

WATER TREATMENT COMPETITION RULES

Hosted by the University of Nevada, Reno

*American Society of
Civil Engineers Mid-
Pacific Conference
2016*

WATER TREATMENT COMPETITION

Dates of Competition: April 7, 2016

April 8, 2016

Competition Location: Lawlor Events Center

Summary:

The ASCE Water Treatment Competition is an undergraduate project that gives students with civil and environmental engineering and related majors a chance to gain hands-on experience with the research, design, and lab testing involved with water treatment principles as well as an opportunity to develop professional skills such as technical writing and presenting. Teams from California, Nevada, Hawaii, Canada and China participate to design a filter made of materials bought in a hardware store that treats a standardized wastewater based on the real-world scenario presented in the competition rules.

The project is judged based on (1) filter construction, (2) water quality results, (3) a design report, (4) a poster, and (5) an oral presentation. Students are encouraged to work closely with university faculty and local engineering professionals to create a practical and innovate method of addressing the problem statement. The Water Treatment Competition occurs at the Mid-Pacific Conference, which will be hosted at the University of Nevada, Reno this school year on the weekend of April 7 – 9, 2016.

Important Deadlines:

- Registration – Saturday, November 14, 2016 via “School Registration” form provided in Mailer I
- Questions and materials requests – Emailed by Sunday, December 6, 2015
- Design report – Submitted electronically (in PDF format) by midnight Friday, March 4, 2016
- Presentation – Submitted electronically by midnight Tuesday, April 5, 2016

*Failure to comply with the deadlines listed above will result in your team’s immediate disqualification in the competition.

Contact and Submission Information:

Water Treatment Competition Coordinator – Jaclyn Wander

Send submissions and questions via email to: watertreatmentmidpac2016@gmail.com.

Thank you!

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INTRODUCTION

In the Water Treatment Competition, ASCE student chapter teams are given a real-world scenario to construct a filter made of materials found in a hardware store that is designed to treat a standardized wastewater. The project is judged based on (1) filter construction, (2) water quality results, (3) a design report, (4) a poster, and (5) an oral presentation. Students are encouraged to work closely with university faculty and local engineering professionals to create a practical and innovative method of addressing the scenario. The competition will be hosted at the University of Nevada, Reno on the weekend of April 7 – 9, 2016.

As one of the 14 Grand Challenges for Engineering in the 21st Century, providing access to clean water is growing increasingly imperative as population grows and fresh water sources are diminishing. While the ASCE Water Treatment Competition helps students develop important engineering skills, the project also teaches the importance of water treatment and helps young engineers establish a passion about finding solutions to this global problem. According to the National Academy of Engineering (NAE), "lack of clean water is responsible for more deaths in the world than war. About 1 out of every 6 people living today do not have adequate access to water, and more than double that number lack basic sanitation, for which water is needed... By some estimates, each day nearly 5,000 children worldwide die from diarrhea-related diseases, a toll that would drop dramatically if sufficient water for sanitation was available," [NAE, 2015]. Addressing the need for clean water not only for potable purposes but for sanitation, this is the inspiration for the 2016 scenario. Visit www.engineeringchallenges.org for more information about NAE's list of Grand Challenges for Engineering.

SCENARIO

Living along the coast, your town has just become the victim of a terrible hurricane. Your neighborhood is unrecognizable with houses torn to shreds and wreckage floating in muddy water. Your family and neighbors have moved into a shelter on the west side of town, which narrowly avoided the storm. Although you are provided with food, bottled water, medical supplies, and some clothing, the tap water supply to the building isn't working due to plumbing damage, hence the showers and washer machines aren't accessible. While most people have friends or family to go to for these services, some people do not.

After one week living in the shelter, there is still no water, and there is an estimated three more weeks before people are to be relocated out of temporary living. Worrying about sanitation, you go out back to inspect the quality of the water from a storm drainage channel behind the building. Unfortunately, the water is worse than usual because it has been polluted with debris from the storm, and it is the only nearby water source that is easily accessible for continuous use. Fortunately, however, you have background in water resources engineering and decide to gather a group of friends to design a reusable water treatment filter so people in need will have access to some clean water for bathing and washing laundry over the next few weeks.

INLET WATER CONSTITUENTS

Two (2) 5-gallon buckets total will be prepared for each team. All constituents will be added and stirred with a wooden stir stick 24-hours prior and then stirred again 5-minutes before the filter loading phase.

Per 5 gallon bucket:

Miracle-Gro Potting Mix	500 g
Great Value Iodized Salt	58 g
Great Value Vegetable Oil	1 cup
Fleischman's Active Dry Yeast	20 g
Kingsford's (Argo) Corn Starch	96 g
Hawaiian Punch Fruit Juicy Red	2 cups
Great Value Apple Cider Vinegar	1 cup

WATER QUALITY TESTING

Immediately after filter construction and loading, the final treated water will be tested using university laboratory equipment. Results will be provided before the team's oral presentation. The following six (6) water quality parameters of your final treated product will be graded based on the scoring methods described below. The water quality section is worth 30 total points.

pH Value

Target: Between 6.75 and 7.25

Grading:

$6.75 \leq \text{pH} \leq 7.25$		will result in 5 points
$6.25 \leq \text{pH} < 6.75$	or	$7.25 < \text{pH} \leq 7.75$
$5.75 \leq \text{pH} < 6.25$	or	$7.75 < \text{pH} \leq 8.25$
$5.25 \leq \text{pH} < 5.75$	or	$8.25 < \text{pH} \leq 8.75$
$4.75 \leq \text{pH} < 5.25$	or	$8.75 < \text{pH} \leq 9.25$
		will result in 1 point

All other pH values outside of these ranges will result in 0 points.

Turbidity

Target: Minimal NTU

Grading: (Your rank / best team's rank) * 5 points

Electric Conductivity

Target: Minimal $\mu\text{S}/\text{cm}$

Grading: (Your rank / best team's rank) * 5 points

Volume

Target: 9 gallons

Grading: (Your effluent volume (gal) / 9 gallons) * 5 points

Please note that there is a maximum of 5 points allotted for volume. It is conceivable, however unlikely, that a team could have a volume greater than 9-gallons; in that case, they would still only receive 5 points.

Total Free/Available Chlorine

Target: 4 ppm

Grading: (Your rank / best team's rank) * 5 points

Dissolved Oxygen

Target: 100% DO

Grading:

100% DO			will result in 5 points
$90\% \leq \text{DO} < 100\%$	or	$100\% < \text{DO} \leq 110\%$	will result in 4 points
$80\% \leq \text{DO} < 90\%$	or	$110\% < \text{DO} \leq 120\%$	will result in 3 points
$70\% \leq \text{DO} < 80\%$	or	$120\% < \text{DO} \leq 130\%$	will result in 2 points
$60\% \leq \text{DO} < 70\%$	or	$130\% < \text{DO} \leq 140\%$	will result in 1 point

All other DO values outside of these ranges will result in 0 points.

DESIGN REPORT

Each team is required to submit a design report detailing the overall project and must include a description of the design process, treatment principles utilized, environmental impacts, a cost analysis, and tables of material and operational costs. The design report is worth 25 total points. Please submit an electronic version of your report (in PDF format) via email to watertreatmentmidpac2016@gmail.com by no later than midnight on March 4, 2016 (11:59 PM). A hard copy submission is not required.

Formatting

One (1) point will be deducted from the team's report score for each violation:

- **Report Cover Page:** Must contain school name, team name, and competition name: "2016 ASCE Mid-Pacific Student Water Treatment Competition."
- **Table of Contents:** Limited to a total of one (1) page.
- **Body of Work:**
 - Must be a minimum of 1000 words
 - May not exceed eight (8) pages
 - Use 12-point font, single spaced, and 1-inch margins on all sides
 - Apart from headings, Times New Roman or Arial font must be used, and the text shall have normal width character spacing
 - Headings may be of any font, size or color
 - Body pages shall be numbered, beginning with '1'
 - Captions used for any photographs, tables, line drawings, graphs or other figures shall have normal width character spacing and be no less than 10-point font.
- **Appendices:** Pages shall be numbered in such a way that the appendix and page number are clearly listed (i.e. A1, A2, B1, B2, etc.). There is no limit to appendix length, but it must only contain relevant materials.
- **Paper:** The Body of Work shall be presented on 8 ½" x 11" with portrait-orientated pages. Appendices shall also be presented on 8 ½" x 11"; however they may include landscape-oriented pages.
- **Miscellaneous:**
 - Photographs, tables, line drawings, graphs, headers, and footers shall be permitted and shall be counted as part of the page limits defined above.
 - A list of references or works cited should be included (if necessary), and will not count towards the report page limit.

Body of Work Content

The design report must include the following content. The point distribution for grading of each section is denoted in parenthesis.

- **Filter Discussion (15):** The body of the design report shall contain an overview of the filter and how it works. The filter design will be judged based on the approach each team used

to solve the problem as well as the industry treatment principles implemented in the design process. This section must include clear descriptions of test results, engineering design processes, and the filters success in achieving the water quality requirements. Any advisors on the project shall be recognized.

- **Materials and Cost Analysis (3):** The design report must include a material list with brief explanation and justification of each material selected. See Appendix A for list of permitted materials. The design report must include a cost analysis, which must include both a material cost estimate and an operational cost estimate. The total cost will be taken as a sum of the material and labor costs. Teams will be ranked by lowest cost estimate.
- **Sustainability (3):** The design report must include an explanation of the sustainability aspects of your filter. This section may include the environmental impacts of materials used to design your filter and decisions made regarding choices to minimize cost or reduce environmental impact.
- **Professional Quality (4):** Professional quality of the design report will be based on organization, appearance, and use of language.

Plagiarism of any kind will not be tolerated. Teams caught plagiarizing any portion of their design report will be disqualified.

CONSTRUCTION AND LOADING

Teams will construct their filter design as shown on their technical report. This phase will include construction, filter loading, and transportation of effluent to the testing lab. This section is worth 20 total points, and will be judged based on orderliness of construction site, construction time, cost of treatment system, and overall teamwork – See scoring and deduction methods described below as well as the breakdown of competition scoring on page 12 for the point distribution.

Site Constraints

The teams will each be given a 10' x 10' area to construct their filters defined by lines on the floor. The site limits will be measured from the inside of the boundary marker. Neither operators nor materials may exceed the boundaries of the area. All sites will be located on level concrete or other hard surface. Teams will be scored on their utilization of the space, the orderliness of the site during construction, and the operators' safety and overall teamwork.

Time Constraints

Teams will be timed on the construction of their filters. Each team will be limited to a total of thirty (30) minutes in which to construct the treatment systems. The treatment phase will follow and includes ten (10) minutes for teams to load their systems and a twenty (20) minute treatment period. The collection basin must be removed from the treatment system immediately following the treatment phase.

Construction Details

- Teams will construct their systems in a 10' x 10' space. Site limits will be based on the inside of the placed markers, using a marking tape.
- Teams will place all their unassembled raw materials and tools in the competition area. Prior to beginning the construction phase, judges will compare the provided materials list in the team's technical report to the materials present at the competition.
- Teams shall not pre-mark, pre-assemble, pre-cut or tamper with materials prior to beginning of the construction, although decoration is encouraged. In order to mark any materials, teams must provide their own markers, tape measure, measuring cups, and scales, on an as-needed basis. Teams should list marking materials neither in the materials list or discuss them in the cost analysis.
- All construction materials should be sorted to match the quantity lengths provided in the Competition Rules. For example, lumber should be 4 linear feet prior to bringing the material to the competition regardless of the initial length of purchase.
- All prewashed materials must be dry and should be placed in their original packaging, with the exception of loose sand, GAC, pebbles, and lava rocks which can be placed in clear containers based on the predetermined quantity sizes in Appendix A. A burlap sack may be used instead of a clear container, but should be opened for judges to inspect. Packaging shall not be added to the materials list or the cost analysis portion of the design report. All materials not being prewashed should be in their sealed state, as if purchased from the store. For example, if hydrogen peroxide is purchased, the hydrogen peroxide bottle should be sealed in the manner bought from the store.
- Powered saws or power blades are not permitted.
- Battery-powered tools are permitted, with the exception being the items listed in the above detail. Corded power tools of any kind are not permitted.
- Teams must provide their own tools based on the approved list given the Competition Rules, Appendix B.
- Teams may use up to 4 operators to construct the team's system. Construction time will start once the chief operator says "ready" and the judge will start the clock. Construction time will end once the chief operator says "stop" and the judge will stop the clock.
- Once the chief operator says "stop" teams may not re-enter the construction region, until the filter loading phase.
- Teams will be given a maximum of 30 minutes for the construction of the system.
- Treatment systems must include a collection basin capable of holding 9 gallons of water.

Treatment Phase

At a designated start time, the 10-minute loading period will begin, in which only 2 operators from each team may add any treatment chemicals to their effluent. A stirring stick will be provided. Operators must be outside of their construction site before the end of the 10-minute loading period. Teams will then have 20 minutes for the treatment system to work. The collection basin must be removed from the treatment system immediately following the 30-minute treatment phase.

Scoring and Deductions:

The Construction category is worth 20 points out of the 100 total points in the competition. Construction points will be based on the construction time remaining (13 points), the cost of the treatment system (5 points), the orderliness of their site during construction (1 point), and the operators' overall teamwork (1 point). The orderliness of their site during the construction phase, and the operators' overall teamwork will be determined based on the judge's discretion.

Points for construction time will be awarded based on the following equation:

$(\text{Your rank} / \text{best team's rank}) * 13 \text{ points}$

Deductions affect the overall "Construction" subcategory score.

- Any violation of construction limits will result in a 1 point deduction (i.e. each time an operator or a construction material goes outside the 10ft. X 10 ft. boundary during the construction phase, 1 point will be deducted).
- Any pre-marked, pre-assembled, pre-cut or tampered materials will result in a 1 point deduction.
- 1 point deduction for any time an operator begins constructing prior to the judge starting the stopwatch.
- Any materials not present in the team's materials list but located in the team's design report will result in a 1 point deduction.
- Any materials present in the team's materials list but not located in the team's design report will result in a 1 point deduction.
- Any tools used that are not present in Competition Rules, Appendix B, will result in a 2 point deduction per tool.
- Usage of powered saws or powered blades will result in a 5 point deduction.
- Teams using more than 4 operators will be asked to dismiss the extra operators; ignorance of this request will result in the team's disqualification.
- A point will be deducted from the team's construction score for every time a worker or material touches or enters into the site boundary during the treatment phase.

Note: It is not possible to lose more than 15 points. **Clear violation of ethical practices, based on judge's discretion, will result in disqualification of the team.**

Cost of Treatment System

The cost of the treatment system is worth 5 points. The lowest cost treatment system will receive the most points. This includes the cost of construction (i.e. operator costs).

Points will be awarded based on the following equation:

$(\text{Your rank} / \text{best team's rank}) * 5 \text{ points}$

Safety

Safety is a vital part of this competition. Operators **must** wear hard hats, safety gloves, safety glasses, closed-toed shoes, and long pants at all times during the construction and treatment phases. If at any point the judge deems safety is being violated by a team, the team's construction will come to a halt and the judge will advise the team on best safety practices, while the stopwatch continues running. Any person handling chemical must be wearing a long-sleeved shirt or other article of clothing to cover arms.

POSTER PRESENTATION

Each team must display a poster board of dimensions no larger than 36" x 24" next to their work site. The posters will be judged by the parameters listed below. The point distribution for each is denoted in parenthesis. The poster section is worth a total of five (5) points. Themes are encouraged.

- **Technical Content (2):** The poster must contain, at a minimum, the purpose of the competition, an overview of the filter design, the material list, and the filter cost.
- **Presentation/Q&A (2):** Immediately after the filter construction phase, at least one member of the team must be present to answer any questions about the poster and/or construction to a judge.
- **Professional Quality (1):** Professional quality of the poster will be scored based on organization, appearance, and use of language.

Stands will not count toward the space limitation of the board. Additionally, teams will provide their own poster stands and/or any other equipment required to display the poster.

ORAL PRESENTATION

The final component of the competition is an oral presentation. Judges will award points based on the team's professionalism and clarity in presenting the design process and analysis of their filter design performance. Oral presentations shall be presented in English. Presentation order shall be randomly selected before the competition begins and shall be provided at the time of on-site registration. The oral presentations shall be open to the public for viewing; however once a presentation begins, the doors will be closed until it ends. People will not be allowed to enter the room once a presentation begins.

Teams are required to use PowerPoint to present their projects. Please submit your team's PowerPoint presentation via email to watertreatmentmidpac2016@gmail.com by midnight on Tuesday, April 5, 2016 (11:59 PM). If you need to request changes made to your slid show after the submission date, you may be allowed to do so, but 4 points will be deducted from your overall Oral Presentation score.

Please note that each team will be presented with their water quality results at least ten (10) minutes before the start time of their presentation. Teams may choose to incorporate these results from the water quality phase into their presentation.

Scoring

The presentations will be scored by the parameters listed below. Point distribution is denoted in parenthesis. The presentation section is worth a total of 20 points.

- **Technical Content (8):** Presentations must include, at least, the filter design and treatment process used, materials used, a cost analysis, and sustainability aspects. The content may be presented in any order and is not limited to these components.
- **Oral Presentation (4):** The duration of the oral presentation is limited to ten (10) minutes. Within this time, six (6) minutes will be allotted to the presentation, and four (4) minutes will be allotted to the question-and-answer session. There will be a 5-second grace period to account for timer (stopwatch) reaction. The presentation shall discuss the design reasoning and give an analysis of the filter performance in a clear and concise manner. No more than two team members may present the PowerPoint and answer questions.
- **Visuals (3):** Teams may only use PowerPoint for their presentations. The maximum length is 20 slides. Teams shall use visual aid including graphs or photographs that enhance the product of the presentation.
- **Question & Answer (5):** There will be question-and-answer session immediately following the presentation. Only the panel judges will be permitted to ask questions. The number of questions asked is limited to the 3-minute time frame.

Deductions

After a 1-point deduction for exceeding the allotted presentation time, for every 10 seconds following the maximum 6 minutes and 5 seconds, teams will be deducted 1 point. See below:

- 6:06 – 6:15 1 point deduction
- 6:16 – 6:25 2 point deduction
- 6:26 – 6:35 3 point deduction and so on...

COMPETITION SCORING

A breakdown of points per section of the competition is detailed below. Please refer all water treatment competition related questions to watertreatmentmidpac2016@gmail.com.

Table 1: Competition Scoring by Points Summary

Category	Sub-Category	Points
Water Quality	pH	5
	Turbidity	5
	Total free/available chlorine	5
	Electrical conductivity	5
	Dissolved oxygen	5
	Volume	5
	Subtotal	/30
Design Report	Filter design and analysis	15
	Materials list/cost analysis	3
	Sustainability	4
	Professional quality	3
	Subtotal	/25
Poster Presentation	Technical content	2
	Professional quality	1
	Presentation and Q&A	2
	Subtotal	/5
Oral Presentation	Technical content	8
	Visuals	3
	Oral presentation	4
	Q&A session	5
	Subtotal	/20
Construction	Construction time	13
	Utilization of space	5
	Orderliness of construction site	1
	Overall teamwork	1
	Subtotal	/20
Total		/100

Appendices

Appendix A: Materials List

Each team is permitted to submit a request to add two (2) materials or tools to this list. Please submit for approval to watertreatmentmidpac2016@gmail.com by Sunday, December 6, 2015. If your suggestions are accepted, these materials will become accessible to all teams.

Note all items must be in its original packaging (see exceptions in construction details). For example if a store sells hardware cloth in 10 square feet sizes, bring the unopened packaging to the competition. The hardware cloth will therefore be charged as \$6.70 in the cost analysis section of the design report, regardless of how much is used during the construction phase.

Table 2: List of Available Materials for Filter Design

Number	Item	Unit	Cost (\$/unit)
1	½" Hardware Cloth	/sq. ft.	0.67
2	½" I.D. Soaker Hose	/lin. Ft.	0.36
3	¼" Hardware Cloth	/sq. ft.	0.53
4	1" High Pressure Washer Hose	/lin. Ft.	2.50
5	13 Gallon Trash Can	/unit	5.00
6	16 Qt. Igloo Can Cooler	/unit	23.00
7	2' Ladder	/unit	30.00
8	2" Adjustable Spring Clamp	/unit	6.00
9	2" PVC Pipe Elbow	/elbow	3.00
10	2"x4" 3M Steel Wool	/pad	0.83
11	20 Gallon Trash Can	/unit	8.00
12	2"x4" Dimensional Lumber	/4 lin. Ft.	1.70
13	2"x6" Dimensional Lumber	/4 lin. Ft.	2.44
14	¾" Black Electrical Tape	/lin. Ft.	0.06
15	¾" Thick Plywood	/4 sq. ft.	1.06
16	3/8" Nylon Rope	/lin. Ft.	0.20
17	3/8" Thick Plywood	/4 sq. ft.	2.00
18	30 Gallon Tote	/unit	12.00
19	32 Gallon Trash Can	/unit	13.00
20	36 Gallon Garbage Bag	/unit	0.63
21	3M Compressed Air Dust Remover	/unit	4.67
22	4' Ladder	/unit	40.00
23	409 Original Cleaner	/fl. Oz.	0.16
24	4"x4" Dimensional Lumber	/4 lin. Ft.	3.00
25	5 Gallon Bucket	/unit	2.50
26	5 Gallon Bucket Lid	/unit	2.50
27	5/8" Carpet Pad	/sq. ft.	0.44
28	5/8" I.D. Garden Hose	/lin. Ft.	0.66

29	6' Ladder	/unit	60.00
30	8"x6"x2" (14pprox..) Grout Sponge	/unit	2.00
31	Alum	/oz.	1.60
32	All-Purpose Gravel (Quikrete)	/50 lb.	8.00
33	Apple Cider Vinegar	/2 cups	1.99
34	Astroturf	/sq. ft.	4.00
35	Banana Boat SPF Sunblock Lotion	/12 fl. Oz. bottle	15.72
36	Bolts	/unit	0.05
37	Bounce Dryer Sheet	/20 units	5.00
38	Brawny Paper Towels	/roll	3.00
39	Burlap	/sq. ft.	0.14
40	Canvas Drop Cloth	/sq. ft.	0.25
41	Charcoal	/lb.	0.50
42	Clorox Bleach, concentrated	/5 cups	1.17
43	Clorox Disinfecting Wipes	/15 units	1.50
44	Coarse Compost	/gallon	3.00
45	Coco Liner, 18"	/unit	8.00
46	Coffee Filter	/unit	0.03
47	Commercial Grade Fine Sand	/lb.	0.16
48	Commercial Grade Sand	/lb.	0.12
49	Cotton Ball	/20 units	0.40
50	Dawn Dishwashing Liquid	/oz.	0.20
51	Diatomaceous Earth	/2 lb. bag	10.00
52	Duct Tape 20 yd. Roll	/unit	10.00
53	Fiber Twine	/ft.	0.01
54	Gelatin (Knox unflavored)	/4 oz.	2.00
55	Granular Activated Carbon	/oz.	0.40
56	Gutter Insert Foam, 3'	/unit	8.00
57	Gypsum	/lb.	0.23
58	Hydrogen Peroxide	/3 cups	1.49
59	50 Qt. Igloo Cooler	/unit	70.00
60	94 Qt. Igloo Cooler	/unit	90.00
61	Lava Rock	/cu. Ft.	6.00
62	Lemon Juice	/5 fl. Oz. bottle	1.00
63	Mylar Emergency Sleeping Blanket	/unit	3.00
64	Nail	/unit	0.05
65	Nut	/unit	0.05
66	Original Swiffer Duster	/unit	1.08
67	OxiClean Stain Remover	/lb.	1.20
68	Paint Tray	/tray	2.00
69	Peat Moss	/cu. Ft.	6.50
70	Pebbles, large	/5 lb.	2.50

71	Pebbles, Pond / Landscape	/5 cu. Ft.	4.99
72	Pickling Lime	/oz.	0.20
73	Pine-Sol All-Purpose Cleaner	/fl. Oz.	0.07
74	[use no other Pine-Sol cleaning product]		
75	Plant Protector Bags	/bag	5.00
76	Plaster of Paris	/lb.	0.70
77	Plastic Tarp	/sq. ft.	0.20
78	Play Sand	/lb.	0.10
79	Plumbing Epoxy Putty	/package	3.49
80	ABS Pipe, 1-1/2" diameter	/5 lin. Ft.	1.50
81	ABS Pipe, 2" diameter	/5 lin. Ft.	20.00
82	Copper Pipe, 1/2" diameter	/5 lin. Ft.	6.00
83	Copper Pipe, 1" diameter	/5 lin. Ft.	16.00
84	Corrugated Pipe, 3" diameter	/5 lin. Ft.	2.50
85	Corrugated Pipe, 4" diameter	/5 lin. Ft.	3.00
86	PVC Pipe, 1" diameter	/5 lin. Ft.	1.00
87	PVC Pipe, 1-1/2" diameter	/5 lin. Ft.	1.50
88	PVC Pipe, 2" diameter	/5 lin. Ft.	2.00
89	Pool Filter Sand	/lb.	0.30
90	Pumice Stone (1 CF)	/cu. Ft.	11.99
91	Rubbing Alcohol	/3 cups	1.49
92	Salt (Morton iodized table salt)	/26 oz.	1.00
93	Screw	/unit	0.05
94	Sham-Wow	/sq. ft.	5.00
95	Stainless Steel Safety Wire	/lin. Ft.	0.25
96	Standard Air Conditioner Filter	/unit	2.67
97	Terrycloth Rags	/lb.	5.00
98	Tide Concentrated Liquid Detergent	/fl. Oz.	0.25
99	Tote, 5 Gallon	/unit	4.00
100	Tote Lid, 5 Gallon	/unit	1.00
101	Tote, 10 Gallon	/unit	5.00
102	Tote Lid, 10 Gallon	/unit	1.00
103	Tote, 13 Gallon	/unit	7.00
104	Tote Lid, 13 Gallon	/unit	1.00
105	Tote, 18.5 Gallon	/unit	8.00
106	Tote Lid, 18.5 Gallon	/unit	1.00
107	TSP/90	/lb.	3.00
108	Turtle Wax Hard Shell Paste Wax	/fl. Oz.	0.55
109	Weed Control Fabric	/sq. ft.	0.11
110	Window Screen Mesh	/3 sq. ft.	1.00
111	Window Squeegee	/unit	6.00
112	Wood Mulch	/cu. Ft.	6.00

Appendix B: Operational Costs**Operator Costs:** \$40/operator/hour**Table 3: Breakdown of Additional Operator Costs**

Number	Item	Cost (\$/unit)
1	Adjustable Wrenches	3.00
2	Basic Socket Set	5.00
3	Caulking Gun	2.00
4	Channel Locks	1.50
5	Cordless Drill	10.00
6	Drill Bits (each)	1.50
7	Hand Saw	10.00
8	Pliers	1.50
9	Scissors	2.00
10	Screwdrivers (each)	1.00
11	Standard Builder's Hammer	5.00
12	Utility Knife	2.00
13	Wire Cutters	2.00
14	Pipe Cutters	10.00
15	Pipe Wrench	5.00