New and Improved
EPA Lagoon Design Manual

14 MGD
480 acres
1.2 miles
Image State of Utah
Google
41°44'36.90" N 111°53'26.11" W elev 4419 ft
Eye alt 14311 ft

Manual Layout

1. Introduction
2. Planning, Feasibility Assessment and Site Selection
3. Design Of Municipal Wastewater Stabilization Ponds
4. Advanced Design Systems
5. Nutrient Removal
6. Physical Design and Construction
7. Upgrading Pond Effluents
8. Cost and Energy Requirements
9. Operation and Maintenance

Introduction

Basic Processes
- Anaerobic
- Facultative
- Aerobic

In Pond Design Evolution and Enhancements
- AIWPS™ (Oswald)
- Deep Sludge Pits
- High Performance Shallow Ponds
- BIOLAC™

Oxygen Addition
- LAS International, Ltd.
- PRAXAIR, Inc.

Introduction

Modifications that require energy

- Partial Mix
- Complete Mix
- High-Performance Aerated Ponds (Rich)
- BIOLAC™

Nutrient Removal

- Nitrogen
  - In pond
  - Modified high performance aerated systems for nitrification/denitrification
  - In pond with wetlands and gravel bed filters
- Phosphorus

Introduction

Effluent TSS (Algae) Removal

- Lemna
- Algae settling basins
- Barley straw

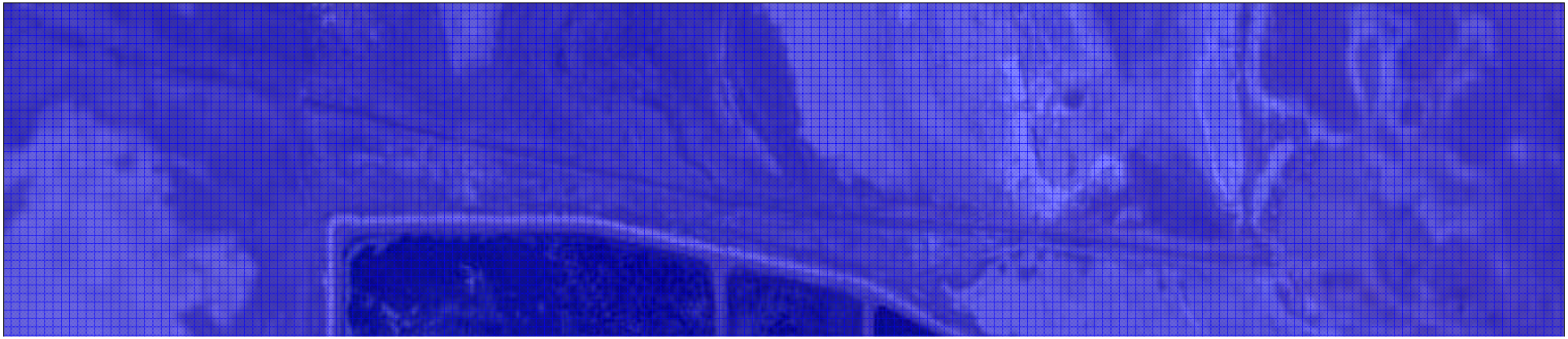
Planning, Feasibility Assessment and Site Selection

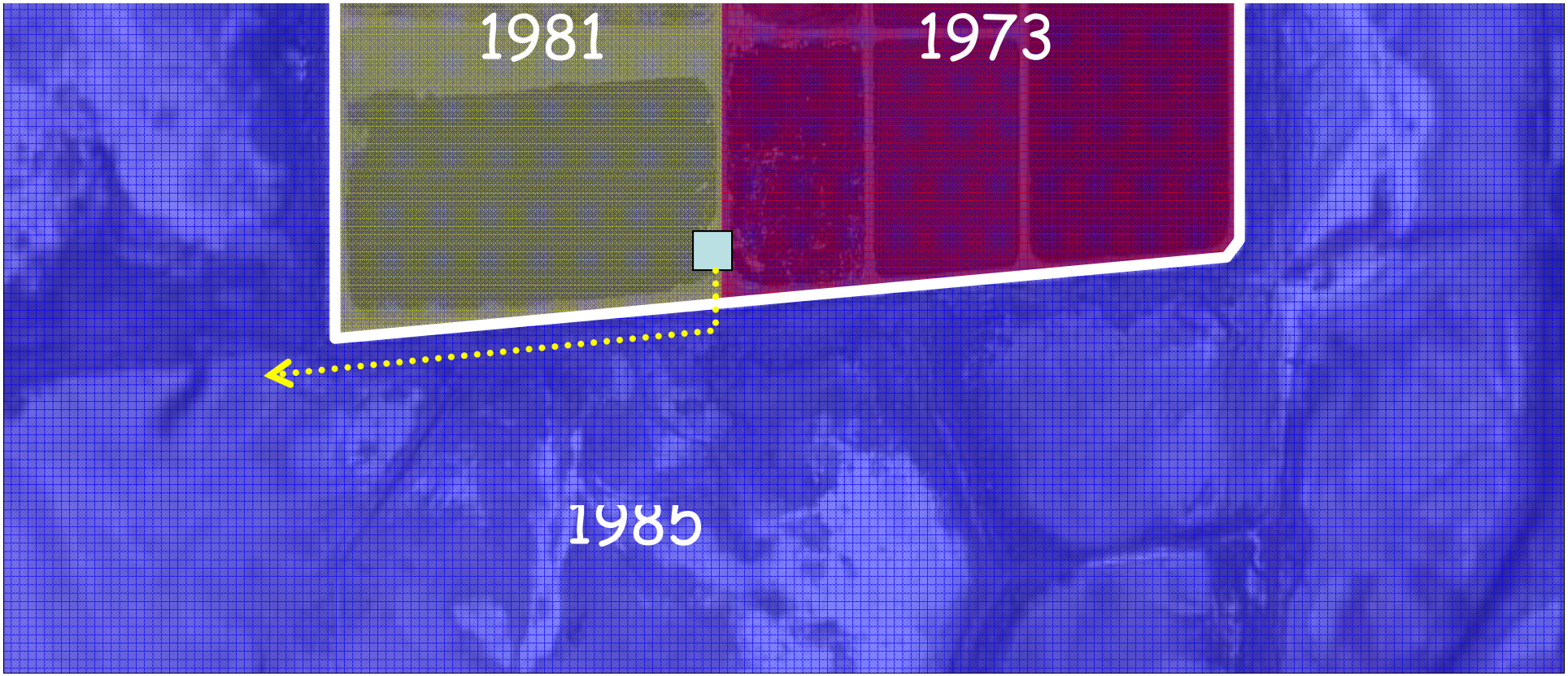
- Estimates for Land Area
- Potential for Floods
- Water Rights

Planning, Feasibility Assessment and Site Selection

- Land Area Estimates for 1 MGD Systems

Treatment System	North	Mid-Atlantic	South
Facultative	165	110	50
Controlled Discharge	160	160	160
Partial-Mix Aerated	50	35	30
Complete-Mix Aerated	5	5	2.5
AIWPS™	30	20	15




1981
1973
1985

Design Of Municipal Wastewater Stabilizationp onds

- Anaerobic ponds
- Facultative ponds
- Aerated pond systems

Anaerobic ponds

Advantages

- Infrequent sludge removal
- High degree of stabilization is possible
- Low or no energy requirements
- Ease of operation

Disadvantages

- Incomplete BOD_5 removal
- Odors
- Processes are sensitive to temperature

Facultative ponds

Advantages

- Infrequent sludge removal
- Effective in removing settleable solids, BOD_5, pathogens, fecal coliform, and, to a limited extent, ammonia
- Easy to operate
- Requires little energy, particularly if designed to operate with gravity flow

Facultative ponds

Disadvantages

- Sludge accumulation is higher in shallow facultative ponds and in cold climates
- Ammonia levels in effluent are not easy to control in all seasons
- Emergent vegetation must be controlled to avoid creating breeding areas for mosquitoes and similar insect vectors
- Requires relatively large areas of land due to shallow depth
- Objectionable odors occur if the aerobic blanket decreases and during spring and fall pond turnover

Aerobic ponds

Advantages

- The advantages are similar to those for conventional facultative ponds with more reliable BOD_5 removal. Significant nitrification of ammonia is also possible, given sufficient mean cell resident time (MCRT). Added O_2 allows for more treatment in less space and reduces the potential for noxious odors.

Disadvantages

- The disadvantages relate to the increased capital and operation and maintenance costs, including the need for more and better trained staff.

Aeration Types

Diffused

- Course bubble
- Fine bubble

Mechanical

- Fixed
- Splash
- Floating
- Turbos

Advanced Design Systems

- Advanced Integrated Wastewater Pond Systems®
- Systems with Deep Sludge Cells
- High-performance Aerated Pond System (Rich design)

Advanced Integrated Wastewater Pond Systems®

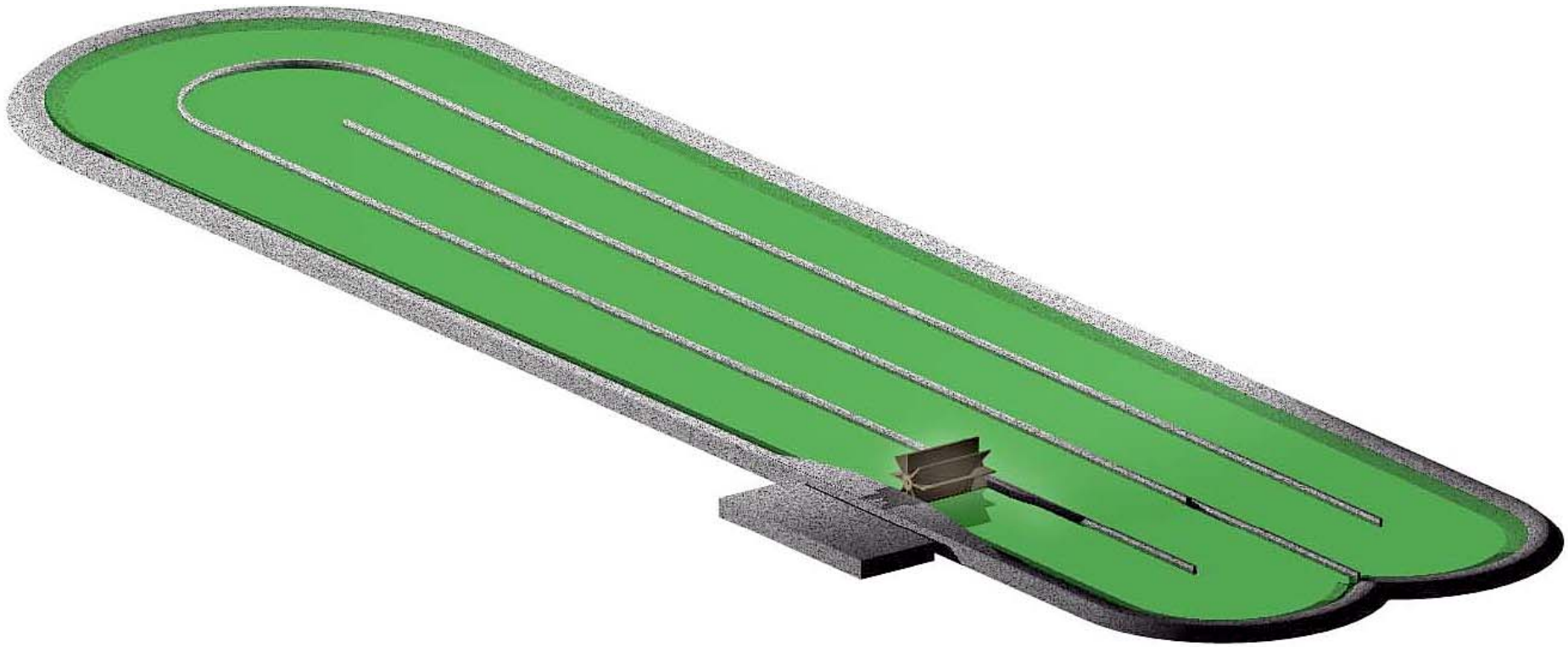
Anaerobic Pretreatment Cell

- HRT = 2 days
- Integrate fermentation pits
- Influent contacts anaerobic biomass
- Provide mechanism for solids removal piping and hookups for vacuum truck
- Several pits in a single pond vs. several ponds each with single pit
- Stuck in acid phase
- Low levels inhibit methane production
- Add alkalinity if needed

Advanced Integrated Wastewater Pond Systems®

Cell #2: Secondary or High Rate Pond

- Oxic environment for dissolved solids digestion
- Oxygen supplied by mechanical aeration equipment or algae using shallow racetrack design with paddle wheel mixer
- Depends on available sunshine



Advanced Integrated Wastewater Pond Systems®

Cell #3: Settling Pond

- Algae removal
- HRT of 1 to 2 days

Cell #4: Maturation Pond

- Provides storage after chlorination
- HRT of 10 to 20 days

Systems with Deep Sludge Cells

Variation of AIWPS

- Cell #1: Anaerobic cell
- Cell #2: Aerated cell
- Cell #3: Settling cell
- Recirculation from cell 3 to cell 1 for odor cap
- HRT of 15 to 20 days

High-performance Aerated Pond System

Two cell system

- Complete mixed cell
- Settling basin
- Solids stabilization and sludge storage.
- Algal growth is controlled by low hydraulic retention time.

BIOLAC® Process

Advantages

- Either a partial mix or complete mix cells
- Operate as an extended aeration activated sludge system to nitrify NH_3 or to achieve nitrification and denitrification.

Disadvantages

- Operation and maintenance are more complex,
- Conventional extended aeration activated sludge when

LEMNA systems

Duckweed system for photo-shading

Required harvesting duckweed

Now using floating covers for same effect

SCANDE

Nitrogen Removal

- Algal uptake
- Sludge deposition
- Adsorption by bottom sediments
- Nitrification
- Denitrification
- Volatilization

Nitrogen Removal

Ammonia removal

- Function of pH
- Function of temperature
- 2 Models used
- Plug flow reactor
- Complete mix reactor

Nitrogen Models

Plug flow

- $N_e = N_o e^{-K_T[t + 60.6 (pH - 6.6)]}$

  - N_e = effluent total nitrogen, mg/L
  - N_0 = influent total nitrogen, mg/L
  - K_T = temperature dependent rate constant
  - $K_T = 0.0064 (1.039)^{(T-20)}$
  - t = detention time in system, day
  - pH = pH of near surface

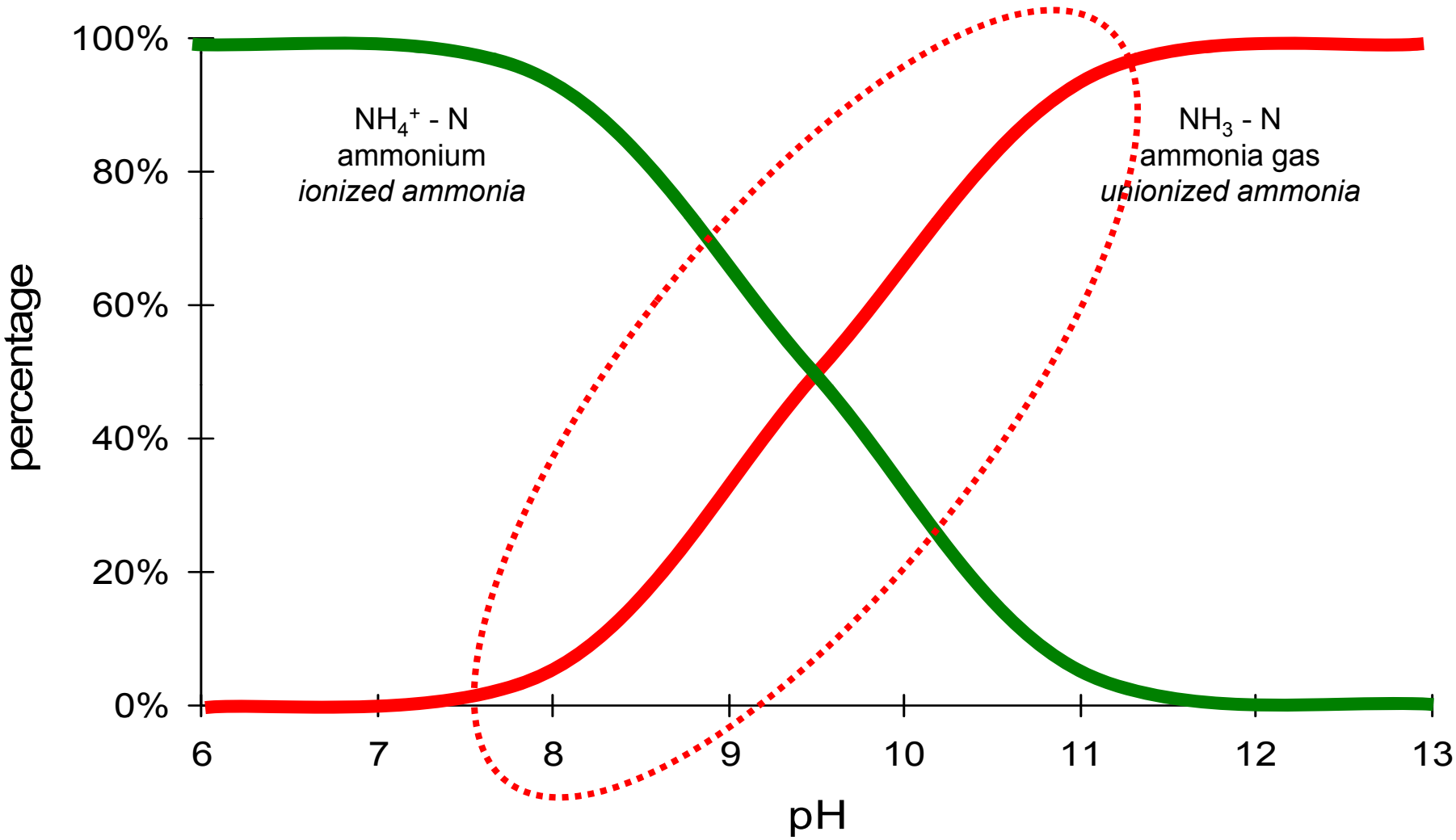
Nitrogen Models

Complete mixed

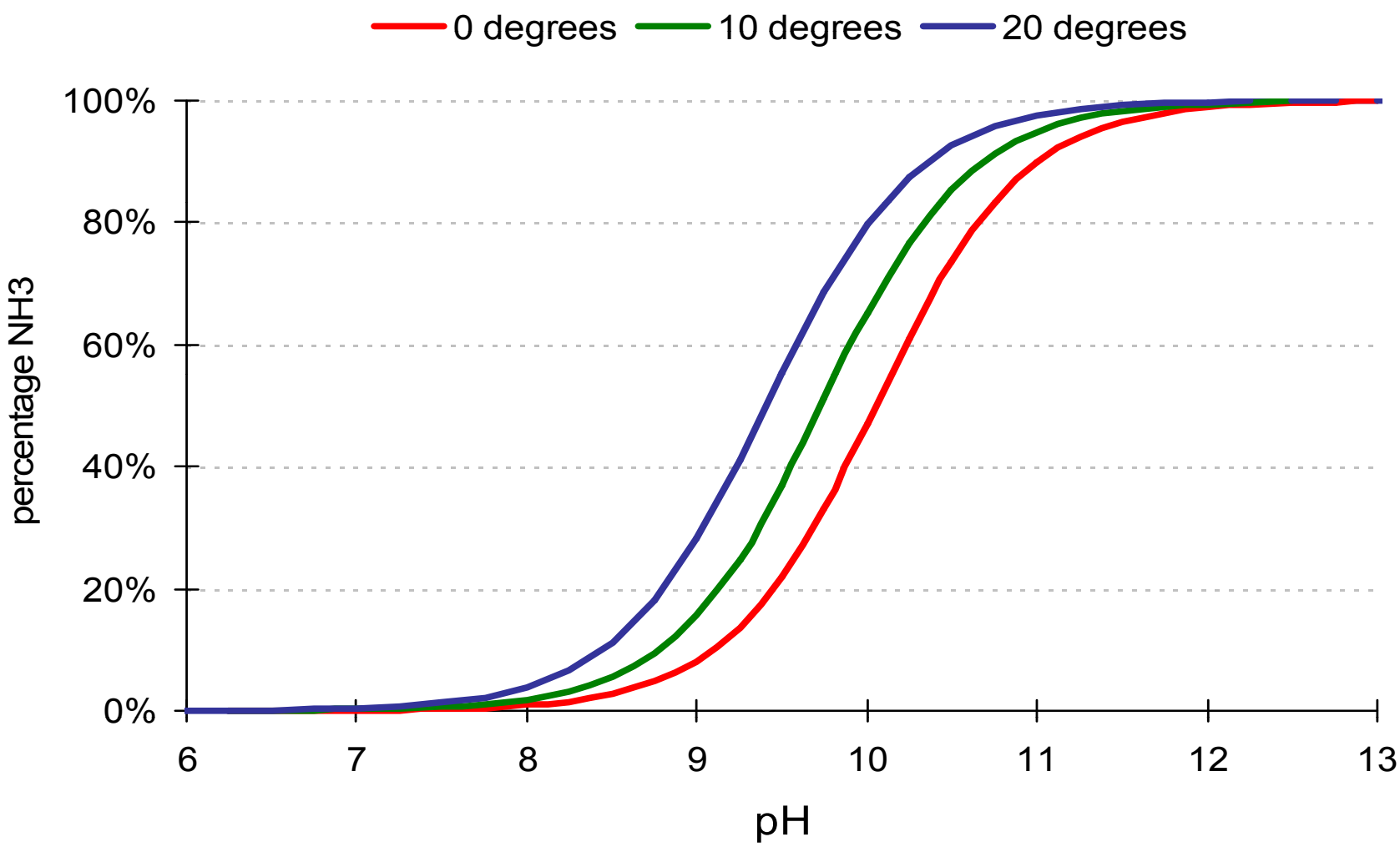
- $$N_e = \frac{N_0}{1 + t(0.000576T - 0.00028)e^{(1.080 - 0.042T)(pH - 6.6)}}$$

  - N_e = effluent total nitrogen, mg/L
  - N_0 = influent total nitrogen, mg/L
  - T = temperature of pond
  - pH = pH of near surface

Ammonia Form Depends on pH



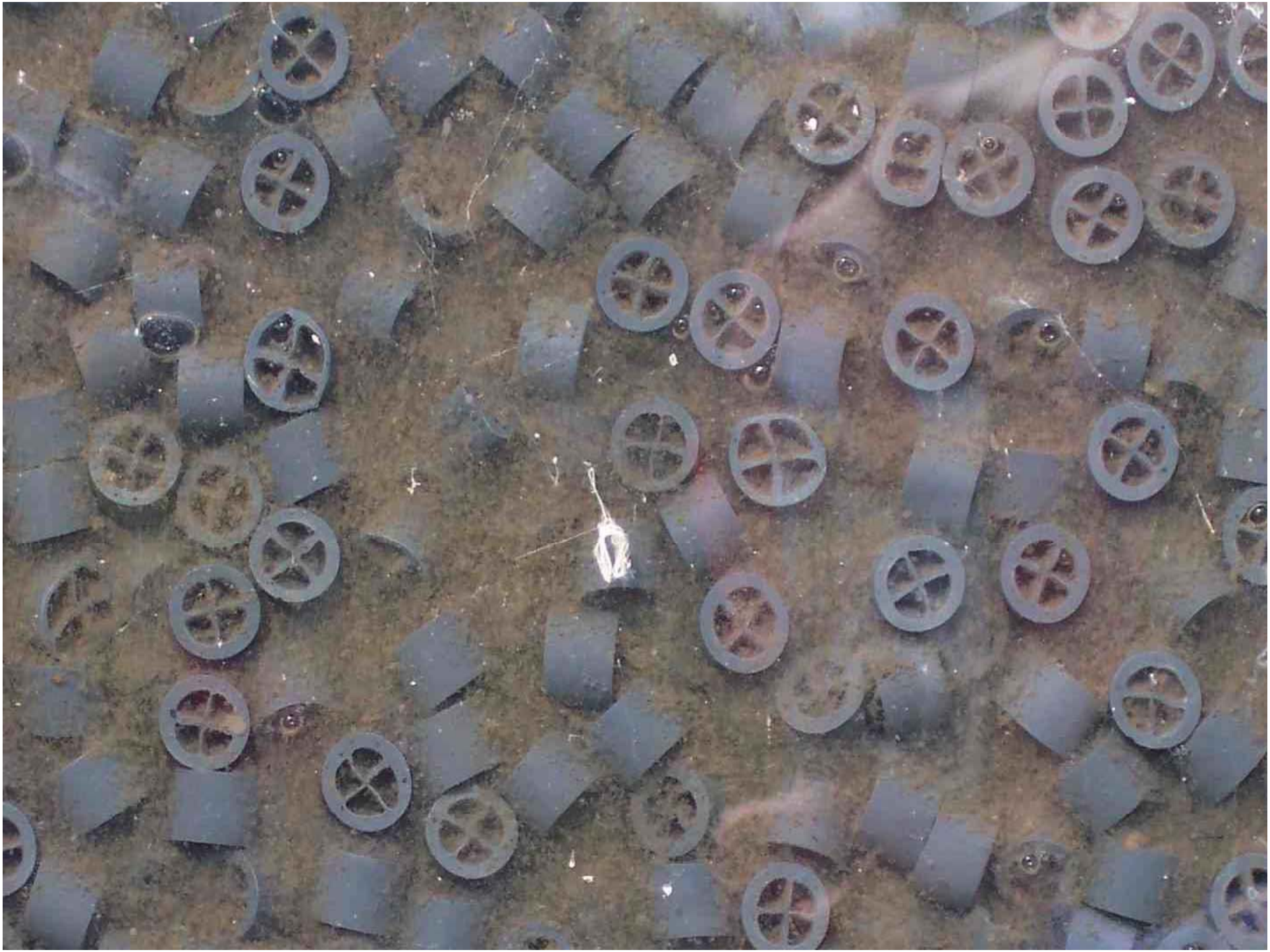
Ammonia Curve depends on Temperature



Nitrogen Removal

Lagoon modifications

- ATLAS IS™ – Internal clarifier system
- CLEAR™ Process – SBR variant
- Ashbrook SBR – SBR variant
- AquaMat® Process – Plastic biomass carrier ribbons
- MBBR™ Process – Plastic biomass carrier elements
- Poo-Gloo™



Phosphorus Removal

Lagoon – Chemical Addition

- Calcium – Lime
- Aluminum – Alum, Polv Aluminum Chloride
- Iron – Ferric Chlorine
- Pickle Liquor - Ferrous sulfate

Total Suspended Solids Removal

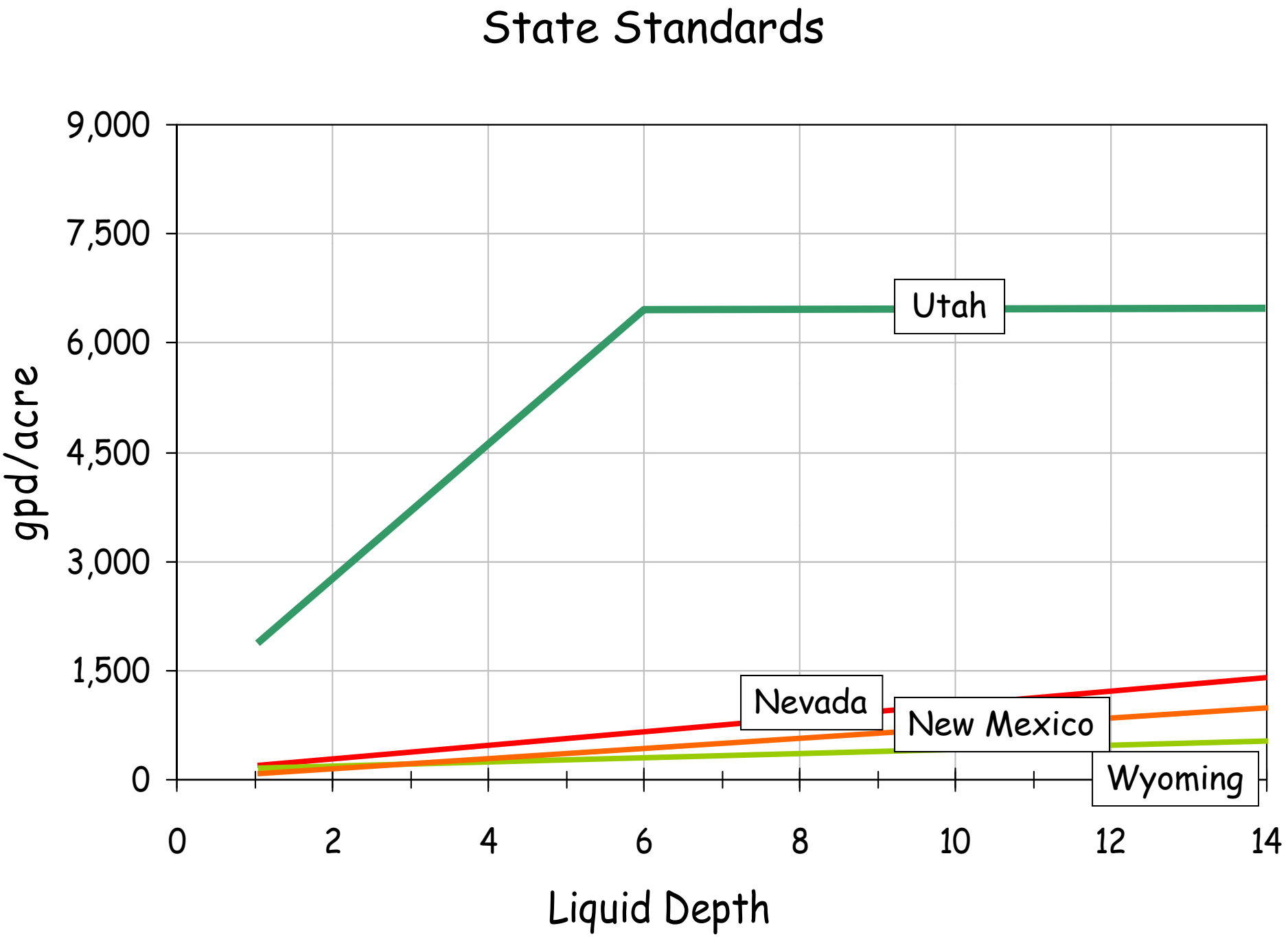
Control of Algal Growth

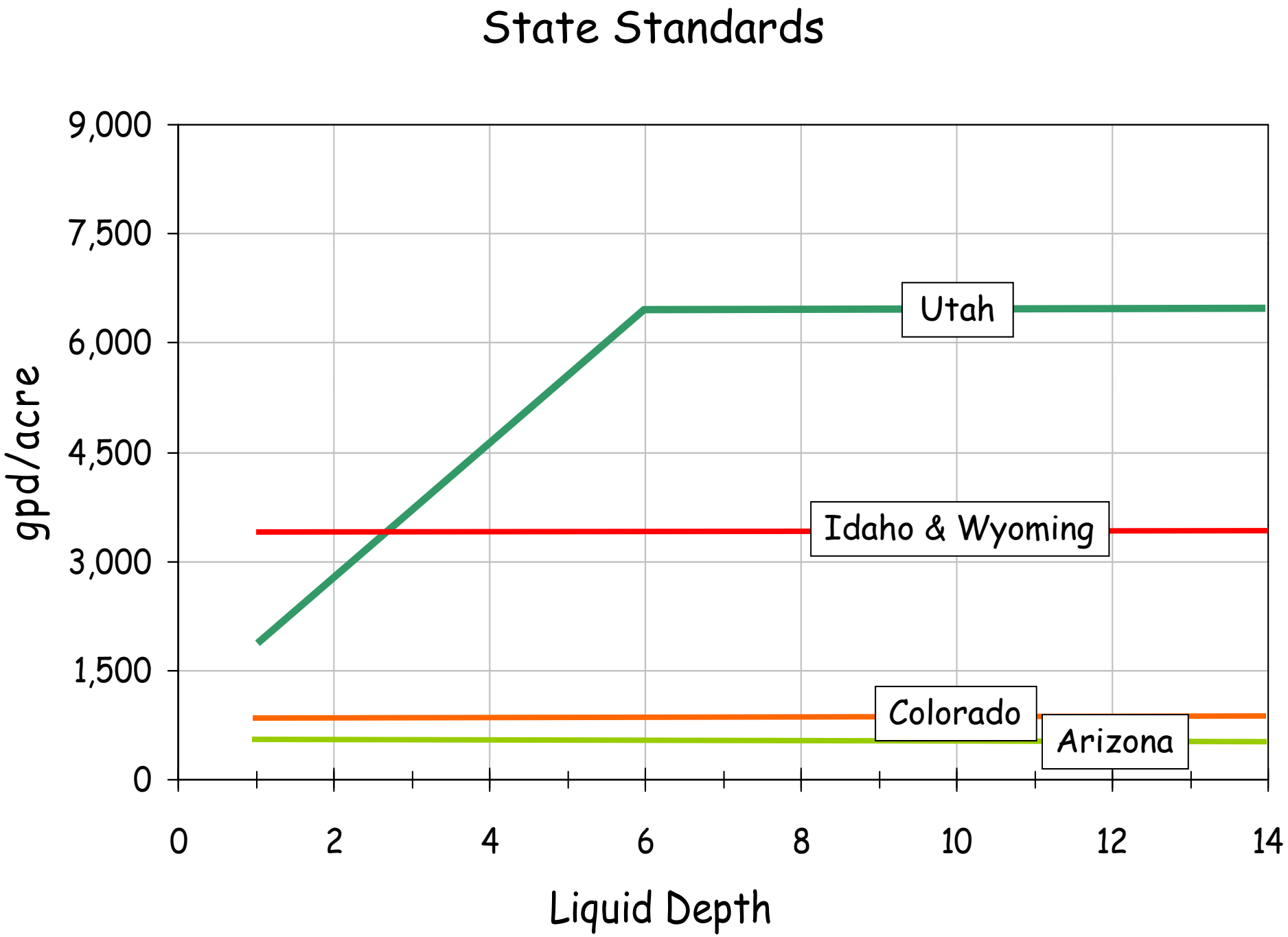
- Shading
- Barley Straw
- Ultra Sound (sonicfication)

Physical Design and Construction

Dike construction

- Wave Protection
- Weather Protection
- Animal Protection
- Seepage


State Standards
9,000
7,500
6,000
4,500
3,000
1,500
0
gpd/acre
Utah
Nevada
New Mexico
Wyoming
0
2
4
6
8
10
12
14
Liquid Depth


State Standards
9,000
7,500
6,000
4,500
3,000
1,500
0
gpd/acre
Utah
Idaho & Wyoming
Colorado
Arizona
0
2
4
6
8
10
12
14
Liquid Depth

Cost and Energy Requirements

- Construction Costs
- Power Costs

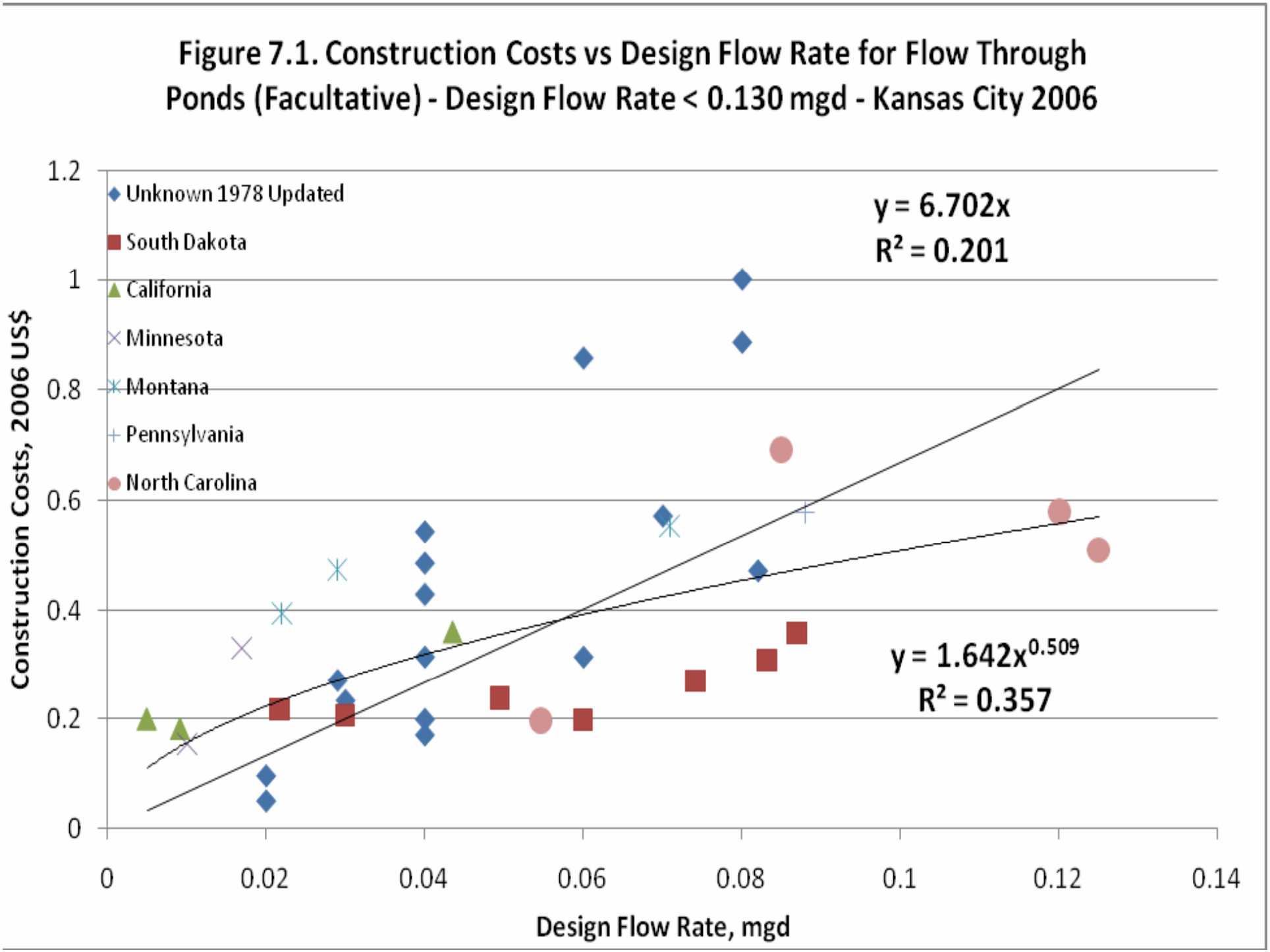


Figure 7.1. Construction Costs vs Design Flow Rate for Flow Through Ponds (Facultative) - Design Flow Rate < 0.130 mgd - Kansas City 2006
Unknown 1978 Updated
South Dakota
California
Minnesota
Montana
Pennsylvania
North Carolina
y = 6.702x
R² = 0.201
y = 1.642x^0.509
R² = 0.357
Construction Costs, 2006 US$
Design Flow Rate, mgd
0
0.2
0.4
0.6
0.8
1
1.2
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14

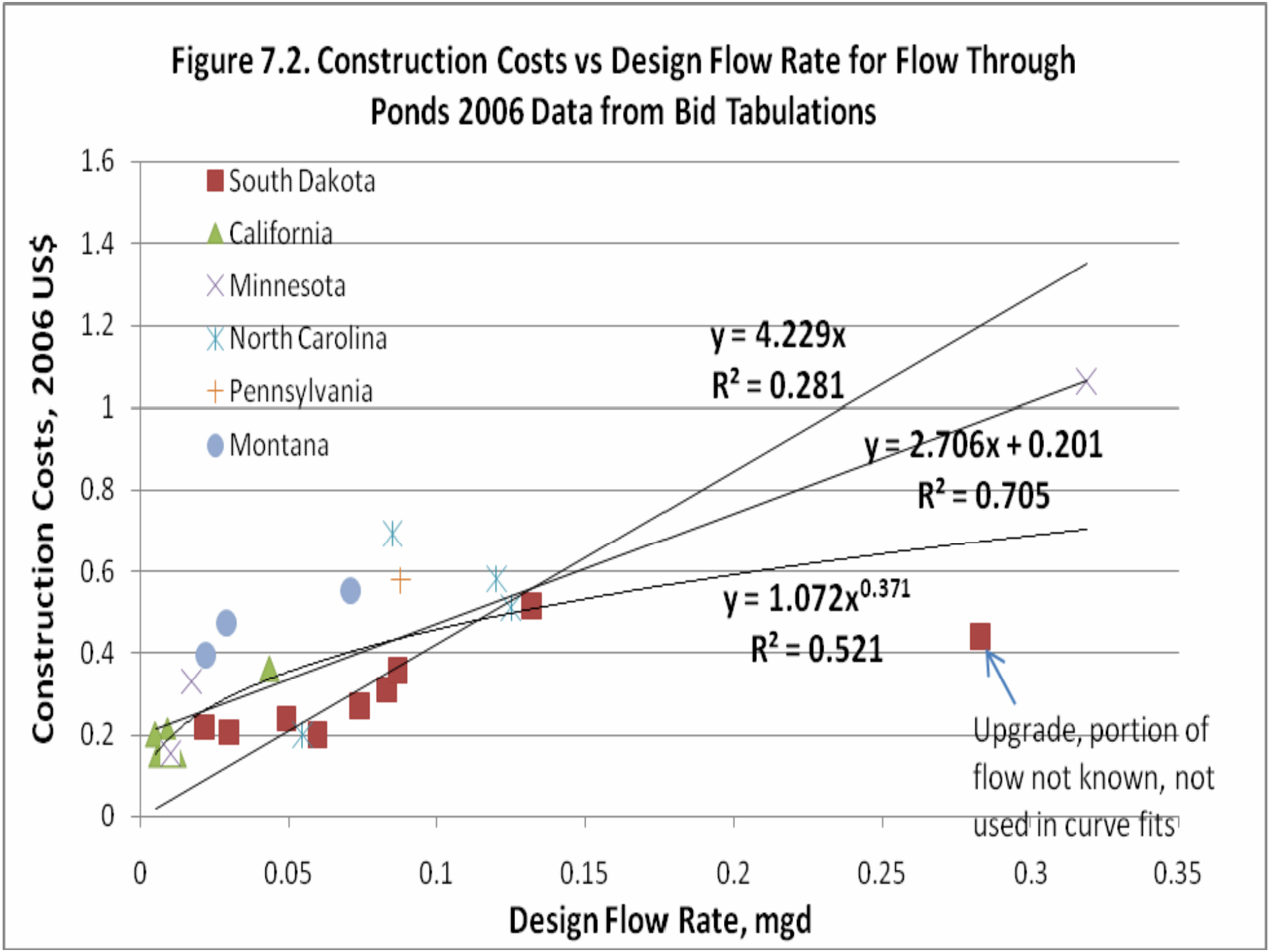


Figure 7.2. Construction Costs vs Design Flow Rate for Flow Through Ponds 2006 Data from Bid Tabulations
South Dakota
California
Minnesota
North Carolina
Pennsylvania
Montana
y = 4.229x
R² = 0.281
y = 2.706x + 0.201
R² = 0.705
y = 1.072x^0.371
R² = 0.521
Upgrade, portion of flow not known, not used in curve fits
Construction Costs, 2006 US$
Design Flow Rate, mgd
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

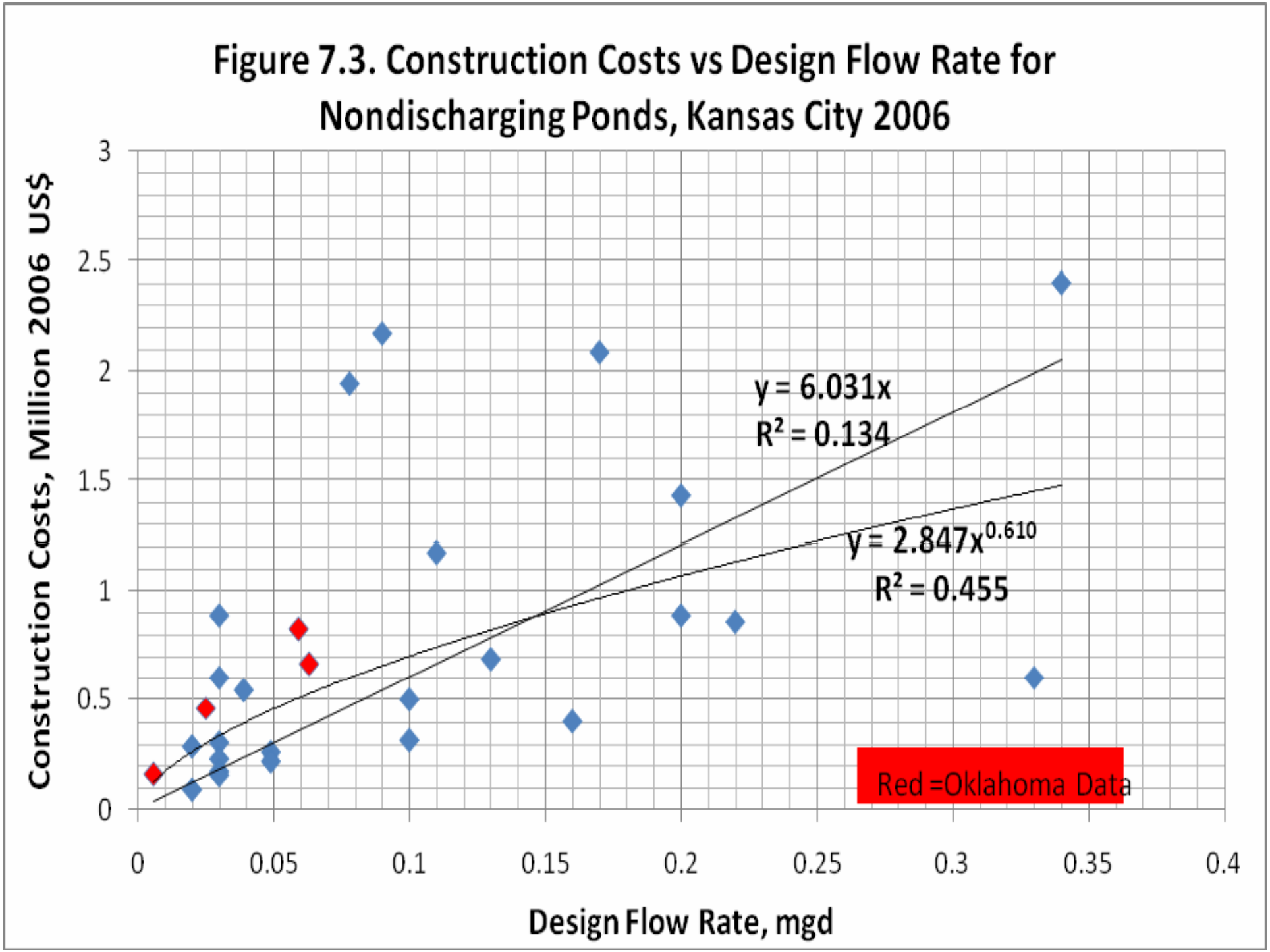
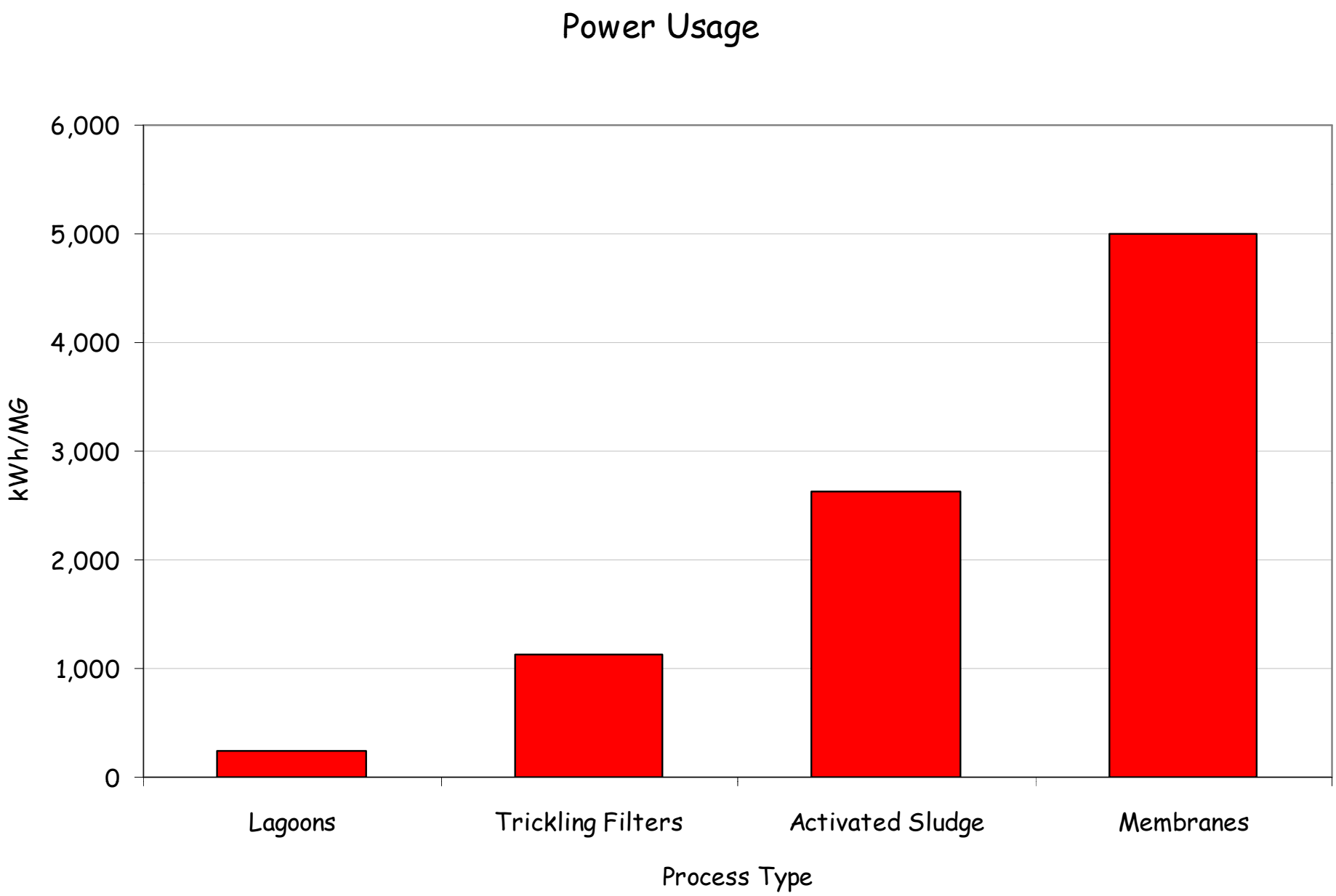


Figure 7.3. Construction Costs vs Design Flow Rate for Nondischarging Ponds, Kansas City 2006
Construction Costs, Million 2006 US$
Design Flow Rate, mgd
y = 6.031x
R² = 0.134
y = 2.847x^0.610
R² = 0.455
Red =Oklahoma Data
0
0.5
1
1.5
2
2.5
3
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4


Power Usage
6,000
5,000
4,000
3,000
2,000
1,000
0
kWh/MG
Lagoons
Trickling Filters
Activated Sludge
Membranes
Process Type