BEE 4750/5750 Homework 2

Ian Shen-Costello (iys2)

2022-09-29

Problem 1

Problem 1.1

```
using Plots

#Initial concentrations
q_river = 100000 #m^3/d
q_1 = 10000 #m^3/d
q_2 = 15000 #m^3/d

do_river = 7500 #mg/m^3
do_1 = 5000 #mg/m^3
do_2 = 5000 #mg/m^3

cbod_river = 5000 #mg/m^3
cbod_1 = 50000 #mg/m^3
cbod_2  = 45000 #mg/m^3

nbod_river = 5000 #mg/m^3
nbod_1 = 35000 #mg/m^3
nbod_2 = 35000 #mg/m^3

cs = 10000; #mg/m^3

#Finding initial concentrations given two inflows with DO, CBOD, and NBOD
concentrations

function int_conditions(inflow1, inflow2, do1, do2, cbod1, cbod2, nbod1, nbod2)
   c0 = (inflow1 * do1 + inflow2 * do2)/(inflow1+inflow2)
   b0 = (inflow1 * cbod1 + inflow2 * cbod2)/(inflow1+inflow2)
   n0 = (inflow1*nbod1 + inflow2*nbod2)/(inflow1+inflow2)

   return [c0, b0, n0]

end
```

int_conditions (generic function with 1 method)

```
#Finding dissolved oxygen concentration as a function of distance and final
CBOD and NBOD concentrations given initial conditions and decay rates.
```

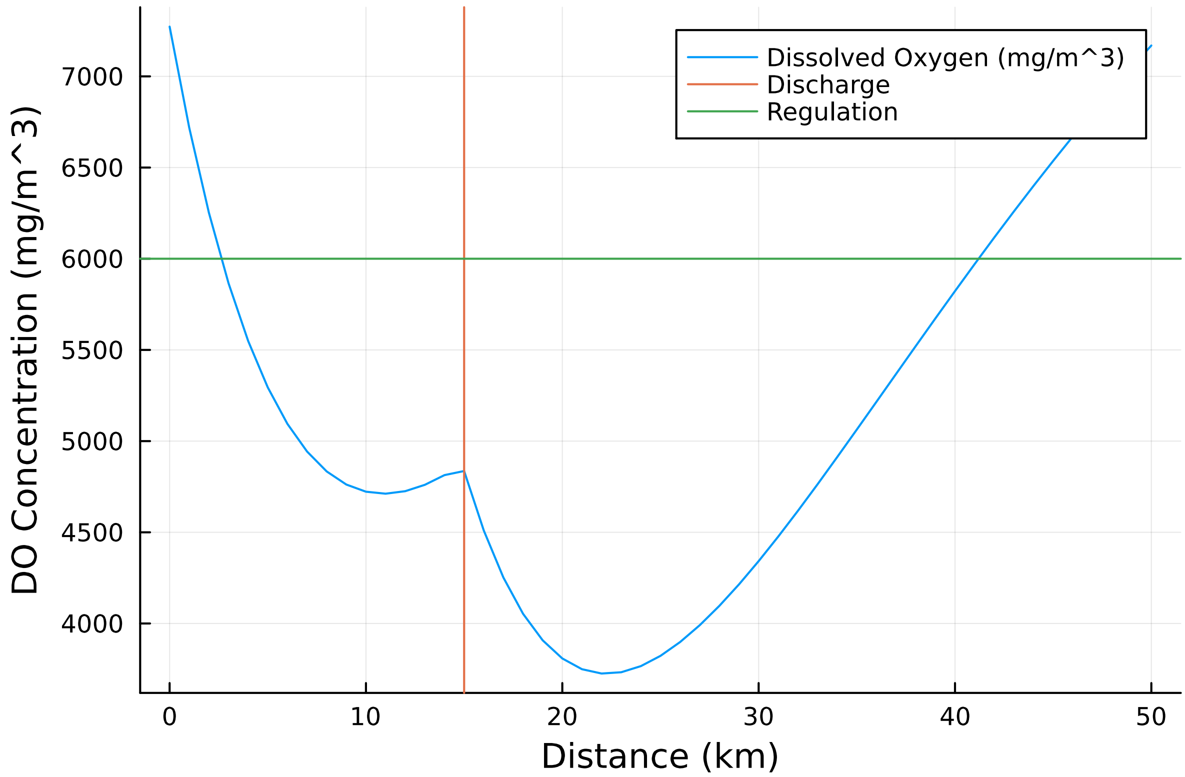
```julia
function dissolved_ox(u, c, cs, c0, b0, n0, ka, kc, kn, x1, x2)


   for i = 0:x2-x1
    a1 = exp(-ka*i/u)
    a2 = (kc/(ka-kc))*(exp(-kc*i/u)-exp(-ka*i/u))
    a3 = (kn/(ka-kn))*(exp(-kn*i/u)-exp(-ka*i/u))

    c[x1+i+1] = (cs*(1-a1))+(c0*a1)-(b0*a2)-(n0*a3)

   end

   b = b0*exp(-kc*x2/u)
   n = n0*exp(-kn*x2/u)

   return [c[x2],b,n]

end
```

dissolved_ox (generic function with 1 method)

```julia
# Return array c that contains the dissolved oxygen concentration varying over
distance and the minimum value of c
function total_do(cbod_river, nbod_river, cbod_1, nbod_1, cbod_2, nbod_2)
   c = zeros(51)

   conc_1 =
int_conditions(100000,10000,7500,5000,cbod_river,cbod_1,nbod_river,nbod_1)
   d = dissolved_ox(6, c, cs, conc_1[1], conc_1[2], conc_1[3], 0.55, 0.35,
0.25, 0, 15)

   conc_2 = int_conditions(110000,15000,d[1],do_2,d[2],cbod_2,d[3],nbod_2)
   dissolved_ox(6,c,cs,conc_2[1],conc_2[2],conc_2[3],0.55,0.35,0.25,15,50)

   return [c, minimum(c)]

end
```

total_do (generic function with 1 method)

```julia
plot([0:50],total_do(cbod_river,nbod_river, cbod_1,nbod_1,cbod_2,nbod_2)[1],
label="Dissolved Oxygen (mg/m^3)", xlabel = "Distance (km)", ylabel = "DO
Concentration (mg/m^3)")
vline!([15], label="Discharge")
hline!([6000], label = "Regulation")
```



Problem 1.2

```
julia> println(total_do(cbod_river,nbod_river,
cbod_1,nbod_1,cbod_2,nbod_2)[1][42])
5970.665310618188

julia> println(total_do(cbod_river,nbod_river,
cbod_1,nbod_1,cbod_2,nbod_2)[1][43])
6116.416168906334
```

Interpolating the values for x = 41 km and x = 42 km, we can determine where exactly the dissolved oxygen concentration reaches 6000 mg/m^3. This occurs at 41.2 km.

Problem 1.3

```
min_2_treated = 0;
t = 0;
while min_2_treated < 4000
      global min_2_treated =
total_do(cbod_river,nbod_river,cbod_1,nbod_1,(1-t)*cbod_2,(1-t)*nbod_2)[2]
      global t = t + 0.001
end

println(t)
```

0.13300000000000001

The minimum level of treatment of waste stream 2 is 13.3%.

Problem 1.4

```
min_both_treated = 0;
t = 0;
while min_both_treated < 4000
      global min_both_treated =
total_do(cbod_river,nbod_river,(1-t)*cbod_1,(1-t)*nbod_1,(1-t)*cbod_2,(1-t)*nbod_2)[2]
      global t = t + 0.001
end

println(t)
```

0.07500000000000005

The minimum level of treatment for both streams is 7.5%.

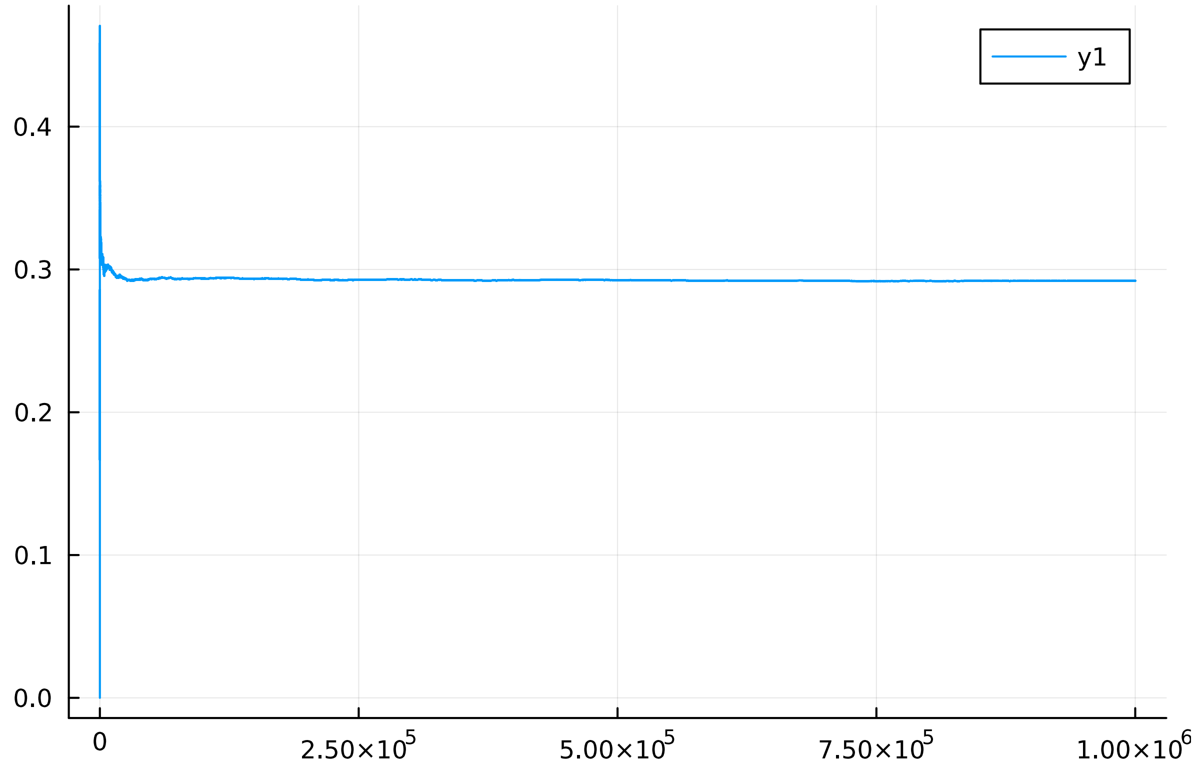
Problem 1.5

With no other information, treating both streams equally seems like the more equaitable approach since both stream are contributing to the pollution of the river. However, to make a more informed deicision, the cost of treating each stream should be taken into account. Additionally, the feasibiliy of treatment should be considered for each option. For example, if there is not enough space for a new treatment facility at one waste stream, the other should be preferred. To make it more equitable in this scenario, the waste stream that is not beging treated could contribute in the cost of treating the other stream.

Problem 1.6

```
julia> n = 1000;

julia> k = zeros(n^2);

julia> total1 = 0;

julia> success_count1 = 0;

julia> for i = 1:n
           for j = 1:n
              r1 = rand(Uniform(4000,7000))
              r2 = rand(Uniform(3000,8000))
              min1 =
total_do(r1,r2,(1-t)*cbod_1,(1-t)*nbod_1,(1-t)*cbod_2,(1-t)*nbod_2)[2]
              if min1 > 4000
                 global success_count1 = success_count1 +1
              end
              global total1 = total1 +1
              k[total1] = success_count1/total1
           end

       end
```

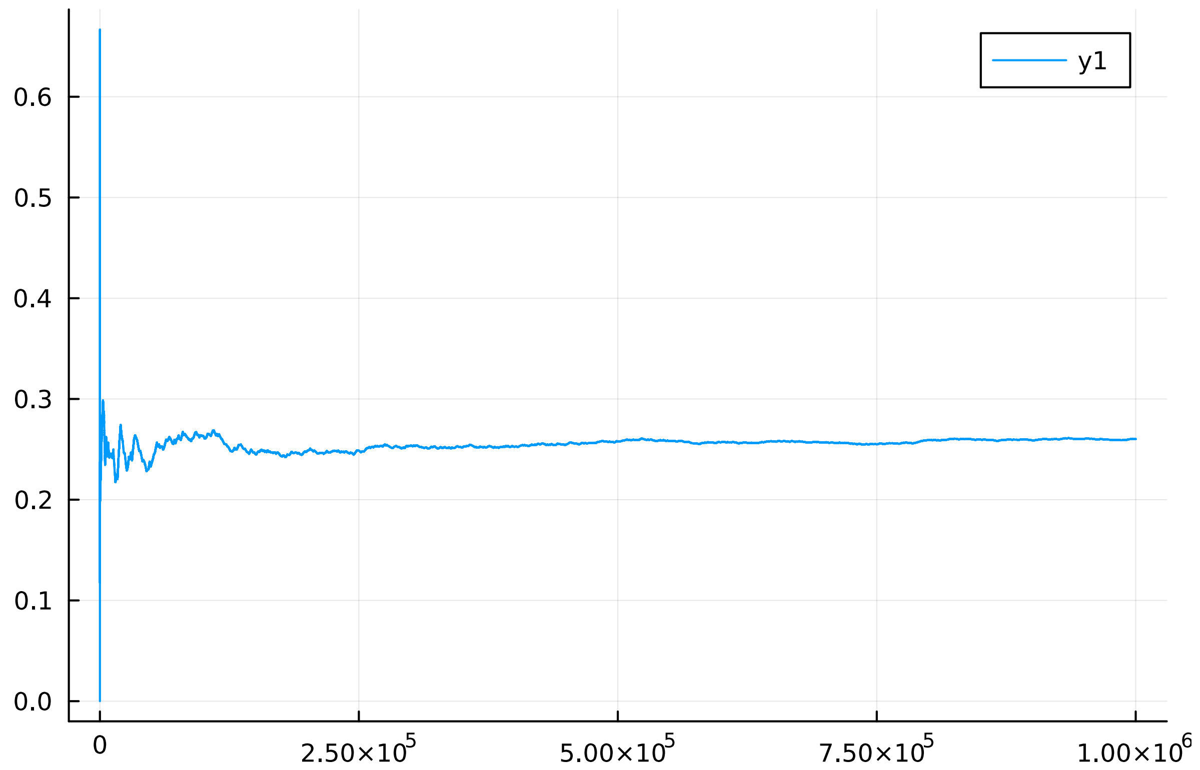
```
julia> println("The probability of maintaining a dissolved oxygen
concentration above 4 mg/L is ", round((1-k[total1])*100, digits = 2), "%")
The probability of maintaining a dissolved oxygen concentration above 4 mg/L is
 70.79%

julia> plot(k)
```



Problem 1.7

```
julia> n = 1000;

julia> p = zeros(n^2);

julia> total2 = 0;

julia> success_count2 = 0;

julia> g = sample_correlated_uniform(n, [4000,7000],[3000,8000]);

julia> for i = 1:n
           for j = 1:n
               min2 =
total_do(g[i,1],g[j,2],(1-t)*cbod_1,(1-t)*nbod_1,(1-t)*cbod_2,(1-t)*nbod_2)[2]
               if min2 > 4000
                   global success_count2 = success_count2 +1
               end
               global total2 = total2 +1
               p[total2] = success_count2/total2
           end
```

```
        end

julia> println("The probability of maintaining a dissolved oxygen
concentration above 4 mg/L is ", round((1-p[total2])*100, digits = 2), "%")
The probability of maintaining a dissolved oxygen concentration above 4 mg/L is
 73.98%

julia> plot(p)
```



Problem 1.8

Uncertainty and depdendency introduces a risk that, even with the treatment outlined above, the regulation of 4 mg/L may still not be met. With about 30% chance of failiure, the treatment strategy would certainly need to be changed. I would probably redefine the treatment amount, (changing the amount of CBOD and NBOD removed individually in each stream), until the percent change of risk reaches a suitable threshold. For example, the regulaiton is met 95% of the time. In reality, the CBOD and NBOD values are probably not uniformly distributed and a better distribution could be found, most likely through empirical data. However, to create a more accurate model the uncertainty and depdency of all variables would need to be considered. For example, the river and waste flows may vary depending on rainfall and the CBOD and NBOD levels in each stream could be correlated.

References

1. Getting rounded value of a number in Julia, Geeks for geeks,

https://www.geeksforgeeks.org/getting-rounded-value-of-a-number-in-julia-round-method/

2. Scopes of Variables, Julia Manual,

https://docs.julialang.org/en/v1/manual/variables-and-scoping/