Verifying Interpretations of Soil Saturation using Hydrologic Measurements

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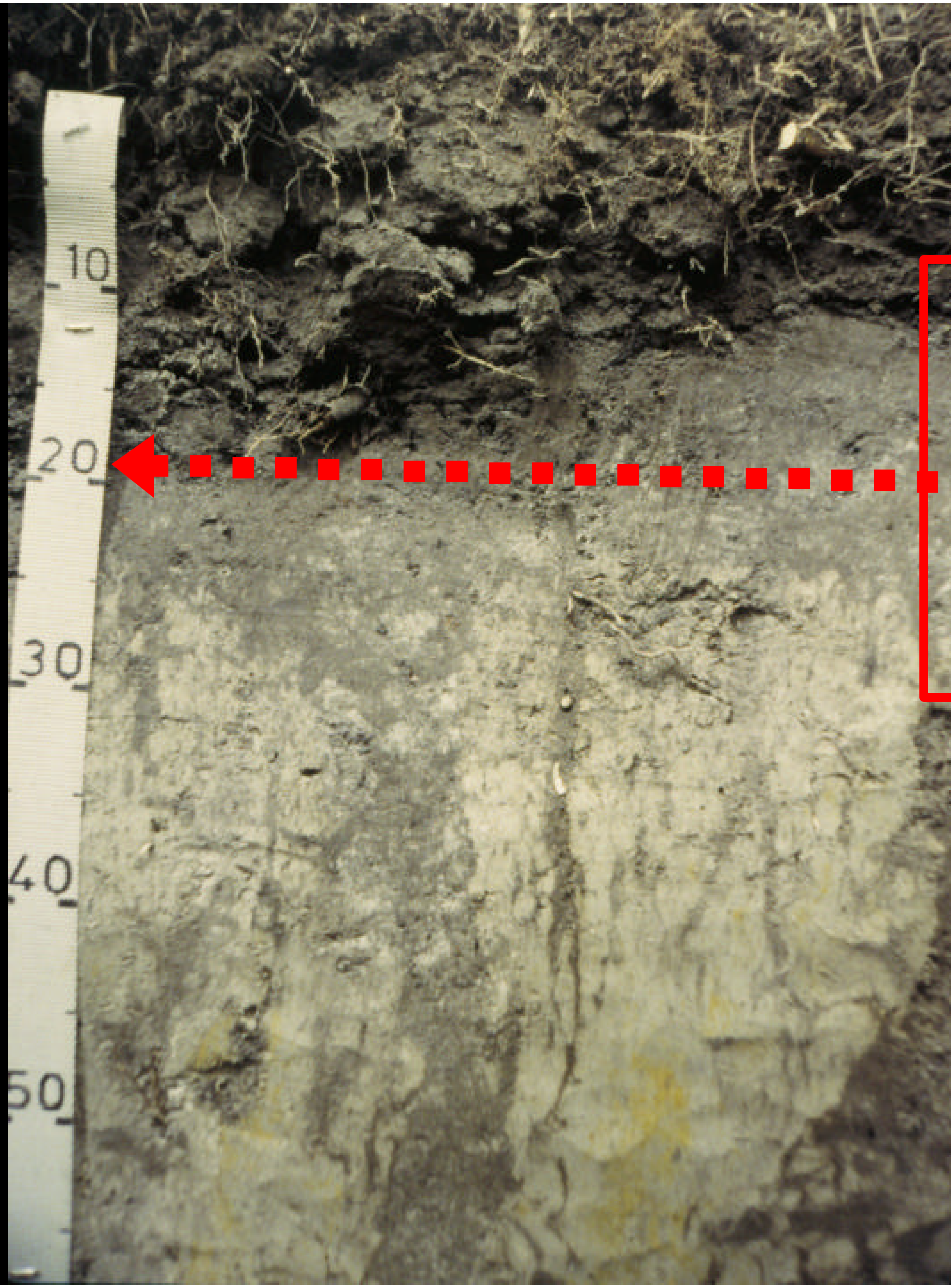
Seasonal High Water Tables

Depth to ***seasonally-saturated*** soil layers determines whether soil is:

- Suitable for a ***home site***
- A jurisdictional ***wetland***

Determining Depth to Seasonal Saturation

- Find depth to ***Low Chroma or gray soil colors***
- These colors mark the ***top*** of the seasonal high water table ***(SHWT)***



Depth of seasonal high water table

Problems with Using Soil Color to Detect Seasonal Saturation

- Colors are not reliable indicators when soils have been ***drained***.
- We don't know ***how often*** or ***how long*** a soil is saturated at a given depth from color alone.

Problems cont'd:

New Needs

Land-use assessments may require information on frequency and duration of saturation--over the long term ***(40+ yrs)***

Examples

- ***Wetlands--***must be saturated for 5% of growing season for $\geq$5 out of 10 years
- ***Soils using septic systems--*** must not be saturated for >14 d in 7 out of 10 years

Objectives

1. Review a method that calibrates ***percentages*** of redox. features (*gray colors)* to long-term ***saturation*** frequency and duration.
2. Review ***applications*** of results.

Background Chemistry

Redoximorphic features form when:

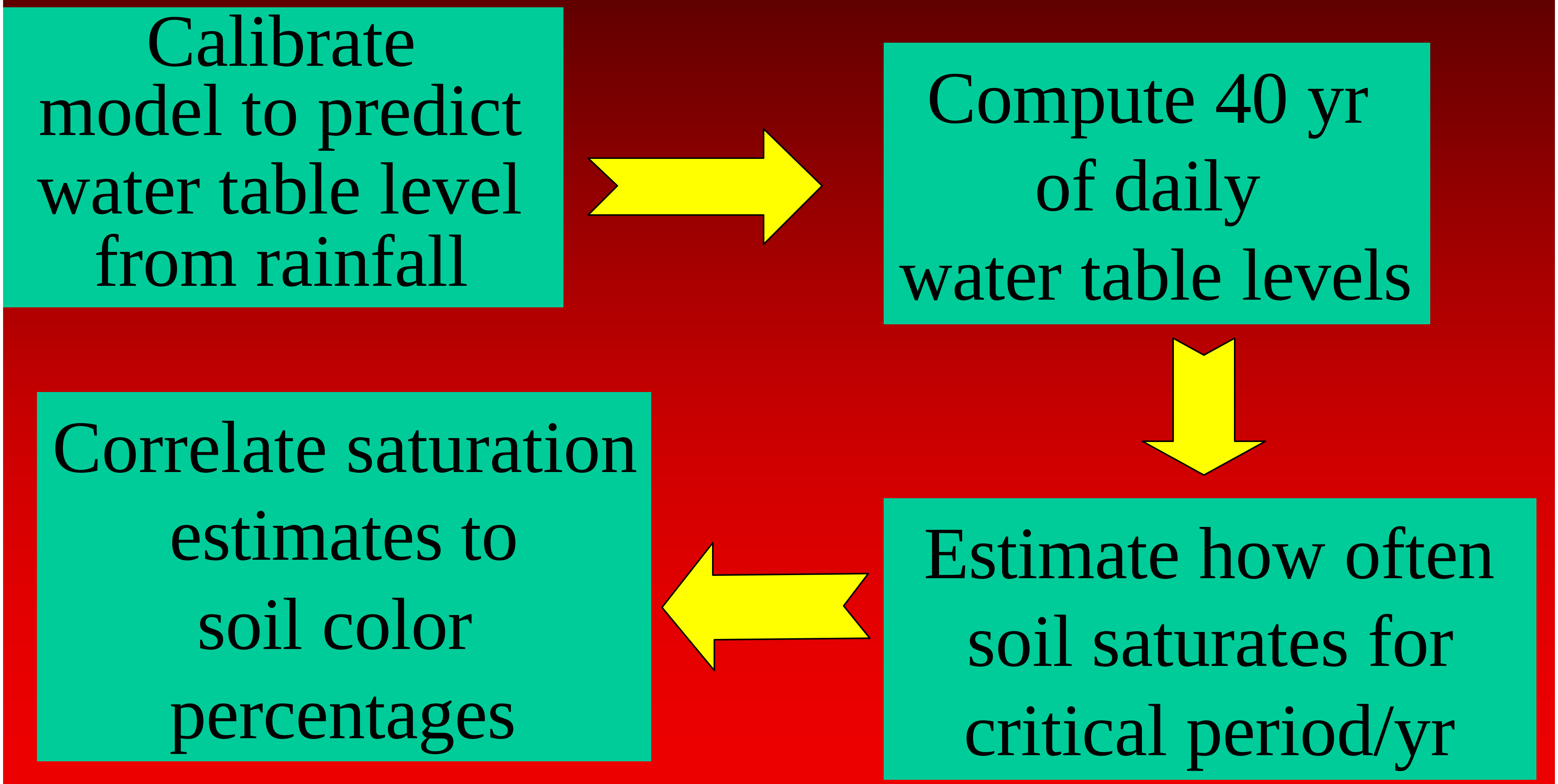
- Soils are ***saturated*** and ***Fe reduction*** occurs.

Gray color is ***natural color*** of soil minerals ***w/o Fe oxide coatings***.

Methods

How to get 40 yrs of daily water table data

4-Step Approach



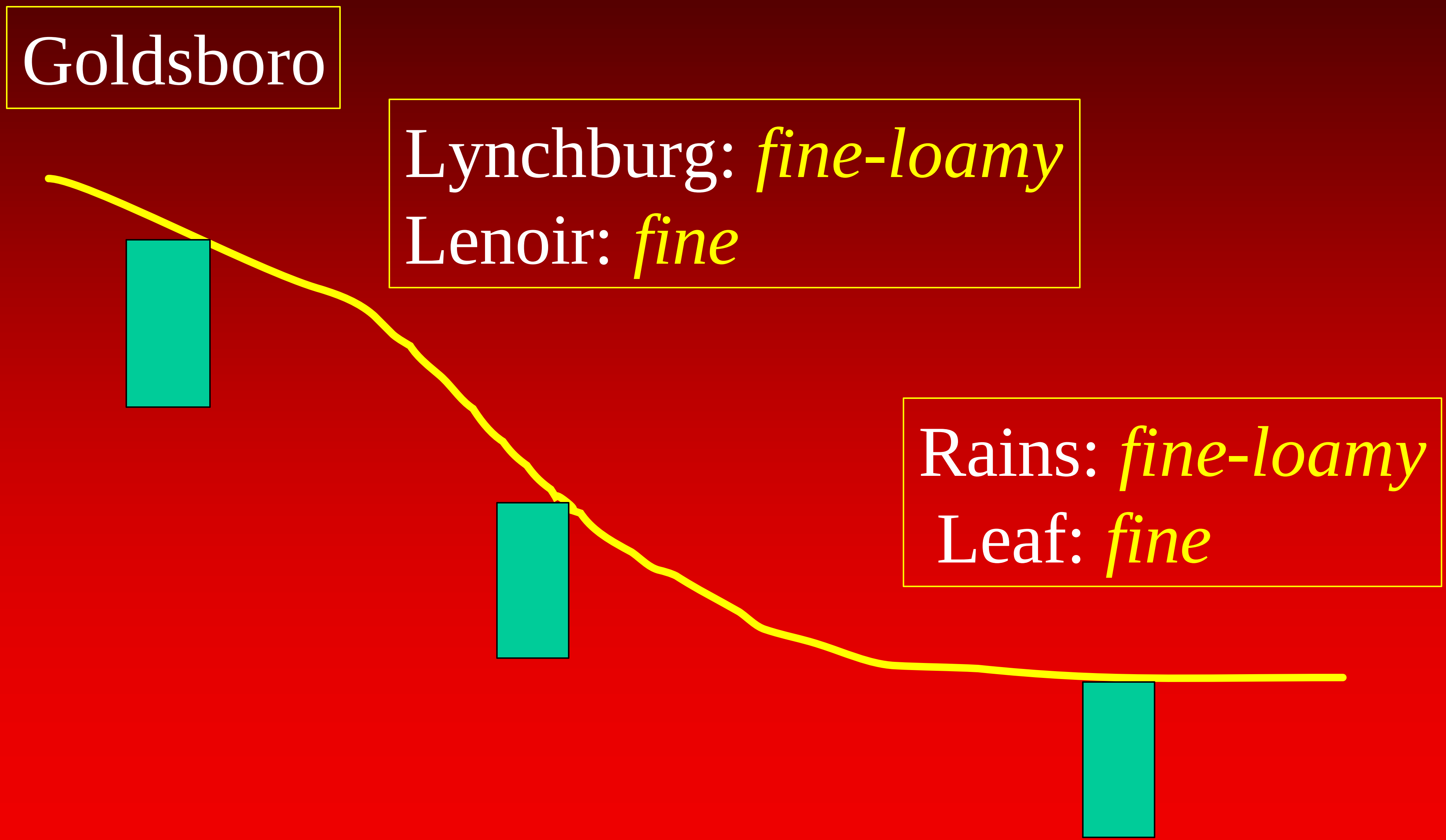
Basic Idea

Calibrate *percentages* of redximorphic features to *long-term* water table data

Soils

- Two sites studied in ***NC Coastal Plain***
- Hillslopes at each site contained plots in ***well***, ***moderately well***, and ***poorly drained*** soils (Kandiudults to Paleaquults)

Soil Series at Two Sites



Soils cont'd.

- Measured the following in 22 soil plots : ***daily water table levels, rainfall, and redox potential***
- ***Percentages*** of redoximorphic features were estimated by eye

Hydrologic Modeling

- DRAINMOD was ***calibrated*** for each soil plot
- Calibrated models were used to compute ***daily water table levels*** for ***40-yr period*** for each soil plot

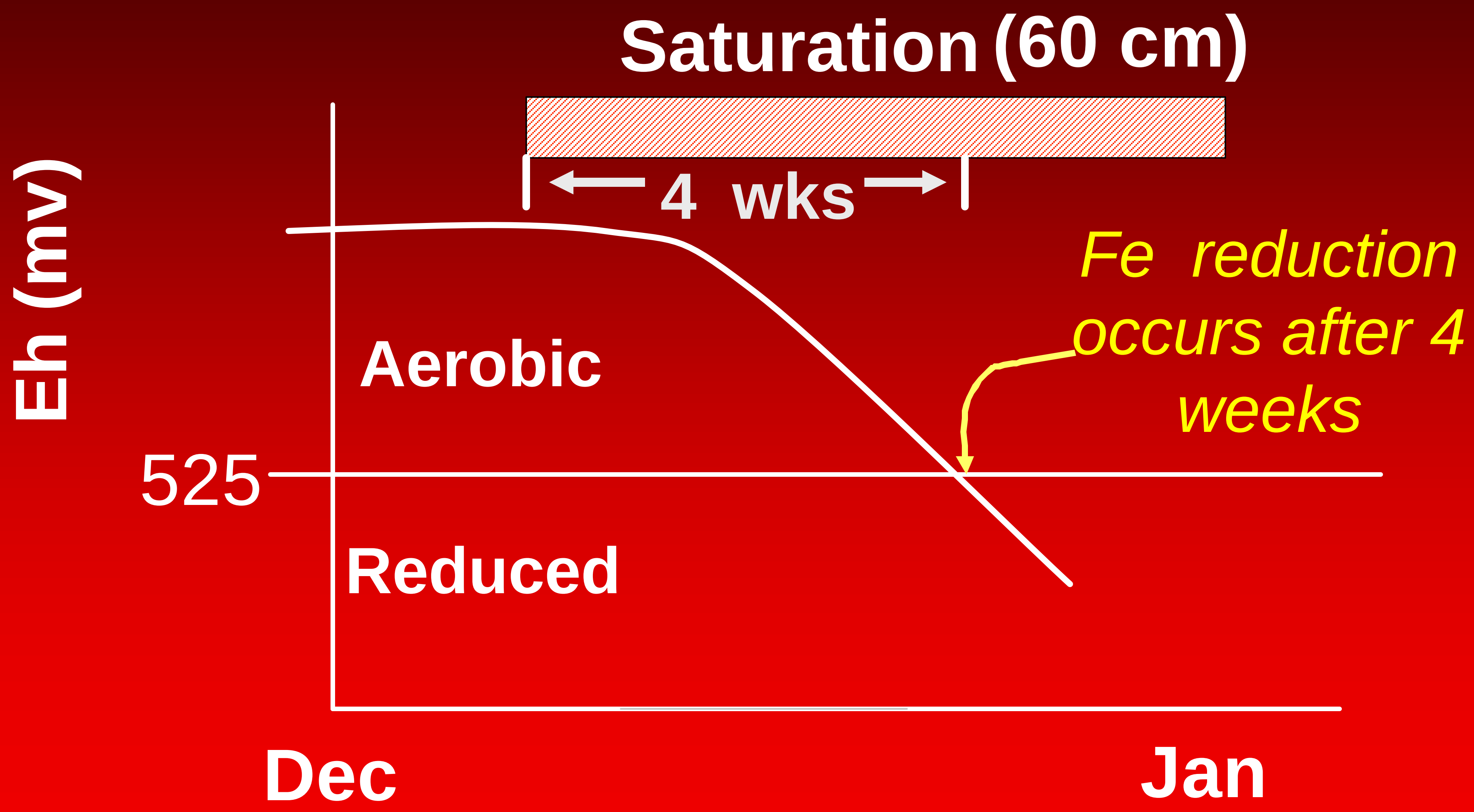
Saturation Parameters

- ***Minimum Duration of Saturation:*** lag between start of saturation and Fe reduction
- ***Saturation Frequency:*** how often the ***Minimum Duration of Saturation*** occurs over time

Estimating Minimum Saturation Durations needed to Reduce Fe

- Redox potential was measured to determine when soils were anaerobic and Fe-reduced
- We assumed the dominant Fe mineral was *goethite*

Finding Minimum Duration of Saturation



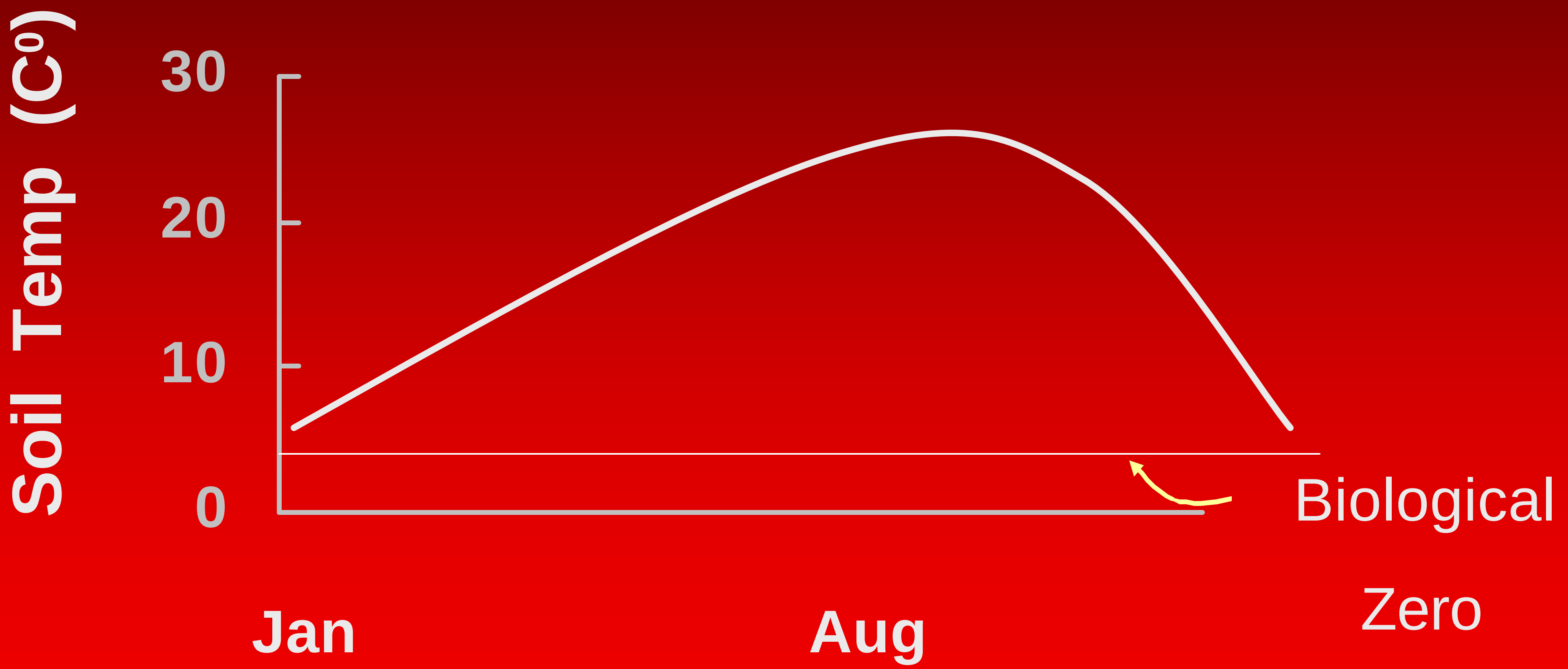
Minimum Durations of Saturation *<u>needed for Fe Reduction to Occur</u>*

<u>Depth</u>	<u>Site 1</u>	<u>Site 2</u>
cm	------------------days	------------------
15	6	45
30	21	5
60	35	21
Mean	*21*	*24*

Minimum Durations of Saturation and Fe Reduction

- Vary with depth for a given site
- Average minimum was 21 days (*winter*)
- Shorter durations of saturation may occur in summer, and where organic matter contents are greater.

Average Daily Soil Temp.



Saturation Events

- Needed a single variable that combined saturation ***frequency and duration***
- Variable used was:

Saturation Event Index (SE)

Saturation Event Formula

For saturation periods $\geq$ 21 days:

- T= no. of times saturation occurs/year
- D= longest period of saturation

$$SE = (T-1) + (D/21\ d)$$

Simulation Data for Site 1, Plot 9, 70 cm

Year	Frequency	Duration	SE
		days	
1959	1	25	1
1960	1	74	3
1998	2	31	2
Mean	--	--	*2.2/yr*

Example

If a soil at 60 cm had a *saturation event index* of 2, then on average over 40 years it might saturate:

- ***once* per year for *42 to 62 days*, or**
- ***twice* per year for *21 to 41 days***

Assumption

A ***long period*** of saturation and reduction produces the ***same percentage*** of gray color as ***two shorter periods*** in a soil horizon.

Saturation Events

- Computed ***by plot*** for depths of 15, 30, 45, 60, 75, and 90 cm.
- Computed ***for each year*** from 1959 to 1998

Saturation Events cont'd.

- Computed ***for periods***:

  During the growing season

  Outside the growing season

  Entire year

- ***Mean values*** (40-yr.) used in regressions

Regression Analyses

Basic equations:

- **SE = slope x *(% redox depletions*)**
- **SE = (A) x *(% redox depletions)* + (B) x *(% redox conc.)***

Results

How accurate were the modeling results?

Model Simulation Results

Predicted and measured
water table levels differed by
<15 cm for most plots
at both sites over a 3-yr. period

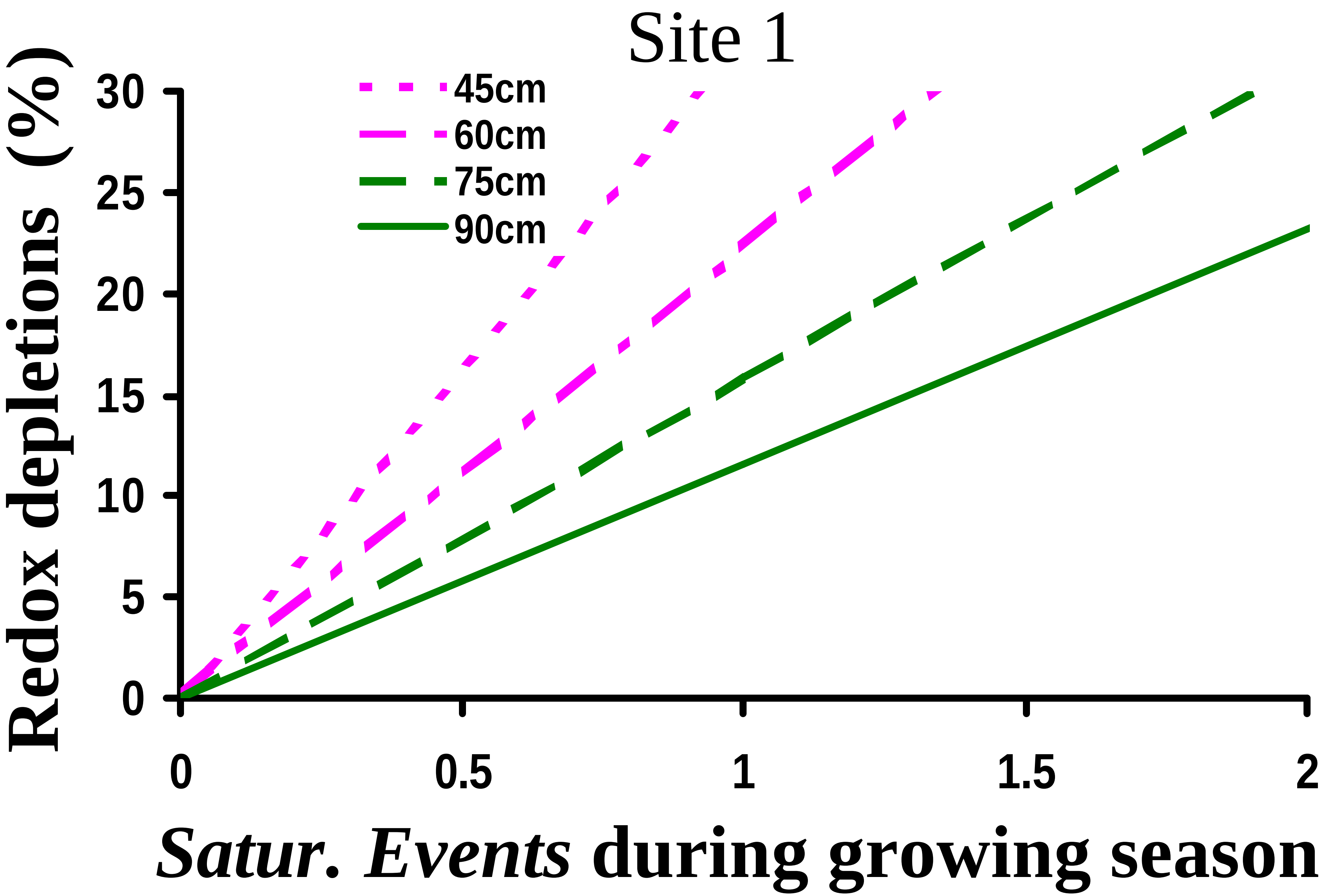
Regression Analyses

Initial data plots showed relationships between ***SE*** and ***Color*** for a site were:

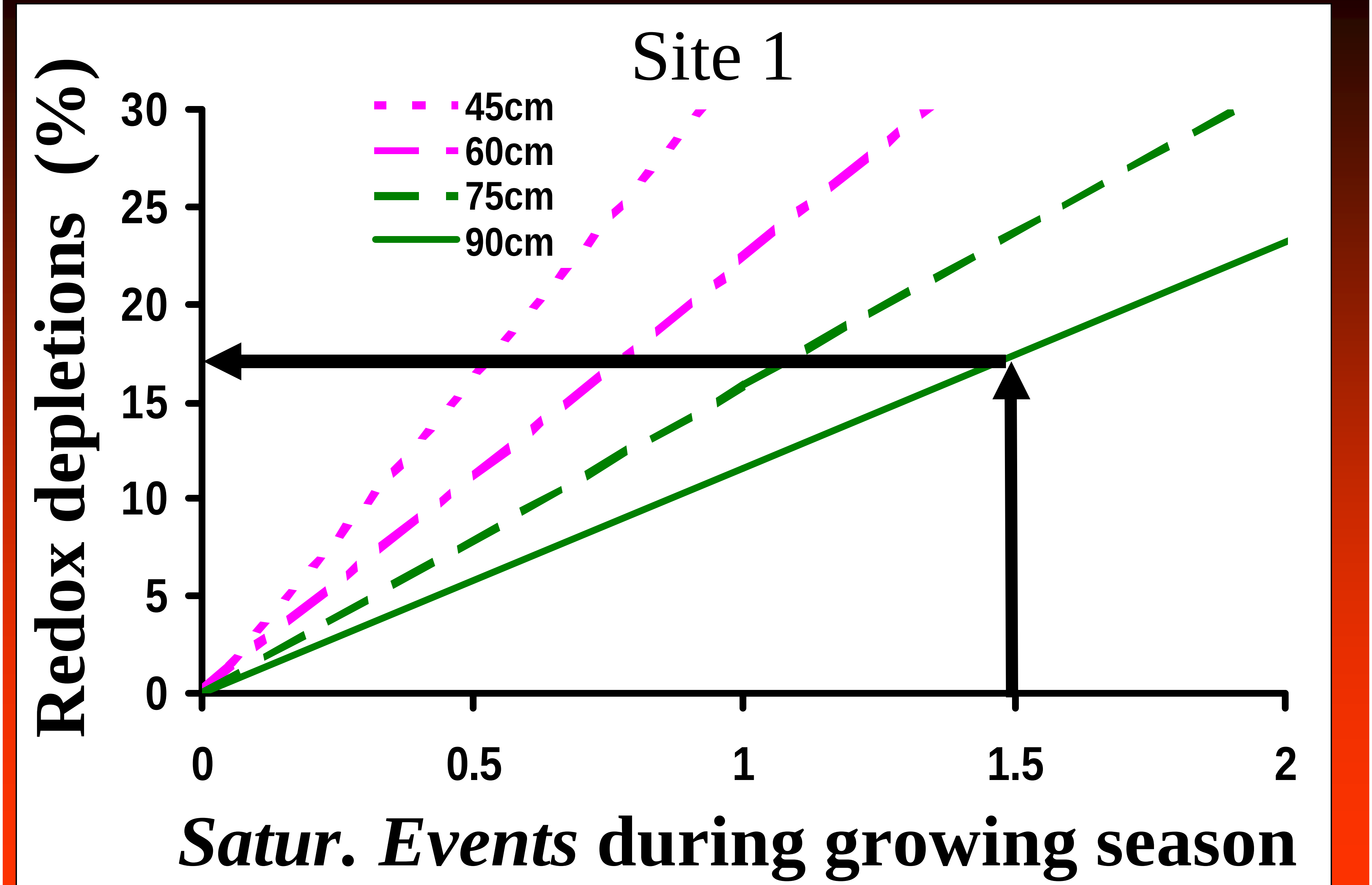
- ***Linear***
- ***Depth dependent***
- ***Soil independent***

Regression Results (r^2) for Relationship between *Saturation Events and % Redox Depletions*

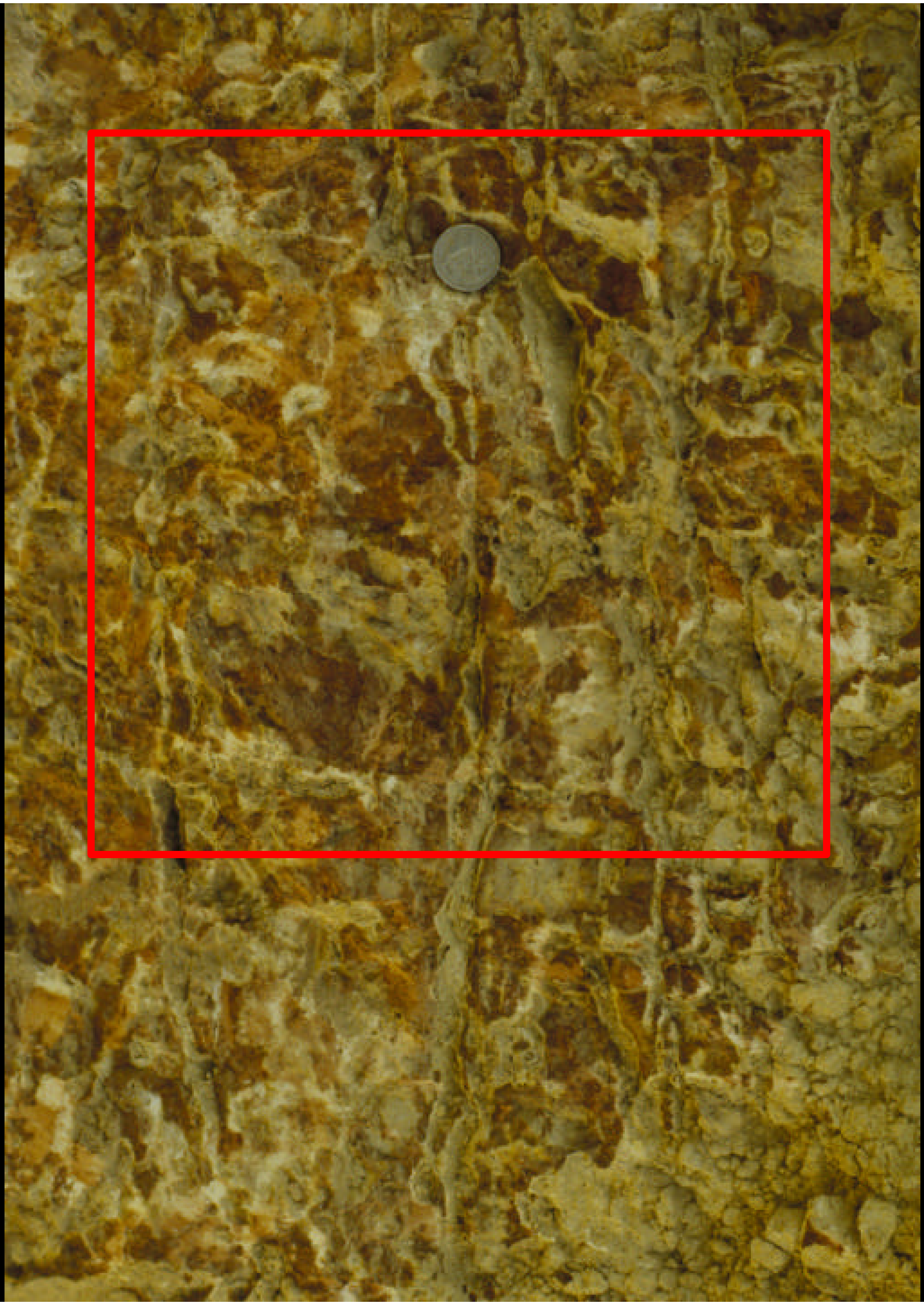
Depth	Site 1	Site 2
30 cm	-----	0.98
60 cm	0.94	0.94
90 cm	0.86	0.91



Site 1
45cm
60cm
75cm
90cm
Redox depletions (%)
30
25
20
15
10
5
0
0
0.5
1
1.5
2
Satur. Events during growing season



Site 1
45cm
60cm
75cm
90cm
Redox depletions (%)
30
25
20
15
10
5
0
0
0.5
1
1.5
2
Satur. Events during growing season



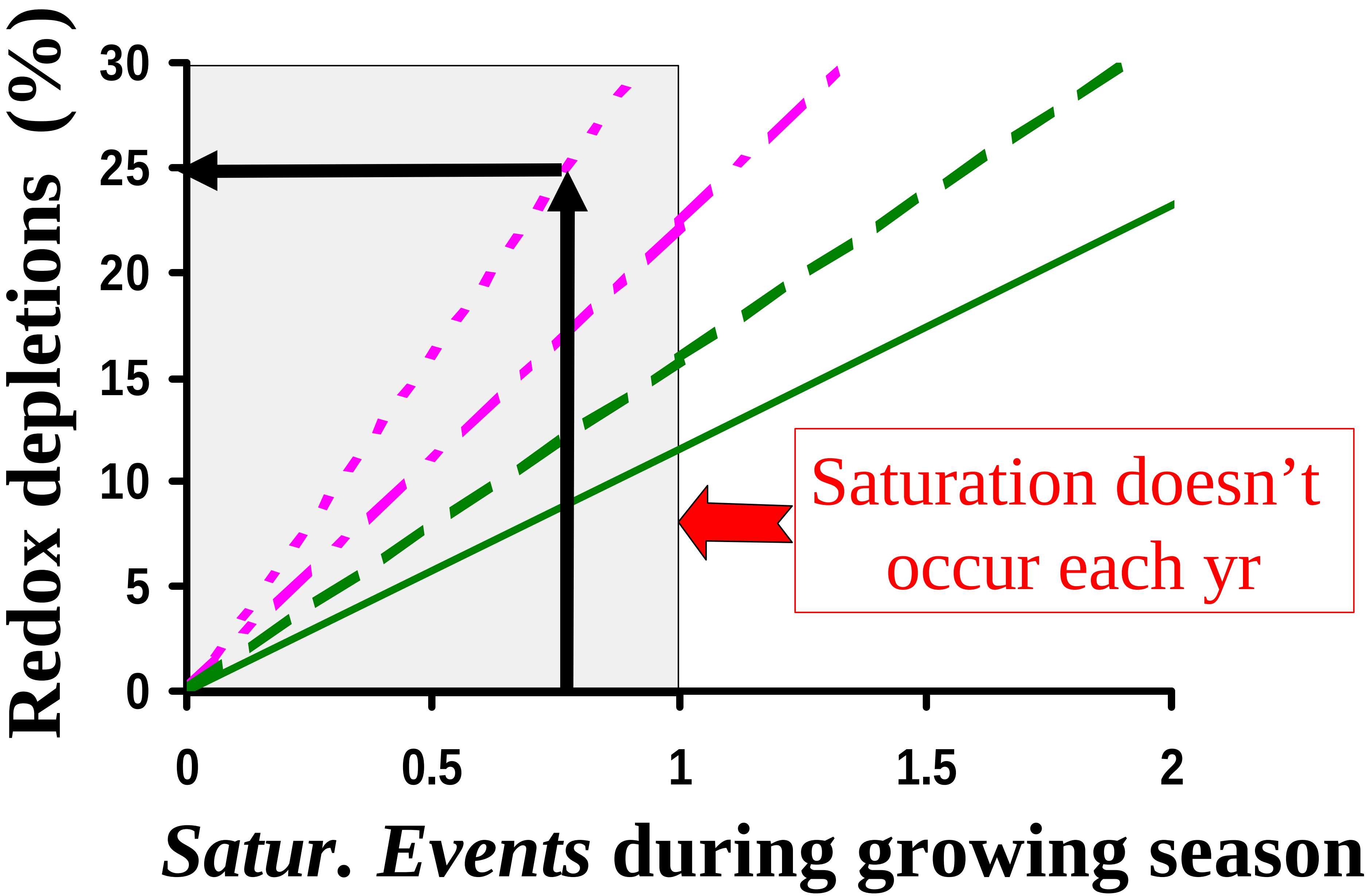
Soil at 75 cm

Contains 60% redox depletions,

Has a *Saturation Event Index* of 2,

and

is saturated for: 42 to 62 d each year

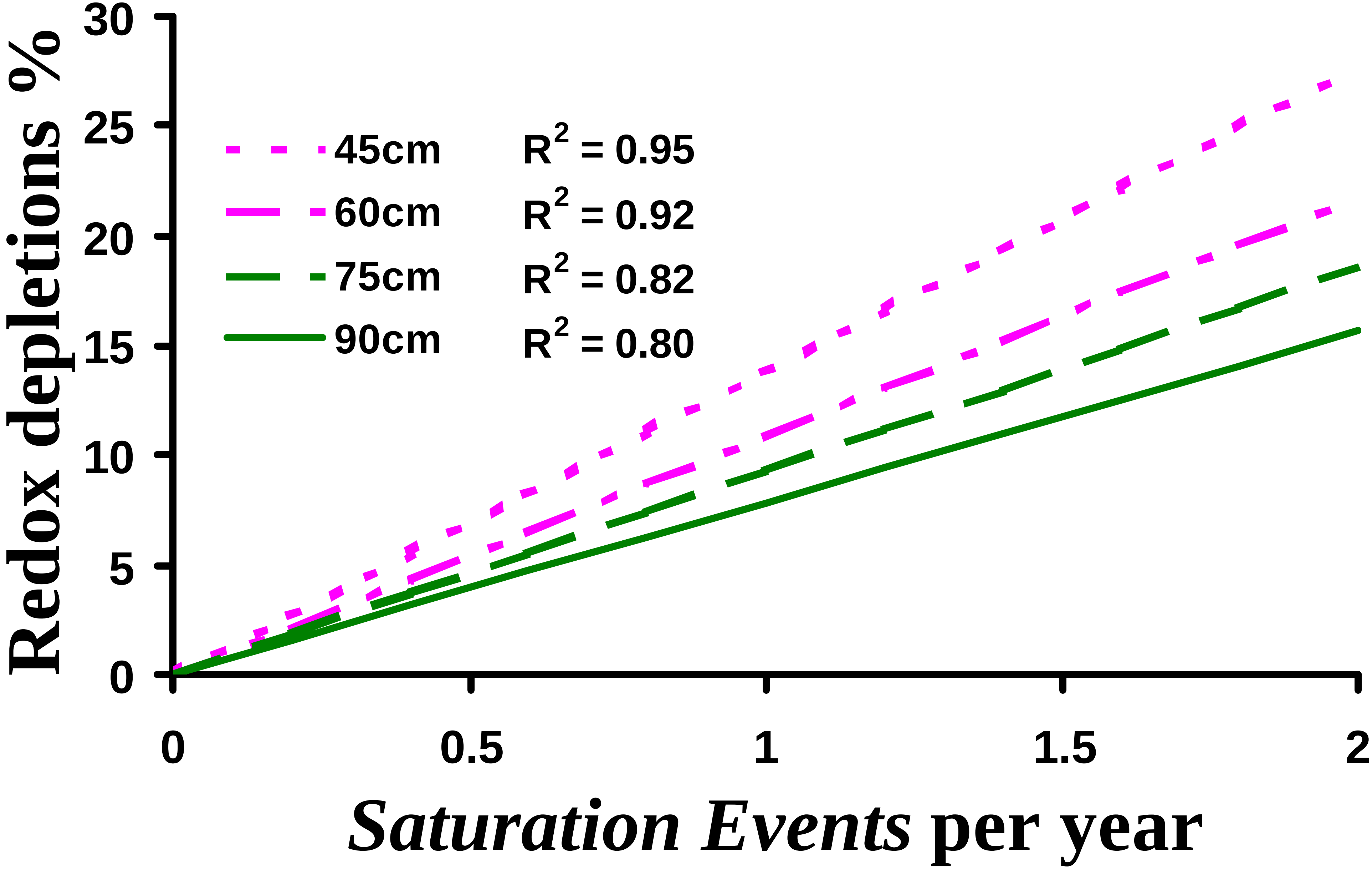

Redox depletions (%)
30
25
20
15
10
5
0
0
0.5
1
1.5
2
Saturation doesn't occur each yr
Satur. Events during growing season

When Saturation Events < 1

Soil saturates for >21 d
less often than every year.

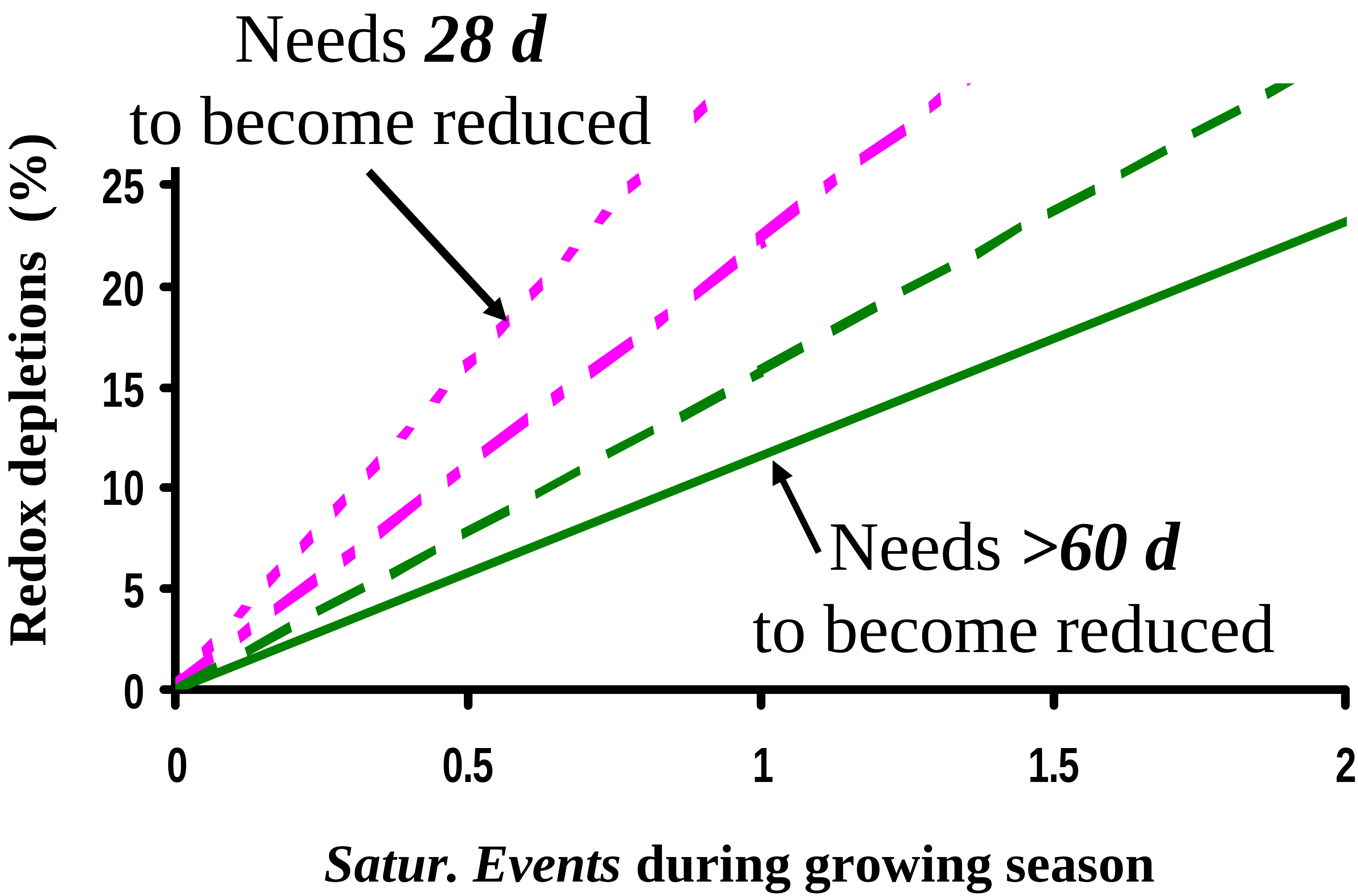
- If SE is ***0.5***, soil saturates ***every other year***.
- If SE is ***0.1***, soil saturates ***once in 10 years***

Sites 1 and 2


45cm R^2 = 0.95
60cm R^2 = 0.92
75cm R^2 = 0.82
90cm R^2 = 0.80
Redox depletions %
0
5
10
15
20
25
30
0
0.5
1
1.5
2
Saturation Events per year

Why Do Lines Have Different Slopes?

Hypothesis: Slopes are related to ***length of time needed*** for a saturated soil to become reduced at depth of interest.


Needs 28 d
to become reduced
Needs >60 d
to become reduced
Redox depletions (%)
25
20
15
10
5
0
0
0.5
1
1.5
2
Satur. Events during growing season

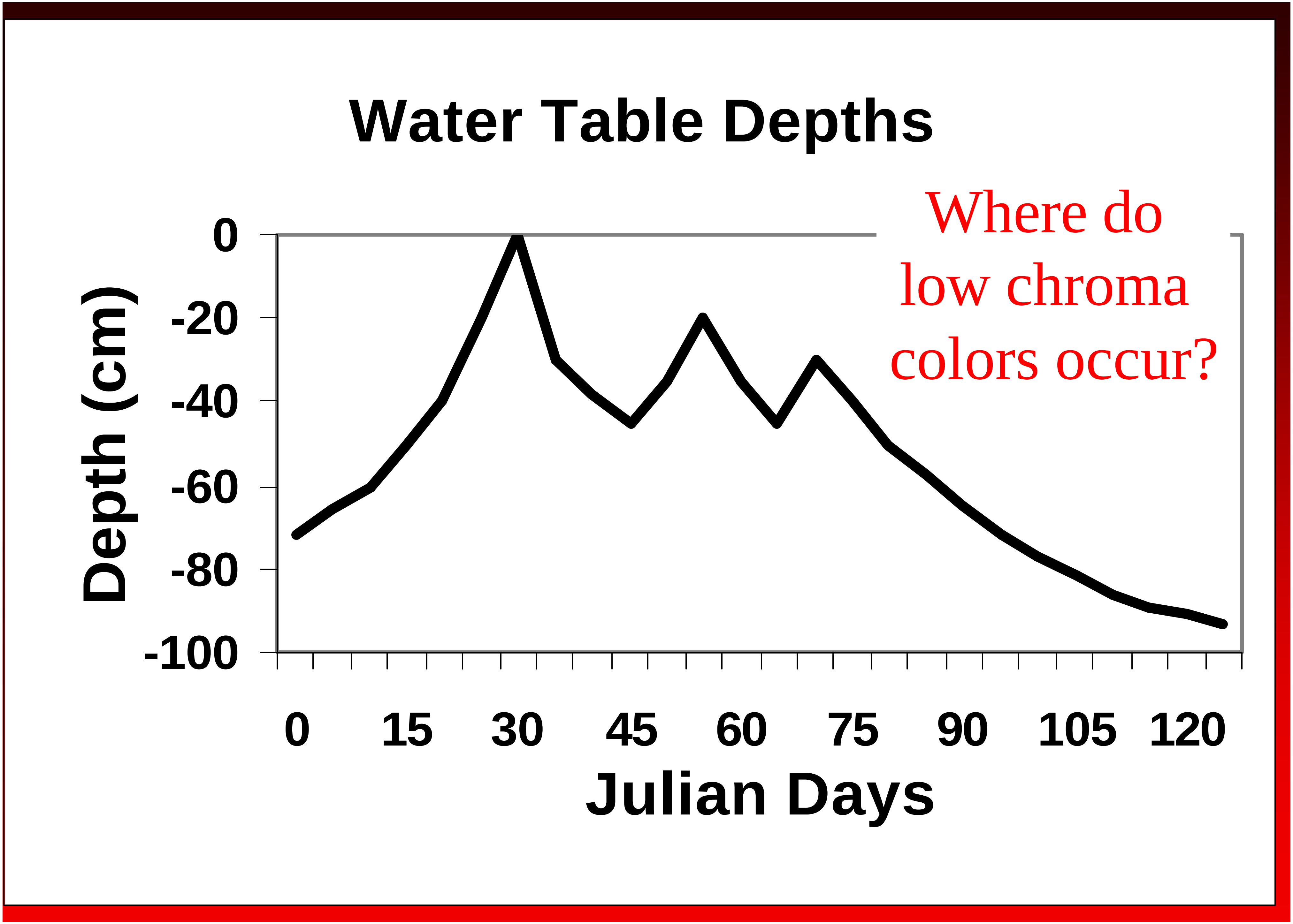
Objectives

1. Review calibration of ***gray colors*** to long-term ***saturation*** frequency and duration.
2. Review ***applications*** of results.

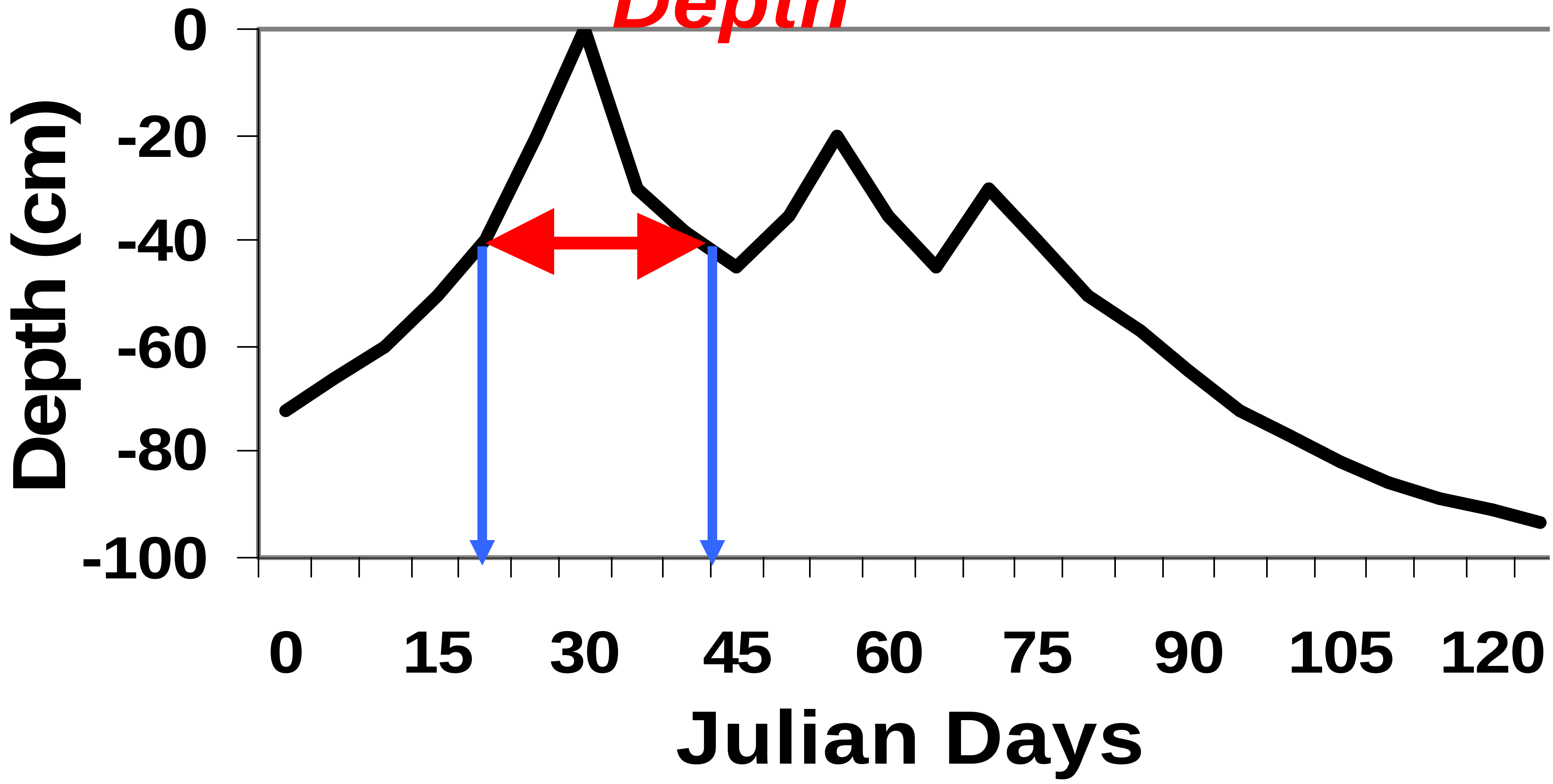
Relating Hydrographs to SHWT

You may be asked by a judge to ***verify*** your predictions of SHWT.

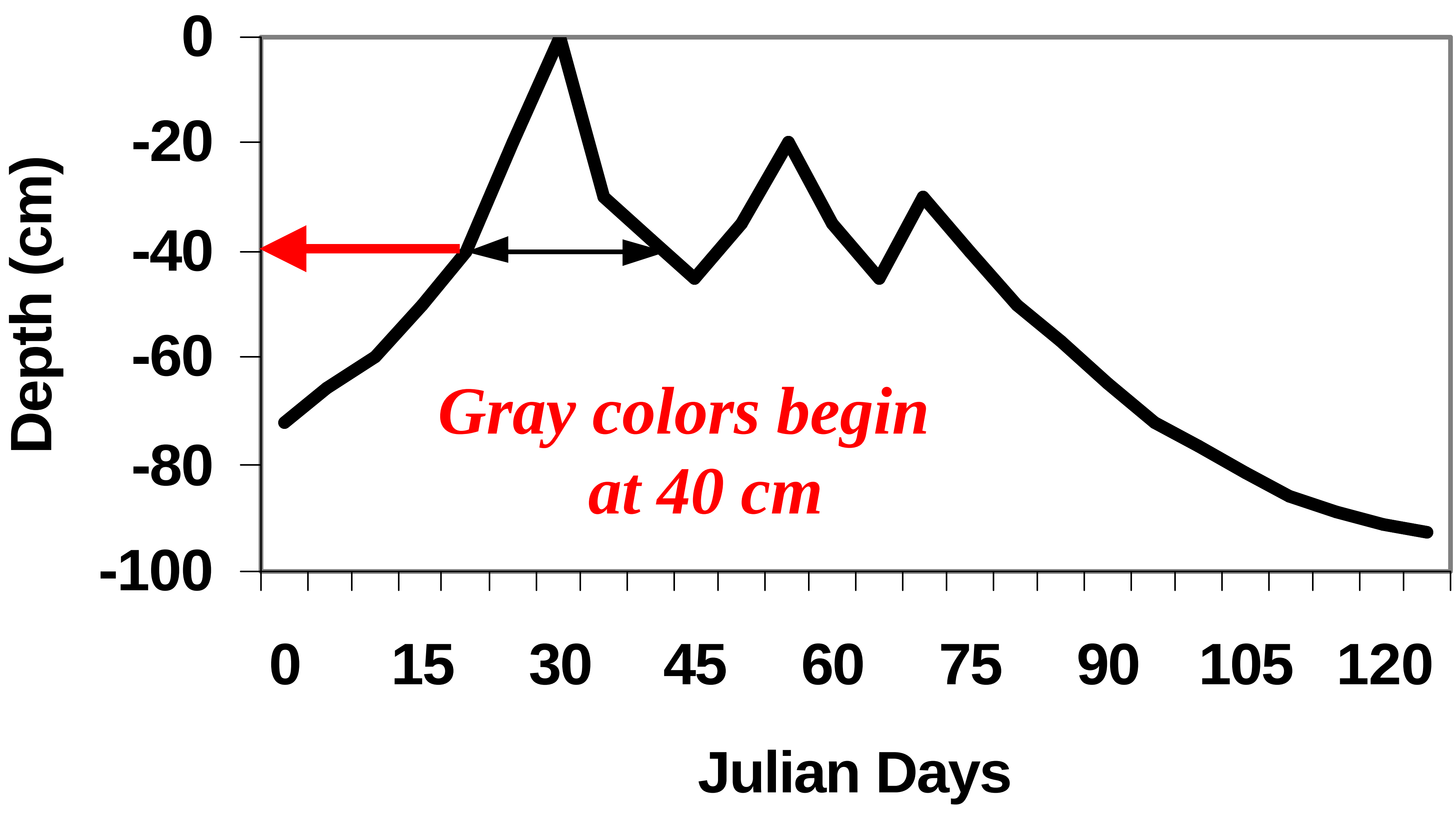
This can be done using ***daily water table measurements*** during the ***wet period*** of a year of ***normal*** rainfall.


Water Table Depths
Where do low chroma colors occur?
Depth (cm)
0
-20
-40
-60
-80
-100
0
15
30
45
60
75
90
105
120
Julian Days

Find the "21-day Saturation Depth"



Depth to SHWT is 40 cm



Wetlands

Identified on the basis of three parameters:

- ***Hydrology***
- ***Soils***
- ***Vegetation***

Hydric Soils

- Must have been *saturated and anaerobic* for part of the growing season
- Identified by *color characteristics* that are rigidly defined (*field indicators*)

Relationship of Hydric Soil Field Indicators and Wetland Hydrology

Depleted Matrix field indicator:

- A layer of soil within 25 cm of surface, with $\geq$60% redox depletions and $\geq$ 2% redox conc.

Hydrology needed for a Depleted Matrix

- At site 2, layers with a depleted matrix had a SE index of 1.
- These layers ***saturate each year during growing season for 21 to 41 days.***

Conclusions

- ***Percentages of*** *redoximorphic features can be calibrated to* ***soil hydrology.***
- *Relationships* ***vary*** *among soils (sites) with different* ***minimum saturation: Fe reduction*** *relationships.*

Conclusions cont'd.

- ***Depth to "<u>Seasonal High Water Table</u>" was point where soil was saturated for "21" consecutive days.***

Conclusions cont'd.

- ***At site 2, the depleted matrix field indicator could be used to identify soils meeting the wetland hydrology requirement.***

The End

Conclusions cont'd.

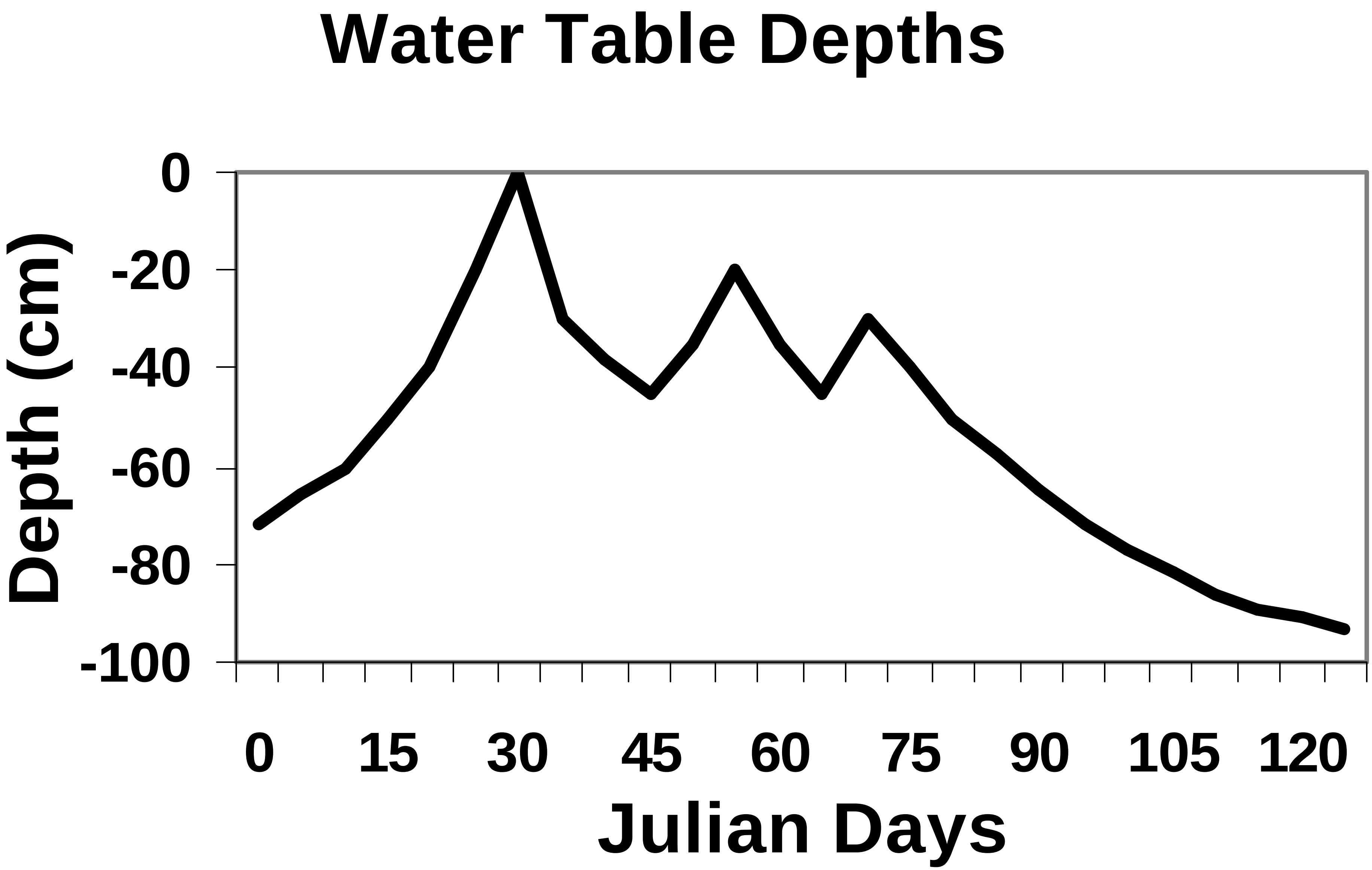
The "21-day" Technical Standard was accepted in principle by a judge in NC, but modified to 14-days of saturation.

Technical Standard

*System for measuring **hydrologic, climatic, and soil chemical properties** to verify morphological interpretations for **regulatory** purposes.*

Measurements

1. Water table levels--***daily preferred for modeling***
2. Rainfall-***daily, onsite***
3. Redox potential-***weekly*** (needed for ***some*** applications)


Water Table Depths
Depth (cm)
0
-20
-40
-60
-80
-100
0
15
30
45
60
75
90
105
120
Julian Days

Duration of Measurements

- ***Ideal***: ***Long-term*** preferred (e.g. 40 yrs.) to establish scientific basis for technical standard
- ***Practical***: One wet season

4-Step Approach

For a *hillslope* of soils:

- ***Calibrated*** a hydrologic model
- Computed water table levels for ***40-yr.*** period

Approach cont'd.

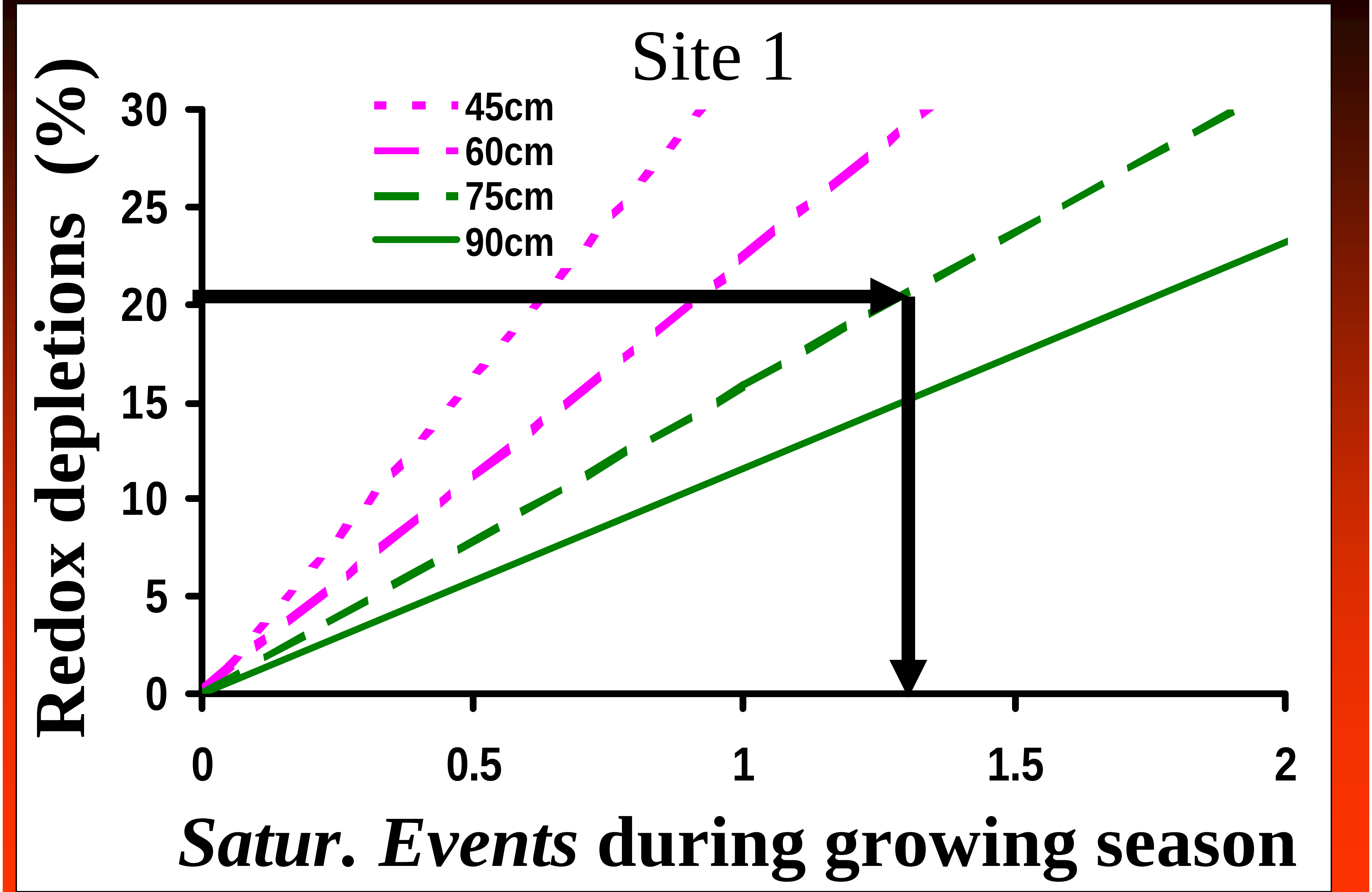
- Computed annual saturation parameters (***frequency of critical durations***)
- Correlated saturation data to ***percentages of gray and red soil colors***

Goal for Research

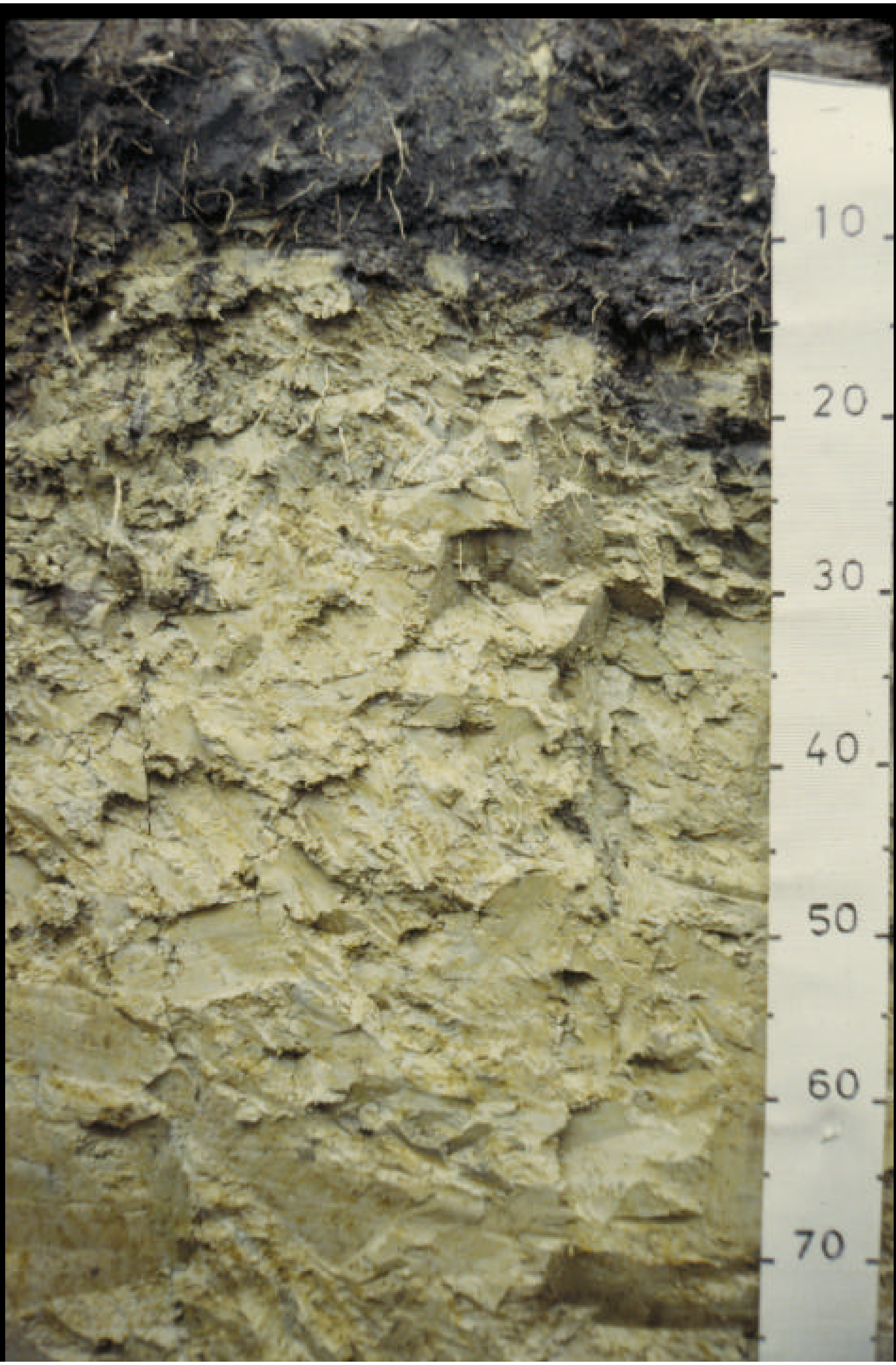
- Determine relationships between ***long-term*** water table measurements and ***percentages of redox. features***.
- Develop a technical standard to find equivalent ***depth*** to SHWT from a ***hydrograph.***

Soils Textures

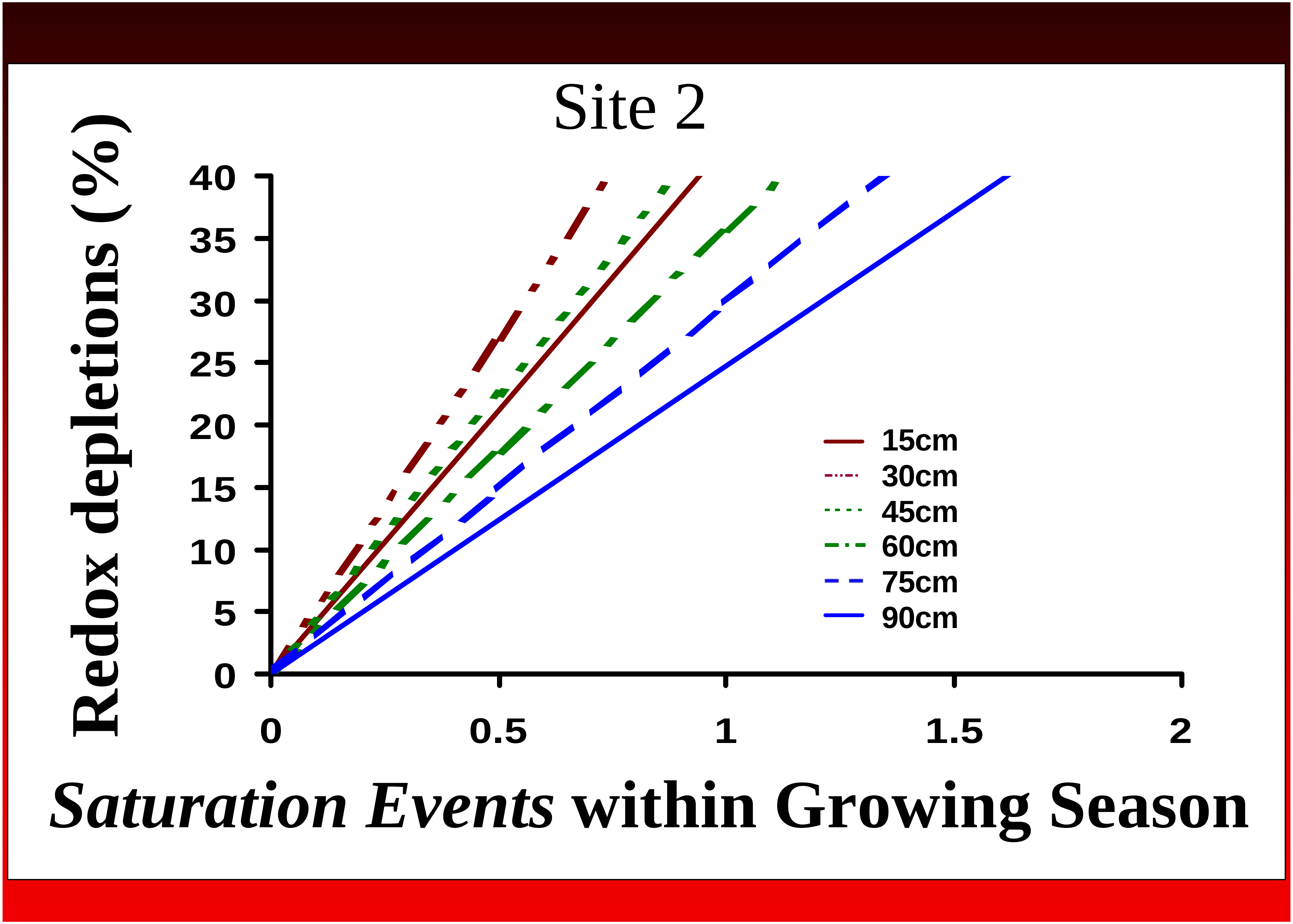
- At site 1 soil textures were ***sand, sandy loam, and sandy clay loam***
- At site 2 soil textures were ***silt, silt loam, and silty clay loam***.



Site 1
Redox depletions (%)
30
25
20
15
10
5
0
45cm
60cm
75cm
90cm
0
0.5
1
1.5
2
Satur. Events during growing season



10
20
30
40
50
60
70



Site 2
Redox depletions (%)
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
Saturation Events within Growing Season
15cm
30cm
45cm
60cm
75cm
90cm