```
[t,y]=ode45(‘bangladesh',[0 tlim], [4 4]);
```

```
function dydt=bangladesh(t,y)
```

Defines your system of equations for $dH_a/dt$ & $dH_p/dt$

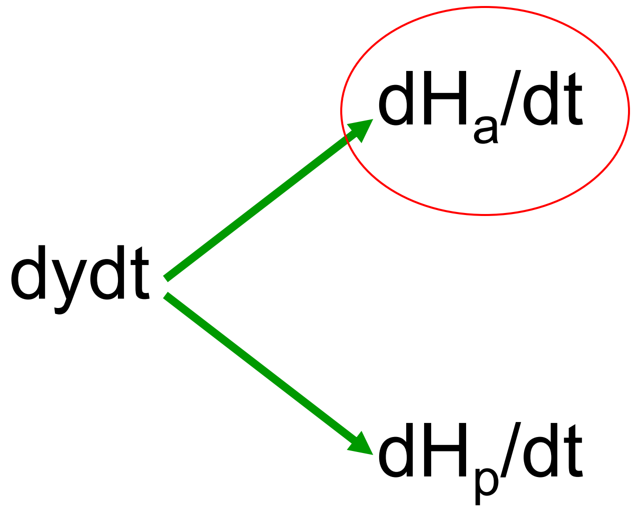
```
[t,y]=ode45('bangladesh',[0 tlim], [4 4]);

function dydt=bangladesh(t,y)

Hr=(2.5*sin(pi+(t/210)*pi))+4;

dydt=[kp*(y(2)-y(1))-Cp*Eo;
      (1/S)*(kp*fp*(y(1)-y(2))+kr*fr*(Hr-y(2))-fag*Cag*Eo];
```

↓

dydt @ t=0

↓

*ode45*




***ode45*** chooses **Δt** based on magnitude of dydt

$\Delta H_a = dH_a/dt * \Delta t$

Update t → t+Δt

$H_a$ @ t=0 = 4

Update $H_a \rightarrow H_a + \Delta H_a$

repeat starting with the new values of t and $H_a$, by inputing them back into the *function* and calculating new values of dydt

# *ode45* now inputs the new values of t and y into the function to get the new dydt

```
function dydt=bangladesh(t,y)

Hr=(2.5*sin(pi+(t/210)*pi))+4;

dydt=[kp*(y(2)-y(1))-Cp*Eo;
      (1/S)*(kp*fp*(y(1)-y(2))+kr*fr*(Hr-y(2))-fag*Cag*Eo];
```

↓

dydt @ t=0+Δt

↓

*ode45* now calculates the *next* Δt, updates t and y (i.e. $H_a$,$H_p$) … *etc* until **t=tlim**

```
function dydt=bangladesh(t,y)

Hr=(2.5*sin(pi+(t/210)*pi))+4;

If t < 180
Eo = 30
else Eo=50
end

dydt=[kp*(y(2)-y(1))-Cp*Eo;
      (1/S)*(kp*fp*(y(1)-y(2))+kr*fr*(Hr-y(2))-fag*Cag*Eo];
```

*You can define your parameters for dydt in terms of t*

*ode45*

*New Δt*

*New t*

*New $H_a$*

So, *ode45* outputs ***t*** values (your independent variable) VECTOR

AND the solutions for **y** (your dependent variable) for each ***t*** value. **y** has two components, $H_a$ and $H_p$. MATRIX

By clicking on WORKSPACE in the Matlab window, you can see the dimensions of your *ode45* outputs.

y is a MATRIX, to refer to it in Matlab, use:

- plot(t,y)

*or*

- plot(t, y(row#,column#))

NOTE that *t* and *y* have the same number of rows. If not, something's wrong.

So, the rows in **y** are the solutions at the different **t** values.

plot(t, y(row#,column#))

- To plot all time values use:

  plot(t, y(**1:n**,column#))

  *or simply*

  plot(t, y(**:**,column#))

# Syntax for *if* statements

```
if  t<180
    qi=0;
elseif t>190
    qi=5;
else
    qi=20;
end
```

*NEED to make sure the parameter values for all possible t 's are covered*

For example:

```
If t<180
qi=0;
elseif t>180
qi=5;
end
```

*WON'T WORK*
*WHAT IF t=180??*

## Subtracting and Adding vectors in Matlab

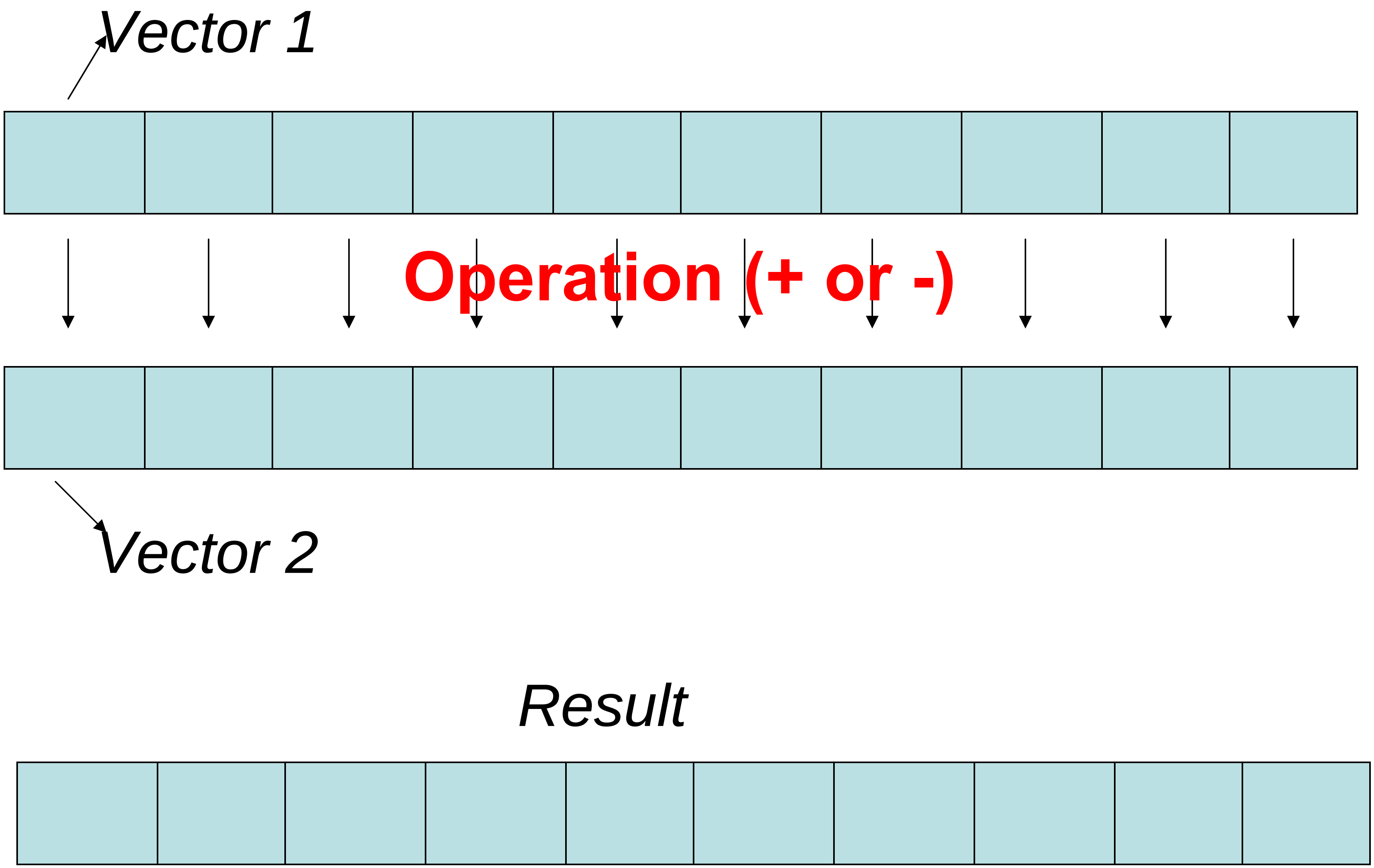
*As long as the vectors have the same lengths*

Matlab will add or subtract them, element by element, and the result will have the same length.

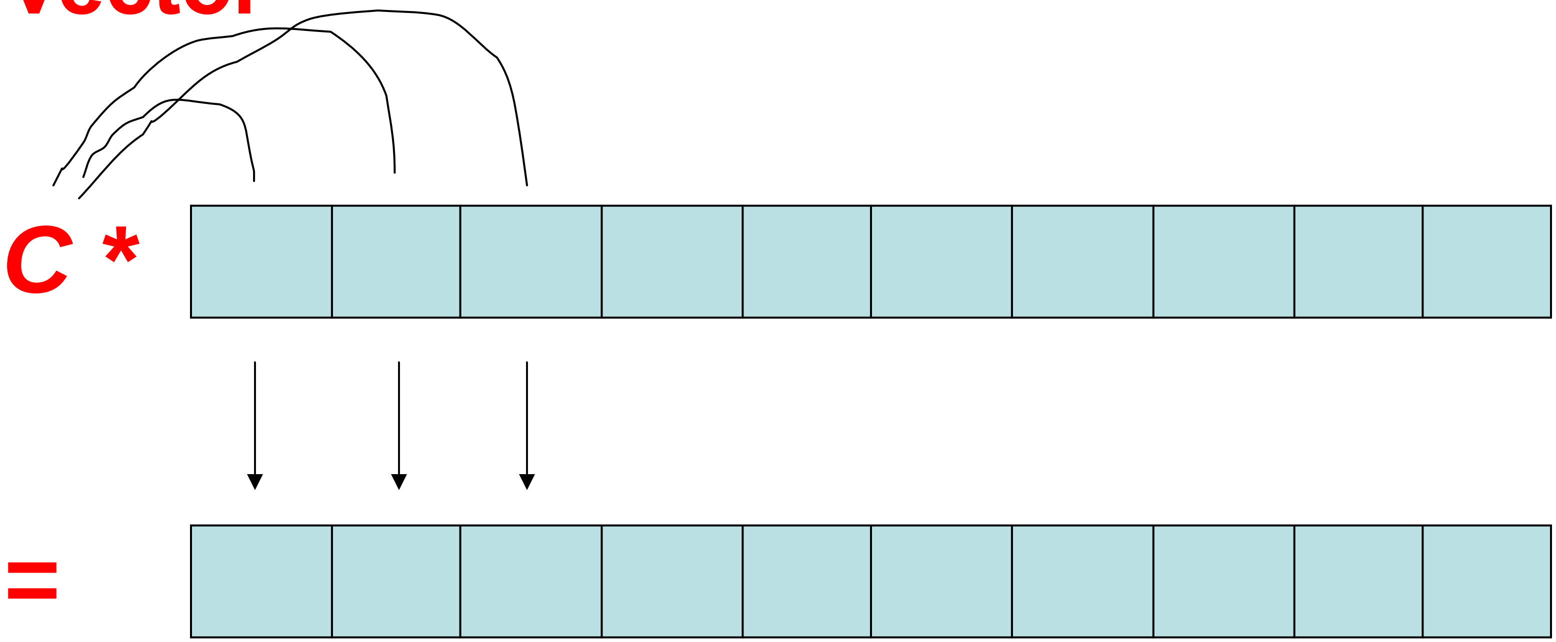
Example:  A=y(:,1)-y(:,2)

*then A will have the same number of rows as y, and 1 column.*

# *Vector 1 + Vector 2 = Result*



Similarly if you **multiply a constant by a vector**




*OR, result = sin(vector1)*

# FluxI

FluxI = 0 outside irrigating period, and equal to Transpiration within the irrigating period

FluxI depends on t, but is not the result of on an operation on t.

So to fill in the values of FluxI

You need to step through each element of *t* one by one, check if it falls within the irrigating period using an *if* statement, and then assign the **corresponding** value of FluxI

# Use a *for* loop

n=size(t)

for i=1:n

*check t(i) and assign Flux(i) using an **if** statement*

end

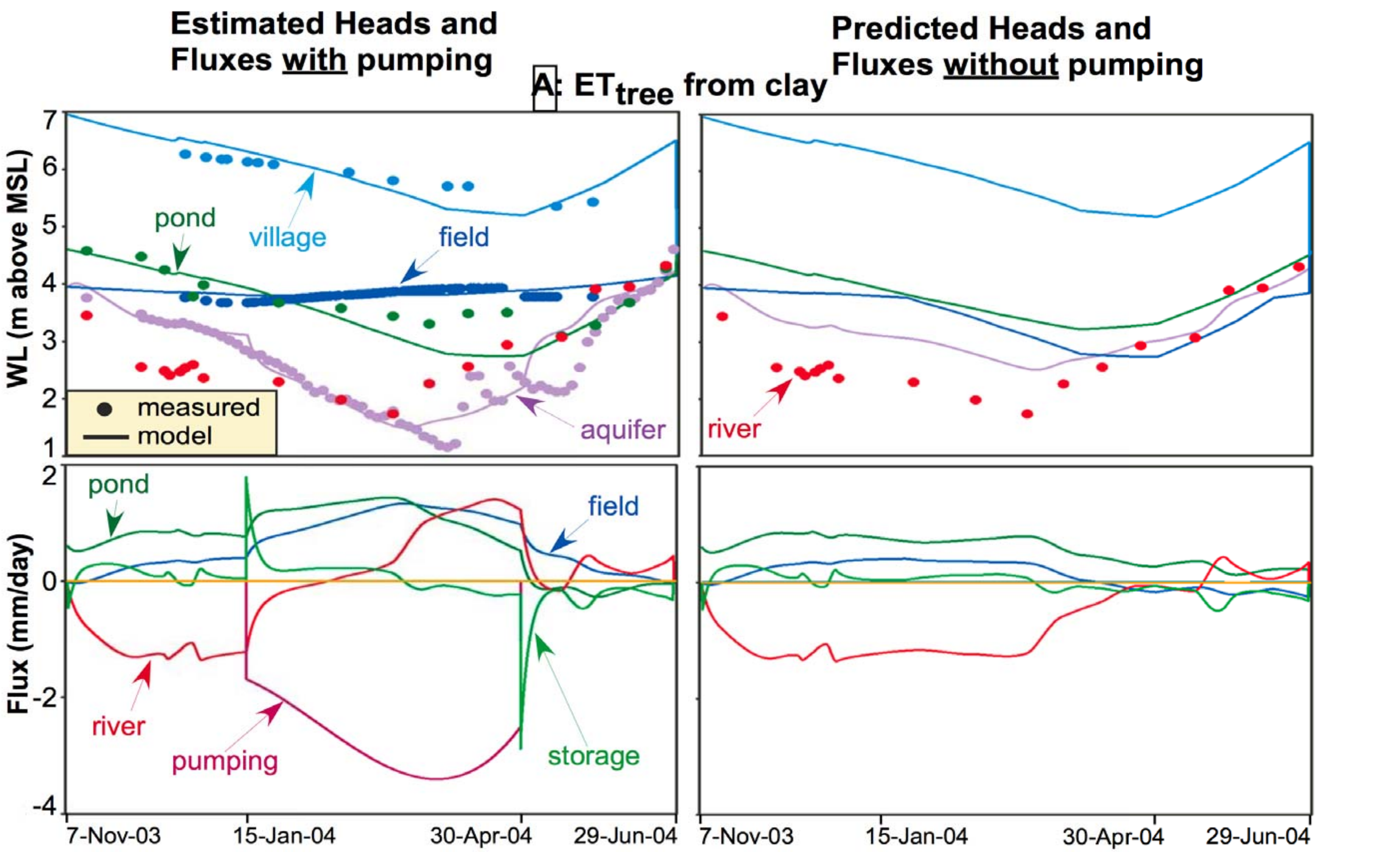
Because **you're assigning a value for FluxI for every value of t**, FluxI and t should end up having the same lengths.

You didn't need to do this when assigning ***qi*** values for ***dydt*** in the *function M-file*, because *ode45* did the stepping through time and checked each value of *t* before calculating the corresponding value of *dydt*.

# Tips

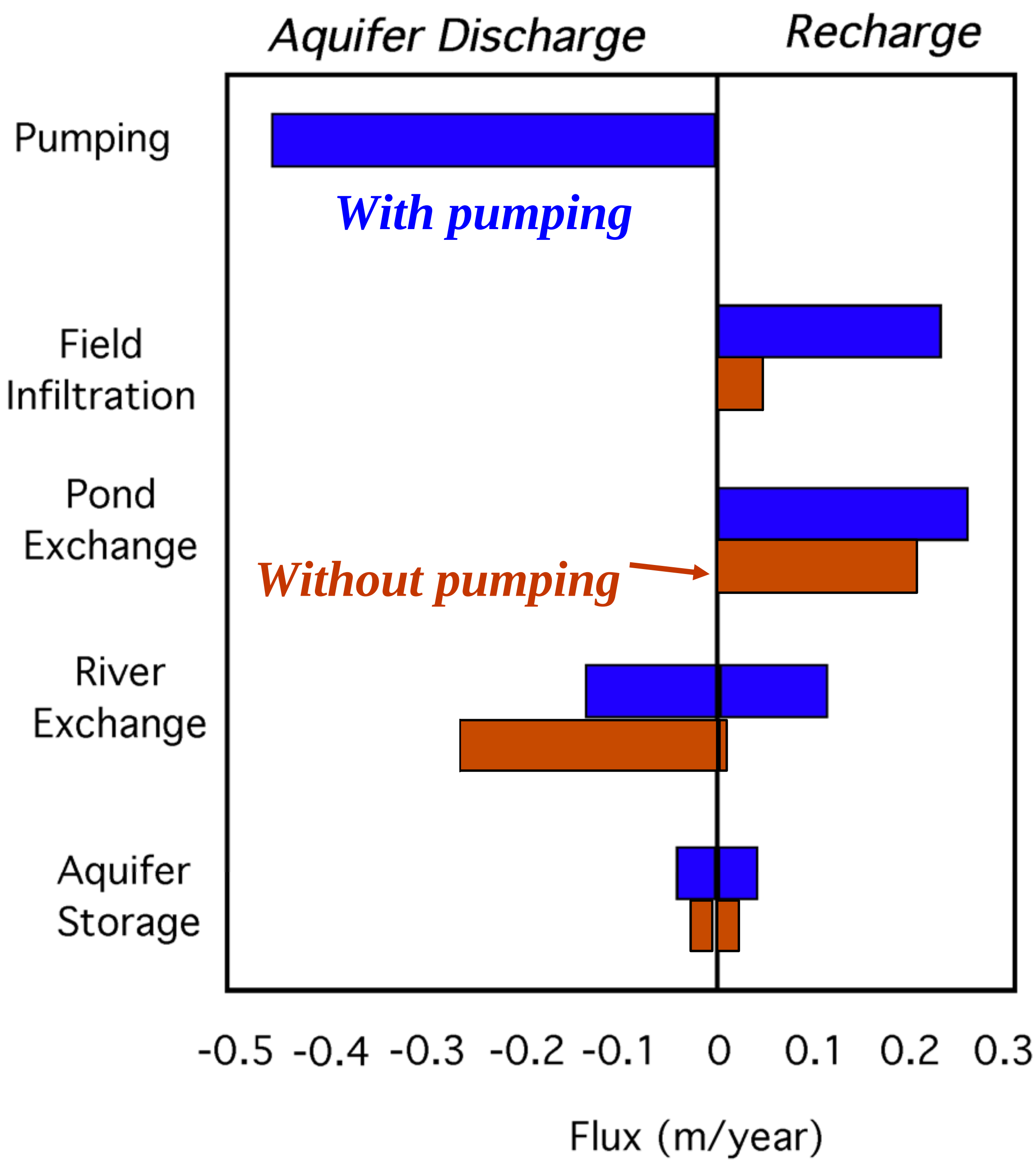
- Save your commands to an M-file
- To plot on top of a figure: **hold on**
- **hold off**
- To start a new figure: **figure**
- To plot in red: **plot(t,V,’r’)**
- To define a vector that starts at 1, ends at 500, with an increment of 5

  **V=[1:5:500];**
- **size(V)** ill give you vector with 2 components: #rows and #columns
- **help size**



Estimated Heads and Fluxes with pumping
A: ETtree from clay
Predicted Heads and Fluxes without pumping
WL (m above MSL)
pond
village
field
aquifer
measured
model
river
Flux (mm/day)
pond
field
river
pumping
storage
7-Nov-03
15-Jan-04
30-Apr-04
29-Jun-04
7-Nov-03
15-Jan-04
30-Apr-04
29-Jun-04

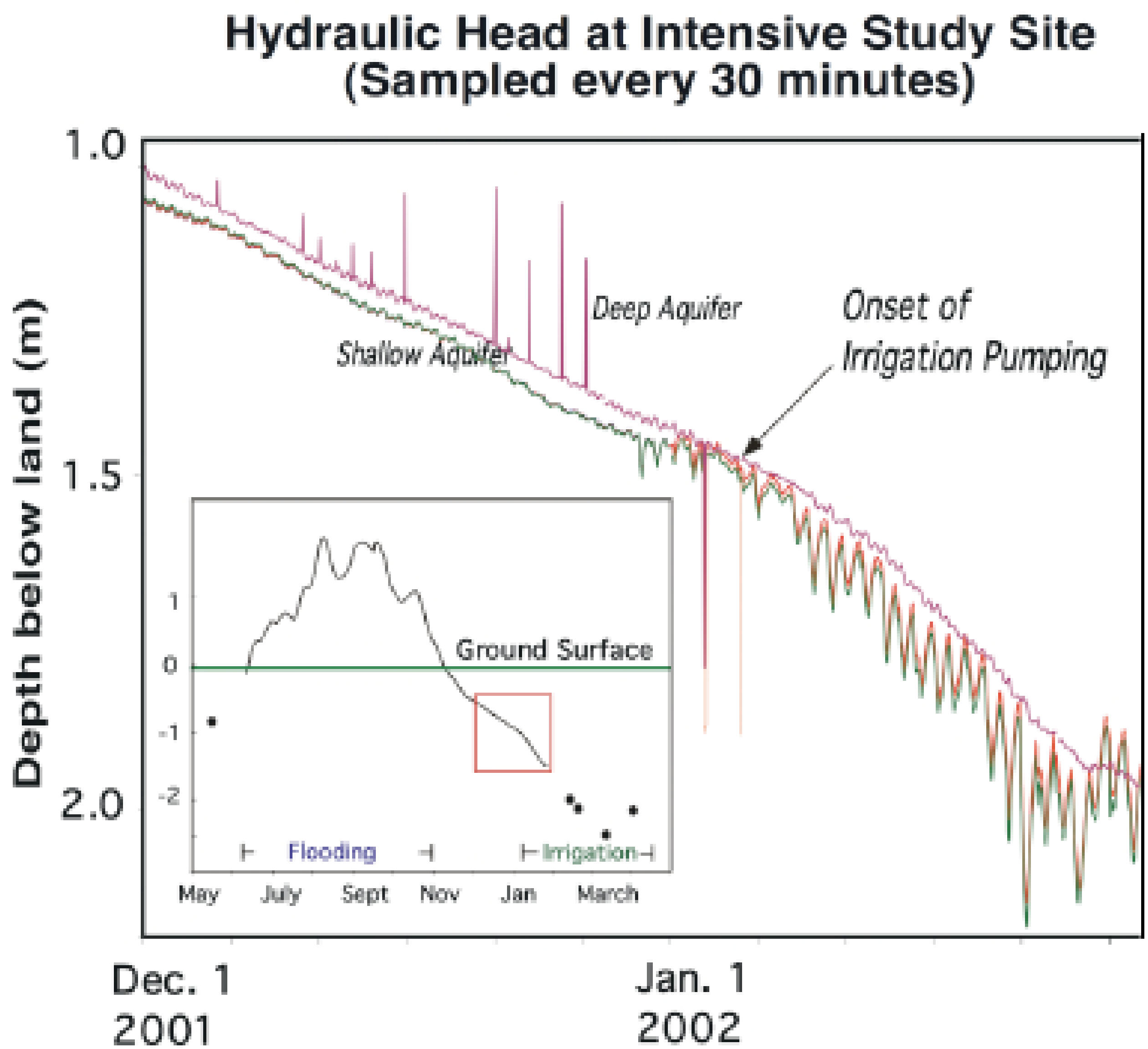
# Annual Aquifer Water Budget

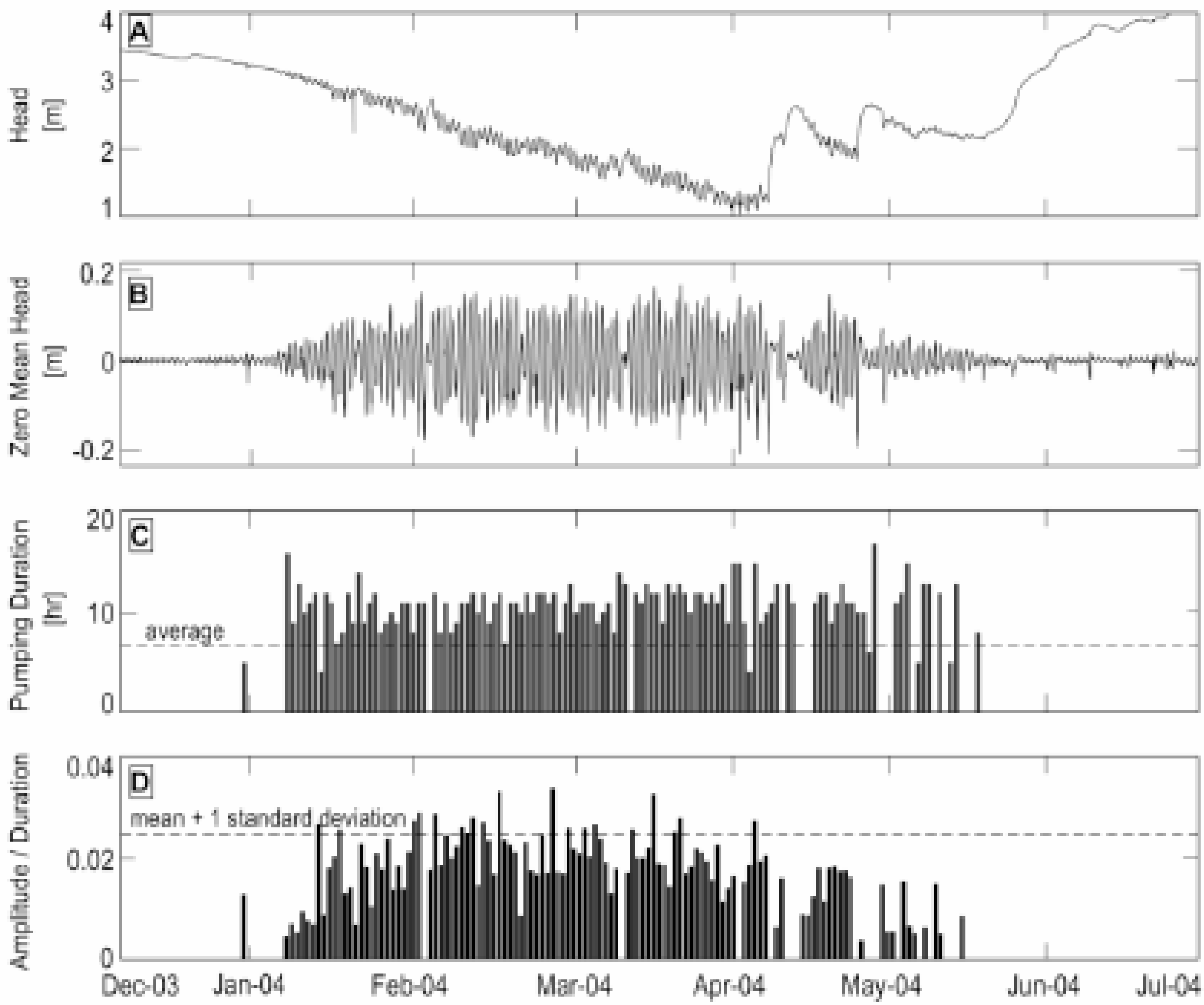



**Residence Times:**

**With pumping - ~40 years**
**No pumping - ~80 years**

**If no ponds, much longer**


Hydraulic Head at Intensive Study Site
(Sampled every 30 minutes)
Depth below land (m)
1.0
1.5
2.0
Deep Aquifer
Shallow Aquifer
Onset of
Irrigation Pumping
Ground Surface
1
0
-1
-2
Flooding
Irrigation
May
July
Sept
Nov
Jan
March
Dec. 1
2001
Jan. 1
2002



A
Head [m]
4
3
2
1
B
Zero Mean Head [m]
0.2
0
-0.2
C
Pumping Duration [hr]
20
10
0
average
D
Amplitude / Duration
0.04
0.02
0
mean + 1 standard deviation
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04

# Additional Discussion Questions

- How are the recharge and discharge flows to and from the aquifer different between the two cases (with and without pumping)?

- How do you think the change in the hydrology of the aquifer produced by pumping for irrigation affects groundwater chemistry?