

# Regulating Water Quality Impacts of Water Column & Sediment Contamination in Port & Harbor Stormwater Runoff

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- Problems in Regulating Urban Stormwater Runoff-Related Water Quality
  - Trying to Regulate Like a Wastewater Discharge
    - Exceedance of Worst-Case-Based Water Quality Standards Requires BMP Ratcheting-Down Process to Ultimately Achieve WQs
  - Total Concentration of Chemical Constituents in Water/Sediments Not Reliable Indicator of Potential Water Quality Impacts
- Recommended Approach
  - Define the Real, Significant Water Quality Problems in Water Column and Sediment Caused by Stormwater Runoff
  - Control Those Pollutants at the Source(s)

# Problems in Regulating Water Quality

## Impacts of Urban Stormwater Runoff

- Stormwater Runoff from Harbors & Ports Is Regulated with Urban Stormwater Runoff (Except for Some Industrial & Designated Commercial Properties)
- Stormwater Runoff from Urban Residential & Commercial Areas Contains Some Chemical Constituents & Pathogen Indicator Organisms in Concentrations That Exceed Water Quality Standards
  - Cu, Pb, Zn, Cd, Fecal Coliforms
  - Lead to Violations of Water Quality Standards in Water Receiving Runoff
- Under Current Regulatory Requirements, Stormwater Discharge Manager Must Implement BMPs in a Ratcheting-Down Process
  - Control Constituents in Runoff That Cause Violations of WQSs with Increasingly Effective BMPs
    - Court Require That Updated BMPs Have Demonstrably Greater Effectiveness in Controlling WQS Violations

# Problems in Regulating Water Quality Impacts of Urban Stormwater Runoff

- Currently-Used BMPs (e.g., Detention Basins, Grassy Swales)
  - Expensive to Retrofit in Developed Areas
  - Cannot Treat Urban Stormwater Runoff to Achieve WQS with  $\leq 1$  Violation of Any Magnitude 1x in 3 yrs
  - \$5 to \$10/person/day – Cost to Urban Population Served by the Stormwater Collection System to Meet WQSs without Violation
    - Impossible Situation
  - Must Develop Alternative Approach for Regulating Water Quality Impacts of Urban Stormwater Runoff

# Background to Properly Regulating Water Quality Impacts of Urban Stormwater Runoff

- Currently Used WQSs Not Designed for Short-Term Pulses of Pollutants Characteristic of Stormwater Runoff
  - 1-hr Average for Acute Criterion – Arbitrary
  - Rare That Exceedance Would Be Adverse to Aquatic Life
- Many of the Potential Pollutants in Urban Stormwater Runoff in Non-Toxic Forms
  - Particulate Forms, Complexed Metals, etc.
- Need Wet-Weather Standards That More Reliably Consider How Potential Pollutants in Urban Stormwater Runoff Impact Aquatic Life & Other Beneficial Uses of Receiving Water

# Recommended Approach

- Should Shift Monitoring of Stormwater Runoff from Chemical Constituent Monitoring to **Chemical Impact Monitoring**
  - Use Evaluation Monitoring Approach
  - Determine the Real, Significant Water Quality Use-Impairments in Waters Receiving the Runoff
  - Determine the Cause of the Use-Impairment(s)
  - Determine Source of Pollutant(s) That Cause the Use-Impairment
  - Control the Pollutant(s) at Source

# Sediments

- Need to Develop Approach for Regulating Particulate Potential Pollutants in Stormwater Runoff
  - US EPA Adopted Ambient-Water-Soluble Metals as Basis for Regulating Potentially Toxic Metals (e.g., Cu, Pb, Zn, Ni, Cd)
    - Results in Elevated Concentrations of Heavy Metals in Receiving Water Sediment
  - Even Though Non-Toxic in Water Column, Many Other Potentially Toxic Organics Are Regulated Based on Total Concentrations
    - Over-Regulation
    - Contaminants Tend to Accumulate in Sediments
      - Potential Threat to Cause Water Quality – Beneficial Use – Impairment

# Regulating Stormwater-Derived Sediment-Associated Potential Pollutants

## KEY ISSUE:

- Potential Pollutant Chemicals Exist in Sediments in Variety of Chemical Forms
  - Only Small Portion Are in Toxic/Available Forms
  - Most of Forms of Potential Pollutants in Sediments Inert – i.e., Not Pollutants
- No Relationship between Total Concentration of a Potential Pollutant in Sediment and Its Impact on Water Quality

# Sediment Concentration/ Binding Issues

- Concentration of Potential Pollutant in Sediment Not Analogous to That in Water
  - Water:  $\text{Mass of Chemical} / \text{Mass (kg) (Volume – L) of Water}$ 
    - The Liter (i.e., kg) of Water Is of Constant Composition – 55moles/kg of water
  - Sediment:  $\text{Mass of Chemical} / \text{Mass of Sediment}$ 
    - The Bulk Mass of Sediment Is of Variable Composition Depending on
      - Input of Erosional & Other Material from Watershed
      - Precipitates ( $\text{CaCO}_3$ ), Sulfides
      - Aquatic Vegetation Remains (Detritus)



# Sediment Concentration/ Binding Issues

- Important Because Bulk Composition of Sediments Determines the Binding of Pollutant to Sediment
  - TOC Binds Many Large, Hydrophobic, Organic Molecules
  - Sulfides Bind Heavy Metals
  - Carbonates Bind Some Heavy Metals Such as Cu
  - Clays Bind Metals & Organics
  - Iron Oxides Bind Metals & Organics

# Sediment Concentration/ Binding Issues

- Must Conduct Toxicity Identification Evaluations (TIEs) to Determine Toxicity of Forms of Potential Pollutants Present to Identify Cause of Toxicity
- Must Conduct Organism-Based Bioavailability Studies to Determine Amount of a Chemical That Can Be Accumulated in Food Web
  - Some Try to Regulate Chemicals in Sediment as They Regulate Chemicals in Water – with Chemical Concentration-Based Criteria/Standards
    - Not Technically Valid

# Approaches for Regulating Sediment Pollutants

## Chemical Concentration vs Biological Impact

- Chemical Concentration Approach
  - Single, Numeric Concentration Criterion/Standard Not Valid
- Must Use Biological Impact-Based Approaches
  - Toxicity
  - Excessive Bioaccumulation in Edible Organisms
- 1970s COE Conducted 5-yr, \$30-million DMRP (Dredged Material Research Program) to Develop Open Water Dredged Sediment Disposal Criteria

# Approaches for Regulating Sediment Pollutants

- G. F. Lee Conducted >\$1million Studies on Dredged Sediment Disposal Criteria
  - About 100 Sediment Sites across US
  - At Each: 30 Parameters
  - ~50,000 Data Points Describing Chemical Release from Sediments and Toxicity
- COE & US EPA Developed Biological Impact Regulatory Approach
  - Based on Toxicity & Bioavailability
  - Worked Well for Regulating Dredged Sediment Disposal for >25 yrs

# Approaches for Regulating Sediment Pollutants

## Chemical Concentration vs Biological Impact

- US EPA Tried for Decade to Develop Chemical Concentration-Based Sediment Quality Criteria in 1990s
  - Found Approach to Be Unreliable
  - Sediment Systems Too Complex for Approach to Work
  - US EPA Indicated It's Adopting Biological Effects-Based Approach
- Some State Regulatory Agencies Try to Develop Chemical Concentration-Based Sediment Quality Criteria
  - Analyze Sediment for Total Chemical Concentration; Compare Concentration to SQC/SQO
  - Ignore/Disregard the Literature & Aquatic Chemistry /Toxicology
  - Administratively Simple to Implement
  - Technically Invalid

# Co-Occurrence Approaches

- Late 1980s Long & Morgan Developed “Co-Occurrence”-Based Sediment Quality Guidelines (SQG)
  - MacDonald Subsequently Proposed His Co-Occurrence-Based SQG
  - Based on Relating Total Concentration of Chemical in Sediment to Some Biological Characteristic Such as Sediment Toxicity
    - Same Endpoint Presumed Associated with Each Chemical in Sediment
- Obviously Not Technically Valid
  - Based on Total Concentration
  - No Cause / Effect Evaluation of Toxicity
    - Toxicity Could Be Due to Chemical Not Measured
  - Ignores Literature, Aquatic Chemistry & Aquatic Toxicology
  - Relies on Coincidence of Chemical Concentrations and Unrelated Impacts

# Co-Occurrence Approaches

- T. O'Connor of NOAA Found That Flipping a Coin More Reliable for Predicting Sediment Toxicity Than Long & Morgan SQG
- Summed Quotients Not More Reliable for Predicting Whether a Chemical in Sediment Is Cause of Toxicity
  - Results Depend on Number of PAHs Included in Summary

# Co-Occurrence Approaches

- Use of Long & Morgan as “Screening Values”
  - Unreliable Approaches Are Also Unreliable for Screening
  - Does Not Consider All of the Chemicals That Are Common in Sediments and Known to Cause Sediment Toxicity
    - Ammonia \* Sulfide \* Low DO
    - Pyrethroid Pesticides
  - Under-Regulate
    - Miss Pollutants Not Measured
    - Ignores Additive & Synergistic Effects
  - Over-Regulate
    - Leads to Control of Non-Pollutants
- Give False Sense of Reliability to Those Who Want a Number to Proceed with Project &/or to Regulate a Sediment



# Co-Occurrence Approaches

- E. Long Now States That SQG Should Not Be Used in Regulatory Programs
  - However, SQG Being Used by Agencies in Multi-Million Dollar Projects
- “Horror Stories” from Misuse of Long & Morgan or MacDonald SQGs
  - Santa Monica Bay Restoration Project - \$42 million to Control Lead in Urban Stormwater Runoff Because Pb Found in Bay above Long & Morgan Co-Occurrence “Effects Level”
  - US EPA TMDL Goals for Sediment Remediation in Upper Newport Bay for Bioaccumulatable Chemicals (PCBs, DDT, Chlordane)
  - CA DFG Regulating Hg in Gold Dredging Sediments Used for Fish Habitat Restoration

# Co-Occurrence Approaches

- Even Though Well-Recognized as Unreliable, Chemical Concentration SQOs Will Be Used by Regulators
  - “Just Give Me a Number so I Can Regulate Sediments”
  - “Don’t Confuse Me with Aquatic Chemistry and Toxicology”
- Recognized Experts in Sediment Quality Evaluation Recommend Against Use
  - A. Burton, P. Chapman, D. DiToro, T. O’Connor, R. Engler, T. Bridges, P. Wenning, and Many Others

# Weight-of-Evidence Approach

- Integrated Use of Multiple Lines of Evidence (LOE) to Develop a Best Professional Judgment (BPJ) Assessment of Water Quality Impact of Chemicals in a Sediment
  - LOE Include
    - Sediment Aquatic Life Toxicity
    - Sediment as Source of Hazardous Chemicals That Bioaccumulate
    - Benthic Organism Assemblages
    - Chemical Information on Cause of Toxicity
  - Cannot Reliably Use Any Component Alone
  - Must Integrate Adequate Information on All Four Aspects
  - No Short-Cut for Adequate, Reliable Chemical Information

# Weight-of-Evidence Approach

- Chemical Information Must Be Based on TIEs, NOT on Total Chemical Concentrations in Sediments
  - See Lee & Jones-Lee (2002) for Incorporation of Chemical Information into WOE Evaluation of Sediment Quality
- Toxicity Assessment Should Be Made Using Several Types of Test Organisms with Appropriate Sensitivity
- Organism Assemblage Assessment Should Include Appropriate Reference Site Information and Gradient Analysis from “Hot Spot” or Source of Pollutant

# Weight-of-Evidence Approach

- WOE Should Be Implemented as Non-Numeric, BPJ by Expert Panel in Public, Interactive Peer-Review Process
- Use of WOE to Regulate Sediments Supported by Experts in Sediment Quality Evaluation
  - No Other Reliable Approach
  - See Burton *et al.* (2002) and Chapman *et al.* (2002) for Further Information on WOE Approach for Regulating Sediment-Related Water Quality Impacts

# Conclusions

- Current Approach for Regulating Water Quality Impacts in Water Column and Sediment Caused by Urban Stormwater Runoff Not Technically Valid
  - Leads to Over-Regulation
- Need to Develop Wet-Weather Standards Based on Non-Numeric Triad, Best-Professional-Judgment, Weight-of-Evidence for Regulating Water Column Impacts
- Need to Develop Non-Numeric Triad, Best-Professional-Judgment, Weight-of-Evidence Approach for Regulating Sediment-Associated Potential Pollutants

**Further Information**  
Consult Website of  
**Drs. G. Fred Lee and Anne Jones-Lee**



**<http://www.gfredlee.com>**

# References

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# Abstract

- Stormwater runoff from areas near ports and harbors contains several potential pollutants such as the heavy metals (copper, lead, zinc and cadmium), nutrients (nitrogen and phosphorus), pesticides, PAHs, an array of uncharacterized organics, oil and grease, dioxins, etc., that are in soluble and particulate forms or will become particulate in the waters receiving the runoff. These constituents are listed as **potential** pollutants since many particulate forms of chemicals are in nontoxic, non-available forms in the water column and sediments. The particulate forms accumulate to cause elevated concentrations in the receiving water sediments. With increasing attention being given to regulating stormwater runoff and contaminated sediments through Clean Water Act 303(d) listings and TMDLs, NPDES-permitted urban and highway stormwater runoff and runoff from industrial and commercial areas will become increasingly regulated because of potential pollutants in the runoff that are present in the water column and/or accumulate in sediments.
- The approach that is typically used for regulating NPDES-permitted stormwater runoff is to compare the concentrations found in the runoff to the water quality standards. If exceedances are found then a BMP ratcheting-down process is initiated, in which ever increasingly more effective BMPs are used to control exceedances of the water quality standards.
- There is considerable unreliable information on the appropriate approach to follow to reliably evaluate the water quality significance of chemical constituents in aquatic sediments. Sediments are complex physical, chemical and biological systems that require a coordinated, integrated approach to determine if a concentration of a heavy metal, organic and/or nutrient is available to impact the overlying waters' water quality. This paper reviews the approaches that should be used to evaluate the water quality significance of chemical constituents in port and harbor sediments, discussing the problems with many of the chemical concentration based approaches that are currently used. It also presents a best professional judgment triad weight-of-evidence approach for regulating stormwater runoff water column exceedances of water quality standards and contaminated sediments.

# Surface and Groundwater Quality Evaluation and Management and Municipal Solid & Industrial Hazardous Waste Landfills <http://www.gfredlee.com>

Dr. G. Fred Lee and Dr. Anne Jones-Lee have prepared professional papers and reports on the various areas in which they are active in research and consulting including domestic water supply water quality, water and wastewater treatment, water pollution control, and the evaluation and management of the impacts of solid and hazardous wastes. Publications are available in the following areas:

- Landfills and Groundwater Quality Protection
- Water Quality Evaluation & Management for Wastewater Discharges
  - Stormwater Runoff, Ambient Waters and Pesticide Water Quality Management Issues, TMDL Development, Water Quality Criteria/Standards Development and Implementation
- Impact of Hazardous Chemicals—Superfund
  - LEHR Superfund Site Reports to DSCSOC
  - Lava Cap Mine Superfund Site Reports to SYRCL
  - Smith Canal
- Contaminated Sediment—Aquafund
  - BPTCP, Sediment Quality Criteria
- Mine Waste Management
- Domestic Water Supply Water Quality
- Excessive Fertilization/Eutrophication, Nutrient Criteria
- Reuse of Reclaimed Wastewaters
- Watershed-Based Water Quality Management Programs:
  - Sacramento River Watershed Program
  - Delta—CALFED Program
  - Upper Newport Bay Watershed Program
  - San Joaquin River Watershed DO and OP Pesticide TMDL Programs