From Left to Right: Alex Winkler, Vivianna Gamez Molina, Rebecca Wertz, and Ahmed Alqallaf. (Class of 2014)

Coming together is a beginning, staying together is progress, and working together is success.

-Henry Ford

Final Design Report for the Drinking Water Stabilization Project

May 1, 2014

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Table of Contents

List of Tables

List of Figures

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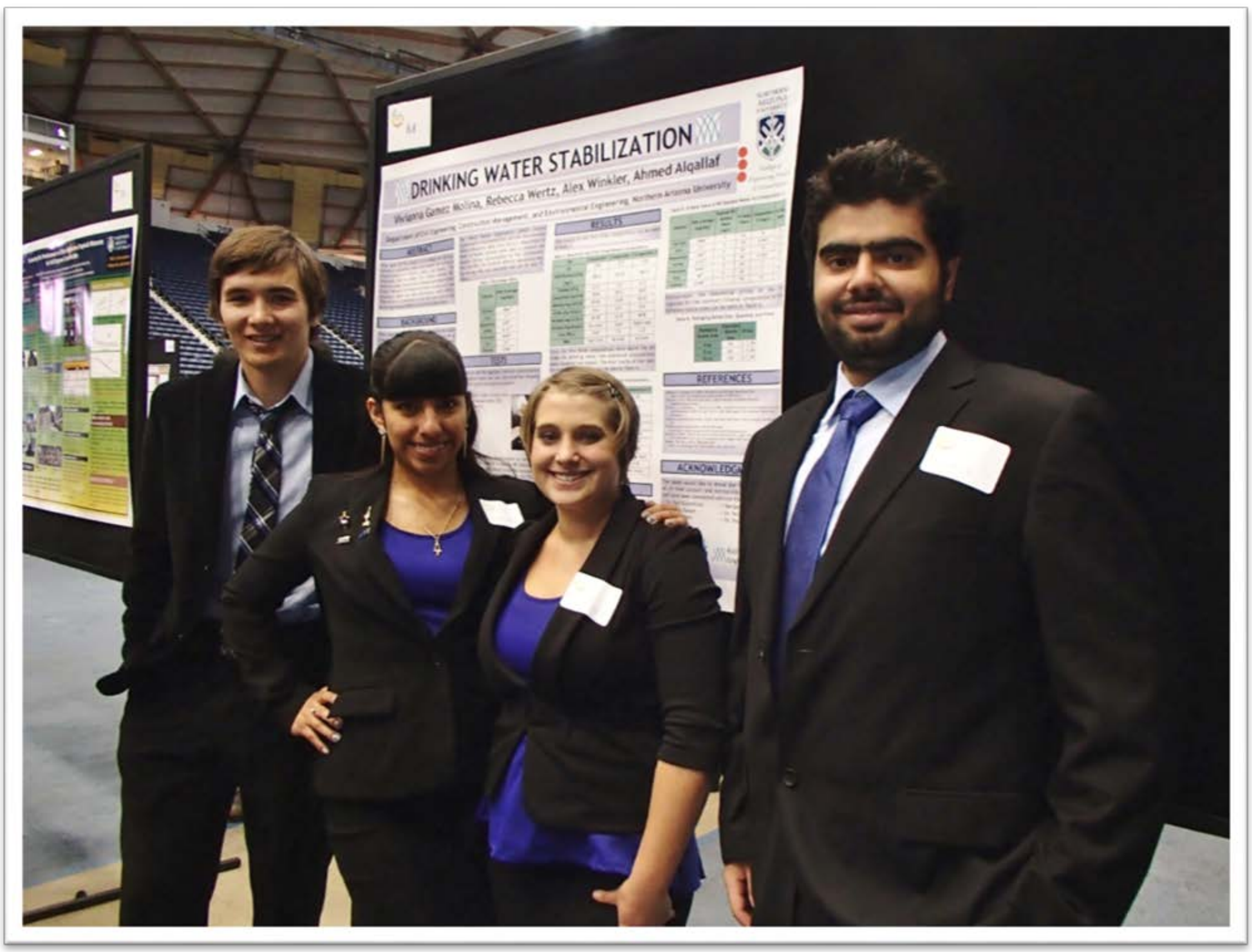
Sincerely,



From left to right: Alex Winkler, Vivianna Gamez Molina, Rebecca Wertz, and Ahmed Alqallaf.

1.0 Project Description

1.1 Purpose of Project

This project, is to determine an innovative way to “stabilize” drinking water that uses the Reverse Osmosis (RO) treatment method. “Stabilization” refers to optimum mineral composition to be added into RO bottled water taking into account the nutritional requirements for children, adults, and seniors to prevent leaching of minerals from the skeletal system.

This project will indicated the following considerations:

- Nutritional requirements for humans;
- Nutritional requirements for livestock;
- Reducing the corrosion impact in the water distribution system due to RO bottled water;
- The development of a marketing plan to sell the optimum mineral additive to the public taking into account possible impacts;
- Development and completion of a cost analysis that takes into account the implementation of adding the supplementary minerals into the bottling process for future bottled waters, and the cost of the added minerals to production.

RAVA Fontus Engineering Inc. is also entering the drinking water stabilization project into the 2014 Environmental Design Contest sponsored by the Waste-management Education and Research Consortium (WERC): An Organization for Environmental Education and Technology Development[2].

2.0 Background Information

2.1 Reverse Osmosis

The drinking water stabilization project entails investigating the amount and type of minerals that are in bottled water which uses the RO process. During the RO process, all the particles that are larger than a water molecule, including the minerals, are removed through a pressurized membrane. When RO bottled water is consumed, the minerals from the skeletal system replace the ones that were lost in the RO process[14]. This happens because of the concentration gradient and need for equilibrium between the minerals within the body and the RO water that was consumed. When a person drinks a significant amount of RO bottled water for a prolonged period of time it can cause health issues such as osteoporosis, cardiovascular disease, and kidney stones [12]. Two of these diseases can be attributed the leaching of minerals from within the body, for osteoporosis it is calcium and for cardiovascular disease it is magnesium, calcium and zinc. Kidney stones can occur when there are too many minerals within the urinary system and when they pass through the kidney, which is predominantly a filter, these minerals build up and generate kidney stones. For the prevention of these diseases occurring by consuming RO bottle water, there is a major need to reintroduce minerals into the water. It is important to know what the variance of minerals in RO bottled water are and how they compare to the Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) standards under the Code of Federal Regulations (CFRs) for bottled water, which will be further discussed in section 1.4.2 Regulatory Requirements. Additionally, information from the U.S. Department of Health and Human Services as well as the World Health Organization will help to determine the maximum mineral concentrations that can be added into RO bottled water.

2.2 Human Nutritional Requirements per Age Group

Regarding human health, consideration of multiple age groups (children, adults, and seniors) must be made. Each age group has a specific list of minerals that are needed for daily nutritional health requirements. The minerals for each age group are shown below in Table 1. Within each of these age groups certain minerals are represented throughout. These minerals are calcium, magnesium, potassium, copper, iron, iodine, sodium, and zinc.

Table 1: Recommended Dietary Mineral Allowances by Age Group.

Minerals	Children (mg/day)	Adults (mg/day)	Seniors (mg/day)
Calcium	1,300	1,200	≤ 2,500
Chromium	N/A	1.5	N/A
Copper	N/A	2	0.70-0.90
Iodine	0.115	0.150	N/A
Iron	11	18	10
Magnesium	400	40	320-420
Phosphorus	N/A	1,000	N/A
Potassium	4,700	10	N/A
Selenium	N/A	0.05-0.20	N/A
Zinc	9	15	2.5

All values and minerals were retrieved from U.S. Department of Health & Human Services[16]. N/A = Not Available.

Within each of these age groups there are certain minerals that are represented throughout. These minerals are calcium, magnesium, potassium, copper, iron, iodine, sodium, and zinc. Therefore, RAVA Fontus Engineering Inc. will take them into consideration for the optimum mineral composition.

2.3 Human Nutritional Maximum Mineral Regulations in RO Bottled Water

Drinking water reports from the World Health Organization (WHO) were used to find the recommended mineral concentration that should be in RO bottled water [21,22,23,32]. Also, since each group has a different recommended dietary allowance (RDA) for each of the eight minerals, the average values were tabulated for future percentage daily value (% DV) calculations, which will be discussed in section 3.0 Identification of Alternatives. The RDAs were obtained from the U.S. Department of Health & Human Services, Colorado State University, Centers for Disease Control and Prevention, and the American Cancer Society. Table 2 shows the WHO mineral concentration recommendation in mg/L and the RDA average in mg/day.

Table 2: WHO Mineral Concentration (mg/L) and RDA Average (mg/day).

Mineral	WHO Mineral Concentration in Drinking Water Recommendation (mg/L)	RDA Average (mg/day)
Calcium	≥20	1000[16]
Iron	≤0.3	11[16]
Copper	≥1	0.9[15]
Magnesium	≥10	270[16]
Iodine	≤0.004	0.12[16]
Potassium	≥8	3450[11]
Zinc	≥1.1	18[16]
Sodium	≥200	>2300[26]

2.4 WERC Competition

The Environmental Design Contest sponsored by WERC started in 1991 in Las Cruses, New Mexico and has been held there annually ever since. The purpose of the competition is to assess young engineers on designed engineering solutions for environmental issues. This year five tasks are open for the competition. They are as follows: open design, drinking water stabilization, power point tracking for solar energy, solar brine concentrator, and floating solar cells. The task that RAVA Fontus Engineering Inc. has entered is the drinking water stabilization [27], see Appendix A for more details.

2.4.1 Livestock Nutritional Requirements

The minerals for the nutritional requirements of livestock (cow, sheep, horse, goat, and pig) need to be reported in the WERC competition report (see Appendix B), but will not be taken into consideration when designing the optimum mineral composition. The daily nutritional mineral values vary from animal to animal, they cannot be compared to human values since they are extremely diverse. However, the common minerals that are required for the nutritional health of livestock are as follows [16].

- Calcium
- Phosphorus
- Magnesium
- Potassium
- Sodium
- Chlorine
- Sulfur

2.4.2 Water Distribution System

The water distribution system is the "piping system that delivers potable water from the treatment plant to consumers"[18]. Since RO water is demineralized, it has similar effects on the water distribution system to the effects on the skeletal system. Demineralized water is also considered soft water, which means that "it contains only small amounts of dissolved minerals such as calcium and magnesium"[14].When RO water flushes through the pipes, it not only corrodes them, but leaches metals and other materials from the pipes. Chemicals such as calcium carbonate or limestone must be added to reduce corrosion on the piping system [14].

2.5 Stakeholders

Key stakeholders are individuals and institutions who sponsor or invest in a specific project so it meets their goals or requirements. The specific stakeholders for this project are as follows: the client, WERC, and potential consumers, which include children, adults, and seniors.

2.6 Existing Conditions

Currently, the bottled water industry profits from advertisements that claim their water is as fresh as natural spring water, or their water is pure and enhanced with minerals and electrolytes [16]. Many of these statements can be misleading because of the lack of nutritional labeling due to minimal regulations.

2.6.1 Current Water Companies

The following three popular RO bottled water brands were selected to gain an understanding of what is currently sold and do a complete water quality report for each brand. This information will aid to the design of the final optimum mineral additive. The three brands are shown below in Table 3.

Table 3: RO Bottled Water Brands.

Brand	Description
Aquafina® by PepsiCo®	This specific brand uses RO for their purification process which makes it potentially unhealthy, but yet they claim their water is "pure with a perfect taste"[20].
Dasani® by Coca-Cola®	This bottled water company claims to sell water enhanced with minerals for a "pure and fresh taste"[20]. Yet, they also use the RO process to remove contaminants from the water which makes the water soft.
365 Spring Water ® by Whole Foods®	Whole Foods® uses RO water, but they do add minerals back into it[20].

2.6.2 Regulatory Requirements

Bottled water is considered food under the FDA. Currently there are regulations about the maximum chemical concentrations allowed in bottled water in the CFRs under Title 21: Food and Drugs, part 165-beverages, subpart B-requirements for specific standardized beverages. Table 4 shows these regulatory maximum concentrations. The inconsistency of the regulated minerals is due to the regulators only focusing on the minerals which can be potentially harmful at low concentrations.

Table 4: Regulatory Maximum Concentrations in Bottled Water (mg/L).

Mineral	Regulatory Maximum Concentration (mg/L)
Calcium	Not Regulated
Copper	1.0
Iron	0.3
Magnesium	Not Regulated
Iodine	Not Regulated
Potassium	Not Regulated
Zinc	5.0
Sodium	Not Regulated
Chloride	250
Sulfate	250
Total Dissolved Solids	500

As shown above, calcium, magnesium, iodine, potassium, and sodium are not regulated in the CFRs under the FDA.

2.7 Technical Considerations

The main goal of the project is to have an optimum mineral composition which will be added to current RO bottled waters. To meet the deliverables for this project, multiple technical considerations must be implemented.

2.7.1 Testing

The first technical consideration is the testing needed for the project. Preliminary testing is needed to determine the physical and chemical qualities of the water that already exist in the market today. Once these are found the focus can be directed to testing the optimum mineral compositions. The criteria for the tests are specified in CFR 165.110(a-b) for bottled water. The tests that will be performed are: acidity, alkalinity, cation and anion identification, color, electro-conductivity, odor, pH, total dissolved solids and turbidity.

2.7.2 Design/Build Bench Scale Model

The next technical consideration is the design and build of a bench scale model which includes, the medium of product, selection of additive mix, and economic analysis. The bench scale model will be used to present the final product to the client and the WERC competition. The bench scale model has both a testing component and a visual component.

The medium in which the product is delivered is an important component of the design. The medium of the product will either be in liquid or powder form. This criteria will be tested by analyzing solubility and TDS of the different mediums. The medium of the end product must meet the standards outlined by the FDA. The packaging of the medium will not be determined.

For the selection of additive mix three different mineral compositions will be created and tested. A decision matrix will be used to determine which of the compositions will be chosen. Each composition will be scored on color, odor, TDS, turbidity conductivity, nutritional value, cost, and water distribution system impact.

Along with the medium of product and the selection of the additive mix, the calculation of the production costs is important to the overall design. It will involve an analysis of the different elements of the bench scale model. A cost analysis to produce the product will be performed.

2.7.3 WERC Competition

2.7.3.1 Safety Summary

The safety summary is one of the major deliverables of this project. This document entails writing a report to identify what, when, where, and how chemicals are used during the bench scale test. The safety summary includes written plans for accident response, the Material Safety Data Sheet (MSDS) for each chemical, and a flow diagram of the bench scale test, which can be seen in Appendix C.

2.7.3.2 WERC Competition Report

The written report has a set of guidelines and details that must be followed for the WERC competition. These can be found in 10.2 Appendix B Guidelines and Details for WERC Written Report. Once the report is submitted, the document will be property of WERC. Thereafter, RAVA Fontus Engineering Inc. and experts will have no affiliation with any use of the document.

3.0 Identification of Alternatives

Three alternatives were originally identified; however, it was necessary to add two additional mineral compositions because the pH of the first three alternatives was too high for drinking water standards. This will be further discussed in section 4.0 Testing/Analysis.

3.1 Round 1 of Testing

Composition 1 can be seen in Table 5.

Table 5: Composition 1 with Regulatory, RDA, and Percentage Daily Value Information.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)	Composition 1 (mg/L)	% DV (3 Liters/day)
Calcium	**Not Regulated**	**$\geq$20**	**1000[16]**	30	9%
Copper	**1.0**	**$\geq$1**	**0.9[15]**	1	333%
Iron	**0.3**	**$\leq$0.3**	**11[16]**	0.3	8%
Magnesium	**Not Regulated**	**$\geq$10**	**270[16]**	26	29%
Iodine	**Not Regulated**	**$\leq$0.004**	**0.12[16]**	0.004	10%
Potassium	**Not Regulated**	**$\geq$8**	**3450[11]**	8	1%
Zinc	**5.0**	**$\geq$1.1**	**18[16]**	5	83%
Sodium	**Not Regulated**	**$\geq$200**	**>2300[26]**	100	13%
Chloride	**250**	**Not Applicable**	**Not Applicable**	42.46	Not Applicable
Sulfate	**250**	**Not Applicable**	**Not Applicable**	95.37	Not Applicable

As shown above, composition 1 has high percent daily values for each of the minerals so as to have one composition at the regulatory maximum concentrations.

Composition 2 can be seen in Table 6.

Table 6: Composition 2 with Regulatory, RDA, and Percentage Daily Value Information.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)	Composition 2 (mg/L)	% DV (3 Liters/day)
Calcium	**Not Regulated**	**≥20**	**1000[16]**	20	6%
Copper	**1.0**	**≥1**	**0.9[15]**	0.5	167%
Iron	**0.3**	**≤0.3**	**11[16]**	0.2	5%
Magnesium	**Not Regulated**	**≥10**	**270[16]**	20	22%
Iodine	**Not Regulated**	**≤0.004**	**0.12[16]**	0.003	8%
Potassium	**Not Regulated**	**≥8**	**3450[11]**	7.5	1%
Zinc	**5.0**	**≥1.1**	**18[16]**	4	67%
Sodium	**Not Regulated**	**≥200**	**>2300[26]**	75	10%
Chloride	**250**	**Not Applicable**	**Not Applicable**	24.77	Not Applicable
Sulfate	**250**	**Not Applicable**	**Not Applicable**	70.12	Not Applicable

Composition 2 was an intermediate composition in the first series of options. The amount of minerals in this composition are moderately lower than the values in the first mineral additive. This choice was to have an intermediary between the regulatory maximum and minimum concentrations.

Composition 3 can be seen in Table 7.

Table 7: Composition 3 with Regulatory, RDA, and Percentage Daily Value Information.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)	Composition 3 (mg/L)	% DV (3 Liters/day)
Calcium	**Not Regulated**	**≥20**	**1000**[16]	15	5%
Copper	**1.0**	**≥1**	**0.9**[15]	0.2	67%
Iron	**0.3**	**≤0.3**	**11**[16]	0.1	3%
Magnesium	**Not Regulated**	**≥10**	**270**[16]	15	17%
Iodine	**Not Regulated**	**≤0.004**	**0.12**[16]	0.002	5%
Potassium	**Not Regulated**	**≥8**	**3450**[11]	7	1%
Zinc	**5.0**	**≥1.1**	**18**[16]	2	33%
Sodium	**Not Regulated**	**≥200**	**>2300**[26]	50	7%
Chloride	**250**	**Not Applicable**	**Not Applicable**	15.92	Not Applicable
Sulfate	**250**	**Not Applicable**	**Not Applicable**	49.12	Not Applicable

The third composition had the lowest amounts of minerals in the first batch of compositions. This alternative was designed with having the regulatory minimum concentrations.

3.2 Round 2 of Testing

Composition 4 can be seen in Table 8. This composition does not have copper which will be later explained in sub-section 4.2 Five Mineral Composition Testing Results. After designing the first three compositions, the sodium concentration had to be adjusted because it was making the pH too high (greater than 8.5), which will be further discussed in sub-section 4.2 Five Mineral Composition Test Results. Composition 4 had significantly fewer minerals which allowed it to be in the appropriate pH range, but greatly reduced the nutritional value.

Table 8: Composition 4 with Regulatory, RDA, and Percentage Daily Value Information.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)	Composition 4 (mg/L)	% DV (3 Liters/day)
Calcium	Not Regulated	≥20	1000[16]	8	2%
Copper	1.0	≥1	0.9[15]	Not Considered	Not Considered
Iron	0.3	≤0.3	11[16]	0.005	0%
Magnesium	Not Regulated	≥10	270[16]	10	11%
Iodine	Not Regulated	≤0.004	0.12[16]	0.001	3%
Potassium	Not Regulated	≥8	3450[11]	7	1%
Zinc	5.0	≥1.1	18[16]	1	17%
Sodium	Not Regulated	≥200	>2300[26]	13	2%
Chloride	250	Not Applicable	Not Applicable	3.54	Not Applicable
Sulfate	250	Not Applicable	Not Applicable	29.05	Not Applicable

Composition 5 can be seen in Table 9. Again, this composition does not have copper which will be later explained in sub-section 4.2 Five Mineral Composition Testing Results.

Table 9: Composition 5 with Regulatory, RDA, and Percentage Daily Value Information.

Mineral (cation or anion)	Regulatory Max Concentration (mg/L)	WHO Mineral Concentration Recommendation (mg/L)	RDA Average (mg/day)	Composition 5 (mg/L)	% DV (3 Liters/day)
Calcium	**Not Regulated**	**$\geq$20**	**1000**[16]	8	2%
Copper	**1.0**	**$\geq$1**	**0.9**[15]	Not Considered	Not Considered
Iron	**0.3**	**$\leq$0.3**	**11**[16]	0.005	0%
Magnesium	**Not Regulated**	**$\geq$10**	**270**[16]	10	11%
Iodine	**Not Regulated**	**$\leq$0.004**	**0.12**[16]	0.001	3%
Potassium	**Not Regulated**	**$\geq$8**	**3450**[11]	7	1%
Zinc	**5.0**	**$\geq$1.1**	**18**[16]	1	17%
Sodium	**Not Regulated**	**$\geq$200**	**>2300**[26]	12	2%
Chloride	**250**	**Not Applicable**	**Not Applicable**	3.54	Not Applicable
Sulfate	**250**	**Not Applicable**	**Not Applicable**	29.05	Not Applicable

The last composition is nearly identical with the 4th one, but the only difference is the concentration of sodium. The sodium was reduced by 1 mg/L from alternative 4 to 5 because it had the greatest effect on the pH value. Composition 5 was designed to contain the least amount of minerals out of all of the options, but it will still improve the nutritional value of RO bottled water.

4.0 Testing/ Analysis

This section discusses the three RO bottled water and five mineral composition testing results. The three RO bottle water testing results were needed to determine which popular brand was going to be used as the standard for testing with the five mineral compositions, which is why it was completed first.

4.1 Three RO Bottle Water Brands Testing Results

The results of the water quality analysis for the three different brands of RO bottle water testing can be seen in Appendix D, and they show that all of the brands do not met the WHO guidelines for minimum drinking water values. The purpose of the water quality analysis is to determine a base water and not for regulatory comparison purposes. There is a very low amount of turbidity dissolved solids, turbidity, and conductivity which means that there is a minimum amount of minerals for all three brands. Additionally, both Aquafina® and Dasani® are soft waters which means that they negatively affect the water distribution system by scaling and corroding due to the fluctuations in the pH of the water.

Since Aquafina® had the lowest amount of minerals and lowest hardness value, this brand was selected to use as the base for the five optimum mineral compositions. The team wants to stabilize the worst popular type of RO bottled water that is on the market.

4.2 Five Mineral Composition Testing Results

The tests results for all five compositions can be seen in Table 10. All of the standard methods that were followed for each test were obtained from the Standard Methods for the Examination of Water and Wastewater lab book. Cupric sulfate was eliminated since it precipitated easily as each composition was being prepared. None of the compositions that were tested had cupric sulfate, even though the first three compositions were designed to have copper. Three samples of each composition were tested for quality and quantity control purposes.

Table 10: Test Results for the Five Optimum Mineral Compositions.

Test Results	Composition 1	Composition 2	Composition 3	Composition 4	Composition 5
pH	**8.90**	**8.75**	**8.60**	7.60	7.50
Total Dissolved Solids (mg/L)[9]	290.67	212.00	148.33	56.67	55.67
Turbidity (NTU)[4]	23.22	5.73	4.31	0.97	0.43
Conductivity (mA/V*m)[9]	54.90	39.33	28.07	10.77	10.63
Alkalinity (mg $CaCO_3$/L)[6]	176.00	134.00	102.67	26.33	25.50
Acidity (mg $CaCO_3$/L)[6]	N/A	N/A	N/A	-23.33	-21.50
Hardness (mg $CaCO_3$/L)[8]	181.98	132.30	66.28	48.80	48.80
Hardness Classification[8]	Very Hard	Hard	Slightly Hard	Slighly Hard	Slightly Hard
Color (PtCo)[3]	10.00	7.33	5.33	4.00	3.33
Odor[5]	Slight Smell	No Smell	No Smell	No Smell	No Smell

4.2.1 pH

The pH measures the hydrogen ion concentration. The EPA recommends drinking water to have pH between 6.5 and 8.5[17]. For round 1 of testing, compositions 1, 2, and 3 are above the 8.5 maximum pH limit, which is why two additional compositions were designed for round 2 of testing. The sodium bicarbonate salt concentration was lowered to adjust the pH by using trial and error and then checked by the Langlier Saturation Index calculation, which is in Appendix E. Compositions 4 and 5 had a pH of 7.6 and 7.5, respectively, which are within the in the mid-range of 6.5 and 8.5.

4.2.2 Total Dissolved Solids (TDS), Turbidity, and Conductivity

The TDS test [10] measures the total solids that pass through the fiberglass filter in mg/L by using the conductivity meter, not the oven drying method. The turbidity test [4] measures the suspended and colloidal matter in units of nephelometric turbidity Units (NTU) using the turbidimeter. Lastly, the conductivity test [9] measures the ability of an aqueous solution to carry an electric current in miliAmperes per Volt meter (mA/(Vm)). The conductivity test can also be a surrogate for TDS. Because of the concentration and volume of the sample the conductivity test was used to find TDS for the five compositions.

From the round 1 of testing, composition 1 had the highest total minerals, followed by composition 2 and 3. From round 2 testing composition 4 had the less minerals than composition 3, and composition 5 had the lowest amount of minerals out of all five compositions. From the TDS, turbidity, and conductivity test results, the trend found was that the higher the mineral concentration, the higher the TDS, turbidity, and conductivity values, and vice versa. Therefore composition 1 had the highest TDS, turbidity, and conductivity values, while composition 5 had the lowest.

4.2.3 Alkalinity and Acidity

The alkalinity and acidity tests[7,6] are both performed by titration in milligrams as calcium carbonate per liter. For alkalinity, sulfuric acid with a normality of 0.01 was used to bring down the pH to 4.5. For acidity, sodium hydroxide titrant with a normality of 0.01 was used to increase the pH to 8.3.

Alkalinity of water is its acid-neutralizing capacity. The higher the alkalinity in drinking water, the better it is because the water can remain at a stable pH. The alkalinity trend results also showed the trend that the higher the mineral composition, the higher the alkalinity. Therefore, composition 1 had the highest alkalinity and compositions 4 and 5 had the lowest alkalinity. Additionally, all the values obtained from the alkalinity and acidity testing were valid because they were within acceptable limits.

Acidity helps to measure the corrosiveness capacity of the water. The optimum mineral composition should not be acidic. Since the pH for compositions 1, 2, and 3 were higher than 8.3, the acidity tests could not be completed. Having a pH greater than 8.3 means that the solution is not acidic, which is a good quality. Compositions 4 and 5 both had a negative acidity value, which represented the net alkalinity. A negative value must be reported because of the standard methods procedure, but a negative value means that the water has more alkalinity than acidity.

4.2.4 Hardness

Hardness is the sum of the calcium and magnesium concentrations measured as calcium carbonate in mg/L. It is more desirable to have softer hardness classification because it means a smaller impact on the water distribution system since the water will have a lower capacity to precipitate minerals from the pipes.

Since composition 1 had the highest calcium and mineral concentration, it had the highest hardness value which classified it as "very hard" under the hardness classifications [29]. Composition 2 had lower mineral concentrations than composition 1, which classified the water as "hard." Compositions 3, 4, and 5 had a hardness classification of "slightly hard" since their calcium and magnesium mineral content were similar. All hardness classifications found during testing were acceptable.

4.2.5 Color and Odor

Color is measured by the dissolved solids of each composition in units of Platinum-Cobalt (PtCo). The lower the color is, the more palatable. Composition 1 had the highest color and composition 5 the lowest color. The higher the color number, the more mineral content is present in the water. Also, the higher the color, the more light was reflected by the color testing instrument, similarly to the turbidimeter. All color results were acceptable because they were less than 15 units.

For the odor test, only composition 1 had a "slight smell" while the rest of the compositions had "no smell." Composition 1 had the highest amount of mineral concentration, which accounts for this result. All smell results were acceptable.

5.0 Identification of Selected Design

In order to identify the final design, the cost of making each mineral composition had to be estimated. Table 11 shows the cost of each food grade salt per composition. These costs are bulk prices. The cheapest salt is magnesium sulfate, while the most expensive salt is zinc acetate. Also, ferrous sulfate and potassium iodide salts show a cost of $0.00 because less than a gram is being used for the composition.

Table 11: Cost of Each Mineral Composition.

Salts	Cost ($)	$/g	Composition 1	Composition 2	Composition 3	Composition 4	Composition 5
Calcium Chloride	165.00[13]	0.007	$0.24	$0.14	$0.09	$ 0.02	$0.02
Ferrous Sulfate	120.00[30]	0.005	$0.00	$0.00	$0.00	$0.00	$0.00
Magnesium Sulfate	80.00[19]	0.003	$0.18	$0.13	$0.10	$0.06	$0.06
Potassium Iodide	60[24]	0.083	$0.00	$0.00	$0.00	$0.00	$0.00
Potassium Sulfate	2688.00[1]	0.108	$0.24	$0.18	$0.12	$0.12	$0.12
Sodium Bicarbonate	51.10[25]	0.102	$17.93	$12.51	$8.59	$1.68	$1.49
Zinc Acetate	158.80[2]	0.159	$1.33	$1.07	$0.53	$0.27	$0.27
		TOTAL	**$19.92**	**$14.03**	**$9.43**	**$2.14**	**$1.96**

The best option for the mineral composition was based on the following criteria; turbidity, color, odor, conductivity (C), total dissolved solids (TDS), cost, nutritional value, and impact on the water distribution system. Depending the importance of the criteria to the overall success of the project, a weighted score was determined for each factor. The decision matrix used to evaluate all five mineral compositions can be seen in Table 12. Criteria color, odor, TDS, EC, and turbidity all received a weight of 0.10 because together these criteria make up the aesthetics of the composition and since it is important that the appearance of the drinking water is not negatively affected by the mineral additive, half of the weighted score would be dedicated to aesthetics. The next most important criteria is nutritional value of the additive (determined by the concentrations of various minerals) which received a score of 0.30. Cost received a weight of 0.15 because the project requires a marketing plan and a cornerstone of that plan is the profitability of the product. Keeping costs down will create more profit and thus make the item more economically feasible. Lastly, the impact on the water distribution system received a weight of 0.05. This value is low because while how the additive affects the water distribution system is a task for this project, it is a minor one compared to the nutritional value and aesthetics of the composition.

Table 12: Decision Matrix to Evaluate the Five Mineral Compositions.

Criteria	Weight	Composition 1	Composition 2	Composition 3	Composition 4	Composition 5
Color	0.10	0.45	0.5	0.6	0.75	0.8
Odor	0.10	0.5	0.7	0.9	0.9	0.9
TDS	0.10	0.4	0.5	0.6	0.85	0.85
Turbidity	0.10	0.3	0.9	1.8	2.7	2.7
Conductivity	0.10	0.5	0.55	0.7	0.8	0.8
Nutritional Value	0.30	2.55	2.1	1.8	1.2	1.2
Cost	0.15	0.45	0.75	0.9	1.35	1.35
Water Distribution System Impact	0.05	0.15	0.2	0.2	0.35	0.35
Total	***1.0***	***5.3***	***6.2***	***7.5***	***8.9***	***8.95***

Compositions 1 and 2 have significantly higher concentrations of minerals than the other compositions. These two options were designed to be the most nutritional additives, but with the large amounts of minerals the aesthetics of the water was reduced, so compositions 1 and 2 received the lowest and second lowest scores respectively. Compositions 3 and 4 had intermediate amounts of minerals which gave the two designs an adequate score, but composition 5 had a better score. All the options were analyzed using the decision matrix and composition 5 scored the highest. This option was selected mainly because it had high scores in criteria linked to aesthetics. The 5 components of aesthetics (C, turbidity, TDS, color, and odor) are dependent on the concentration of the minerals. The lower the amount of minerals, the higher the score. Since composition 5 had the lowest amount of minerals, it received a high score for all of those criteria as well as cost. Composition 5 was also the least expensive choice because of its relatively low amounts of minerals. Even though it received the lowest score for nutritional value it still meets the goals of the project so composition 5 was chosen to be the final design of the project.

6.0 Final Design

This section will discuss the nutritional benefits, effect of the water distribution system, and the impacts of the final design. The composition that has been chosen is not only a healthy and aesthetically pleasing design, but does not negatively affect the water distribution system.

6.1 Mineral Composition Benefits

The optimum mineral composition is a healthy product that supplies the body with essential minerals that would otherwise be leached from the body by the RO water. The mineral composition provides anywhere from 0.1% to 17% of the daily value of minerals, which can be seen in Table 13. The daily value is calculated using the mineral concentration, RDA, and assuming a drinking rate of three liters a day. This design will prevent damages brought to the body due to the long term consumption of water treated by reverse osmosis.

Table 13: Percent Daily Values of the Optimum Mineral Composition.

Mineral	RDA Average (mg/day)	Popular RO Bottled Water (mg/L)	% Daily Value	Composition 5 (mg/L)	% Daily Value
Calcium	**1000** [4]	0	0%	8	2%
Iron	**11** [4]	0	0%	0.005	0.1%
Magnesium	**270** [4]	0	0%	10	11%
Iodine	**0.12** [4]	0	0%	0.001	3%
Potassium	**3450** [1]	0	0%	7	1%
Zinc	**18** [4]	0	0%	1	17%
Sodium	**>2300** [7]	1	0%	12	2%

6.2 Water Distribution System Impact

The optimum mineral composition would not negatively affect the water distribution system. As indicated in Table 10, the composition is not acidic and is only slightly alkalinity. The alkalinity of the final design was 25.50 $mgCaCO_3/L$ which is a low value and indicates that neither scaling nor corrosion will occur.

6.3 External Impacts

Not only does the optimum mineral additive have a direct impact on RO bottled drinking water but it has a broader impact on many areas. This project will cause environmental, social, cultural, and political impacts. Each of these impacts will be discussed further below.

6.3.1 Environmental

There are a great number of environmental impacts for this project. It is the goal to purchase and produce materials that are environmentally sustainable. It is a goal to be as carbon neutral as possible and most of the waste produced will be diverted entirely from the waste stream or recycled. Our wastewater will meet and exceed all EPA clean water act regulations and that the process of making the optimum mineral additive will be as efficient as possible so that the least amount of water is wasted. One negative impact that the product may have on the environment is that it might entice people to drink more bottled water which will cause more waste to be produced and more demand on already dwindling resources such as petroleum that is used to make plastic bottles.

6.3.2 Social

The social impact of the optimum mineral additive is that it can change the perception of how people view RO bottled waters. Currently, many people, especially in areas where the taste of the tap water is not appealing, choose to drink RO water because it tastes better and they believe it is healthier from them. When in actuality, RO water can cause harm when consumed regularly. The public must be informed of the dangers of drinking RO water and that by adding the optimum mineral additive it will nullify them.

6.3.3 Cultural

The cultural impact are very similar to the social impact, but that the perception has to do with a cultural practice than one person’s perception of RO bottled water. For example people who are from or have family who come from countries that do not have potable drinking water through the public water distribution system drink bottled water out of necessity. It is these people that will be impacted culturally by the optimum mineral additive because they are the ones who are likely to drink RO bottled water and the ones that will benefit the most from the mineral additive.

6.3.4 Political

The political impact deals with how if and when people change their view point on bottled water and start to demand that the bottled water they drink should have reinstituted minerals for health benefits. Sooner or later, the FDA and the EPA will have to require stricter regulations on RO bottled water. Where they will have to institute minerals back into the RO water before it can be bottled and sold..

7.0 Cost of Implementing the Design

The design could be implemented in two different scenarios. The first scenario is selling the mineral composition as an independent company, while the second scenario is selling the composition through a partnership with a current bottled water distributor.

7.1 Salts

The cost of the chosen optimum mineral composition would be $1.96 per liter (1000 mL doses), as can be seen in Table 14. These costs are accounting for obtaining the food grade minerals from environmentally sustainable companies. This cost would be the same for both scenarios.

Table 14: Cost of Final Optimum Mineral Composition.

Salts	Cost ($)	$/g	Composition 5
Calcium Chloride	165.00[13]	0.007	$0.02
Ferrous Sulfate	120.00[30]	0.005	$0.00
Magnesium Sulfate	80.00[19]	0.003	$0.06
Potassium Iodide	60[24]	0.083	$0.00
Potassium Sulfate	2688.00[1]	0.108	$0.12
Sodium Bicarbonate	51.10[25]	0.102	$1.49
Zinc Acetate	158.80[2]	0.159	$0.27
		TOTAL	**$1.96**

7.2 Independent Company Scenario

For the independent company scenario, the product would be sold as 1-mL vegetarian pear shaped capsules packaged in three different bottle sizes. The packaging will be 100% recyclable and BPA-free. It was necessary to make assumptions for the present worth calculation, such as an interest rate of 6% for 10 years, and not accounting for growth or sales. The present worth of this scenario is $680,000. Additionally, this scenario would break-even by the third year. The total cost included expenses such as manufacturing, personnel, utilities, office space, materials, and overhead. Some specific equipment needed for this scenario includes labeling machine, capsule filling machine, and stainless steel tanks. The total cost resulted to be $430,000, which are only start-up expenses. The revenue was calculated by assuming selling six million capsules per year, which was projected to be $541,000. Appendix F shows more specific values used for the total cost and revenue calculations. The profit for this scenario was estimated by subtracting the total cost from the revenue, which would be $111,000. Table 15 summarizes the present worth, total cost, revenue, and profit values.

Table 15: Present Worth, Total Cost, Revenue, and Profit Values for the Independent Company Scenario.

Present Worth	$ 680,000
Total Cost	$ 430,000
Revenue	$ 541,000
Profit	$ 111,000

7.3 Partnership with Current Bottled Water Distributor Scenario

For the partnership with current bottled water distributor scenario, the composition would be sold directly to a bottled water company so they can add it to their current production process. The same economic assumptions from the independent company scenario were made for comparison purposes. Therefore, for the present worth calculation, the interest rate was 6% for 10 years, and growth or sales were not accounted. The present worth of this scenario came up to be $1,660,000, and the break-even point will happen after the second year. The total cost included the same expenses in the independent company scenario, such as manufacturing, personnel, utilities, office space, materials, and overhead. Some specific equipment needed for this scenario includes a liquid handling robot and shipping tanks. The total cost resulted to be $233,000. The revenue was calculated by also assuming selling the same six million 1-mL optimum mineral compositions, which was projected to be $480,000. Every 500 mL of RO bottled water needs 1 mL of the designed optimum mineral composition. Appendix G shows more specific values used for the total cost and revenue calculations. The profit for this scenario was estimated to be $247,000, which makes this scenario more profitable and economically feasible. Table 16 summarizes the present worth, total cost, revenue, and profit values.

Table 16: Present Worth, Total Cost, Revenue, and Profit Values for the Partnership with Current Bottled Water Distributor Scenario.

Present Worth	$	1,660,000
Total Cost	$	233,000
Revenue	$	480,000
Profit	$	247,000

7.4 Marketing Plan

The purpose of the marketing plan is to connect the consumer with the product. A marketing plan consists of four consecutive stages; the purpose statement, the target market, the SWOT analysis, and the final execution. Since it is only necessary to provide the mineral additive to the water bottle company, the team is not responsible for the marketing strategies for the partnership with current bottled water distributor scenario, thus the following information only pertains to independent company scenario.

a) **Purpose Statement:** The purpose statement sets up how the marketing plan will be conducted. The purpose statement contains, but isn't limited to the price range of the product, the image of the product, and the style of marketing. This initial step will set up the guiding principles of the marketing plan**.** The purpose statement of the team's marketing plan is to create an economic, healthy beverage.

b) **Target Market:** Determining a specific target market for this product is a vital component of the marketing plan. This step primarily comprises of brain storming specific markets the product will be more likely to succeed in, by analyzing the pros and cons of the market. There will be three different markets that will be analyzed. The three alternatives are; the elderly (65 and up) and adults (18-64), families, and the environmentally conscious.

c) **SWOT Analysis:** The SWOT analysis can be seen in Table 17, and it stands for strengths, weaknesses, opportunities, and threats. Strengths are words, phrases, or facts pertaining to the product that appeals to the target market. A few strengths of the team's product has for the elderly include phrases such as lowers blood pressure, osteoporosis prevention, and strengthening the skeletal system. Weaknesses are problems within the creation or image of the product that can weaken sales. These problems are internal and can be controlled by the team. The product poses a choking hazard to young children, which is a weakness when marketing to families. But child-proof caps will be installed on the bottles to prevent this weakness. Opportunities are essentially partnerships, avenues, and social/political/global movements that the team can work with to appeal to the target market. If a product is being marketed as environmentally friendly, one opportunity the team can utilize is getting a contract to sell at a whole foods supermarket or donating money toward environmental restoration. Threats to a product include unforeseen events and pre-existing market conditions. What differentiates threats from weaknesses is threats are external and cannot be controlled by the team. One threat to the team is if the market is already heavily populated with successful competitors.

d) **Final Execution:** The last step of the marketing plan is the final execution, which in itself has 3 steps. The first step is to determine the marketing mix which are the avenues of marketing (i.e. magazine ads, tv ads, social media, etc). The separate marketing avenues will differ for each alternative, but all marketing mixes will be designed to target the specified markets. The next step is creating a marketing calendar which outlines when and where the team's product will be released. The beginning of the marketing calendar includes the team setting up contracts with supermarkets and other entities in September 2014 and releasing the product for sale in July 2015. The last step of the final execution is the promotion. During this step, the physical aspect of the marketing plan is put in the public. This final component satisfies the goal of the marketing plan, which is to connect the consumer with the product.

Table 17: SWOT Analysis.

SWOT	Alt 1: Elderly & Adults	Alt 2: Families	Alt 3: Environmentally Friendly
Strengths	-Osteoporosis prevention -Improves heath -Vital Minerals	-Natural -Alt for sugary drinks -Hydration -Best for your family -Exceptional water -No BPA	-Natural -100% recycled plastics -1% for the planet -Eco-friendly suppliers -No BPA in bottle -Capsules bio-degradable
Weaknesses	-Improper use may lead to mineral poisoning -May be concerned about minerals added -Breaking capsules may prove difficult	-Improper use may lead to mineral poisoning -Capsules can be choking hazard	-Improper use may lead to mineral poisoning -Plastic waste generation -Possible eco-unfriendly suppliers -Damaging reports about water bottles
Opportunities	-Work with National Osteoporosis Foundation -Working with Flagstaff medical center -Advertise at medical businesses	-Partnership with elementary schools about -Work with local children sport organizations	-Partnership with NAU Dining -Set up refill stations on NAU -1% for the planet
Threats	-Competition	-Competition	-Competition

8.0 Summary of Project Costs

8.1 Gantt Chart Comparison

The project was divided into five main tasks which are: background research, testing, design/build bench scale model, documentation, and WERC competition. The critical path is highlighted by the yellow line and it begins with the background research. It is necessary to have the background research completed in order to initiate the testing. The data from testing provides the parameters for the bench scale model design. After the testing was concluded, the design and build of the bench scale model could start. Also, it is necessary to have the design and build bench scale model task completed before the written report can be started. This critical path is important in order for the project to be successfully completed. The project will begin in October 1, 2013 and end in May 1, 2014, and the original Gantt chart can be seen in Figure 1.

The original Gantt chart had to be edited as the project continued. Figure 2 shows the modified project schedule. The time to complete task three the design/ build bench scale model had to be extended. The task was completed by February 1, 2014 instead of December 20, 2013. This task was delayed because the second round of testing had to be completed in January since the error from the first round of testing was not identified until late December of 2013. Therefore, the testing and analysis sections of the competition report were not started until early February. This delay did not affect the completion of the project, it only reduced the editing time for the competition written report.

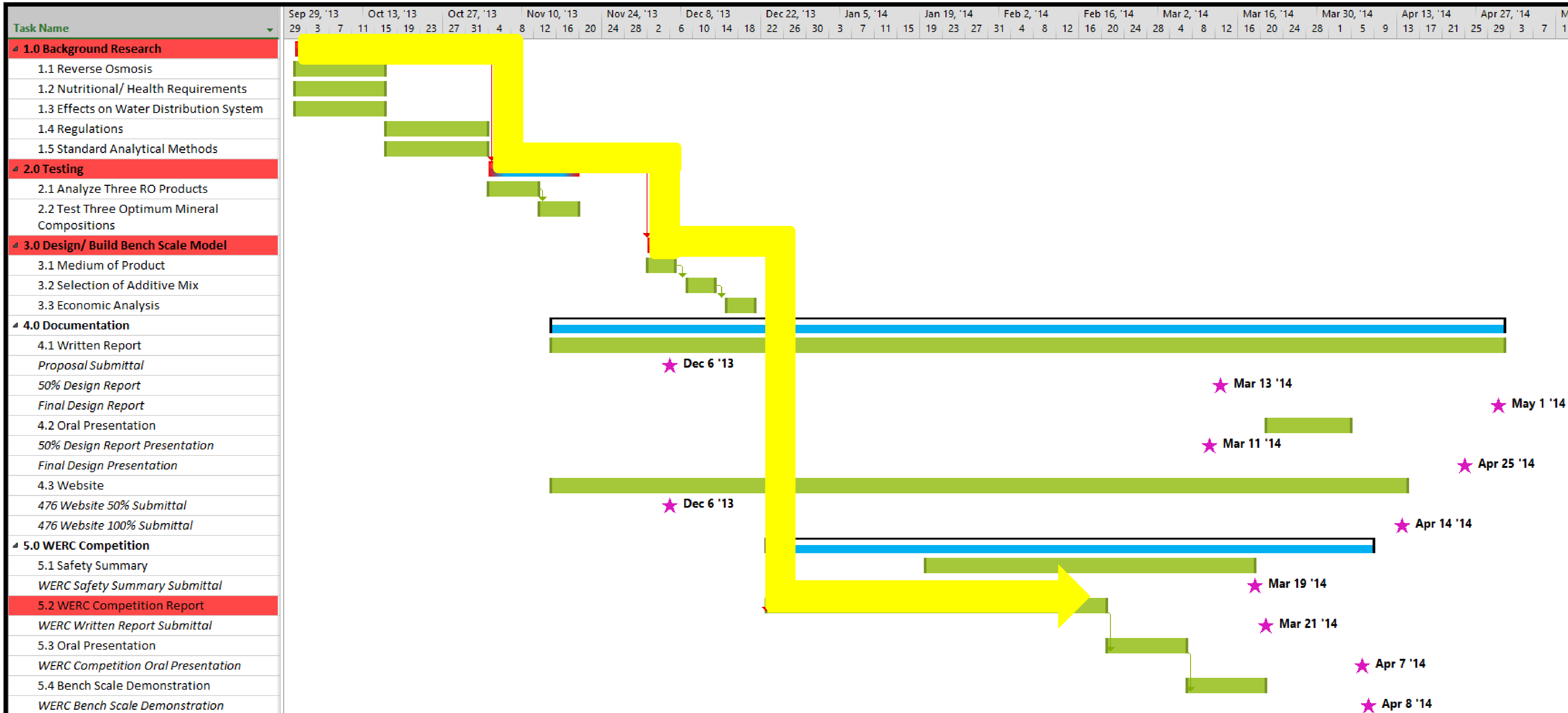


Figure 1: Original Gantt Project Schedule from October 1, 2013 to May 1, 2014.

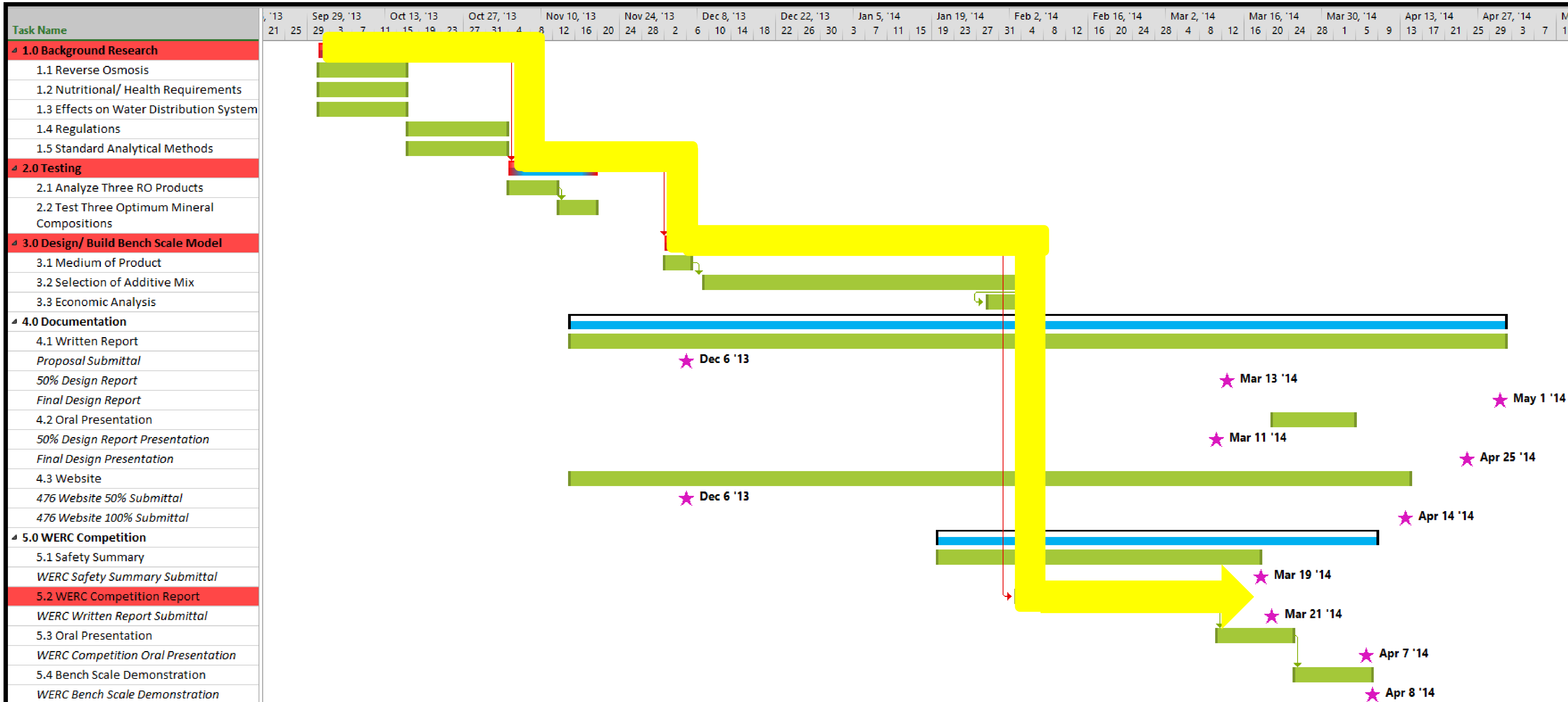


Figure 2: Modified Gantt Project Schedule from October 1, 2013 to May 1, 2014.

8.2 Cost of Engineering Services Comparison

As shown in Table 18, the total estimated cost of the engineering services for this project will be $79,532. This total was found by adding the personnel, travel, and subcontracting costs. The personnel costs totaled at $79,466 and it was the vast majority of the costs for the project. Personnel costs were broken down by rate of pay per level of employee and the number of hours worked. The overhead costs were accounted in each person's billing rate. The overhead for each person is different depending on the level of that employee. The different levels are: the senior engineer, the engineer, the lab technician and the intern. The senior engineer will have the highest overhead followed by the engineer. Both the intern and lab technician have little to no overhead. There is no expense for local meetings that happen in the office because there is no long distance travel involved. Thus the price was zero for local meetings. The subcontractor used was the Colorado Plateau Analytical Laboratory for cation and anion testing, which came to a total of $66.

Table 18: Estimated Cost of Engineering Services.

1.0 Personnel	Person	Hours	Rate, $/hr	Cost, $
	SENG	170	172	29172
	ENG	600	70	41818
	LAB	20	45	905
	INT	380	20	7571
	Total Personnel			*$ 79,466*
2.0 Travel	*Local Meetings*	0		*$ 0*
3.0 Subcontractor	*Lab*	6	11	*$ 66*
4.0 TOTAL				**$ 79,532**

The project was completed by March 15, 2014 and the actual cost of engineering services can be seen in Table 19. The estimated cost was higher than the actual cost by $22,512. The hours for the senior engineer, engineer, and intern were overestimated, while the hours for the lab technician were underestimated. The percent difference of the estimated and actual cost of engineering services was around 28%.

Table 19: Actual Cost of Engineering Services.

1.0 Personnel	Person	Hours	Rate, $/hr	Cost, $	
	SENG	118	172		20249
	ENG	381	70		26554
	LAB	127	45		5747
	INT	221	20		4403
	Total Personnel			*$*	*56,954*
2.0 Travel	*Local Meetings*	0		*$*	*0*
3.0 Subcontractor	*Lab*	6	11	*$*	*66*
4.0 TOTAL				**$**	**57,020**

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10.0 Appendices

10.1 Appendix A- WERC Task Description

Environmental Design Contest – 2014

Join us on Facebook – search for NMSU IEE or click here: Facebook

WERC's Environmental Design Contest is a unique event that brings together industry, government and academia in the search for improved environmental solutions. Held annually since 1991 at New Mexico State University in Las Cruces, New Mexico, the contest draws hundreds of college students from throughout the United States and around the world.

The student teams design solutions for real-world problems while developing fully operational bench-scale solutions that are presented to panels of judges comprised of environmental professionals. The teams prepare four different presentations: written, oral, poster and bench-scale model. You may enter as many teams as your university would like in any of the tasks.

Many universities use the contest as part of their capstone design courses. After the contest, WERC provides the judges' feedback to the participants. Feedback to the students has become an important part of ABET accreditation.

Our current plan is to hold the contest at the New Mexico Farm and Ranch Museum in Las Cruces (Directions). Please be aware that this may change based on the number of teams that register.

Background

Water treated through reverse osmosis (RO) is depleted of minerals. Minerals are essential for health as well as for stabilizing water to prevent corrosion of distribution systems. Post treatment involves adding back hardness to achieve a positive Langlier Saturation Index (LSI).

Bottled water is sometimes obtained from springs or wells but often it is tap water that may or may not have been treated with reverse osmosis. There are no regulations for the mineral content of bottled water. Nevertheless bottled water is often marketed as a healthy alternative to other beverages or tap water. Some companies add "Vitamins" to their bottled water with or without flavoring and artificial or natural sweeteners.

Problem Statement

The objective of this task is to find the best fortification for desalted water most commonly obtained from Reverse Osmosis processes.

Specifically your task is to:

- identify minerals that would improve taste and prevent the water from leaching minerals from the skeletal system and review nutritional requirements for people and livestock
- address the additionally beneficial use for protection of water distribution system from corrosion

Additionally your team must address the existing types of bottled water and bottled beverages in North America; their source of origin, added minerals content and specifics on the type of mineral and its beneficial use. This should include determining the composition of the most popular and local bottled water products – by analysis or by questioning the bottling company specific to the southwestern United States. Your research must also address how close the actual products are to the optimum mineral composition determined by your team and what impact it may have on taste and odor.

Design Considerations

The following outcomes are required:

- identification of detailed mineral content required for healthy skeletal life cycle existence including childhood development and geriatric impacts
- identification of mineral content in existing bottle waters obtained from Reverse Osmosis processes and springs
- identification of corrosion potential or improvement to water systems resulting from the addition or lack of minerals

Once your team identifies the available bottle waters or beverages from reverse osmosis systems based processes and determines the ideal mineral content, your team must provide specific details on:

- how to implement the addition of supplementary minerals to existing bottle waters on the grocery store shelves, the cost to the consumer and the producer, the "enticement" to the public to use the supplementary minerals with their bottled water
- how to implement adding the supplementary minerals into the bottling process for future bottled waters, and the cost of the added minerals to production
- beneficial and adverse impacts to the water treatment and delivery systems by the added/removed minerals

Your team should demonstrate your process, analyze several bottled waters for mineral content, present mineral addition or removal approach, identify steps required to protect the drinking water standard include water stabilization process if needed, discuss energy impacts, environmental constraints, taste and odor and other pertinent regulatory driven issues. Innovative approaches to the issue including demonstration of the process will be given extra credit.

Bench-Scale Demonstration

During the contest, your team will be provided with several (anticipated to be up to 5 different labels and 4 bottles of each of the labels) types of bottle water available in Las Cruces. These will be used for demonstrating your proposed process and details identified in the Design Consideration section above.

Written Report Requirements

The written report should demonstrate your team's insight into the full scope of the issue that you have chosen and include all aspects of the problem and your proposed solution. The report will be evaluated for quality of writing, organization, clarity, reason, and coherence. Standards for publications in technical journals apply. In addition to the listed requirements, your report must address in detail the items highlighted in the Problem Statement, Design Considerations, and Evaluation Criteria sections.

Evaluation Criteria

Each team is advised to read the Participation Guide for a comprehensive understanding of the contest evaluation criteria. Upon registration, WERC will provide you with a copy of the Public Involvement Plan and Participation Guide. Additionally, your proposed design will be evaluated on issues stated in the problem statement as well as the following:

- Degree of innovativeness
- Ease of implementation including cost
- Effectiveness of public enticement plan
- Manufacturing modification requirements including cost, energy requirement, environmental impacts and other relevant issues
- Overall degree to which design considerations are met including taste, odor and impact to a water system
- Final report clarity, logic, well supported conclusions
- Presentation skills
- Team involvement

10.2 Appendix B- Guidelines and Details for WERC Written Report

- Guidelines for Written Report
  - Task identification
  - Full-scale design description
  - Bench-scale/prototype lab results
  - Waste generation considerations
  - Technical evaluation
  - Length of 26 pages
  - Report cover identifying the school and task (not included in the page limit)
  - Title page (counted as the first page)
  - Table of contents
  - Executive summary (maximum of two pages) highlighting the proposed solution
  - The report body
  - Photographs, line drawings and graphs are permitted for illustrative purposes (included in the page limit)
  - References pages (included in the page limit)
  - Audits are not included in the page limit

- Details for Written Report
  - Manuscript Preparation
    - The paper length should not exceed 26 pages.
    - Use of laser or ink jet printers is recommended.
    - Font:
Times, Times New Roman, or TMS Roman (If unavailable, a similar type with serifs is preferred over sans serif).
Size: 12 point
Major Headings: 12 point, Bold
Title: 14 point, Bold
    - Margin settings:
    - Cover page (Title page)
Title: 2″ top margin
Centered (school name, team name, task number, advisor name and team member names)
Body
Top and bottom margins – 1″
Right and left margins – 1″
    - Each page of the written report must have a footer that includes the task number and the name of the participating school.
    - Use 1.5 line spacing
    - Paper:
White, 8 ½” X 11″
  - Headings
    - Title: Center, upper case, bold; 14 point type
    - Major Headings: Left justify, upper case, bold; 12 point type
    - Subheadings: 1 tab (5 spaces); bold, 12 point type

    - Sub-subheadings: 2 tabs (10 spaces); underline, 12 point type
- References
    - List and number all bibliographical references at the end of the paper.
    - When referring to references in the text, type the corresponding reference number in superscript form.
    - Equation Numbers
    - Enclose equation numbers in parentheses
    - Page Numbers
    - Center bottom of the page
    - Symbols and Abbreviations
    - Use only standard symbols and abbreviations in text and illustrations.
- Illustrations, Drawings and Photographs
    - Line drawings and photographs should be reduced to proper size and placed as close to where they are referenced as possible.
    - All lines should be black on white paper and heavy enough to be legible.
    - All lettering should be large enough to be legible.
    - Original illustrations should not exceed 8.5″ X 11″.
    - Omit all unessential illustrations.

10.3 Appendix C- Safety Summary

SAFETY SUMMARY FORM

IEE/WERC ENVIRONMENTAL DESIGN CONTEST

Task Number and Title:

Task 2: Drinking Water Stabilization

University and Team Name:

Northern Arizona University, RAVA Fontus Engineering Inc.

Design Abstract:

Will have a 1-Liter stock solution of the optimum mineral additive that will be pipetted into each of the water bottles. Along with the demonstration, there will be a video on the optimum mineral composition. For the video we will be using a screen and a portable projector or a laptop that will need access to AC power. There will also be a poster with a tripod stand.

Chemicals & Quantities:

Acids:	**Qty:**	**NFPA Hazard Ratings (see MSDS):**
Ferrous Sulfate	**0.0085 g**	**Health= 2; Fire= 0; Reactivity= 0**
Magnesium Sulfate	**17.33 g**	**Health= 1; Fire= 0; Reactivity= 0**
Potassium Sulfate	**1.1149 g**	**Health= 3; Fire= 0; Reactivity= 0**
Zinc Acetate	**1.679 g**	**Health= 2; Fire= 1; Reactivity= 0**

Bases:	**Qty:**	**NFPA Hazard Ratings (see MSDS):**
Calcium Chloride	**2.769 g**	**Health= 1; Fire= 0; Reactivity= 1**
Potassium Iodide	**0.00131 g**	**Health= 1; Fire= 0; Reactivity= 0**
Sodium Bicarbonate	**14.6163 g**	**Health= 1; Fire= 0; Reactivity= 0**

Reactivity Issues:

Furan-2-peroxycarboxylic acid + calcium chloride causes explosion at room temperature.

Physical Hazards: (Please address all categories)

Compressed Gasses (type, volume, psi):

Not applicable

Heat Sources/Open Flames/Temperatures:

Not applicable

High Pressure Operations:

Not applicable

Moving Components:

Not applicable

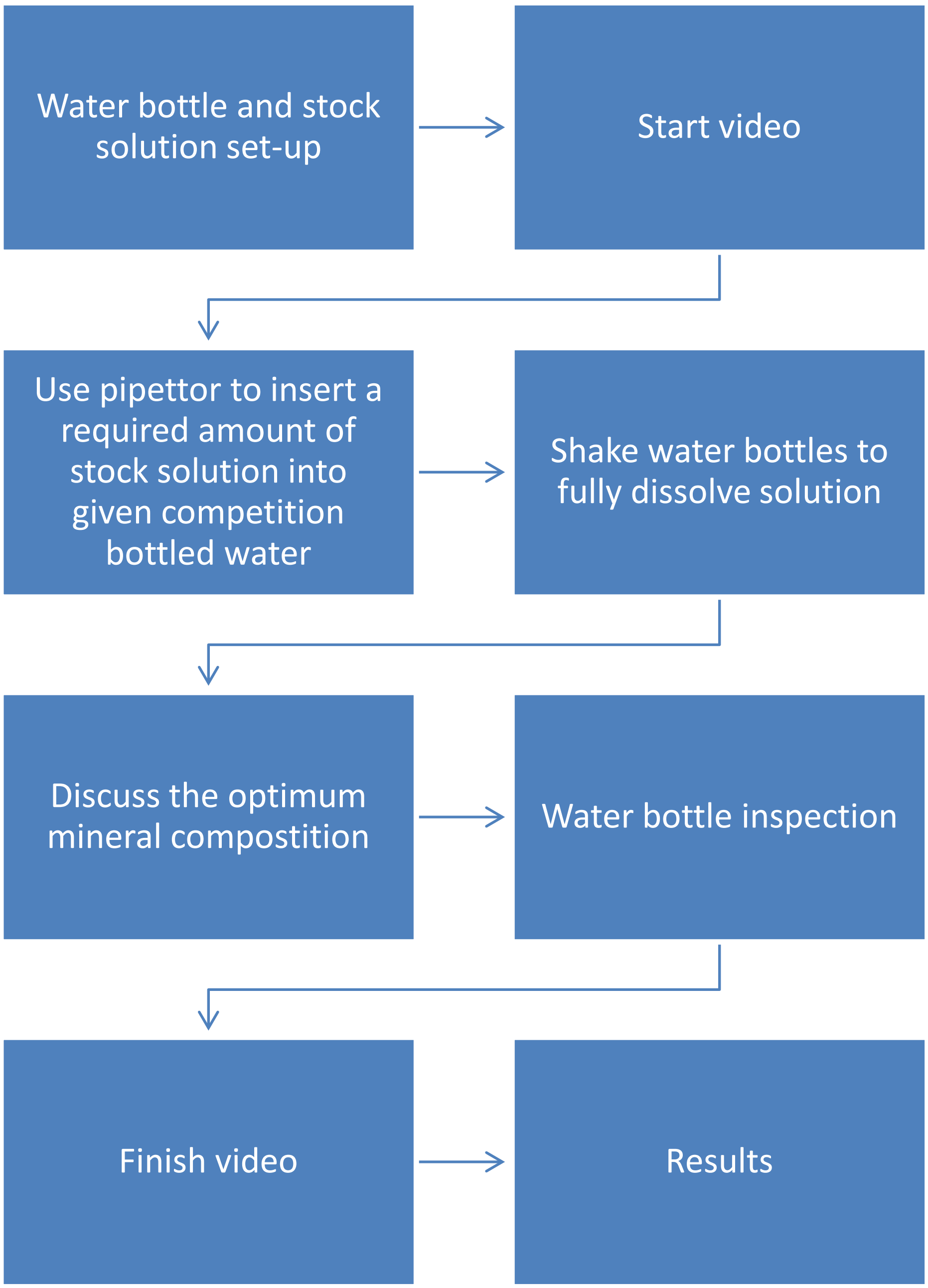
Electrical Hazards & Loads:

Not applicable

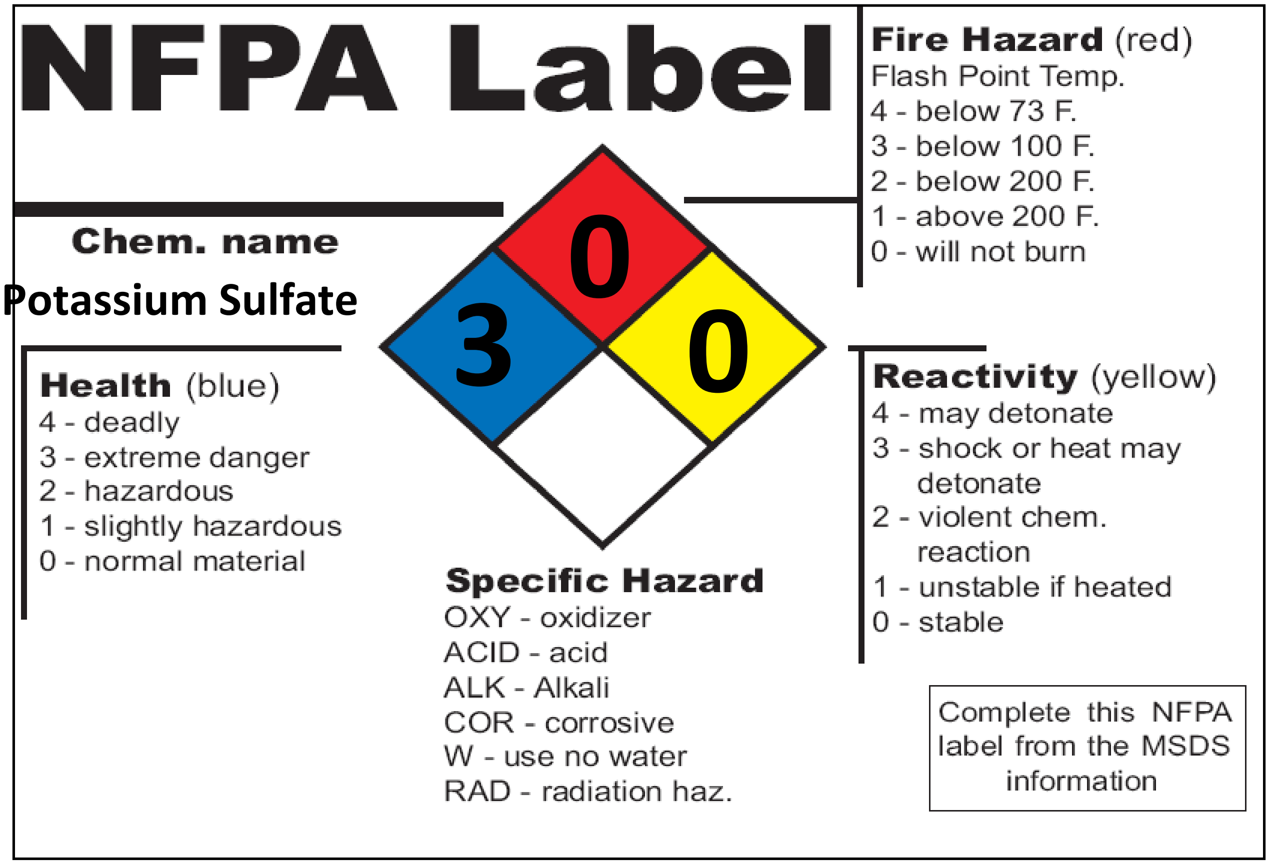
Health Hazards:

Most of the chemicals have the ability to cause skin irritation and eye irritation. So eye protection and gloves should be worn when handling solution.

<u>Bench-Scale Flow Diagram</u> (single page process flow diagram):



NFPA Hazard Ratings:



HEALTH (Blue) - The degree of health hazard of a chemical or material is based on the form or condition of the material, as well as its inherent properties. The degree of health hazard of a material should indicate the degree of personal protective equipment required for working safety with the material.

FLAMMABILITY or FIRE HAZARD (Red) - The flammability or fire hazards deal with the degree of susceptibility of the material to ignite and burn. The form or condition of the materials, as well as their properties, affects the extent of the hazard. Many hazardous materials such as acetone and gasoline, have a flash point (ignition temperature) far below freezing and will readily ignite with a spark if the vapor concentration is sufficient.

REACTIVITY (Yellow) - The reactivity hazards deal with the potential of a material or chemical to release energy. Some materials are capable of rapid energy release without any catalyst, while others can undergo violent eruptive or explosive reactions if they come in contact with water or other materials. Generally this rating is used to indicate the potential to react if the material is heated, jarred, or shocked.

SPECIFIC HAZARD (White) - An open space at the bottom of the NFPA diagram can be used to indicate additional information about the chemical or material. This information may include the chemical or material's radioactivity, proper fire extinguishing agent, skin hazard, its use in pressurized containers, protective equipment required, or unusual reactivity with water.

10.4 Appendix D- Water Quality Analysis for Aquafina, Dasani, and 365 Spring Water.

Test Results	Aquafina®	Dasani®	365 Spring Water®
pH	6.58	6.03	7.35
Total Dissolved Solids (mg/L)(10)	0.01	0.04	0.08
Turbidity (NTU)(4)	0.21	0.22	0.43
Alkalinity (mg $CaCO_3$/L)(7)	Below Detectable Limit	Below Detectable Limit	0.71
Acidity (mg $CaCO_3$/L)(6)	Below Detectable Limit	Below Detectable Limit	-0.71
Conductivity (mA/V*m)(9)	3.42	7.44	14.30
Hardness (mg $CaCO_3$/L)(8)	0.00	12.35	24.04
Hardness Classification(8)	Soft	Soft	Slightly Hard
Color (PtCo)(3)	2.00	7.00	0.00
Odor(5)	No Smell	No Smell	No Smell

10.5 Appendix E- Langlier Saturation Index Calculation

LSI = pH -(pCa^{2+} + pAlk + C)

Parameters					
LSI =	1.00				
pH =	7.70				
C =	2.40	*			
Ca^{2+}_3	0.02	mol Ca^{2+}/L			
Ca^{2+}_2	0.17	mol Ca^{2+}/L			
Ca^{2+}_1	0.30	mol Ca^{2+}/L			
$p(Ca^{2+})_3$	1.60	mol Ca^{2+}/L			
$p(Ca^{2+})_2$	0.76	mol Ca^{2+}/L			
$p(Ca^{2+})_1$	0.52	mol Ca^{2+}/L			
$p(Alk)_3$	2.70	Eq Ca^{2+}/L			
$p(Alk)_2$	3.54	Eq Ca^{2+}/L			
$p(Alk)_1$	3.78	Eq Ca^{2+}/L			
Alk_3	0.00	Eq $CaCO_3$/L			
Alk_2	0.00	Eq $CaCO_3$/L			
Alk_1	0.00	Eq $CaCO_3$/L			
Na^+_3	0.05	g	=	0.00	g N^+/L
Na^+_2	0.01	mg Na^+/L	=	0.00	g N^+/L
Na^+_1	0.00	mg Na^+/L	=	0.00	g N^+/L

Notes:

* this assumption was made by the fact that the TDS was so small.

10.6 Appendix F- Independent Company Scenario Costs

Starting Costs									
		Size		Quantity		Price		Cost	
Manufacturing	Stainless steel mixing tank	500	L	10	tanks	$ 3,000.00	price/tank	$ 30,000.00	cost /10 year
	Chemicals	1	mL	6.00E+06	doses/yr	$ 0.00196	price/batch of chemicals	$ 11,760.00000	cost/year
Company	Office /production facility	4,500	ft^2	1	production facility	$ 36,000.00	price/year	$ 36,000.00	cost/year
	Electric	NA				$ 4,800.00	price/year	$ 2,400.00	cost/year
	Internet	NA				$ 960.00	price/year	$ 960.00	cost/year
	Water/Sewage/Trash	NA				$ 1,200.00	price/year	$ 1,200.00	cost/year
Personnel	Office manager	NA		1	person	$ 38,400.00	wage/year	$ 38,400.00	cost/year
	Production worker	NA		2	people	$ 53,760.00	wage/year	$ 53,760.00	cost/year
	Maintenance	NA		1	person	$ 28,800.00	wage/year	$ 28,800.00	cost/year
Other	Overhead	NA		12	%	NA		$ 19,382.40	cost/year

Costs for Independent Company Scenario									
		Size		Quantity		Price		Cost	
Materials	Pear Shaped Capsules	1	mL	6.00E+06	capsules/yr	$ 0.02	price/capsule	$ 120,000.00	cost/year
	28 capsule sizebottle	4	oz	3.05E+04	bottles/yr	$ 0.18	price/bottle	$ 5,490.00	cost/year
	60 capsule size bottle	8	oz	2.51E+04	bottles/yr	$ 0.34	price/bottle	$ 8,534.00	cost/year
	140 capsule size bottle	16	oz	2.60E+04	bottles/yr	$ 0.40	price/bottle	$ 10,400.00	cost/year
	bottle labels	NA		8.16E+04	labels/yr	$ 0.12	price/lable	$ 9,792.00	cost/year
	tamper evident heat shrink seal	NA		8.16E+04	seals/yr	$ 0.06	price/seal	$ 4,896.00	cost/year
	Shipping boxes	48 x 40 x 36	in	2.00E+03	boxes/yr	$ 19.10	price/box	$ 38,200.00	cost/year
Machines	Capsule filling machine	NA		1	machine	$ 5,000.00	price/machine	$ 5,000.00	cost/10 year
	Labeling machine	NA		1	machine	$ 5,000.00	price/machine	$ 5,000.00	cost/10 year

Revenue for Independent Company Scenario									
		Size				Price		Revenue	
Materials	28 capsule sizebottle	4	oz	8.54E+05	bottles/yr	$ 2.99	price/bottle	$ 91,195.00	profit/year
	60 capsule size bottle	8	oz	1.51E+06	bottles/yr	$ 5.49	price/bottle	$ 137,799.00	profit/year
	140 capsule size bottle	16	oz	3.64E+06	bottles/yr	$ 11.99	price/bottle	$ 311,740.00	profit/year

10.7 Appendix G- Partnership with Current Bottled Water Distributor Scenario Costs

Starting Costs									
		Size		Quantity		Price		Cost	
Manufacturing	Stainless steel mixing tank	500	L	10	tanks	$ 3,000.00	price/tank	$ 30,000.00	cost /10 year
	Chemicals	1	mL	6.00E+06	doses/yr	$ 0.00196	price/batch of chemicals	$ 11,760.00000	cost/year
Company	Office /production facility	4,500	ft^2	1	production facility	$ 36,000.00	price/year	$ 36,000.00	cost/year
	Electric	NA				$ 4,800.00	price/year	$ 2,400.00	cost/year
	Internet	NA				$ 960.00	price/year	$ 960.00	cost/year
	Water/Sewage/Trash	NA				$ 1,200.00	price/year	$ 1,200.00	cost/year
Personnel	Office manager	NA		1	person	$ 38,400.00	wage/year	$ 38,400.00	cost/year
	Production worker	NA		2	people	$ 53,760.00	wage/year	$ 53,760.00	cost/year
	Maintenance	NA		1	person	$ 28,800.00	wage/year	$ 28,800.00	cost/year
Other	Overhead	NA		12	%	NA		$ 19,382.40	cost/year

Costs for Partnership with Current Bottled Water Distributor									
		Size		Quantity		Price		Cost	
Materials	Shipping tanks	275	Gal	5	tanks	$ 479.00	per/ tank	$ 2,395.00	cost/ 10 year
Machines	Liquid handling robot	NA		1	machine	$ 8,000.00	price/machine	$ 8,000.00	cost/ 10 year

Revenue for Partnership with Current Bottled Water Distributor								
	Size		Quantity		Price		Revenue	
Manufacturing Products	1	mL	6.00E+06	doses/yr	$ 0.08	per/dose	$ 480,000.00	profit/year