Aquaculture Effluents and the Environment

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Characteristics of catfish pond effluents

Impacts of catfish pond effluents

Ways to reduce impacts of effluents

What is a pond?

“A small, confined body of standing water”

Implications of long hydraulic residence time

Most of the initial waste loading is removed before discharge

Net Pens

Raceways

Feed → Fish → Waste → Discharge

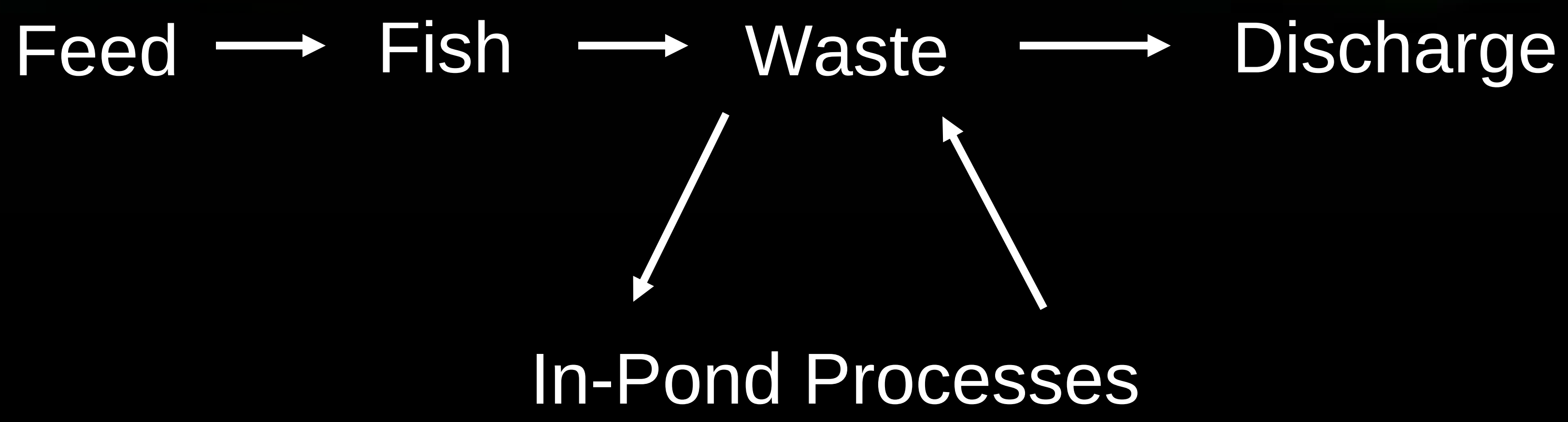
Effluent management in hydraulically connected systems

Improve FCR = less pollution

- Don’t waste feed
- Increase nutrient uptake efficiency

Use settling to remove solids

- Raceway design
- Offline settling basins



Feed → Fish → Waste → Discharge

In-Pond Processes

Annual feed loading, waste generation, and pollutant discharge from levee -style catfish ponds

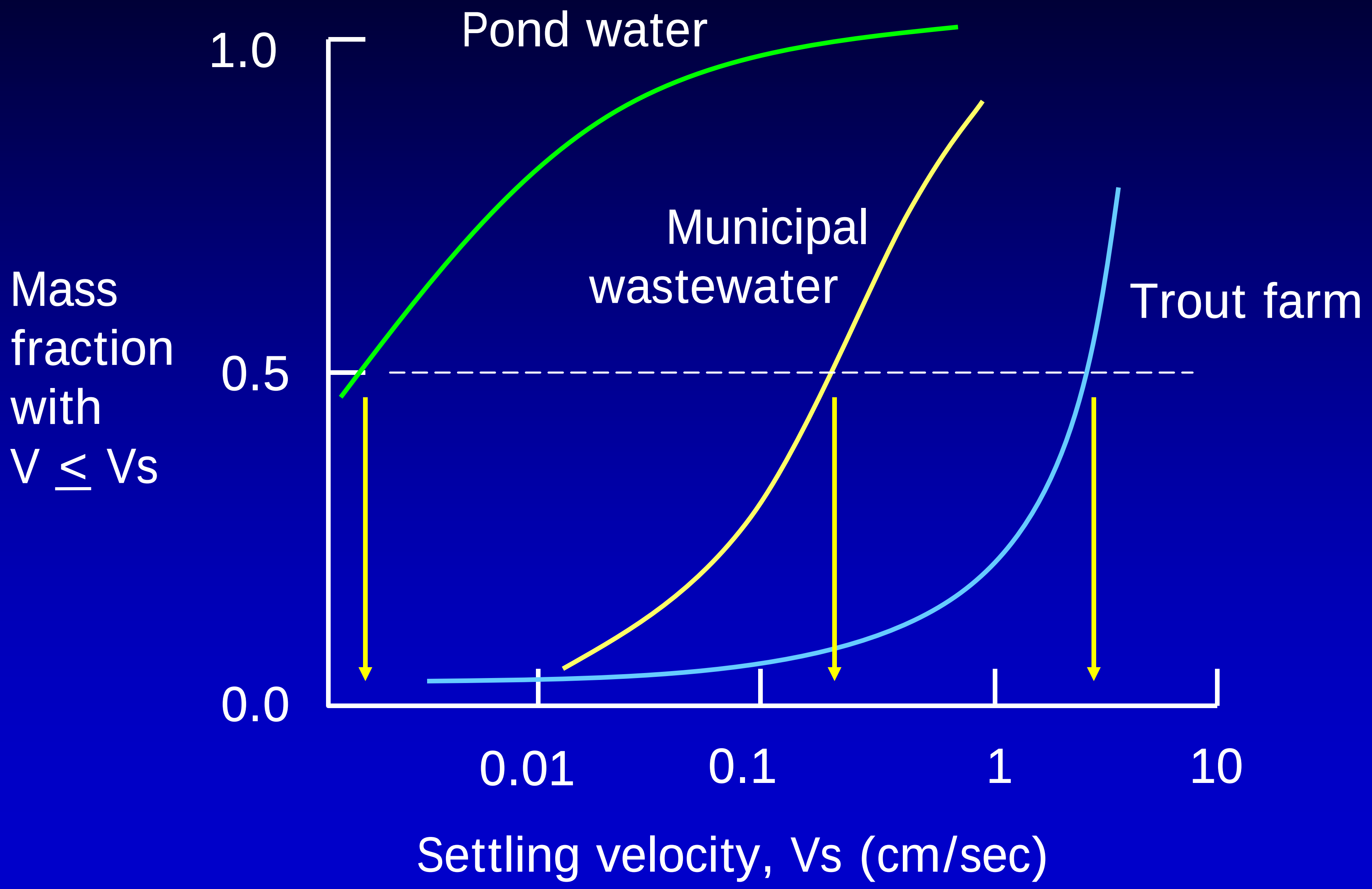
	Nitrogen	Phosphorus
In feed (lbs/acre)	500	100
Excreted (lbs/acre)	400	80
Discharged (lb/acre)	30	2
Percentage removed	93%	97%

Implications of long hydraulic residence time

Most of the initial waste loading is removed before discharge

Settling characteristics of solids are poor

Solids Settling Characteristics

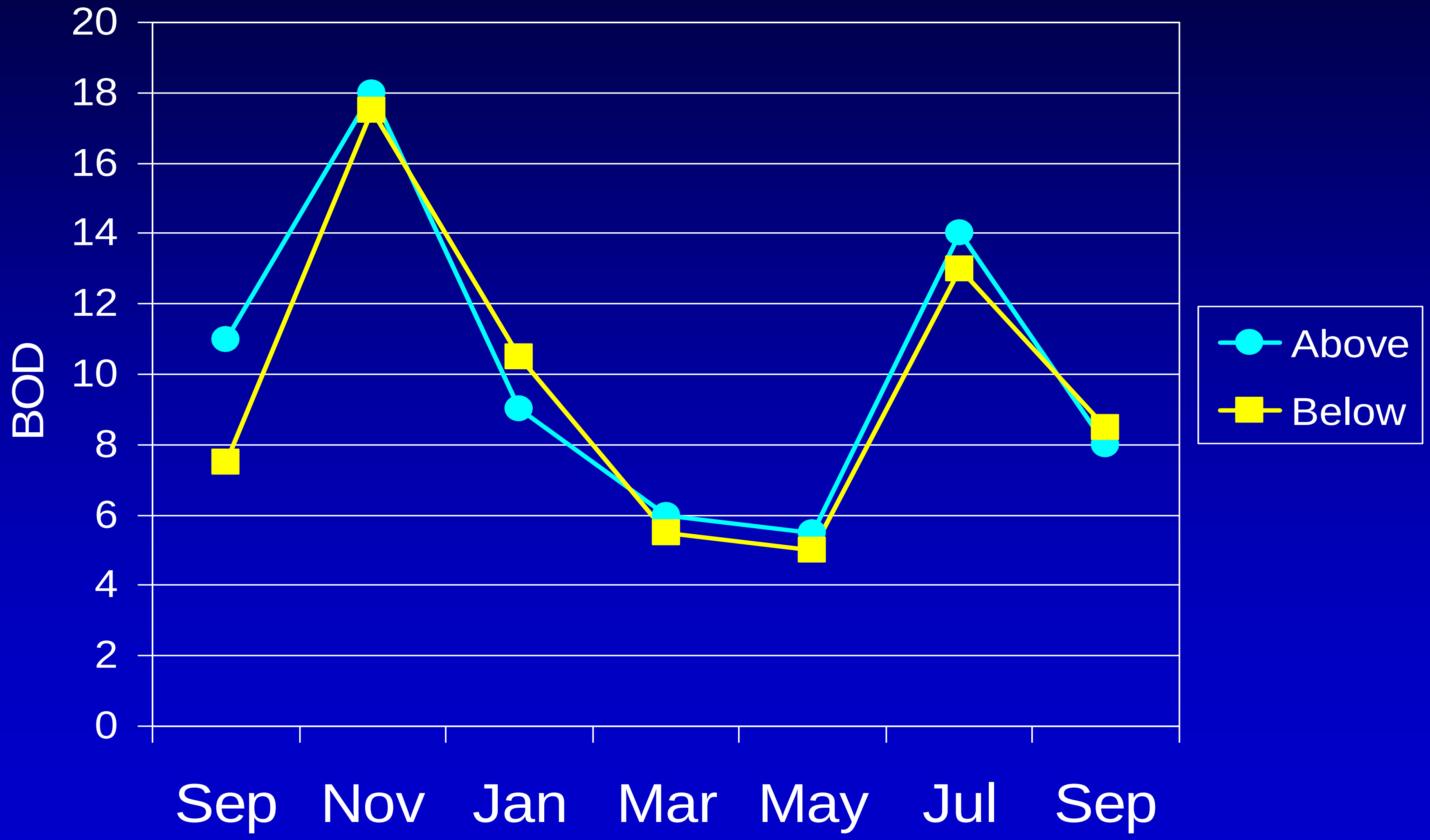


Impacts on receiving water bodies

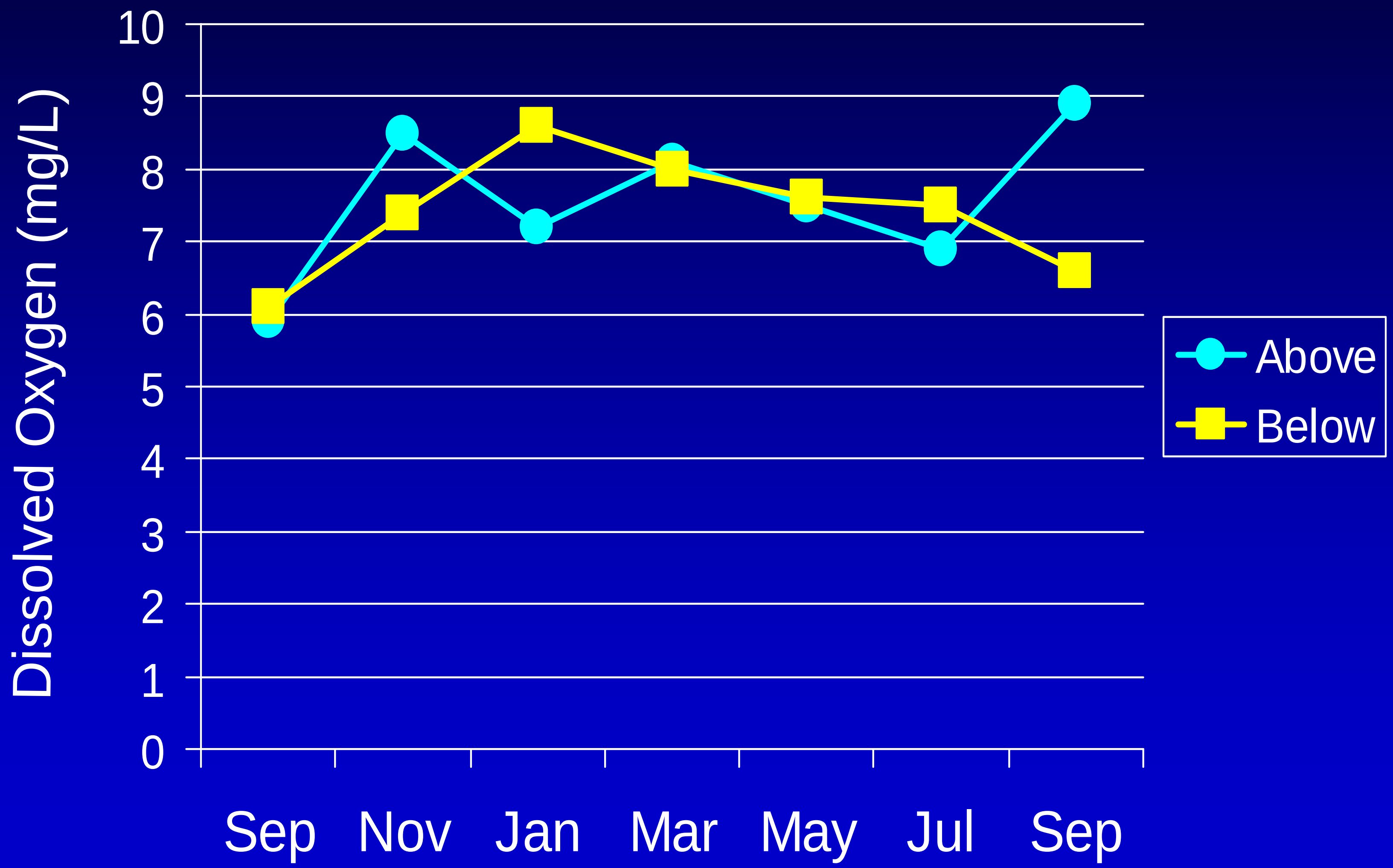
Alabama environmental assessment

Apportionment of waste loading to Wolf Lake, MS

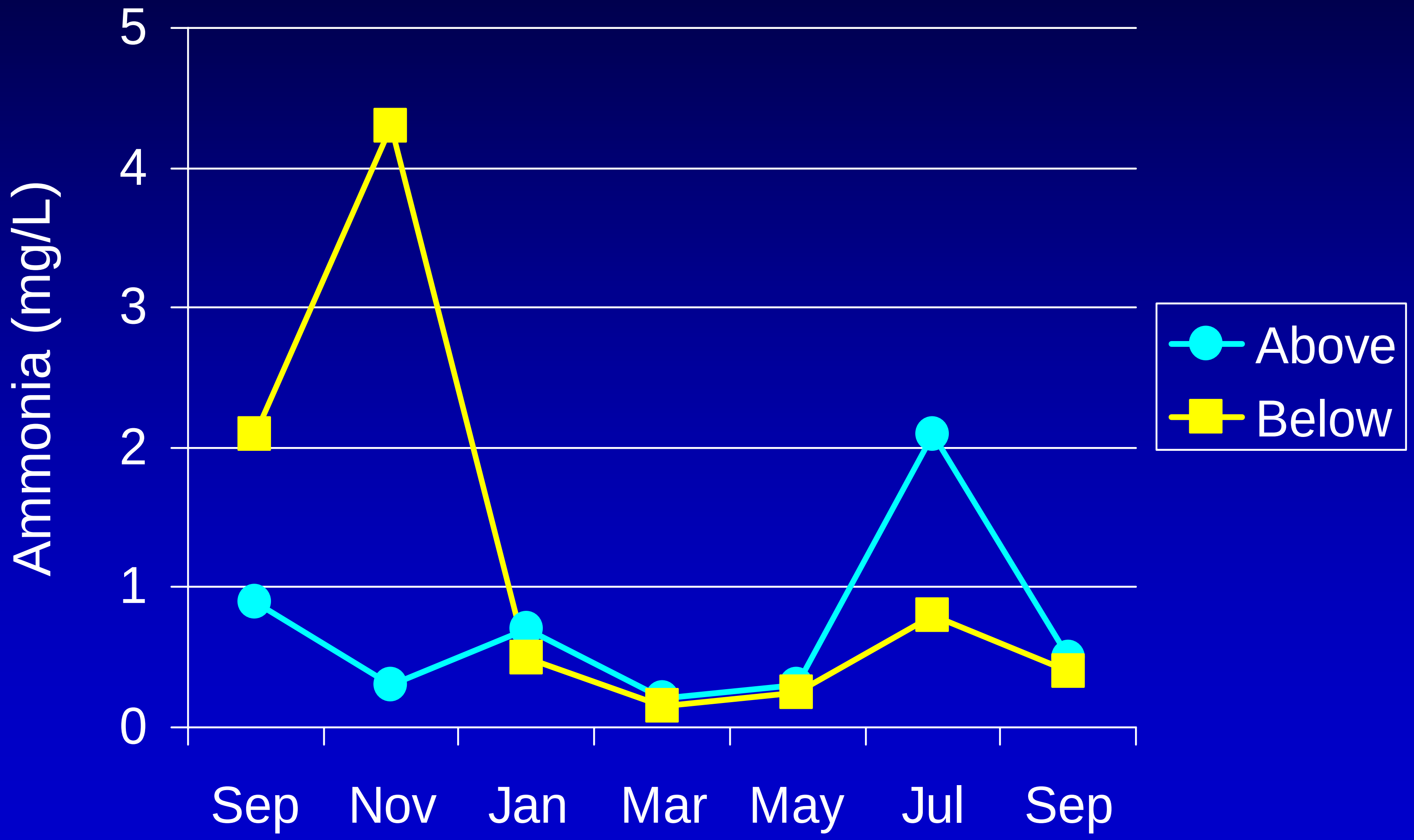
5-day BOD in Alabama Streams Above and Below Catfish Farms

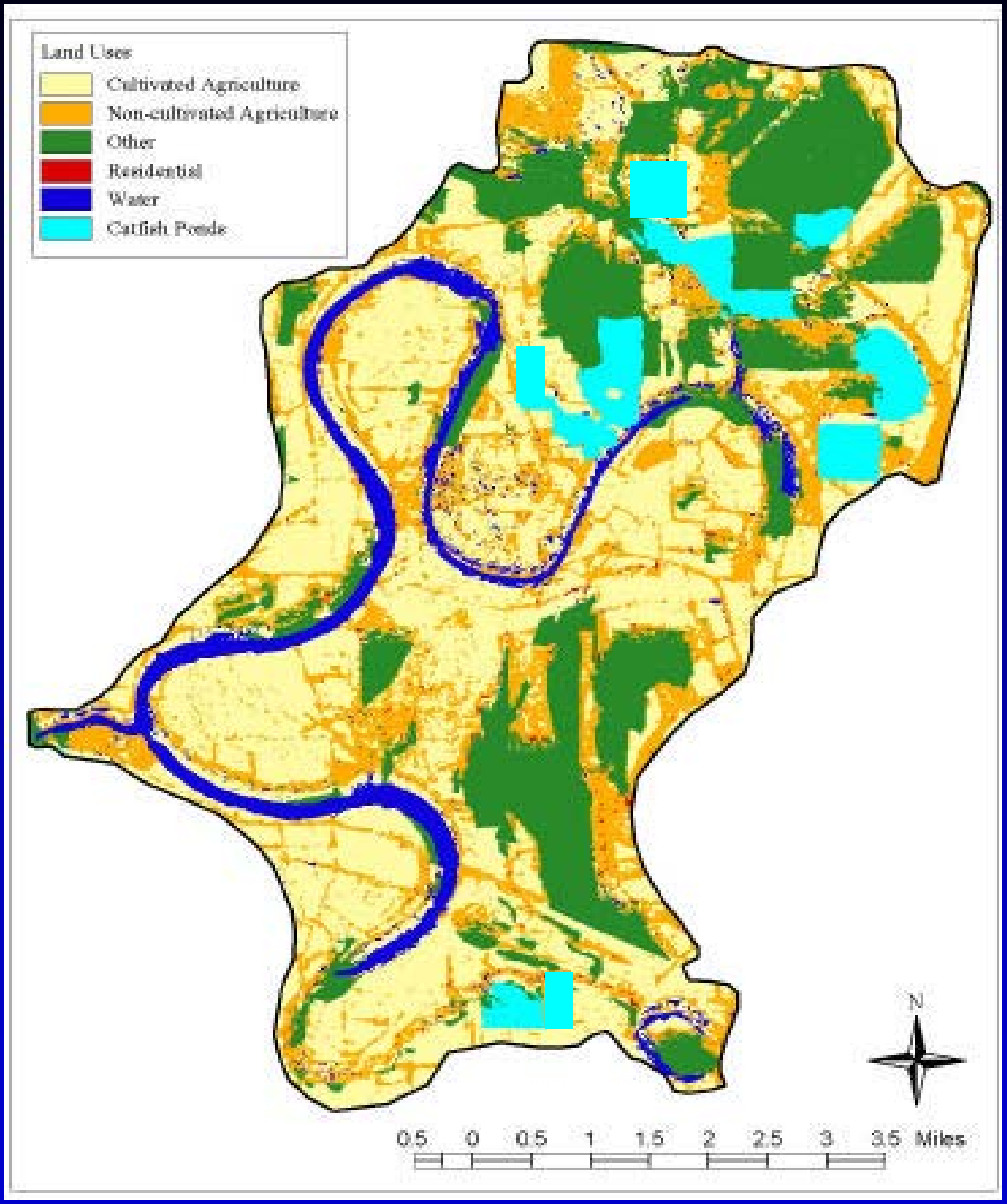


Oxygen in Alabama Streams
Above and Below Catfish Farms



Ammonia in Alabama Streams Above and Below Catfish Farms





Wolf Lake Watershed

Northwest Mississippi

Cropland	44%
Forest	28%
Pasture	23%
Ponds	5%
Residential	1%

Solids Loading to Wolf Lake, MS

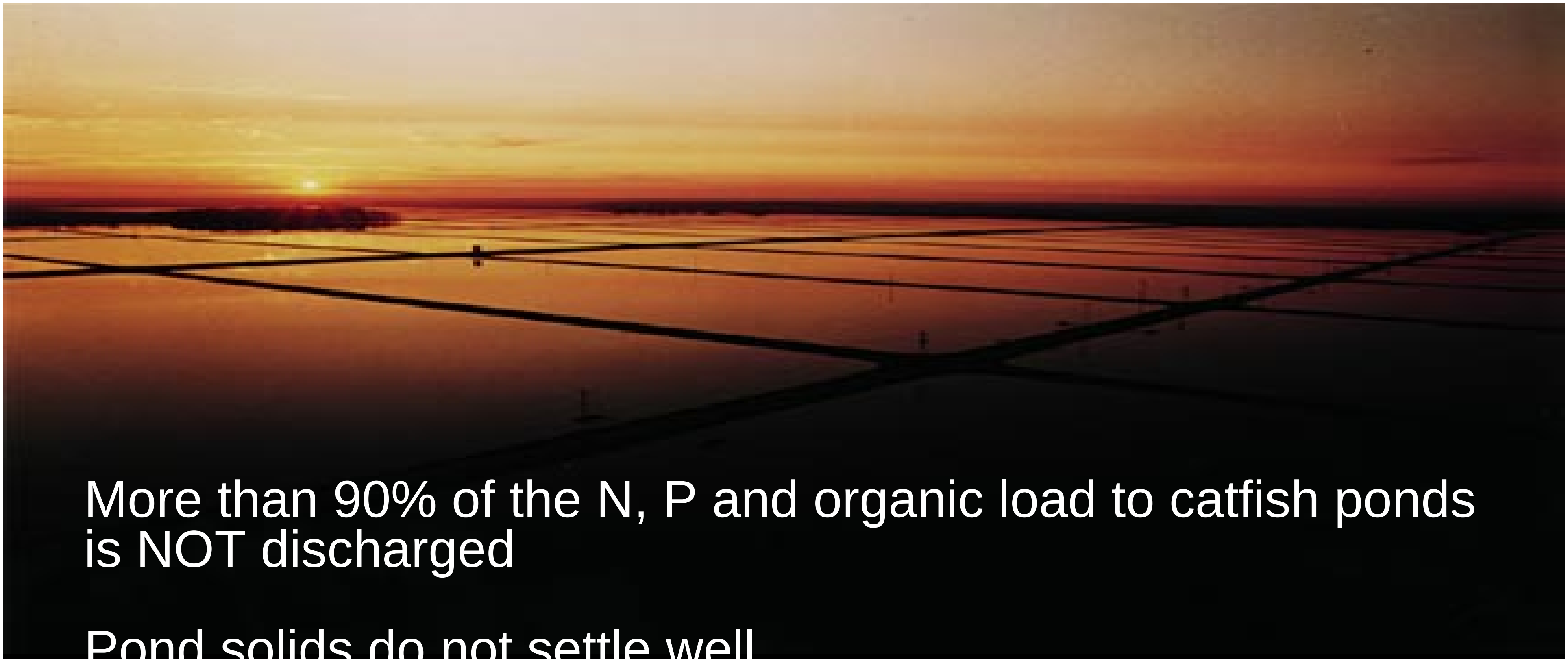
Land Use	Area (%)	TS (%)	TS/A
Row Crops	44	82	1.9
Hardwood Forest	28	6	0.2
Pasture/Fallow	23	12	0.5
Catfish Ponds	5	0.4	0.1
Residential	1	0.2	0.2

Phosphorus Loading to Wolf Lake, MS

Land Use	Area (%)	TS (%)	TP/A
Row Crops	44	80	1.8
Hardwood Forest	28	8	0.3
Pasture/Fallow	23	11	0.5
Catfish Ponds	5	1.5	0.3
Residential	1	0.3	0.3

Nitrogen Loading to Wolf Lake, MS

Land Use	Area (%)	TS (%)	TN/A
Row Crops	44	64	1.5
Hardwood Forest	28	6	0.2
Pasture/Fallow	23	19	0.8
Catfish Ponds	5	11	2.2
Residential	1	0.4	0.4



More than 90% of the N, P and organic load to catfish ponds is NOT discharged

Pond solids do not settle well

Catfish ponds are the lowest per-acre contributors of P and TSS of all land uses in the Yazoo-Mississippi River floodplain

Ponds can be significant source of N in regions with highly developed aquaculture

Significant opportunities exist for improvement

Pond effluent management

No discharge

Post-discharge treatment

Pre-discharge treatment

Reduce waste production

Reduce effluent volume

No discharge: retention ponds

Retain water drained from ponds and normal overflow, plus storage for 25-yr storm

Levee ponds:

1.5 acres of retention per acre of production

Watershed ponds (6.3:1):

11 acres of retention per acre of production

Pond effluent management

No discharge

Post-discharge treatment

Pre-discharge treatment

Reduce waste production

Reduce effluent volume

Post-discharge treatment

Traditional wastewater treatment

Constructed wetlands

Settling ponds

Irrigation of terrestrial crops

Post-discharge treatment: economic constraints

- Discharge is sporadic

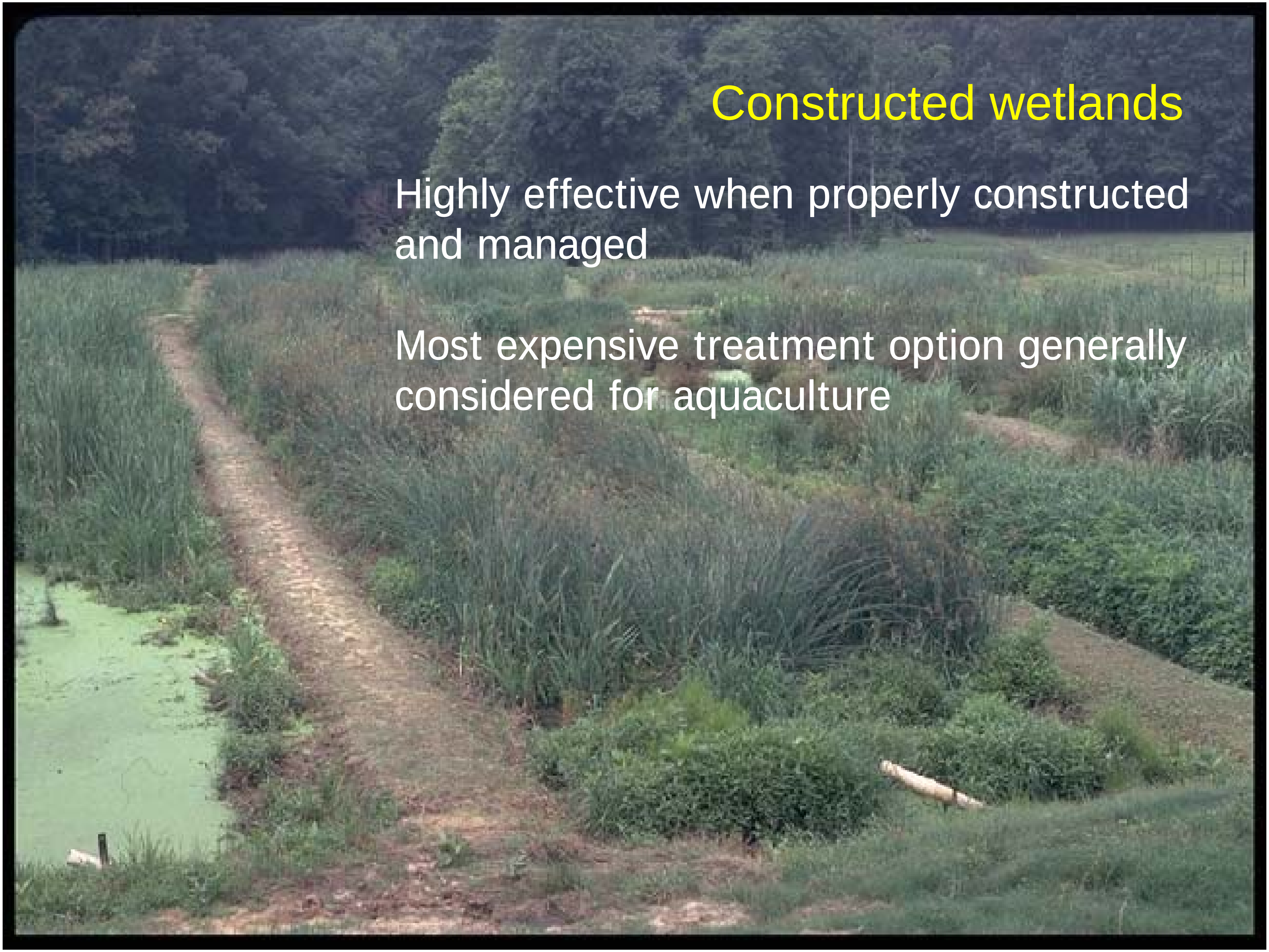
  wet year (1979) = 23 discharge events (57 days)

  dry year (1966) = 1 discharge event (2 days)

- Discharge is seasonal

  wet year = 14 events in winter, 6 in early spring, 3 in late fall (November), 0 in summer

Constructed wetlands



Constructed wetlands

Highly effective when properly constructed and managed

Most expensive treatment option generally considered for aquaculture

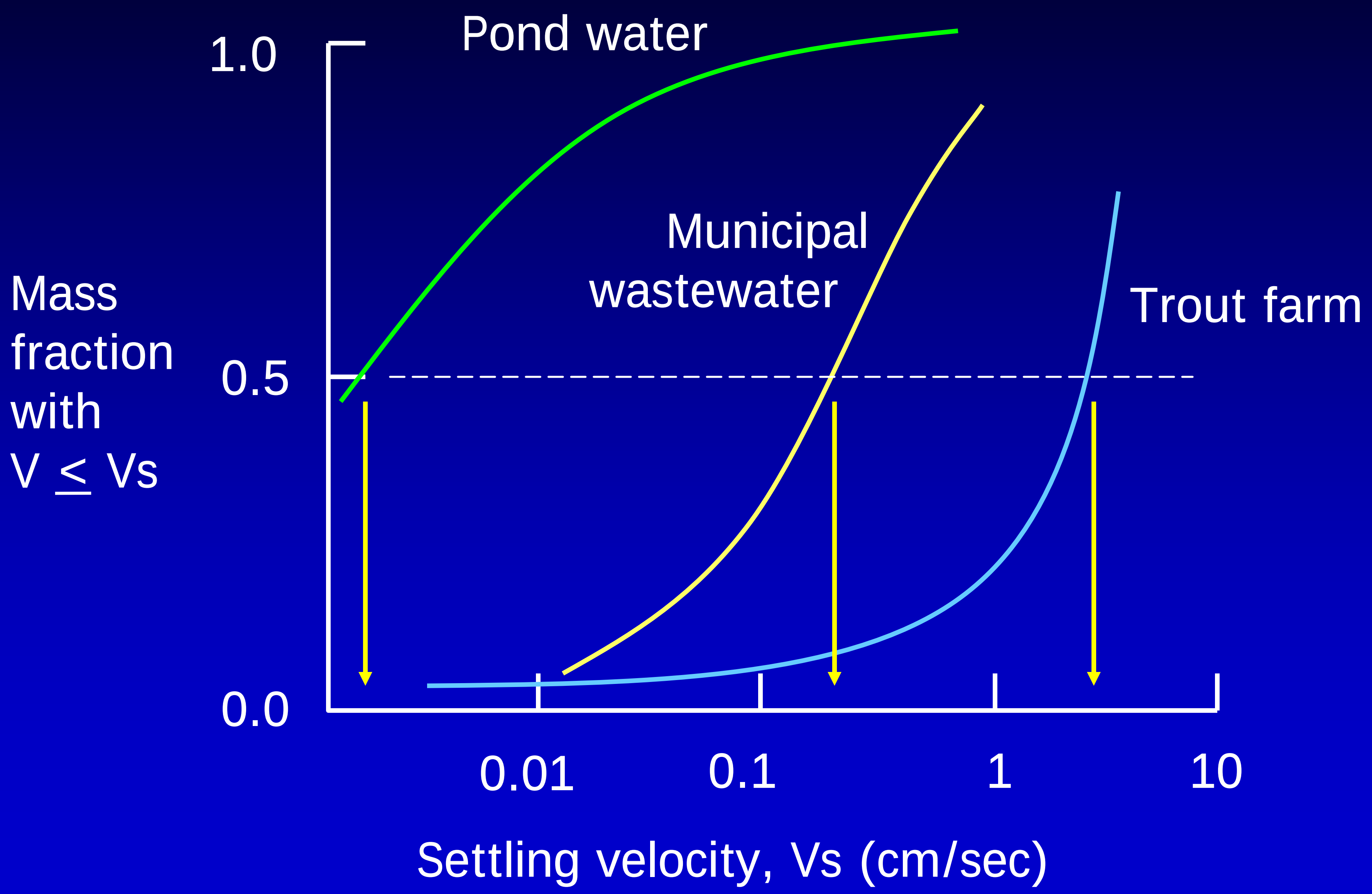
Settling basins

1) Determine settling characteristics of pond overflow effluent

2) Use settling rate curves to model settling basin design parameters

3) Assess economics of using settling basins

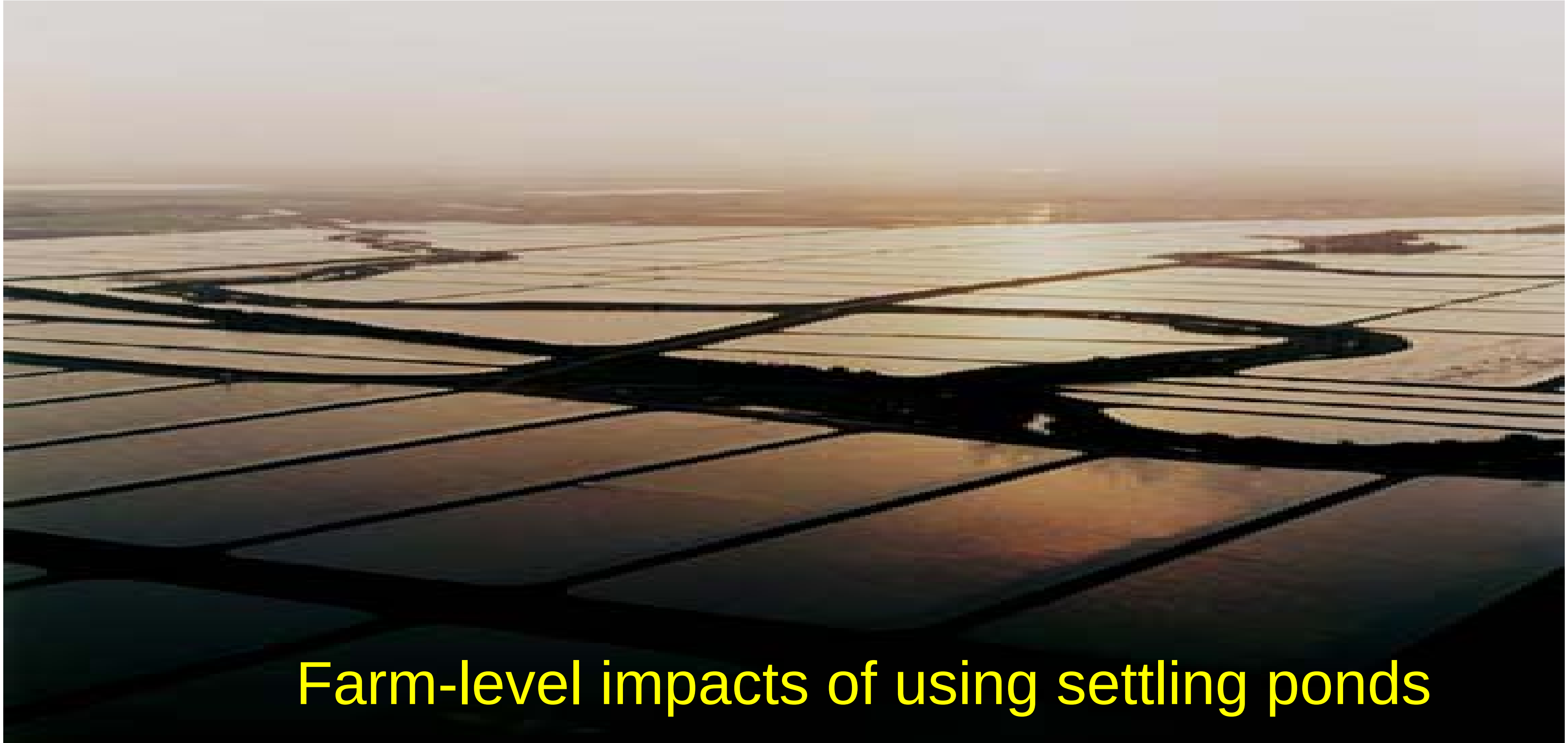
Solids Settling Characteristics



Settling basin areas (acre per acre of production) needed to treat maximum 24-hour rainfalls with return frequencies of 2, 10, and 25 years

Storm frequency (yr)	Basin area (acre/acre)*
2	0.30
10	0.45
25	0.60

*assuming 1-m deep basin and 50% removal efficiency (OFR$_{50}$ = 0.005 cm/sec)



Farm-level impacts of using settling ponds

Investment costs increase 15 to 20%

Operating costs increase 5 to 10%

Disproportionate burden on small farms

Irrigation

Sounds great

For most crops, timing is poor

- The time when irrigation is needed (droughty late summer) does not coincide with time when ponds discharge (late winter, early spring)

For rice, timing and supply are problems

The nutrient contribution is insignificant

Pond effluent management

No discharge

Post-discharge treatment

Pre-discharge treatment

Reduce waste production

Reduce effluent volume

Pre-discharge treatment

Remove potential pollutants from ponds before water is discharged

Phosphorus precipitation

- Alum, gypsum, iron sulfate

Bioaugmentation

- Bacterial inocula

Bioaugmentation studies in Mississippi

Nine studies in catfish ponds

Various product types

Used according to label directions or advice of manufacturer

Most studies either single or double blinded

No effect on phosphorus or solids in any study

Pond effluent management

No discharge

Post-discharge treatment

Pre-discharge treatment

Reduce waste production

Reduce effluent volume

Reduce feeding/stocking rates

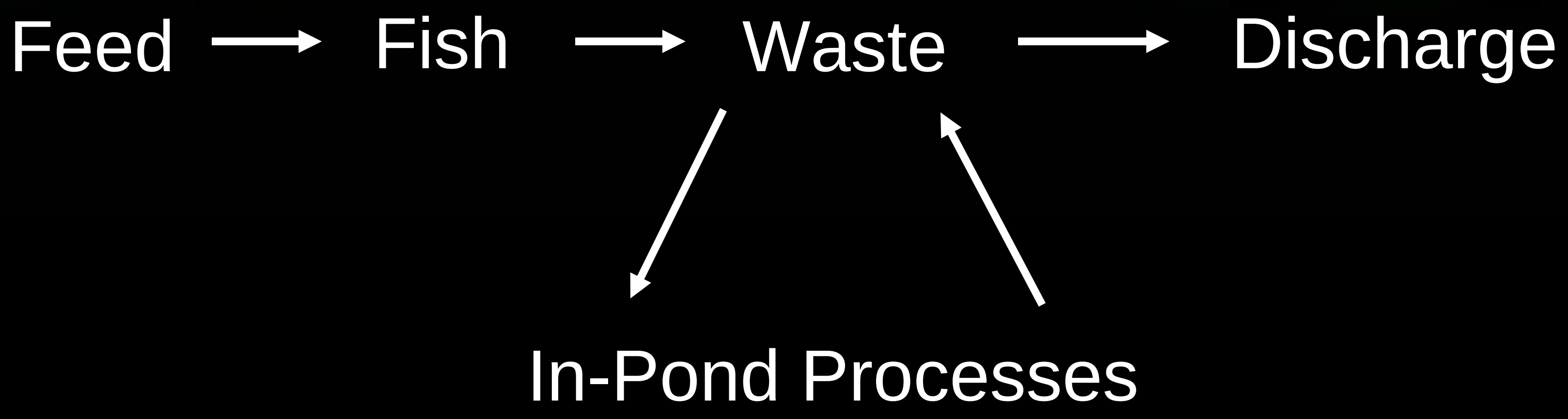
Modify diets to improve nutrient retention or reduce waste production

Feed-effluent relationship in ponds

The feed-effluent relationship becomes very disconnected” as hydraulic retention time increases

In true ponds (as opposed to quasi- flow-through systems), there is little opportunity to reduce solids and total phosphorus concentrations through feed manipulation

However, total nitrogen concentrations do seem to respond to reduced feed nitrogen inputs



Feed → Fish → Waste → Discharge

Waste → In-Pond Processes → Waste

Feed-effluent relationship in ponds

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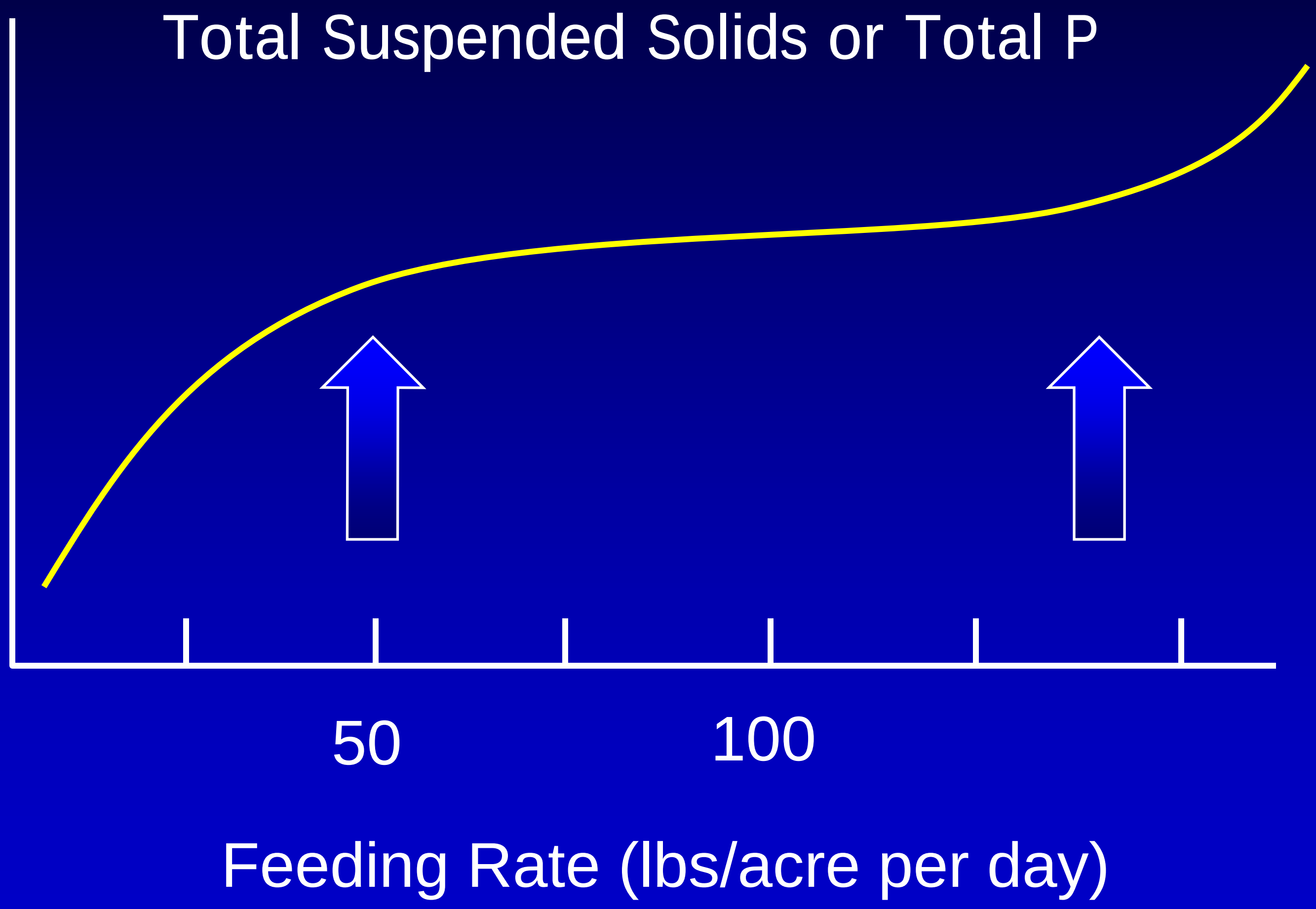

Total Suspended Solids or Total P
50
100
Feeding Rate (lbs/acre per day)

Feed-effluent relationship in ponds

The feed-effluent relationship becomes very disconnected” as HRT increases

In true ponds (as opposed to quasi- flow-through systems), there is little opportunity to reduce solids and total phosphorus concentrations through feed manipulation

However, total nitrogen concentrations do seem to respond to reduced feed nitrogen inputs

Protein content (satiation feeding)

36% protein feed = 5.0 mg/L mean total nitrogen
28% protein feed = 3.6 mg/L mean total nitrogen

(no change in fish production or FCR)

Feeding rate (across feed protein levels of 28 to 40%)

Satiation = 4.2 mg/L mean total nitrogen
Restricted = 3.3 mg/L mean total nitrogen

(11% reduction in gain and 12% improvement in FCR)

Pond effluent management

No discharge

Post-discharge treatment

Pre-discharge treatment

Reduce waste production

Reduce effluent volume

Reducing discharge volume

Mass discharge = (concentration) x (volume)

Modeling showed that mass discharge responded more to achievable reductions in discharge volume than to achievable reductions in concentration

Managing discharge volume may be easier than managing concentration

Reducing effluent volume

Reduce or eliminate water exchange (flushing)

for catfish; water exchange is not needed if you operate with the assimilative capacity of pond

Reuse water for multiple crops

Maintain water storage capacity in the pond

Maintaining water storage capacity: drop-fill water-level management

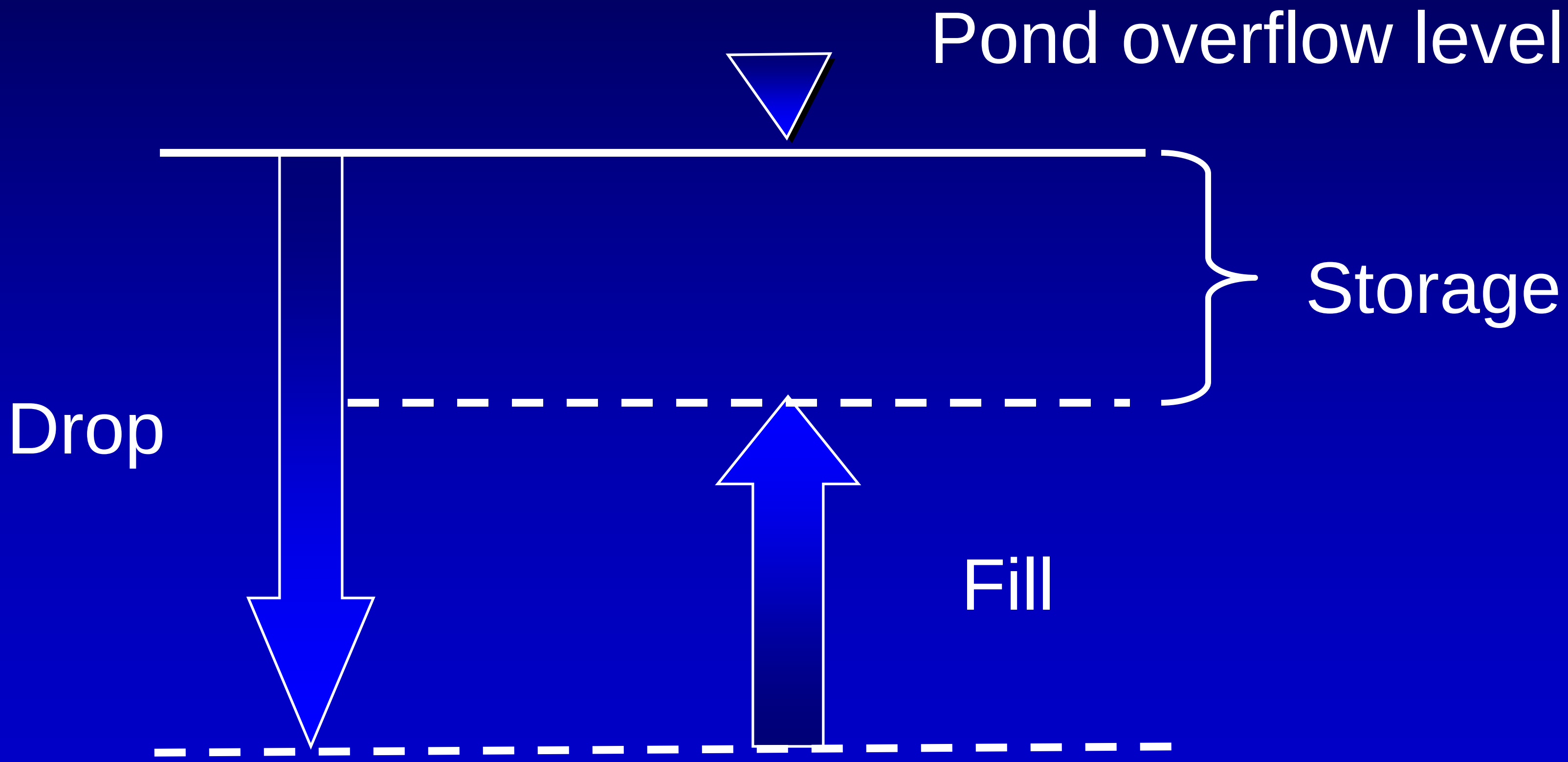
Originally envisioned as a water conservation practice

Most farmers use it whether they know it or not

Can be formalized into a highly effective effluent-management practice

When combined with water reuse for multiple crops, it is the best way to manage effluents

“Drop/fill” water level management



Pond overflow level

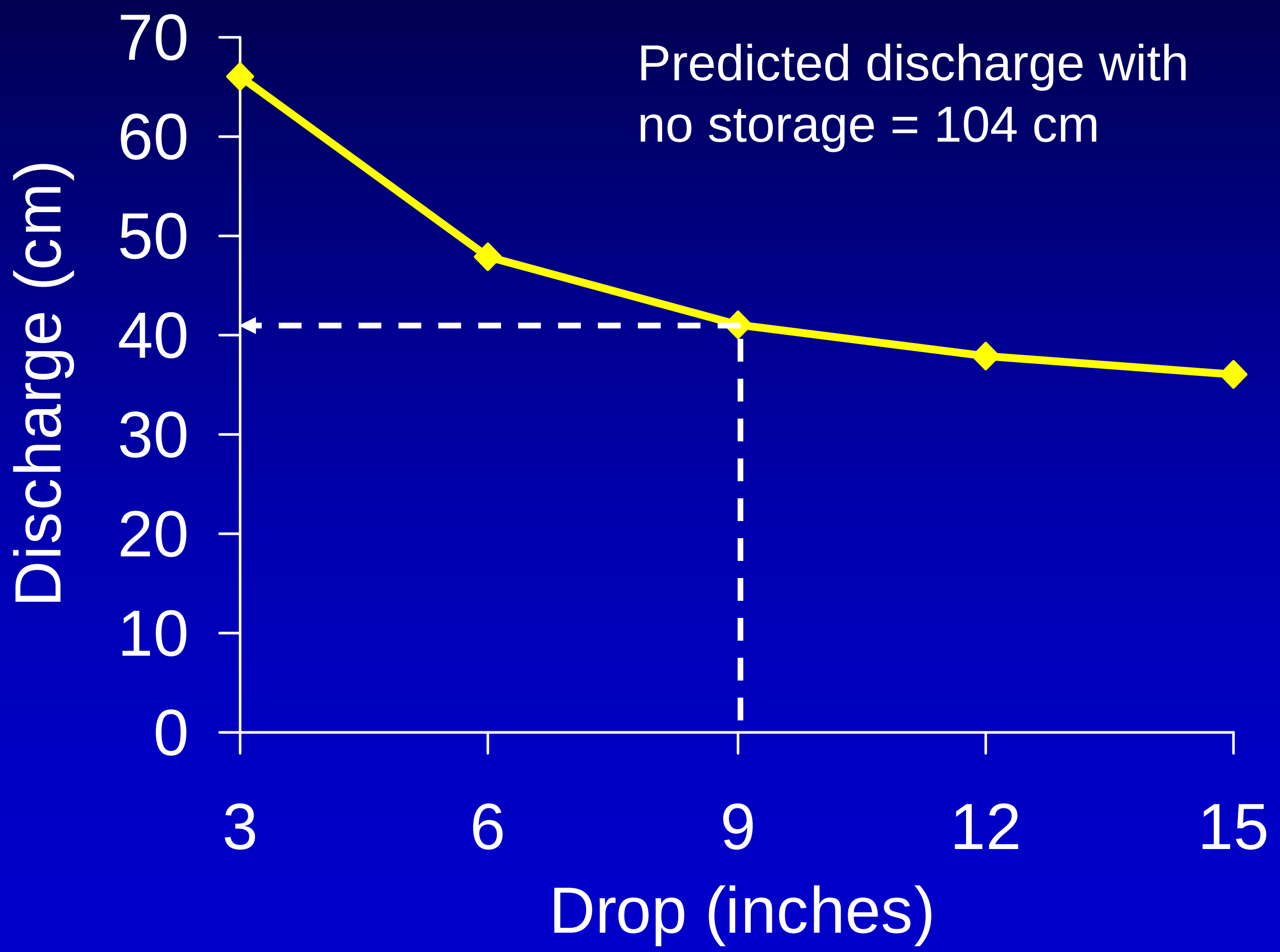
Storage

Drop

Fill

Discharge as a function of drop-fill

(3-inch fill; 29-year model for Stoneville MS)



Predicted discharge with
no storage = 104 cm

Assessment of effluent BMP effectiveness

Feed management

Reduce nitrogen loading by decreasing feed protein level from 32% to 26%

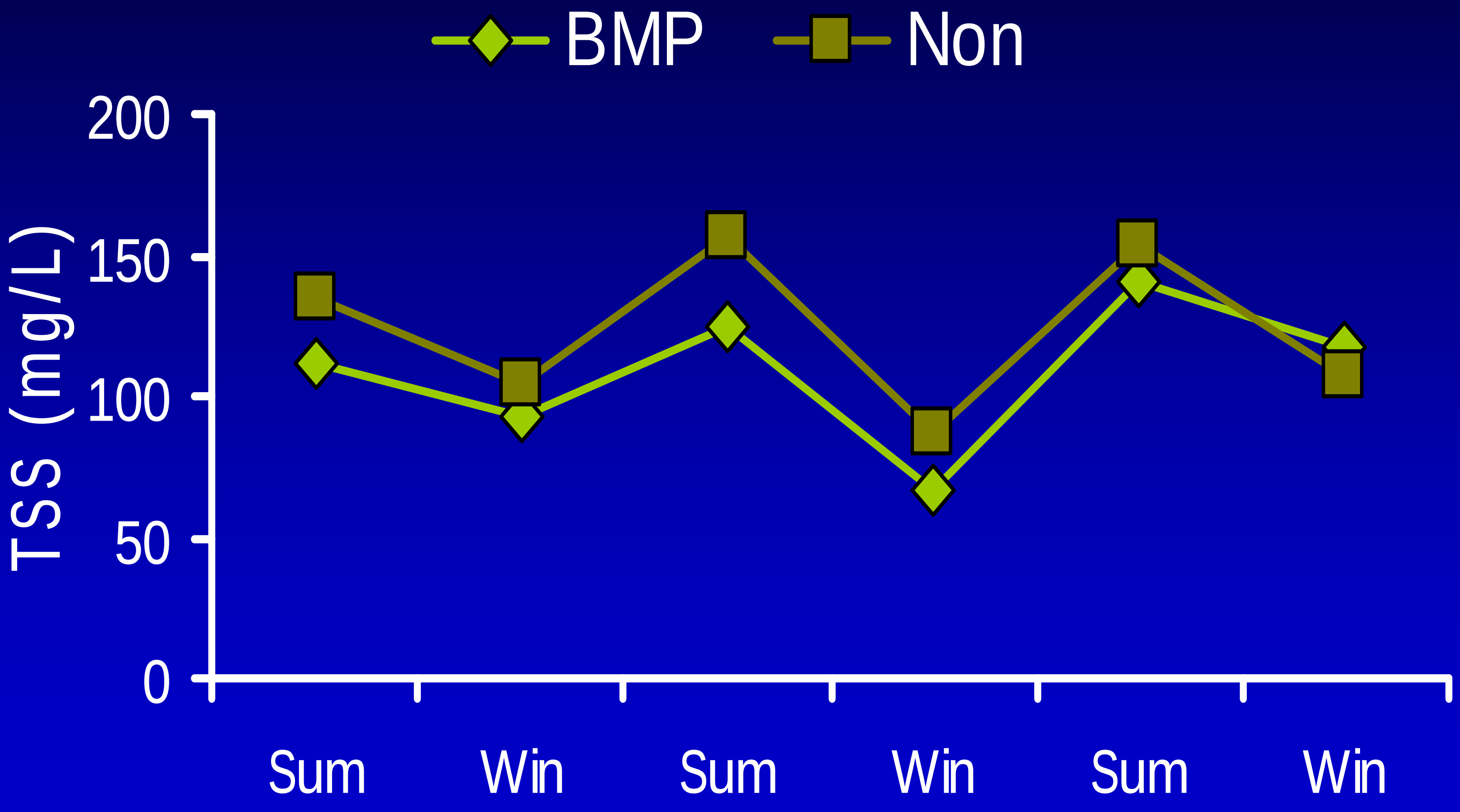
Already demonstrated to be nutritionally feasible

Discharge volume management

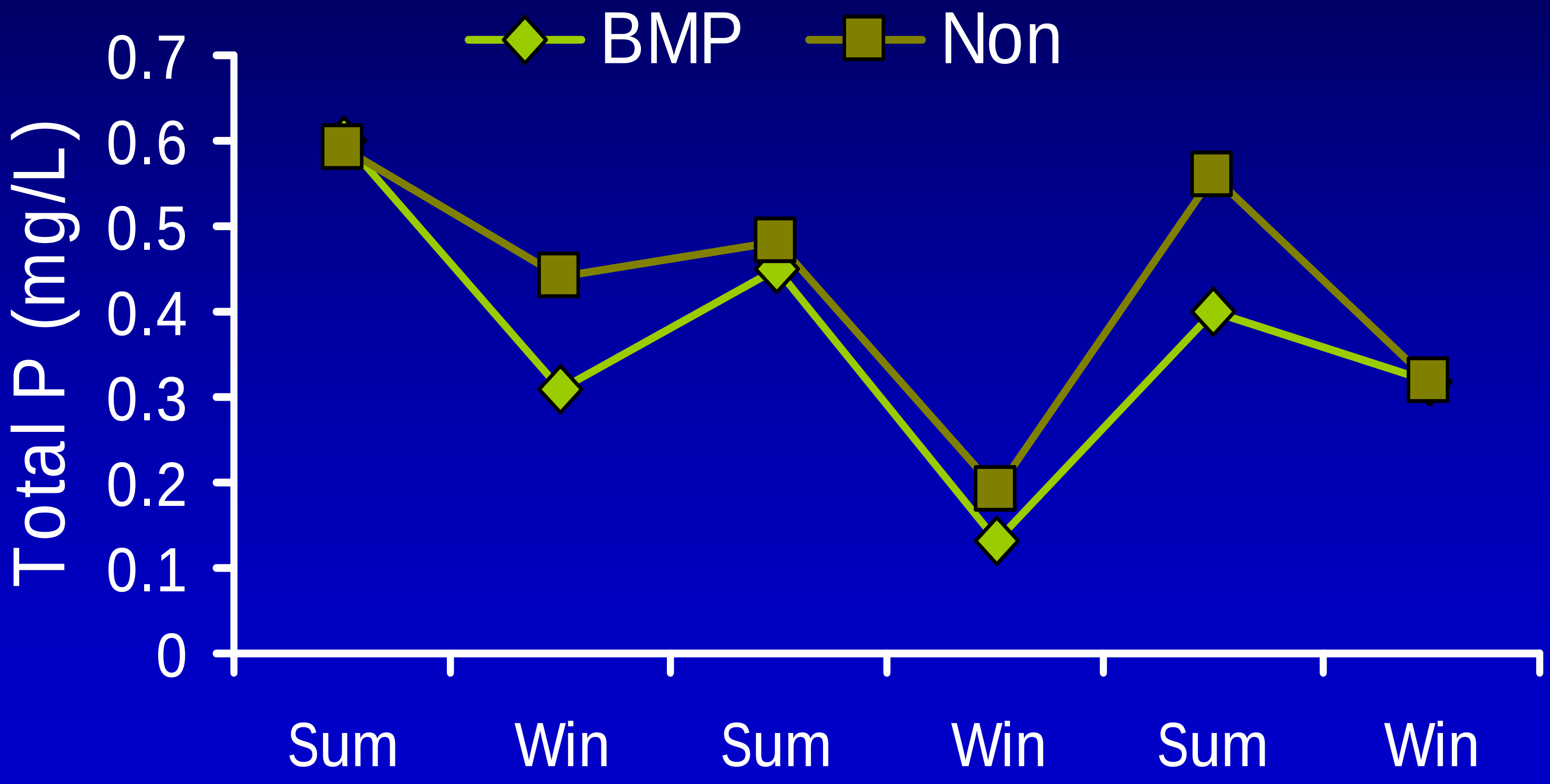
Increase water-storage capacity by using a 9-3 drop-fill routine

Already practiced for water conservation

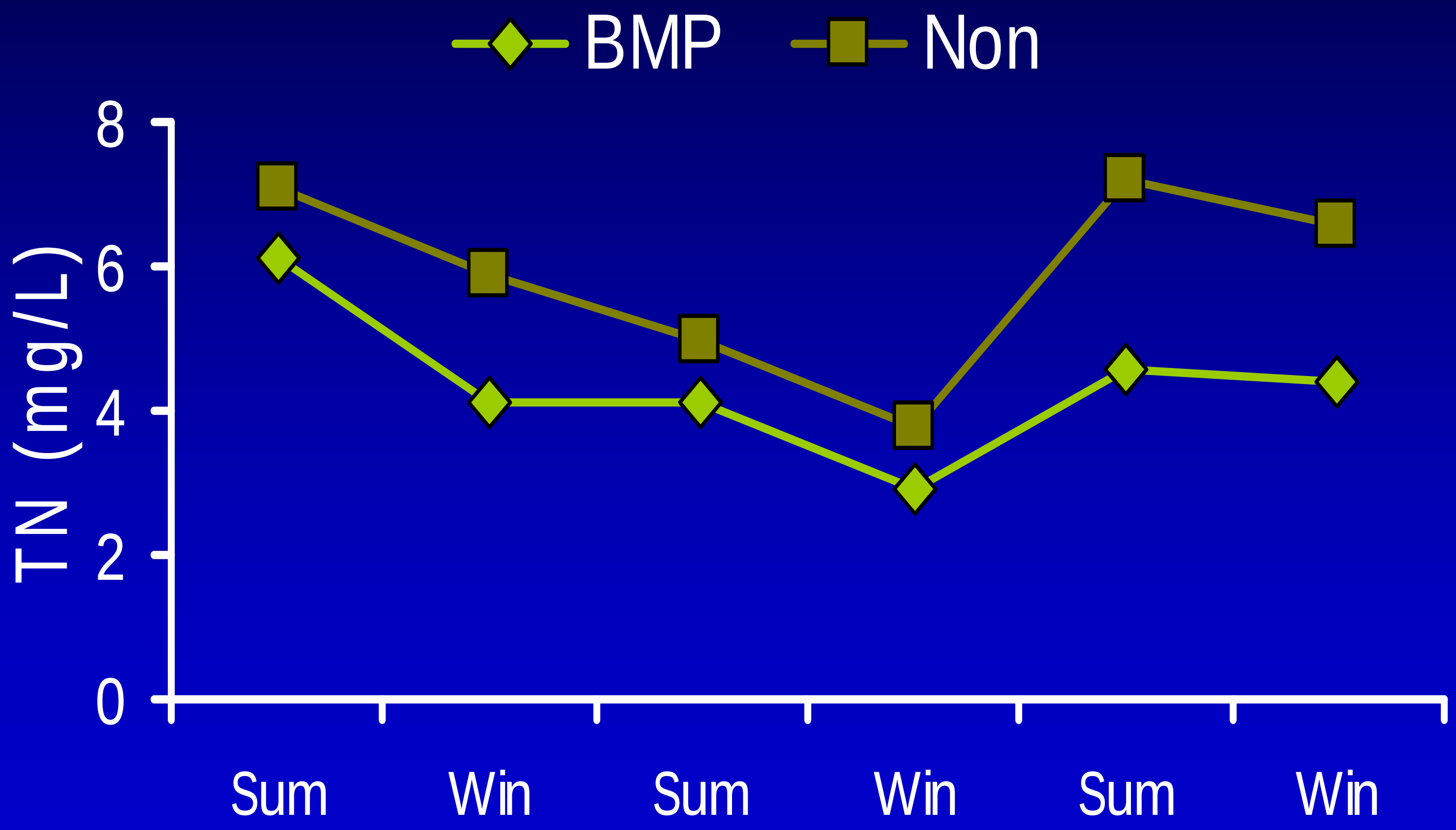
Total Suspended Solids (mg/L, by season)



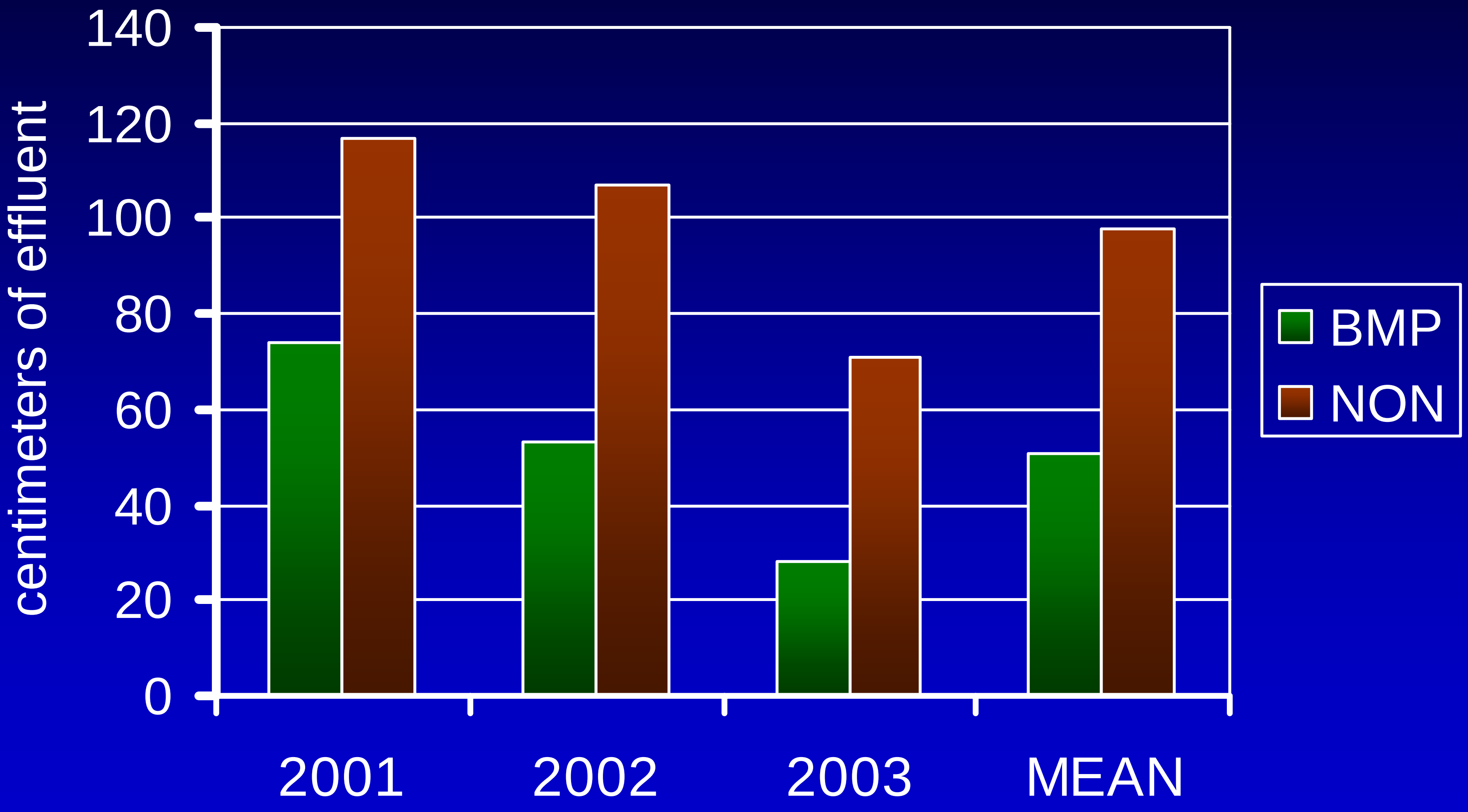
Total Phosphorus (mg/L, by season)



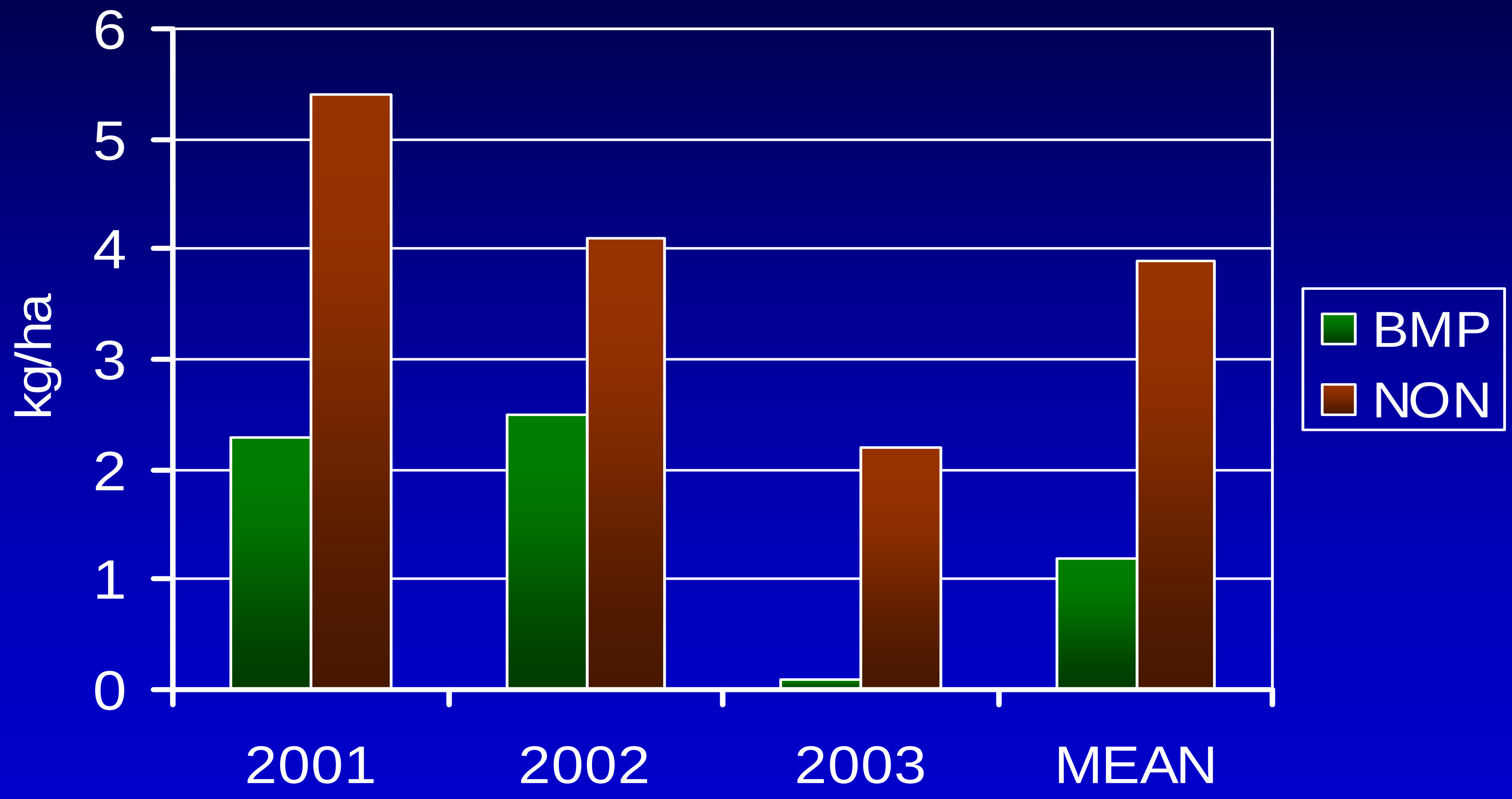
Total Nitrogen (mg/L, by season)



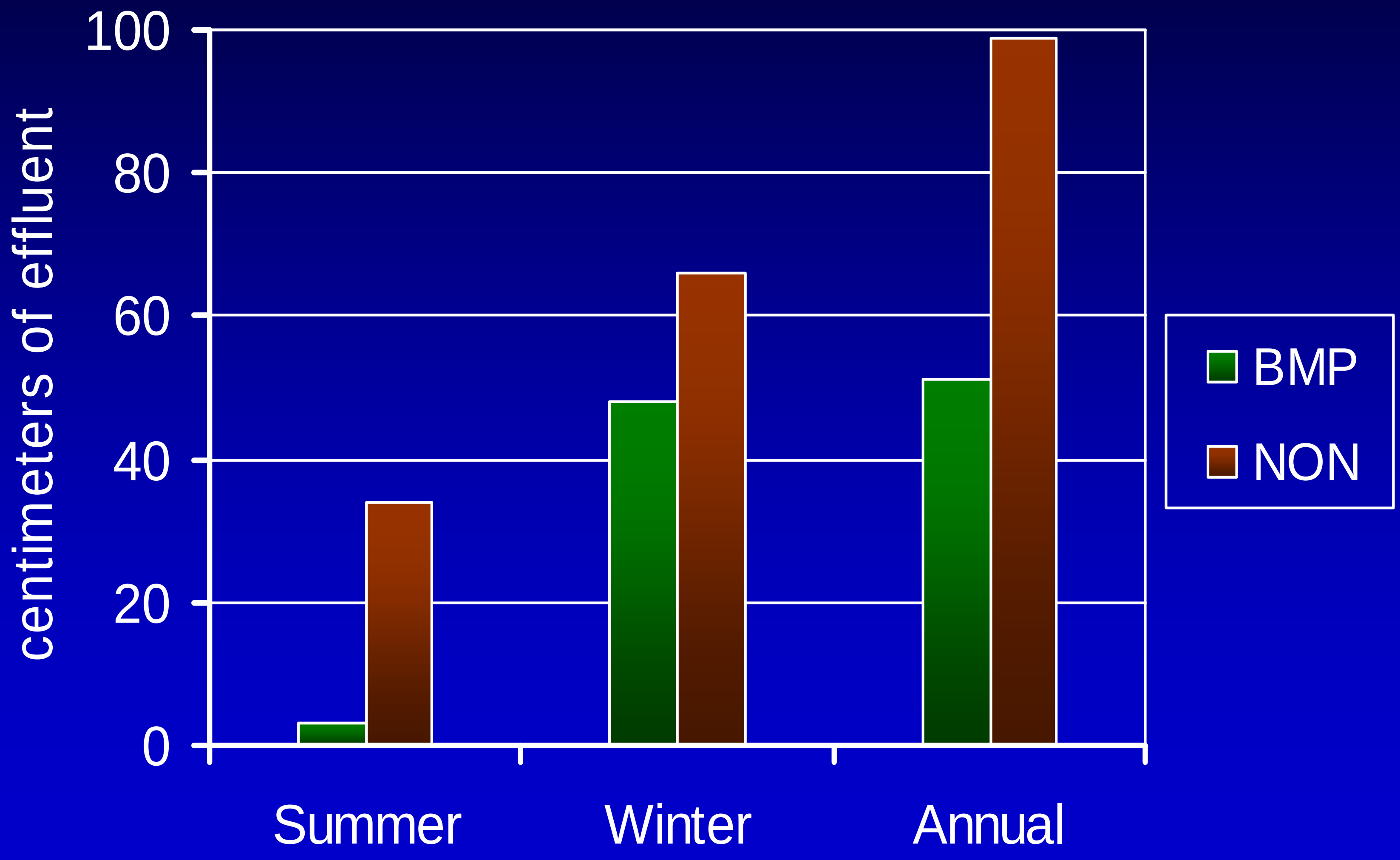
Annual discharge volume reduced by 45%



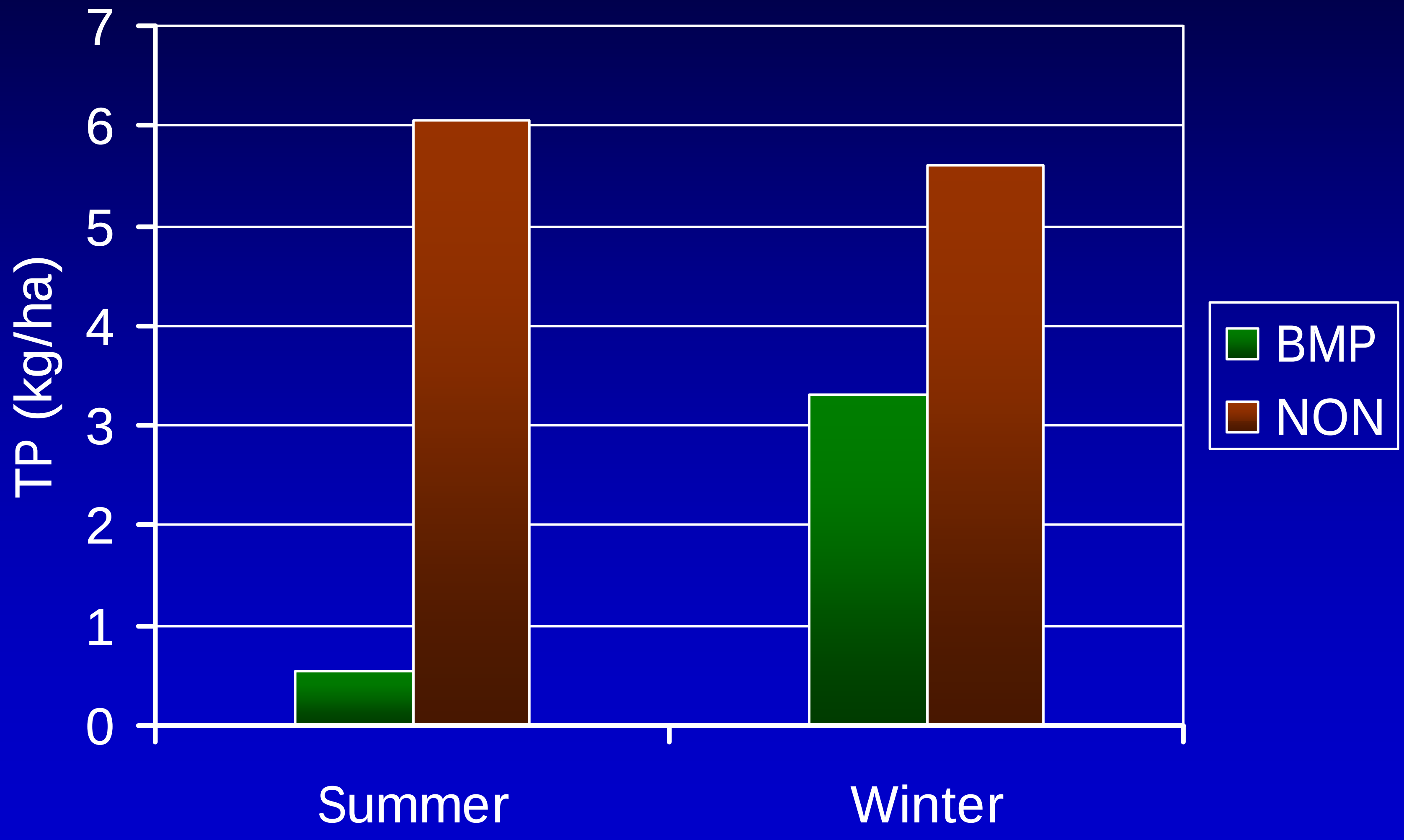
Total phosphorus mass discharge reduced by 70%



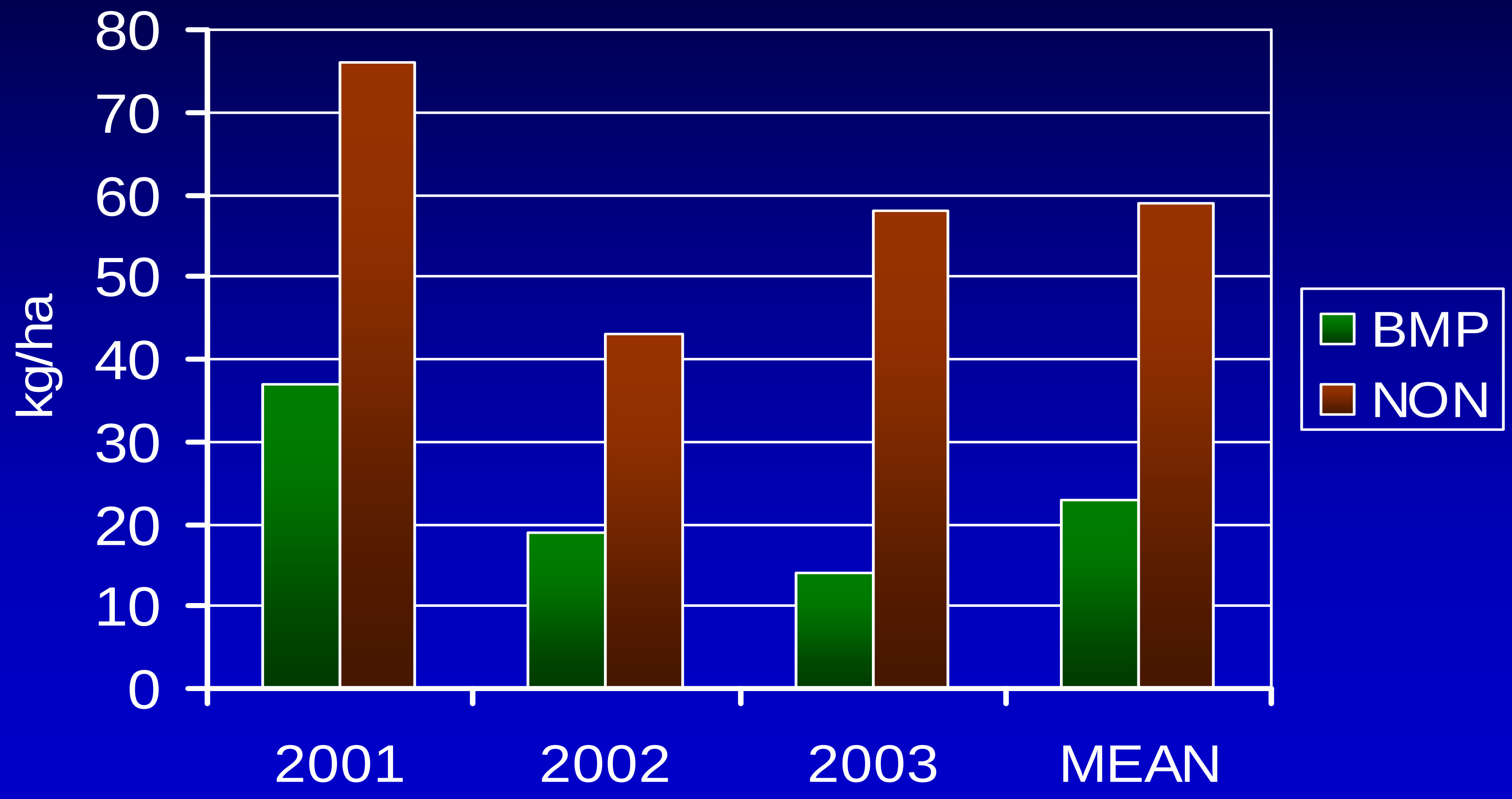
Annual discharge by season



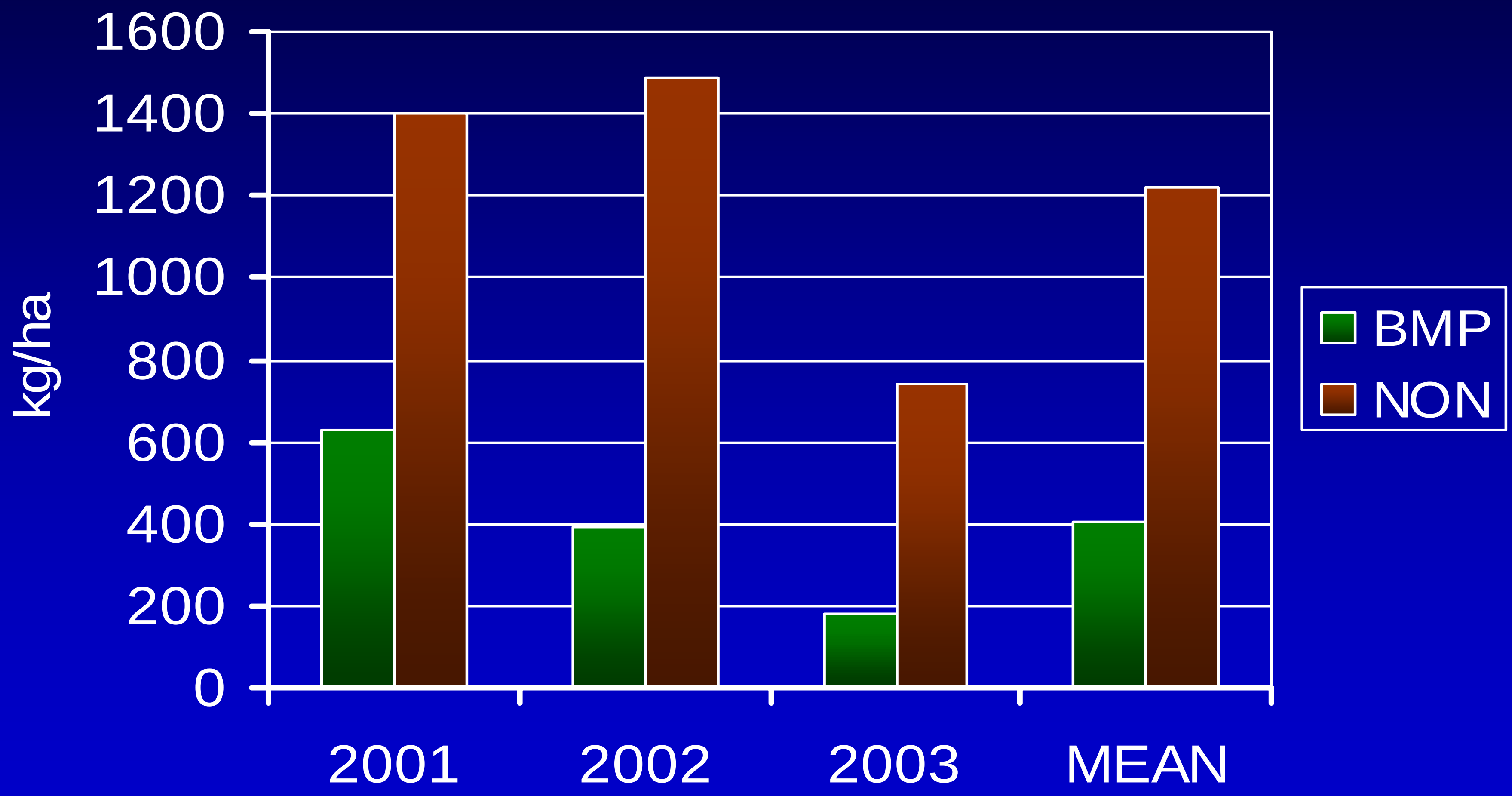
Total phosphorus mass discharge, by season



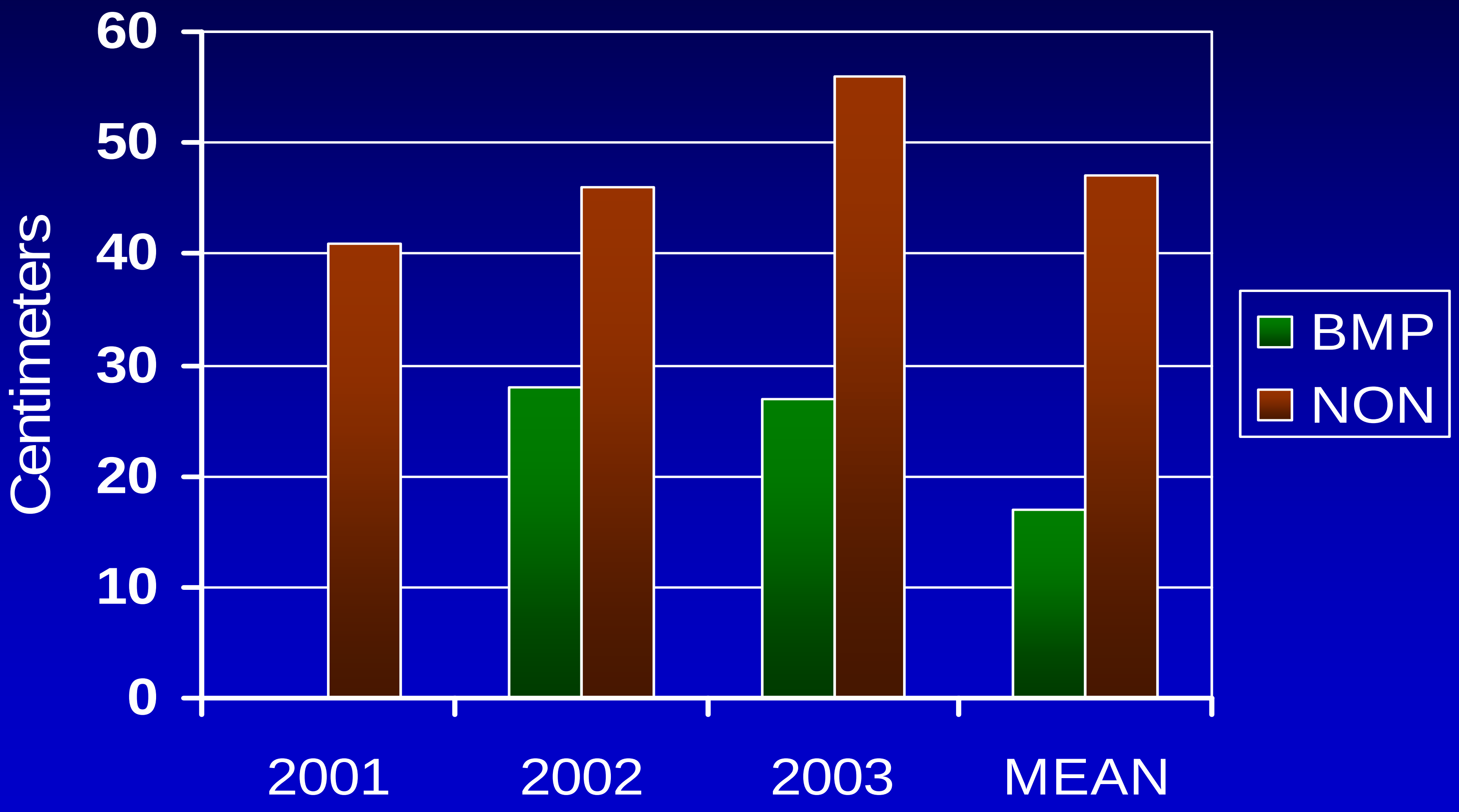
Total nitrogen mass discharge reduced by 70%



Total suspended solids discharge reduced by 65%



Annual groundwater use reduced by 64%



5-year average annual fish yield

BMP = 6,500 pounds/acre
Non BMP = 6,160 pounds/acre

Manage within the pond assimilative capacity

Make efficient use of feed protein

Use water for multiple crops, if possible

Minimize water exchange to the extent possible

Manage water levels to capture rainfall