Nutrient TMDLs & BMPs

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Topics

- What Are Nutrients?
- Nutrients as a Cause of Water Quality Problems
- TMDL Targets
  - Water Quality Criteria for Nutrients:
    - Regulatory Approaches
  - Site-Specific Evaluation of Allowable Nutrient Loads
- BMPs - Development & Evaluation of Management Practices

Presented at UC Farm Advisors & Specialists Workshop, Surface Water Quality in Agriculture, Woodland, CA, March 1 (2005)

G. Fred Lee Background in Evaluation & Management of Nutrient Impacts

- Education
  - Raised on Grape Ranch near Delano, CA
  - BA San Jose State University, 1955
  - MSPH University North Carolina, 1957
  - PhD Harvard University – Environmental Engineering (Emphasis: Aquatic Chemistry), 1960
- Professional
  - 30 yrs University Professor - Graduate Teaching & Research
    - > $5 million University-Based Research
    - Published > 1000 Papers & Reports
    - Supervised Theses/Dissertations of 100 MS & PhD Students
  - Consultant to Governmental Agencies & Industry
    - Part-Time While University Professor
    - Full-Time Since 1989 (16yrs)

G. Fred Lee Background in Evaluation & Management of Nutrient Impact

- Excessive Fertilization of Waterbodies – Major Emphasis
  - Conducted Several Million Dollars of Research on Management of Excessive Fertilization
  - Published Several Hundred Papers & Reports on Topic
  - Presented 2-day Short Courses on Eutrophication Evaluation & Management throughout US and in Several Other Countries
  - Advisor Worldwide: US, France, Italy, Norway, Israel, Jordon, Tunisia, South Africa, India, Netherlands, USSR, International Joint Commission for Great Lakes, Numerous US States and Local Governments/Industry
    - OECD Eutrophication Studies – US EPA Contractor for Synthesis Report for US Waterbody Component
      - Synthesis of Nutrient Load & Response Data for 100 Waterbodies
    - US Representative to OECD Eutrophication Studies Steering Committee
      - 200 Waterbodies in Western Europe, North America, Japan, Australia
      - $50 million, 5-yr Study

G. Fred Lee Background in Evaluation & Management of Nutrient Impact

- Excessive Fertilization of Waterbodies – Major Emphasis
  - Developed Database Describing Nutrient Load—Eutrophication Response Relationships & Use for Nutrient Management
    - Incorporates 750 Waterbodies throughout World Including Antarctica
  - PI for CALFED's $2 million Study of Low-DO Problem in Stockton Deep Water Ship Channel
    - Excessive Algal Growth Major Cause of Problem
    - Developed Synthesis Report on Findings
- Developed 4 Reports for SWRCB/CVRWQCB on Non-Point Source Pollution Control
  - Monitoring
  - Management Practices
  - Excessive Bioaccumulation of Legacy Pesticides & PCBs
  - Organophosphate Pesticides in Stockton

Types of Aquatic Plants

- Algae Planktonic (Suspended) and Attached (Filamentous)
  - Diatoms, Green, Bluegreen, Yellow etc.
- Higher Aquatic Plants – Aquatic Macrophytes (with Roots)
  - Emergent – Cattails
  - Attached – Watercolumn – *Egeria*
  - Floating – Water Hyacinth, Duck Weed
- Each Type Has Its Own Impacts on Water Quality
  - All Are Beneficial to Aquatic Ecosystem
    - Food Web
    - Habitat
  - Balance between Beneficial & Adverse Impacts Poorly Understood – Waterbody-Specific

What Are Aquatic Plant Nutrients?

- Nitrogen Compounds
  - Nitrate, Nitrite, Ammonia, Organic Nitrogen
- Phosphorus Compounds
  - Soluble Orthophosphate, Organic Phosphorus, Inorganic Particulate Phosphate
- Silica for Diatoms in Some Waterbodies
- Available Nutrients – Those That Can Be Used by Algae to Support Algal Growth
  - Soluble Ortho-P + ~20% Particulate Phosphorus in Land Runoff
  - Nitrate/Nitrite, Ammonia, Some Fraction of Organic N (Fraction Depends on Source & Age of Organic N)
  - US EPA Ignoring Fact That Large Amounts of Particulate P & N Are Not Available to Support Algal Growth
  - Dead Algae Are Mineralized – Release Available N & P

Limiting Nutrient Issues

- Limiting Nutrient – Nutrient Present in Least Amount Compared to Need; Greater Growth if Given More
  - Freshwater: Usually P, but on West Coast Frequently N
  - Marine Water: Usually N, but under Polluted Conditions, Can Be P
  - Potassium Not Limiting Nutrient for Algae
- Determination of Limiting Nutrient
  - Cannot Use "Redfield Ratio" to Determine Limiting Nutrient
    - 15 N : 1 P (atomic ratio)
  - Measure Available Nutrients When Algal Growth at Maximum
    - Limiting Nutrient Present at Concentrations below Growth-Rate-Limiting Levels
      - Soluble Ortho-P: 5μg/L P
      - Nitrate + Ammonia: 20 to 30 μg/L N
    - If Levels Greater, Not Limiting the Algal Growth
  - Can Sometimes Force System to P Limitation for Management

Nutrient Export Coefficients

- Mass of Nutrient Derived/Discharged from Unit Area of Land per Unit Time
  - e.g.: $gP/m^2/yr$
- Useful for
  - Characterizing and Quantifying (Estimating) Nutrient Input to Waterbody Derived from a Watershed
  - Estimating Impact of Land Use on Nutrient Load to Waterbody and Management Practices Effectiveness
- Originally Developed at University of Wisconsin-Madison in 1960s
  - Refined through Work of Rast and Lee (1983)
  - Need to Be Evaluated for Central Valley Agricultural Runoff/Discharges

Watershed Nutrient Export Coefficients

(from Rast and Lee, 1983)

Land Use	**Export Coefficients ($g/m^2/y$)**		
	Total Phosphorus	**Total Nitrogen**	
Urban	0.1	0.5	0.25*
Rural/Agriculture	0.05	0.5	0.2*
Forest	0.01	0.3	0.1*
Other:			
Rainfall	0.02	0.8	
Dry Fallout	0.08	1.6	
Domestic Wastewater	1 kgP/person/yr	3 kgN/person/yr (nitrate, nitrite, ammonia, organic N)	

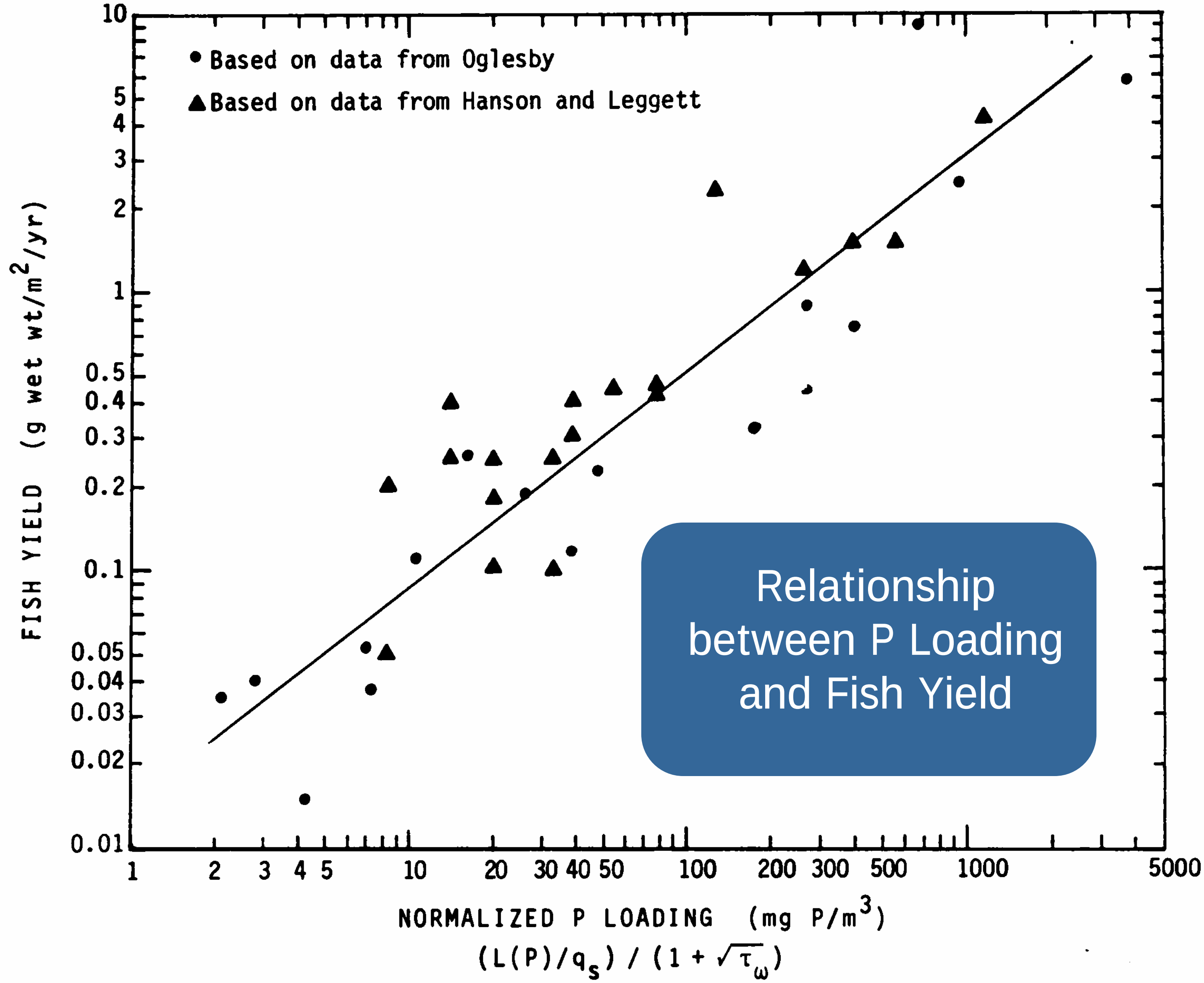
* Export Coefficients Used in Calculating Nitrogen Loadings for Waterbodies in Western US

TMDL Targets

- Properly Establishing the TMDL Target is the Key to Developing a Technically Valid, Appropriate Regulatory Program to Control Excessive Fertilization of a Waterbody
  - Nutrient Criteria
  - Site Specific Evaluation

Water Quality Problems Caused by Excessive Fertilization

- Domestic Water Supplies – Increased Treatment
  - Tastes & Odors
  - THM Precursors
  - Shortened Filter Runs
  - Increased Cost of Treatment
- Violations of Water Quality Standards – Photosynthesis Related
  - pH
  - Dissolved Oxygen
- Recreation – Odors & Scum
  - Impaired Boating
  - Impaired Swimming/Wading
- Shallow-Water Habitat
  - Loss of Attached Vegetation & Aquatic Life Habitat
- Fisheries
  - Improved Fish Production (Biomass)
  - Less Desirable Fish at High Levels of Fertilization



Based on data from Oglesby
Based on data from Hanson and Leggett
FISH YIELD (g wet wt/m^2/yr)
10
5
4
3
2
1
0.5
0.4
0.3
0.2
0.1
0.05
0.04
0.03
0.02
0.01
1 2 3 4 5 10 20 30 40 50 100 200 300 500 1000 5000
NORMALIZED P LOADING (mg P/m^3)
(L(P)/q_s) / (1 + √τ_ω)
Relationship between P Loading and Fish Yield

Water Quality Problems Caused by Excessive Fertilization

- Overall – Excessive Fertilization One of Most Important Causes of Water Quality Impairment
- US EPA National Water Quality Inventory
  - Listed Nutrients as Leading Cause of Impaired Lakes & Reservoirs
  - Agriculture Cited as Primary Sources of Constituents That Impair Lakes (Nitrogen & Phosphorus)

Water Quality Criteria & Regulations for Nutrients

- From Regulatory Perspective, Desirable to Develop Numeric, Chemical-Specific Criteria
  - Bureaucratically Simple to Administer
    - Do Not Require Understanding of How Nutrients Impact Water Quality/Beneficial Uses
- US EPA Tried to Develop Generic, Default Nutrient Criteria
  - Failed
  - Technically Invalid Approach
  - RTAG for US EPA Region 9 Determined Generic Criteria Unreliable
  - Currently CA Should Show Satisfactory Progress to Developing Nutrient Criteria in 2007
    - No Funds Available to conduct the Needed Studies
- Relationships Among Nutrient Concentrations – Loads – Aquatic Plant Biomass – Water Quality
  - Depend on Variety of Site-Specific Factors
  - Require Site-Specific Assessment

Water Quality Criteria & Regulations for Nutrients

- CVRWQCB Basin Plan Regulates Excessive Aquatic Plant Nutrients Based on Excessive "Biostimulatory Substances" in Narrative Water Quality Objective (WQO):

  *"**Biostimulatory Substances***

  Water shall not contain biostimulatory substances which promote aquatic growths in concentrations that cause nuisance or adversely affect beneficial uses."

- No Guidance Provided on How to Implement Narrative WQO
  - Will Need to Be Addressed in Interpreting Ag Waiver Monitoring Results of Nutrient Monitoring

Water Quality Criteria & Regulations for Nutrients

- CVRWQCB Staff Requested That GFL Develop Guidance on How This WQO Can Be Achieved as Part of Developing Guidance on Non-Point Source Management Practices

  Lee, G. F., and Jones-Lee, A., "Review of Management Practices for Controlling the Water Quality Impacts of Potential Pollutants in Irrigated Agriculture Stormwater Runoff and Tailwater Discharges," California Water Institute Report TP 02-05 to California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 128 pp, California State University-Fresno, Fresno, CA, December (2002). http://www.gfredlee.com/BMP_Rpt.pdf

- Require Site-Specific Evaluation

Ag Waiver Nutrient Monitoring/ Management Requirements

The CVRWQCB Agricultural (Ag) Waiver Water Quality Management Program requires that agricultural dischargers (runoff and tail water) shall develop a Monitoring and Reporting (MRP) Plan.

"The MRP Plan shall be designed to achieve the following objectives as a condition of the Waiver:

a. Assess the impacts of waste discharges from irrigated lands to surface water;

b. Determine the degree of implementation of management practices to reduce discharge of specific wastes that impact water quality;

c. Determine the effectiveness of management practices and strategies to reduce discharges of wastes that impact water quality;

d. Determine concentration and load of waste in these discharges to surface waters; and

e. Evaluate compliance with existing narrative and numeric water quality objectives to determine if additional implementation of management practices are necessary to improve and/or protect water quality."

Other Wastes include "*salt, sediment, nitrogen, etc.*",

[Based on "Monitoring and Reporting Program Order no. R5-2003-0826 for Coalition Groups under Resolution no. R5-2003-0105 Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands," Adopted by CVRWQCB in 2003.]

Ag Waiver
Nutrient Monitoring/Management Requirements

"The MRP Plan shall describe a phased monitoring approach and provide documentation to support the proposed monitoring program. The program shall not consist of more than three phases.

Phase 1 monitoring shall, at a minimum, include analyses of physical parameters, drinking water constituents, pesticide use evaluation, and toxicity testing.

Phase 2 monitoring includes chemical analyses of constituents that were identified in toxicity testing in phase one that may include pesticides, metals, inorganic constituents and nutrients and, additional monitoring site in the watershed.

Phase 3 monitoring includes management practice effectiveness and implementation tracking and additional water quality monitoring sites in the upper portions of the watershed."

Ag Waiver
Nutrient Monitoring/Management Requirements

Phase 2 is expected to begin no later than 2 years after the start of the first phase. Since Phase I was to start in April 2004, Phase 2 in which Includes nutrient monitoring is supposed to begin in April 2006. This could mean that by 2007 there will be need for information on how to interpret the nutrient monitoring data.

"Phase 3 shall determine statistically significant changes in waste concentrations based on various management practices. Phase 3 monitoring shall begin no later than two years from the start of Phase 2 monitoring."

Minimum Requirements for Monitoring include *"Total Kjeldahl Nitrogen, Phosphorus and Potassium."* See comments by Lee (2004) on the changes that need to be made in this monitoring program to develop interpretable data.

Need for Study

- In Order to Have the Information Needed to Interpret the Ag Waiver Nutrient Monitoring Data That Will Be Generated in 2007, Need to Begin Studies Now on,
  - Nutrient-Related Water Quality Problems Downstream of Monitoring Station
  - Desired Water Quality in Downstream Waterbodies
    - Consider Impact of Altered Nutrient Loads on Fisheries
- No Funds Available to Conduct the Needed Studies
    - Nutrient Data Will Be Uninterpretable until This Information Is Available

Site-Specific Evaluation of Allowable Nutrient Loads

- Recommended Approach for Developing Allowable Nutrient Loads for a Waterbody
  - Develop Statement of Excessive Fertilization Problem of Concern
  - Establish Desired Eutrophication-Related Water Quality Characteristics (Goal of Nutrient Management)
  - Determine Nutrient Sources Focusing on Available Forms
  - Evaluate Nutrient Loads That Lead to Water Quality Problems of Concern
    - Nutrients Added During Part of the Year Can be Responsible for Water Quality Problem
  - Establish Linkage between Nutrient Load & Eutrophication Response (Modeling)
    - Consider Year-to-Year Variability
  - Initiate Phase I Nutrient Control Implementation Program to Control Nutrients to Level Needed to Achieve Desired Water Quality Characteristics and Fisheries

Site-Specific Evaluation of Allowable Nutrient Loads

- Monitor Waterbody for 3 to 5 Years after Nutrient Control Implementation to Determine Whether Desired Water Quality Is Being Achieved
- If Not Achieved, Begin Phase II
  - Review Loading Sources and Estimates
  - Improve Load—Response Model Applicability to Specific Waterbody
  - Evaluate Achievement of Nutrient Control Measures
  - Assess Further Available Nutrient Load Reduction Needed to Achieve Desired Water Quality Characteristics
  - Adjust Nutrient Control Measures
- Site-Specific Evaluation Is Iterative Process
  - Over 5-15-yr Period, with 2+ Iterations, Will Be Possible to
    - Achieve Desired Water Quality
    - Translate Nutrient Loads to Waterbody Concentration & Thereby Nutrient Criteria for Waterbody

Development & Evaluation of Management Practices
Recommended Approach

- Determine Nutrient Load Management Goal – Desired Water Characteristics
  - Balance Low Algae Levels & Fish Production
- Determine Nutrient That Is, or Can Be Made to Be, Limiting Algal Growth
- Evaluate & Quantify Sources of Limiting Nutrients
- Evaluate Transformation of Limiting Nutrient between Sources & Waterbody That Impact Availability in Waterbody
- Evaluate Hydrology & Nutrient Transport from Sources
  - Conditions That Lead to Nutrient Releases from Source That Lead to Water Quality Problems

Development & Evaluation of Management Practices
Recommended Approach

- Conduct Site Studies of Most Promising Management Practices
  - Should Also Monitor for Other Potential Pollutants in Ag Runoff
    - Pesticides, TOC, Sediments
  - Consider Ability of Each Practice to Result in Achievement of Desired Nutrient Management
  - Consider Cost-Effectiveness & Implementability of Each MP
  - Consider Year-to-Year Variability of Climate & Other Factors
- Develop Overall Recommended Management Approach
- Refine Management Practices Based on Monitoring/ Evaluation Results
- Evaluate Whether Management Practice Leads to Groundwater Pollution (Salt, Nitrate) or Has Other Adverse Consequences

Development & Evaluation of Management Practices
Recommended Approach

- Assess Load Reductions Necessary to Achieve Goals through Reliable Modeling
- Based on Literature, Estimate Amount of Nutrient Control Likely by Various Management Practices, e.g.,
  - Tail Water Ponds
  - Vegetated Strips
  - Cover Crops
  - Fertilization Application Practices (Precision Farming)
    - Optimize Nutrient Application to Minimize Runoff

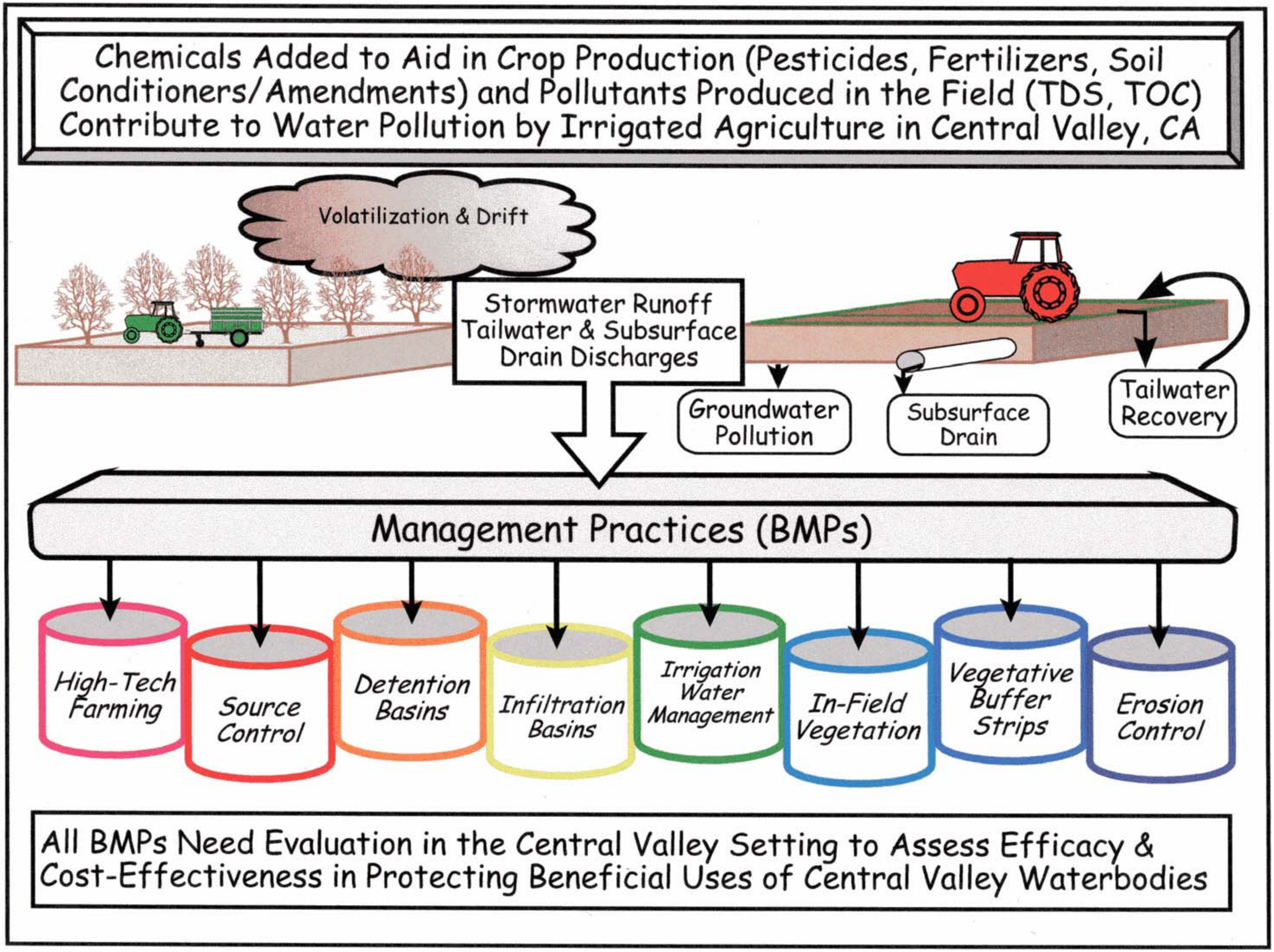
See Lee and Jones-Lee 2002 Review & CA Stormwater Quality Association BMP Handbooks at www.casqa.org

Review of Management Practices for Controlling the Water Quality Impacts of Potential Pollutants in Irrigated Agriculture Stormwater Runoff and Tailwater Discharges

G. Fred Lee, PhD, DEE and Anne Jones-Lee, PhD

California Water Institute
California State University, Fresno
Fresno, California

December 2002



Chemicals Added to Aid in Crop Production (Pesticides, Fertilizers, Soil Conditioners/Amendments) and Pollutants Produced in the Field (TDS, TOC) Contribute to Water Pollution by Irrigated Agriculture in Central Valley, CA
Volatilization & Drift
Stormwater Runoff Tailwater & Subsurface Drain Discharges
Groundwater Pollution
Subsurface Drain
Tailwater Recovery
Management Practices (BMPs)
High-Tech Farming
Source Control
Detention Basins
Infiltration Basins
Irrigation Water Management
In-Field Vegetation
Vegetative Buffer Strips
Erosion Control
All BMPs Need Evaluation in the Central Valley Setting to Assess Efficacy & Cost-Effectiveness in Protecting Beneficial Uses of Central Valley Waterbodies

Caltrans BMP Retrofit Pilot Program

Scott Taylor, P.E.

RBF Consulting

Irvine, CA

and

Michael Barrett, Ph.D., P.E.

Center for Research in Water Resources

University of Texas at Austin

Austin, TX

http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/_pdfs/new_technology/CTSW-RT-01-050/AppendixA/Scoping/scoping_11.pdf

Design Storm Concentrations

Constituent	Concentration
TSS	114
Nitrate (as N)	0.97
Total Kjeldahl Nitrogen	2.36
Ortho-Phosphorus	0.12
Particulate Phosphorus	0.26
Dissolved Copper	18
Dissolved Zinc	122
Dissolved Lead	8

Concentrations in mg/L except metals which are μg/L.

Summary of Constituent Removal

	TSS	Nitrate	TKN	P
Wet Basin	93%	61%	27%	5%
MCTT	75%	-63%	18%	18%
Austin MF	90%	-71%	41%	39%
Delaware MF	81%	-55%	44%	44%
Bio Strip	83%	36%	47%	7%
Extended Det.	76%	35%	37%	53%
Bio Swale	77%	60%	69%	8%

Strips, Swales, EDBs are Load Reduction

Additional Information

- Lee, G. F. and Jones-Lee, A., "Developing Nutrient Criteria/TMDLs to Manage Excessive Fertilization of Waterbodies," Proceedings Water Environment Federation, TMDL 2002 Conference, Phoenix, AZ, November (2002). http://www.gfredlee.com/WEFN.Criteria.pdf

- Lee, G. F. and Jones-Lee, A., "Assessing the Water Quality Impacts of Phosphorus in Runoff from Agricultural Lands," In: Hall, W. L. and Robarge, W. P., ed., Environmental Impact of Fertilizer on Soil and Water, American Chemical Society Symposium Series 872, Oxford University Press, Cary, NC, pp. 207-219 (2004). http://www.gfredlee.com/ag_p-1_012002.pdf

- Lee, G.F. and Jones-Lee, A., "Developing Central Valley, California, Agricultural Runoff/ Discharges Water Quality Monitoring Programs," Proceedings of 2003 AWRA Spring Specialty Conference," Agricultural Hydrology and Water Quality," American Water Resources Assn, Kansas City, MO, May (2003). http://www.gfredlee.com/AWRA_KC_Pap-Lee-web.pdf

- Lee, G. F. and Jones-Lee, A., "Issues in Developing a Water Quality Monitoring Program for Evaluation of the Water Quality - Beneficial Use Impacts of Stormwater Runoff and Irrigation Water Discharges from Irrigated Agriculture in the Central Valley, CA," California Water Institute Report TP 02-07 to the California Water Resources Control Board/ Central Valley Regional Water Quality Control Board, 157 pp, California State University Fresno, Fresno, CA, December (2002). http://www.gfredlee.com/Agwaivemonitoring-dec.pdf

Additional Information

- Lee, G. F. and Jones-Lee, A., "Review of Management Practices for Controlling the Water Quality Impacts of Potential Pollutants in Irrigated Agriculture Stormwater Runoff and Tailwater Discharges," California Water Institute Report TP 02-05 to California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 128 pp, California State University Fresno, Fresno, CA, December (2002). http://www.gfredlee.com/BMP_Rpt.pdf

- Lee, G. F., "Proposed Regionalization of Nutrient Criteria Development within the Central Valley of California," Submitted to the US EPA RTAG Nutrient Criteria Program, Report of G. Fred Lee & Associates, El Macero, CA (2001). http://www.gfredlee.com/nut-cri-reg8-4-01.pdf

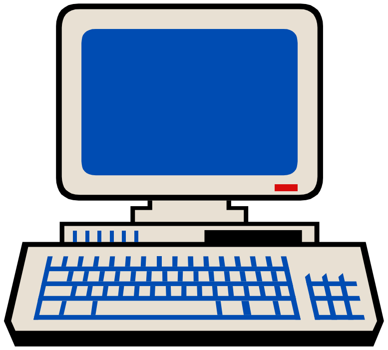
- Lee, G. F., "Comments on SWRCB January 9, 2004 Review of Irrigated Agriculture Waiver Water Quality Monitoring Requirements," Comments submitted to the California State Water Resources Control Board by G. Fred Lee & Associates, El Macero, CA, January 19 (2004). http://www.gfredlee.com/AgWaiverComments1-19-04.pdf

Other papers and reports on Lee and Jones-Lee website, www.gfredlee.com in the Surface Water and Excessive Fertilization Eutrophication sections.

Further Information

Consult Website of

Drs. G. Fred Lee and Anne Jones-Lee



http://www.gfredlee.com

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Publications on:

- Landfills-Groundwater Quality
- Surface Water Quality
- Hazardous Chemical Sites
- Mine Waste Impacts
- Contaminated Sediment
- Domestic Water Supply
- Excessive Fertilization
- Reclaimed Wastewater
- Watershed Studies San Joaquin River Watershed & Delta
- Stormwater Newsletter
  - E-mail-Based – Sent Periodically to > 8,000