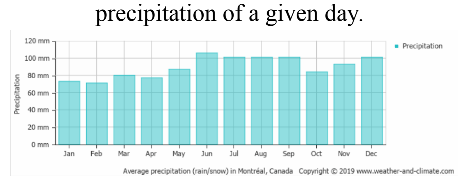
Conclusion:

In conclusion, Team 5 has used the knowledge gained from the past prototype to create a second partially functional prototype of the drainage sub system. We were able to set forth new prototyping objectives for both the creation of the prototype and the testing process. The main objectives included creating a drainage system that was capable of taking water from the surface of the panels into the panels and then out into the sewer. The tests performed have now allowed the team to gather analytical data to better understand how much water is capable of being drained at a time and how quickly the water can flow. The physical and OnShape prototype have been shown above, both showing the design of the drainage system connected to the outer shell of the heating device. In the next two weeks, Team five will produce a third prototype that shows the three subsystems. We will also be able to test the functionality of the entire system as a whole. With the test results, improvements may be made until the final product is shown at design day.

Appendices:

Appendix A: Prototyping Test Plan

Table 6: Prototyping Test Plan

<table>
<tr><th>Test ID</th><th>Test Objective
(Why)</th><th>Description of Prototype used and of Basic Test Method
(What)</th><th>Description of Results to be Recorded and how these results will be used (How)</th><th>Estimated Test duration and planned start date
(When)</th></tr>
<tr><td colspan="5">Prototype 2: Drainage system</td></tr>
<tr><td>1</td><td>Volumetric flow rate</td><td>We must determine the capacity of the liquid that the device (piping/drainage system) can withhold. It must be able to match the average precipitation rate of snow/rain throughout the winter months (months of usage). This is essential to make sure that the size of the piping usage will be able to output 100% of the input without leaks or spill that could compromise the integrity of the whole system.</td><td>On average, for the highest month outputs a precipitation fall of apromatmty 110 mm [https://weather-and-climate.com/average-monthly-precipitation-Rainfall,ottawa,Canada] in a given month. The diameter of the piping system is 3 inches at a length of 2 feet of a regularly sectioned component plate of the device. The volume contained by a single unit pipe is 678.584 inches squared This is more than enough for the average precipitation of a given day.


Mathematically based analytical tests must be used as it gives a close approximation of the conditional factors that cannot be replicated.</td><td>1 hour to research weather-databased sites that show graphical representation of the precipitation per unit time. Additionally time (~20 minutes) to compute related mathematics.</td></tr>
<tr><td>2</td><td>Maximum capacity of pipes within the drainage system</td><td>Pressure and temperature capabilities of all tubing pieces must be documented and recorded. This will ensure that all action taken upon them is appropriate. As this device has the futur goal of being a sustainable, long term alternative to salt, it needs to be able to withstand many external environments.</td><td>There are 3 components that make up the piping/drainage system; the SharkBite 3/4 Inch x 5 Feet WHITE PEX PIPE, 3 in. x 24 in. PVC Sch. 40 Pipe by VPC and 3/4 in. PEX Barb Plastic 90-Degree Elbow Fitting by SharkBite.
<table><tr><td>Parametres</td><td>SharkBite</td><td>SharkBite 90°</td><td>VPC</td></tr><tr><td>Temperature (℃)</td><td>60</td><td>93.33</td><td>60</td></tr><tr><td>Pressure (psi)</td><td>140</td><td>160</td><td>100</td></tr></table>
A research based analysis is required due to limitation in resources required to carry out such experiments. This equipmentation may also destroy the product, therefore to maintain the products bought, resch-based analysis will be more effective.</td><td>Approximately 10 minutes inspect the integrity of the pieces bought. Check for any tear, cracks or scratches that may be present and that can affect the functionality of the components. Additional 20 minutes to research the maximum pressure and temperature of each product via the links attracted with the Bill of Materials found on the Project Deliverable E report.</td></tr>
<tr><td colspan="5">Final Prototype Testing (assembly, drainage and electrical)</td></tr>
<tr><td>3</td><td>Dissipation of current from each connector</td><td>We must determine how much internal resistance is present in the electrical system. As this device is a component-based system, there is the possibility that numerous individual plates will be connected together. As the electrical subsystem is an individually functionable system, the point of attachment between the two points of the</td><td>Must determine the percent efficiency of the materials used; the Automatic Electric Heat Cable Kit by Frost Kinghas many reviews on many sites, research must be done in order to determine this critical information. Research-based verification is optimal as this test is the determine a long term feasible</td><td>Research other companies and hardware stores that sell this exact device. Determine, through customer reviews and product information the insulation resistance value (1 hour; minimum five sites)</td></tr>
</table>

<table>
<tr><td></td><td></td><td>input and output can have long term negative impacts on the functionality of the device.</td><td>solution which is hard to create with our resources.

Insulating R-value = 0
[https://www.homedepot.com/p/Frost-King-9-ft-Automatic-Electric-Heat-Cable-Kit-HC9A/205933690#product-overview]</td><td></td></tr>
<tr><td>4</td><td>Ideal curvature for anti tripping/wheel chair friendly device</td><td>Comparative analysis of other such products found on the market. Ramped devices are optimal. After an ideal angle range is found, test for one that would work with the materials purchased as well as the ease of a wheelchair over the ramp</td><td>Must determine the ramp angle using research as well as physical experiments. Maximum slope for hand-propelled wheelchair ramps should be 1" of rise to every 12" of length (4.8 degree angle)
[https://www.brainline.org/article/wheelchair-ramp-information#:~:text=Maximum%20slope%20for%20hand%2Dpropelled,(48%22%20is%20ideal).]
<table><tr><td>Dimensions of single end component</td><td>Angle required</td><td>Length of the ramp required</td></tr><tr><td>5 in. x 20 in. x 15 in</td><td>4.8 degrees</td><td>59 inches</td></tr></table>**Pythagorean Theorem applied**

It can be confirmed that 59 inches is a very large length and that this component cannot be part of out final prototype due to budget limitations</td><td>A small scaled device was implemented to test the ramp angle (2:1 scaled) and it was sufficient. With a large budget/more resources having an effective ramp would be an ideal component of the device.</td></tr>
<tr><td>5</td><td>Typical life of basis materials (typical life) of surface material</td><td>Our main concern was how well the external friction-creating surface would maintain its coefficient of friction for. Corrosion has the effect of decreasing the coefficient of friction which would disable the purpose of the anti-slip surface material. We picked this option over silicon as silicon becomes highly slippery when wet.</td><td>Research information about the sandpaper to determine how well the sandpaper alternative really is.

Coefficient of friction:
[Sandpaper on wood>silicon on rubber]

Sandpaper can be toughened by using different materials, but in general this device will probably require additional tracks and grooves.</td><td>A large section of sandpaper was used as a" welcome mat" type device one which repetitively rubbed the soles of our shoes. A lot of sandpaper residue was found on the soles of our shoes. This was done in less than 10 minutes therefore it can be confirmed that a sandpaper solution will not be ideal, yet it can be a seasonally replaceable</td></tr>
</table>

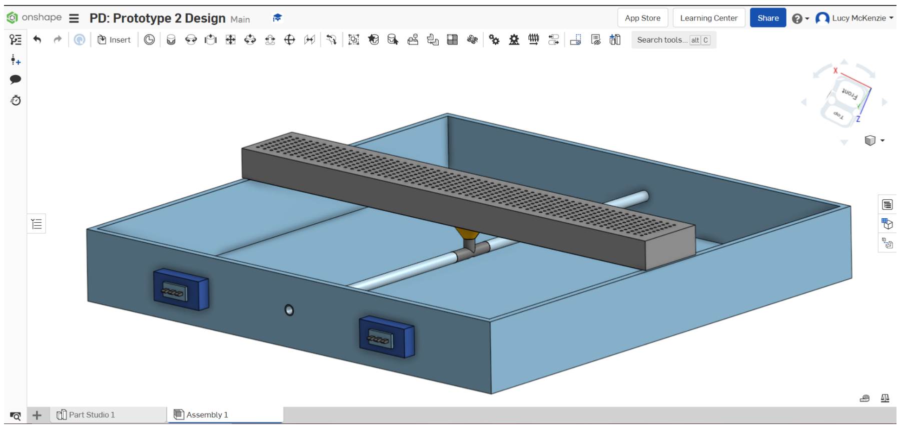
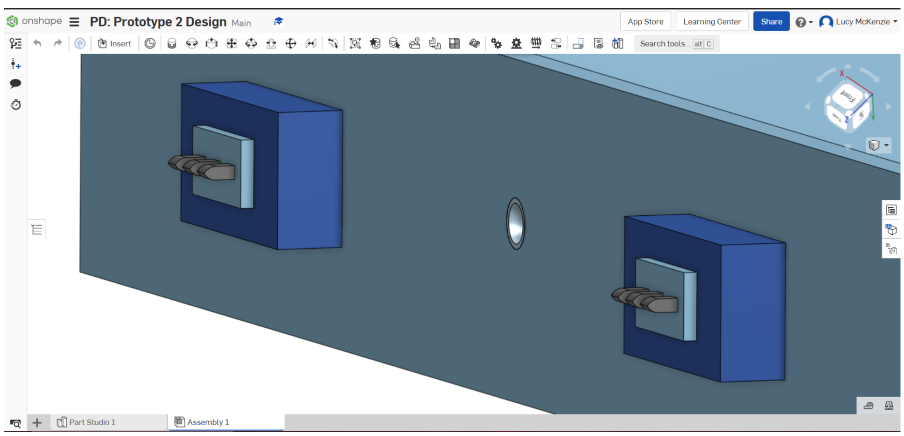
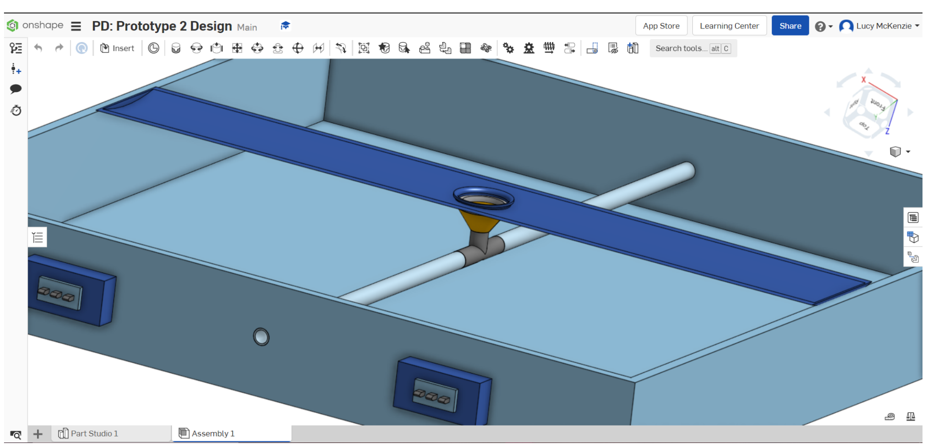
Appendix B: Physical Prototype II Images

Table 7: Physical Prototype II Images

Side View	
Top View	
Side View (gutter and pipe connection)	

Appendix C: OnShape Prototype II Screenshots

Table 8: OnShape Prototype II Screenshots

View of Design	Screenshot
Overall System	
Assembly Subsystem	
Drainage Subsystem	
Link to OnShape Platform	https://cad.onshape.com/documents/db9810abd37e6fa39e9326b7/w/4d8be3c85ba8c5cf7b83e25e/e/5c6118eab30f657fcdcd49f7