Project Nepal Pani

Engineering Empowerment Solutions
The Office of the United Nations High Commissioner for Refugees
Nepal Engineers' Association
Barefoot College

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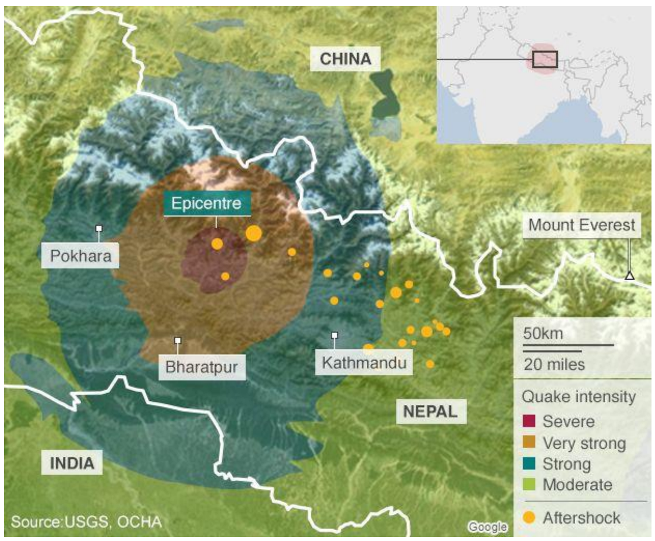
Introduction

On April 25, 2015, a magnitude 7.8 earthquake struck the country of Nepal to be one of the most devastating disasters to hit the region in the past century. To date, more than 6000 deaths have been reported and 29 districts have been proclaimed crisis zones.[1] At the request of the Nepali government, an international response has been initiated to provide for the 8 million people affected by the earthquake.



(Figure 1: Map of Earthquake Effects)

The Office of the United Nations High Commissioner for Refugees (UNHCR) has contacted Engineering Empowerment Solutions (EES) to contract a water system for a refugee camp. For the purposes of this project, EES and UNHCR are to be seen as equal partners wherein the UNHCR is the monetary sponsor and EES is acting as the implementing organization. UNHCR has advised that EES place the system outside of Nepal's fifth largest city Bharatpur (See Figure 1). The population there has been assessed and is in need for a long-term refugee infrastructure.

Founded in 2005, ESS's specialty as an organization has historically been using engineering projects to empower communities in developing countries mainly concentrating in India, Ecuador, and Senegal. However, since the EES does not have any previous experience in

[1] http://www.theguardian.com/world/2015/may/01/nepal-earthquake-death-toll-passes-6000-with-thousands-still-missing

the region, they will be working with regional offices of Barefoot College (BC)[2] and Nepal Engineers' Association (NEA)[3]. In accordance to its mission statement, ESS will be "using engineering expertise of the international community to develop disadvantaged communities on a partnership basis through hands-on training in real-time community projects".[4]

Although UNCHR expects to eventually relocate the displaced persons back into permanent settlements, they have required that the system built by this project have a lifetime sustainability of twenty years. Often times, refugee camps turn into permanent settlements and UNCHR requests settlements to be built with long-term sustainability.

Ideation

For the purposes of this project, all involved parties recognize the difficult nature of the presented timeframe as well as cost associated with the building of such as water system. After much time and deliberation, the partnering organizations agreed upon proposing two designs: the Alpha and Beta designs. The purpose of this is an attempt to take into consideration engineering, social, and economic factors that may go into deciding the implementation of the project. The main intent of each proposal is as follows:

Alpha Design

i. To provide water to the main and satellite camps
ii. To follow minimums and maximums suggested by manufacturer and engineering norms
iii. To ensure twenty year sustainability

Beta Design

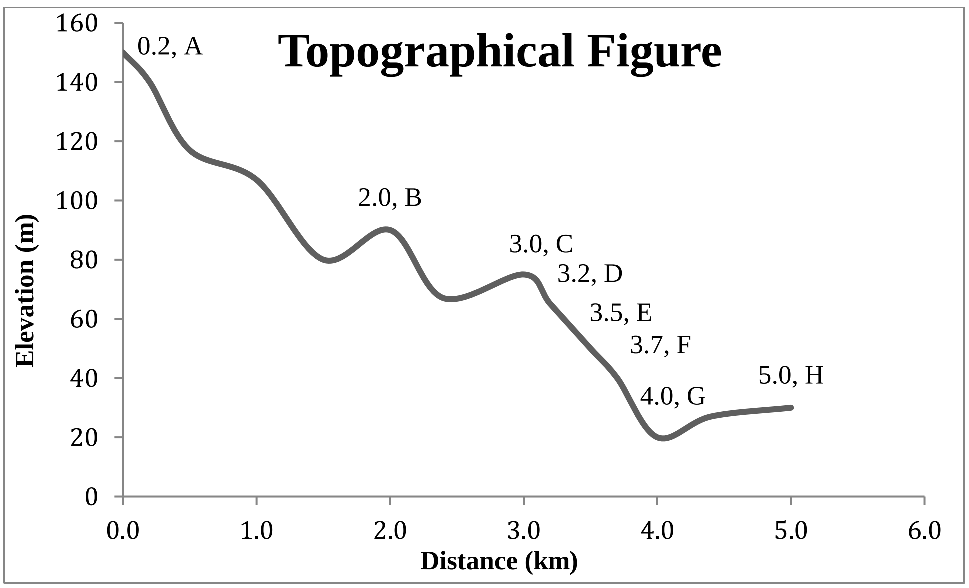
i. To provide water to main camp
ii. To minimize the construction time of the project
iii. To simplify the engineering of the system

[2] http://www.barefootcollege.org
[3] http://www.neanepal.org.np/
[4] Taken from EES's mission statement.

Although a recommendation is given in this report as to the desired system, both systems were engineered to provide the community with water in a sustainable manner. Although both designs are different in their construction, they do not differ in their implementation. Also, it should be noted that this project is intended for a humanitarian crisis and differs from development projects that EES has implemented in the past. Therefore, the recommendation is given based upon sustainability practices and not immediate humanitarian relief.

Community Topography and Requirement

When surveying the surrounding area, ESS and NEA representatives were able to map the topography as seen surrounding the camp placement (See Figure 2).



(Figure 2: Topography Leading to Refugee Camp)

Referring the Figure 2, the water source is located at point A and water systems are needed to reach the primary camp at location G and then a satellite camp at H. Upon survey, EES Engineers aptly noticed that the topography would be cause for concern as at some points in the elevation differential may problematic for pressure flows to reach G and H. Specifically of concern is between point B and C which will be discussed further in the design portion of this report.

Calculating Water Requirement

NEA and ESS collected data about the expected and current population existing in this refugee camp. This data can then provide a basic metric to calculate the basic necessary water needed from the water system.

	Daily Requirement per capita	Total Requirement
People	30 (L/day)	12000 (L/day)
Horses	20 (L/day)	300 (L/day)
Cows	20 (L/day)	1000 (L/day)
	Total:	13,300 (L/day)

From this we can then say that 13,300 $\frac{L}{day}$ is necessary to sustain the current daily requirements reported. This then would mean that a raw flow rate of 0.153 $\frac{L}{s}$ is required at the tap. However, in calculating the overall desired flow rate, one must take into certain considerations and scaling factors to find the desired flow rate (Q) which was found to be 0.4618 $\frac{\mathrm{L}}{\mathrm{s}}$. This is an extremely important estimate, as it will determine the type, size, and even entirety of the project implementation.

Piping

Following the flow rate calculated (0.4618 $\frac{\mathrm{L}}{\mathrm{s}}$) and restrictions of the pipe manufacturer, two HDPE 10 pipes are available for purchase at the closest regional supplier in Kathmandu:

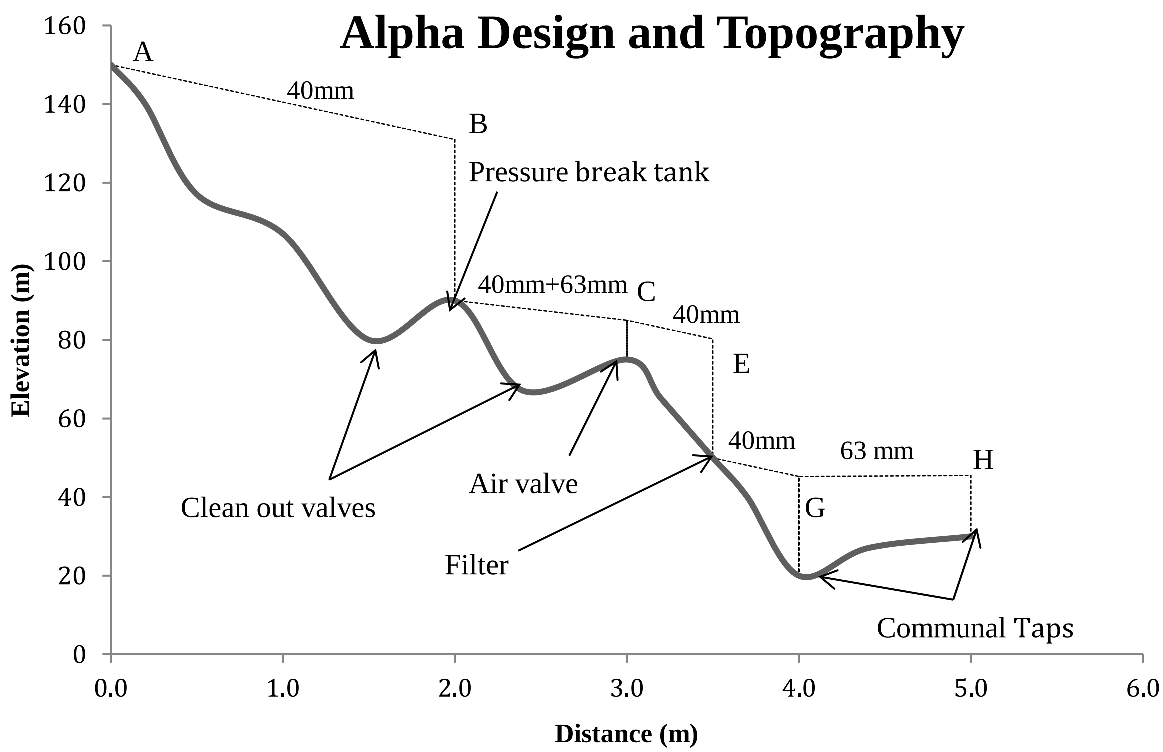
Diameter (mm)	Flow Rate (Q, L/s)	Headloss Rate (J, m/km)
40	0.462	9.5
63	0.463	1.10

Throughout the design, these two pipes are the only two considered due to the supplier restriction.

Design

While some portions of the water systems may be similar, many variations are made that alter the effective delivery of the water. It is important to note that both designs will include air valves and clean out valves in the same places and may be ignored as cost negligible. As mentioned before, the two designs are divided into Alpha and Beta Designs.

Design Alpha



(Figure 3.1: Alpha Design)

The logic behind design Alpha was to quickly yet efficiently build a gravitational water system that would supply the refugee camps at G and H with clean water while stringently following engineering protocol. For detailed calculations, please see the appendix.

Referring to Figure 3.1, from A to B 40mm pipe was used due to its cheaper price when compared to 63 mm piping. Due to a pressure exceeding 80m of pressure (the recommended maximum of the manufacturer) a pressure break tank is placed at B. If piping is placed directly from A to C, we would exceed this amount, thus a pressure break tank is needed.

Since the pressure break tank is placed at B, the pressure is reset to 0m. Continuing from B to C a combination of piping sizes is used in order to maintain a minimum pressure of 10m throughout the pipeline. This minimum is roughly designed for throughout the system as it ensures the delivery of water in the midst of potential unforeseen frictional loses. If we were only to use 40mm piping from B to C, there would be less than the desired 10m of pressure. Furthermore, a combination of these pipes is used rather than just using 63mm pipe in order to reduce cost.

Going from C to E, 40mm piping is used since there is no concern for a pressure minimum being met. A sand filtration system is placed at E in order to clean the water and also serve as a pressure break tank, which helps us reach our goal at providing the community with 10-25m of pressure at the communal taps. The filter is also placed at E rather than B so that it can be easily accessible to the community for repairs and maintenance. Like at B, the pressure again is reset to 0m at E.

From E to G, 40mm pipe can be used the entire way. This again saves money while also meeting all requirements. Thus, the water will hit the communal taps at G with a pressure of 25m, which is a little higher than desired but still tolerable.

This pressure continues through 63mm pipe to the second communal tap at H. This last portion of piping laid is 63mm instead of 40mm because the 63mm pipe has a smaller headloss rate. The 63mm piping is necessary because if the 40mm piping is used the headloss rate is much higher which would cause there to be less than 10m of pressure at H.

Cost

Although only an estimate, the overall expenditure of the above design is given bare cost approximations as seen below:

Pipes

- 40 mm → 0.918 ($/m)
  - Total amount of pipe → 3.4642km

    Total Cost = (0.918*3464.2m) = $3180
- 64 mm → 1.445 ($/m)
  - Total amount of pipe → 1.5357km

    Total Cost = (1.445*1535.7m) = $2219

Tank(s)

- Pressure break tank → $200 per tank

  Total cost = ($200 *1) = $200

Other Costs

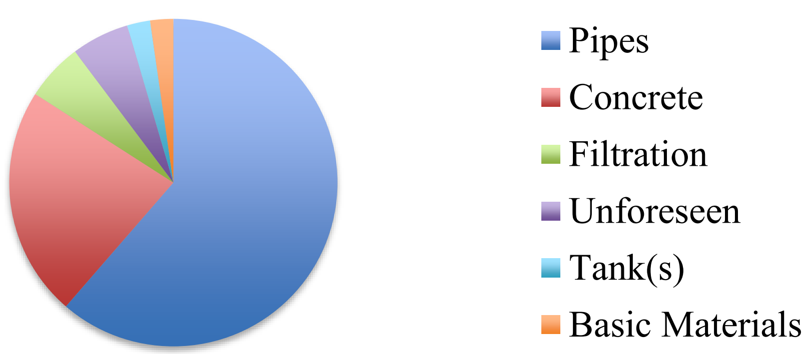
- Sand Filtration System → $500
- Concrete material → $2000

Unforeseen

To avoid underestimate, an additional 500 USD is included as what may be called as "unforeseen" costs.

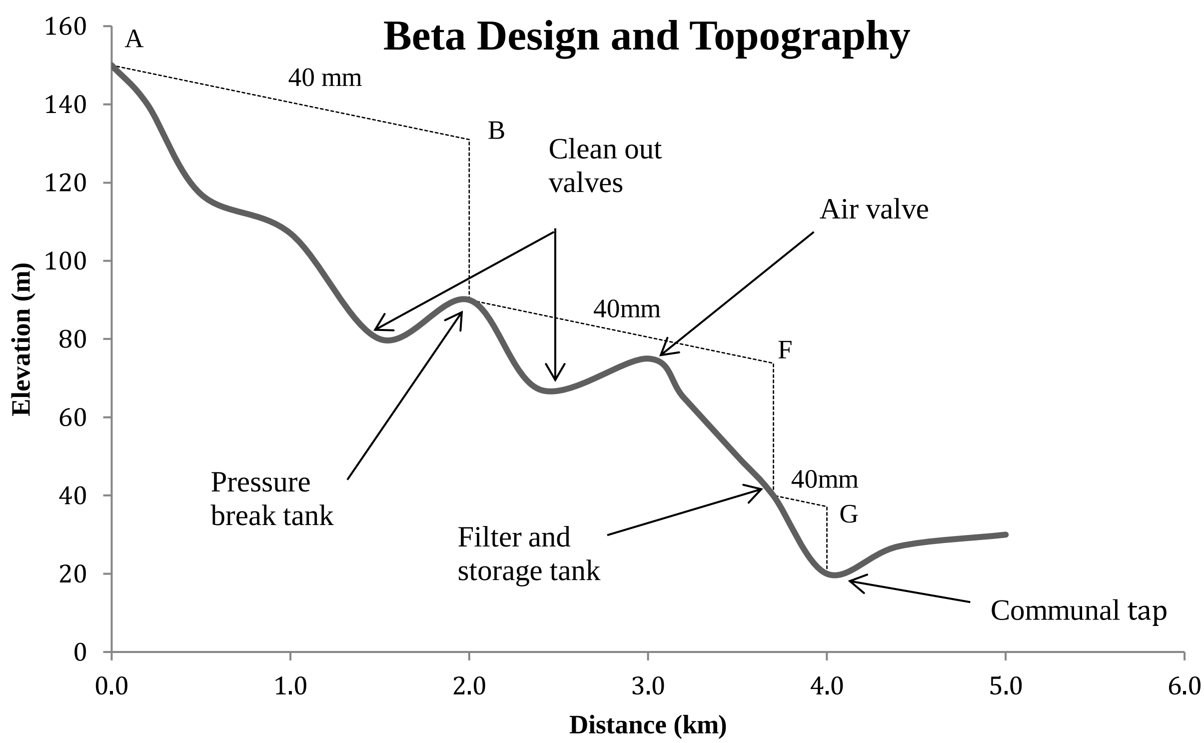
Material	**Cost (USD)**
Pipes	5399.23
Concrete	2000
Filtration	500
Unforeseen	500
Tank(s)	200
Basic Materials	200

Estimated Alpha Design



Total Estimated Cost = 8800 USD

Design Beta



(Figure 3.2: Beta Design)

As mentioned before, the logic behind the Beta design was to purpose a system to be easily construcatble with little complexity and in a short timeframe. The initial pipeline laying bewteen A and B is not different than the before mentioned design and will therefore not be discussed.

However, an important difference in this design is its choice of piping from B to F. As seen in Figure 3.2, the only pipline used is 40mm. Not only was this chosen due to associated lower costs, but it was also intented to streamline the design by only using one size of piping.

This way there is not unintended confusion with different pipe sizing mantainence or repairs in the future. With this choice comes a potential downfall which is the pressure existing over point C at 3km would be calculateted to be 5.5m of pressure. This may be cause for concern because if increased friction of the pipline between B and C occurs due to minor losses (e.g. connections and elbows) then water may not have enough pressure to flow. In regards to the construction of the pipeline, the implementing team should be observant of the possible ways in which the layout of the pipeline from B to C could increase the friction and ultimately hindering water from flowing over C.

Once the water reaches F, a filtration system and storage tank may be placed to clean and store the water. Since this system was designed to not provide water to the satellite refugee camp, the filtration system may be placed at F as it does not need further potential energy to reach point H. Even though it was at first desired to build piping directly from B to G, unfortunately, the pressure differential would be too great. Nevertheless, the placement of the filtration system at F allows for an even closer location to the main camp for maintenance and repairs.

Finally, 40mm piping is used to build the final segment of the system to the communal tap at G. The final pressure at the communal tap at G would be 15m.

Cost

As mentioned in the previous design, the below estimations should be seen as the approximate cost to build this design:

Pipes

- 40mm → 0.918 ($/m)
    - Total amount of pipe → 4km →
      Total Cost = (0.918*4000m) = $3672

Tanks

Pressure break tank → $200 per tank → 1 Total Cost → ($200 *1) = $200

Other Costs

Sand Filtration System → $500
Concrete material → $1000

Material	**Cost (USD)**
Pipes	5399.23
Concrete	1000

Filtration	500
Unforeseen	500
Tank(s)	200
Basic Materials	200

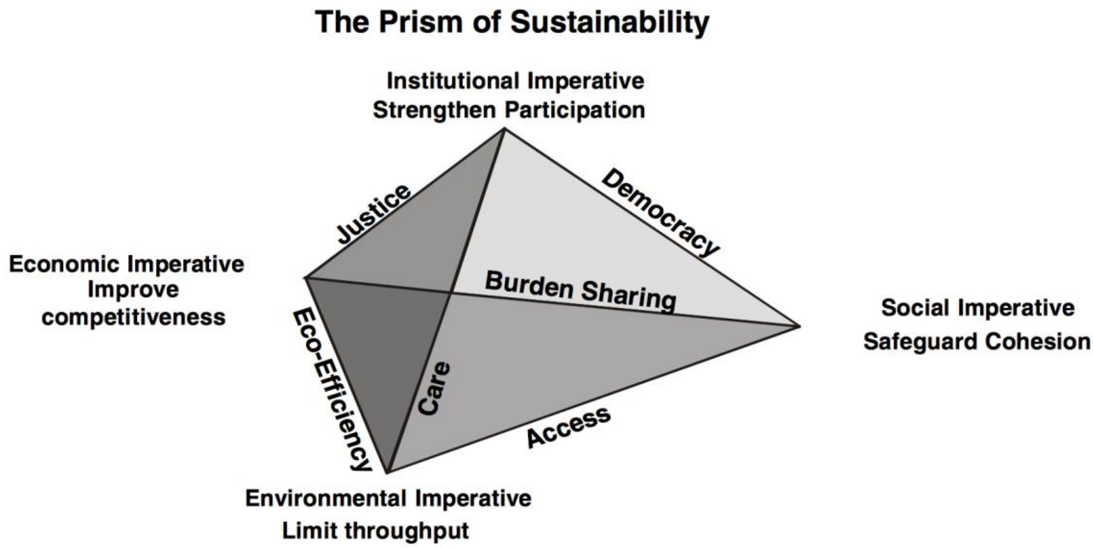
Estimated Cost, Beta Design

Total

Estimated Cost = 6100 USD

Sustainability

Pursuing EES's ultimate goal of sustainability and local ownership, the German Wuppertal Institute's *Prism of Sustainability* will be used as its model for project development (see Figure 4). Following its idea of a triple bottom line, environmental, social, and economic



(Figure 4: The Prism of Sustainability)

factors are carefully considered. The three of the main goals of EES in this project are as follows:

(1) Build a water system for the refugee camp
(2) Provide skills training to Nepalese workers
(3) Help educate the public to reduce waterborne illnesses

In order to a sure these steps towards sustainability, first and foremost, the project will be headed by Nepalese Engineers. ESS will provide technical advision and oversight but will interact with the project as to allow participating Nepali engineers autonomy. Eventually, ESS intends for the oversight of the project 1 year after its completion to be completely transferred to the responsibility of NEA allowing them to assess the best way in which to approach the end ownership of the water system (e.g. create a water board, have informal water team, etc). It is important to take under consideration here that the UN has expressed that it will provide a fund if necessary to the NEA to pay for the maintenance of the system.

Furthermore, EES will have a group of local community members join each one of the teams mentioned in the project implementation. These community members will partake in the designing and construction of the system so as to learn the process and acquire knowledge through applied learning practices. In concurrence with Barefoot College, they will also complete engineering training and certification so that once the EES leaves they will be able to sustain the water system themselves.

Beyond the water system itself, health educators from UNHCR will provide training to address the difficulties and intersectionality of health, culture, and engineering. This will be the most important factor to the social success of the project, as a successful engineering design does not fully merit its success to the consumer. Best water practices will then be employed via campaigns and workshops by these educators to further ensure the project's realization in the community.

To ensure well-defined goals and tangible sustainability outcomes, a project hierarchy was created. Please see Form 1A for the project hierarchy proposal as it is intended to outline the before mentioned ideas.

In regards to the execution of the project hierarchy, the United Nation's Development Program's *Results Based Management*[5] (RBM) practice will be used to review and evaluation project progression. In addition to this, the UNHCR will act as an independent auditor to confirm that the goals and tangible deadlines are being met by all parties.

Construction and Implementation

Please see Form 1B for the proposed Gant chart.

As seen in the Gantt Chart attachment, EES is looking to design and build the water system in as little as fourteen weeks. The reason behind this is because the refugee camp needs water as soon as possible and fourteen weeks is the fastest construction time that the EES can successfully provide the necessary water. In order to get water to the refugee camp as soon as possible ESS will construct a water system using four Teams: Team 1, Team 2, Team 3, and Team 4. The goal in doing this is to optimize the amount of time needed to construct a water system. In order to help optimize the amount of time needed to finish the project, each

[5] Amadai, Bernard. "Engineering for Sustainable Human Development." p. 144-145

team will be assigned to build a specific part of the water system allowing all four teams to be working on the system at once.

While taking on the water system with four teams will vastly decrease the total amount of time needed for construction, it will also cause issues such as making concrete more difficult. If time wasn't of the essence, one could start installing pipe from the source (A) down to B where the pressure break tank is, and because you have accessible water from the source (A), you could use it to mix with the cement to make the concrete slab at B. Since time is of the essence, there would be a team working on installing the pipe from A to B while another team is building the concrete slab and pressure break tank. It will be more difficult for the second team to get water to mix with the cement in order to make the concrete but this will be a necessary difficulty in order to finish the project in as little as fourteen weeks. Presumably, construction teams will be able to transport water from already existing wells.

Recommendation and Conclusion

The Alpha system should be seen as a more comprehensive engineering design wherein it is designed for utility. However, there are two major issues facing this design. First, it may be more complicated in its usage of two piping systems, which can be problematic for future repairs. Second, it is timelier in its construction when compared to Beta as it is estimated to be a faster process by around a month.

However, the Beta design also retains flaws. Although it provides water in a faster and cheaper fashion, this comes with a price. Concerns should be raised not only regarding the pressure at point C but also the inability of the system to supply water to the satellite camp at H. Furthermore, the Beta system has a serious paradox with time. This is to say that an essential part of engineering projects is to continuously evaluate a project's efficacy and validity over its timeline; however, since the timeline is rushed, incomplete evaluation and monitoring may lead to project failure.

Monetarily, a price differential of 2,700 USD remains between the two designs. In conclusion, though, it may in fact be in the best interest of both the UNHCR and those in the refugee camp to implement the Alpha design while providing temporary means of potable water via alternate methods.

Appendix

Detailed Calculations

Design Alpha

- From A→B

Elevation at A: 150m
Elevation at B: 90m

To calculate the pressure at B, when water is not flowing, a difference in elevation may be calculated:

$$P_{\text{No Flow}} = 150\text{m} - 90 = 60\text{m}$$

$$H_{\text{Loss, A}\rightarrow\text{B}} = 9.5\frac{\text{m}}{\text{km}} \times 2\text{km} = 19 \text{ m will be lost to friction.}$$

Finally, a pressure at point B can be understood to be

$$P_B = 60\text{m} - 19\text{m} = 41\text{m}$$

- From B → C

Elevation at B: 90m
Elevation at C: 75m

Since the pressure break tank was placed at B, a reset of pressure to 0m may be assumed to the calculation of no flow pressure:

$$P_{\text{No Flow}} = 90\text{m} - 75\text{m} = 15\text{m}$$

$$(90\text{m} + 0\text{m}) - (75\text{m} + 10\text{m}) = 5\frac{\text{m}}{\text{km}}$$

$$J = 5\frac{m}{km}$$

Since a coefficient of headloss rate is determined to be $J = 5\frac{m}{km}$, a ratio of pipes can be found for the provision of the minimum pressure.

$$X\left(9.5\frac{\text{m}}{\text{km}}\right) + (1 - X)1.1\frac{\text{m}}{\text{km}} = 5\frac{\text{m}}{\text{km}}$$

$$X=0.464$$

Using the ratio of J values found through the manufacturer's advision, below are the required distances of the pipes necessary:

0.4642 km of 40mm
0.5357 km of 63mm

- From C → E

Elevation at C: 75m
Elevation at E: 50m

While maintaining a pressure of 10m at C, the system is then designed to transport water to E. The no flow pressure associated with this equals 25m.

$$P_{\text{No Flow}} = 75\text{m} - 50\text{m} = 25\text{m}$$

Assuming that the 40mm piping is used, headloss rate is calculated:

$$H_{C\rightarrow E} = 9.5\,\frac{m}{km}\ (.5\ km) = 4.75m$$

Therefore, the final pressure at E:

$$P_E = (25m + 10m) - 4.75m = 30.25m$$

A filter and storage tank is then recommended at E. This therefore resets the pressure at E = 0m.

- From E → G

Elevation at E: 50m
Elevation at G: 20m

With pressure reset to 0m, pressure at G with no flow equates to:

$$P_{No\ Flow} = 50m - 20m = 30m$$

Using 40mm, a headloss rate is expected:

$$H_{E\rightarrow G} = 9.5\,\frac{m}{km}\ (.5\ km) = 4.75m$$

Finally, a final pressure at the communal tap at G can then be expected to be:

$$P_G = 25.25m$$

- From G → H

Elevation at G: 20m
Elevation at H: 30m

Calculating the no flow pressure at H:

$$P_{No\ Flow} = (30m + 20m) - 30m = 20m$$

In order to maintain a minimum of 10m of pressure, the less friction inducing available pipe—63mm—can then be calculated for headloss rate.

$$H_{G\rightarrow H} = 1.1\,\frac{m}{km}\ (1\ km) = 1.1m$$

The overall pressure at H after headloss rate can then be estimated to be

$$P_H = 20m - (1.1m + 4.75m) = 14.15\ m$$

Design Beta

- From A→B

Elevation at A: 150m
Elevation at B: 90m

To calculate the pressure at B, when water is not flowing, a difference in elevation may be calculated:

$$P_{No\ Flow} = 150m - 90 = 60m$$

$$H_{Loss,\ A\rightarrow B} = 9.5\,\frac{m}{km} \times 2km = 19\ m \text{ will be lost to friction.}$$

Finally, a pressure at point B can be understood to be

$$P_B = 60m - 19m = 41m$$

- From B → C

Elevation at B: 90m
Elevation at C: 75m

$$P_{No\ Flow} = 90m - 75m = 15m$$

However when using 40mm to calculate the headloss rate:

$$H_{B\rightarrow C} = 9.5\,\frac{m}{km}\ (1\ km) = 9.5m$$

Therefore, the final pressure at C:

$$P_C = 15m - 9.5m = 5.5m$$

- From B → F

Elevation at C: 90 m
Elevation at F: 40m

The non-flowing pressure found at F can be calculated as

$$P_{No\ Flow} = 90m - 40m = 50m$$

Under this design, 40mm is the only pipe sizing used to insure simplicity. Using the corresponding J value to calculate headloss rate:

$$H_{B\rightarrow F} = 9.5\frac{m}{km}(1.7\ km) = 16.15m$$

A final pressure at can then be

$$P_F = 50m - 16.15m = 33.85m$$

However, this pressure will be reset to 0m by the placement of a filter and storage tank.

- From F → G

Elevation at F: 40m
Elevation at G: 20m

$$P_{No\ Flow} = 40m - 20m = 20m$$

Using 40mm piping again, the headloss rate is

$$H_{F\rightarrow G} = 9.5\frac{m}{km}(.5km) = 4.75m$$

Finally, the pressure at G is

$$P_G = 20m - 4.75m = 15.25m$$

Further References

- Figure 1: http://www.bbc.com/news/world-asia-32492232

- http://www.theguardian.com/world/2015/may/01/nepal-earthquake-death-toll-passes-6000-with-thousands-still-missing

- Figure 4: Stenberg, J. (2001): Bridging gaps—Sustainable Development and local democracy processes. Gothenburg.