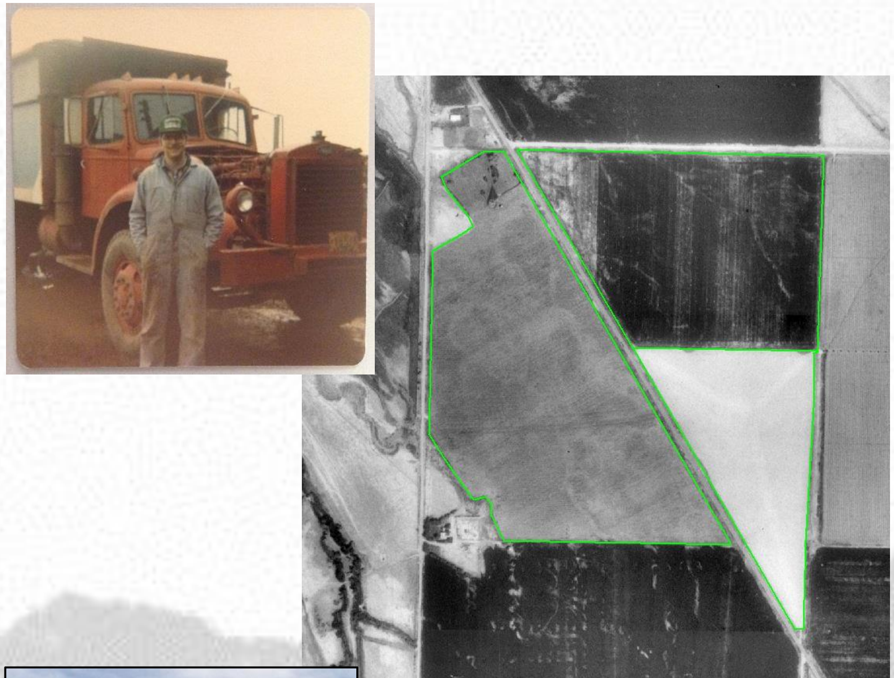
Economic Rivalry, Irrigation Abstraction, And Partition to Fates

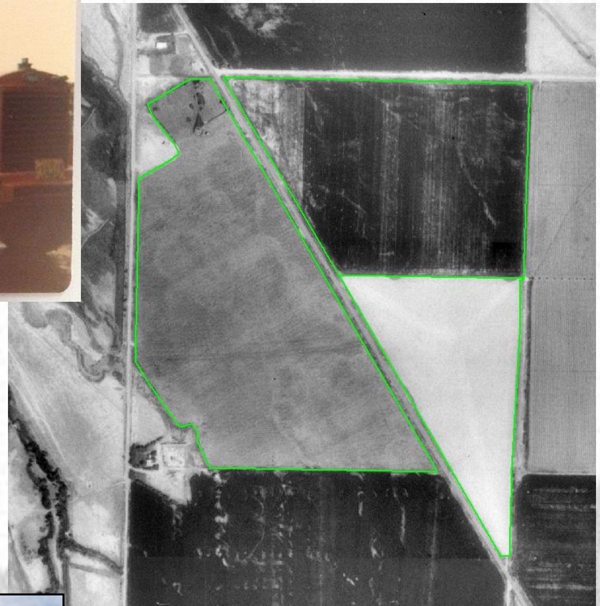
11th Annual Meeting of the International Water Resource Economics Consortium (IWREC)
September 2014

B. Contor and Dr. R. G. Taylor



- 1992
  - 58 hectares
  - Groundwater source
  - Hand lines & wheel lines
  - 70% consumptive-use fraction of field-applied water

- 2014
  - 56 hectares
  - Groundwater source
  - Mostly pivots
  - Mostly 85% consumptive-use fraction of field-applied water



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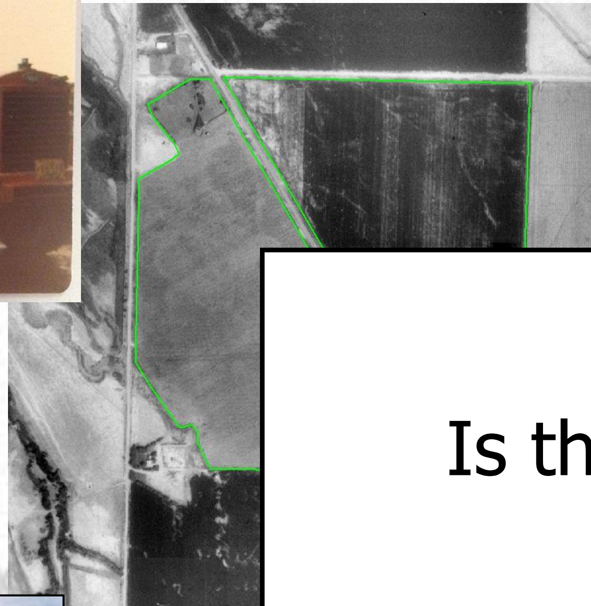


- 1992
  - 58 hectares
  - Groundwater source
  - Hand lines & wheel lines

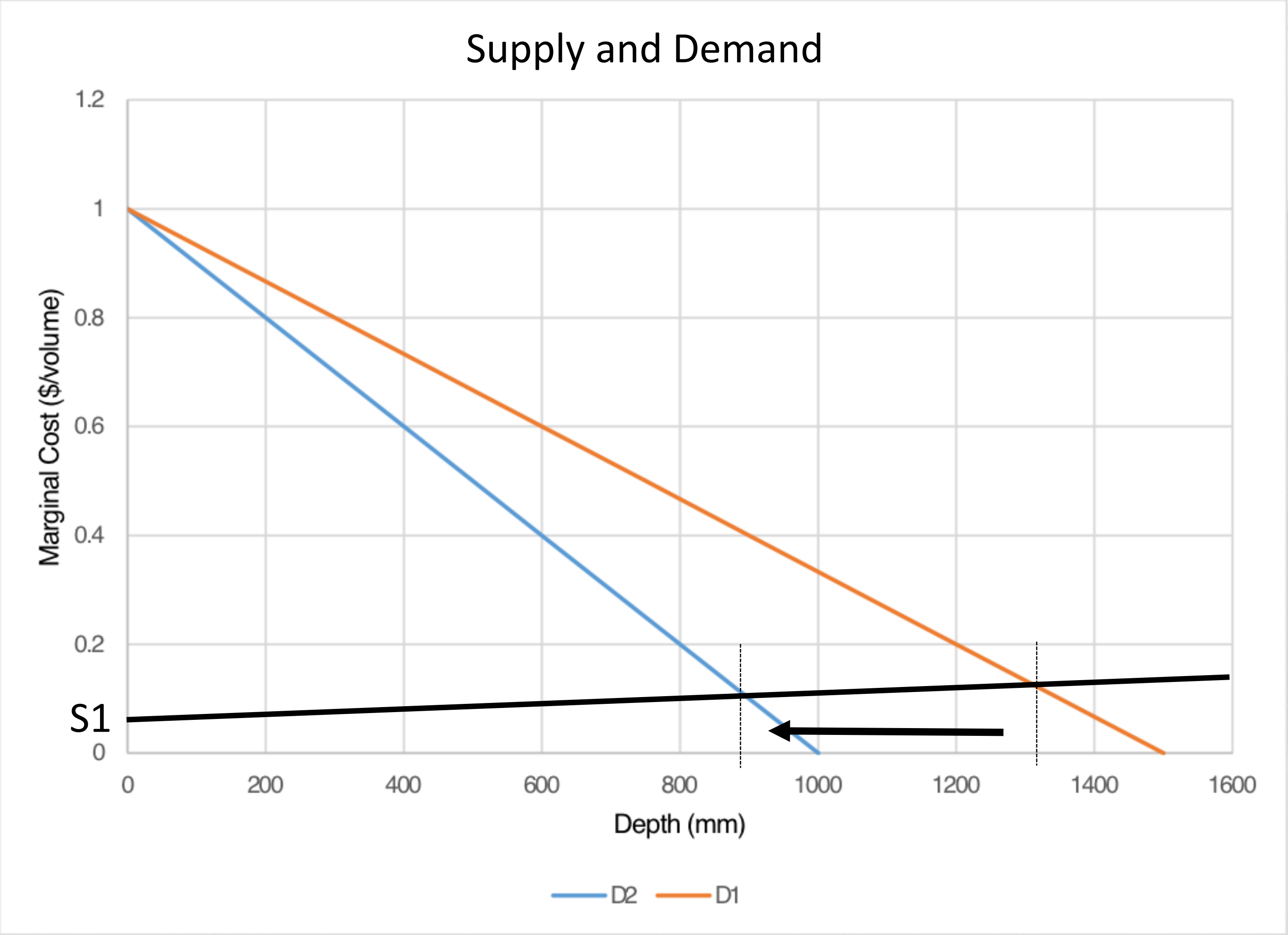
Is this Improvement?

- 2014
  - 56 hectares
  - Groundwater source
  - Mostly pivots
  - Mostly 85% consumptive-use fraction of field-applied water

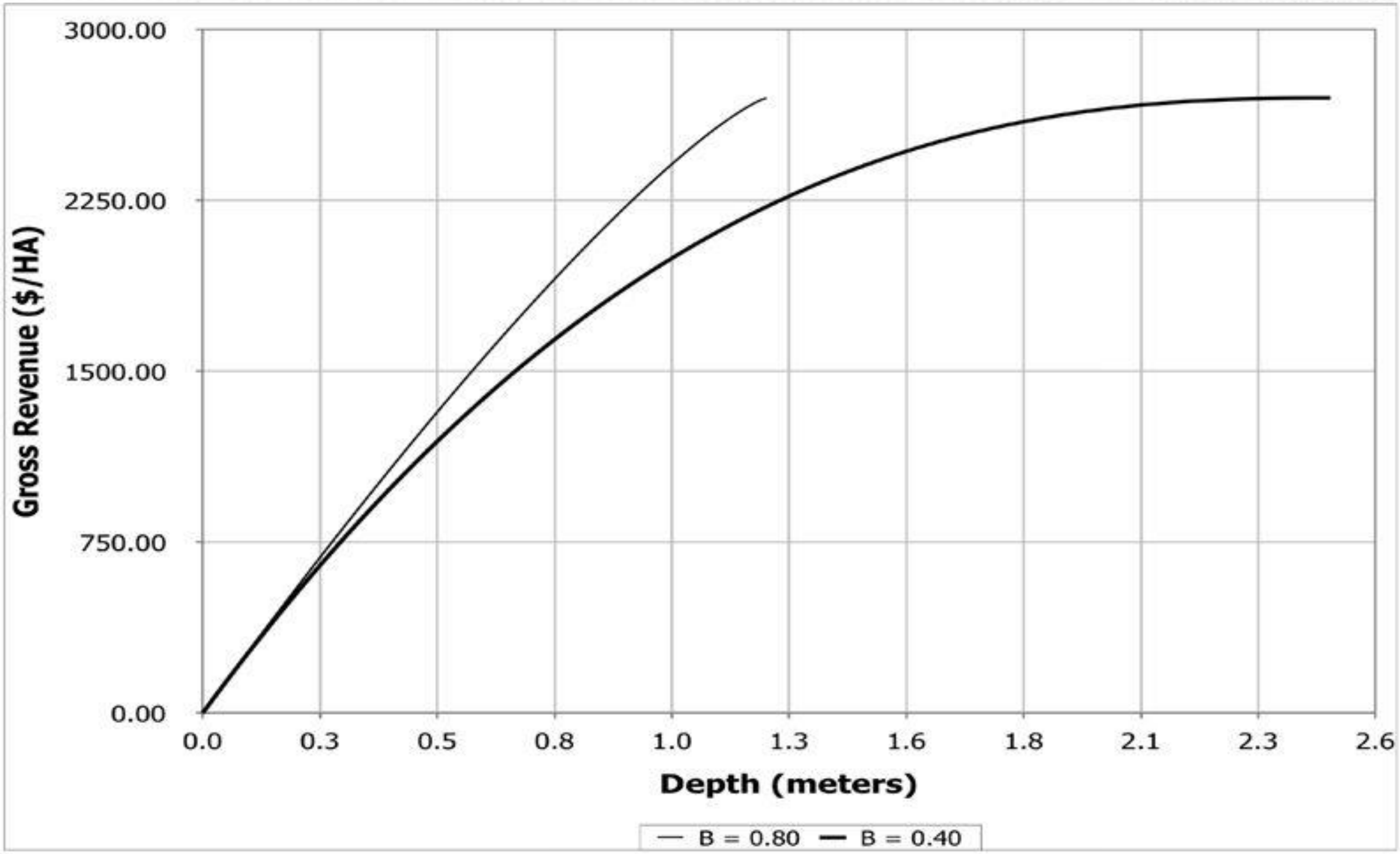
How do we assess irrigation improvements?

- Consider Irrigator Response
- Close the Water Budget
- Consider Economic Rivalry
- Do the Numbers

Consider Irrigator Response



Supply and Demand
1.2
1
0.8
0.6
0.4
0.2
0
Marginal Cost ($/volume)
S1
0
200
400
600
800
1000
1200
1400
1600
Depth (mm)
D2
D1


3000.00
2250.00
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Gross Revenue ($/HA)
0.0
0.3
0.5
0.8
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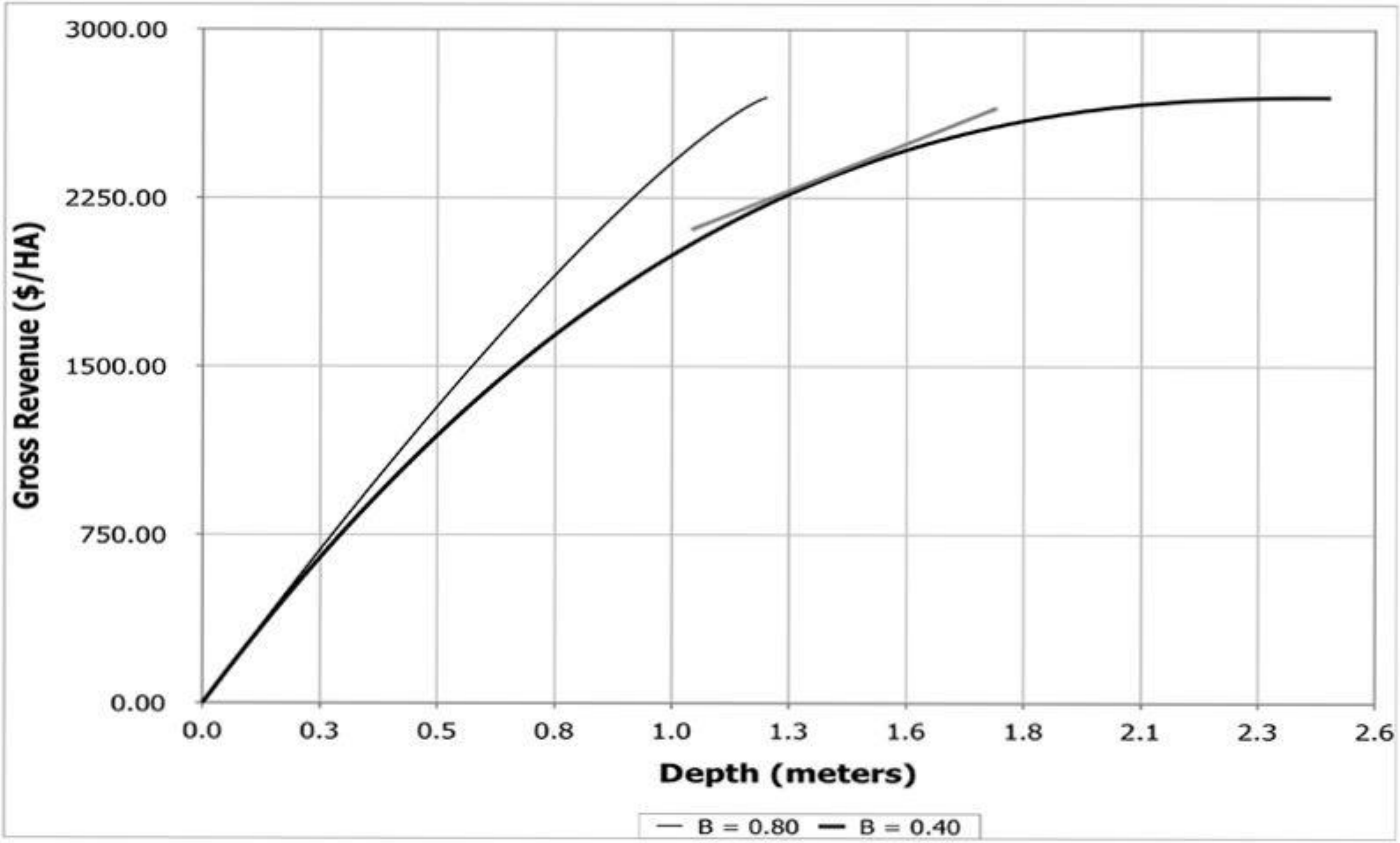
Depth (meters)
B = 0.80
B = 0.40



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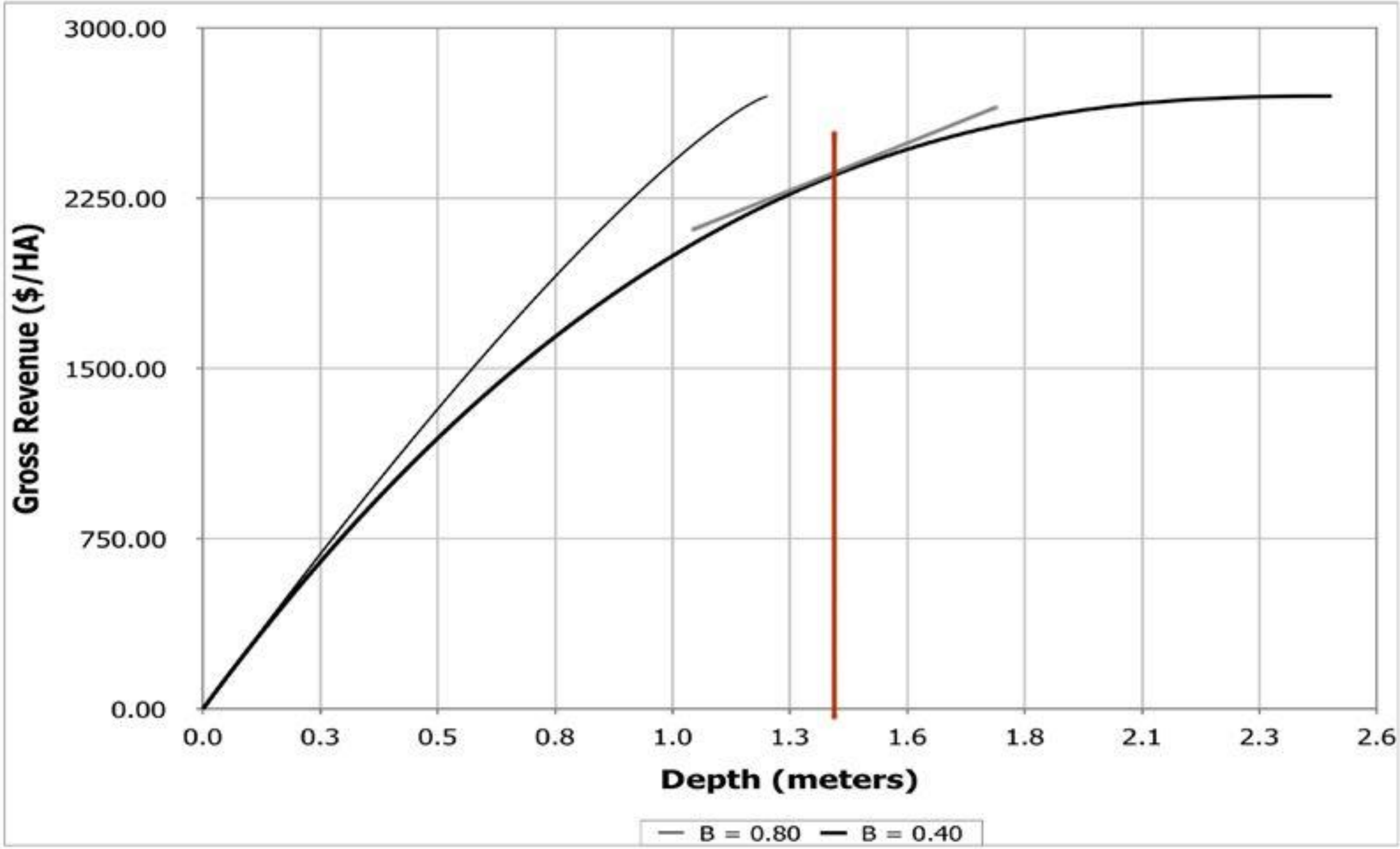
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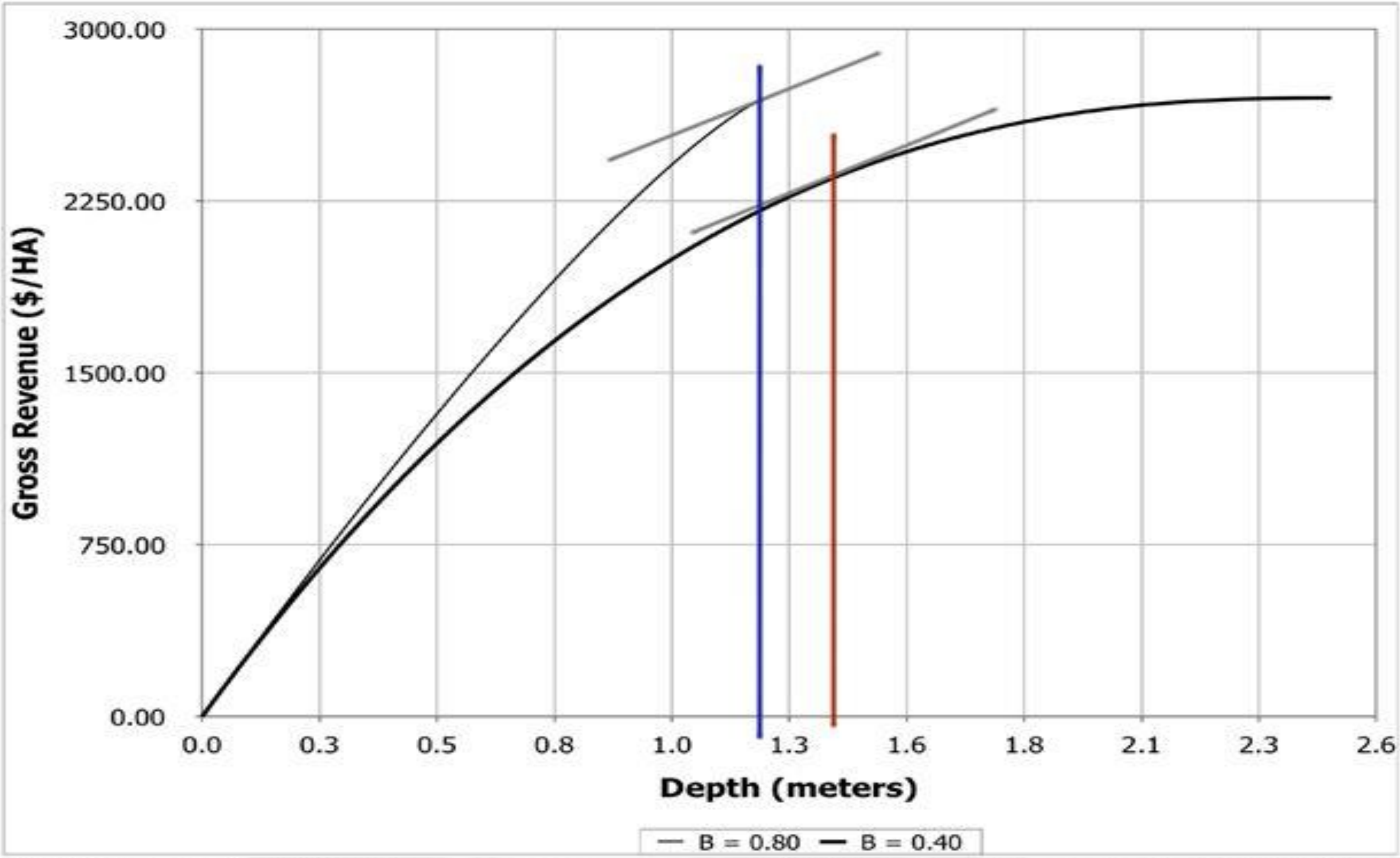
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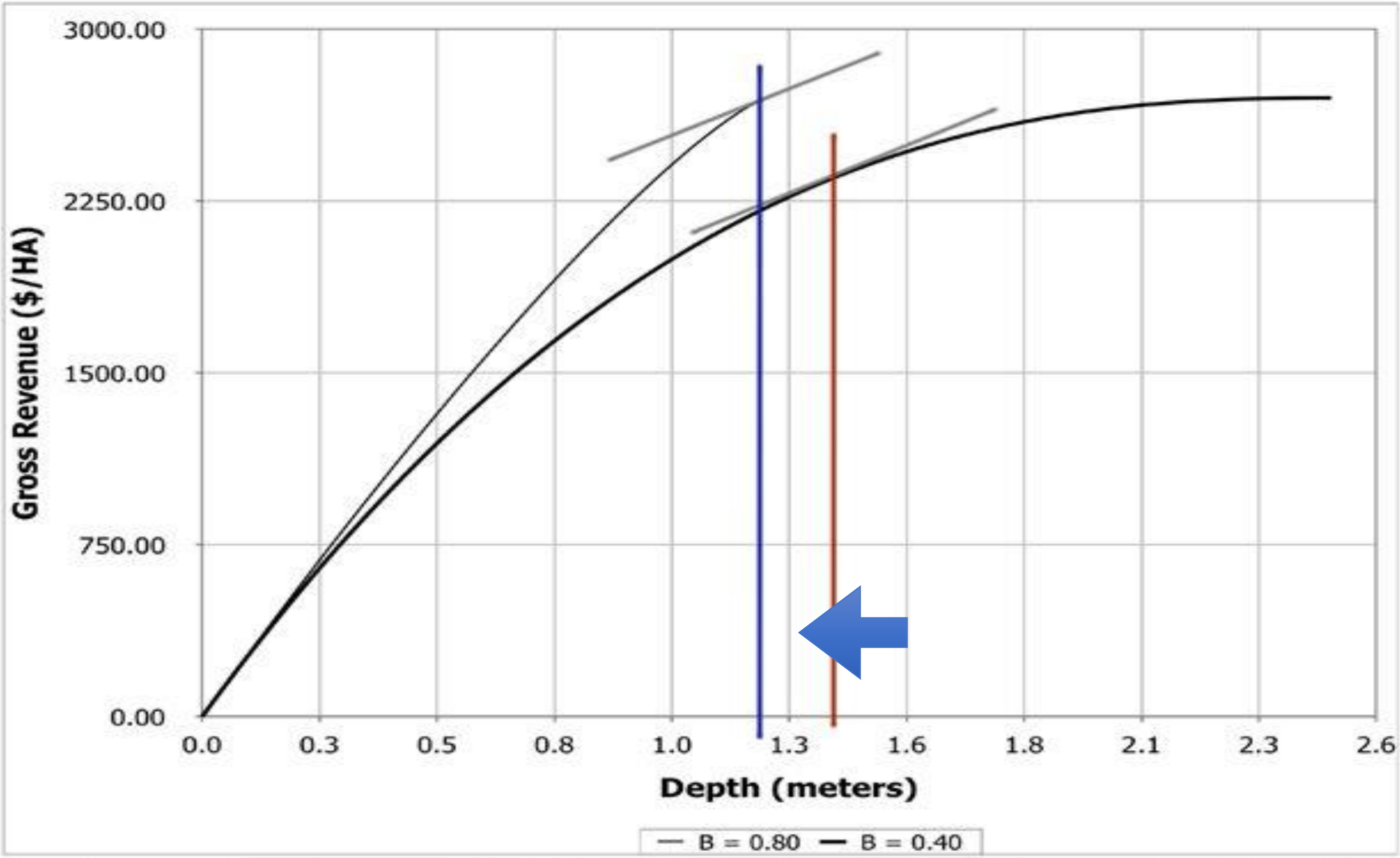
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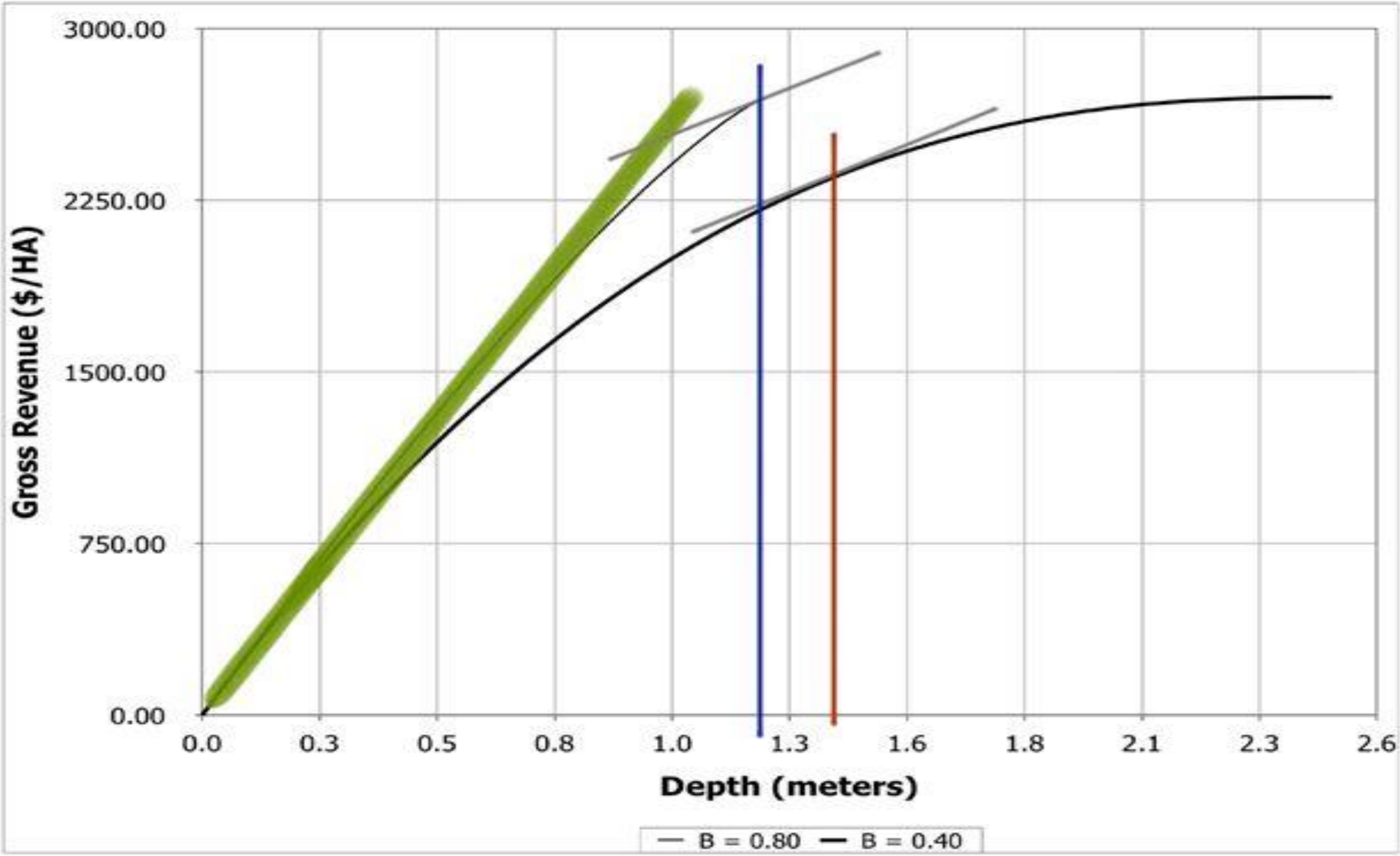
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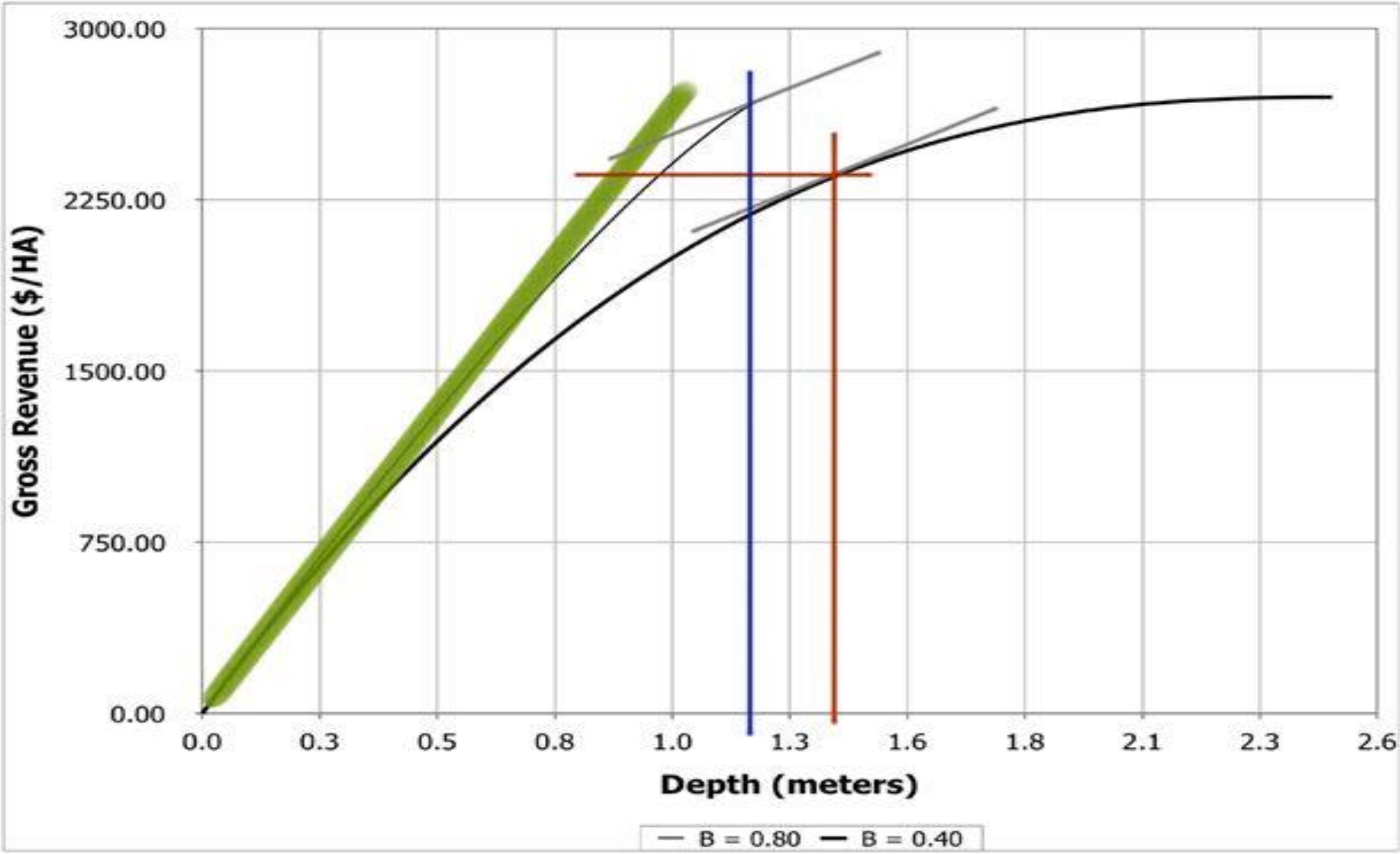

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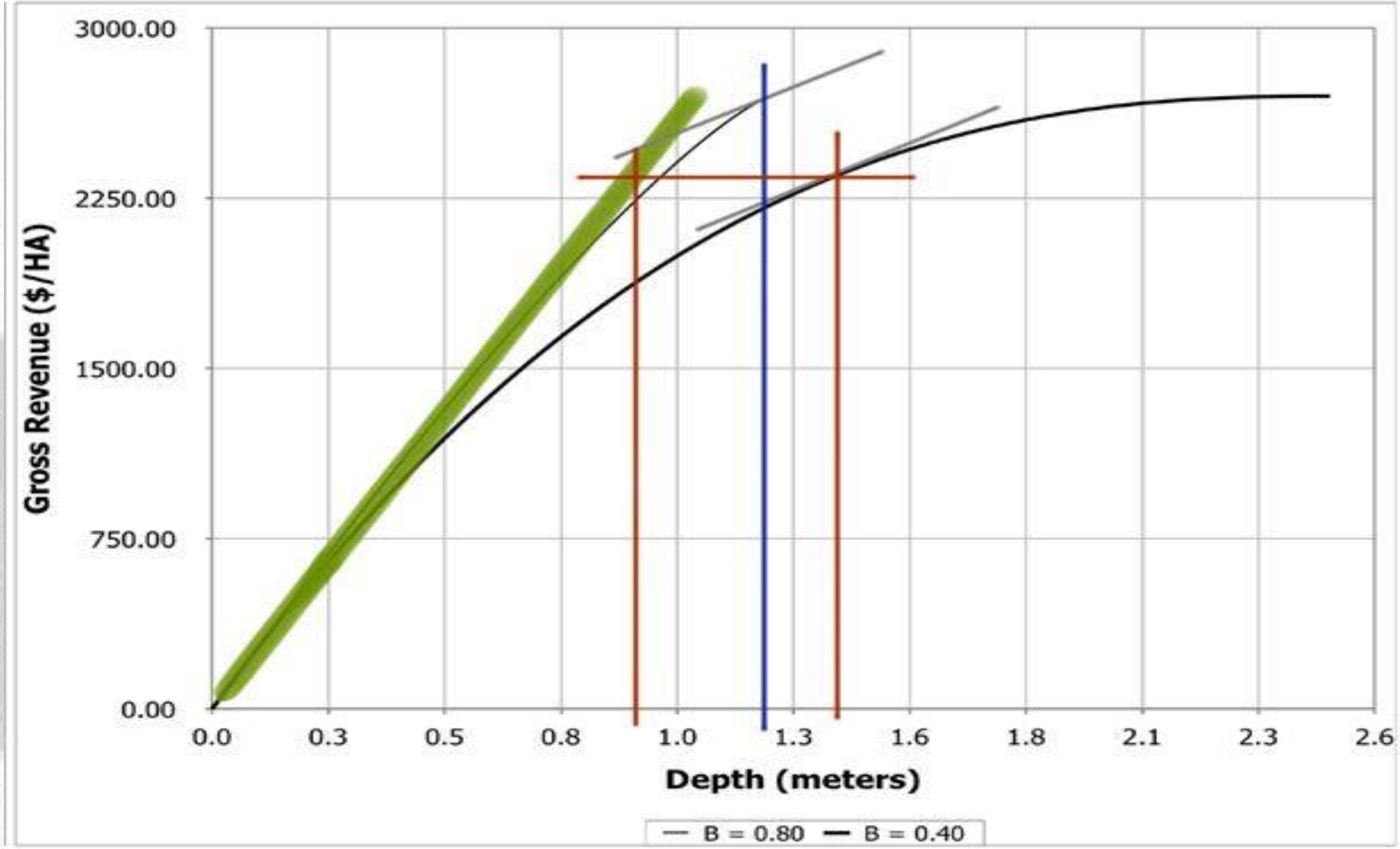
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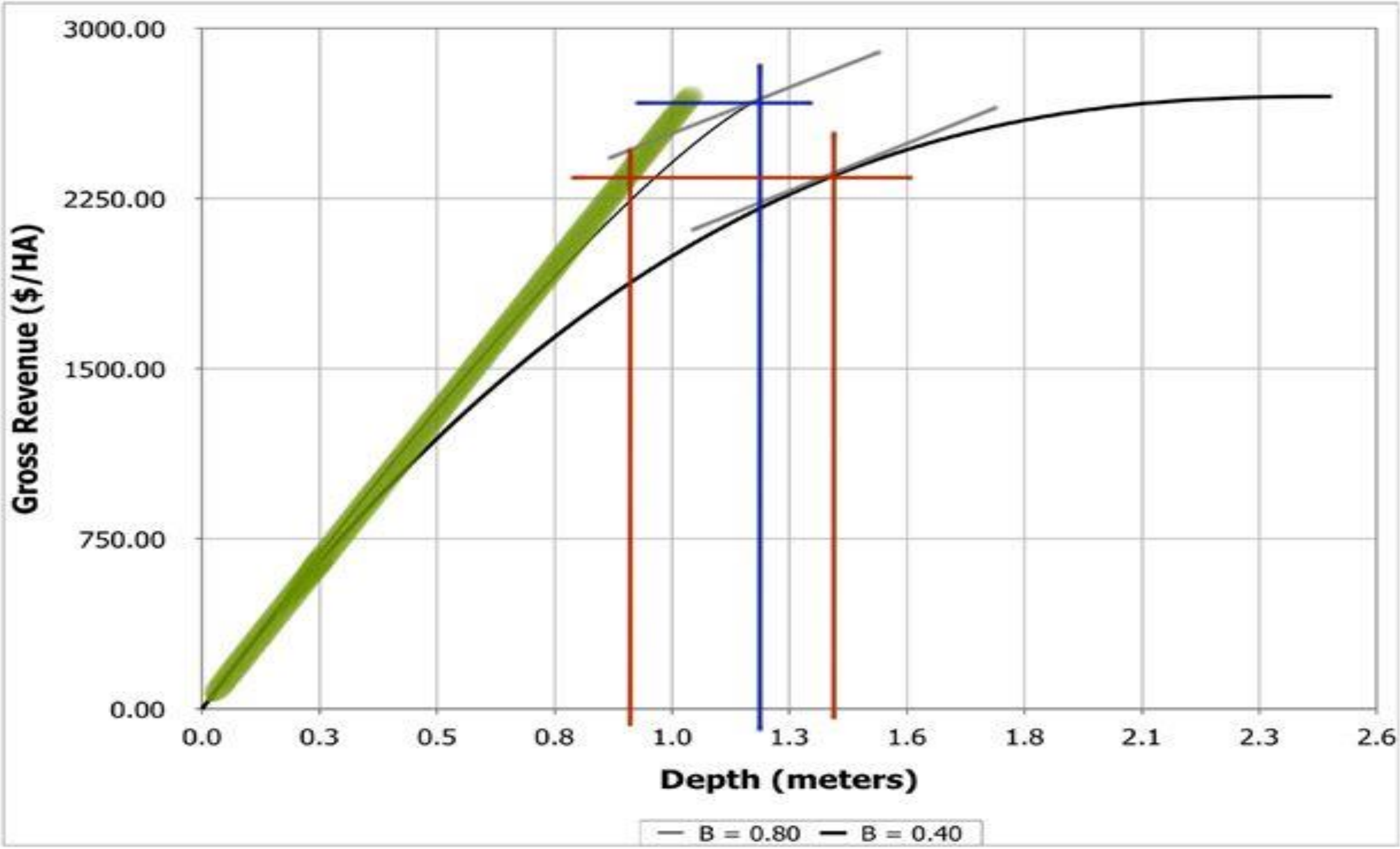
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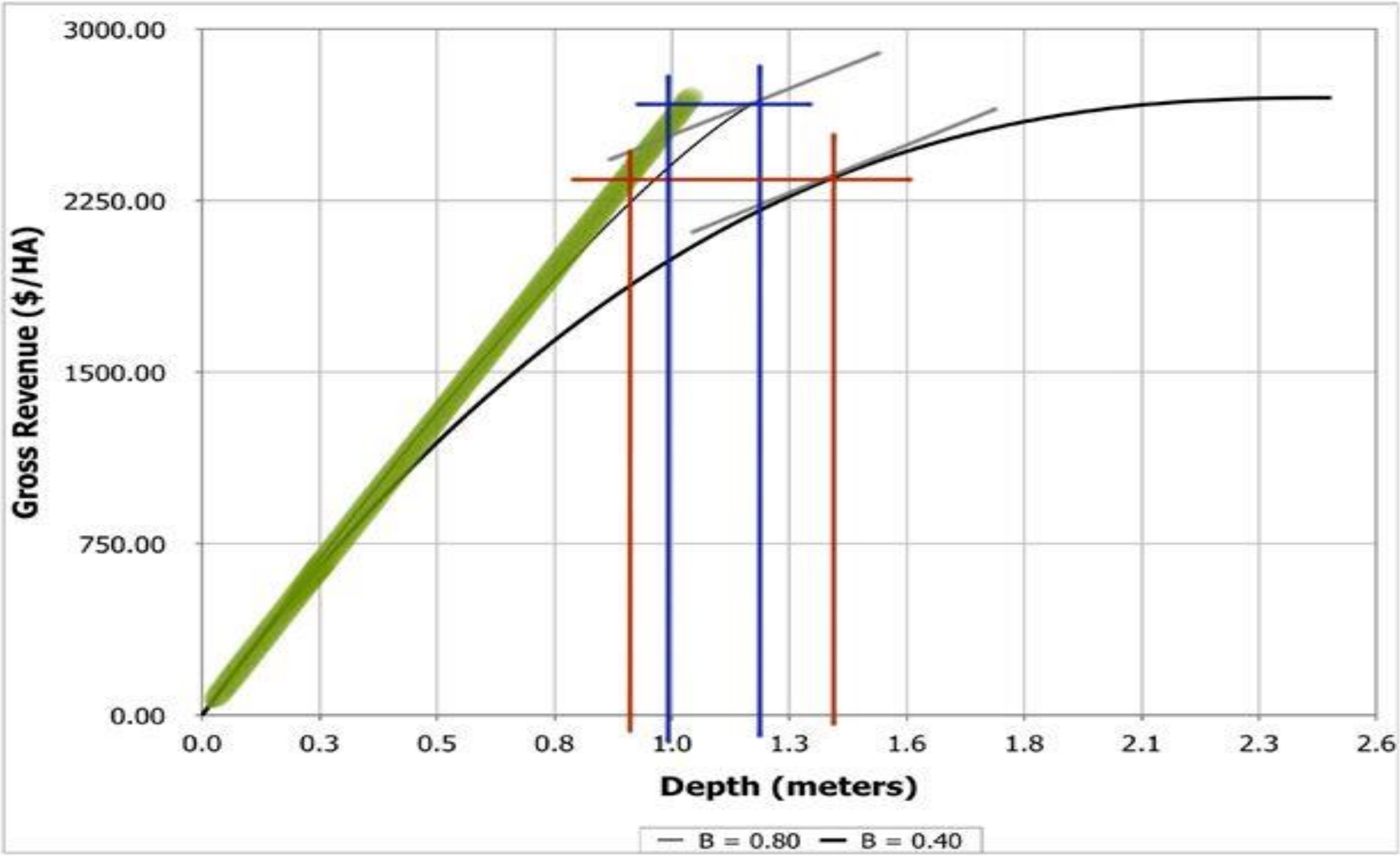
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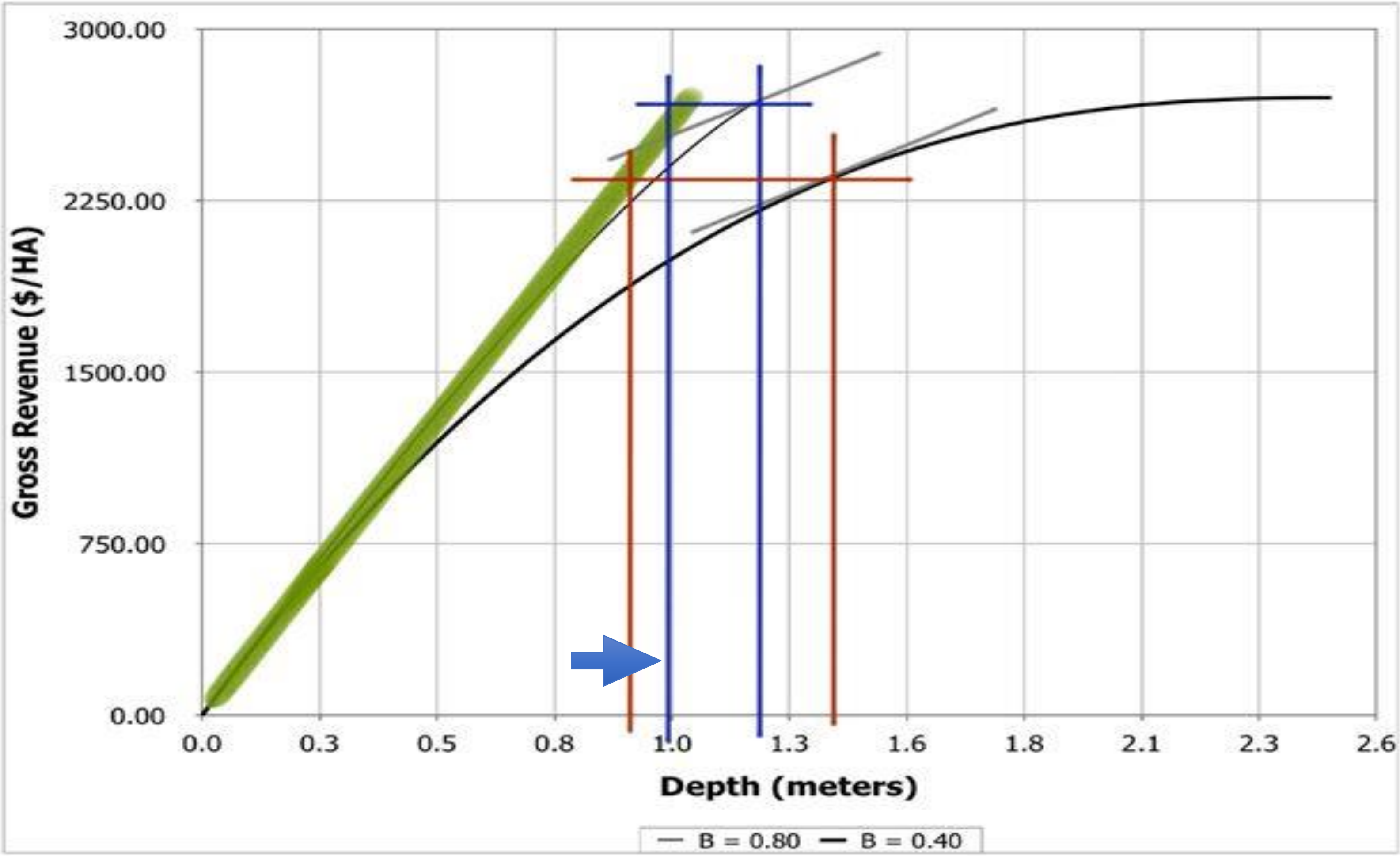

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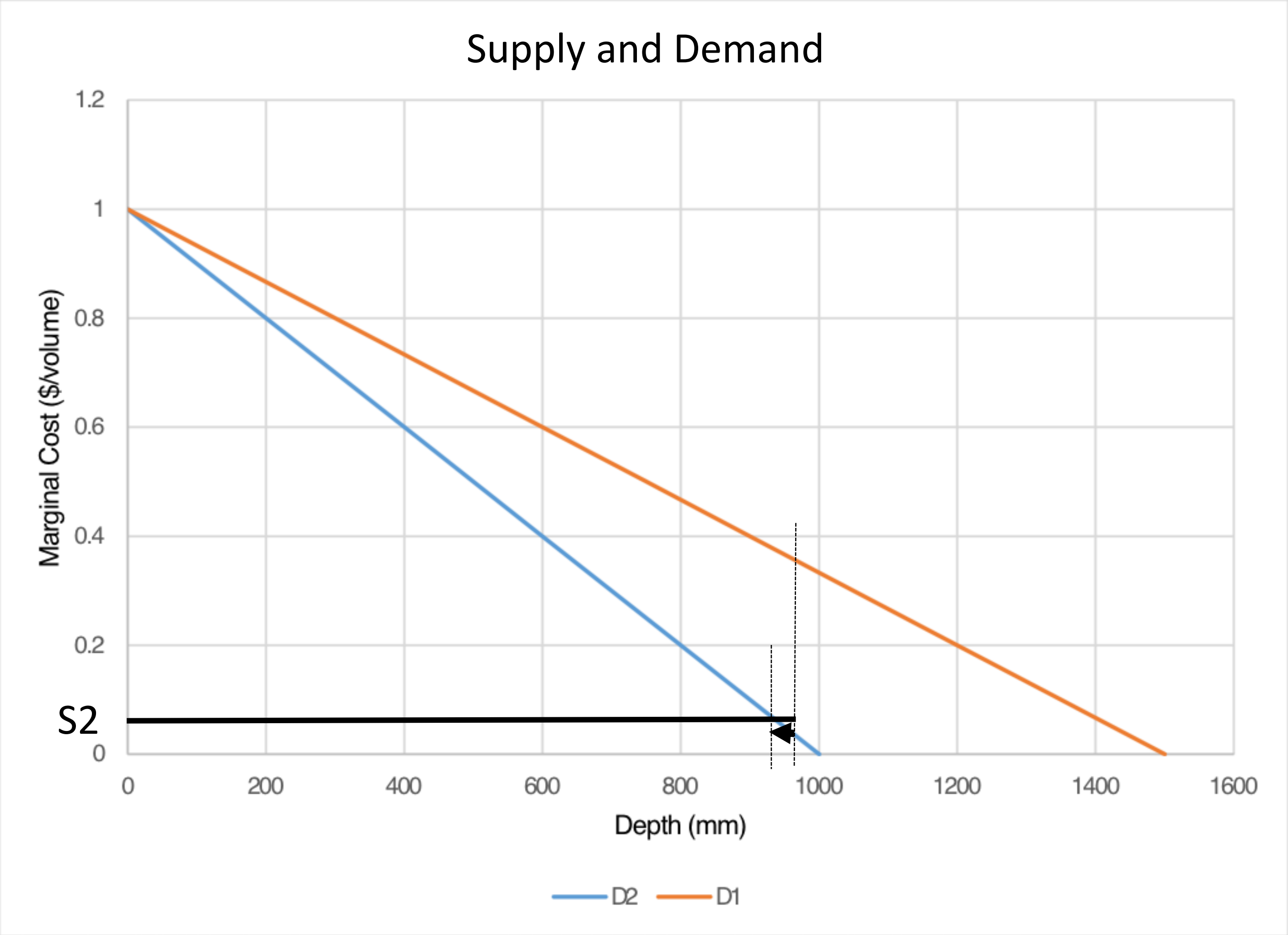
Consider Irrigator Response



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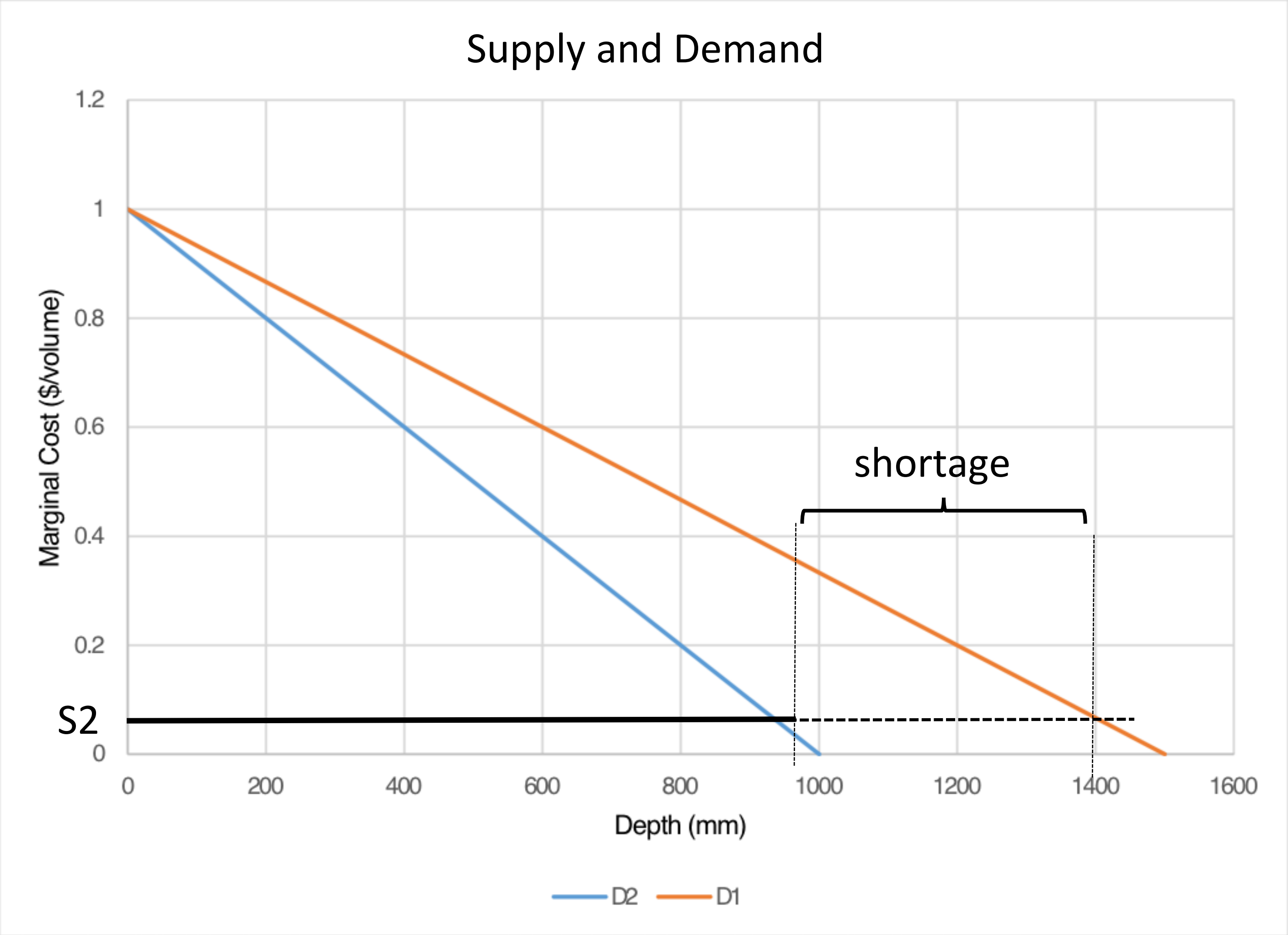
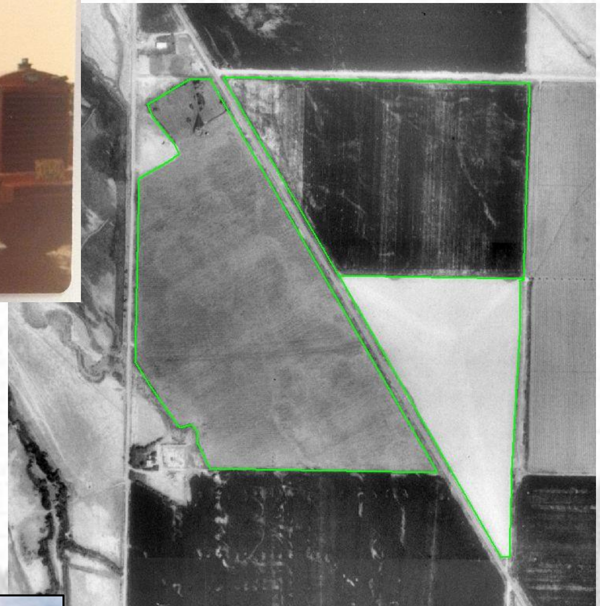
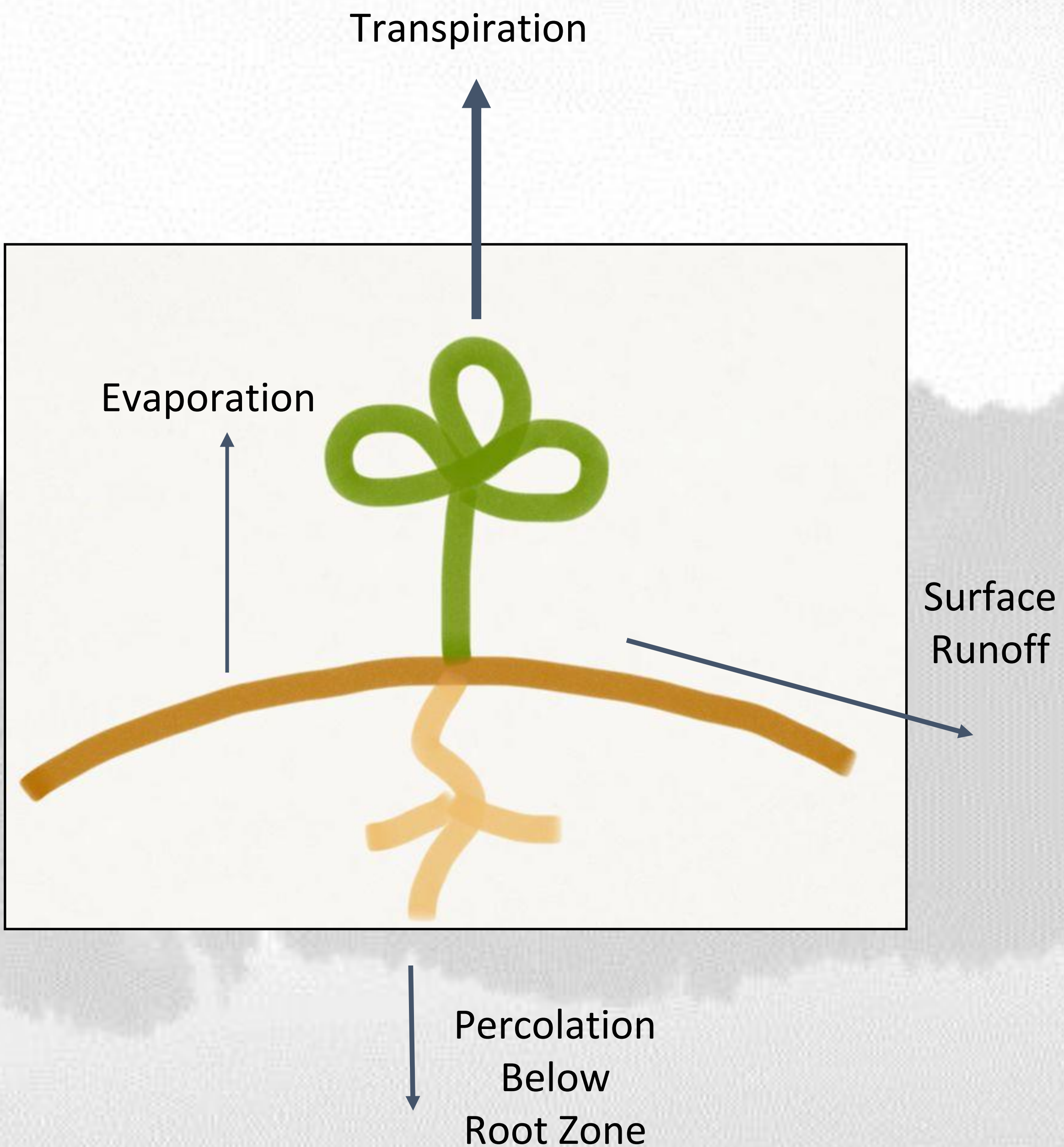


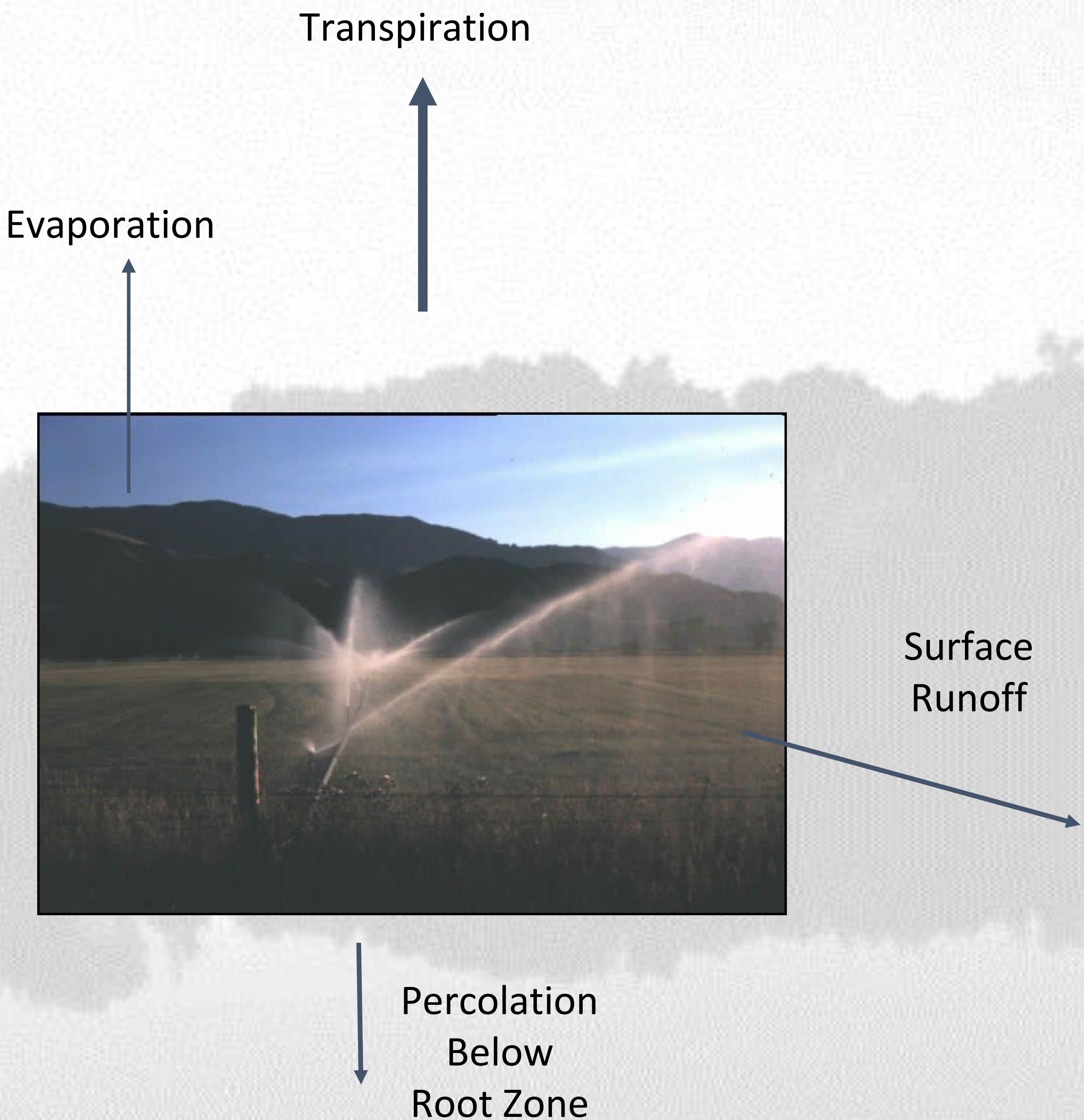


- 1992
  - 58 hectares
    - 47 hectares barley
    - 12 hectares alfalfa

- 2014
  - 56 hectares – all alfalfa

Close the Water Budget


Transpiration
Evaporation
Surface
Runoff
Percolation
Below
Root Zone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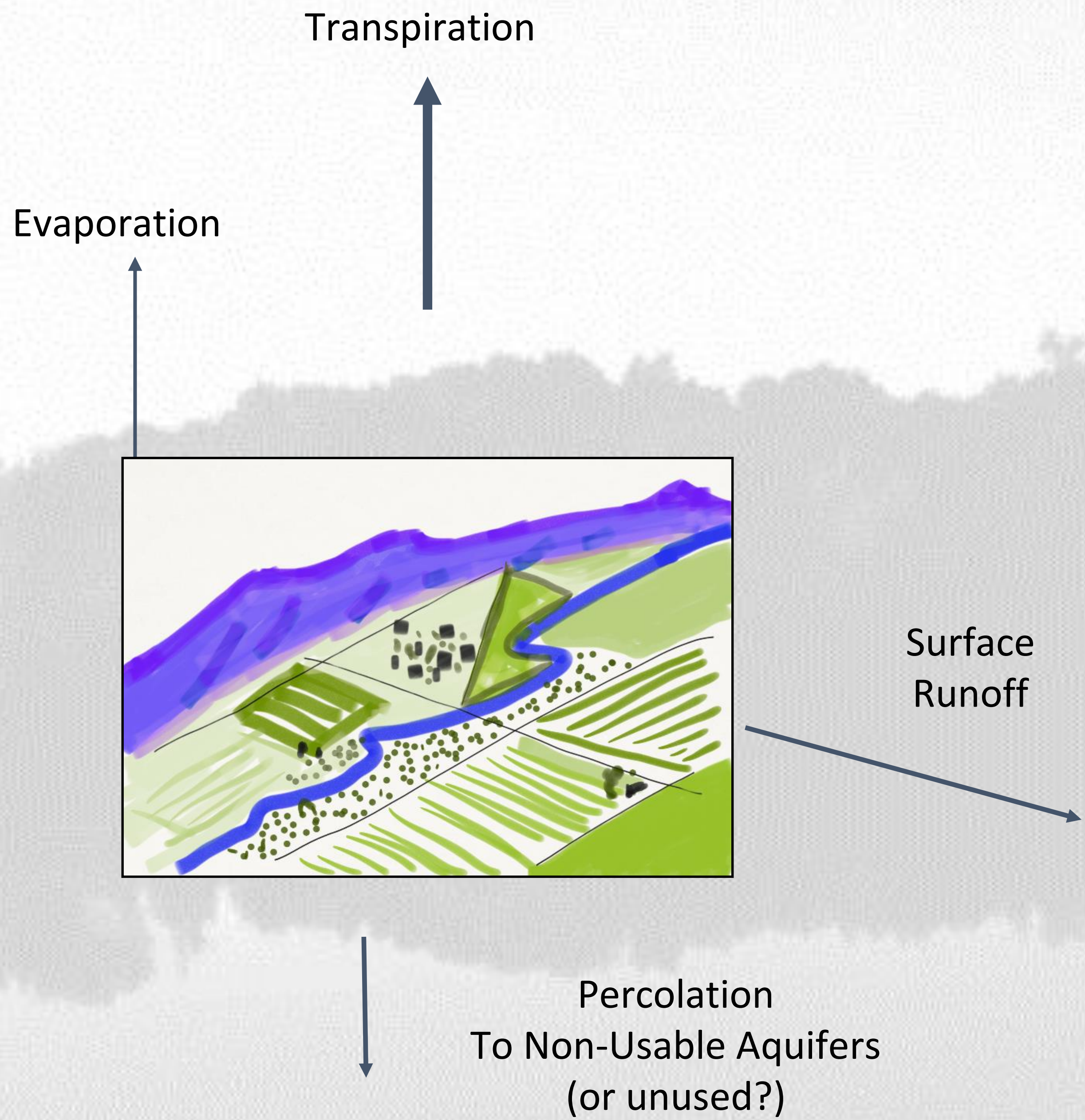
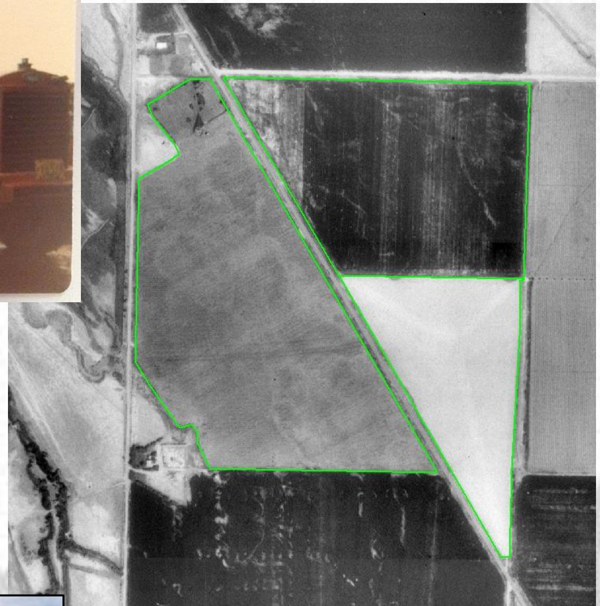

Transpiration
Evaporation
Surface
Runoff
Percolation
To Non-Usable Aquifers
(or unused?)

Take Home Messages:

- It is not complicated
- It MUST be sorted out

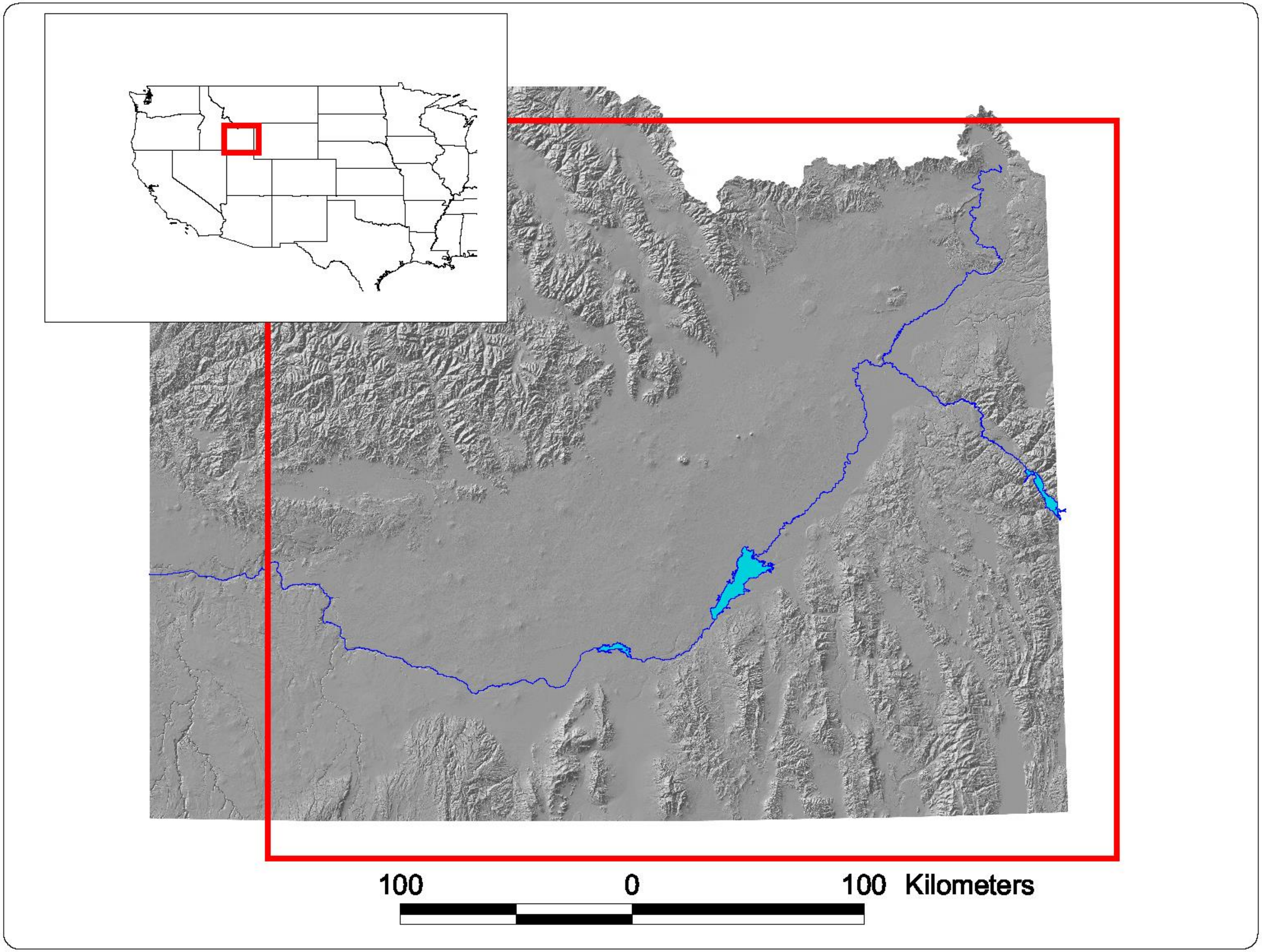
Surface Runoff

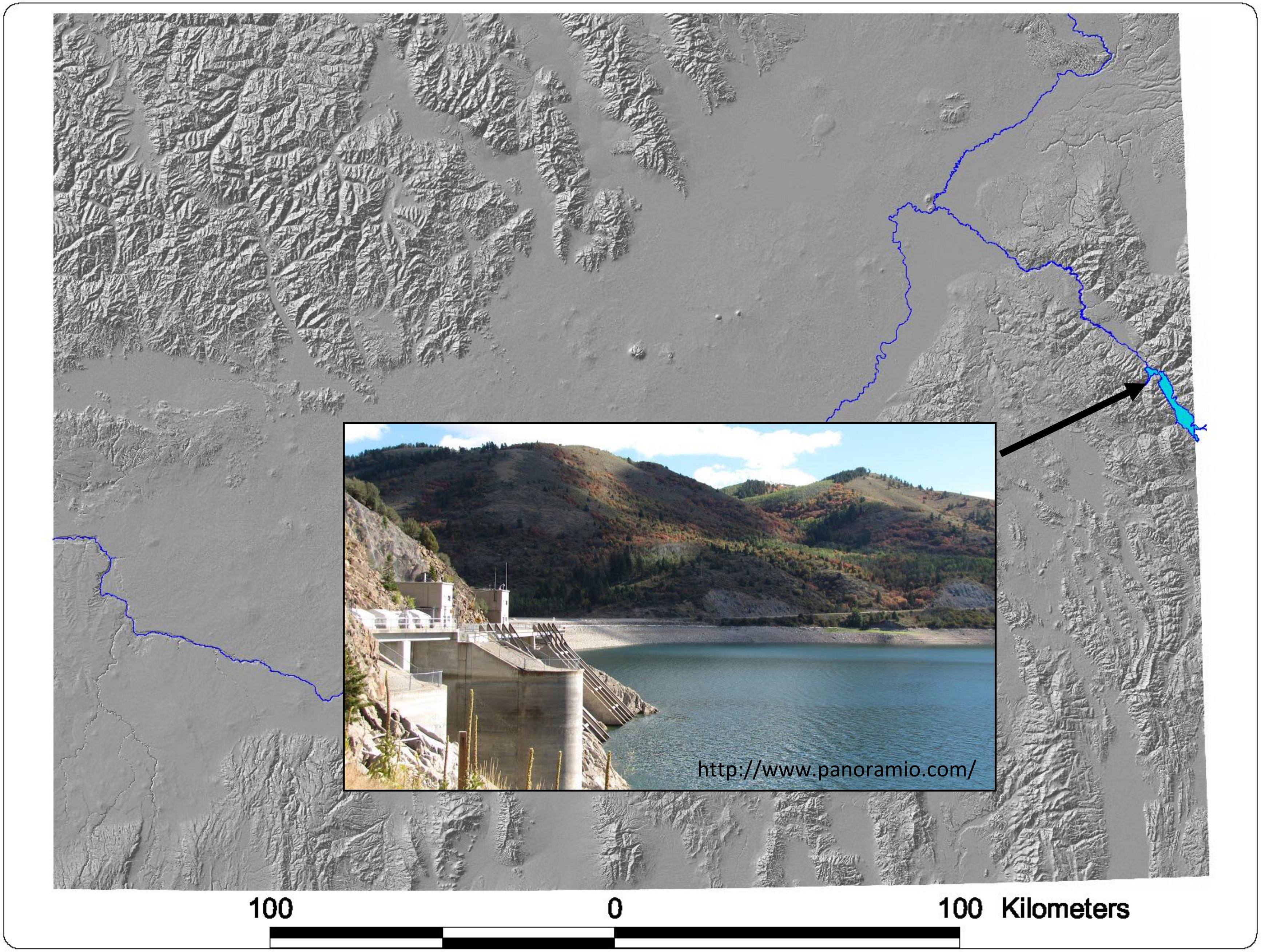
Percolation
To Non-Usable Aquifers
(or unused?)



- Abstraction (i.e. diversion)
  - *Decreased after improvement (case specific)*
- Transpiration
  - *Increased after improvement (typical)*
  - *Lost to basin*
- Evaporation
  - *Increase or decrease?*
  - *Lost to basin*
- Runoff
  - *Typically would decrease*
  - *None in this case*
- Percolation
  - *Typically would decrease*
  - *Returns to pumped aquifer*

Consider Rivalry


100
0
100 Kilometers


http://www.panoramio.com/
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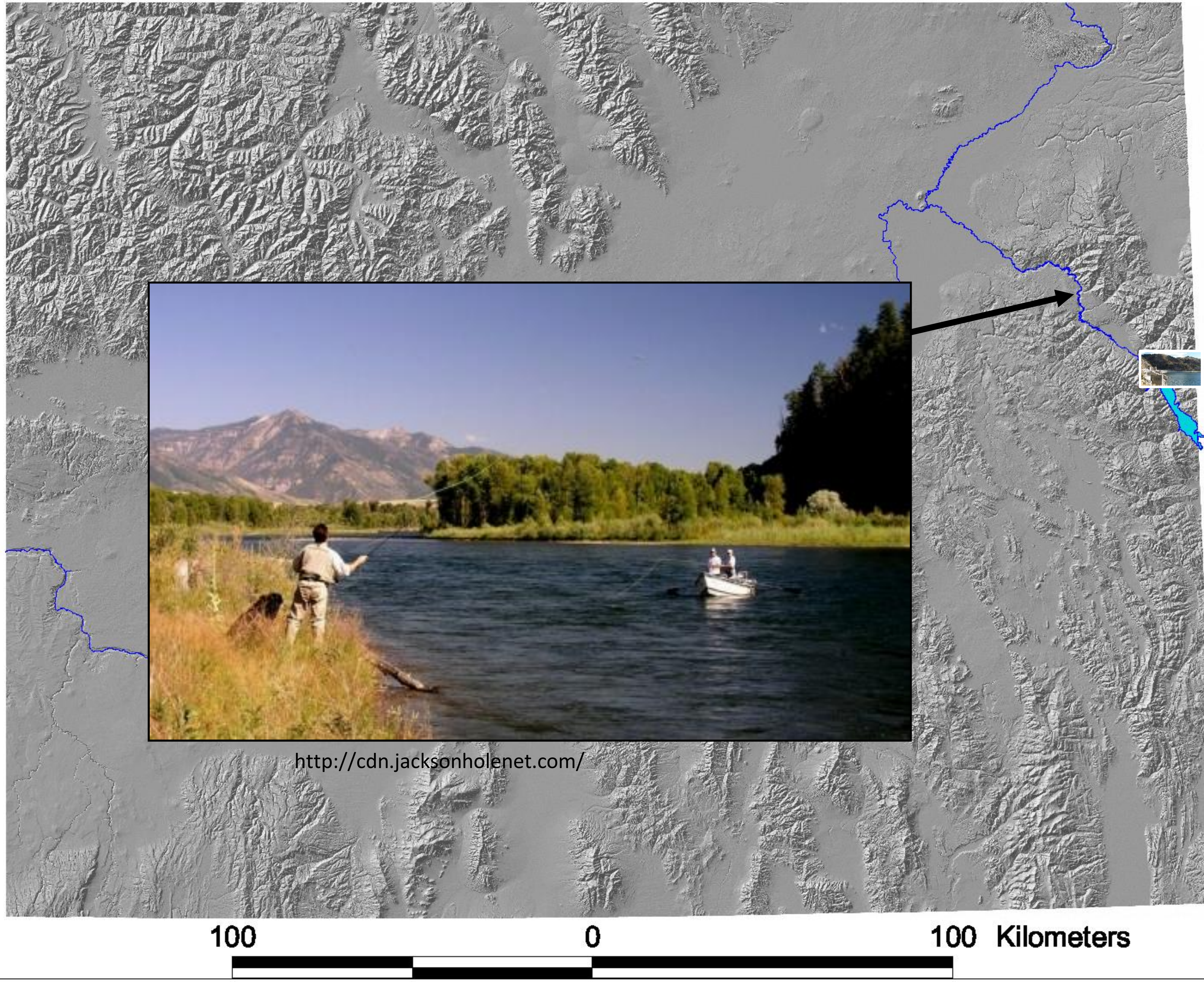
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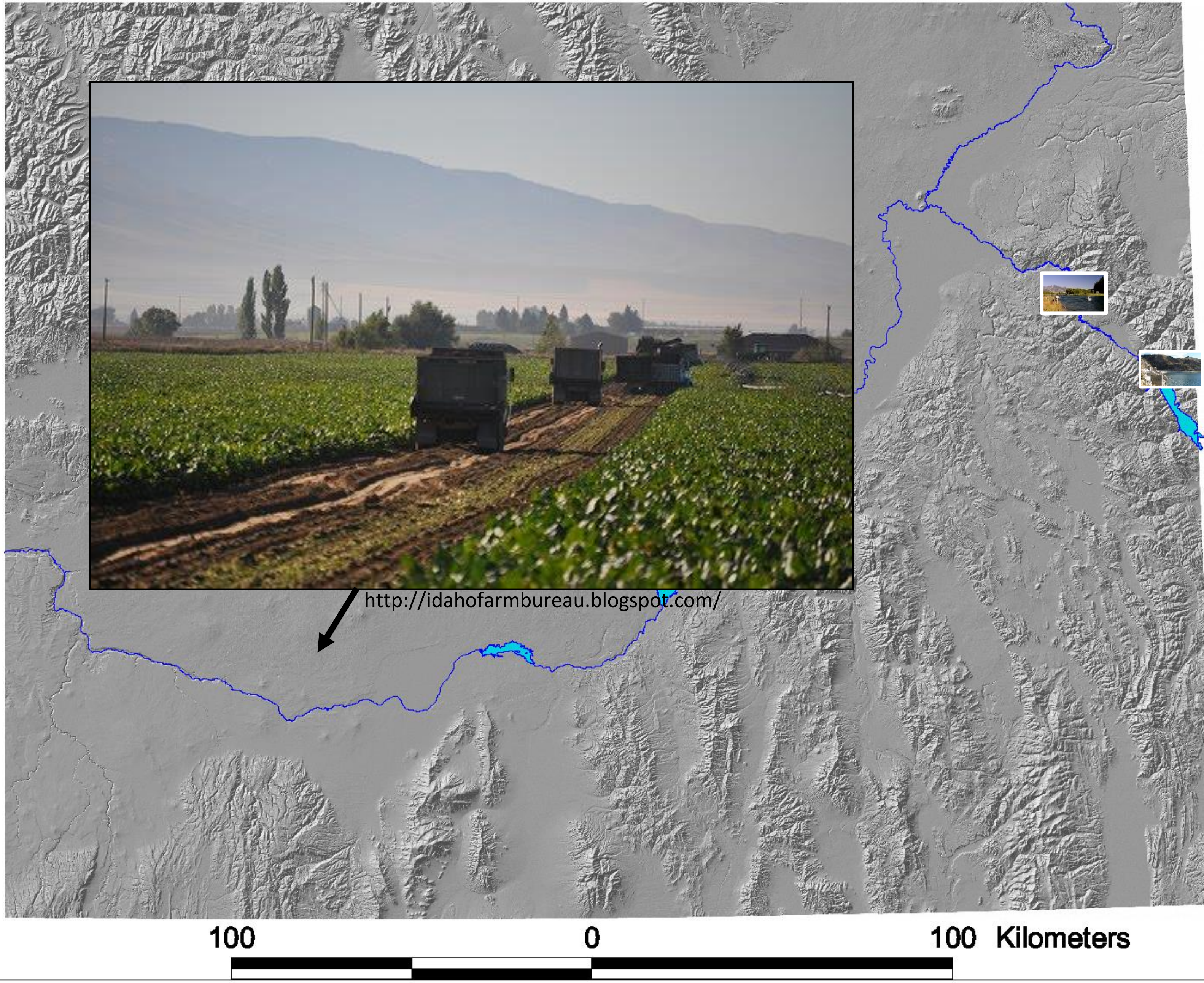
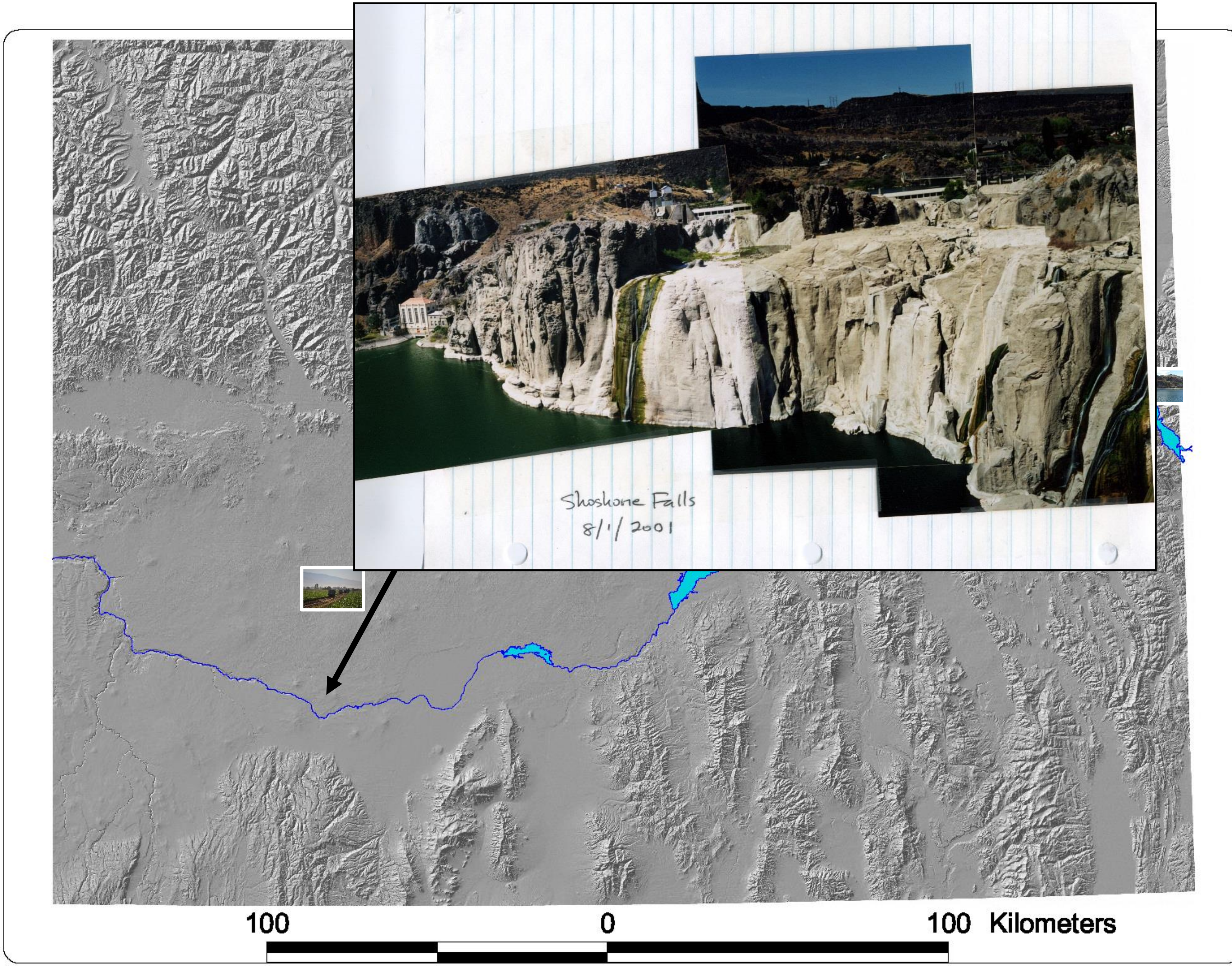
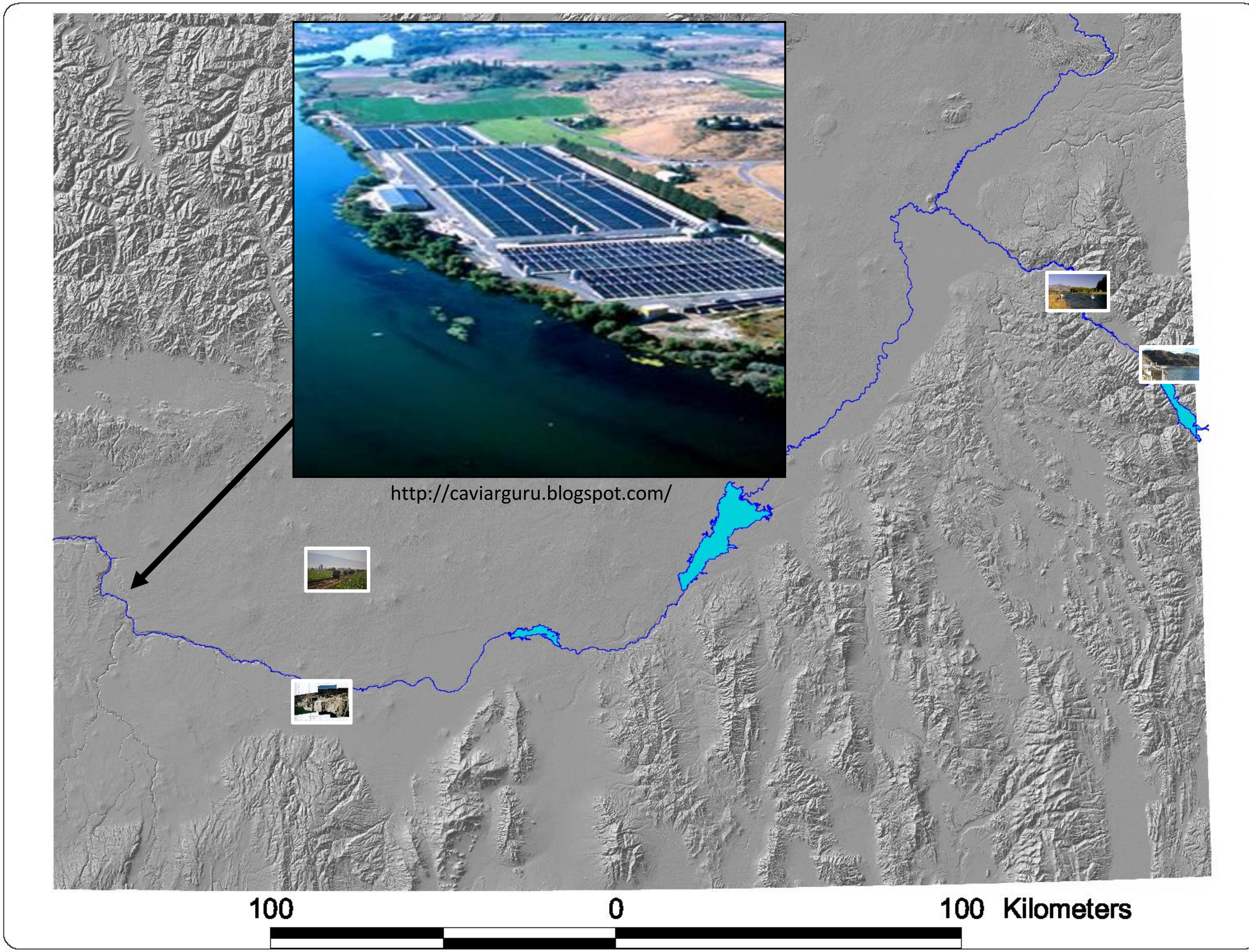
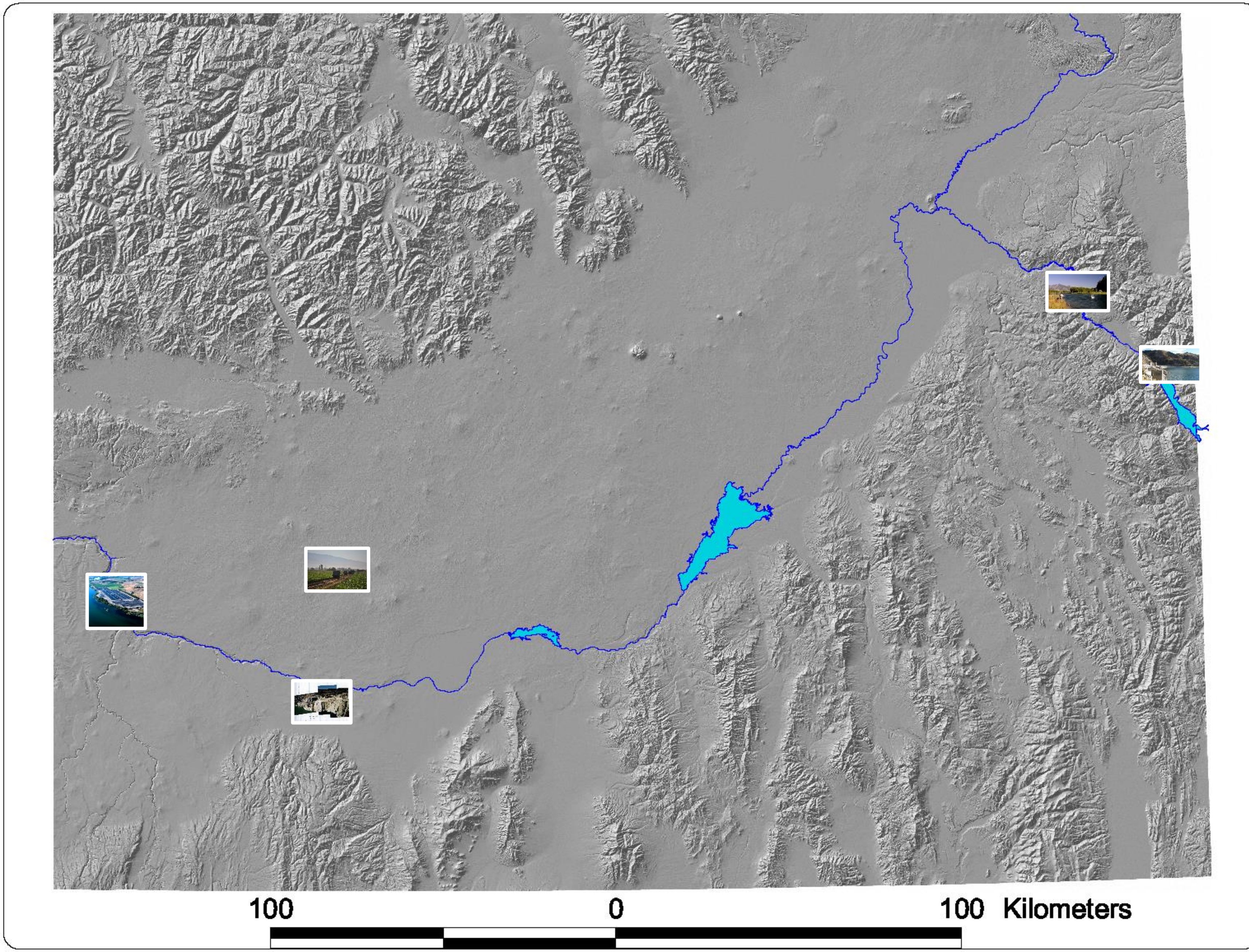

http://idahofarmbureau.blogspot.com/
100
0
100 Kilometers

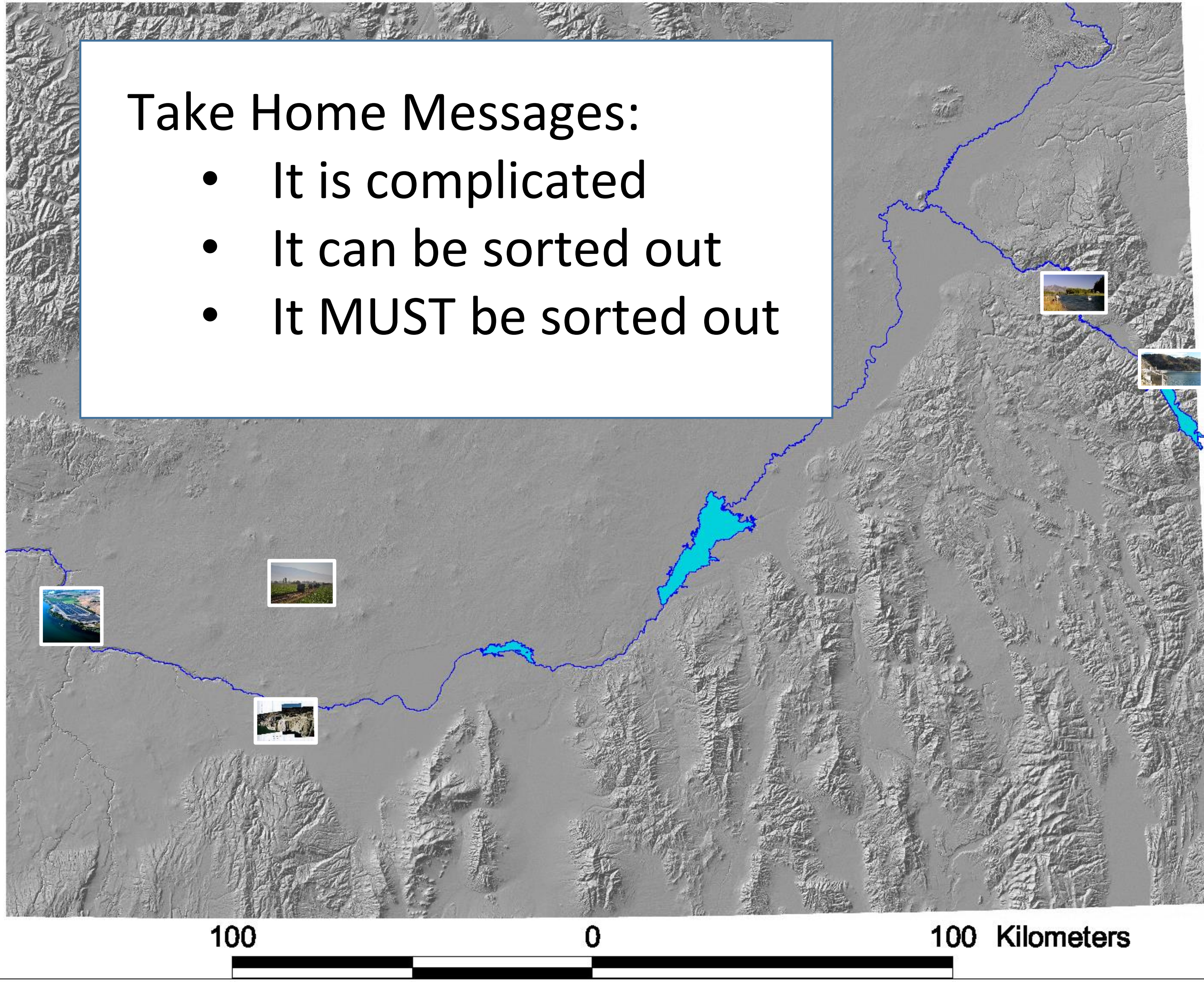

Shoshone Falls
8/1/2001
100
0
100 Kilometers

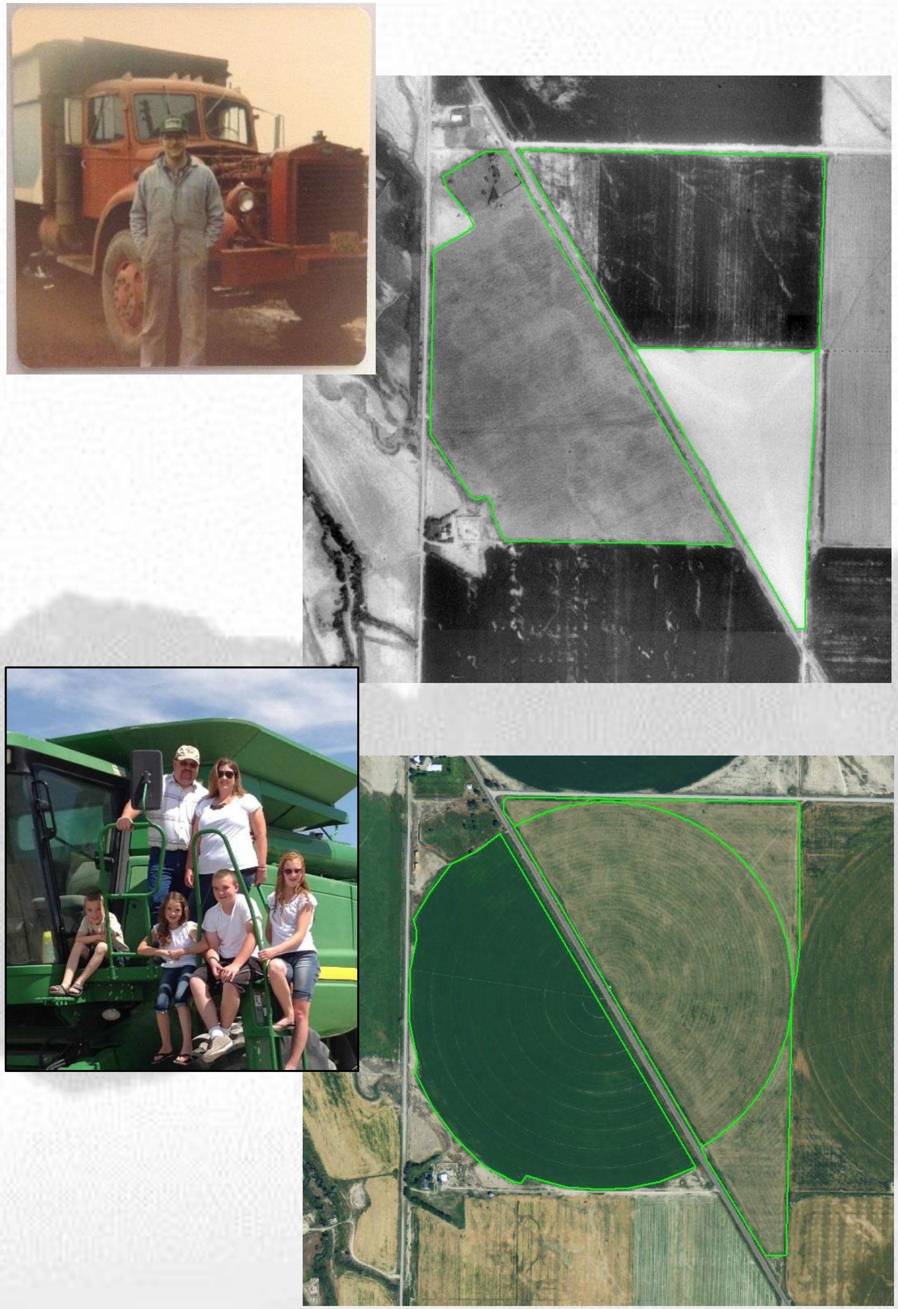

http://caviarguru.blogspot.com/
100
0
100 Kilometers


100
0
100 Kilometers

Take Home Messages:

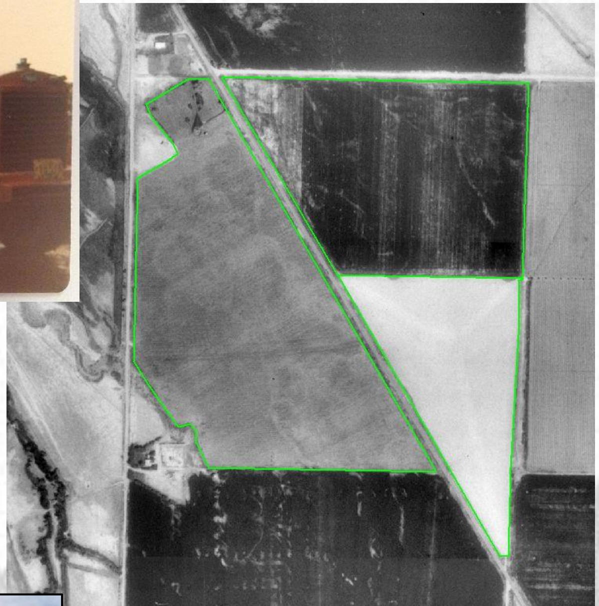
- It is complicated
- It can be sorted out
- It MUST be sorted out





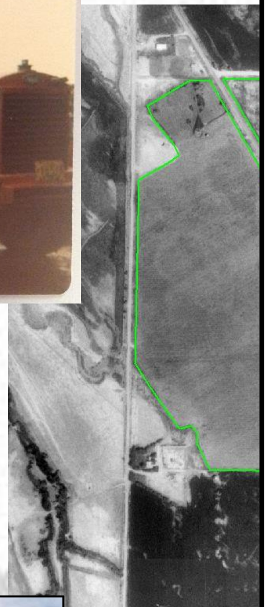
- Rivalry
  - The aquifer is connected to the springs that supply aquaculture
  - *Therefore: The increase in net consumptive use is* ***rival*** *to aquaculture*

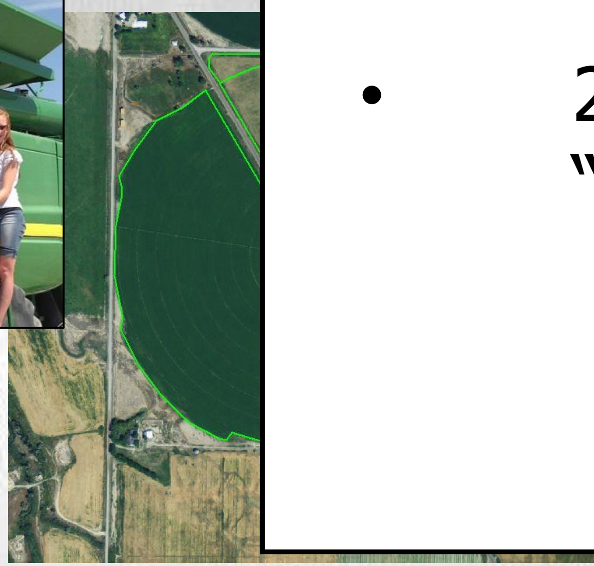
Do the Numbers



- 1992
  - 617 K m^3 pumping
  - 432 K m^3 consumptive
  - 0.7 tonne/K m^3 pumping (alfalfa)
  - 1.0 tonne/K m^3 consumptive (alfalfa)

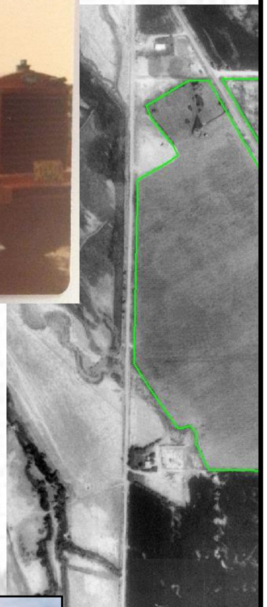
- 2014
  - 611 K m^3 pumping
  - 502 K m^3 consumptive
  - 0.9 tonne/K m^3 pumping
  - 1.2 tonne/ K m^3 consumptive





Is this Improvement?

- 16% increase in consumptive use
- Rival to aquaculture
- 20 – 30% increase in "crop per drop"



Is this Improvement?

- 16% increase in consumptive use
- Rival to aquaculture
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NOT related to irrigation improvements

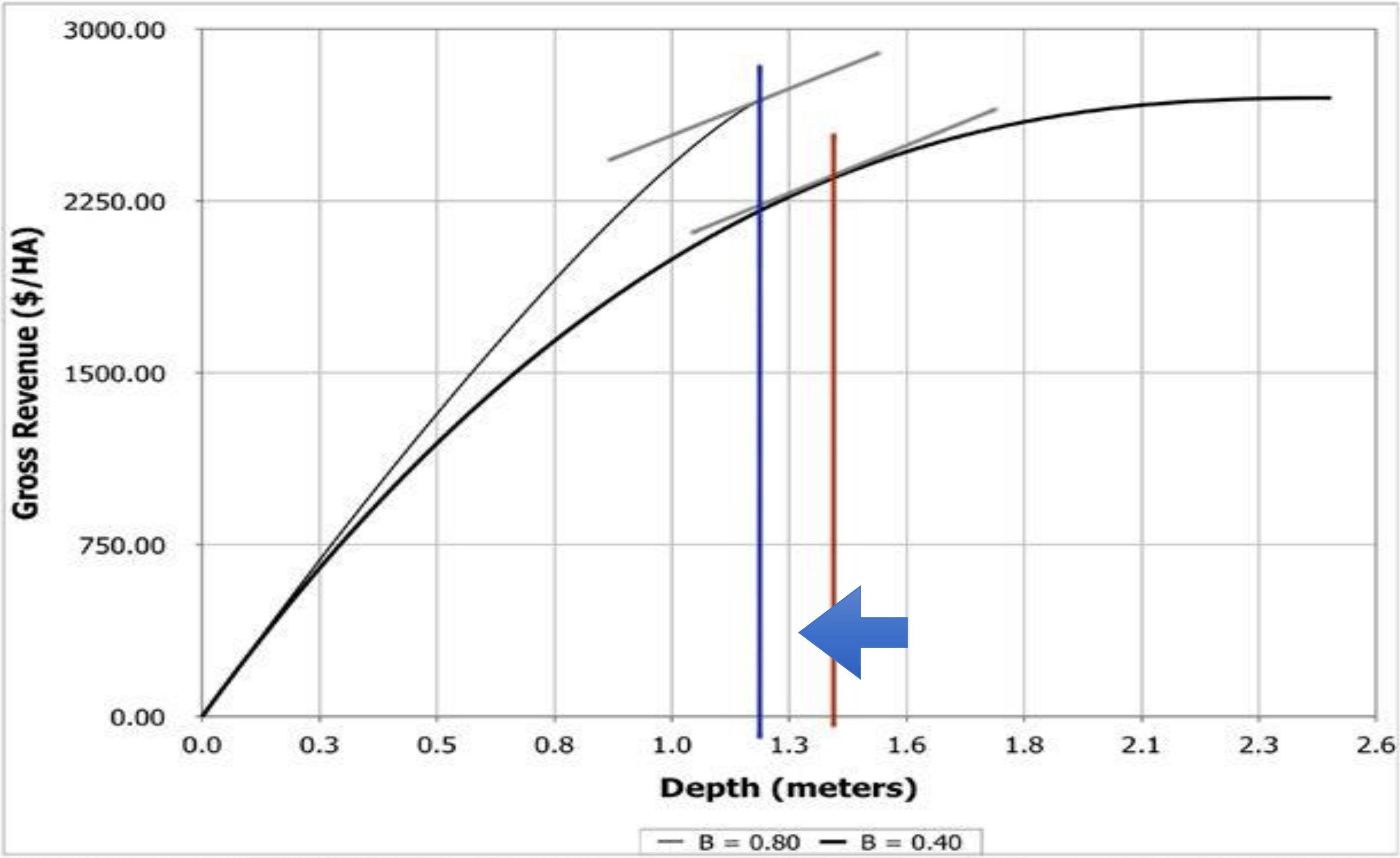
How to assess irrigation improvements:

- Consider Irrigator Response
- Close the Water Budget
- Consider Economic Rivalry
- Do the Numbers

Thank You

- bcontor@mirabwater.com
- gtaylor@uidaho.edu

Backup Slides


3000.00
2250.00
1500.00
750.00
0.00
Gross Revenue ($/HA)
0.0
0.3
0.5
0.8
1.0
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1.6
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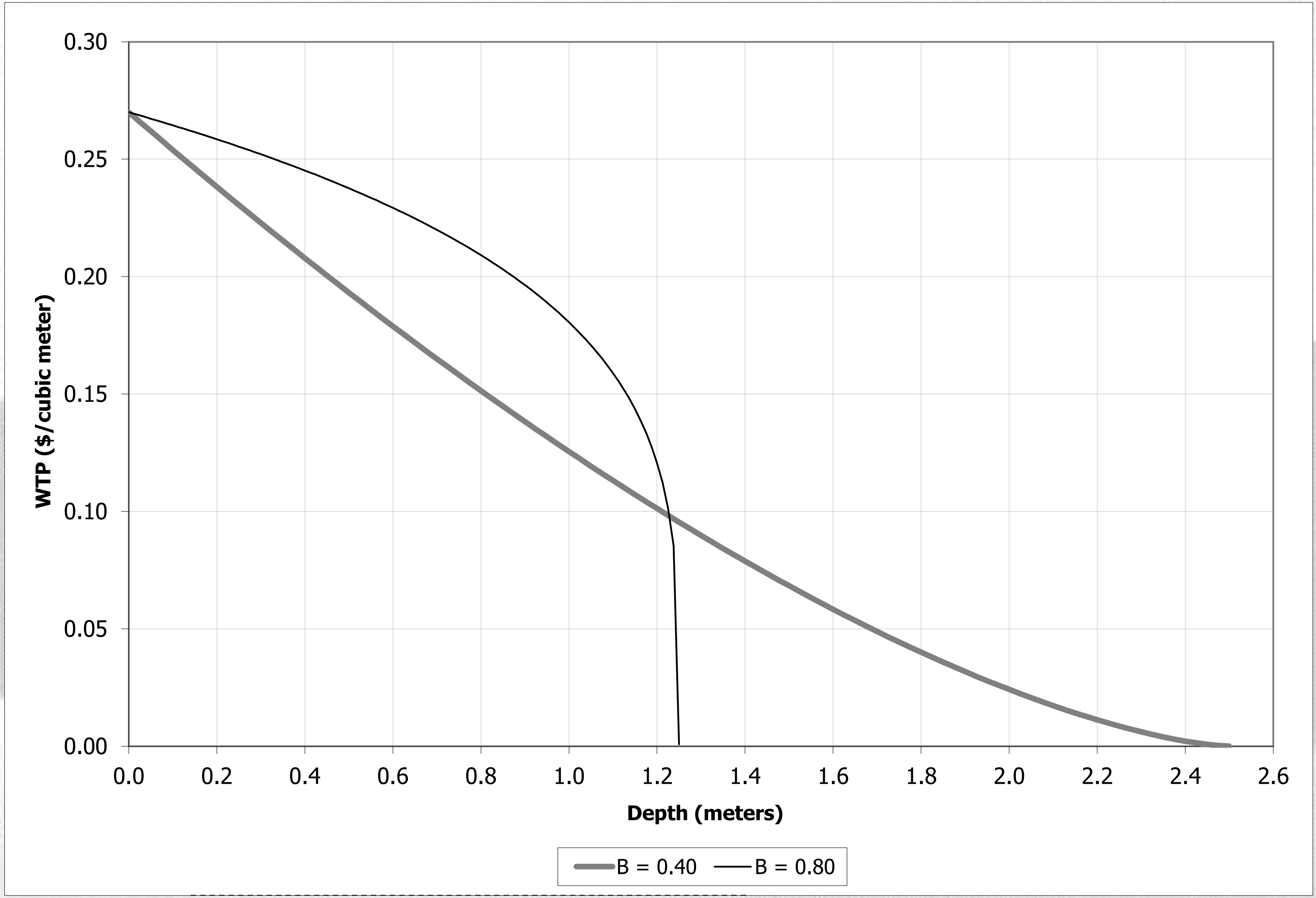

0.30
0.25
0.20
0.15
0.10
0.05
0.00
WTP ($/cubic meter)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
Depth (meters)
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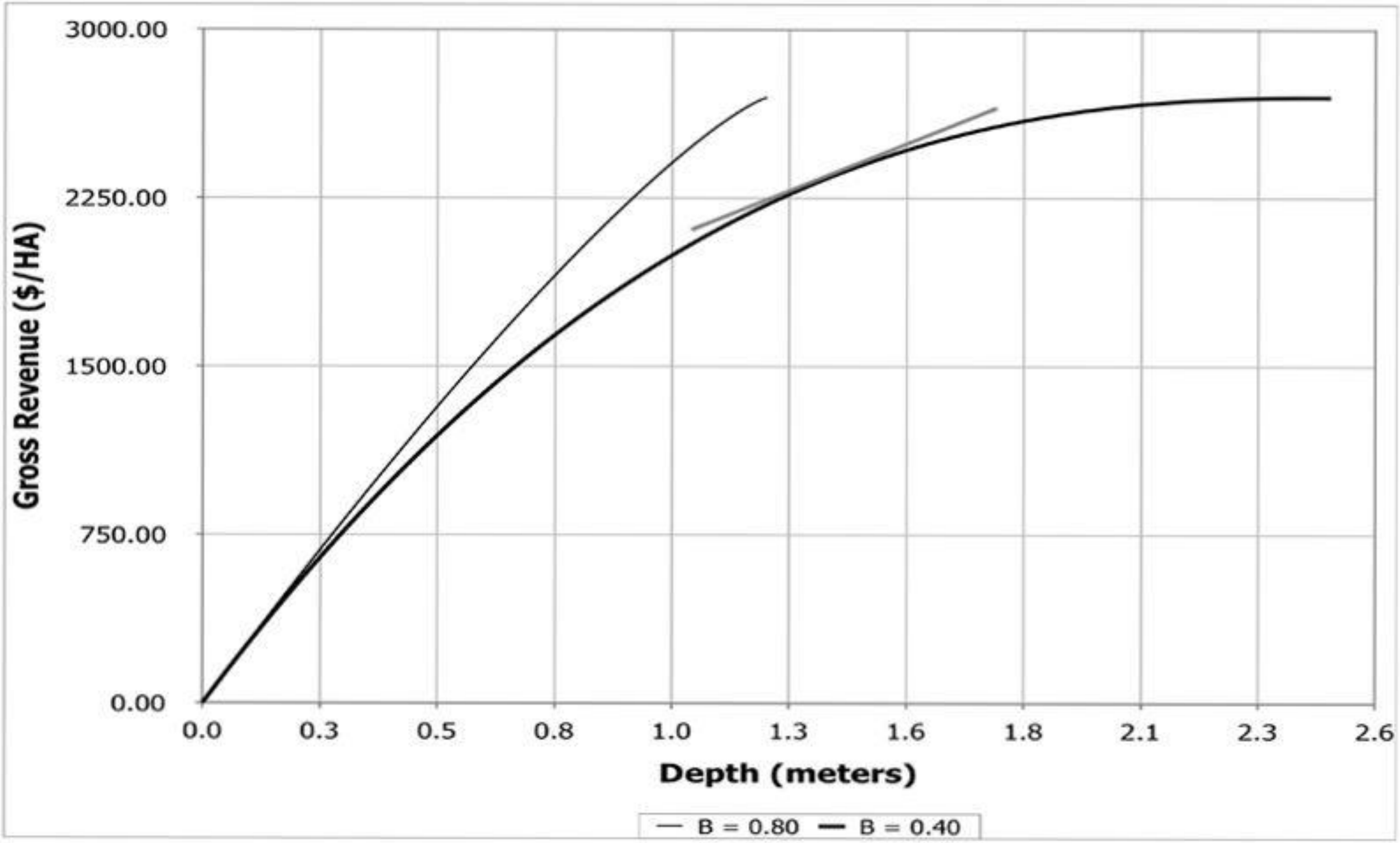
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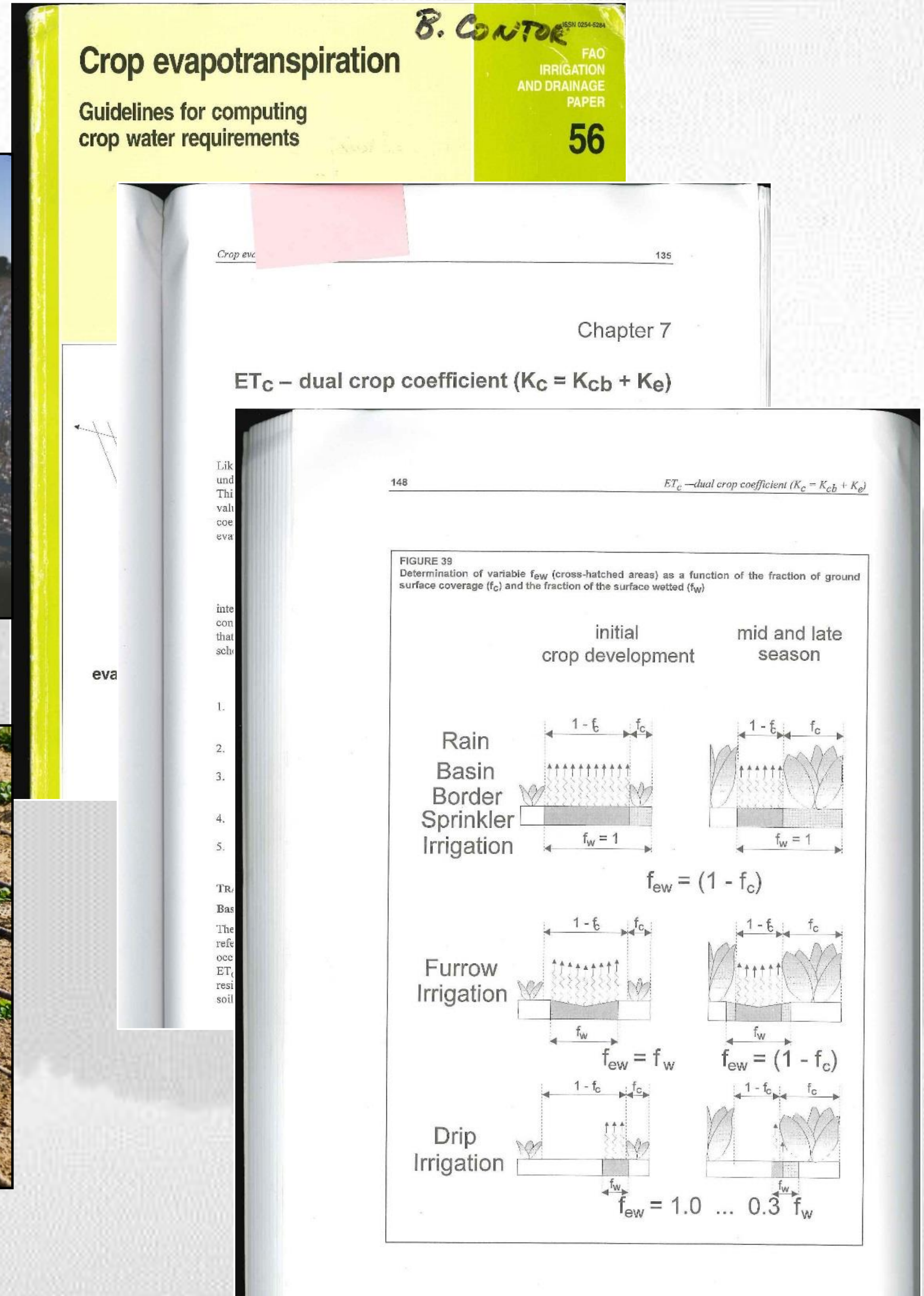
http://www.irrigationoutlet.com/images/



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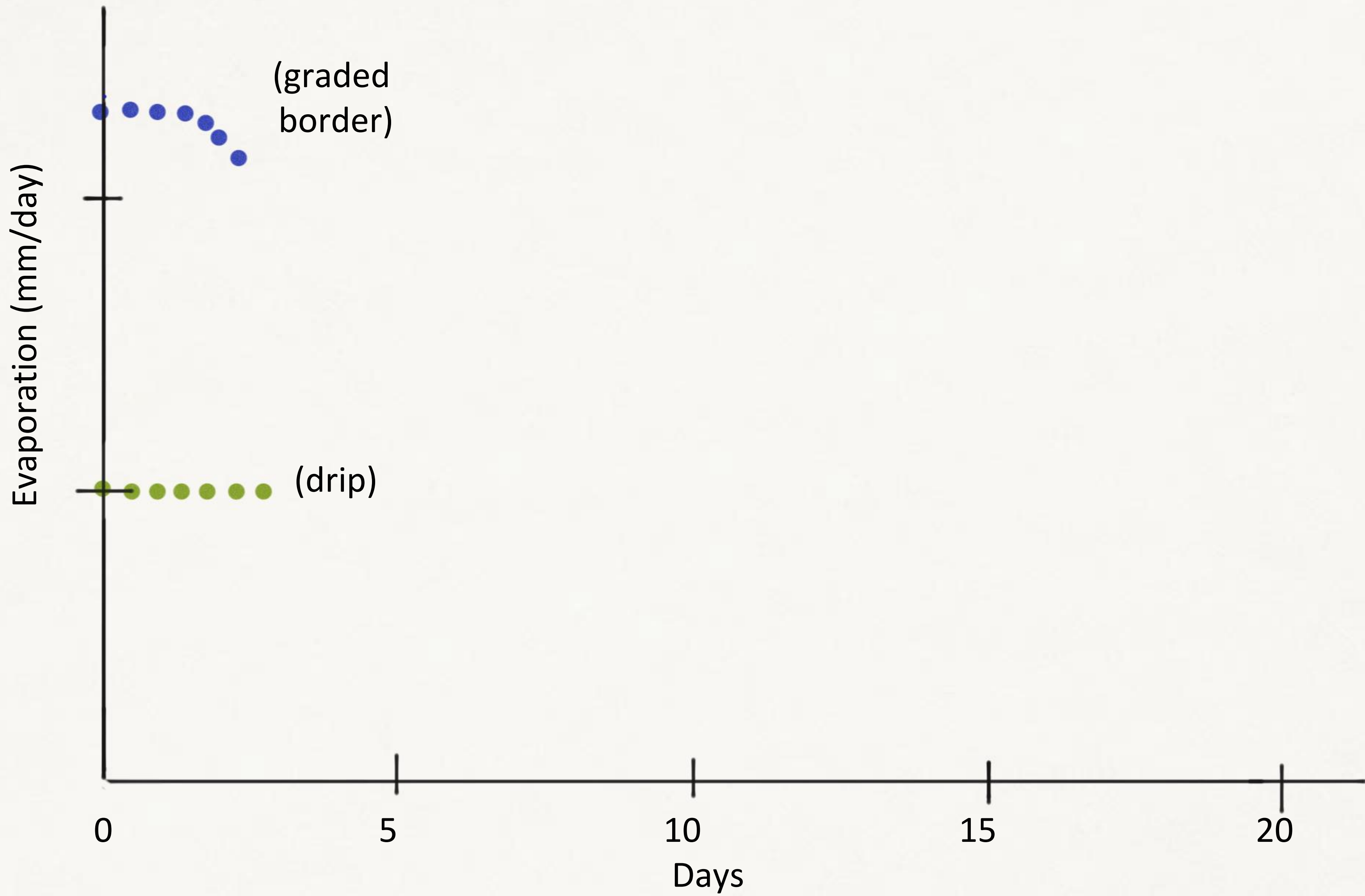
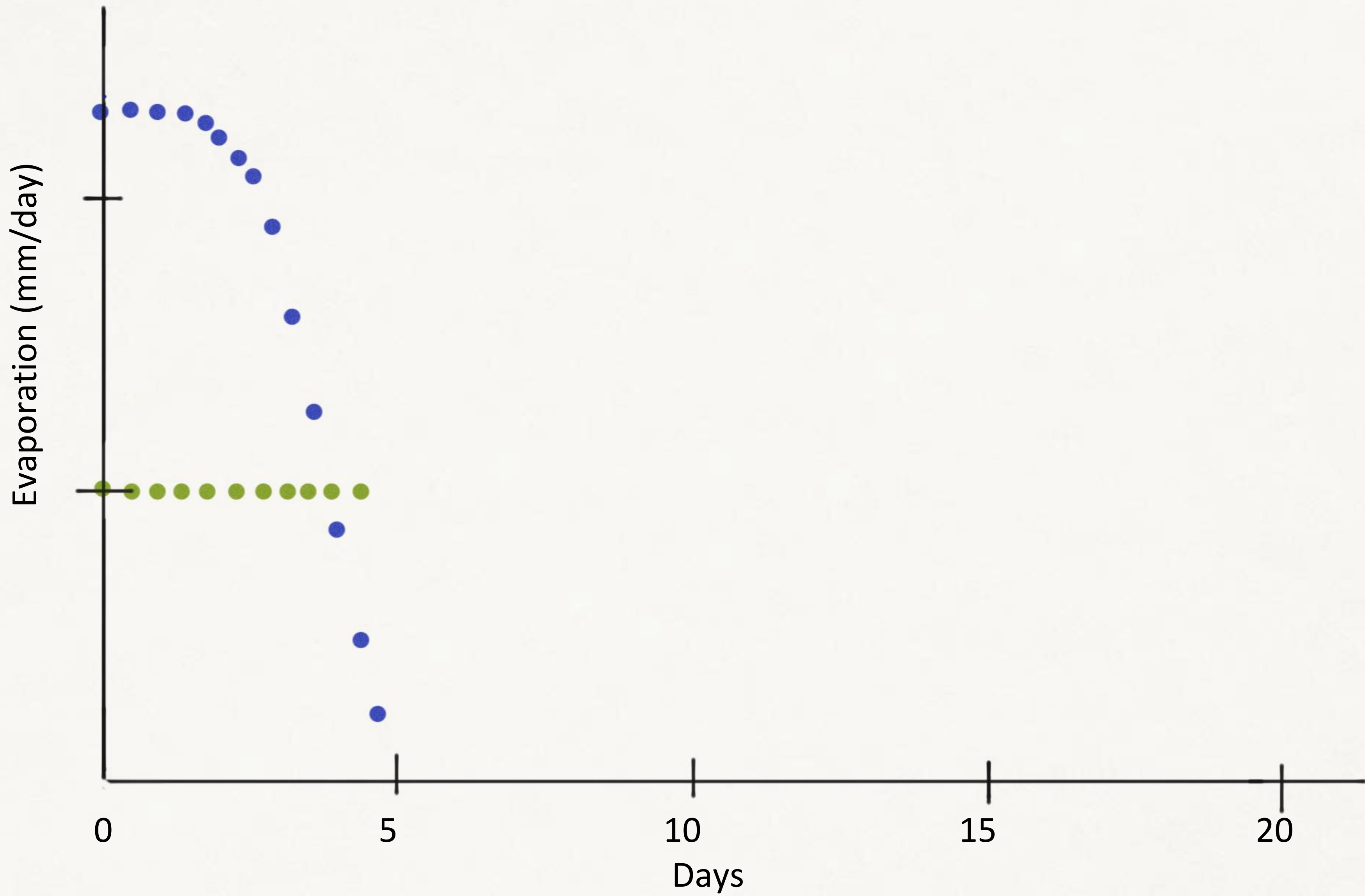
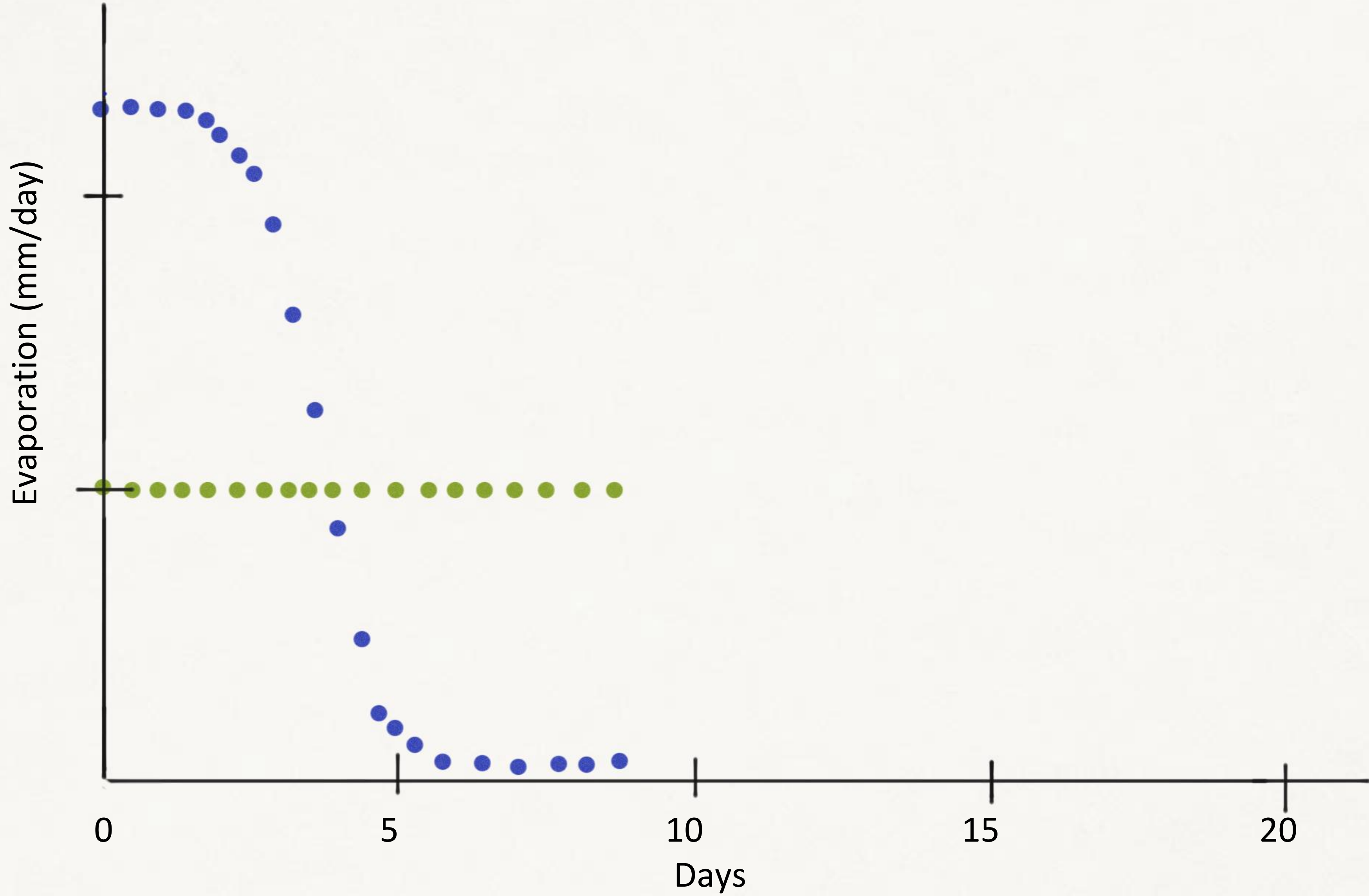
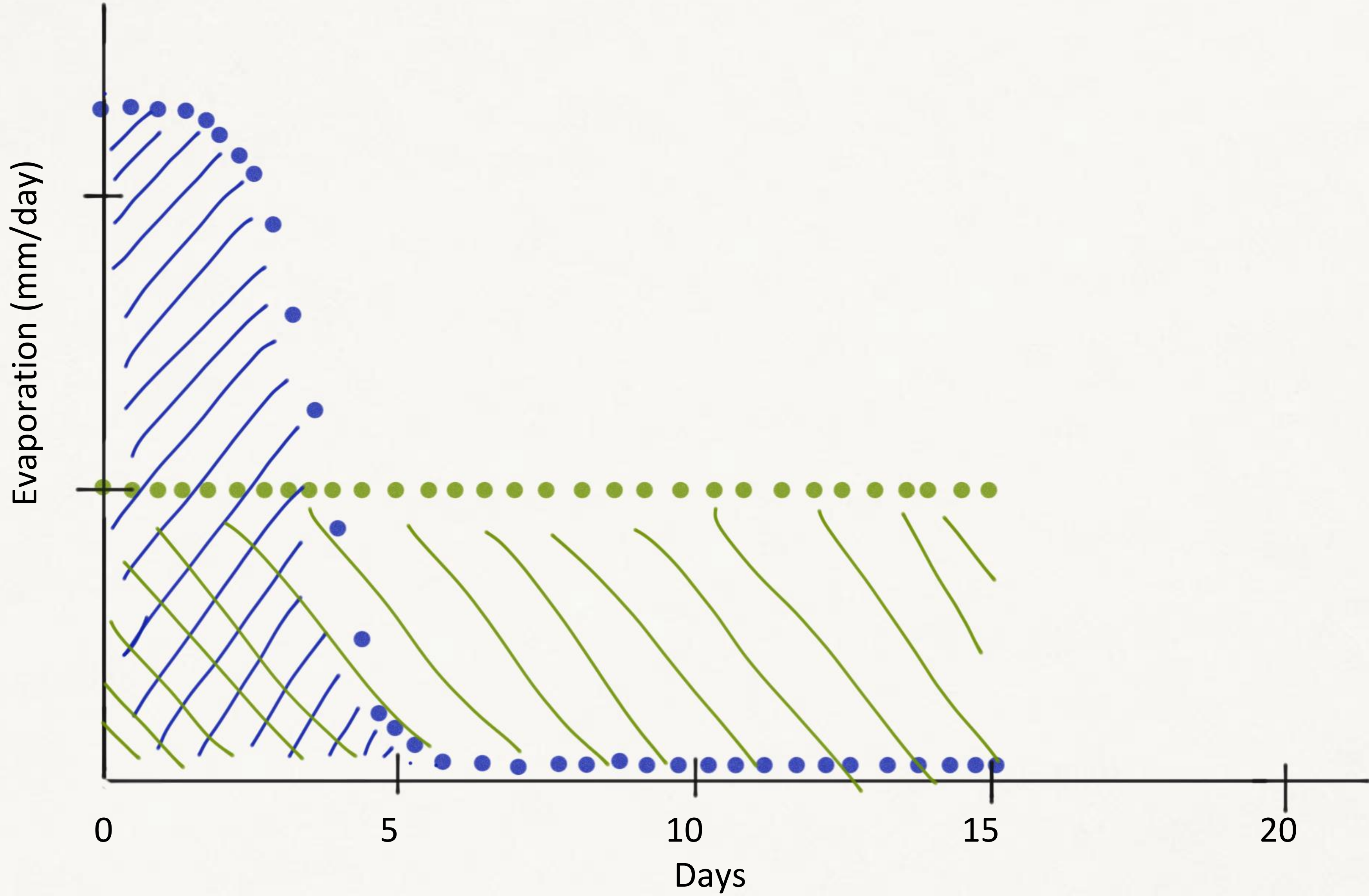



Evaporation (mm/day)
0
5
10
15
20
Days

< Projects





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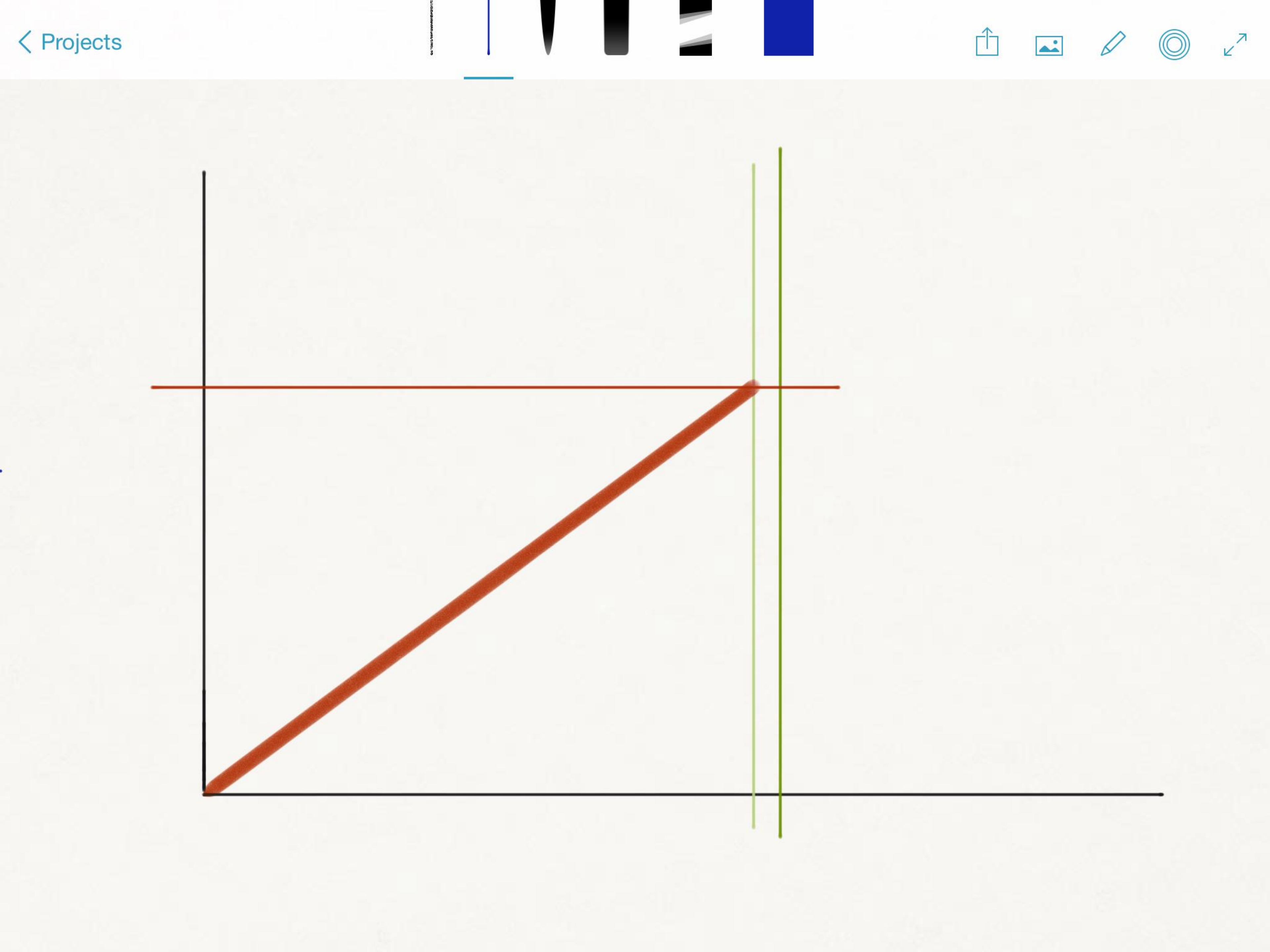
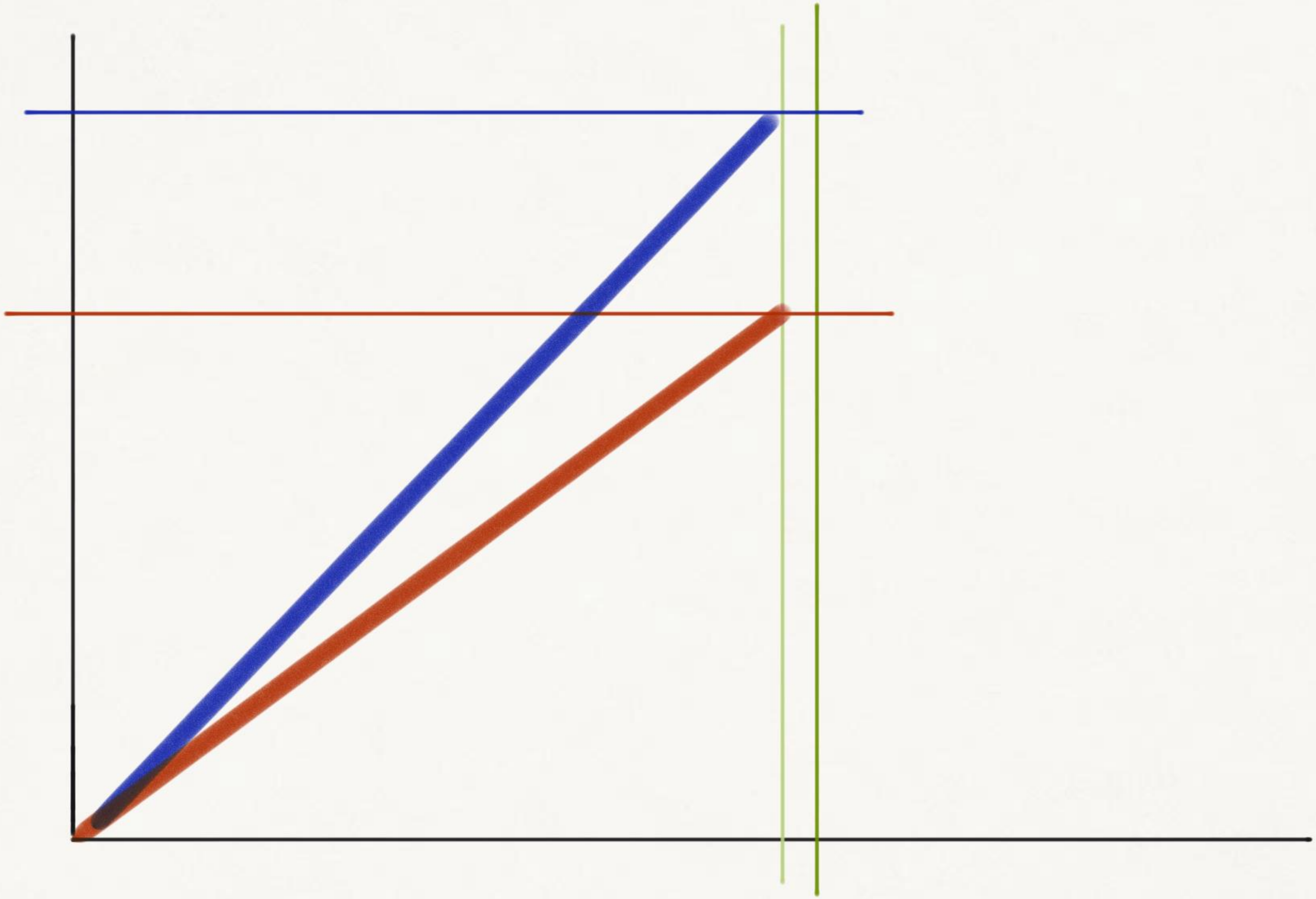

Projects



IRRIGATION DEMAND CALCULATOR: Spreadsheet Tool for Estimating Economic Demand for Irrigation Water

University of Idaho
Idaho Water Resources Research Institute

Bryce A. Contor
Garth Taylor
Greg L. Moore

August 2008

Idaho Water Resources Research Institute Technical Report 200803

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Demand_Price_Effect.xls [Compatibility Mode] - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW

V18

	A	C	D	E
1	One-crop Demand per Unit Area (1 Hectare)			
2				
3	ETm	Evapotranspiration depth at full yield		
4	Im	Irrigation depth at max yield		
5	Ym	Yield/area at full irrigation		
6	Yd	Yield/area rainfed (dryland)		
7	Pm	Commodity price at full irrigation, currency units per yield unit		
8	z	Exponent for price relationship (Pc/Pm) = (Y/Ym)^z		
9	K	Yield/ET coefficent, yield units/mm		
10	ETd	Dryland ET = effective precipitation		
11	B	CU fraction of applied irrigation water at full irrigation (this is one definition of irrigation ef		
12	I	Irrigation depth		
13	Y	Yield/hectare		
14	Pc	Commodity price		
15	R	Gross revenue/hectare		
16				
17	Crop Name	Name		
18				
19	ETm	914	mm	
20	Im	1328	mm	
21	Ym	13.5	metric ton	units/ha
22	Yd	3.692560175	metric ton	
23	Pm	110.00	$/metric to	currency/unit
24	z	0.1		
25	K	0.014770241		
26	ETd	250	mm	
27	B	0.5		
28				
29	Match Point from Data			
30				
31	I	500	mm	
32	Y	9.5	metric ton	
33	Pw	0.11	currency/m^3	

mirab water specialties, llc

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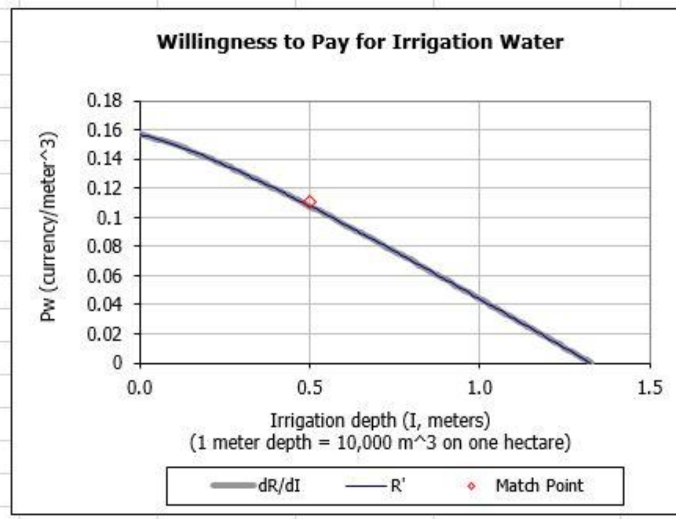
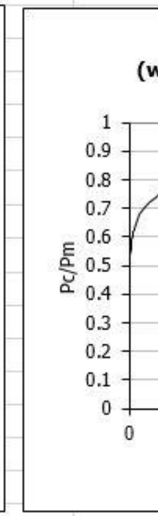
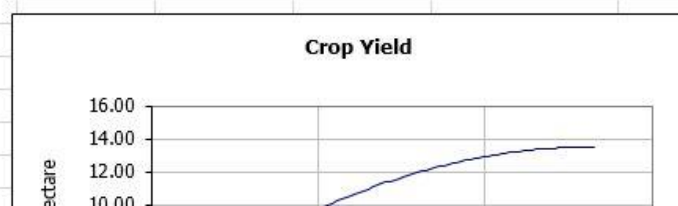
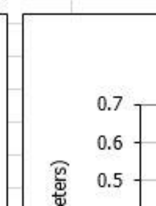
bcontor@mirabwater.c

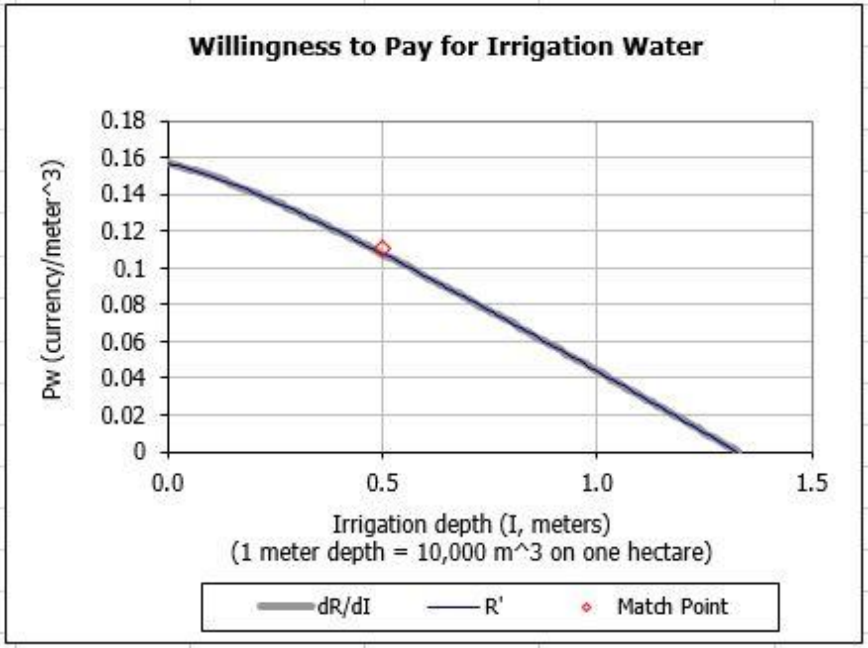


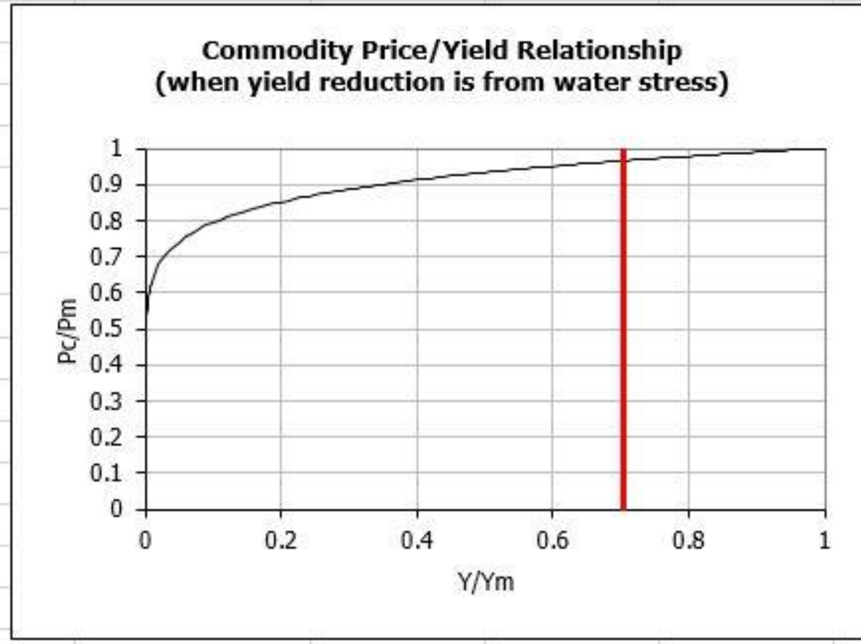


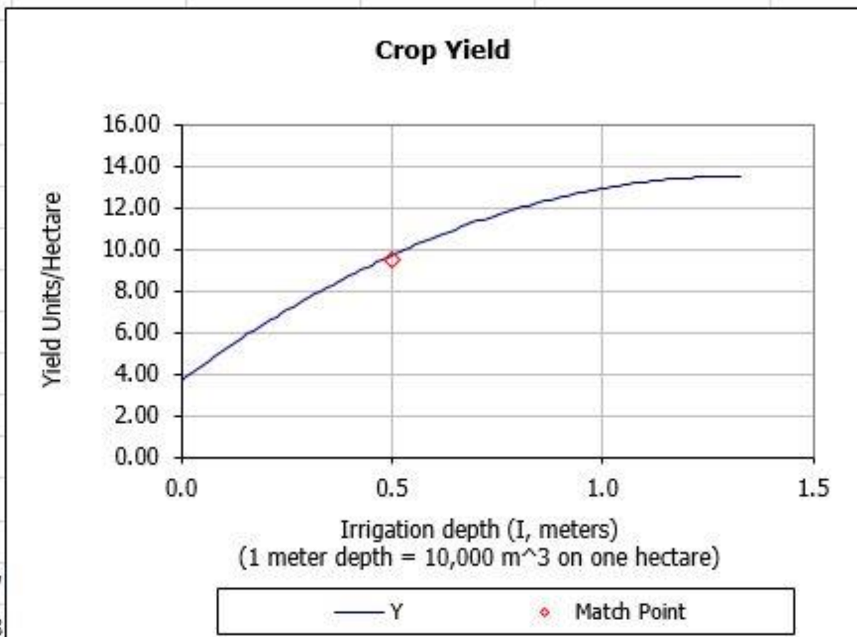


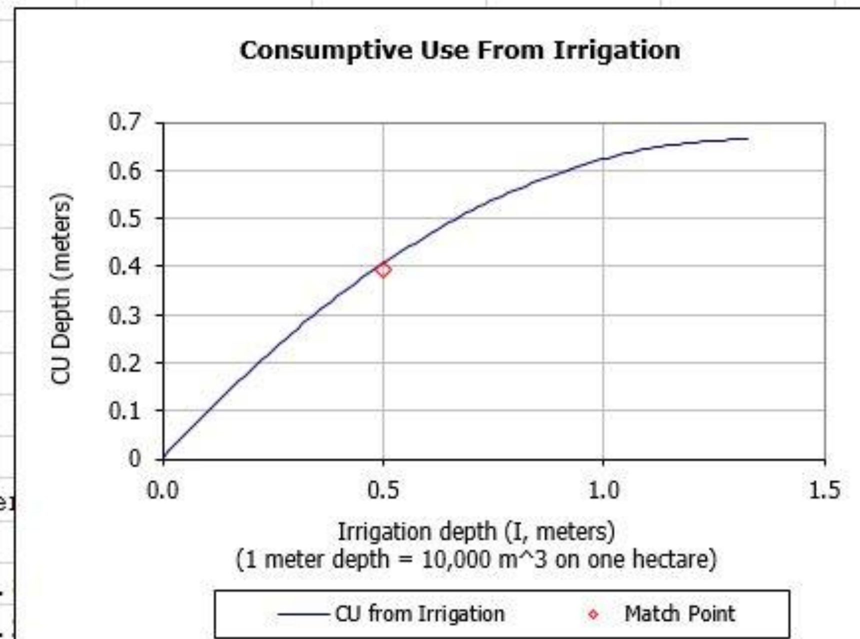


: full irrigation (this is one definition of irrigation efficiency) (calculated as (ETm - ETd)/I









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4475	0.034617	1.553966	1.553966	1553.96634	1553.966	0.155396634	0.155397	155.3966	155.3966

C	D	E
CU fraction of applied irrigation water at full irrigation (this is one definition of irr		
Irrigation depth		
Yield/hectare		
Commodity price		
Gross revenue/hectare		
Name		
914	mm	
1328	mm	
13.5	metric ton	units/ha
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2		
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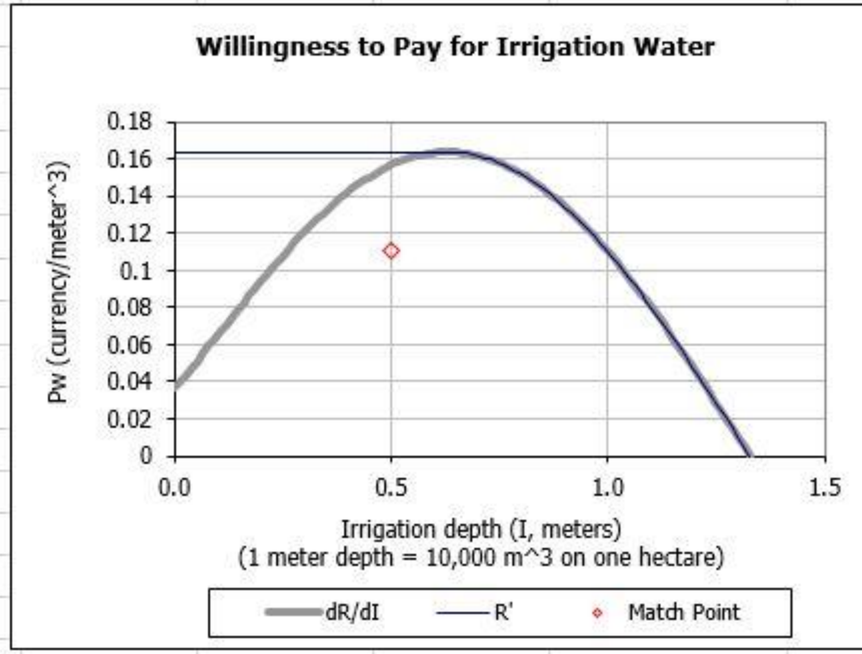
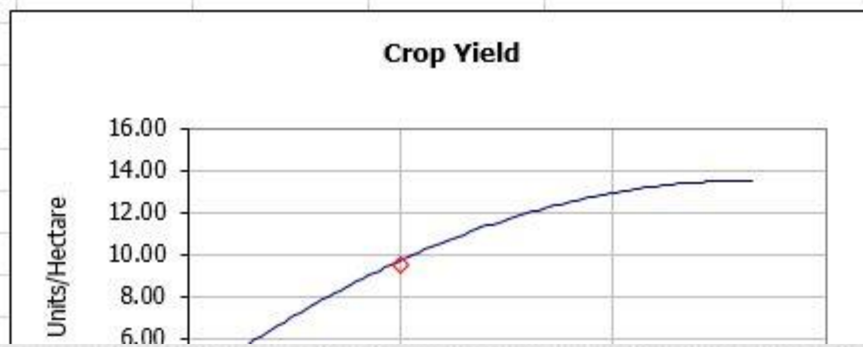
m Data		
500	mm	
9.5	metric ton	
0.11	currency/m^3	
elow)		





A = Irrigated area, acres
Pwv = Price of water, dollars/acre foot
Pc = Price of crop, dollars/crop unit
a = 1/B
R = Revenue, dollars/acre
Pm = Price of crop at full irrigation, dollars/crop unit
z = price exponent

Relationship between transpired water and dry-matter yield.

The relationship between full-season transpired water and dry-matter yield was describe as approximately linear by Doorenbos et al (1979; see also Allen et al 2002 (FAO56)). This relationship generally applies to the full-season growth of agronomic crops, across a wide range of crop types and climate regimes. Some imprecision is introduced by considering a harvested portion that is not the entire plant (for instance, harvesting only seeds or fruit) and by combining evaporation with transpiration. However, a linear relationship still generally describes crop yield as a function of evapotranspiration. The relationship terminates at an upper limit of yield and evapotranspiration determined by agronomic characteristics of the crop and site-specific constraints such as soils, solar radiation, temperature and day length. It may be expressed as:

(C1) Y = K1 (ET)

Relationship between applied irrigation water and crop yield.

No irrigation system is 100% efficient; if any meaningful quantity of water is delivere to an irrigated parcel, some of it is lost to other fates besides supporting crop evapotranspiration. Empirically and intuitively, we see that as irrigation depth increases, a smaller and smaller fraction is devoted to evapotranspiration and a larger and larger fraction is lost. At some depth of application, additional application of water begins to reduce yield. This is a classic example of decreasing marginal returns to a production input. The consequence is that, while the production function for transpired water is linear, the production function for applied water is non-linear. Th first derivative is monotonically decreasing with increased application depth.

Only the rising portion of the production function (first derivative positive) is of interest for economic analysis, since rational producers will never enter the region beyond zero marginal production. For this rising portion of the yield/applied water first derivative is monotonically decreasing with increased application depth.

Only the rising portion of the production function (first derivative positive) is of interest for economic analysis, since rational producers will never enter the region beyond zero marginal production. For this rising portion of the yield/applied water relationship, an elegant production function by Martin et al (1984, 1989) incorporates the linear yield/evapotranspiration relationship of Doorenbos et al (1979) with the consumptive-use fraction considerations described above. It expresses the relationship in terms of dryland and full-irrigation yield characteristics. Equation (C2a) is the original presentation. Equation (C2b) rearranges terms and makes one substitution for convenience:

$$\text{(C2a)}\quad Y = Yd + (Ym - Yd)\ [\ 1 - (1-I/Im)^{(1/B)}\ ]$$

$$\text{(C2b)}\quad Y = Ym - (Ym - Yd)\ (1 - I/Im)^{a}$$

Relationship between applied water and commodity price.

For some irrigated crops the value of dry matter production is essentially independent of crop yield. For other crops, as water stress reduces yield, quality and therefore commodity price also decline dramatically. As a first approximation, equations (C3a) and (C3b) express commodity price as a function of water-reduced crop yield, though research is needed into the proper functional form of this relationship.

$$\text{(C3a)}\quad Pc/Pm = (Y/Ym)^{z}$$

$$\text{(C3b)}\quad Pc = Pm\ (Y/Ym)^{z}$$

Low values of "z" correspond to crops whose value is insensitive to irrigation adequacy, such as pasture and forage. Higher values correspond to crops where quality and price are sensitive to adequacy.

Multiplying Equation (C2) by commodity price to obtain revenue generates a function that expresses revenue as a function of application depth. The first derivative is the marginal production value, which we assume here to be the marginal utility and therefore the economic demand. Contor et al (2008) derived a demand equation that assumed a constant commodity price (i.e. parameter "z" equals zero). However, it is more correct to instead use the yield-dependent price defined by equation (C3b).

```
    * [(a/Im) (1 - Yd/Ym) (1 - I/Im)^(a-1)]
```

Since gross crop revenue is price times yield, per-acre revenue is:

```
 (C6) R = Pc Y
```

By the product rule, the partial derivative of per-acre revenue with respect to irrigation depth is:

```
 (C7) dR/dI = Pc (dY/dI) + Y (dPc/dI), or in other words
 (C8) dR/dI = [Equation (C3b) times Equation (C4)] plus
    [Equation (C2b) times Equation (C5)]
```

This can be expressed as:

```
 (C9) dR/dI = Pm [(Ym - (Ym - Yd) (1 - I/Im)^a)/Ym]^z
  * [(a/Im) (Ym - Yd) (1 - I/Im)^(a-1)]
  + [Ym - (Ym - Yd) (1 - (I/Im))^a]
  * [z Pm [1 - (1 - Yd/Ym) (1 - I/Im)^a]^(z-1)
  * [(a/Im) (1 - Yd/Ym) (1 - I/Im)^(a-1)]]
```

Equation (C9) gives the per-acre demand for irrigation water depth for a single crop. For practical use, it requires conditional constraints to avoid indicating negative prices at very high quantities, or negative quantities at very high prices. Further, i application in horizontal summation to obtain aggregate demand requires consideration o total acreage irrigated, for each crop.

Assumptions. The following assumptions are applied to determine acreage by crop:

1. Total irrigated acreage may be less but cannot be more than some fixed total acreag
2. We assume that the acreage of the highest revenue-per-acre crop is limited by something other than available water, such as:

a. Agronomic rotation requirements;
b. Labor;
c. Management;