College of Engineering, Informatics, and Applied Sciences

Memorandum

Design4Practice (D4P) Program

To: Dr. David Trevas

From: Aaron Curley

Due: 7/19/20

Re: Individual Analytical Analysis

Introduction

Our capstone team has been tasked with building a small scale residential vertical farming system. The system should occupy the least amount of space and provide owners with a supply of healthy nutritious vegetables. Vertical farming systems have the potential to revolutionize farming because the amount of crops that can be produce per land area is unprecedented. Our main design currently is a vertically stacked aquaponics system.

The purpose of this assignment is to select pumps that will provide the flow rates necessary for our aquaponics system. The hydroponics aspect of our design utilizes the nutrient film technique. In this method plant roots are soaked by thin layer of water flowing at the bottom of a tube or trough. The water is filled with oxygen and nutrients which are absorbed by the plant.

Assumptions

The fundamental equation used to select pumps is the energy equation expressed in terms of head. This equation defines conservation of energy within a fluid. In our calculations we set P_1, P_2, v_1, v_2, and H_T equal to zero because the water at points one and two are held in tanks, exposed to the atmospheric pressure, and there is no turbine in the system.

$$\boldsymbol{\frac{P_1}{\rho G} + \frac{v_1^2}{2G} + z_1 + H_P = \frac{P_2}{\rho G} + \frac{v_2^2}{2G} + z_2 + H_T + H_L}$$

Equation 1 Energy equation [1]

Table 1 Energy equation variables

Variable	Description
P	Pressure
v	Velocity
ρ	H20 Density (62.4 lbs/ft^3)
G	Gravity (32.2 ft/s^2)
z	Height
H_P	Pump head
H_T	Turbine head
H_L	Total head loss

Project schematic

Below is a simple diagram of the team's foremost design. The system has three subsystems used to move water. The first (orange) will move water to a manifold at the top which will distribute water to the seven troughs below it. The second (green) will move water to 4 troughs below the fish tank. The water will then drain into a tank at the bottom and then subsystem 3 (blue) will move the water back into the fish tank.

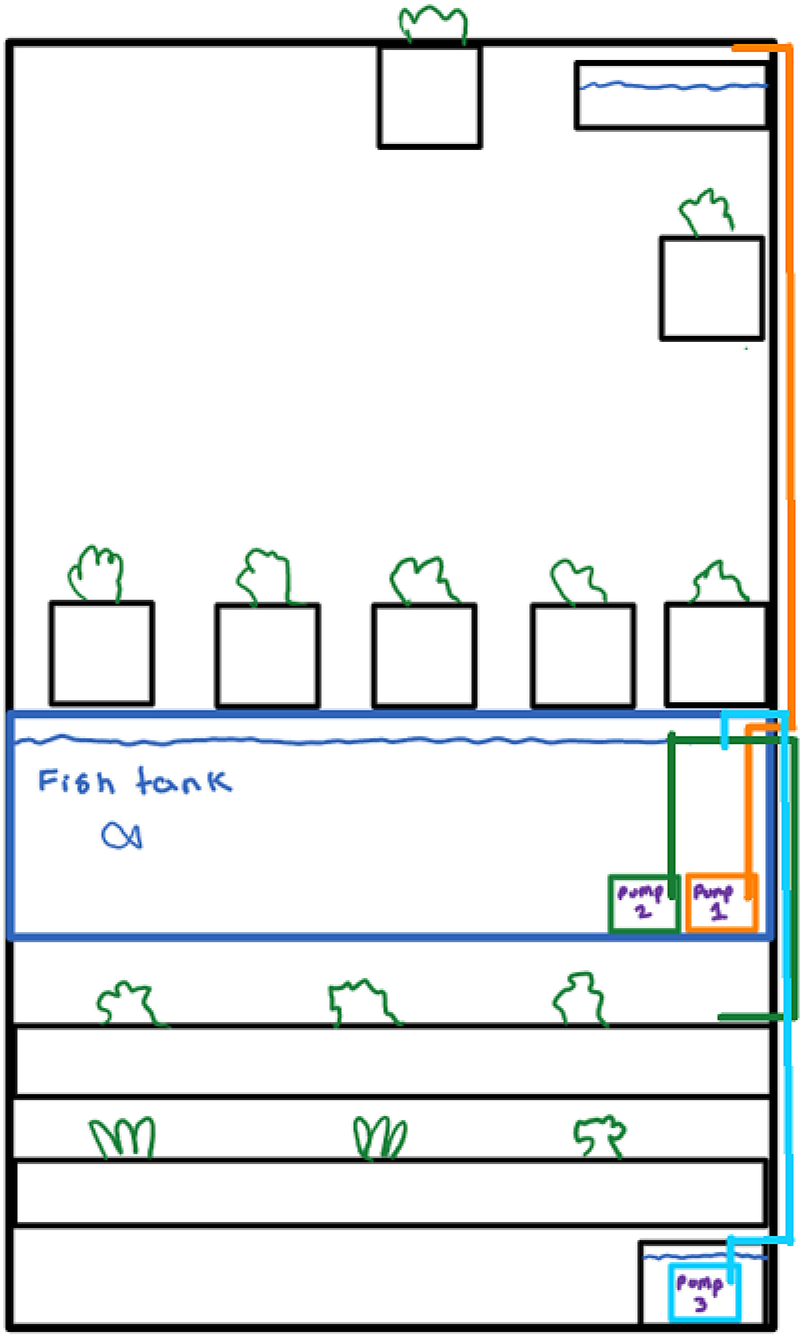


Figure 1 Right Side view of aquaponics design

Calculations

The procedure we used to select pumps for our team's design is shown in the flow chart below.

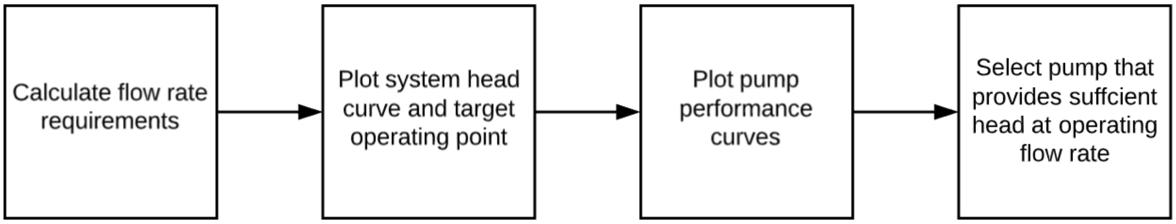


Figure 2 Analysis procedure

All troughs in the system will hold ¼ inch of water used to feed and water the plants. The top troughs are all the same size and will hold a total of .2337 gallons of water. The water will be recirculated every five minutes which will require a flow rate of 19.63 gallons per hour. The bottom troughs will hold a total of .1168 gallons. With the water being recirculated every five minutes the flow rate required will be 5.60 gallons per hour.

Three pumps are required by the design. Pump #1 will pump water up to a manifold above the top troughs and distribute water to the troughs. Pump #2 will pump water to the troughs below the fish tank. The water in these troughs will drain into a tank and be pumped back into the fish by pump #3

The pump selected to provide water to the top troughs is the Ponic pump model #PP-291xx. The system head curve for subsystem 1, target operation point, and the PP-291xx performance curves is shown below in figure 3.

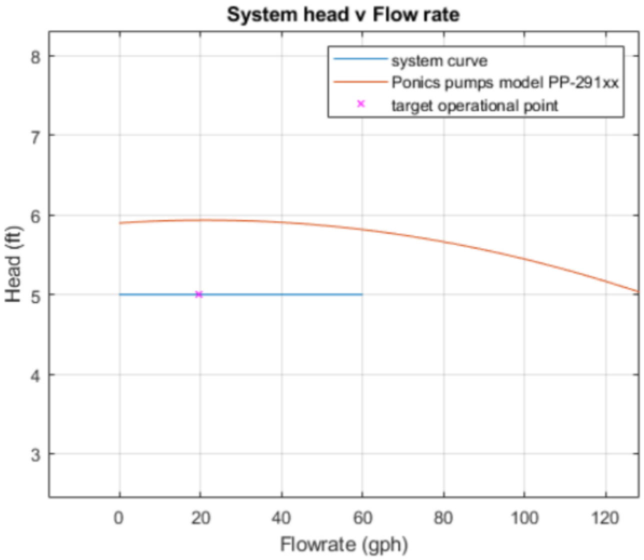


Figure 3

The pump selected for subsystem 2 is the Ponic pump model #PP-040xx. The system head curve for subsystem 2, target operation point, and the PP-040xx performance curve are plotted in the graph below in figure 4.

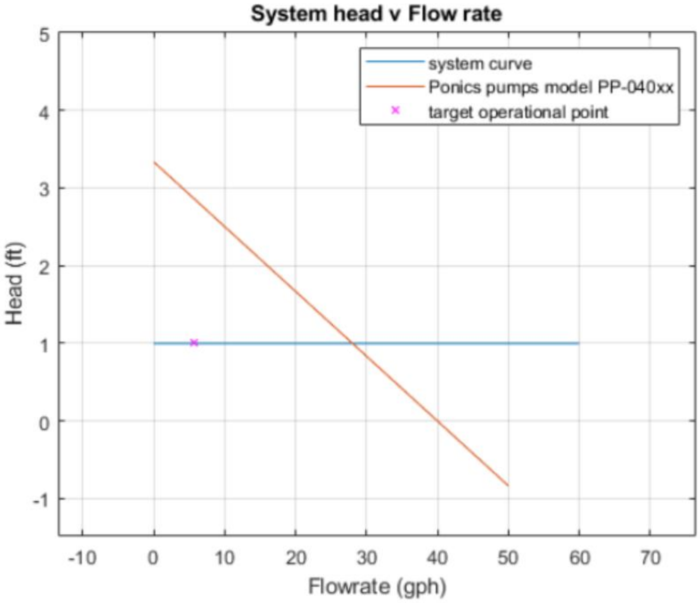


Figure 4

The pump chosen for subsystem 3 was the Ponics pump model #PP-211xx. The system head curve for subsystem 3, target operation point, and PP-211xx performance curves is shown in figure 5.

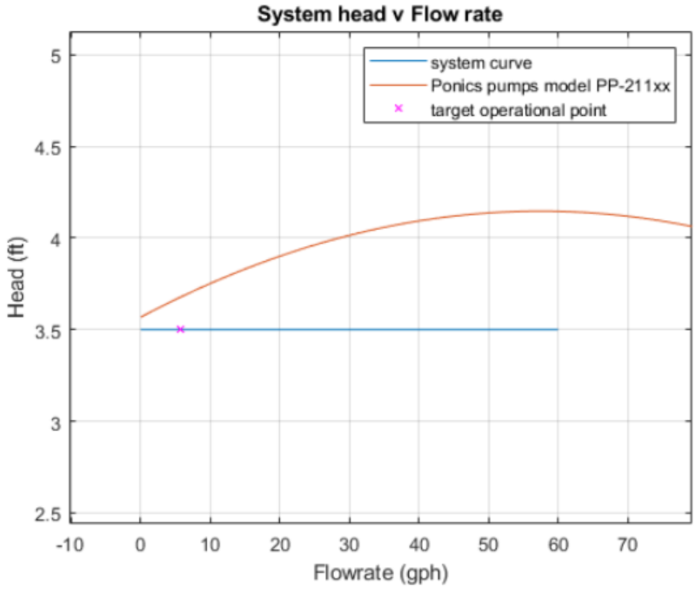


Figure 5

The MATlab code use to perform these calculations are in appendix A.

Results

This analysis provided us with information that allowed us to pick three pumps that would provide the flow rates necessary for our aquaponics system. The calculations done in this analysis were done in MATlab which make it easy to scale the system up or down in the future. The pumps selected can provide more than enough head required which will allow for expansion in the future.

Works Cited

[1] Çengel Yunus A. and J. M. Cimbala, *Fluid mechanics: fundamentals and applications*. New York, NY: McGraw-Hill Education, 2018.

Appendix A

Define constants

```
nu=1.06e-5 %ft^2/s fox and mcdonalds Table A.7
```

```
nu = 1.0600e-05
```

```
gpm2ft3ps = .0022801;
ft3s2gpm = 448.831;
g = 32.2 %ft^2/s
```

```
g = 32.2000
```

Pump 1

```
A1 = .00135 %ft
```

```
A1 = 0.0014
```

```
L1 = 5.5 %ft
```

```
L1 = 5.5000
```

```
D1 = .0416 %ft
```

```
D1 = 0.0416
```

```
DelZ = 5 %ft
```

```
DelZ = 5
```

```
E1 = .000023 %ft
```

```
E1 = 2.3000e-05
```

Plot system head curve

```
Q_vec = [0:.1:1]*gpm2ft3ps; %ft^3/s
V1_vec = Q_vec/A1; %calculate velocities from flow rate
Re1_vec = V1_vec*D1/nu; %calculate reynolds number from flow rate
epsD1_vec = E1/D1*ones(size(Re1_vec)); %pre allocate epsilon/diamter vector
f1_vec = (.3086)./(log((epsD1_vec.*Re1_vec+25.530)./Re1_vec)-.5682).^2.22; %halland equation solved for f to get friction factors
H_sys = DelZ+f1_vec*(L1/D1).*(Q_vec.^2./2*g*A1^2); %system head curve

figure;
plot((Q_vec/gpm2ft3ps)*60,H_sys); %gal/hour vs ft
```

```
Warning: Imaginary parts of complex X and/or Y arguments ignored.
```

```
xlim([0 30])
title('System head v Flow rate')
ylabel('Head (ft)')
xlabel('Flowrate (gph)')
grid on
hold on
```

Plot pump performance curve

```
% Ponics pumps model PP-291xx 16 watt
Q1 = [291 271 251 218 175 120 26] %gph
```

```
Q1 = 1�7
   291   271   251   218   175   120    26
```

```
H1 = [0 1 2 3 4 5 6] %ft
```

```
H1 = 1�7
     0     1     2     3     4     5     6
```

```
performance=polyfit(Q1,H1,2);
plot(0:300,polyval(performance,0:300))
xlim([0 30])
```

Plot target operational point

```
Q_rec_gpm = .3271 %gpm
```

```
Q_rec_gpm = 0.3271
```

```
Q_rec = Q_rec_gpm*gpm2ft3ps
```

```
Q_rec = 7.4582e-04
```

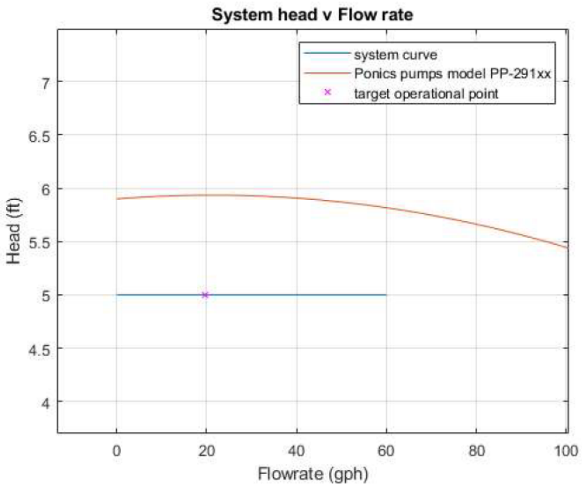
```
H_req = interp1(Q_vec,H_sys,Q_rec)
```

```
H_req = 5.0000 - 0.0000i
```

```
plot((Q_rec/gpm2ft3ps)*60, H_req,'mx','Markersize',5)
```

```
Warning: Imaginary parts of complex X and/or Y arguments ignored.
```

```
legend('system curve','Ponics pumps model PP-291xx','target operational point')
```



Pump 2

```
A2 = .00135 %ft
```

```
A2 = 0.0014
```

```
L2 = 4 %ft
```

```
L2 = 4
```

```
D2 = .0416 %ft
```

```
D2 = 0.0416
```

```
DelZ2 = 1 %ft
```

```
DelZ2 = 1
```

```
E1 = .000023 %ft
```

```
E1 = 2.3000e-05
```

Plot system head curve

```
Q_vec = [0:.1:1]*gpm2ft3ps; %ft^3/s
V2_vec = Q_vec/A2; %calculate velocities from flow rate
Re2_vec = V2_vec*D2/nu; %calculate reynolds number from flow rate
epsD2_vec = E1/D2*ones(size(Re2_vec)); %pre allocate epsilon/diamter vector
f2_vec = (.3086)./(log((epsD2_vec.*Re2_vec+25.530)./Re2_vec)-.5682).^2.22; %halland equation solved for f to get friction factors
H_sys = DelZ2+f2_vec*(L2/D2).*(Q_vec.^2./2*g*A2^2); %system head curve

figure;
plot((Q_vec/gpm2ft3ps)*60,H_sys); %gal/hour vs ft
```

```
Warning: Imaginary parts of complex X and/or Y arguments ignored.
```

```
xlim([0 10])
title('System head v Flow rate')
ylabel('Head (ft)')
xlabel('Flowrate (gph)')
grid on
hold on
```

Plot pump performance curve

```
% Ponics pumps model PP-040xx 2.5 watt
Q2 = [40 28]
```

```
Q2 = 1�2
    40    28
```

```
H2 = [0 1]
```

```
H2 = 1�2
     0     1
```

```
performance2=polyfit(Q2,H2,1);
plot(0:50,polyval(performance2,0:50))
```

Plot target operational point

```
Q_rec_gpm = .09344 %gpm
```

```
Q_rec_gpm = 0.0934
```

```
Q_rec = Q_rec_gpm*gpm2ft3ps
```

```
Q_rec = 2.1305e-04
```

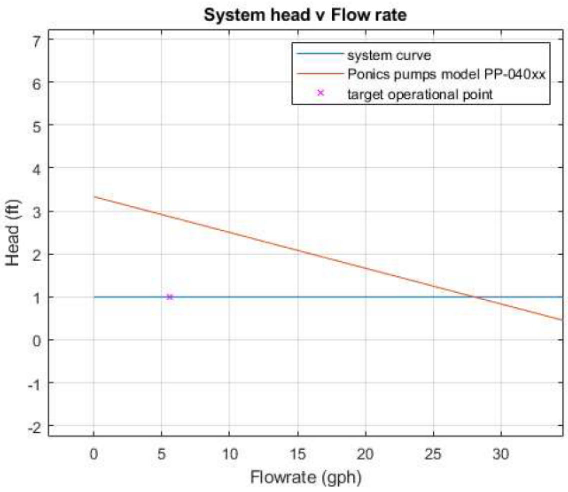
```
H_req = interp1(Q_vec,H_sys,Q_rec)
```

```
H_req = 1.0000 - 0.0000i
```

```
plot((Q_rec/gpm2ft3ps)*60, H_req,'mx','Markersize',5)
```

```
Warning: Imaginary parts of complex X and/or Y arguments ignored.
```

```
legend('system curve','Ponics pumps model PP-040xx','target operational point')
```



Pump 3

```
A3 = .00135 %ft
```

```
A3 = 0.0014
```

```
L3 = 3.5 %ft
```

```
L3 = 3.5000
```

```
D3 = .0416 %ft
```

```
D3 = 0.0416
```

```
DelZ3 = 3.5 %ft
```

```
DelZ3 = 3.5000
```

```
E1 = .000023 %ft
```

```
E1 = 2.3000e-05
```

Plot system head curve

```
Q_vec = [0:.1:1]*gpm2ft3ps; %ft^3/s
V3_vec = Q_vec/A3; %calculate velocities from flow rate
Re3_vec = V3_vec*D3/nu; %calculate reynolds number from flow rate
epsD3_vec = E1/D3*ones(size(Re3_vec)); %pre allocate epsilon/diamter vector
f3_vec = (.3086)./(log((epsD3_vec.*Re3_vec+25.530)./Re3_vec)-.5682).^2.22; %halland equation solved for f to get friction factors

H_sys = DelZ3+f3_vec*(L3/D3).*(Q_vec.^2./2*g*A2^2); %system head curve
figure;
plot((Q_vec/gpm2ft3ps)*60,H_sys); %gal/hour vs ft
```

```
Warning: Imaginary parts of complex X and/or Y arguments ignored.
```

```
xlim([0 10])
title('System head v Flow rate')
ylabel('Head (ft)')
xlabel('Flowrate (gph)')
grid on
hold on
```

Plot pump performance curve

```
% Ponics pumps model PP-120xx 6 watt
Q3 = [119 95 66 20]
```

```
Q3 = 1�4
   119    95    66    20
```

```
H3 = [0 1 2 3]
```

```
H3 = 1�4
     0     1     2     3
```

```
performance3=polyfit(Q3,H3,2);
plot(0:120,polyval(performance3,0:120))

% Ponics pumps model PP-211xx 12 watt
Q4 = [211 192 167 139 86]
```

```
Q4 = 1�5
   211   192   167   139    86
```

```
H4 = [0 1 2 3 4]
```

```
H4 = 1�5
     0     1     2     3     4
```

```
performance4=polyfit(Q4,H4,2);
plot(0:211,polyval(performance4,0:211))
```

Plot target operational point

```
Q_rec_gpm = .09344 %gpm
```

```
Q_rec_gpm = 0.0934
```

```
Q_rec = Q_rec_gpm*gpm2ft3ps
```

```
Q_rec = 2.1305e-04
```

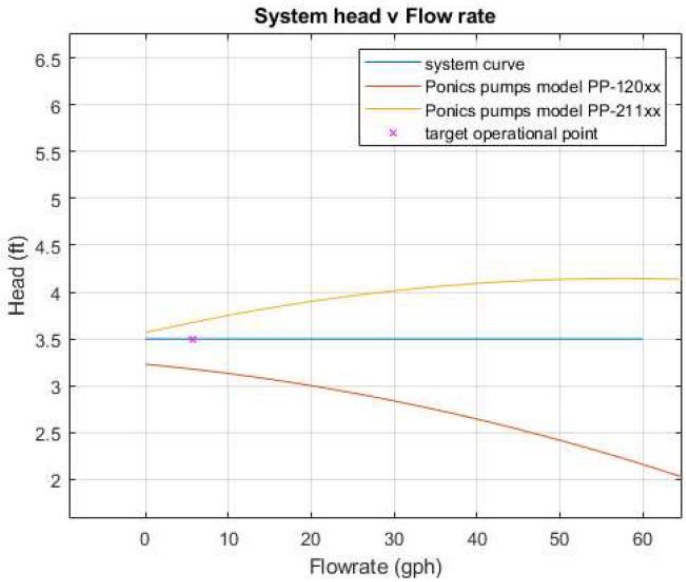
```
H_req = interp1(Q_vec,H_sys,Q_rec)
```

```
H_req = 3.5000 - 0.0000i
```

```
plot((Q_rec/gpm2ft3ps)*60, H_req,'mx','Markersize',5)
```

```
Warning: Imaginary parts of complex X and/or Y arguments ignored.
```

```
legend('system curve','Ponics pumps model PP-120xx','Ponics pumps model PP-211xx','target operational point')
```


System head v Flow rate
system curve
Ponics pumps model PP-120xx
Ponics pumps model PP-211xx
target operational point
Head (ft)
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
Flowrate (gph)
0
10
20
30
40
50
60