

# Transparency:

A function of suspended solids and chlorophyll

Flathead Lake Nutrient Standards

Advisory Group Meeting

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Polson, MT

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# Purpose

- To illustrate the relative importance of both suspended solids and chlorophyll in affecting transparency
- To provide a mathematical basis to determine relevant parameters

# Light Transmission (Beer's Law)

$$I_d = I_0 e^{-K(d)}$$

$I_d$  = Light intensity at depth,  $d$

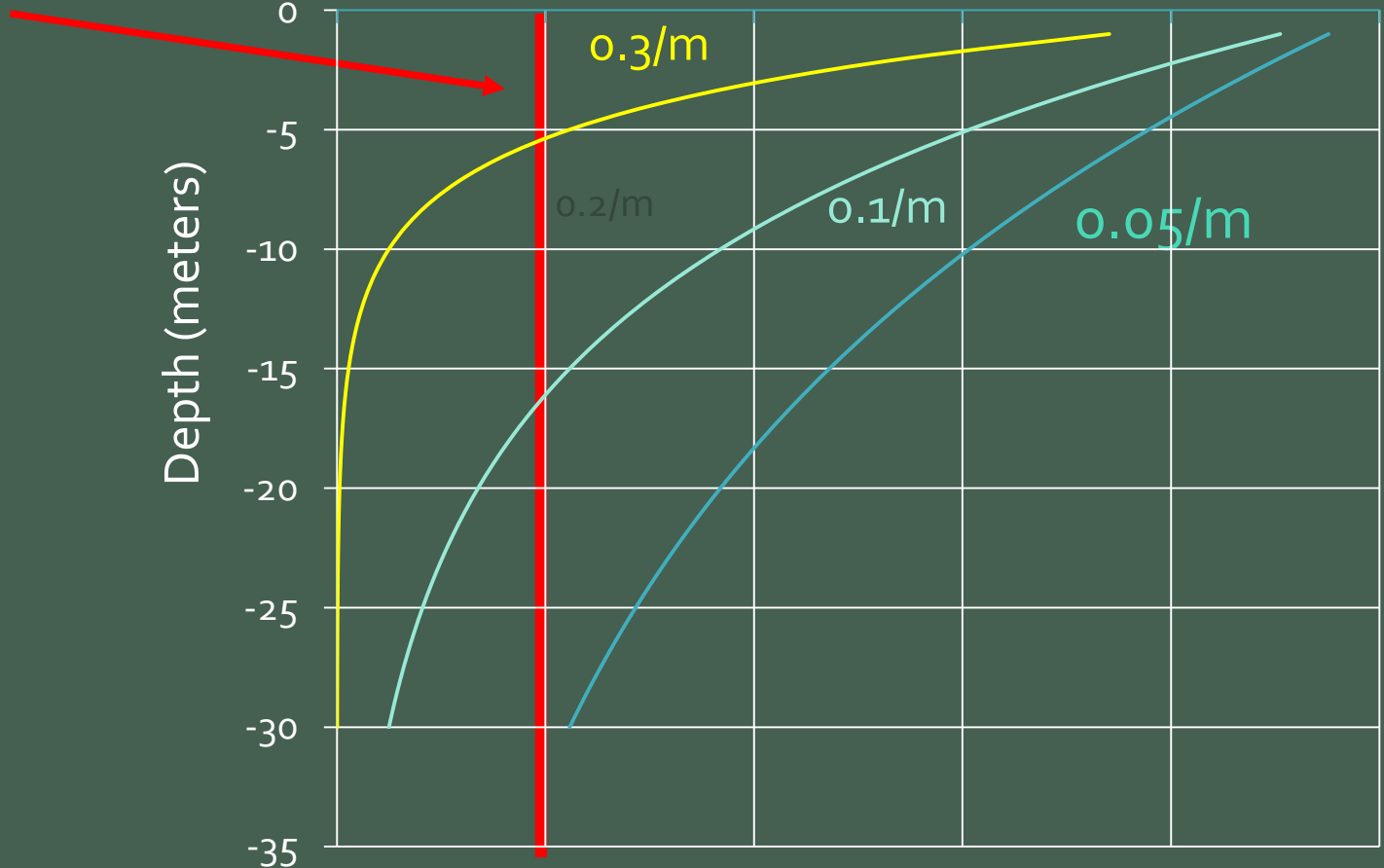
$I_0$  = Surface light intensity

$K$  = Attenuation coefficient

# Light penetration for different K values

Light Penetration  
(Fraction of Surface light)

Secchi Disc



# Attenuation Coefficient (K)

$$K = \sum (a_0 + a_1 c_1 + a_2 c_2 \dots + a_i c_i)$$

$a_i$  = Incremental attenuation from substance  $i$

$c_i$  = Concentration of substance  $i$

Let:

$a_0$  = Pure water

$c_1$  = Suspended Solids, mg/l (SS)

$c_2$  = Chlorophyll a,  $\mu\text{g/l}$  (Chl)

# “Assumptions”

$$a_0 = 0.05 / \text{m}$$

$$a_1 = 0.25 / \text{m} / \text{mg} / \text{l}$$

$$a_2 = 0.02 / \text{m} / \mu\text{g} / \text{l}$$

$$\text{Secchi Depth, SD} = 20\%$$

$$I_{\text{SD}} / I_0 = 0.2$$

# Secchi Disc (SD)

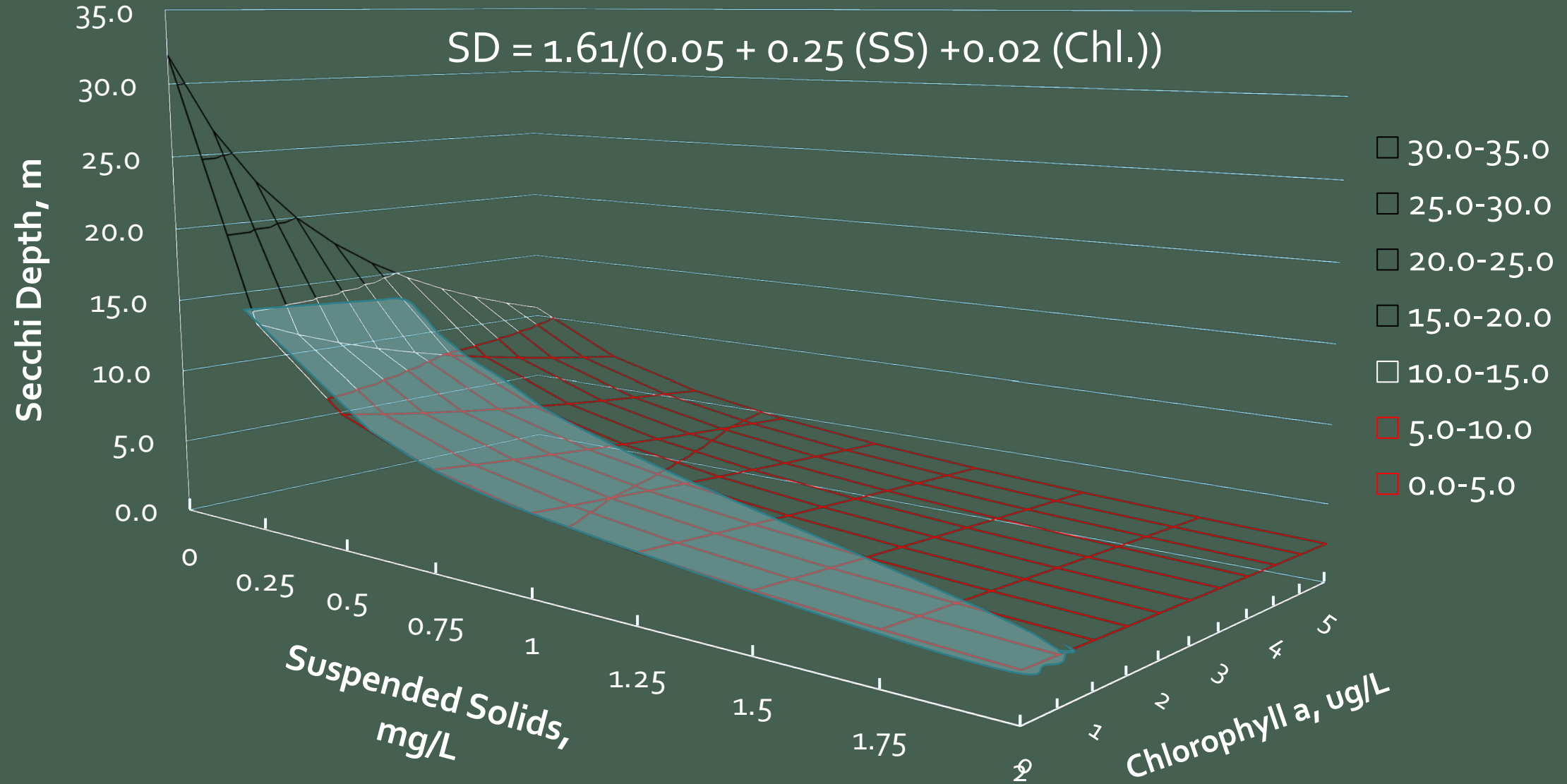
$$\begin{aligned} I_{SD} &= I_0 e^{-K(d)} \text{ (Beer's Law)} \\ &= I_0 e^{-(0.05 + 0.25(SS) + 0.02(Chl.)) SD} \end{aligned}$$

$$I_{SD} / I_0 = 0.2 = e^{-(0.05 + 0.25(SS) + 0.02(Chl.)) SD}$$

$$\ln(0.2) = -(0.05 + 0.25(SS) + 0.02(Chl.)) SD$$

$$SD = 1.61 / (0.05 + 0.25(SS) + 0.02(Chl.))$$

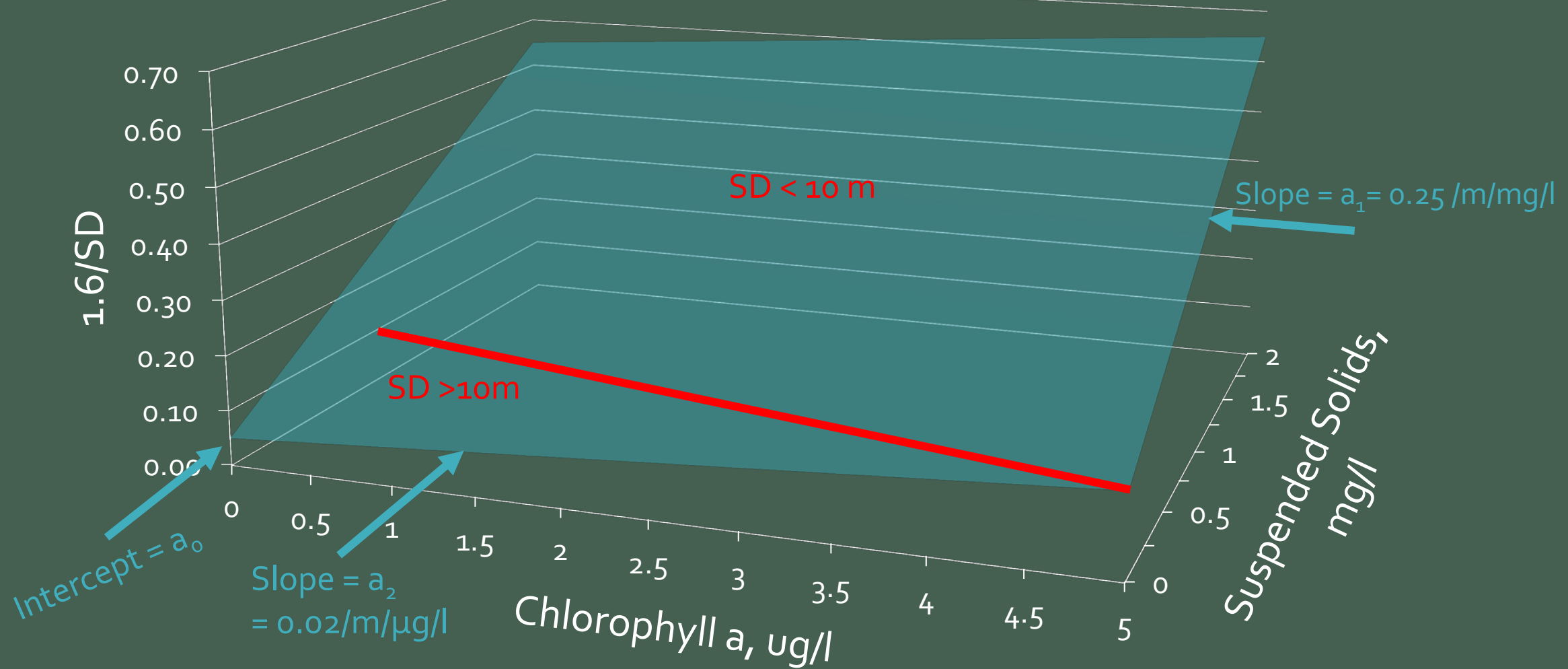
# Combined Effects of Chlorophyll *a* and Suspended Solids on Secchi Depth



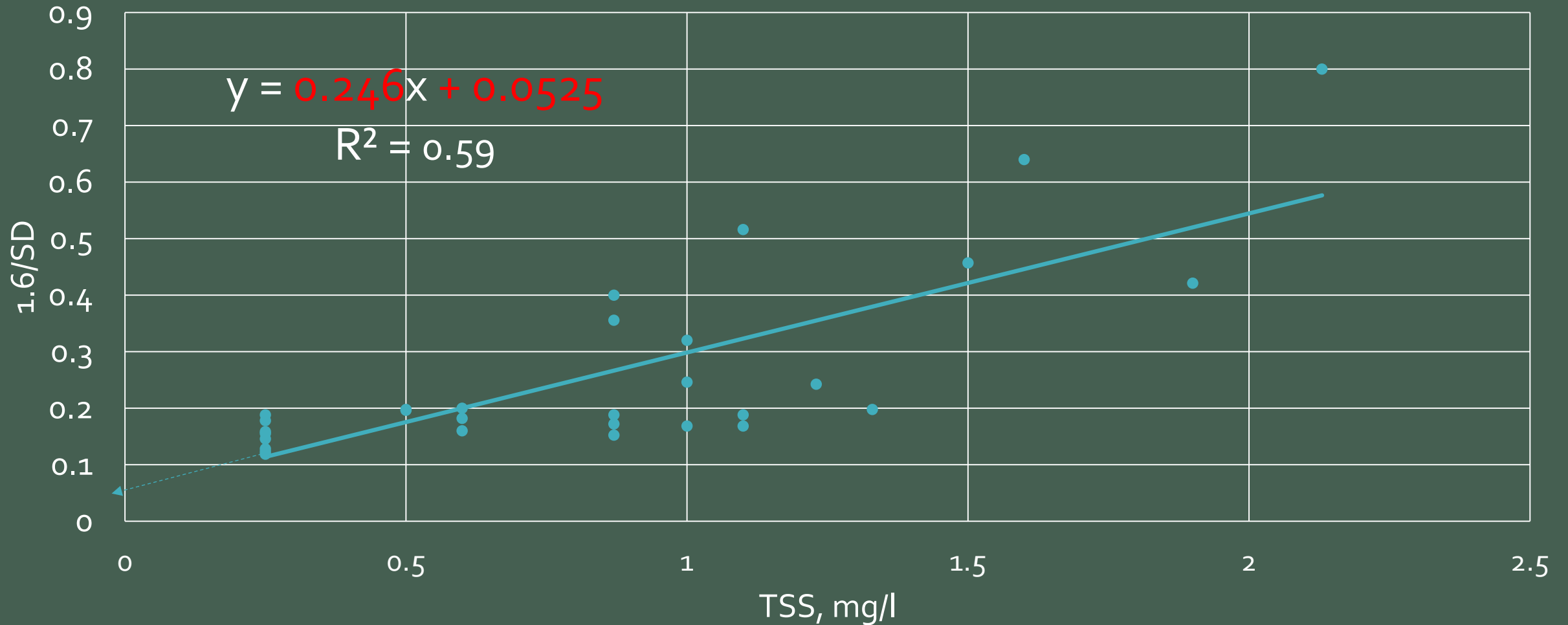


# Combined Effects of Chlorophyll and Suspended Solids On Secchi Disc (Linearized)

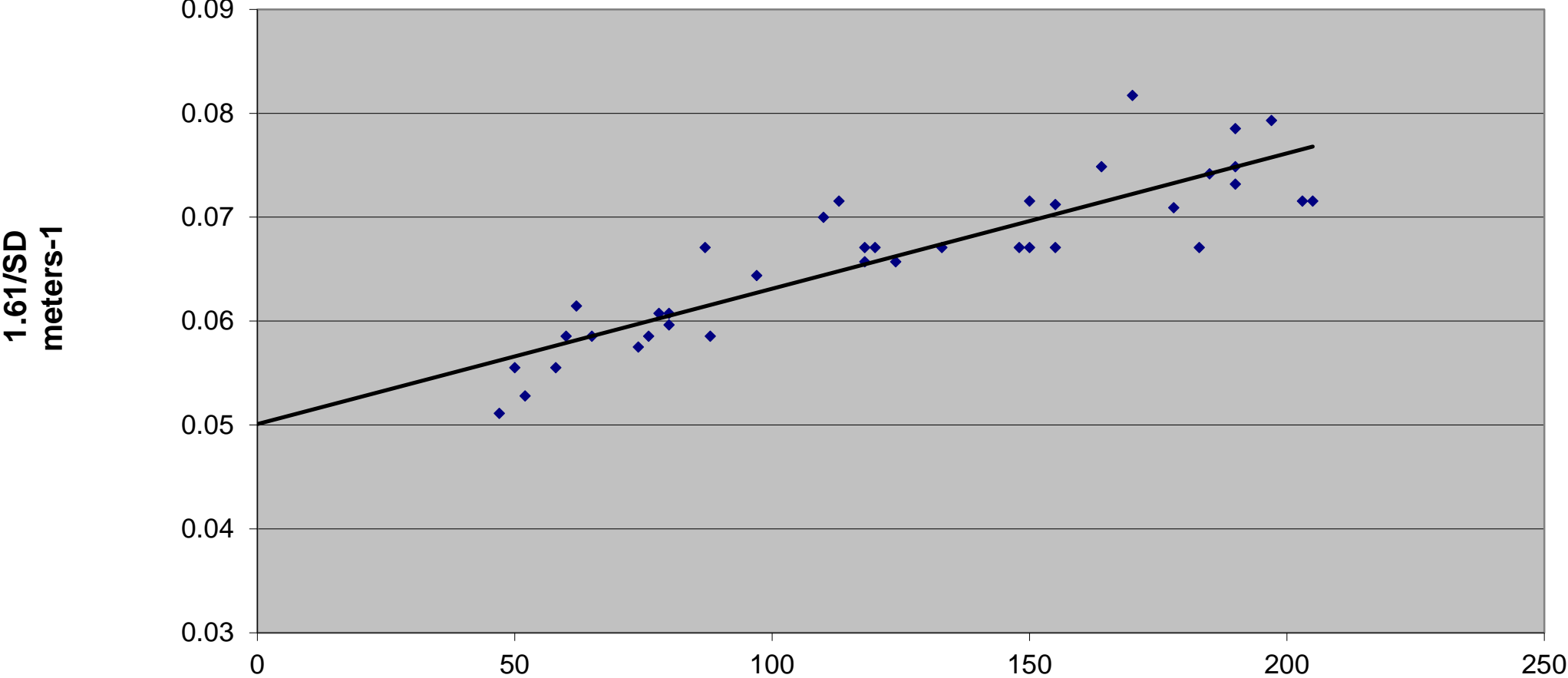
$$1.61/SD = 0.05 + 0.25 (SS) + 0.02 (Chl.)$$



# Sediment Beneficial Use Support Assessment Flathead Lake (Nov. 2014)



# Lake Tahoe



**g/m2/yr**  
**Primary Production**

$y = 0.0001x + 0.0501$   
 $R^2 = 0.7818$

# Conclusions

- Suspended Solids  $\geq 0.5$  mg/l  $\longrightarrow$  Secchi Disc  $\leq 10$   
(With zero Chlorophyll)
- Suspended Solids = 0
  - Chlorophyll =  $1.5$   $\mu$ g/l  $\longrightarrow$  Secchi Disc = 20 m
  - Chlorophyll =  $3.0$   $\mu$ g/l  $\longrightarrow$  Secchi Disc = 14.6 m

$0.5$  mg/l Suspended Solids =  $6.4$   $\mu$ g/l Chlorophyll

# Recommendations

- The parameter values ( $a_0$ ,  $a_1$ ,  $a_2$ ) be better quantified with Flathead Lake data:
  - Secchi Disc
  - Suspended Solids
  - Chlorophyll
  - Transparency (Attenuation Coefficient)

# Recommendations (Con't.)

- Refine Chlorophyll – Phosphorus Relationship
  - Consider Maximum Chlorophyll Concentrations
  - Consider Depth Average to SD

# Recommendations (Con't.)

- Phosphorus Mass Balance

- Influent
- Mid-Lake
- Effluent



Retention Coefficient