Western University Faculty of Engineering
Studio Section 24 – John Dickinson
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Team Progress Report – Phase 3:
Water on Wheels

Design Description: An elevated water tank on wheels with an attached hose that differently abled volunteers can use to water raised beds outside.

1 Testing and Validation

Your design assessments need to reference your final design as it would be implemented in practice, not about your prototype. For example, if you used cardboard and wood to represent what would ideally be a metal and plastic component or system, then your assessments need to be based on the metal and plastic version of your design, particularly (but not exclusively) regarding weight, cost, and strength. If you are assessing cost, remember that there is a difference between your cost to build your prototypes and the cost you would incur if you were to build a final useable version for your client.

Live test results will understandably be based on your prototype but note any expected differences in performance for your design in the final form.

1.1 Compliance Matrix: Constraints

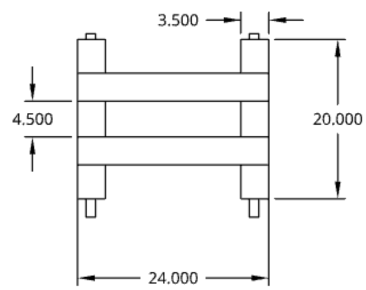
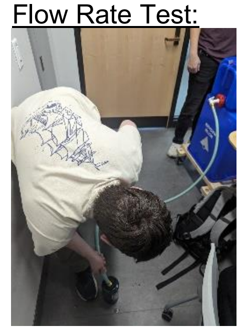
[20] Take into account any feedback you have received on your Constraints in the past two reports when entering your constraints into the Compliance Matrix as documented in the Winter Project Tools Template Excel file. Replace the table below with the template version, adjusting the formatting (e.g. column widths, page orientation …) appropriately if required.

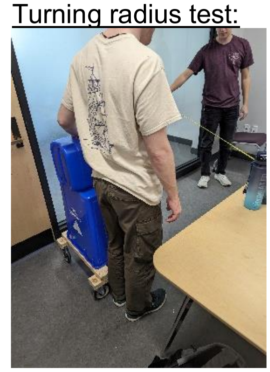
- Column 2 Constraint: should show your team's final constraints (you should have at least 5-10)
- Column 3 Assessment: indicate clearly if the constraint was satisfied by your final *product design* (not just your final *prototype*)
- Column 4 Rationale: include what evidence the team used to support this assessment – this may be a short summary and a link/reference to an appendix with the data/details supporting the assessment if lots of evidence available.

  For example, include short descriptions of testing done, along with images of actual tests, links to test videos, external feedback reports (e.g. from 3rd party tests/observations), small charts of measured values, analytical modelling or excerpts from supplier's specifications … whatever concisely presents the case for the assessment of the constraint. Remember, the assessment relates to your final product (not your prototype), but you will clearly need to use your prototype to conduct some of your assessments. Therefore, *where applicable, indicate how/why your ES1050 prototype evidence extrapolates or applies to your final product assessments*.

Note: Valid assessment options are: **Not Verified Yet**, **Not Met**, **Partially Met**, **Met**, and **Exceeded**. Recognizing that it could be difficult and/or costly to fully assess some constraints, you are expected to have assessments and supporting evidence for at least half of your constraints, based on nature of the constraints and how easily they could be assessed. ***For all "Not Verified Yet" constraints, you are expected to indicate why they were not assessed and how they could be assessed with more resources.*** Do not take shortcuts here, as the graders will be watching for incomplete assessments that could have reasonably been completed. "Running out of time" is ***not*** a valid reason.

Place larger and more detailed analytical work, testing data or specifications etc. in appendices and reference the appropriate appendix sections in the table for the reader to review if they wish. If one Appendix of evaluation data supports multiple constraint assessments, do not document it twice and instead reference multiple times as needed in the table. Constraints assessed as "Not Met" or "Partially Met" are good elements for discussion in Section **Error! Reference source not found.**. **[Target 1 page for Table - Max 2 pages]**

#	Constraint	Compliance Assessment	Rationale/Evidence
1	Water pressure cannot be greater than that of the pressure generated by gravity from the tank	Met	Our design relies upon the gravity of the tank to generate any pressure – thus, it cannot exceed that pressure.
2	Hydro power cannot be used – electrical potential difference is 0 at all points on our design	Met	Measurements with a voltmeter yielded no non-zero voltages across any point on the design.
3	Volunteers must retain agency and be doing work – users should experience at least an increase of 10 bpm above resting heartrate	Met	Our testing found that our user experienced an increase in 12 bpm above their resting heartrate during use. Usage Test: 
4	Solution must not obstruct movement of other garden users – no part of our solution should overlap / block more than 1m^2 when static / in storage	Exceeded	Final footprint is measured at 20”x24”, or 0.3 m^2. Wheelbase Design Drawing: 
5	Assembly of our solution takes less than an hour on average	Not Verified Yet	Because the prototype was constructed in parts, over a long period of time, we cannot report an accurate timeframe for construction from scratch without buying parts all over again
6	Releases water at a fixed and controllable rate – less than or equal to 100 ml/s	Met	Our testing measured a flow rate of 95ml/s with a greater height differential than that of the tank to the beds – thus, the practical flow rate will be even less than this, and much less than the maximum of 100ml/s. This ensures the flow rate from the hose is easily manageable and controllable. Flow Rate Test: 
7	Moving any part of our design must require less than 15 lbs of force	Met	If our design is not stuck against an obstacle, it takes ~0.5 lbs of force to start it moving. Moving the hose & attachment arm

#	Constraint	Compliance Assessment	Rationale/Evidence
8	Durability – can survive being dropped – will continue to function with minimal damage after a drop of 1.5 meters	Not Verified Yet	We are not confident enough in the structural integrity of our prototype to make this test – with a fully functional prototype, and no concerns over having nothing to present at showcase, we could complete this test
9	Water transport aspect of solution must be able to hold at least 4L of water at a time	Exceeded	Our container has a volume of 20L, and our tests found that when filled to 18 L, there was no spillage during transport.
10	Requires less than or equal to 2 hours of maintenance a month	Not Verified Yet	Our prototype has yet to go through regular, repeated use, and thus we are unsure as to what maintenance tasks will be required monthly.
11	Compatible with wheelchairs and walkers	Partially met	We did not have access to a wheelchair during our testing but could easily test this constraint with access to one. During the showcase we had a wheelchair visitor that confirmed our design would work with a wheelchair.
12	Must be able to deliver water above a height of 60 cm	Exceeded	Our faucet height of ~80 cm means that we can deliver water to any height below that.
13	Must fit in the space between beds – 1.5 meters at a minimum	Exceeded	Our solution is 24 inches or 61 cm wide at its widest, with a maximum turning radius of 1.1 m. Turning radius test: 
14	Any part that contacts the water must not negatively affect the quality of the water	Partially Met	Our water container is food safe, FDA approved (certifications listed on product site here: https://relianceoutdoors.ca/products/aqua-pak-5g-20l , while our hose (although intended for gardening) does not have the same certifications.

1.2 Objectives Evaluation

[20] Follow the same instructions and guidance as per the “Compliance Matrix: Constraints” section above. Be aware that because objectives are goals and not required for the product to be successful, these assessments are referred to as simply “evaluations” and not “compliance assessments”, but you still assess and document them generally in the same manner. Additional details may be provided to identify the performance on the spectrum (maximize and minimize) such as “Met - less than upper limit by 25%” or “Met - 50% less than status quo” or “Met - 50% less than first prototype”.

[Target 1 page - Maximum 2 pages]

#	Objective	Evaluation	Rationale/Evidence
1	Low price – ideally less than $100	Not met – greater than upper limit by 35%	The total cost of our solution is ~$135, but several of the parts of our solution are items that organizations/individuals might have lying around unused – e.g. recycling bins, a water container, and rope/cord. However, our wheels are not items that anyone is likely to have on hand, and do cost ~$40, restricting how cheaply our solution can be made.
2	Easy to assemble by anyone	Partially met	As mentioned above, the construction of our prototype in parts means we don't have an accurate number for construction time. However, the number of steps needed to assemble is ~10, none of which require a high level of technical expertise.
3	Easily portable and maneuverable	Met	Our entire solution can be moved around easily, by anyone, thanks to our wheelchair attachment & rope handle, as well as our low-friction wheels. Since the cart can be moved in any direction, from any position, it's almost impossible to get stuck.
4	Easy to store / disassemble	Partially met	Our design isn't one that requires disassembly, but it does have a relatively large footprint of 0.3m^2, making it mildly inconvenient to store.
5	Weather resistant	Met	Our design was frequently exposed to adverse conditions, including rain and snow while being transported to and from the lab with no negative effects or reductions in functionality.
6	Ergonomic	Partially met	Users that pulled our cart via the rope handle reported that it was comfortable, but we didn't have enough users who were using the cart in tandem with a mobility device to report a level of ergonomics for that group.
7	High visibility	Met	 Several of the parts on our solution are made of high-visibility, brightly coloured materials, including our water tank, wheel base, and our rope handle.
8	Should not obstruct the view of the user	Met	Users either drag the cart behind them or pull it alongside. In both cases, it is not between them and the direction of motion, and thus doesn't obstruct their view.
9	Should not hinder the user's mobility	Not Met	The size of our solution means that it does hinder mobility – any user must move slower and more carefully while using it to avoid bumping into obstacles.

#	Objective	Evaluation	Rationale/Evidence
10	Visually appealing solution(s)	Met	Several showcase attendees commented on the high aesthetic quality of our design.
11	Provide clear instructions to volunteers via a clear map with colored routes	Not Met	Not knowing what Hutton House's planting arrangement & schedule will look like, we did not believe we could construct an effective map.
12	Should not reduce volunteers' ability to complete other tasks (e.g. harvesting)	Met	Our solution can be left behind by users at any time- if they need to complete another task, they can simply disconnect / let go of the cart somewhere that doesn't get in their way, and complete other tasks as needed.
13	Compatible with all mobility devices	Partially met	We did not have access to mobility devices during our testing. However, during the showcase a wheelchair user verified that our design would be viable with a wheelchair.
14	Solution allows the entire garden to be watered in less than 6 man-hours	Not Yet Verified	Once the prototype was complete, we did not have any way to get it to the site and run a test – additionally, the site isn't in use now.
15	Less spillage than current solution	Met	During testing, no water was spilled from the top of our cart while in motion. Since the current solution is reported to at least incur some spillage, this is a clear improvement.
16	Easy to teach new users	Met	We were able to effectively explain the use of our solution to both judges & a wheelchair user at the showcase in under five minutes.
17	Water distribution system distributes water equally without extra effort on the user's part	Partially met	Our water distribution solution, the hose attached to the cart, does make equal distribution easy, but is not entirely without effort on the part of the user – they must direct the hose to the different parts of the garden bed.
18	Can have a varied water distribution rate	Met	Because our hose is attached to a faucet on our water tank, the rate at which water leaves the tank can be controlled via the faucet.
19	Should be able to hold an adequate volume of water without needing frequent refills	Met	Our design can safely transport 18L of water at a time– substantially more than the current solution, and enough to water multiple beds in one trip.
20	Sustains repeated use over multiple years	Not Yet Verified	Although we believe that our design has effectively spread-out forces to prevent any excessive wear on the joints, we cannot verify this objective without extensive repeated use over a time frame greater than that available to us.

2 Comparison

[15] **Concisely compare** your final solution to the status quo (current approach or workarounds deployed by the client) **OR** to an existing **competitive** market available solution(s). Comparisons should cover the following basic attributes: practicality (including cost and use), strengths and weaknesses (pros/cons), and should also cover other aspects relevant to the project as selected at the team's discretion. ***If the alternative is a product, a link to material on the product needs to be provided***.

Some cases where the solution is realised as an aggregate of approaches/elements may require or be easier to compare at the component level. In these cases, duplicate Section 2.1 (making Sections 2.2, 2.3 …) as many times as required and complete the comparison of each sub-system independently.

[300 words maximum PER alternative – annotated figures/images are preferred]

2.1 Comparison

Existing Competitor Name / Description / Link (as applies): Status quo – Watering Can – example: https://www.canadiantire.ca/en/pdp/bloem-watering-can-green-7-5-l-1590932p.html?rq=watering+can#srp

Our Solution: Watering Cart

Practicality Comparison	Our solution is more expensive than the status quo – a typical 7.5L watering can costs ~$13 at Canadian Tire, while our solution costs ~$135 to assemble, assuming all parts are purchased new. Our solution is much more efficient in transporting water – 15-20L of water can be moved at once using our cart compared to the 7.5L of the can. Additionally, our solution is easier to transport than a full watering can – our cart can be pulled around with minimal effort from the user, while a full watering can weigh ~7-8 kg, that must be supported by the user.
Comparison of Strengths	<u>Watering Can</u> The watering can is cheap, convenient for users, and easy to store. Additionally, because it's a well-known solution, no explanation is required for its use. <u>Watering Cart</u> The watering cart requires very little effort to use, can transport lots of water at a time, and makes water distribution very easy using the hose. Additionally, the watering cart can be used with a wheelchair, and likely walkers – users with a walker can hold the rope handle to pull the cart behind them, while wheelchair users can use the attachment arm or the rope handle to pull the cart alongside them.

Comparison of Weaknesses	Watering Can The watering can is not an effective watering solution for users with any physical disability – users in wheelchairs can't reach the middle of raised garden beds to water them, and users that have reduced strength can't comfortably carry a filled can. Watering Cart The watering cart is large, and thus somewhat inconvenient to store. Additionally, it does require some explanation before use, especially when compared to a watering can, and is much more expensive.
Other Comparisons	The watering cart requiring less force to use and having attachment options for mobility devices makes it much more accessible than the status quo.

3 Appendix A – Any Rationale/Evidence for Constraint …

Test	Purpose	Description of test	Outcomes					Insights Derived / Lessons Learned
			Metric 1	Metric 2	Metric 3	Metric 4	Metric ...	
1	Determine flow rate of water out of the hose	The container was filled, and then we timed how long it took to fill a 1L water bottle	1L	10.5s	95 ml/s			Our design distributes water at a satisfactory rate - we can consider recommending the faucet not be opened all the way when in use.
2	Determine force required to move from stopped	We used an airport luggage scale to determine the force needed to start the cart moving when it was full of water.	0.5 lbs					The fact that the cart is so easy to move could represent a risk - users should be reminded not to lean on it.
3	Determine if the use of the solution helps users engage their body & retain agency	We measured a team member's resting heart rate, and then measured their heart rate after using the cart for 5 minutes	Resting - 70 bpm		After use - 82 bpm		Change in	Our design does increase the heart rate of users, indicating that it will help them exercise and
4	Determine turning radius when the cart is pulled alongside	A team member pulled the cart along with it right beside them, with another measuring their maximum distance form the corner they turned around	Max distance: 1m					From these two tests, we found that turning radius is actually higher for users that are not in wheelchairs - this wasn't what we expected. Regardless, both turning radii are within the limitations of the space.
5	Determine turning radius when the cart is pulled behind	A team member pulled the cart along with the handle pulled behind them, with another measuring their maximum distance form the corner they turned	Max distance: 1.1m					
6	Determine tipping moment (wheels locked)	We put the cart up against a short obstacle, and determined the amount of force needed to tip it when pulling on the handle.	Force: 2.5 lbs					Although our design is very hard to tip in general, if it does come into contact with any obstacle that causes the wheels to lock, users should be careful to not apply excessive force.
7	Determine tipping moment (wheels unlocked)	We approximated instantaneous force needed to tip the cart when the wheels were unlocked by pulling at various strengths with the aiport scale.	Force: ~50 lbs					This isn't an exact number, as we had to pull at varying increasing strength intervals, instead of constantly increasing, since the cart would just roll. We were able to tip the cart at a minimum of 51.2 lbs applied. This tells us that tipping with unlocked wheels shouldn't be a big concern for our users - if something is hitting our cart with that much force, there are other problems going on.
8	Determine the maximum amount of water that the container can hold without spilling when being pulled	increased volume by 1L each time until spilling occured at estimated normal speeds in turns	max volume without spilling: 18L					this being less than the total volume of the water jug tells us that there will be some unused space, this means we did not use the space as effectively as possible and couldve improved upon our design, considering methods of preventing spillage like a