Urban Coast

The Journal of the Center for Santa Monica Bay Studies

Climate Change | Water Sustainability | Stormwater | New Zealand Mudsnail
Aerial Deposition | Marine Protected Areas | Stream Restoration

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Los Angeles Skyline, *Photo: Brian Wallace*

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Cover Photo: View from Palos Verdes Drive, *Photo Dick Heiser*

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ABOUT URBAN COAST

This multidisciplinary journal is a product of the Center for Santa Monica Bay Studies, a program of Loyola Marymount University's Seaver College of Science and Engineering and the Santa Monica Bay Restoration Foundation. *Urban Coast* fulfills the Center's goal of providing a much-needed forum to highlight research that informs the most pressing issues of our day and policies that affect the condition of urban coastal resources.

Urban Coast provides a forum for researchers, agencies, advocacy groups, and other science and policy leaders to engage in constructive discussion and information exchange on issues that are pertinent to our coastal environments. In this way, we can find common ground and highlight the robust science, analysis, and assessment needed to catalyze good policy, design, and management measures.

THE CENTER FOR SANTA MONICA BAY STUDIES

The Center for Santa Monica Bay Studies is a program of the Seaver College of Science and Engineering at Loyola Marymount University and the Santa Monica Bay Restoration Foundation. The mission of the Center is to engage in multidisciplinary research on environmental and social issues affecting Santa Monica Bay and its watershed and to contribute to policies and actions that improve the environmental condition of the Bay.

SUBMISSIONS

Urban Coast is a peer-reviewed publication. Feature articles are generally between 4,000 and 6,000 words, while short submissions are between 1,000 and 3,000. Submissions are accepted for all four sections of the journal, including: Perspectives, essay and editorial reviews of current conditions or policies; Research & Policy, feature articles on scientific or policy studies; Case Studies, detailed project reports with implications for the urban coastal environment; and Environmental Notes & Abstracts are short descriptions of research, policy, and events relevant to our urban coastal environment. Submissions for the Environmental Notes and Abstracts section are between 250 and 500 words, and should be an abstract or short summary about your innovative environmental research, technical study, restoration project, BMP or LID implementation or other projects. All submissions should be written according to the standards of the Chicago Manual of Style, 15th Edition. References should be placed at the end of the document. Tables and images should be separated from the text. Images should be provided in .tif format, not exceeding a width of five inches and a resolution of 600 dpi (a width of 3000 pixels). Include the article's title; the author's name, phone number, and email address; and a two-sentence biographical statement. Article submissions should include a 250 word abstract. Submissions will be accepted on a rolling basis. Feel free to contact us by email to discuss your ideas. Manuscripts should be submitted by 5pm on January 30, 2010, for inclusion in the April 2010 issue, as .doc attachments via email to: sbergquist@santamonicabay.org.

We welcome submissions for science and policy topics pertinent to the urban coastal environment. Some initial topics for consideration include: Stream Restoration Science, Stormwater Permit, Aerial Deposition, Water Conservation/Independence, Carbon Sequestration – Wetlands, Rapid Indicators, BMP Effectiveness, Emerging Contaminants, Aquatic Invasive Species – Impacts, Control Measures.

SPONSORSHIP

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Mola Mola, Monterey Bay Aquarium, *Photo: Fred Hsu*

Introduction

We are excited to introduce the inaugural issue of *Urban Coast*. This multidisciplinary journal is a product of the Center for Santa Monica Bay Studies, a program of Loyola Marymount University's Seaver College of Science and Engineering and the Santa Monica Bay Restoration Foundation. *Urban Coast* fulfills the Center's goal of providing a much-needed forum to highlight research that informs the most pressing issues of our day and policies that affect the condition of urban coastal resources.

Shelley L. Luce, *Photo: Lorna Apper*

Urban Coast is the ideal forum for researchers, agencies, advocacy groups, and other science and policy leaders to engage in constructive discussion and information exchange on issues that are pertinent to our coastal environments. In this way, we can find common ground and highlight the robust science, analysis, and assessment needed to catalyze good policy, good design, and good management measures.

Urban Coast features four general sections. In Perspectives, essays and editorials review current conditions or policies; the Research & Policy section features articles on scientific or policy studies; Case Studies are detailed project reports with implications for the urban coastal environment; and Environmental Notes & Abstracts are short descriptions of research, policy, and events relevant to our urban coastal environment.

In this inaugural issue of *Urban Coast* you will find work by many individuals contributing to the science and policy so important to restoring and protecting our resource-rich and highly-impacted coasts. The work also points to new opportunities and better solutions that we seek to realize for restoring a healthy urban coastal environment. We welcome your feedback on what you read in this issue and look forward to your contribution to future issues of *Urban Coast*.

I would like to extend a special thank you to all our sponsors who have made this publication possible with their generous support.

Shelley L. Luce, Executive Director
Santa Monica Bay Restoration Foundation

Arizona Crossing Malibu Creek,
Photo Jack Topel

Letter from the Editor

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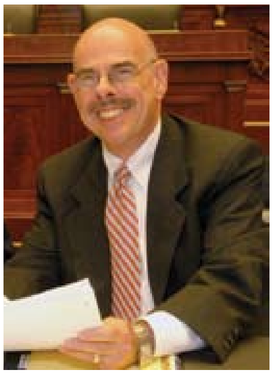
This issue of *Urban Coast* features articles on today's hot topics, new areas of research and policy, and long-standing issues in our region. U.S. Congressman Henry A. Waxman and California State Senator Fran Pavley, two of the region's political leaders and authors of ground-breaking climate change policies in their respective legislative bodies, present their views on the issue, as well as inspiration for continued progress. In addition, two managers of local water resources, Richard Nagel and Stephen Maguin, discuss the future of our water supplies and their visions for sustainable water use. Bart Lounsbury and Keith Stolzenbach present new developments in water pollution policy and research, through the analysis of the new Ventura County municipal stormwater permit and recent research on air-borne pollutants impacting our waterways. Mark Abramson tracks the spread of an invasive species, the New Zealand mudsnail, wreaking havoc on streams in the Santa Monica Mountains. For a better understanding of how scientific researchers are assisting in the development of Marine Protected Areas in California, Dan Pondella has provided a detailed analysis and specific examples of the use of scientific guidelines and expert review in their development. Finally, case studies documenting restoration of Malibu and Topanga Creeks detail methods to restore precious habitat in our region.

Sean P. Bergquist, *Photo: Lorna Apper*

In future publications, *Urban Coast* will continue to highlight issues affecting human and environmental health in urban coastal regions. Whether today's hot topics, new areas of research and policy, or long-standing issues, *Urban Coast's* focus on research and policy bridges the gap between these often separate fields. We welcome your submissions and support as partners in the development of *Urban Coast*.

Los Angeles Leads the Way in Tackling the Challenge of Global Warming

Henry A. Waxman



Los Angeles has a remarkable history of rising to meet its environmental challenges. Our local smog problem helped spur national action that led to the highly successful Clean Air Act. And after our own Santa Monica Bay was choked with sewage, it become one of the first water bodies designated as part of a national effort to protect and restore estuaries, the diverse and special places where rivers meet the oceans.

Los Angeles is now leading the way in tackling the challenge of global warming. Some of the same policies that are cutting pollution and spurring renewable energy here at home are now being considered at the federal level. I'm proud to have co-authored legislation that would cut global warming pollution to the levels scientists say are necessary to mitigate climate change impacts. It will do this while creating millions of new clean energy jobs, saving consumers billions of dollars in energy costs, and enhancing America's energy independence.

The American Clean Energy and Security Act (H.R. 2454) is a comprehensive approach to moving our nation to a clean energy economy. The bill continuously ratchets down the amount of global warming pollution that can be emitted between now and 2050, along with complementary policies that will stimulate new economic growth in the clean energy sector and protect consumers and industry from high energy prices.

We need this new law for our economy and to address our dangerous dependence on foreign oil. We also need it to prevent destabilizing environmental impacts. For example, the Santa Monica Bay is likely to suffer as global temperatures increase. Scientists predict that sea levels will rise and warming air and ocean temperatures will change storm patterns. In addition, the same pollution causing global warming is also changing the ocean's chemistry, making it more acidic and unlivable for certain species. The science is clear – these changes are already beginning to take place and are happening with alarming speed. Even without exacerbated water supply problems and disruption of agricultural activities we are likely to face in a warmer world, these impacts issue a call to action.

We must act now, and we must act decisively. The House of Representatives passed my bill in June 2009. Soon, the U.S. Senate will begin discussing it. Unfortunately, no matter how quickly the bill is passed, the planet and the Bay will be subjected to some future warming. That's why the legislation also invests in adaptation. It will provide an estimated $20 million each year to California for expenses associated with building resiliency into our ecosystems and infrastructure, in response to the anticipated impacts of a changing climate.

This investment will help address impacts associated with climate change, including protecting and restoring our kelp forests and coastal wetlands which will absorb some of the impacts of sea level rise and resulting coastal erosion as well as store significant amounts of carbon. In addition, restoration of our inland streams and wetlands will help to absorb and process pollutants, mitigate the increased intensity of storms, and provide infiltration and recharge of our overtaxed groundwater system.

Finally, there is a need for climate change research focused on Santa Monica Bay to pinpoint potential impacts and to inform the development of restoration and infrastructure improvements, which target vulnerable land to protect and establish plans for areas where no protections will suffice.

We have worked hard for decades to preserve and improve our environment in Los Angeles. I hope you'll join me in supporting this crucial legislation and protecting that critical legacy.

Representative Henry A. Waxman represents California's 30th Congressional District, which includes the cities of Santa Monica, Beverly Hills, Agoura Hills, Calabasas, Hidden Hills, Malibu, Westlake Village and West Hollywood, as well as such areas of Los Angeles as Beverly-Fairfax, Pacific Palisades, Brentwood, Beverlywood, Topanga, Agoura, Chatsworth, West Hills, Canoga Park, and Westwood.

Doing Nothing: The Real Risk of Climate Policy

Fran Pavley

This past year has seen enormous progress in the realm of climate policy in the United States, arguably the most progress we have ever seen in a single year on this most pressing issue of our generation.

In California, the implementation of the state's historic 2006 climate legislation, AB 32, has moved forward on schedule. An outline of how the state can achieve its goal of a 25 percent reduction in greenhouse gases by 2020, called the AB 32 Scoping Plan, was approved in December of 2008. Several early implementation measures, including a low-carbon fuel standard, have also already been approved.

While critics complain of the costs associated with climate policy, they conveniently overlook that many approaches to reduce climate pollution can also provide a way out of the economic crisis. Our climate and energy policies over the last 35 years have enabled Californians to redirect billions of dollars saved toward other goods and services. Energy efficiency policies have saved our state's consumers $56 billion between 1972 and 2006, which spurred approximately 1.5 million full-time jobs with a $45 billion payroll.

The costs of adapting to climate change, with expected water shortages, sea level rise, wildfires, and cropping changes, among many other problems, may have been underestimated by a factor of two to three, according to a UK study published in September of this year. The 2006 Stern Report has estimated that while the costs of addressing climate change could cost 1 to 2 percent of annual global gross domestic product (GDP), the cost of adapting to uncontrolled climate change could reach 5 to 20 percent of annual global GDP.

Putting California's plan to curb global warming into action is far cheaper than the cost of doing nothing. We are already feeling climate change impacts, which, if left unchecked, could cost California as much as $47 billion every year in direct damages and put at risk trillions of dollars of real estate, infrastructure, and other assets. Climate change also threatens water resources and important industries like tourism, entertainment, agriculture, and recreation, which all fuel the state's economic engine.

While reducing the potential impacts of climate change is important, it does not eliminate the need for adapting to inevitable changes in sea level, coastal erosion, and water supply. Throughout the state, local governments need to take actions to assess and prepare for these future impacts. In Santa Monica Bay for example, detailed modeling of sea level rise, coastal erosion, and changing rainfall patterns needs to be conducted on a local scale. This is essential to informing local planning, instigating the necessary protection or relocation of infrastructure, and planning for reduced water supplies.

Actions at the local level will require coordination across agencies and municipalities. Protection of our natural areas, such as coastal wetlands and kelp forests, will buffer us against the impacts of sea level rise and coastal erosion. Retrofitting our urban areas to allow rainwater infiltration will reduce polluted runoff and help recharge diminished ground water resources.

Mitigating and adapting to a changing climate will be expensive, but will also catalyze green jobs and prevent even greater costs later. Clearly, when it comes to climate, the greatest risk we face is the risk of inaction, and the biggest cost we will incur is the cost of doing nothing.

Senator Fran Pavley represents Senate District 23 - including portions of Los Angeles and Ventura Counties - in the California Legislature. She was elected to the forty member State Senate in November, 2008 and was immediately appointed to chair the Senate Natural Resources and Water Committee by Senate pro Tempore Darrell Steinberg. While in the Senate Fran will also serve on the Transportation and Housing, Budget, Health, Environmental Quality and the Food Safety and Agriculture Committees. As Chair of the Select Committee on Global Warming, Senator Pavley will be holding hearings to help guide the implementation of AB 32, the landmark law she offered as serving in the Assembly.

The Water We Drink … and the Water We Don't

Introduction

Southern California's water supply issues are often controversial and present a variety of perspectives and solutions. More and more people have made the intellectual connection between the rainwater that is wasted as polluted runoff, and the enormous amounts of imported water required to sustain our current Southern California lifestyle. However, the practical connections are harder to forge. Separate agencies, established in a by-gone era of siloed thinking, are asked to cooperate on projects large and small and without an existing infrastructure or framework to link the costs and benefits of all the various activities.

We asked leading thinkers and decision-makers in the Southern California water debate to weigh in on how to forge these connections and move toward a sustainable water supply. Adán Ortega, Jr. and Michael Gagan provide a starting point for our discussion with their historical perspective on the evolution of water management in the region and a proposal for a new governance paradigm. Richard Nagel, General Manager of the West Basin Municipal Water District, and Stephen Maguin, General Manager of the Sanitation Districts of Los Angeles County, each respond to the Ortega-Gagan article and provide their thoughts and opinions on what is needed for a truly sustainable water future.

Success and Lost Opportunities in Water Management in Los Angeles County and the Future that May Still Be Possible

Adán Ortega, Jr. & Michael Gagan

Hidden in plain sight around Los Angeles are hundreds of symbols of our common quest for water, from an oddly fake-looking well at the Metro station in Artesia, to the Music Center's jumping fountain, and the 28–foot, seven–ton steel pitcher tipping water into Ballona Creek (Figure 1) (Hanna 2001). Each generation of people in Southern California has wrestled with acute water issues, seeking to grow food, control floods, build cities, and now, to quench the thirst and manage the waste of 15 million people. One outcome of this quest is Southern California's enormous water distribution, flood control, and sewage treatment systems – the largest in the world. With chronic drought and a changing climate, it is now our generation's turn to deal with water challenges in the form of decreasing availability of imported water, serious pollution problems, an unstable economy, and rapidly changing demographics in a region that keeps on growing.

Records of water agency actions over the last century demonstrate the sometimes brilliant, sometimes unwise choices that have been made (Gagan 2008, 2009). The disregard of the "Olmstead Report," written by Frederick Olmstead and paid for by the Los Angeles Area Chamber of Commerce in 1930, is considered by many to be the epitome of lost opportunity in our water history. While beauty, parks, and clean and ample beaches are the most celebrated aspects of Olmstead's plan, it also anticipated deliberate management of entire watersheds. This entailed protecting people and property by managing land use near our rivers, rather than channelizing waterways in concrete, as local and federal officials ultimately decided to do.

Water development in Los Angeles evolved in an almost *ad hoc* manner, following economic development and drought. In fact, the demand for more water needed to build the metropolis of Los Angeles began to exceed the natural water

Figure 1. *Cross Currents* by Don Merkt, 1991


Los Angeles Aqueduct *Photo: Calwest*

supply in the 1860s (Mendenhall 1905). While recycled wastewater and captured storm water are beginning to be used in parts of the region, there is potential for much more and there are greater efficiencies still to be met.

The Historical Puzzle of Water in L.A.

Water management in Los Angeles County watersheds is like a giant puzzle with pieces that do not readily fit together. There is a maze of public and private entities whose origins go back, in one instance to the pueblo era and in many others to the early days of the 20th century, to when the region established itself as the agricultural capital of California.

This has led to many institutional obstacles to cohesive water resource management in Los Angeles County. One obstacle is that most individual water entities were organized over the past 100 years for singular purposes – controlling the flow of water, acquiring and distributing it, treating the wastewater after human use, or more recently, providing clean aquatic habitats. Another obstacle is that jurisdictional boundaries are political rather than hydrologic. No single water supply entity overlies a complete groundwater basin or an entire watershed, so no one entity is able to take a true watershed management perspective.

Flood control became an urgent priority during the early 1930s, when rain events devastated parts of Los Angeles and the region. The Los Angeles River and other waterways were contained in concrete channels designed to flush flood waters quickly and directly to the ocean. Land along the banks was paved over with roads and occupied with houses and businesses, creating immediate sources of potential pollution. The pavement also diminished overall opportunities to naturally replenish groundwater in nearby porous soils.

The need to nurture growth in the midst of dwindling local ground and surface water led the City of Los Angeles to build the Owens Aqueduct in 1913 and the Metropolitan Water District of Southern California (MWD) to build the Colorado River Aqueduct in the 1940s. Referring to these two massive works of engineering, both political and physical, Dr. Stephen P. Erie observed that, "Early on, Los Angeles dealt itself nearly all the trump cards," when it came to water supply management (Erie and Brackman 2006).

The most notable exception to Erie's statement is the California Aqueduct, part of the State Water Project as envisioned by Governor Edmund G. Brown during the late 1960s. Operating since the early 1970s, the State Water Project remains incomplete due to the defeat of the "peripheral canal" initiative in 1982. Now under consideration by state lawmakers once again, the peripheral canal would bypass the ecologically sensitive Bay–Delta near Sacramento, where water from the north currently flows through earthquake-vulnerable levees before reaching pumps that send it south to the Los Angeles region.

Until a legislative agreement to fund and authorize the peripheral canal is reached, the amount and availability of Northern California water to Los Angeles is threatened, especially if existing levees fail because of floods or earthquakes. There would simply be no way to get water from its source, past the Delta, and to the California Aqueduct. Until 1964, groundwater was the principal water supply in the Los Angeles and San Gabriel River watersheds. Until 2007, when it was no longer available, MWD's imported water was the major source of water for recharge in most years and provided up to 60 percent of Southern California's water (Water Replenishment District of Southern California 2009). Today, despite persistent drought and reductions in supply from the State Water Project, half of all the imported water is wasted through inefficient outdoor irrigation practices in Southern California (Laird 2005).

Sewage treatment demand generally grows with the population. Over time, treated wastewater has become available for non-drinking purposes, such as landscape irrigation, through the City of Los Angeles Bureau of Sanitation and the Sanitation Districts of Los Angeles County and their contracts with water districts. The Los Angeles Regional Water Quality Control Board assures that "tertiary treated" water from sewage treatment plants is "blended" with stormwater or imported water. With declining reliable imported water available for blending, we will be able to use less and less treated wastewater, unless we invest in more advanced treatment technologies.

Furthermore, disposing of ever more treated wastewater requires construction of new outfalls into the sea, while new data on emerging contaminants fuel public concern about the environmental impacts of such disposal in the ocean environment.

Finally, we have yet to meaningfully grapple with the impacts of climate change on our various water sources. In our current mode, each separate decision by respective layers of government is a step away from the possibility of Olmstead's vision – trading it for more *ad hoc* planning and waste.

A Historic Opportunity: Watershed Authorities

Thankfully, things are beginning to change through integrated efforts. In 2002, California State Proposition 50 attempted to introduce an integrated watershed approach to water planning and spurred the voluntary establishment of multi-agency watershed management groups throughout the state. Subsequently, another ballot measure, Proposition 84, has attracted 1,600 funding applications from 128 separate entities in Los Angeles County alone. The city of Los Angeles also launched initiatives to integrate its water supply and wastewater agency activities in 2004; fund stormwater programs through Measure O in 2005; and revitalize the Los Angeles River through a landmark public participation process in 2007.

Today, an average of 54,000 acre-feet of storm water are captured each year in the Montebello Forebay area of the Los Angeles and San Gabriel River watersheds. Yet, the potential is an additional 260,000 acre-feet, which are currently lost to the ocean (Whitaker 2008).

Pending amendments to the Central and West Coast Basin Judgments in Los Angeles County could also result in greater motivation to store stormwater in local groundwater basins. These amendments will create a legal framework and economic incentive for storing and extracting water underground from the Los Angeles Coliseum to the Orange County line. In other words, parties who infiltrate stormwater runoff will gain more than simply avoiding fines by meeting the stormwater runoff requirements of the Los Angeles Regional Water Quality Control Board. Under the amendments, storm and other water runoff may be captured on-site, measurably infiltrated into an underlying aquifer, and subsequently extracted without payment of a replenishment assessment. The economic value of an acre-foot of such water in today's market is approximately $600.

There is great potential to expand the amount of recycled water we use as well. The City of Los Angeles, directly or through the West Basin Municipal Water District, annually recycles 37,500 acre-feet or 9.5% of its 394,800 acre-feet of treated wastewater. It plans to recycle a modest 50,000 acre-feet more by 2019. The long-term potential is actually 282,250 acre-feet (Los Angeles Department of Water and Power 2009).

The Sanitation Districts of LA County, in partnership with the Water Replenishment District of Southern California (WRD), pioneered the regulated use of recycled water for groundwater replenishment in 1962. Today, an average of 50,000 acre-feet per year of recycled water is recharged in the Montebello Forebay area, totalling 1.5 million acre-feet since 1962. Yet studies by MWD, as well as the Upper San Gabriel Municipal Water District and the WRD, demonstrate that 130,000 acre-feet of recycled water remains untapped. There is plenty of space to store water underground as well. MWD's Draft Groundwater Assessment Report, March 2007, found 695,000 acre-feet of unused storage capacity from the San Gabriel Valley to the Los Angeles County coastline.

Finally, the Santa Monica Mountains Conservancy and the Rivers and Mountains Conservancy are purchasing land along rivers in their watersheds. Both conservancies have been encouraging the involvement of water agencies, who largely control the timing, volume, and quality of water that flows through the region's rivers. This cooperation allows facilitation and investment in integrated regional planning efforts.

Achieving water sustainability in Los Angeles may hinge on our ability to restructure water management along watershed boundaries rather than traditional political boundaries. Future local, regional, and state funds should be allocated to agencies that are empowered with science and data to understand water supply, pollution prevention, and recreation and habitat needs within their watersheds. In turn, those agencies could allocate funds to other agencies for projects that meet those needs in a system of priorities, which are determined in a systematic and open manner. Empowered watershed councils could be governed by a new generation of water leaders emerging from the broad demographic and ethnic spectrum that comprises our new mainstream.

This concept would move us toward truly watershed based management and has already been attempted elsewhere. The Santa Ana Watershed Project Authority (SAWPA), which encompasses the Santa Ana River and its entire watershed across three counties, coordinates with over a dozen water supply agencies, wastewater treatment authorities, and open space conservancies. In Minnesota, 45 "watershed districts" are responsible for everything from surface and groundwater monitoring to stormwater management, water conservation, and habitat improvement (www.mnwatershed.org).

According to Christopher Lant, author of *Watershed Governance in the United States: The Challenges Ahead* (Lant 2003):

> This shift in management challenges also requires an institutional transformation. If our institutions are to solve these new problems, they must move… to a system of state-facilitated, locally-led watershed management. In the absence of such strong institutions with decision making authority, watersheds become politically passive actors...

A new era of leadership and talent in water resources proceeds with the vision that appropriate management of water in the Los Angeles region will improve our quality of life. As our common quest for water continues, the transformation of the symbols of our past into the living and dynamic spaces within our watersheds is the best monument our generation can leave the next. Look around, the answers are hidden in plain sight beneath concrete, debris, and inertia.

Michael Gagan is a consultant with Rose & Kindel, a public affairs firm in Los Angeles and Sacramento.

Adán Ortega, Jr., is a public affairs consultant with Rose & Kindel, serves as Chairman of the California State Board of Food and Agriculture's Water Committee and is a principal at Water Conservation Partners Inc.

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The Future of Water in Southern California is an Array of Locally Controlled, Reliable, Diverse, and Environmentally Sensitive Water Projects

Richard Nagel

I write this article not as the General Manager of West Basin Municipal Water District, but as a water professional with over 20 years of service in the exciting Southern California water industry. The views expressed are mine and not necessarily those of West Basin.

The mission of every Southern California water agency is to provide high-quality and reliable water in an ever-changing and very complex environment. Unfortunately, the situation is complicated by the fact that we have all the characteristics of an area that will have future water problems – an arid region, little local water supplies, reoccurring droughts, dependence on water from outside our political boundaries, and strong competition for existing supplies. This is why any dedicated water manager works long hours, weekends, and when needed, holidays to keep the water flowing here. Today, in this challenging water environment we face increasing populations, the current and future droughts, regulatory restrictions, and new environmental needs that the water industry has never faced in its entire history. William Mulholland would be turning over in his grave.

Since the last major drought in the late 1980s and early 1990s, Southern California water agencies have focused on the development of local, diverse supplies. West Basin Municipal Water District (West Basin) started down that road in the early 1990s with the development of the Edward C. Little Water Recycling Facility (Figure 1) that has since been expanded four times and whose production will double again in the future. The movement to locally-controlled, reliable supplies is needed to make up for continued loss of imported water. Even when the complex and emotionally charged Bay–Delta situation is resolved years from now, the amount of water delivered to Southern California will be more predictable, but will not increase to meet growing needs.

Figure 1. Edward C. Little Water Recycling Facility, *Photo: West Basin*

Local water sources will have to meet the water needs of our ever increasing populations and to stave off water rationing. Those new or expanded sources will include: all types of water recycling, including indirect and direct potable drinking water use (yes, sewer to tap); expanded water efficiency; groundwater storage; groundwater cleanup; brackish and stormwater cleanup; and ocean water desalination. West Basin will look at all of these new supplies to meet its current and future water needs once institutional, political, financial, and public acceptance hurdles have been cleared. West Basin is now embracing "responsible" ocean water desalination, which means that West Basin will go to great lengths to protect the ocean (Figure 2). West Basin has been protecting the ocean since the 1990s with its award winning water recycling, conservation, and public education programs. Trying to conserve water to make up for having less and raising rates to compensate is not a sustainable strategy. There is a pressing need for "wet" water supplies that can be put into

Figure 2. Desalination Intake Pipe, *Photo Silke Baron*

pipes now. Ocean-water desalination fills that need, and in the future, when the health regulations and public opinion are in place, desalination will be augmented with direct potable use of sewer water.

A recent survey (July 2009) showed that voters now view a safe and adequate supply of water as the second most important issue to them, barely behind the economy. In fact, public opinion showed voters are willing to invest in water reliability, surpassing the critical issues of public education, transportation, and public safety. Why? Metropolitan Water District's, Association of California Water Agencies', and local water agencies' public awareness campaigns, as well as new city ordinances and water rationing, have created this new paradigm and captured the public's attention.

California is the economic powerhouse and food basket of the nation and is still the most populous state in the nation because of its history of massive water development projects. Today, the historical water industry is dead or dying. We are now in an era of environmentalism and regional water projects. The future of water in Southern California is an array of locally-controlled, reliable, diverse and environmentally sensitive water projects. West Basin will be leading the way into a new water industry paradigm with its Water Reliability 2020 program, which will double its water recycling, double its water conservation, expand its public education, and add 10% of its future water supply from the ocean.

Richard Nagel has worked in the Southern California water industry for over 20 years and is currently the General Manager of the West Basin Municipal Water District.

Water Recycling Can Finally Grow to Maturity with Concerted Effort by Stakeholders and Educated Public

Stephen Maguin

> "The Board of Engineers recommends that the Board of Supervisors take the following action: Approve the feasibility of the reclamation of usable water from the spent and waste waters flowing in the sewerage system of the County Sanitation Districts of Los Angeles County, and adopt a policy looking toward such reclamation."

From the Report Upon the Reclamation of Water From Sewage And Industrial Wastes in Los Angeles County, California, April 1949.

So began an astute report prepared sixty years ago by the Sanitation Districts' Chief Engineer, the County Engineer & Surveyor, and the Chief Engineer of the Los Angeles County Flood Control District. This report laid the groundwork for a regional wastewater system designed to recycle water from sewage. It contained the fundamental framework that is still relevant today as we plan for the next generation of water recycling projects and set the groundwork for interagency collaboration to bring together the available resources and specialized expertise. Importantly, this report was initiated long before the need became as acute as it is today. Even more importantly, the Sanitation Districts acted on that original planning document. A regional system was designed to implement the basic concept of directing the less salty wastewater to a system of upstream water reclamation plants, while sending the saltier wastewater to a large treatment plant in Carson, which discharges to the major "salt sink" for this arid region – the Pacific Ocean.

Though not highly publicized, these local agencies have long worked together on both local and regional scales to serve the water needs of the region's burgeoning population. An excellent example of this regional cooperation, as noted by Ortega and Gagan (Page 5), is the Montebello Forebay groundwater recharge project. Almost 50 years ago, the Los Angeles County Flood Control District, the Water Replenishment District of Southern California, and the Sanitation Districts began working together to replenish groundwater supplies using locally captured stormwater,

Figure 1. Aerial View of Rio Hondo Spreading Grounds, Montebello, CA, *Photo: Sanitation Districts of Los Angeles County*

recycled water, and imported water (Figure 1). In addition to the 1.5 million acre-feet of recycled water that have supplemented our groundwater supplies as a result of this project, the Sanitation Districts also work with dozens of cities and water agencies to supply over 570 sites with recycled water for municipal and industrial uses.

The question facing us today is how we move beyond our past accomplishments to bring to fruition the next generation of water recycling projects that will reuse even more wastewater. The answer lies not in another layer of government, such as creation of "super-watershed councils" empowered to make all water-related decisions in each watershed. Rather, we must continue to build partnerships between existing institutions that recognize our collective strengths. In recent years, the Greater Los Angeles Integrated Regional Water Management Planning Group has come together to identify and encourage regional cooperation and collaboration on multi-benefit projects. This group, as well as others in the Los Angeles region, continues to foster new alliances as well as build bridges across the traditional "silos" within which Los Angeles County's public infrastructure agencies are often accused of operating.

Without a doubt, the current drought and constraints on imported water supplies pose major challenges for the region, but these pressures on existing water supplies are also creating opportunities. To address the dwindling availability of our water supplies, the feasibility of several new large-scale, inter-agency recycled water projects is currently being explored. The San Gabriel Valley and Upper San Gabriel Valley Municipal Water Districts, Water Replenishment District, and Sanitation Districts are working towards an integrated, regional recycled water project known as the Groundwater Reliability Improvement Program (GRIP). This project is intended to replace nearly 50,000 acre-feet per year of imported water with advanced-treated recycled water, to recharge the Central and Main San Gabriel Groundwater Basins. The Sanitation Districts, in partnership with the Metropolitan Water District, have also begun investigating the feasibility of a much larger project involving advanced treatment of a major portion of the wastewater that is currently discharged to the ocean. These projects represent a potentially substantial new supply of clean, safe drinking water that will provide the region with increased independence from our increasingly unreliable imported water sources.

Because the scale of new recycled water supply development being contemplated far exceeds the potential irrigation and industrial demand in the region (in addition to the high cost of building extensive purple pipe distribution systems), future recycled water use in Los Angeles County must necessarily involve more potable reuse projects. Potable reuse projects are regulated by the Regional Water Quality Control Board and the California Department of Public Health, but formal regulations have not yet been promulgated. To streamline the already lengthy process of developing new recycled water projects, the California Department of Public Health must move forward to promulgate final groundwater recharge regulations, as well as begin rapid development of regulations for other types of potable reuse projects. The State and Regional Water Boards must provide a regulatory framework that permits the discharge of the brine, which results from advanced treatment of recycled water for potable reuse, to the ocean through existing outfalls without the need for further treatment or blending.

Figure 2. Reverse Osmosis Membranes at the Leo J. Vander Lans Water Treatment Facility, Long Beach, CA, *Photo: Water Replenishment District of Southern California*

Moreover, the biggest barrier to achieving our goals is not the lack of suitable institutions, but the need for large amounts of capital investment to be brought to bear at the same time that the region's decades-old water, wastewater, and flood management infrastructure all require major investments. To be sure, the comparative cost and scarcity of other sources of water are key drivers for new interest in development of local water resources, such as stormwater and recycled water. Nonetheless, even with those drivers, state and federal assistance with capital costs is imperative to encourage the timely development of this new green infrastructure.

As alluded to by Ortega and Gagan, the next generation of recycled water projects will require new investments in advanced treatment technologies or hundreds of miles of additional purple pipe distribution systems throughout the Los Angeles Basin. As we reach not for the "low-hanging fruit," but for the much more difficult projects, it will be far more expensive to build this infrastructure (Figure 2). Key to this endeavor is an increase in funding and prioritization of these types of water recycling projects in any new state water bonds and federal funding programs. Also, the region's local agencies must work together cooperatively, as opposed to competing against each other for funding. This would garner an increased share of state and federal funds that is more commensurate with the size of our population than recent years' allocations for the Los Angeles region have reflected.

In addition to creating a more predictable regulatory framework and obtaining supplemental funding, the final major challenge that must be faced is whether the public is ready to accept potable reuse of recycled water on an unprecedented scale. With California's population continuing to grow and climate change likely to reduce Southern California's available drinking water supplies even more than current constraints, in reality there may be little choice. I am confident that, with concerted efforts by a wide array of stakeholders and the support of an educated public, water recycling can finally grow to maturity and fulfill a substantial portion of the future water needs of this region.

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Riding a New Wave to Clean Water: Stormwater Management Under the New Ventura County Stormwater Permit

Bart Lounsbury

Abstract

One of the principal vehicles for mandating reductions in stormwater pollution is the Clean Water Act's NPDES permitting system, which requires that all urban areas meeting certain threshold criteria obtain an NPDES permit to operate their municipal separate storm sewer systems (MS4). Reducing the detrimental impacts of stormwater runoff as expeditiously as possible is the central aim of the MS4 permitting system. In the past few years, stormwater experts have begun redirecting the attention of regulators and the regulated community to the importance of replicating pre-development hydrological conditions. The third Ventura County MS4 permit (NPDES No. CAS004002)—the subject of this article—was issued in May 2009 by the Los Angeles Regional Water Quality Control Board. The Ventura County MS4 Permit takes a notable leap forward in stormwater regulation in California and parallels similar developments around the country. The Permit's requirements for LID practices and the onsite retention of stormwater, in particular, shift attention away from traditional infrastructure and treatment devices and toward site features that more closely replicate natural hydrology. By requiring the infiltration, evapotranspiration, and/or harvest and reuse of the design storm, the Permit should ensure better results than permits that merely require the treatment of stormwater without any associated performance standards. The Permit's numeric requirement for LID implementation, encapsulated in the EIA limitation, should generate considerably improved water quality results and enable municipal and Regional Board staff to more easily enforce the Permit and achieve pollution reduction goals. The most obvious potential downside of the new provisions, is regulators' and developers' relative lack of experience with and knowledge of the LID practices required by the Permit. This makes Ventura County a laboratory for other jurisdictions around the United States that are considering the adoption of what is likely a new and superior trend in stormwater regulation.

The Cuyahoga River hasn't caught fire recently, but we are still a long way from returning our nation's waters to their natural, unpolluted state. Poor water quality resulted in more than 20,000 beach closing or advisory days in 2008 (Dorfman 2009), and 64% of lakes and reservoirs and 44% of rivers and streams are not clean enough to support their designated uses (USEPA 2009). While sewage and industrial discharges may have been the impetus for the Clean Water Act, in many urbanized parts of the nation, including California, stormwater runoff from developed areas now tops the list of pollution sources (Figure 1). Indeed, it is listed as the "primary" source of pollution for 32% of all estuaries, 18% of all lakes, and 13% of all rivers in the country. Given that urban development covers only 3% of the United States' land mass, the influence of stormwater runoff is "disproportionately large," as recently noted by a panel of stormwater experts (Welty, et al. 2009). For this reason, regulators have begun to focus their efforts on stanching the flow of polluted stormwater runoff into the nation's waters.

Figure 1. Polluted Stormwater Runoff, *Photo: Garrick Yoong*

One of the principal vehicles for mandating reductions in stormwater pollution is the Clean Water Act's National Pollutant Discharge Elimination System (NPDES) permitting system, which requires that all urban areas meeting certain threshold criteria obtain an NPDES permit to operate their municipal separate storm sewer systems (MS4s). These permits are supposed to be renewed every five years to promote the adoption of newer and more effective stormwater treatment practices. Large cities and counties, those with a population over 100,000, fall under EPA's "Phase I" regulations, issued in 1990 (USEPA 2009). Less populous locations, those within an "urbanized area" or as otherwise defined by states, fall under EPA's "Phase II" regulations, issued in 1999 (USEPA 2009). Generally, Phase I permits are specifically tailored to the regulated locality, while Phase II permits cover an entire state. California contains several Phase I regions, including Ventura County, which received its first MS4 permit in 1994. The third Ventura County MS4 permit (NPDES No. CAS004002), the subject of this article, was issued in May 2009 by the Los Angeles Regional Water Quality Control Board (LA Regional Board).

MS4 Permits and Treatment Requirements

Reducing the detrimental impacts of stormwater runoff as expeditiously as possible is the central aim of the MS4 permitting system. As shown by the statistics above, stormwater runoff seriously affects the health of our nation's waters, with consequent effects on human communities. These impacts range from increased pollution (including trash, heavy metals, toxic chemicals, and bacteria) in rivers, lakes, and oceans to the erosion and scouring of streams, which lead to habitat destruction, alteration of sedimentation patterns, and other physical and chemical changes in riparian ecosystems. Even during dry weather conditions, excessive lawn irrigation and activities like car washing generate polluted runoff that flows into MS4s and contaminates receiving waters.

Lack of Progress Through Conventional Management Practices

Traditional stormwater infrastructure has focused on routing water away from human structures as quickly as possible. This has created a legacy of concrete pipes and channels that do nothing to alleviate pollution or the unnaturally high runoff flows resulting from such infrastructure and the impervious surfaces that characterize urban development. In the traditional scenario, a typical raindrop falls on an impervious surface (a roof or driveway, for example), runs into a gutter, enters a storm drain and network of pipes, and ends up in a river or directly in the ocean. The raindrop speeds through this system of conveyances and accumulates pollutants along its path. This system has allowed developers to build in floodplains and to treat stormwater as an evil that must be promptly shunted away. Unfortunately, this type of development has also generated or exacerbated the many problems associated with stormwater runoff, and our challenge now is to implement new management paradigms that avoid these pitfalls.

The controversy over how to shift away from traditional concrete infrastructure in California began more than a decade ago. Importantly, in 1996, the LA Regional Board issued an MS4 permit for Los Angeles County that contained "numerical design criteria" for stormwater best management practices (BMPs) (RWQCB 2001). These standards obligated all regulated projects to mitigate runoff through either treatment or infiltration of a certain volume of stormwater. The simplest allowed measurement was "the volume of runoff produced from a 0.75 inch storm event," which roughly equals another of the allowed measurements, "the 85th percentile 24-hour runoff event…" (SWRCB 2000). In the so-called "Bellflower Descision," the State Water Resources Control Board (State Board) upheld these requirements, often described as the Standard Urban Stormwater Mitigation Plan (SUSMP) sizing criteria, against a challenge by building industry groups and various permittees (SWRCB 2000).

Although the State Board's decision was momentous at the time, the requirements that it established statewide have not proven particularly effective in the intervening decade. For example, Heal the Bay's beach water quality grading system, rated 65% of LA County beaches as "F" and 8% as "D" for wet weather events in 2000-2001, while 61% received "F" and 13% received "D" grades in 2008-2009 (Heal the Bay 2001, 2009). Only 11% of LA County beaches received an "A" in 2000-2001 for wet weather events, yet slightly fewer (10%) received an "A" in 2008-2009 (Heal the Bay 2001, 2009).

The principal problem with the SUSMP sizing criteria mandated by the Bellflower decision is that they fail to require the implementation of effective pollution reduction practices. Under these criteria, developers could install proprietary filtration or separation devices that do not remove substantial quantities of most pollutants from stormwater and do nothing to attenuate the erosive effects of unnaturally high peak runoff flows and volumes from impervious surfaces (also known as adverse hydromodification).[1] Thus, despite the inclusion of these performance requirements in MS4 permits after Bellflower, many sites that meet the SUSMP sizing criteria still contribute significantly to the overall stormwater predicament.

Emergence of New Paradigms Focused on Natural Processes

In the past few years, stormwater experts have begun redirecting the attention of regulators and the regulated community to the importance of replicating pre-development hydrological conditions. This means both reducing pollutant loading in stormwater runoff and mimicking, as closely as possible, pre-development hydrographs in order to arrest adverse hydromodification. Rather than necessitating complicated new technologies, this shift in focus has underscored the need for stormwater management practices that depend mostly on natural processes, such as filtering runoff through soil and using landscaping to capture and evapotranspirate or slowly release stormwater. These practices are frequently called "Low Impact Development" (LID) or "green infrastructure."

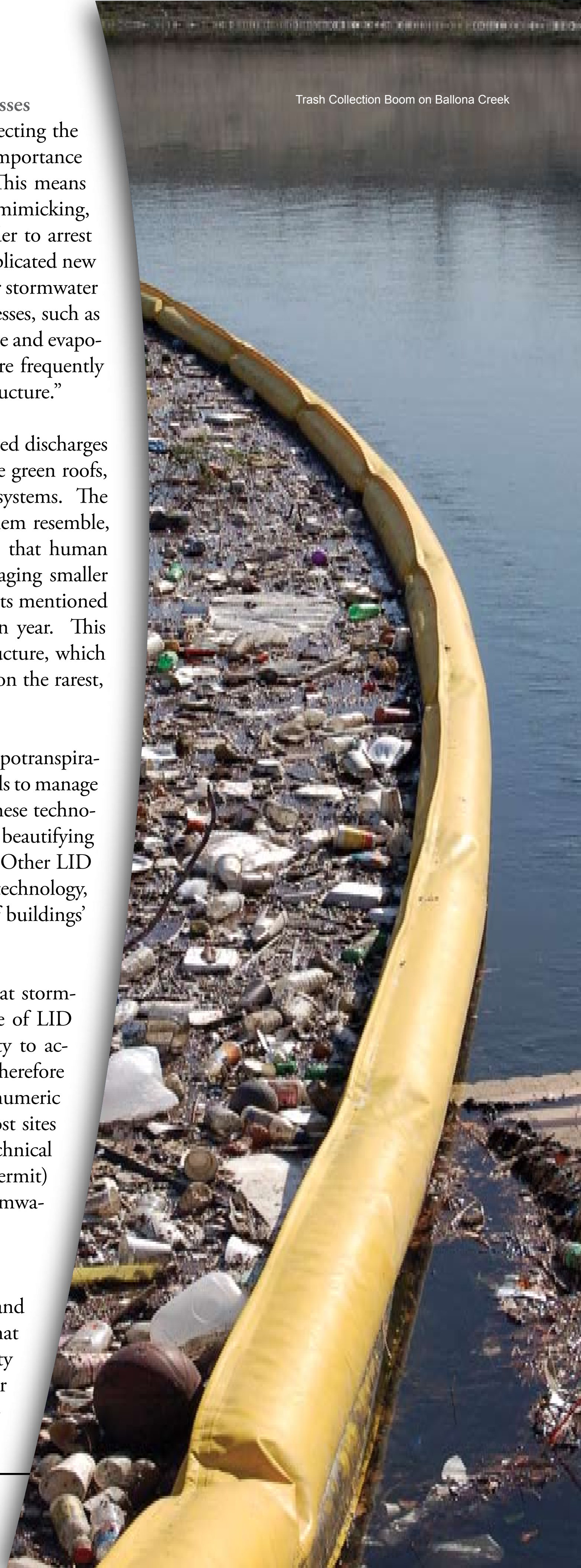
LID encompasses various site features that all reduce polluted discharges and diminish the rate and volume of runoff—these include green roofs, planter boxes, porous pavement, and rainwater collection systems. The key to the effectiveness of LID practices is that most of them resemble, and function in the same manner as, the natural systems that human development displaces. LID practices also focus on managing smaller storms, such as the 0.75 inch or 85th percentile storm events mentioned above, which constitute the majority of rainfall in a given year. This is drastically different from traditional stormwater infrastructure, which prioritizes flood prevention above all else and thus focuses on the rarest, largest storm events.

LID's reliance on natural processes like infiltration and evapotranspiration means that many LID features utilize vegetation and soils to manage stormwater. By replacing concrete gutters with greenery, these technologically simple designs produce additional benefits, such as beautifying developments and mitigating the urban heat island effect. Other LID practices, like graywater recycling, require more advanced technology, but also generate other benefits, including the reduction of buildings' potable water demand.

The major issue for current regulators is how to ensure that stormwater regulations require developers to maximize their use of LID practices while still allowing developers sufficient flexibility to accommodate different site characteristics and constraints. Therefore the regulators' goal must be to establish robust, enforceable numeric standards for LID implementation that can be met on most sites with alternative compliance options for situations of technical infeasibility. The new Ventura County MS4 Permit (Permit) contains standards that represent this new paradigm of stormwater management.

Advancements in the Ventura County MS4 Permit

The Permit's most notable advancement from a regional and national perspective is its imposition of a requirement that all regulated development projects retain a certain quantity of water onsite through infiltration, evapotranspiration, or harvest and reuse. As discussed below, this type of requirement, properly implemented, should guarantee better results



Trash Collection Boom on Ballona Creek

and greater pollution reduction than previous approaches. One other advancement, the creation of BMP performance standards, also deserves special attention, although the LID requirements overshadow its significance.

Numeric, Retention-Based Standards for BMP Implementation

The Permit's principal advance beyond the SUSMP sizing criteria is to mandate the use of LID practices that will necessarily reduce polluted runoff through onsite retention of the design storm volume. This volume is equivalent to the SUSMP sizing criteria (i.e., the 85th percentile storm, 80% of the total annual volume, or the 0.75 inch storm event) (RWQCB 2009). The critical difference between the SUSMP standard and the Permit's standard is that the Permit requires the design storm volume not to be merely treated (with no guarantee of performance), but rather to be retained onsite – through infiltration, evapotranspiration, or harvest and reuse – without any surface discharge to receiving waters (RWQCB 2009). Through this onsite-retention standard, stormwater pollution will be entirely eliminated for all volumes of rainfall up to the design storm.

The Effective Impervious Area Limitation

The Permit establishes this onsite-retention standard through a limitation on the Effective Impervious Area (EIA) of a developed site (RWQCB 2009). EIA is a measurement of the area of a site that functions hydrologically as impervious surface. This measurement is important in determining the impacts of runoff from developed sites because the high percentage of impervious surfaces in urban development is largely responsible for its deleterious effects on riparian ecosystems (Horner 2007). By reducing a site's EIA, developers more closely approximate natural hydrological conditions and hence reduce the problems caused by stormwater runoff. The Permit caps EIA at 5% of a site's area, meaning that 95% of the site must function as if it were undeveloped. In other words, while impervious surfaces will undoubtedly occupy far more than 5% of a developed site, the site must infiltrate, evapotranspirate, or harvest stormwater so that (at most) only 5% of the site's area discharges to receiving waters under design storm conditions.

For this type of EIA limitation to provide a meaningful numeric standard for LID implementation, two issues must be addressed: (1) the definition of what qualifies as EIA, and (2) the design storm that LID features must be sized to accommodate. On the first issue, the Permit specifies that impervious surfaces may be rendered "ineffective" for purposes of the EIA limitation "if the stormwater runoff from those surfaces is fully retained onsite for the design storm event…" (RWQCB 2009). In other words, the Permit considers im-

Figure 2. Water Quality Sampling of Urban Runoff

pervious surfaces to be "disconnected" from the MS4 (i.e., they are effective pervious areas) when they allow no drainage to the MS4 under design storm conditions. One can argue that this definition does not reflect pre-development hydrology because even in their natural, undeveloped state, sites discharge some stormwater. However, due to the size of the design storm, the EIA limitation does allow the discharge of stormwater (around 25% of total annual volume) in quantities greater than most sites would discharge under natural conditions (Horner 2007).

On the second issue, the Permit continues to apply the SUSMP sizing criteria's volume calculations, as mentioned above (RWQCB 2009). This means that development projects will intercept and retain the vast majority of a site's potential runoff. Indeed, under one of the allowed design storm measurements, 80% of the total annual stormwater volume (minus the runoff from the site's 5% EIA) must be retained onsite (RWQCB 2009). The other allowed design storm measurements would result in similar levels of onsite retention. The EIA limitation does not, therefore, require developers to hold every drop of stormwater onsite, and it will allow some discharge. The EIA limitation will result, nonetheless, in drastically less runoff (at least 76% less)[2] in comparison to the SUSMP standard, which allows all stormwater to be discharged after an undefined level of treatment.[3]

The Pollution Reduction Benefits of the EIA Limitation and Alternative Compliance Through Offsite Mitigation

Analyzing a representative site highlights the benefits of the Permit's onsite retention standard (Figure 2). Dr. Richard Horner provided such an analysis on behalf of the Natural Resources Defense Council during the Permit drafting process (Horner 2007). His study showed that on a typical restaurant site, for instance, conventional stormwater treatment BMPs would reduce total suspended solids loading by 22.0% to 80.6%, total copper loading by 0.0% to 78.2%, total zinc loading by 22.9% to 84.3%, and total phosphorus loading by 40.7% to 69.1% (Horner 2007). On the other hand, a comprehensive LID approach, as required by the Permit would yield reductions of 99.5%, 98.0%, 98.9%, and 98.8%, respectively, which constitute improvements of 14.5% to 98.0% over conventional BMPs (Horner 2007). These pollution reduction calculations also underscore the wide variability in the effectiveness of different conventional BMPs, in contrast to the reliably high effectiveness of the LID approach mandated in the Permit.

Certain sites with severe constraints may not have the capacity to retain the required volume of stormwater. For such sites, the Permit allows alternative compliance through offsite mitigation of any portion of the design storm volume that is not retained onsite (RWQCB 2009). However, all sites must achieve an EIA of 30% or less, meaning that all developments must retain at least 70% of the design storm volume onsite, regardless of any site constraints. Since this is a new standard for Southern California, it remains to be seen whether this cap on offsite mitigation will prove too stringent for any development projects. Two reports, Dr. Horner's study, mentioned above, and an analysis performed by Larry Walker and Associates for the Ventura County and Orange County permittees, indicate that high levels of onsite stormwater retention (in most cases, significantly more than the design storm volume) are feasible even on constrained urban sites (Horner 2007, Geosyntec and LWA 2009).

The Permit specifies that offsite mitigation must achieve stormwater volume and pollutant load reductions equivalent to what would have been achieved onsite if the project had met the Permit's requirements (RWQCB 2009). To ensure that these benefits offset the detrimental impacts of the development in question, offsite mitigation projects must be located in the same sub-watershed as the development (i.e., they must drain to the same hydrologic area, defined in the Basin Plan) (RWQCB 2009). This restriction attempts to strike the proper balance between allowing sufficient area to find offsite mitigation opportunities and locating offsite mitigation projects reasonably close to the source of pollution. Although with no stormwater offsite mitigation programs yet operating in Southern California, Ventura County will provide our first insight into such issues.

Offsite mitigation may take the form of either private projects, which will likely be more feasible for large developers, or in-lieu funds paid to municipalities that will construct public mitigation projects. Opportunities for the latter, such as green-street or parking lot retrofits, are widely available in Ventura County, although the municipal permittees now must identify specific projects and establish funding requirements. Additionally, though not specified in the Permit, the permittees' determination of the cost and location of mitigation projects must consider factors

Inline Stormwater BMP Unit

like land use type since project-by-project analysis of pollutant loads would probably be infeasible, but different land uses generate significantly different pollutant loads.
Although mitigation has become commonplace in the environmental realm, it remains relatively untested in the stormwater context, so Ventura County will provide a valuable perspective on the benefits and drawbacks of offsetting stormwater runoff through offsite mitigation. Nonetheless, most development projects will likely not need to utilize the alternative compliance option because onsite compliance should be feasible in most situations.

The Significance and Potential Pitfalls of the Permit's New Requirements

Whatever the end result of this iteration of Ventura County's MS4 Permit, requiring the onsite retention of stormwater or the achievement of equivalent results through offsite mitigation is a major step beyond merely requiring treatment of stormwater with no accompanying performance criteria, as MS4 permits in California have done in the past. By meeting the Permit's retention requirements, sites simply will not discharge stormwater, polluted or otherwise, under design storm conditions, and the pollutant removal effectiveness of treatment devices will no longer be of great concern. However, the effectiveness of the retention features used will be of concern. Follow up documents required by the Permit, principally the Ventura County Technical Guidance Manual (RWQCB 2009), must set forth clear design guidelines and the permittees must train municipal staff in LID practices to prevent the construction of ineffective retention-based BMPs (Figure 3).

LA Regional Board staff must also analyze whether developers are generally able to comply with the Permit's requirements and how frequently alternative compliance options are utilized. This should indicate whether the Permit has set the bar too high or too low. If it appears that the Permit has missed the mark, numeric requirements like the design storm size and allowed offsite mitigation volume could be adjusted accordingly.

Standards for the Pollutant Removal Effectiveness of Stormwater BMPs

To address the aforementioned concerns about the effectiveness of treatment BMPs, the Permit establishes "Treatment BMP Performance Standards" (RWQCB 2009). These standards require treatment BMPs in six categories (detention pond, wet pond, wetland basin, biofilter, media filter, and hydrodynamic device) to achieve at least median performance, based on the WERF-ASCE/U.S. EPA International BMP Database (RWQCB 2009). This is the type of performance standard that prior iterations of MS4 permits in

Figure 3. LID at Bimini Slough Ecology Park

California should have included to avoid the limited usefulness of the SUSMP sizing criteria, which merely require a certain volume of treatment without any reference to a given BMP's pollutant removal effectiveness. For example, under the new Permit, a biofilter may not discharge stormwater with a total copper concentration higher than 9.6μ/L, whereas the previous Permit did not specify any effluent concentration that a biofilter must achieve. One could question whether, by selecting the median pollutant removal performance values, the Regional Board established the most appropriate effluent concentrations for the six regulated BMPs, but the significance of including BMP performance criteria in the Permit at all is notable.

However, the irony is that the new Permit's EIA limitation renders these BMP performance criteria relatively unimportant. In most cases, sites will not discharge considerable quantities of stormwater from the six BMPs to which the Treatment BMP Performance Standards apply. Indeed, the principal aim of the EIA limitation is to avoid the use of these treatment BMPs with their variable effectiveness. When a site meets the new Permit's onsite retention requirement, it will be allowed to discharge only 5% of the design storm volume from such BMPs. On the other hand, if a project maximizes the offsite mitigation option, that project would be allowed to discharge up to 30% of the design storm volume from such BMPs, which would constitute a much more substantial quantity of stormwater. Additionally, if future iterations of the Permit require treatment of a quantity of stormwater larger than the required onsite retention volume (e.g., retain the 85th percentile storm and ensure treatment up to the 2-year storm), the Permit's Treatment BMP Performance Standards will assume greater significance. For these reasons, the Permit's establishment of these standards may play an important role in the implementation and effectiveness of the Permit even if the EIA limitation overshadows them.

Conclusion

The Ventura County MS4 Permit takes a notable leap forward in stormwater regulation in California and parallels similar developments around the country (WVDEP 2009, RWQCB 2009, City of Philadelphia 2007, 2009). The Permit's requirements for LID practices and the onsite retention of stormwater, in particular, shift attention away from traditional infrastructure and treatment devices and toward site features that more closely replicate natural hydrology. By requiring the infiltration, evapotranspiration, or harvest and reuse of the design storm, the Permit should ensure better results than permits that merely require the treatment of stormwater without any associated performance standards. Of course, the irony in this case is that the Permit has also established "Treatment BMP Performance Standards," which have been rendered somewhat superfluous by the Permit's onsite-retention LID provisions.

The Permit's numeric requirement for LID implementation, encapsulated in the EIA limitation, should generate considerably improved water quality results and enable municipal and Regional Board staff to more easily enforce the Permit and achieve pollution reduction goals. The Permit also attempts to create sufficient flexibility through alternative compliance options to accommodate constraints that could impede the development of certain sites.

The most obvious potential downside of the new provisions, though, is regulators' and developers' relative lack of experience with and knowledge of the LID practices required by the Permit. This makes Ventura County a laboratory for other jurisdictions around the United States that are considering the adoption of what is likely a new and superior trend in stormwater regulation. By virtue of being at the forefront of this trend, Ventura County will have to endure the inevitable difficulties of being one of the first areas to adopt such LID requirements, but it will also reap the benefits earlier. Hopefully, the Ventura County MS4 Permit and the projects that comply with it will provide a model for other areas. Perhaps we can turn stormwater from a hazard into an asset that replenishes aquifers, irrigates landscapes, and creates new water supplies for in-building uses. This would be a coup, but it is now within sight.

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[1] See, e.g., United States Environmental Protection Agency, "Catch Basin Inserts," http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=77 (accessed September 24, 2009), United States Environmental Protection Agency, "Manufactured Products for Stormwater Inlets," http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=79 (accessed September 24, 2009).

[2] Using the 80%-of-total-annual-volume measurement for the design storm, the EIA limitation would allow 5% of the site to discharge under design storm conditions (equivalent to 4% of total annual rainfall—80% times 5%) and yield an onsite retention of 76% of the total annual rainfall.

[3] For simplicity's sake, an EIA limitation is not necessary to accomplish the Permit's objectives. A pure onsite-retention standard would function just as well and eliminate the need for the subtraction of a certain percentage of the design storm volume based on allowed EIA. Another recently adopted permit—the North Orange County MS4 Permit (Order No. R8-2009-0030, NPDES Permit No. CAS618030)—has taken this approach, with the exception of allowing "biotreatment" as a means of meeting that permit's volumetric standard when retention-based practices are technically infeasible.

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Tracking the Invasion of the New Zealand Mudsnail, *Potamopyrgus antipodarum*, in the Santa Monica Mountains.

Mark Abramson

Abstract

The New Zealand mudsnail, *Potamopyrgus antipodarum,* has wreaked havoc on streams in North America. Capable of parthenogenetic reproduction, or cloning, a single snail can produce a colony of 40 million progeny in a single year. These massive colonies disrupt the food web by displacing native aquatic invertebrates that fish and amphibians rely on for food. The recent discovery of New Zealand mudsnails in benthic macroinvertebrate samples created the unique, although disturbing, opportunity to monitor the spread of this highly invasive species. Results show mudsnails spreading from three streams in one watershed to eight different streams in three hydrologically separate coastal watersheds within three years. In addition to tracking the spread of the snails, the author provides recommendations for minimizing their impacts and for future studies on control measures and potential eradication of the New Zealand mudsnail.

In the spring of 2005, benthic macroinvertebrate (BMI) samples were collected from streams in the Malibu Creek watershed by the nonprofit environmental group Heal the Bay. When they were analyzed by California Department of Fish and Game scientists one year later, those samples were found to contain a tiny snail not previously seen in three years of regular monitoring of that watershed. It was *Potamopyrgus antipodarum*, the invasive New Zealand mudsnail, and its presence in the samples provided the unwelcome opportunity to document the invasion and spread of this tenacious species.

Background

Individual New Zealand mudsnails (Figure 1) measure only 3-5 mm long, but in large numbers they can completely cover a stream bed and wreak havoc on local stream ecosystems (Figure 2). They are capable of parthenogenetic reproduction, or cloning, so that a single snail can produce a colony of 40 million progeny in a single year. Studies have documented mudsnail densities in streams at more than 500,000 organisms per square meter (Dorgelo 1987). These massive colonies disrupt the food web by displacing native aquatic invertebrates that fish and amphibians rely on for food. New Zealand mudsnails are easily transported from stream to stream by hitchhiking; they attach themselves to shoes and boots, recreational equipment (e.g. fishing gear, bicycle tires), domestic and wild animals, and even boats. Anything that contacts a streambed infested with New Zealand mudsnails can easily become contaminated.

Figure 1. New Zealand Mudsnail, *Photo: by D.L. Gustafson*

New Zealand mudsnails were discovered in the U.S. in Idaho's Snake River in the mid-1980s (Taylor 1987). They have since spread to every western state except New Mexico. In the Santa Monica Bay watershed, the presence of mudsnails was unknown until 2006, when analysis of one-year-old BMI samples were analyzed (Abramson et al. 2006).

New Zealand mudsnails pose a significant danger to streams throughout the Santa Monica Mountains and threaten the many habitat restoration and protection efforts, particularly those to restore populations of the endangered steelhead trout in this region.

Figure 2. New Zealand Mudsnails at High Density Clinging to a Single Rock, *Photo: D.L. Gustafson*

Methods

Surveys were conducted in July 2006 at 44 sites in 19 streams immediately following the discovery of the New Zealand mudsnail in the Malibu Creek watershed. Sites were increased to 56 for the 2007 and 2008 surveys. Five sites on two additional streams were surveyed in mid-2009 after reports that mudsnails had been observed in Ramirez Canyon Creek, bringing the total to 61 survey sites in 21 streams. The density of survey sites was increased in 2007 in an effort to determine the upstream extent of the New Zealand mudsnail invasion in various streams. Site selection focused on sites that are frequently monitored for water quality, BMI, amphibians, or fish. These sites were targeted because of the high probability of transfer of New Zealand mudsnails between sites by scientific field crews.

Additionally, several popular recreational sites were also surveyed because of the likelihood of transmission of mudsnails from known locations to new locations by cyclists, anglers, hikers, and other recreational users.

To prevent the unintentional spread of mudsnails during the survey, separate (non-felt bottom) waders were used at each survey location. Immediately following a site visit, used waders were thoroughly cleaned on-site using stiff bristle brushes to remove any New Zealand mudsnails, dirt, rocks, and debris from the treads of the waders. Used waders were then placed into plastic garbage bags and isolated from clean waders to prevent cross contamination. Finally, used waders were placed in a chest freezer for a minimum of 48-hours after each use.

Surveyors visited each site and surveyed a minimum of 100 yards upstream and 100 yards downstream from the point of entry. Transects spanning the entire width of the stream, including wetted banks, were surveyed by randomly collecting rocks and/or small woody debris from the bottom of the stream and inspecting them for the presence or absence of mudsnails. A minimum of five samples were inspected along each transect and a minimum of 100 samples were inspected at each site.

Field identification of New Zealand mudsnails was based on color, size, and shell shape. Adult mudsnails have an average shell length of 3-5 mm and may vary in color, but are most commonly light brown to black (Figure 3). Mudsnails have conical shells with five, occasionally six, convex whorls or spirals. When held tip up, with the opening (aperture) facing the observer, the opening is on the right and the whorls spiral up and to the right.

If snails were present but could not be confidently identified by the surveyors, samples were collected for visual confirmation by Gwen Noda (UCLA) or, if necessary, genetic analysis by Mark Dybdahl (Washington State University).

The extensive geographic scope of the survey, the need to quickly determine the extent of the invasion, and limited funding, made a quantitative assessment of mudsnail densities impractical. Instead, the survey team evaluated the “density” of New Zealand mudsnails using the following criteria (Table 1):

Table 1. New Zealand Mudsnail (NZMS) Density Survey Criteria

Density	Criteria
Non Detect	No NZMS found or No water—unable to survey
Low	NZMS found on less than 10% of the substrate samples
Medium	NZMS found on more than 10% and less than 70% of substrate samples
High	NZMS found on more than 70% of substrate samples

Results

In 2006, New Zealand mudsnails were confirmed at 14 of the 44 sites surveyed. The confirmed sightings were in three different streams in the Malibu Creek watershed: Medea, Malibu, and Las Virgenes Creeks. No mudsnails were detected outside of the Malibu Creek watershed during the 2006 survey.

In 2007, mudsnails were detected at 20 of the 56 sites surveyed, with two additional streams testing positive, Lindero and Solstice Creeks. This brought the total to five streams testing positive for the presence of the New Zealand mudsnail. Solstice Creek was the first stream outside of the Malibu Creek watershed where the surveys detected the presence of mudsnails.

In 2008, mudsnails were detected at 24 of the 56 sites surveyed. Twenty-two of the sites testing positive for mudsnails were in the Malibu Creek watershed. Two sites on Solstice Creek, outside of the Malibu Creek watershed, also tested positive for the presence of mudsnails. Mudsnails were also detected in two additional streams within the Malibu Creek watershed, Cold Creek and Triunfo Creek.

In mid-2009, a potential sighting of mudsnails in a new stream was reported, and additional surveys (5 sites) were conducted in Ramirez Creek. Mudsnails were identified at three of these sites, increasing the spread of the New Zealand mudsnails to an additional watershed.

In total, the surveys have detected the presence of New Zealand mudsnails at 27 survey sites, in eight different streams, and in three discrete watersheds (Figure 4).

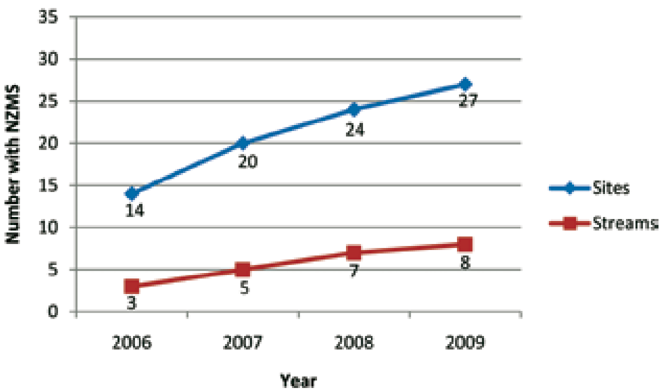

Figure 4. Number of Sites and Streams with New Zealand Mudsnails (NZMS) in the Santa Monica Mountains, 2006-2009

The spatial extent of New Zealand mudsnails and the creeks surveyed within the Santa Monica Mountains are presented in Figure 5.

New Zealand mudsnail density at most sites appears to have increased dramatically between 2006 and 2008. In 2006, mudsnails were identified at fourteen sites. In 2007, mudsnails were documented at six additional sites. As of 2008, fifteen of these sites had shown an apparent increase in mudsnail densities. Four of the sites were judged to be high density sites when the surveys began in 2006 and have remained unchanged. One of the sites in Malibu Creek has remained "medium" density throughout the surveys. None of the sites have shown decreased mudsnail densities in any survey year.

Discussion

It is apparent that the New Zealand mudsnail has become established within the Malibu Creek watershed, and has spread to at least two other nearby watersheds (Figure 5). In 2008, mudsnails were discovered in Cold Creek and Solstice Creek, two of the highest quality streams, in terms of the diversity of BMI communities and water quality, in the Santa Monica Mountains. New Zealand mudsnails were documented in a third watershed, Ramirez Creek, in mid-2009. The mudsnails are now well-established (high density) in Las Virgenes, Malibu, Solstice, Ramirez and Medea Creeks (Table 2).

Table 2. Number of Sites with New Zealand Mudsnails

Watershed	Creek (Sites)
Malibu Creek	Malibu (8) Medea (4) Las Virgenes (6) Lindero (2) Cold (1) Triunfo (1)
Solstice Creek	Solstice (2)
Ramirez Creek	Ramirez (3)

Figure 3. New Zealand Mudsnail detail, *Photo: D.L. Gustafson*

Figure 5. Spatial Extent of New Zealand Mudsnails (NZMS) in the Santa Monica Mountains

This novel infestation of Malibu Creek and nearby watersheds by the invasive New Zealand mudsnail has provided the opportunity to document the spread of the species and to attempt to curtail that spread. Within three years of the initial detection, we have seen the mudsnail spread rapidly throughout the Malibu Creek watershed and witnessed their introduction into two other watersheds within the Santa Monica Bay.

Although there are many possible vectors for the introduction and spread of the New Zealand mudsnail in the Santa Monica Bay watershed, we suspect that the most likely source of introduction was human activity, specifically, water quality monitoring activities. It is highly unlikely that the mudsnail was introduced as a result of recreational activities, particularly fishing, which is the activity most frequently associated with the spread of the mudsnail. The first documented evidence of the invasion was from BMI samples collected in Medea Creek, in the upper Malibu Creek watershed. Medea Creek is not associated with recreational angling, but it has been extensively monitored by numerous entities. Some of those entities also frequently monitor streams outside of the Santa Monica Bay watershed in locations where mudsnails have already invaded (e.g. Piru Creek). The initial discovery of mudsnail infestations appears to closely track the most intense monitoring activities in the watershed.

The spread of mudsnails continued, despite a suspension of most monitoring activities by agencies in 2007, after the initial mudsnail discovery. Monitoring activities by some researchers continued, and most monitoring was restarted within a few months. Many agencies adopted special techniques to avoid spreading the mudsnails from site to site, but it is not known whether these techniques are 100% effective or how rigorously monitoring crews are trained in their use.

To help develop protocols to prevent the introduction and spread of New Zealand mudsnails and other aquatic invasives, a group of concerned agencies and nonprofit organizations hosted a workshop devoted to Hazard Analysis and Critical Control Point (HACCP) planning. There attendants learned the 5-step process used to perform a comprehensive review of planned actions (monitoring, channel maintenance, restoration, construction activities, etc.) and to identify critical control points where specific actions should be implemented (dedicated equipment, decontamination protocols, etc.) to prevent the introduction or spread of invasive species, including New Zealand mudsnails (see insert on facing page for California's plan to address aquatic invasive species).

California's Plan for Aquatic Invasive Species

Jack Topel

Invasive species are "…alien (or non-native) species whose introduction does, or is likely to cause economic or environmental harm or harm to human health" (Department of Fish and Game 2008). Aquatic Invasive Species (AIS) are invasive animals and plants that live in or near the water and can be easily dispersed to distant water bodies or new ecosystems by natural processes such winds, currents, and tides, as well as human activities like recreation, commercial fishing, shipping, and even environmental restoration activities.

No matter the vector or pathway, AIS are major local, national, and global threats to biodiversity and public health and safety. In the U.S. alone, infrastructure damage and measures to control zebra mussels (*Dreissena polymorpha*), amount to a staggering $1 billion annually. Invasive fish and aquatic weeds account for another $5.5 billion in direct and indirect losses (Pimentel et al. 2005). AIS also have tremendous environmental impacts through loss of diversity and abundance of native plants and animals and degradation of habitat and water quality. AIS threaten public health via the spread of parasites and diseases, like the West Nile Virus, and threaten public safety by destabilizing stream banks and levees, leading to erosion and flooding concerns.

California's state agencies have been addressing AIS concerns for many years. However, until recently, most agencies acted individually, with little interagency coordination. With AIS problems becoming more widespread, costly, and complex, managers and policy makers realized that a comprehensive, statewide approach was necessary. In 2002, the Department of Fish and Game began developing a plan to "coordinate state programs, create a statewide decision-making structure and provide a shared baseline of data and agreed-upon actions so that state agencies may work together more efficiently." In January 2008, with input from multiple state agencies, the public, and other stakeholders, the California Aquatic Invasive Species Management Plan (CAISMP) was formally approved by Governor Schwarzenegger (Department of Fish and Game 2008).

CAISMP seeks to identify the steps necessary to minimize the harmful impacts of AIS in California. More than 160 management actions are organized under the following eight objectives: Coordination & Collaboration, Prevention, Early Detection & Monitoring, Rapid Response & Eradication, Long-term Control & Management, Education & Outreach, Research, and Laws & Regulation.

The highest priorities among the actions identified in CAISMP are:

- Formalize the creation of two major new coordinating entities, one entirely for state agencies and one for a broader range of AIS interests.
- Formalize a process for the team of state AIS managers to share information with and get input from agency executives.
- Secure funding for state AIS staff.
- Conduct a statewide assessment of the risk from four specific AIS vectors or pathways: commercial fishing, recreational boating, live bait, and live imported seafood.
- Fund and launch early detection and rapid response actions, emphasizing the coordination of monitoring programs and the expanded monitoring of freshwater systems.

The implementation of the highest priority actions was initiated in 2008 with the formation of the California Aquatic Invasive Species Team (CAAIST). CAAIST's mission is to coordinate the activities of state agencies charged with implementation of the CAISMP. CAAIST is composed of representatives from over 25 California state agencies, including the Santa Monica Bay Restoration Commission. The CAAIST first convened in December 2008 and has two standing committees.

CAAIST Coordination Committee
The CAAIST Coordination Committee focuses on implementation of the following objectives from the CAISMP: Cooperation and Collaboration, Education and Outreach, Research, and Laws and Regulations.

CAAIST Technical Committee
The CAAIST Technical Committee focuses on implementation of the following objectives from the CAISMP: Early Detection and Monitoring, Rapid Response and Eradication, Long-Term Control and Management.

Aquatic invasive species are already a serious problem for California. Financial constraints and a lack of a coordinated effort have made preventing additional introductions and controlling the hundreds of aquatic invaders that have already become established a challenge for California's resource managers and policy makers. Unfortunately, all indications are that the environmental and economic costs of these invasions will continue to rise in the future.

However, the creation and interagency process of implementing the CAISMP's actions, along with deciding which entities will undertake them, provides a road map for improving state AIS management and coordination. If the priority actions of the CAISMP can be successfully implemented, California resource managers and policy makers will have taken a huge step forward in the effort to prevent new invasions and minimize impacts from established AIS.

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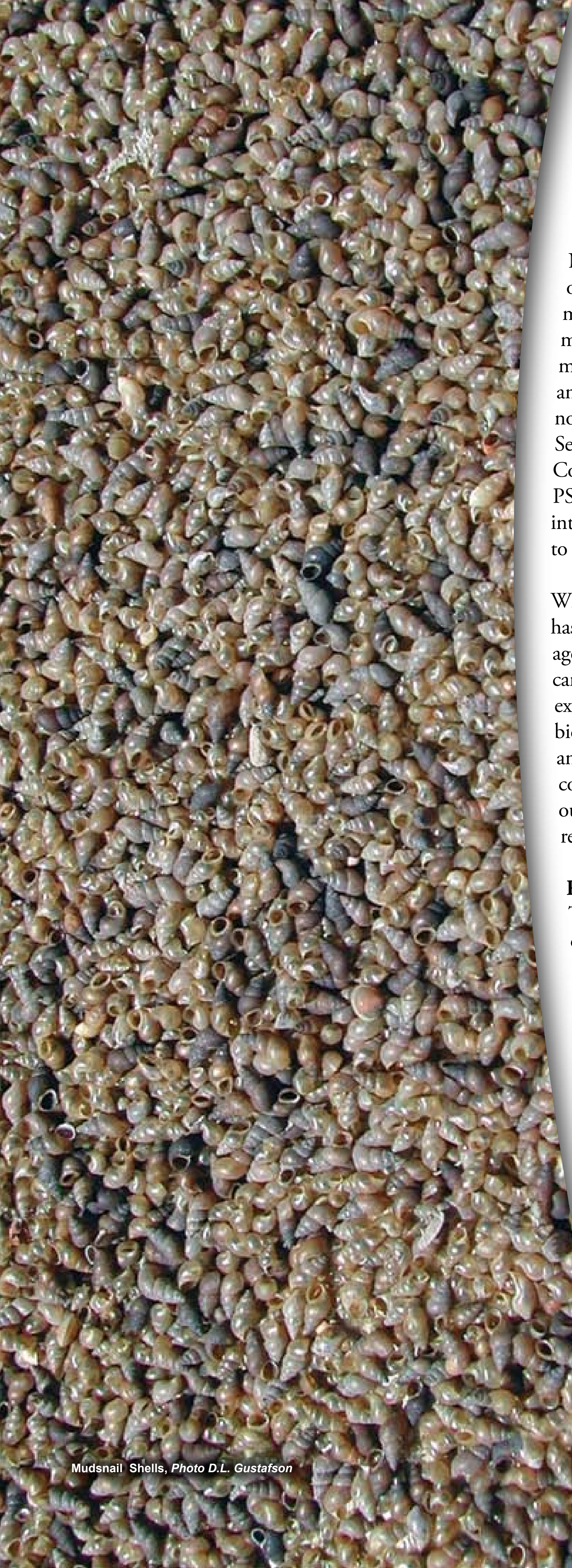

Mudsnail Shells, *Photo D.L. Gustafson*

It is likely that recreational activities such as hiking, horseback riding, biking, and fishing are hastening the spread of the New Zealand mudsnail. Efforts to educate the general public about the negative impacts of the mudsnail invasion were also implemented. With the input of local resource management agencies, property owners, and other groups, New Zealand mudsnail warning/prevention signs were developed in both English and Spanish versions. The signs were made available at no cost to resource management agencies, municipalities, and other interested groups. Several environmental groups offered to post the signs for the municipalities and resource agencies that manage property in the region at no charge. To date, very few signs have been posted. A Public Service Announcement (PSA) was also created by the Resource Conservation District of the Santa Monica Mountains. The PSA was broadcast on local television and made available on the internet. However, without additional research, it is impossible to know if these measures have had positive effects.

When an invasive species has become established, eradication has proven extremely difficult or impossible. Ongoing management is then necessary to restore native communities. This can be both expensive over time as well as controversial. For example, much debate arises over the use of pesticides and herbicides or the introduction of one non-native species to control another. Preventing new introductions is the easiest and most cost-effective way to protect habitat and the beneficial uses of our aquatic resources and prevention must be a priority of our resource management agencies.

Recommendations

The author would like to provide the following recommendations to reduce the spread and study the effects of New Zealand mudsnails in the Santa Monica Mountains.

Presence/absence surveys are important tools in mapping the spread of the New Zealand mudsnail and may help determine the effectiveness of outreach efforts. It is important that they be repeated annually. Additionally, it is critical that BMI sampling be conducted to help further our understanding of the ecological impacts of the invasion on benthic communities, especially at sites where pre-infestation data is available. It may also be useful to compare pre- and post-infestation water quality data.

Resource monitoring activities can be a pathway for the unintentional introduction and spread of both aquatic and terrestrial invasive species, as is probably the case for the New Zealand mudsnail in the Malibu Creek Watershed. On several occasions during the surveys, various agency personnel were encountered performing routine tasks such as channel clearing, restoration work, and, ironically, vector control. None were aware of any procedures their agencies had in place to prevent the spread of invasive species. Therefore, all agencies involved in natural resource management should develop and implement plans to minimize the possibility of spreading the New Zealand mudsnail, as well as other invasives. These plans should be specific to the agency's activities and should be reviewed by independent experts. Additionally, agencies with regulatory authority, including the Department of Fish and Game, Coastal Commission, and State and Regional Water Quality Control Boards should make approved, project-specific invasive species management plans a condition of any grant or contract award or permit. Non-regulatory agencies should follow this same recommendation before awarding grants or contracts for projects that involve activities such as restoration or monitoring.

Administered by the United States Environmental Protection Agency (USEPA), the Clean Water Act requires the State to assess the status of the State's water quality and develop a list of impaired water bodies (Section 303(d)) every two years. Inclusion on the 303(d) list obligates the Regional Water Quality Control Boards to develop programs to address the impairments. Recently, the Los Angeles Regional Water Quality Control Board (LARWQCB) approved the listing of Malibu, Medea, Lindero, and Las Virgenes Creeks in the Malibu Creek watershed, along with Solstice Creek, as impaired for invasive species, specifically the New Zealand mudsnail. The listing is currently awaiting approval by the State Water Board and USEPA. While it will be extremely challenging to develop a program to regulate established invasive species, the State Water Board and the USEPA should approve these listings. Additionally, the LARWQCB should consider the following streams for inclusion on the next 303(d) list; Cold Creek, Ramirez Creek and Triunfo Creek.

Multilingual public outreach programs should be developed to target recreational users of the Santa Monica Mountains. Outreach should focus on encouraging simple behavioral changes to reduce the odds of unwanted wildlife, vegetation, parasites, and viruses invading our watersheds. Outreach should emphasize the dangers of invasive species, along with simple ways users can help prevent the introduction and spread of mudsnails and other unwanted invaders.

An on-line invasive species reporting system should be developed or adapted from an existing system. The on-line system would centralize the reporting of new invasives, and help resource managers track the spread of existing invasive species.

Finally, it is important that funding sources be identified and secured to support the following research and planning efforts:

- Possible mechanical, biological, and chemical control measures;
- Developing methods for detecting new populations;
- Developing rapid response measures when new populations are detected;
- Research to further our understanding of biological and economic impacts; and
- Developing risk assessments to predict the potential for new invasions.

Mark Abramson is the Director of Watershed Programs for the Santa Monica Baykeeper. Working in stream and wetland restoration for 15 years, he created the highly successful Malibu Creek watershed Stream Team program for Heal the Bay during his 10 years of employment before joining the Santa Monica Baykeeper 3 years ago. Mark is also managing the Malibu Lagoon restoration project for the State Coastal Conservancy and State Parks, and he is engaged in stream restoration on Stone Creek at the UCLA campus.

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Air Meets Water: Atmospheric Deposition on the Horizon

Keith Stolzenbach

Abstract

Metals released from industrial processes, vehicle emissions, constructions sites, and other sources exist as particles in the air. They settle directly into receiving water bodies or onto streets and rooftops and are then washed into water bodies with urban runoff. In this study, air quality computer models of the transport and fate of metals in the Los Angeles region indicated that atmospheric deposition may be a significant source of metals to local water bodies. The findings are that nearly all the metals deposited on impervious urban surfaces wash off with the next rainfall, but on more natural land surfaces, between 20% and 30% of the metals are sequestered from immediate runoff. Recommendations to deal with the effects of atmospheric deposition on water quality include modifying air quality regulations to allow greater consideration of water quality impacts, reducing known sources of airborne metals, regulating land uses to minimize exposure to these contaminants, and expanding air quality monitoring to include identified water pollutants.

Anyone who has dusted a room or washed a car has encountered the effects of atmospheric deposition. Pollutants in the atmosphere can deposit on all of the solid surfaces of a watershed and then can be washed off by rain, becoming part of the stormwater runoff that reaches rivers, lakes, and coastal waters. Pollutants may also be deposited directly from the atmosphere onto the surface of a water body. A secondary, but important, reason to be concerned about atmospheric deposition is that pollutants that are not washed off may accumulate on surfaces such as soil, forming a reservoir of toxic substances that may later be resuspended back into the air, causing a threat to human and ecosystem health even after the original sources of the pollutant have been removed.

Substances exist in the atmosphere either as molecules of gases or as solid or liquid particles, called aerosols, that range in size from 0.001 to 100 microns. Both gases and particles are deposited on surfaces by one of two general mechanisms. Wet deposition occurs when raindrops drag molecules of gases and particles down with them as they fall. Dry deposition results from the combination of molecular diffusion, impaction, and gravitational settling. Wet deposition is the most important deposition mode in regions with appreciable annual rainfall, but in semi-arid regions such as Southern California, atmospheric deposition is likely to be dominated by dry deposition processes. The most rapid dry deposition rate is the gravitational settling of particles in the 10 to 100 micron size range.

Water pollutants of concern that may deposit from the atmosphere include compounds that increase the acidity of rainfall or fog, nutrients that may cause excess algal growth (eutrophication), and toxic organic and inorganic (metals) compounds. Acid rain, primarily caused by the emission of nitrogen and sulfur from motor vehicles, industries, and power plants, harms vegetation and impairs water quality. Acid rain has been one of the longest standing issues involving atmospheric deposition in the United States and has been addressed at the federal level by the National Atmospheric Deposition Program (NADP). Eutrophication of water bodies by excess nutrients results in lowered, often zero, dissolved oxygen levels and consequent death of fish and other organisms in addition to dramatic changes in taste and odor of the water. Eutrophication of major water bodies in the United States, notably Lake Erie, was one of the driving forces behind the federal Clean Water Act of 1972 and is still of concern in many regions. In California, nutrient additions by atmospheric deposition are thought to be a primary cause of the decrease in the clarity of Lake Tahoe (Tahoe Environmental Research Center 2008).

Among the organic compounds of interest in aquatic systems are pesticides such as dichlorodiphenyltrichloroethane (DDT), polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenols (PCBs), all of which are internationally recognized as important persistent organic pollutants (POPs). Metals identified as important water pollutants are copper, cadmium, chromium, lead, mercury, nickel, and zinc. These organic compounds and metals are present in the sediments of many water bodies and are of concern because of their effects on aquatic organisms and, in the case of lead and mercury, on human health. Mercury currently receives special attention from the NADP because of its ability to travel long distances as a gas before entering water bodies by atmospheric deposition.

Many of the inputs of water pollutants from point sources like treatment plants and other facilities have been reduced by successful treatment and source reduction efforts. However, it is now recognized that non-point sources originating from urban and agricultural activities in a watershed are sufficiently large that water quality improvement objectives have not been met in many locations. Regulatory efforts to improve and protect water quality, particularly by establishing Total Maximum Daily Loads (TMDL), should consider the contribution of atmospheric deposition relative to other point and non-point sources in the watershed. It may be that solving water quality problems resulting from stormwater runoff may need to focus, at least in part, on resolving air pollution/deposition problems.

This article, using the findings of studies conducted over the last ten years at UCLA and the Southern California Coastal Water Research Project (SCCWRP), summarizes the current state of understanding of atmospheric deposition as a contributor to water quality problems. The article focuses on the Los Angeles region as a model for urbanized areas, particularly those in relatively dry climates where dry deposition is the dominant mode of deposition. The discussion deals mainly with the metals identified as water pollutants, but many of the conclusions presented here also apply to acid rain, nutrients, and organic compounds. Deposition of atmospheric mercury is not discussed here, largely because of the absence of upwind sources of mercury on the U.S. West Coast. The article identifies the important sources of metals in Los Angeles, the resulting patterns of deposition, and the relative importance of atmospheric deposition of metals, followed by a discussion of what scientific and institutional steps can be taken to deal with atmospheric deposition.

Sources of Metals to the Atmosphere

Estimates of pollutant emissions to the atmosphere have been developed by the combined efforts of the U.S. Environmental Protection Agency (EPA), California Environmental Protection Agency (Cal/EPA), and the South Coast Air Quality Management District (SCAQMD) for three categories of sources (South Coast Air Basin 1997). Point sources are fixed sources associated with specific large industrial facilities; mobile sources are moving vehicles; and area sources include construction vehicles, distributed smaller industrial sources, and resuspended dust.

The most significant source of metals to the atmosphere, in Los Angeles and elsewhere, is resuspension of dust, often called "fugitive" dust, from roads by moving vehicles and from other paved and unpaved surfaces by wind (Figure 1). Chemical studies of the dust indicate it is primarily composed of natural material typical of the earth's crust, but it also contains significant amounts of the metals, which are water pollutants of concern. These metals have become intimately mixed with the crustal material, making identification of their "real" sources difficult. Recent measurements indicate wild fires can also be a significant source of metal laden dust.

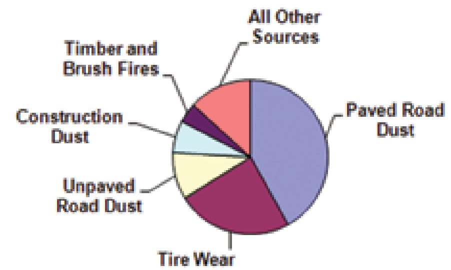

Figure 1. Sources of Zinc Emissions to the Los Angeles Region

Regulatory programs designed to protect human health have successfully reduced emissions of many substances from point and mobile sources. However, tire wear remains a significant source of zinc and brake pad wear is a significant source of copper from mobile sources. The heaviest and largest of the particles containing copper and zinc may deposit directly on the road or surrounding area, but a large fraction is dispersed into the atmosphere.

Studies focusing on lead in the Los Angeles region have shown the current levels of lead present in resuspended dust far exceeds the supply from contemporary sources, especially now that the main historical source of lead to the environment, leaded gasoline, has been reduced to near zero levels (Harrison 2005). Lead levels in the atmosphere and in newly deposited material appear to be supplied by resuspension of "old" lead present in soils and other surfaces. This phenomenon is likely to be important for other pollutants subject to atmospheric deposition.

Traffic on the 110 Freeway, *Photo: Miwa Tamanaha*


Smog on Skyline at Venice Beach, *Photo: Ania Garrett*

Patterns of Atmospheric Deposition

Scientists from UCLA and SCCWRP have used air quality computer models to determine the transport and fate of metals in the Los Angeles region using as inputs the estimates of sources described above (Lu 2003). The models indicate about a fourth to a third of the material emitted into the atmosphere is deposited within the region, and the rest is carried away by the wind. Most of the deposited material falls on land or urban surfaces rather than directly on a water surface, but there is some deposition on coastal waters because of night-time breezes from the land and because of persistent Santa Ana winds. Because of the relatively small total rainfall in Southern California, dry deposition is much more important than wet deposition. The UCLA/SCCWRP measurement program also documented for the first time the presence of significant amounts of particles between 10 to 100 microns in size in the air above Los Angeles (Lim 2006). Although there are substantial amounts of metals on particles smaller than 10 microns, it is the largest particles that are responsible for most of the atmospheric deposition of metals.

The pattern of dust and metal concentrations in the atmosphere and the associated deposition on land is relatively uniform spatially in the Los Angeles urban region. Although deposition near major sources, such as freeways, is higher than the regional background rate within about 100 meters of the road (Sabin 2006). In the urban areas, daytime concentration and deposition of metals is greater than nighttime because of the influence of traffic on resuspension. These patterns have been documented by direct measurements of deposition using specially designed deposition surfaces. The modeled and observed patterns of atmospheric concentrations and deposition of heavy metals, combined with the measured properties of regional dust, have led scientists to hypothesize that dust-associated substances, including metals, deposit relatively close to the original source of the material, but then are resuspended and redeposited numerous times before being carried out of the region by winds, sequestered on the land surface, or washed off by rainfall (Figure 2). Thus deposition from the atmosphere is only one component of a complex system of pollutant transport operating at the land-air boundary.

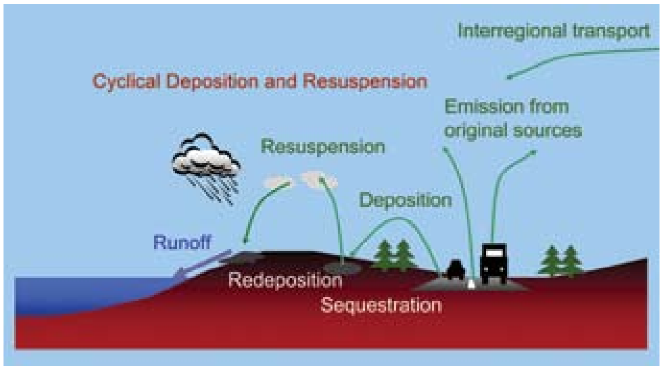

Figure 2. Hypothesized Mechanisms for Course Particle Transport

Importance of Atmospheric Deposition

The relationship between atmospheric deposition of metals and water quality has been documented by a combination of model simulations and water sampling in the Los Angeles region. The findings are that nearly all the metals deposited on impervious urban surfaces wash off with the next rainfall (Sabin 2005), but on more natural land surfaces, between 20% and 30% of the metals are sequestered from immediate runoff (although the data on lead indicate sequestered pollutants may be available for resuspension by wind over longer time periods) (Sabin 2006).

Comparison of the mass of metals reaching the land surface by atmospheric deposition, with the mass found in runoff, and with known mass inputs from other sources clearly shows atmospheric deposition is a potentially significant source of metals to water bodies (Table 1). The contribution of atmospheric deposition can be as high as 99% in the case of lead, for which other contemporary sources are negligible.

Table 1. Relative Importance of Atmospheric Deposition of Metals to Santa Monica Bay

	Annual Loadings to Santa Monica Bay (mt/yr) from Different Sources			
	Aerial Deposition	POTW	Industrial	Power GS
Chromium	0.5	0.6	0.02	0.14
Copper	2.8	16.0	0.03	0.01
Lead	2.3	<0.01	0.02	<0.01
Nickel	0.45	5.10	0.13	0.01
Zinc	12.1	21.0	0.16	2.40
		NON-AERIAL SOURCES		

Mitigation

Important scientific and institutional steps can be taken to deal with the effects of atmospheric deposition on water quality. It is important to refine current estimates of original sources and of resuspended dust sources of pollutants. Many emissions estimates are based on outdated information. Current estimates of these sources leave many questions unanswered about the relative importance of vehicles and wind as mechanisms for resuspension in urban regions. In addition, it is vital to assess the relative magnitude of local and distant sources of potential pollutants, including intra-regional sources.

Our understanding of key processes is incomplete. In particular, we need to know more about the spatial and temporal variability of resuspension, sequestration, and wash-off to assess the importance of older sources and design and evaluate remediation and control schemes.

The most important institutional step is to modify air quality regulations to allow greater consideration of water quality impacts. It is important for air and water agencies to work together in ways they have not done previously and to take a multidisciplinary approach. This change is long overdue and is key to progress in dealing with atmospheric deposition. Fortunately, agencies such as the California Air Resources Board and the State Regional Water Quality Control Board are beginning to interact for the first time in an interdisciplinary manner to address this issue.

Regulators should continue to reduce known sources of water pollutants. Efforts are already underway in the San Francisco Bay area, for example, to examine the potential benefits of reducing copper in brake pads, and similar studies should be undertaken for zinc in tires.

Land use regulations can take advantage of what we already know about patterns of deposition near roads and freeways by minimizing use of these hot zones for sensitive uses such as residences and schools. In some cases, it may be possible to provide vegetative buffer zones that reduce the size of the high deposition region near sources.

Finally, regulators should authorize and fund the extension of routine air quality monitoring to include particles larger than 10 microns and identified water pollutants such as metals, as well as conduct direct measurement of deposition rates. These measurements would inform future scientific studies of atmospheric deposition.

Conclusion

It is clear that achieving air and water quality objectives requires a consideration of atmospheric deposition of pollutants as a significant non-point source of pollutants. The effects of atmospheric deposition are linked to a system of dust transport at the air-land interface. Inferences about and control of the effects of human sources to this system are made difficult by the presence of natural material and by the complexity of the transport processes. Progress in understanding and dealing with atmospheric deposition as a non-point source will require continued acquisition of scientific information and the evolution of cross-media and multi-disciplinary regulatory and monitoring approaches.

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His research during the last eight years has involved measurements and modeling of atmospheric deposition in the Los Angeles regions.

Professor Stolzenbach received his Ph.D. from MIT in 1971 after which he worked for the Tennessee Valley Authority for three years and then as a faculty member at MIT for eighteen years before moving to UCLA in 1992.

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Science Based Regulation: California's Marine Protected Areas

Dan J. Pondella, II

Abstract
In 2008, the California Department of Fish and Game (DFG) began a one-year process to develop a preferred alternative for a network of marine protected areas in Southern California. To comply with the state Marine Life Protection Act's mandate for sound science, the DFG appointed marine scientists to a Science Advisory Team to set up guidelines that stakeholders and decision makers could rely upon to determine how well proposals met the goals of the MLPA to provide some protection for marine life. As the final debates over where to draw the lines of the new reserves continue, this article explains the scientific underpinnings of this groundbreaking process.

While various forms of marine protections and reserves exist along the California coast, they were created for discrete purposes and are often too permissive to provide any real protection. As such, human activities over the last century, including water pollution, fishing, and development have severely impacted the marine ecosystem. In 1999, the state of California passed the Marine Life Protection Act (MLPA) to reevaluate and redesign the existing Marine Protected Areas (MPAs) into a comprehensive network to preserve and protect the marine life and habitats along the coast. The MLPA requires the use of the best available science to develop California's new system of MPAs with the assistance of scientists, resource managers, and stakeholders. The process of developing MPAs includes scientific guidelines, which are mandated by the MLPA, to ensure coherent and effective protections for the State's marine ecosystems and natural heritage, while improving recreational, educational, and study opportunities provided by undisturbed habitats.


Kelp Forest

The MLPA has the following six goals that are designed to protect biodiversity:

- Protect the natural diversity and abundance of marine life and the structure, function, and integrity of marine ecosystems.
- Help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.
- Improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and manage these uses in a manner consistent with protecting biodiversity.
- Protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value.
- Ensure that California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement that are based on sound scientific guidelines.
- Ensure that MPAs are designed and managed, to the extent possible, as components of a statewide network.

It is important to note that the MLPA is not a fisheries management tool, nor does it address socioeconomic issues associated with MPAs. Traditionally, fisheries management is approached species by species and has the dual goal of simultaneously ensuring the survival of the fish stock and the fishermen. This type of management has repeatedly failed in California and elsewhere. Thus, fisheries management has begun to take an ecosystem approach, as opposed to single species, as is evident by the mandate in the Marine Life Management Act (MLMA), which was also passed in 1999 as sister legislation to the MLPA. Both the MLMA and MLPA were a response to the generally poor and declining health of our state's marine resources. Under the MLMA, regulators set take limits based on the optimal sustainable yield of the fishery, establish size limits to ensure reproduction, and enact gear restrictions to prevent unnecessary harm to other marine life or habitat. Under the MLPA, regulators can close a discrete area to human disturbance (e.g. fishing, dredging, oil extraction) and allow the system within to flourish intact.

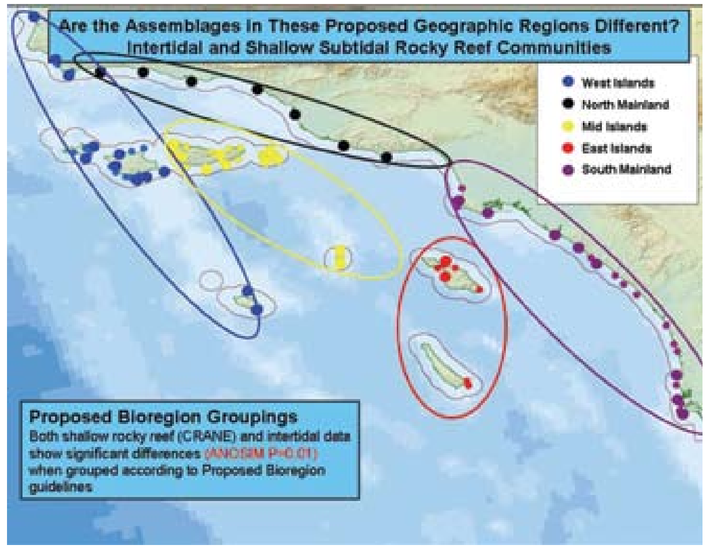

Figure 1. Biogeographic Subregions in the Bight Determined by the SAT from PISCO/CRANE and MARINE Data Sets.

Managing ecosystems is a complex scientific endeavor. One of the critical components of successfully implementing the MLPA, was the establishment of a Science Advisory Team (SAT) to develop scientific guidelines for inclusion in the MLPA Master Plan (Master Plan). The SAT's role is to use the best available science to achieve the goals of the MLPA. In the current process, the Regional Stakeholder Group (RSG) creates reserve network designs based upon the SAT guidelines. These networks are then evaluated by the SAT and the evaluations are forwarded to the Blue Ribbon Task Force (BRTF). The BRTF has the responsibility of making a recommendation to the Fish and Game Commission.

In tackling this problem, the first layer of information provided by the SAT as an evaluation criterion concerns the representation of habitats. In the simplest paradigm, to maximize the conservation effects on biodiversity an MPA network and an individual reserve will optimally incorporate as many marine habitats as possible. The SAT identified 22 'key' habitats in the Southern California Bight (Bight) (Table 1). The distribution of all of these habitats was provided in to the RSG in a user-friendly, web-based, interactive GIS system called Marine Map.

Table 1. 'Key' Habitats Identified in the Bight by the SAT

Rocky shore	Kelp	Soft bottom 0-30m
Sandy beach	Rocky reef 0-30m	Soft bottom 30-100m
Surfgrass	Rocky reef 30-100m	Soft bottom 100-200m
Coastal marsh	Rocky reef 100-200m	Soft bottom >200m
Tidal flats	Rocky reef >200m	Upwelling centers
Estuarine waters	Submarine canyons	Retention zones
eelgrass	Pinnacles	River plumes
		Fronts

In the Bight, there are multiple biogeographic regions based upon the transition between the San Diegan (warm temperate) fauna from the south to the Oregonian (cold temperate) fauna to the north. Island and mainland faunas are distinct and there are transitional zones at Santa Barbara, Anacapa, and Santa Cruz Islands. These biogeographic subregions were determined from analyses of nearshore rocky reef surveys conducted by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and Cooperative Research and Assessment of Nearshore Ecosystems (CRANE), deep reefs as described by submersible research under the direction of Dr. Milton Love, soft bottom habitats from trawl surveys conducted by the Southern California Coastal Water Research Project (SCCWRP), and rocky intertidal habitats from surveys of community structure conducted by the Multi-Agency Rocky Intertidal Network (MARINe).

The different regions are best displayed by the nearshore and intertidal reef data sets (Figure 1). Santa Monica Bay contains both of the mainland biogeographic zones. The SAT recommended that the optimal reserve network would incorporate each key habitat in all five biogeographic subregions. Since the species assemblage varies within each habitat in each subregion, the SAT recommends that all key habitats be replicated throughout in each region.

The next crucial evaluation criteria, from a scientific perspective, are the size and spacing of the reserves within the network. The size guideline is straightforward. Optimally, a reserve should be large enough to protect adult populations from fishing pressure. If a reserve is too small, the natural movement of animals will take them outside of the reserve boundary and reduce its effectiveness. The SAT calculated the amount of habitat necessary to include 90% of the associated species as a guideline for minimum MPA size using a species-area plot from the aforementioned studies (Figure 2). According to the guidelines in the Master Plan, at a minimum benchmark, reserves should be between 5 to 10 linear km of coastline, but optimally between 10 to 20 km.

Spacing guidelines concern the connectivity of the network. The connectivity of the reserves is determined by the vagility of the taxa or populations within them. Vagility represents a taxa's capacity to move about or disperse in a given environment, typically through two avenues: adult movement and the planktonic larval stages of most fishes, algae, and invertebrates. The size guidelines, coupled with the list of species most likely to benefit from protected areas (discussed below), generally encompass adult movement. Therefore, connectivity is generally viewed as larval connectivity or the connection between different reserves.

Most fishes, algae, and invertebrates have an extended planktonic larval stage, typically between 30 and 120 days. One of the interesting modeling products from the SAT is the adaptation of the Regional Oceanic Modeling System (ROMS) model to include the probability of larval connectivity throughout the Bight. This work is being done in Dr. Dave Siegel's lab in the Institute for Computational Earth System Science and Department of Geography at UC Santa Barbara. The model is based upon CRANE data of larval production by adults along the coastline, spawning period, and larval stage duration. The production of larvae is then modeled using Lagrangian Particle Tracking. An example using kelp bass is shown in Figure 3. This plot shows an unexpected result of the modeling – larvae from the mainland are seeding the islands, but the islands are not a significant source of kelp bass larvae to the mainland. In addition to the connectivity among reserves, larval outputs from reserves could increase the recruitment of organisms in non-reserve areas. Using these types of data products, the SAT developed guidelines for within-reserve habitats at 50 to 100 km apart and determined that spacing should be evaluated for each habitat.

The SAT also generated a list of species most likely to benefit from MPAs based upon the life history characteristics of the taxa. The four major filters used to classify organisms in this list were fishing effects, feature association, adult home range, and whether or not the population level was depressed. These filters were defined as follows:

- Fishing effects refers to species that are actively fished or removed as bycatch by fishers.
- Feature association refers to organisms that are associated with key habitat features during all or part of their life histories. A good example of feature association is recurring spawning aggregations, in which a species uses particular habitat features as a cue for spawning aggregations, which in turn are targeted by fishers.
- Home range size was considered critical to delineate organisms that would likely remain within the confines of a reserve.
- Finally, organisms that had depressed or reduced populations, generally due to overfishing, would be likely to benefit from such closures.

One of the top examples of fish that are most likely to benefit are kelp bass. Kelp bass have a relatively small adult home range, are currently targeted intensively by sportfishers, create spawning aggregations on the outside of kelp beds (where they are targeted), and their population has declined precipitously over the last two decades. This is similar for some invertebrates, for example, all of our abalones (red, pink, white, green, black) scored high in this metric. They have a very small home range, they have been fished out of the Bight to the point that the fishery was closed, they need to aggregate

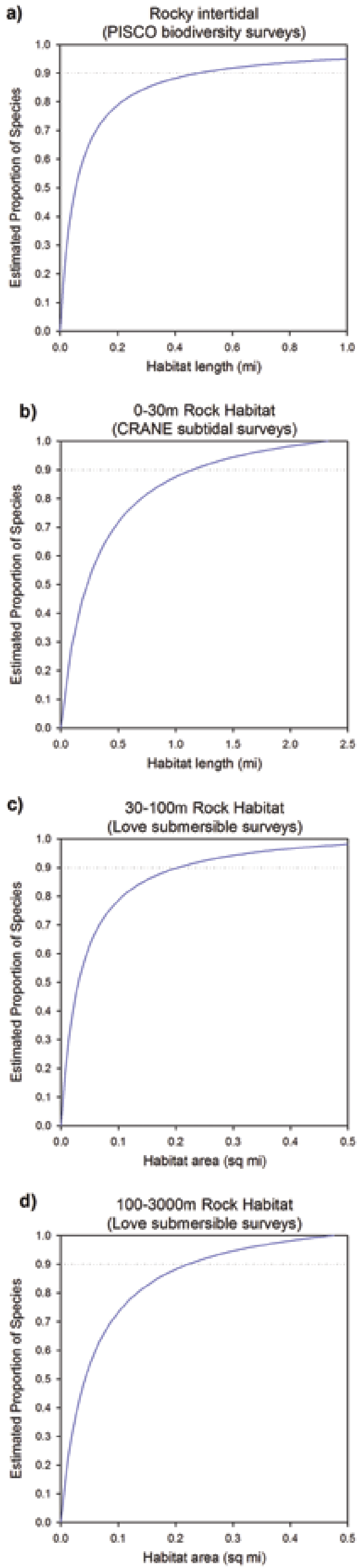

Figure 2. Estimated Proportion of Species per Amount of Rocky Habitat versus the Area or Length of Habitat

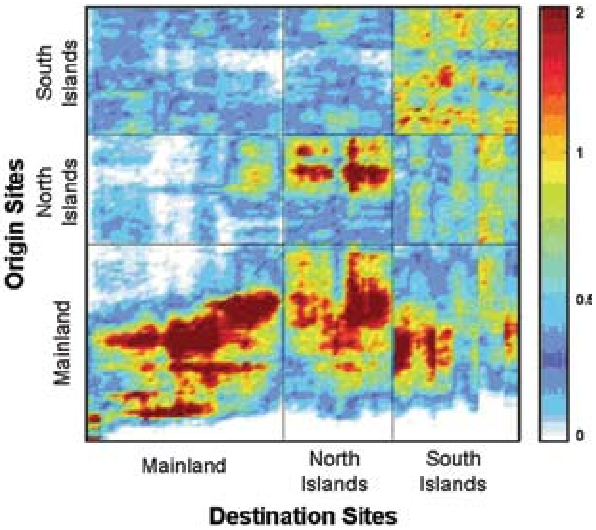

Figure 3 Probability of Dispersal of Kelp Bass Larvae from an Origin Patch to a Destination Patch by Geographical Region.
Note: Color intensity at each point shows the probability of dispersal of kelp bass larvae from an origin patch (vertical axis) to a destination patch (horizontal axis) by geographical region.

to reproduce and they are associated with very specific habitat characteristics of reefs. In fact, the white abalone has been recently listed as an endangered species due to overfishing.

Optimally and practically, a reserve should incorporate as many habitats as possible. The goal of the MLPA is to protect biodiversity, thus the more habitats represented the more species protected. The best reserve network will optimize all three of these parameters: habitat representation, size, and connectivity. From a scientific perspective, the best designs will have multi-habitat reserves that are larger and relatively close together.

As I write this article, the SAT has completed its final evaluations of the RSG proposals and the BRTF recommendation is forthcoming. So, what can we expect for Santa Monica Bay? The most scientifically desirable habitats for MPAs in Southern California are rocky reefs and associated kelp beds. These occupy about a quarter of the nearshore habitat and are separated by large expanses of soft bottom habitats. In addition, most other critical habitats (e.g. rocky intertidal, surfgrass, deep reefs, canyons, upwelling zones) are associated with rocky reefs and kelp beds. Therefore, Santa Monica Bay represents a perfect microcosm of the challenges our coastline. Santa Monica Bay has two major rocky headlands, Malibu and Palos Verdes, separated by a long uninterrupted stretch of sandy beaches. These expansive, world-renowned beaches are the biggest challenge to this process. For example, it is nearly 43 km from Rocky Point to Point Dume. Without accounting for habitat types or size, it is practically impossible to meet the SAT spacing guidelines without proposing an MPA in each of these two regions.

After the establishment of the reserves, it will be critical to evaluate their effectiveness for the entire region. One important component of this objective is the last goal of the MLPA (stated above), which is interpreted as a call for adaptive management. Within the reserve network, there are primarily State Marine Reserves (SMRs) where no extractive activities are allowed. There will also be State Marine Conservation Areas (SMCAs), where some types of fishing and harvesting will be allowed. The SAT evaluated extractive activities, developed a Levels of Protection (LOP) analysis, and ranked each activity from high to low. "High protection activities" were considered unlikely to affect the habitat or population structure of the SMCA, while "low protection activities" alter community structure and damage habitat. SMCAs allow the opportunity to evaluate and study the effects of certain activities in a relatively controlled setting.

To measure effectiveness and manage adaptively, MPAs need to be monitored against a specified set of metrics or goals. This type of monitoring and research dovetails with work the Santa Monica Bay Restoration Commission (SMBRC) MPA Technical Advisory Committee (MTAC) – a subcommittee to the SMBRC Technical Advisory Committee – has already begun. MTAC began studying the nearshore rocky reefs and kelp beds in Santa Monica Bay in both anticipation of the MPA process (data collection and baseline monitoring) and as part of other projects (e.g. the SMBRC's Comprehensive Monitoring Plan and SCCWRP's Bight '08). The Vantuna Research Group at Occidental College, Santa Monica Baykeeper, and Los Angeles County Sanitation Districts have been cooperatively and systematically surveying the rocky reefs of Malibu and Palos Verdes for three years. Each of these research programs has been individually working in the Bay for decades. The coordination of these three research programs will provide the information needed for the optimal management of our nearshore rocky reef resources. We anticipate these steps will enable the effective evaluation and management of our nearshore resource.

Dan Pondella is an assistant professor of Biology and the Director of the Vantuna Research Group at Occidental College. He has been studying the nearshore fish populations in the Southern California Bight since 1986.

Topanga Creek Restoration: Rodeo Berm Removal

Rosi Dagit

Abstract
Approximately 30 years ago, a trapezoidal earthen berm, 1000 feet long and 40 to 100 feet wide, was placed directly in the channel of Topanga Creek to protect private property and homes built in the floodplain. The berm was augmented several times with asphalt and waste products from various road-building projects. After the property was purchased by the California Department of Parks and Recreation, a multi-agency partnership convened to fund and implement a berm removal and creek restoration project. Berm removal resulted in 3000 linear feet of connectivity critical for migrating steelhead trout, as well as invasive species removal and establishment of native wetland and riparian communities on over 12 acres of floodplain. Snorkel surveys after restoration revealed trout ranging from five to eight inches using newly formed pools in the restored channel.

Disturbance of the floodplain in Lower Topanga Creek has a long history. Using the 1876 U.S. Coast Survey map as the basis for pre-disturbance condition, it appears that the floodplain once supported a mixed oak and sycamore riparian woodland with a channel following the low contours of the west hillslope. By the 1920s, the property had been purchased by the Los Angeles Athletic Club, who envisioned creating a deep water harbor in Topanga lagoon and associated amenities in the surrounding area. Evidence of a small rodeo ground riding ring and dirt roads are noted on a 1924 USGS geology map. Over the years, the manipulation of the floodplain with impacts on the creek channel continued. By the 1940s, aerial photos indicate that the channel had been shifted due east with a dirt road and fill evident in the west section of the floodplain.

The Rodeo Grounds Road Berm was installed without plans or permits in 1969 and rebuilt in 1980 and 1995 by tenants to protect their rental homes from flooding. It was built in several stages, realigning and replacing a lower, smaller dirt road that had been installed in the 1920s (Figure 1). According to local residents, asphalt and paving from the Lincoln Blvd. repaving project were placed on the site in the late 1960s. Additional road spoils from throughout the watershed were added to raise the berm higher following the 1980 flood (Envicom 2006).

In 2001, the property was purchased by California Department of Parks and Recreation (CDPR) to connect upper Topanga State Park with the ocean. Between 2001 and 2005, several preliminary surveys were conducted and the Lower Topanga Interim Plan was produced (California Department of Parks and Recreation 2002). The Interim

Figure 1. Topanga Creek Rodeo Berm, *Photo: RCDSMM*

Plan called for the relocation of the remaining tenants and removal of the structures within the floodplain. This phase of the floodplain restoration was completed by 2006.

The Rodeo Grounds Road Berm was trapezoidal in shape – 1,000 feet long, between 40 to 100 feet wide and between 12 to 18 feet above natural creek grade. The berm bisected the Topanga Creek floodplain in a north-south alignment in a low gradient depositional area 2,500 feet upstream from the interface with the Pacific Ocean at Topanga Beach. The total surface area from toe to toe covered approximately 80,000 square feet (1.8 acres), and the volume of fill material was estimated to be approximately 19,000 cubic yards weighing approximately 26,000 tons (GeoPentech 2005).

Preliminary soil testing in six boreholes along the berm found that a significant portion of the fill qualified as non-RCA lead contaminated California Hazardous Waste (GeoPentech 2005). A detailed Berm Removal Plan incorporating sequential removal steps, stockpiling needs, and Best Management Practices (BMPs) for controlling erosion and preventing spread of lead contamination during and following excavation was developed (Envicom 2006). Extensive biological and hydrological studies were conducted to develop a wetland delineation and Caltrans approved Traffic Control Plan (Figure 2). A Mitigated Negative Declaration was prepared and certified in 2006 and all regulatory permits were obtained by spring 2008. The final construction plans and bid documents were prepared and posted in June, with the contract awarded in late July to Miller Environmental, Inc.

Figure 2. Project Impact Area

Restoration Goals

The Rodeo Grounds Road Berm was identified as a keystone barrier impeding fish passage for endangered southern steelhead trout (CalTrout 2005). The berm had caused buildup of sediments for over 1,000 meters of creek channel and caused the creek to flow subsurface for much of the year. Topanga Creek is one of only three creeks in the Santa Monica Bay that support endangered southern steelhead trout (Dagit et al. 2005). This population is severely at risk and Topanga Creek was identified by National Oceanographic and Atmospheric Administration National Marine Fisheries Service (NOAA-NMFS) as a priority system for recovery purposes due to its good water quality, relatively natural hydrologic regime, lack of invasive aquatic species, and overall ecological quality (NOAA-NMFS 2009). Monitoring of the steelhead from 2001 to the present indicates that their abundance has increased yearly and reproduction and recruitment are taking place (Dagit et al 2009).

The primary objective of the Revegetation and Restoration Project was to restore the area previously covered by the berm and integrate required revegetation and tree mitigation plantings into the restoration area that included the surrounding 12 acre floodplain (Goode and Cox 2006). Plants were selected to match the surrounding wetland, riparian, and coastal sage communities (Table 1).

Funding

It took several years and many grant applications to assemble the estimated $3.3 million project cost. The Resource Conservation District of the Santa Monica Mountains (RCDSMM) took the lead on writing the grants, eventually securing $500,000 from the Santa Monica Bay Restoration Commission (SMBRC), which provided the foundation of matching funds needed to obtain $1,591,300 from the Wildlife Conservation Board, $450,000 from Supervisor Zev Yaroslavsky, $240,000 from the California Department of Fish and Game (CDFG) Fisheries Restoration Grant Program, $50,000 from the NOAA Community Based Restoration Program, $90,000 in-lieu wetland mitigation fees from the Mountains Recreation and Conservation Authority, and over $400,000 of in-kind contributions.

Implementation

The on-site excavation commenced on August 9, 2008 and was completed on October 9, 2008. A total of 1,334 truck loads, each carrying up to 20 tons of materials, were removed. All but the 96 loads of lead contaminated soil were recycled as either landfill soil cover, greenwaste mulch, or rock debris converted to roadbed material.

Biological, archeological, and Native American monitoring before, during, and following the project provided guidance on preserving any relevant significant resources. It is known that the Tongva people used the area in the mouth of Topanga, and it was possible that the project could reveal evidence of Native American use. Although no cultural resources were found, vigilant monitoring provided useful guidance to the construction staff.

Table 1. Species Palette for Revegetation of the Rodeo Grounds Berm Project

Scientific Name	Common Name	Upland/ CSS	Floodplain	Berm Footprint
TREES				
Alnus rhombifolia	White Alder		X	X
Heteromeles arbutifolia	Toyon	X	X	
Juglans californica	CA Walnut	X	X	
Platanus racemosa	CA Sycamore		X	X
Populus f. fremontii	Fremont Cottonwood	X	X	X
Quercus agrifolia	Coast Live Oak	X	X	
Salix exigua	Narrow-leaf Willow		X	X
Salix laevigata	Red Willow		X	X
Salix lasiolepis	Arroyo Willow		X	X
Sambucus mexicana	Mexican Elderberry	X	X	
Umbellularia californica	California Bay	X	X	
SHRUBS				
Baccharis salicifolia	Mulefat	X	X	X
Eriogonum cinereum	Ashyleaf Buckwheat	X		
Eriogonum fasciculatum foliolosum	CA Buckwheat	X	X	
Malosma laurina	Laurel Sumac	X	X	
Rhus integrifolia	Lemonadeberry	X	X	
Salvia mellifera	Black Sage	X	X	
HERBACEOUS PERENNIALS AND SUB-SHRUBS				
Encelia californica	CA Bush Sunflower	X	X	
Eriophyllum c. confertiflorum	Golden Yarrow	X	X	
Lotus scoparius	Deer Weed	X	X	
Lupinus succulentus	Arroyo Lupine	X	X	
Mimulus aurantiacus	Orange Bush Monkey Flower	X	X	
Oenothera elata hirsutissima	Evening Primrose	X	X	
GRASSES				
Elymus g. glaucus	Blue Wild Rye			X
Nassella pulchra	Purple Needlegrass	X	X	

Unfortunately, the berm was built around several large Fremont cottonwood (*Populus fremontii* ssp. *fremontii*) and western sycamore (*Platanus racemosa*) trees. When the fill material was removed, the trunks that were buried up to 20 feet in the ground were too rotten to support the trees and they were removed. The trunks were cut into 20 foot sections and strategically placed along the restored banks to provide erosion control. Cuttings were taken from the cottonwood and grown out in the California Department of Parks and Recreation Angeles District nursery for later outplanting.

A critical component of the restoration was removal of the existing exotic and invasive species, and re-establishment of native aquatic, riparian woodland, and coastal sage scrub communities. Immediately following excavation, the 40,000 square foot staging, stockpiling, and haul route areas, as well as the newly configured stream bank were hydroseeded with a native seed mix (Table 2). All seeds came from local sources approved by CDPR. Between December 2008 and July 2009, volunteers have contributed over 1,000 hours of time to weed and plant over 400 native plants (Table 3).

Hand Watering New Seedling,
Photo: RCDSMM

Table 2. Seed Species List

Species	Number lbs/Acre
Ambrosia psilostachya	2
Eriogonum cinereum	6
Leymus codensatus	3
Lotus scoparius	6
Lupinus bicolor	4
Lupinus succulentus	6
Plantago erecta	4
Trifolium gracilentum	2
Trifolium wildenovii	4
Verbena lasiostachys	2
	39 total

Table 3. List of Plants Installed on December 13, 2008

Species	Common Name	Size container	Number Planted
Platanus racemosa	CA Sycamore	2 gallon 1 gallon	2 3
Populus f. fremontii	Fremont Cottonwood	15 gallon D cell	1 2
Quercus agrifolia	Coast Live Oak	5 gallon 2 gallon Acorns	3 1 40
Juglans californica	CA Walnut	2 gallon	1
Umbellularia californica	CA Bay	2 gallon	4
Salix exigua	Narrow Leaf Willow	1 gallon stakes	10 25
Salix lasiolepis	Arroyo Willow	1 gallon	10
Baccharis salicifolia	Mulefat	1 gallon stakes	20 25
Elymus g. glaucus	Giant Wild Rye	D cell	40
Rosa californica	Wild Rose	1 gallon	4
Rubis ursinus	CA Blackberry	D cell	25
Artemesia vulgaris	Mugwort	D cell 50	50

Results

The restoration of the floodplain and riparian corridor in the Rodeo Grounds Road Berm area of Topanga State Park has allowed natural re-alignment of the creek channel in response to storm events, re-adjustment of the channel bed as accumulated sediments are naturally entrained, and natural recruitment of riparian species. Volunteer seedlings of mulefat (*Baccharis salicifolia*), giant rye (*Leymus condensatus*) and sycamores are abundant. The channel flow was fully connected to the ocean from the first big rainstorm in December 2008 until late March 2009. Snorkel surveys revealed that trout ranging from five to eight inches were using newly formed pools.

Eventually, restoration will result in a more natural creek channel. Over 12 acres of wetland and riparian floodplain were reconnected hydrologically and ecologically. Restored above surface creek flow will provide summer rearing habitat as well as improve over-winter habitat and critical passage links for endangered southern steelhead trout between the main stem of Topanga Creek and the ocean.

Additionally, it is anticipated that restoration will allow natural storm flushing of accumulated sediments from upstream of the project area, restoring over 3,000 linear feet of creek connectivity that is critical for migrating adult and juvenile steelhead trout. The removal of these sediments should also result in a more natural diversity of geomorphologic habitat units, which should provide additional spawning and rearing habitat for fishes.

Hydroseeded Streambank. *Photo: RCDSMM*

Lessons Learned

It always takes longer than you think it will to accomplish a restoration project! We started the effort in 2003 and it took until 2008 to implement.

It always costs more than you think it will! We were faced with yearly inflation and cost changes that averaged about 20% per year. Since it took almost three years from the time we secured the first grant until the project was implemented, we were really glad that we had estimated the overall project cost based on a worse-case scenario. It also helped to have obtained three different bids when we were developing the project costs to help guide us.

The devil is in the details! It is really critical to try to anticipate problems and incorporate language into the CEQA documents, permits, and bid document that allows for flexible response to unforeseen problems. It is also critical to define the project limits with sufficient buffer, so that if an unexpected diesel oil spill contaminates the boundary, the contractor will work with you to remove the problem!

The biggest lesson learned was persistence. These projects are the cumulative effort of numerous bureaucracies, regulatory agencies, and funders, each of which has their own agenda and timeline. It was only by continuous effort at moving the project forward step by step that we were able to achieve our goal.

Acknowledgements

Thanks to the project team: CDPR Angeles District staff, CDPR Southern Service Center staff, RCD of the Santa Monica Mountains staff and Topanga Creek Stream Team volunteers, Mary Larson, CDFG, Adrian Morales, Gabrielino/Tongva monitor; and our contractors Miller Environmental Inc., Huitt-Zolars, Inc., Envicom, Inc., GeoPentech Inc., Katz, Okitsu and Associates. We also thank the members of the Technical Advisory Committee and Topanga Community who participated in the evolution of this project. Finally, the revegetation has been largely manned by the Mountains Restoration Trust, RCD of the Santa Monica Mountains, TreePeople, Temescal Canyon Association and the Sierra Club Trail Crew.

Rosi Dagit has been leading research and restoration projects in the Santa Monica Mountains since 1987. She is currently the Senior Conservation Biologist for the Resource Conservation District of the Santa Monica Mountains.

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Texas Crossing Removal in Malibu Creek

Mark Abramson

Abstract
Many streams in our coastal areas are impacted by road structures, including bridges and instream crossings. Environmental groups and state agencies in the Santa Monica Mountains are reconsidering the need for and design of such crossings. This article documents the low-cost techniques used to remove a large Texas crossing in Malibu Creek State Park. The Texas crossing in Malibu Creek was in disrepair and presented a serious safety issue. Large amounts of sediment had accumulated upstream of the structure, and heavy scouring had created a large pool immediately downstream. The removal of the crossing has improved stream hydrologic features and habitat. Restoration efforts will allow unimpeded movement of the federally endangered steelhead trout within a one-mile stretch of the creek.

Malibu and Las Virgenes Creeks, both within the Malibu Creek State Park, are impacted by a variety of road structures within the stream channels, including bridges, concrete (Texas) crossings, and unpaved crossings. Heal the Bay and the California Department of Parks and Recreation (State Parks) have been working together to remove or redesign many of these structures to improve stream habitat within the Park. The most recent effort by these two organizations was the removal of a Texas crossing in Malibu Creek in 2006 and 2007.

The Texas crossing in Malibu Creek, owned and operated by State Parks, was an elevated creek crossing in disrepair. Undersized culverts had led to massive scouring by streamflows and the collapse of portions of the 220 foot long stretch of concrete forming the base of the crossing. The crossing posed a safety risk for users and caused severe degradation of upstream and downstream habitat. Elevated road crossings such as this often end up functioning similarly to dams, in that they cause water slowing and sediment build-up immediately upstream of the structure. As the upstream bed becomes elevated, water flows over the top of the crossing and scours out the stream bed at the downstream end of the crossing. This scouring eventually creates a deep pool on the downstream end, which forces upstream migrating fish to jump onto the concrete road bed and then swim through 30 feet of shallow water, across the road, to migrate upstream. The jump height for fish was five feet at this Texas crossing (Figure 1). Downstream erosion on both banks of the stream was also severe.

The Texas crossing was 220 feet long, 30 feet wide, 10 to 12 inches thick, and was constructed of steel reinforced concrete. There were five 24 inch corrugated metal pipe culverts running through the center of the structure that no longer transported water due to excessive sedimentation upstream of the crossing.

Figure 1. Dilapidated Texas Crossing Prior to Removal, *Photo: Heal the Bay*

Removal of Texas Crossing

State Parks worked closely with Heal the Bay's Stream Team to remove the Texas crossing. State Parks was instrumental to the project, helping to prepare environmental impact assessments, acquiring all necessary permits, and securing labor from State Parks. Direct support provided by State Parks included four staff members for 20 days to assist with the barrier removal and a large backhoe and operator for two days to assist with removing large debris from the stream channel. State Parks also insured that resources were protected through frequent visits to the site by a staff Resource Ecologist and involvement of State Parks personnel with experience working in sensitive habitat areas.

The Texas crossing barrier removal project took 39 work days between October 4, 2006 and November 28, 2006. Approximately 1/3 of the structure was located in the water, and was removed by hand, using a gas powered jackhammer/drill, and feathers and wedges (Figure 2). This manual technique enabled the removal of concrete that was in contact with the water while minimizing environmental damage. The feather and wedge removal process can be seen in the "Adiós Texas Crossing" time-lapsed video available on Heal the Bay's website at http://www.healthebay.org/videos/default.asp.

Figure 2. Drilling Holes with the Gas Powered Jackhammer and Placing Feathers and Wedges, *Photo: Heal the Bay*

The remaining 2/3 of the crossing located outside of the stream channel was removed using heavy equipment, specifically a bobcat with backhoe and breaker bar attachments. Thirty-seven 10-yard concrete dumpsters were removed and recycled from the project site, totaling 304.5 tons of concrete. Additionally, two 32-yard dumpsters with approximately 50 tons of steel in the form of rebar and culverts were removed from the site and recycled. The overall cost of the Texas crossing removal; including labor, equipment rentals and supplies, and concrete and steel removal and recycling; was approximately $38,000. This funding was provided by State Parks, the Santa Monica Bay Restoration Commission, and the State Coastal Conservancy.

After removing the crossing, Heal the Bay and State Parks replanted the site with native vegetation. Approximately 1,450 plants were installed to mitigate the disturbance to the stream banks adjacent to the Texas crossing removal site. Plant species included purple needlegrass (*Nassella pulchra*) in areas with bare soil above the riparian zone, California blackberry (*Rubus ursinus*) in the higher riparian zone, and arroyo willow (*Salix lasiolepis*) stakes near the waters edge in the lower riparian zone. Native riparian vegetation is also naturally recruiting at the site.

Results

The site is performing as expected. The large scour pool below the crossing is filling in and a riffle has formed in the former crossing location (Figure 3). Additionally, the sediment deposit behind the old crossing has been dramatically reduced, despite the fact that no large storm events (greater than four inches in 24 hours) have occurred since the removal (Figure 4). No head cutting or upstream channel erosion has occurred, as is typical with these projects and the stream bed is relatively stable. We expect the site to continue to improve over time while we wait for some more significant rain events.

Figure 3. Texas Crossing Removal Site after Rain Storm, January 29, 2007, *Photo: Heal the Bay*

The Texas crossing will not be replaced and has opened approximately 1 mile of high quality habitat for spawning and rearing for the federally endangered southern steelhead trout upstream of the Rindge Dam. Since the crossing was removed, cobble and gravel have replaced finer sediments and algae on the stream bed, providing improved habitat for benthic invertebrate species and fish at this location.

Figure 4. Texas Crossing Removal Site after Rain Storm, January 9, 2008, *Photo: Heal the Bay*

Mark Abramson is the Director of Watershed Programs for the Santa Monica Baykeeper. Working in stream and wetland restoration for 15 years, he created the highly successful Malibu Creek watershed Stream Team program for Heal the Bay during his 10 years of employment before joining the Santa Monica Baykeeper 3 years ago. Mark is also managing the Malibu Lagoon restoration project for the State Coastal Conservancy and State Parks and is engaged in stream restoration on Stone Creek at the UCLA campus.

Environmental Notes & Abstracts

Ballona Wetlands, Photo: Karina Johnston

The Environmental Notes and Abstracts section contains summaries of research and policy submitted to *Urban Coast*, as well as abstracts from current literature. In this section *Urban Coast* brings together innovative environmental research, technical studies, BMP or LID implementation and policy developments to keep our readers abreast of the latest developments in urban coastal research and policy. We welcome suggestions for abstracts to include in this sections as well as submittals. By submitting to *Urban Coast* you will be reaching our stakeholders and decision-makers and keeping them apprised of the latest thinking about environmental issues and solutions and helping practitioners to share knowledge of how the vast array of techniques and tools available are being applied in urban coastal regions. Please direct correspondence to sbergquist@santamonicabay.org.

Policy

Groundwater Replenishment and Watershed Restoration. Lillian Kawasaki. 2009. Water Replenishment District of Southern California.

Project Summary

The Water Replenishment District of Southern California (WRD) was created 50 years ago to restore the groundwater basins underlying the lower reaches of the Los Angeles and San Gabriel River Watersheds. The Central and West Coast Basin aquifers at the time were threatened by over-pumping on the one hand and the intrusion of seawater on the other.

Through an aggressive program of groundwater replenishment, adjudicated limitations on the amount of groundwater pumping and the construction by the Los Angeles County Flood Control District of the largest seawater barrier system in the world, the groundwater basin components of the watersheds are in better condition today than they have been since the 1930s.

The WRD experience demonstrates that watershed stewardship and groundwater replenishment are inextricably linked. Steadily over time the reliance on imported water has been replaced with local sources of supply. WRD's Water Independence Now (WIN) objective to be completely free of imported water for replenishment by 2015 is an example of the growing need to move to regional self reliance for water resources.

Local supply in the form of conservation, recycled water, stormwater capture and Low Impact Development (LID) has key advantages over imported water. It is a far more reliable and secure water source that helps reduce the export demand from the Bay Delta and Colorado River. The cost of local water supplies has proven in most cases to be far more cost effective than imported water. The energy to produce an acre-foot of advanced treated recycled water is half as much as imported water. Proven technology is available today to jointly manage surface and groundwater (conjunctive use) to optimize available groundwater storage. Within WRD's area alone, there are more than 450,000 acre-feet of available storage capacity. In recent years, 56,000 acre feet of stormwater has been captured annually for replenishment, but an estimated 260,000 acre-feet of storm flow still is lost to the ocean. Proposed groundwater storage amendments now pending before the courts demonstrate that it is possible to create a predictable framework for groundwater producers that foster groundwater storage. Coupled with a comprehensive groundwater monitoring system, management of scarce water resources can be optimized for both supply and quality.

Local groundwater supply is better for watersheds, assures a more reliable source at less cost with significantly reduced energy and carbon footprints, while reducing the demand for dwindling imported water.

Lillian Kawasaki is Division 3 Director of the Water Replenishment District of Southern California (WRD), which manages the groundwater for 4 million people in 43 cities in South LA County. Lillian also serves on the Executive Committee of the Carpe Diem: Western Water and Climate Change Project.

Water Quality Improvement Policies: Lessons Learned from the Implementation of Proposition O in Los Angeles, CA. Park, M-H, M. Stenstrom, and S. Pincetl. 2009. Environmental Management. 43:514-522.

Abstract
This article evaluates the implementation of Proposition O, a stormwater cleanup measure, in Los Angeles, California. The measure was intended to create new funding to help the city comply with the Total Maximum Daily Load requirements under the federal Clean Water Act. Funding water quality objectives through a bond measure was necessary because the city had insufficient revenues to deploy new projects in its budget. The bond initiative required a supermajority vote (two-thirds of the voters), hence the public had to be convinced that such funding both was necessary and would be effective. The bond act language included project solicitation from the public, as well as multiple benefit objectives. Accordingly, nonprofit organizations mobilized to present projects that included creating new parks, using schoolyards for flood control and groundwater recharge, and replacing parking lots with permeable surfaces, among others. Yet few, if any, of these projects were retained for funding, as the city itself also had a list of priorities and higher technical expertise in justifying them as delivering water quality improvements. Our case study of the implementation of Proposition O points to the potentially different priorities for the renovation of urban infrastructure that are held by nonprofit organizations and city agencies and the importance of structuring public processes clearly so that there are no misimpressions about funding and implementation responsibilities that can lead to disillusionment with government, especially under conditions of fiscal constraints.

Research Review of Collaborative Ecosystem-Based Management in the California Current Large Marine Ecosystem. Coleman, Kary. 2009. Coastal Management. 36(5).

Abstract
The welfare of the marine environment is threatened worldwide. In order to maintain ecosystem services management must shift from single sector to ecosystem approaches. To support this transition in marine management, this article reviews collaborative ecosystem-based management in the California Current Large Marine Ecosystem (CCLME), through an overview and comparison of three collaborations on the United States West Coast of California, Oregon, and Washington. The achievements of these collaborations are demonstrated. Networking and extending collaboration throughout the entire region is shown to be essential for environmental conservation and sustainable development in the CCLME.

Investigating the Potential Role of Visualization Techniques in Participatory Coastal Management. Jude, Simon. 2008. Coastal Management. 36(4).

Abstract
The current shift toward "soft" forms of coastal defense as means of adapting to future sea level rise requires careful communication and consultation if they are to gain widespread public acceptance. For this to be achieved then coastal managers must improve the manner in which they communicate with stakeholders and members of the public. One possible solution may be through the application of landscape visualization techniques to illustrate how new policies or management interventions may shape the coast. This article investigates the potential role of such methods in participatory coastal management. Using interviews with coastal managers, the potential application of visualization techniques in coastal management processes are explored in detail. The findings suggest that while a number of possible roles for visualization techniques exist, there is an urgent need for practical testing and evaluation of the technology in participatory decision-making processes.

Catchment-Wide Assessment of the Cost-Effectiveness of Stormwater Remediation Measures in Urban Areas. Davis, B.S. and G.F. Birch. 2009. Environmental Science and Policy. 12(2):84-91.

Abstract
The cost effectiveness of catchment-wide funding for the environmental remediation of urban waterways on the scale of a major metropolitan catchment is examined considering the typical land-use and pollutant-export characteristics of urban catchments. The evaluation is performed by comparing the effectiveness of the major stormwater treatment modes for the pollutants of concern with the proportion of pollutant export to which the measure applies. The heavy metals copper, lead, and zinc in the aqueous phase or bound to fine particulates are identified as representative of the pollutants of concern in drainage from urban catchments. The analysis suggests that these priority pollutants are predominantly (79–87%) derived from runoff from residential property and roads as disseminated urban surfaces. Analysis of a specific case of catchment-wide funding of stormwater remediation in the Sydney Harbour catchment, Australia reveals that the funding allocation cannot be expected to have achieved reductions in the loads of priority pollutants due to the types of treatment measures implemented and the sources addressed. The apportionment of funding in better accordance with the maximum potential effectiveness of stormwater treatment modes and the pollutant-export characteristics of urban catchments could thus be expected to achieve a more cost-effective result from such funding initiatives.

Reflecting Ecological Criteria in Laws Supporting the Baja to Bering Sea Marine Protected Areas Network Case Study. Vásárhelyia, Charlotte and Vernon G. Thomas. 2008. Environmental Science and Policy. 11(5):394-407.

Abstract
Canadian and US marine conservation law, and other related law, was analyzed to determine if it reflected ecological criteria needed to implement connectivity among marine protected areas of the northeast Pacific in the proposed trilateral Baja to Bering Sea (B2B) initiative. The analysis included both nations' federal laws and those of California, Oregon, Washington, Alaska, and British Columbia. While legal provisions exist already to implement marine protected areas for varying reasons, there is little capacity in most laws to create connectivity among them for conservation purposes. Only California's legislation contained explicit provisions for all the criteria. Other federal, state, and provincial laws, while containing provisions for species at risk and vulnerable habitats, generally lacked explicit provisions for the vital criteria, size of area, migratory patterns, and recruitment patterns. Implementation, future management, and protection of the proposed B2B marine network would be facilitated by amendment of both Canadian and US laws. Some of the ecological criteria are already implied implicitly or vaguely, but they need to be made explicit in the amended law. The legislative model of California could serve as a template for amending the laws of other jurisdictions in the B2B venture.

More Than Information: What Coastal Managers Need to Plan for Climate Change. Tribbia, J. and S.C. Moser. 2008. Environmental Science and Policy. 11(4):315-328.

Abstract
Climate change and sea-level rise (SLR) increasingly threaten the world's coastlines, managers at local, regional, state, and federal levels will need to plan and implement adaptation measures to cope with these impacts in order to continue to protect the economic, social, and environmental security of the state and of local communities.

In this paper, we explore the information needs of California coastal managers as they begin confronting the growing risks from climate change. Through this case study we examine the challenges managers face presently, what information they use to perform their responsibilities, what additional information and other knowledge resources they may need to begin planning for climate change. We place our study into the broader context of the study of how science can best support policy-makers and resource managers as they begin to plan and prepare for adaptation to climate change.

Based on extensive interview and survey research in the state, we find that managers prefer certain types of information and information sources and would benefit from various learning opportunities (in addition to that information) to make better use of available global change information. Coastal managers are concerned about climate change and willing to address it in their work, but require financial and technical assistance from other agencies at the state and federal level to do so. The study illustrates the strong need for boundary organizations to serve various intermediary functions between science and practice, especially in the context of adaptation to global climate change impacts.

Conceptual Issues in Designing a Policy to Phase Out Metal-Based Antifouling Paints on Recreational Boats in San Diego Bay . Carsona, Richard T., Maria Damonb, Leigh T. Johnson and Jamie A. Gonzalezc 2009. Journal of Environmental Management. 90(8):2460-2468.

Abstract
In marine areas throughout the world where recreational boats are densely located, concentrations of copper in the water are being found to be in excess of government standards, due to the hull coatings used on these boats. Copper-based hull coatings are intended to be antifouling in that they retard the growth of algae, barnacles and tubeworms; but alternatives exist that can eliminate the harm that copper contamination does to marine organisms. A variety of policy options are available to mandate or provide economic incentives to switch to these less harmful alternatives. This paper puts forth a conceptual framework for thinking about how to design and evaluate alternative policies to transition to nontoxic boat hulls, drawing from the authors' experience designing a policy for use in San Diego Bay. Many of the issues raised are broadly applicable to environmental problems where the solution involves a large-scale replacement of durable consumer goods.

A Dynamic Analysis of the Wetland Mitigation Process and its Effects on No Net Loss Policy. Todd Bendor. 2009. Landscape and Urban Planning. 89(1-2):17-27.

Abstract
Since 1980, U.S. regulations have required compensatory mitigation for wetland losses, often through wetland creation or restoration. In 1987, the National Wetlands Policy Forum recommended that federal policy should aim to achieve overall "no net loss" of the country's remaining wetland acreage and function. Controversy has surrounded recent reports that laud the achievement of no net loss while citing the virtual elimination of certain types of wetland losses in certain areas. However, little discussion in this debate has centered on the dynamic nature of wetland loss and restoration. Evidence has shown that temporal lags in wetland restoration can temporarily reduce wetland function and impose high costs on society. This paper analyzes wetland loss and compensation as dynamic processes that include temporal lags prevalent in various mitigation techniques. Here, a system dynamics model of the mitigation process is used to explore wetland alteration and mitigation data collected between 1993 and 2004 for the Chicago, IL region. This model includes vital factors associated with mitigation policy, including mitigation failure rates, varying mitigation ratios, and the temporal lags and head starts inherent in mitigation banking, permittee responsible mitigation, and in-lieu fee mitigation programs. Results demonstrate that

delays in initiating and completing restoration activities mean that frequent, temporary wetland losses can easily contribute to a consistent and considerable net functional loss over time. I conclude by discussing methods for minimizing net temporary losses and reducing wetland restoration lag costs.

Pollution

Water Resources Action Plan (WRAP). 2009. Port of Los Angeles and Port of Long Beach.

Project Summary
The Ports of Los Angeles and Long Beach, the two largest container ports in North America, face water quality issues that include not only stormwater runoff from port lands, but also the on-water activities of industrial harbors, legacy sediment contamination, and inputs from intensely developed urban watershed areas upstream. Recognizing the advantages of addressing these issues on a harbor-wide basis, the two ports worked cooperatively to develop a joint plan for managing water and sediment quality in the entire port complex. This was undertaken with input from U.S. EPA, the Regional Water Quality Control Board, and a public stakeholder process. The WRAP's driving forces are: 1) the need to achieve the ports' mission of protecting and improving water and sediment quality, and 2) the imminent promulgation of Total Maximum Daily Loads (TMDLs) for harbor waters. Much of the harbor area is designated as impaired under Clean Water Act Section 303(d); because the listings are driven by sediment contamination, rather than elevated pollutant concentrations in the water, the WRAP addresses sediment issues as well as water quality. The WRAP's purpose is to put into place the programs and mechanisms through which the ports will achieve the goals and targets that will be established by upcoming TMDLs and to comply with the stormwater permits.

The WRAP identifies the key issues in the port complex; identifies control measures to address those issues; and assembles existing, as well as proposed, water and sediment programs into those measures. Eight control measures address the various types of activities and sources on port-owned land, including construction, operations, litter control, and new development. Three measures address on-water activities, including structures and vessels. Two measures address sediment quality issues, including guidance for routine dredging and management of sediment hotspots. Finally, one control measure commits the ports to working with watershed stakeholders in order to reduce pollutant inputs from sources outside port jurisdiction. The WRAP describes the implementation tools available to the ports (lease and tariff provisions, incentives, and port-sponsored initiatives) and establishes a schedule for implementing the control measures. A key aspect of the WRAP is its dynamic nature: the WRAP will be revisited periodically in order to add detail and to add or modify measures where appropriate. Accordingly, as TMDLs and the corresponding permits are promulgated, the WRAP will respond rapidly by incorporating numerical goals for pollution reduction without a massive program development effort.

Bio-Remediation Treatment Study to Control the Algae and Odor Problems at the Oxford Retention Basin in Marina Del Rey, California. 2009. The Los County Flood Control District.

Project Summary
The Los Angeles County Flood Control District has initiated a bio-remediation treatment study to control the algae and odor problems at the Oxford Retention Basin in Marina Del Rey. Bio-remediation takes advantage of naturally occurring microbes which act symbiotically to out-compete the algae for nutrients in the basin. The project is a one year pilot study which began in the Summer of 2009. The first phase of the study was completed on August 24, 2009. The work consisted of the analysis of three pre-treatment water quality samples for 33 different constituents and five water treatments to introduce the microbes into the basin. Initial observation of algae quantity, color, and thickness indicate that the treatments are beginning to produce results; however, more time is needed to allow the microbe colonies to build and slow the rate of algae growth.

In addition, to controlling algae and odor the Los Angeles County Flood Control District is conducting a Sediment and Water Quality Analysis for Oxford Retention Basin and is proposing to remove excess sediment to restore capacity, and ultimately constructing a wetland feature that will improve the overall water quality within the basin."

Pilot- and Bench-Scale Testing of Faecal Indicator Bacteria Survival in Marine Beach Sand Near Point Sources. Mika, K.B., G. Imamura, C. Chang, V. Conway, G. Fernandez, J.F. Griffith, R.A. Kampalath, C.M. Lee, C-C. Lin, R. Moreno, S. Thompson, R.L. Whitman and J.A. Jay. 2009. Journal of Apllied Microbiology. 107:72-84.

Abstract
Aim: Factors affecting faecal indicator bacteria (FIB) and pathogen survival/persistence in sand remain largely unstudied. This work elucidates how biological and physical factors affect die-off in beach sand following sewage spills.

Methods and Results: Solar disinfection with mechanical mixing was pilot-tested as a disinfection procedure after a large sewage spill in Los Angeles. Effects of solar exposure, mechanical mixing, predation and/or competition, season, and moisture were tested at bench scale. First-order decay constants for *Escherichia coli* ranged between -0.23 and -1.02 per day, and for *enterococci* between -0.5 and -1.0 per day. Desiccation was a dominant factor for E. coli but not enterococci inactivation. Effects of season were investigated through a comparison of experimental results from winter, spring, and fall.

Conclusions: Moisture was the dominant factor controlling E. coli inactivation kinetics. Initial microbial community and sand

temperature were also important factors. Mechanical mixing, common in beach grooming, did not consistently reduce bacterial levels.

Significance and Impact of the Study: Inactivation rates are mainly dependent on moisture and high sand temperature. Chlorination was an effective disinfection treatment in sand microcosms inoculated with raw influent.

Natural Catchments as Sources of Background Levels of Stormwater Metals, Nutrients, and Solids. Yoon, V.K., E.D. Stein. 2008. Journal of Environmental Engineering. 134:961-973.

Abstract
A key challenge in managing water quality and meeting compliance standards is accounting for both the anthropogenic and natural contributions of a range of water quality constituents. This study quantified levels of solids, metals, and nutrients in storm-water runoff from 18 sites across 11 watersheds representing a range of natural conditions in southern California. Constituent concentration and flux were measured over the course of a variety of storms in order to investigate temporal and spatial patterns in constituent levels, and to identify the most important environmental attributes affecting background water quality. Metals and nutrient concentrations from the natural catchments were typically one to two orders of magnitude lower than those from developed catchments. In contrast, total suspended solids levels were comparable to those found in urban storm water from Los Angeles. Geologic setting had the greatest effect on constituent levels at natural sites. Unlike urban systems, natural catchments do no appear to exhibit a first flush phenomenon, with a substantial portion of the constituent load occurring later in the storm. Ratios of particulate to dissolved metals concentrations changed considerably over the course of storms suggesting that bioavailability of constituents from natural areas may vary over storm duration.

Watershed and Land Use-Based Sources of Trace Metals in Urban Stormwater. Tiefenthaler, L.L., E.D. Stein and K.C. Schiff. 2008. Environmental Toxicology and Chemistry. 27:277-287.

Abstract
Trace metal contributions in urban storm water are of concern to environmental managers because of their potential impacts on ambient receiving waters. The mechanisms and processes that influence temporal and spatial patterns of trace metal loading in urban storm water, however, are not well understood. The goals of the present study were to quantify trace metal event mean concentration (EMC), flux, and mass loading associated with storm water runoff from representative land uses; to compare EMC, flux, and mass loading associated with storm water runoff from urban (developed) and nonurban (undeveloped) watersheds; and to investigate within-storm and within-season factors that affect trace metal concentration and flux. To achieve these goals, trace metal concentrations were measured in 315 samples over 11 storm events in five southern California, USA, watersheds representing eight different land use types during the 2000 through 2005 storm seasons. In addition, 377 runoff samples were collected from 12 mass emission sites (end of watershed) during 15 different storm events. Mean flux at land use sites ranged from 24 to 1,238, 0.1 to 1,272, and 6 to 33,189 g/km2 for total copper, total lead, and total zinc, respectively. Storm water runoff from industrial land use sites contained higher EMCs and generated greater flux of trace metals than other land use types. For all storms sampled, the highest metal concentrations occurred during the early phases of storm water runoff, with peak concentrations usually preceding peak flow. Early season storms produced significantly higher metal flux compared with late season storms at both mass emission and land use sites.

Evaluating the Potential Efficacy of Mercury Total Maximum Daily Loads on Aqueous Methylmercury Levels in Coastal Watersheds. Rothenberg, S.E., R. Ambrose and J.A. Jay. 2008. Environmental Science and Technology. 42(15):5400-5406.

Abstract
Of the 780 U.S. EPA approved mercury total maximum daily loads (TMDLs), most specify a reduction in total mercury (HgT) loads to reduce methylmercury levels in fish tissue, assuming a 1:1 correspondence. However, mercury methylation is more complex, and therefore, proposed load reductions may not be adequate. Using multiple regression with microlevel and macrolevel variables, the potential efficacy of mercury TMDLs on decreasing aqueous methylmercury levels was investigated in four coastal watersheds: Mugu Lagoon (CA), San Francisco Bay Estuary, Long Island Sound, and south Florida. HgT and methylmercury levels were positively correlated in all watersheds except in Long Island Sound, where spatial differences explained over 40% of the variability in methylmercury levels. A mercury TMDL would be least effective in Long Island Sound due to spatial heterogeneity but most effective in south Florida, where the ratio between aqueous HgT and methylmercury levels was close to 1 and the 95% confidence interval was narrow, indicating a probable reduction in aqueous methylmercury levels if HgT loads were reduced.

Nutrient Transport Through a Vegetative Filter Strip with Subsurface Drainage. Bhattarai, Rabin, Prasanta Kumar Kalita and Mita Kanu Patel. 2009. Journal of Environmental Management. 90(5):1868-1876.

Abstract
The transport of nutrients and soil sediments in runoff has been recognized as a noteworthy environmental issue. Vegetative Filter Strips (VFS) have been used as one of the best management practices (BMPs) for retaining nutrients and sediments from surface runoff, thus preventing the pollutants from reaching receiving waters. However, the effectiveness of a VFS when combined with a subsurface drainage system has not been investigated previously. This study was undertaken to monitor the retention and transport of nutrients within a VFS

that had a subsurface drainage system installed at a depth of 1.2 m below the soil surface. Nutrient concentrations of NO3-N (Nitrate Nitrogen), PO4– (Orthophosphorus), and TP (Total Phosphorus) were measured in surface water samples (entering and leaving the VFS), and subsurface outflow. Soil samples were collected and analyzed for plant available Phosphorus (Bray P1) and NO3-N concentrations. Results showed that PO4–, NO3-N, and TP concentrations decreased in surface flow through the VFS. Many surface outflow water samples from the VFS showed concentration reductions of as much as 75% for PO4– and 70% for TP. For subsurface outflow water samples through the drainage system, concentrations of PO4– and TP decreased but NO3-N concentrations increased in comparison to concentrations in surface inflow samples. Soil samples that were collected from various depths in the VFS showed a minimal buildup of nutrients in the top soil profile but indicated a gradual buildup of nutrients at the depth of the subsurface drain. Results demonstrate that although a VFS can be very effective in reducing runoff and nutrients from surface flow, the presence of a subsurface drain underneath the VFS may not be environmentally beneficial. Such a combination may increase NO3-N transport from the VFS, thus invalidating the purpose of the BMP.

Bacteria Load Estimator Spreadsheet Tool for Modeling Spatial Escherichia coli Loads to an Urban Bayou. Petersen, Christina M., Hanadi S. Rifai and Ronald Stein. 2009. Journal of Environmental Engineering. 135:203.

Abstract
The model developed in this paper, the bacteria loading estimator spreadsheet tool (BLEST), was designed as an easy to use indicator bacteria model that can overcome the shortcomings of many of the simpler total maximum daily load (TMDL) modeling approaches by integrating spatial variation into load estimates. BLEST was applied to the Buffalo Bayou watershed in Houston, Texas and incorporated loading from point and nonpoint sources, such as wastewater treatment plants, sanitary sewer overflows, septic systems, storm sewer leaks, runoff, bed sediment resuspension, and direct deposition. The dry weather Escherichia coli load in Buffalo Bayou was estimated using BLEST to be 244 billion MPN/day and would require an overall 48% reduction to meet the contact recreation standard, while wet weather loads would need to be reduced by 99.7%. Dry weather loads were primarily caused by animal direct deposition, septic systems and discharges from storm sewers under dry weather conditions, while wet weather loads were mostly attributable to runoff and resuspension from sediment. Unlike most simple TMDL load allocation strategies, BLEST can be used to evaluate spatially variable load reduction strategies. For example, septic system load reductions implemented in less than 10% of the subwatersheds resulted in a decrease in bayou loading of more than 20%.

Predictive Modeling of Storm-Water Runoff Quantity and Quality for a Large Urban Watershed. Ha, Simon J. and Michael K. Stenstrom. 2008. Journal of Environmental Engineering. 134:703.

Abstract
A predictive model for storm-water runoff was implemented on a GIS platform based on the unit area loading method and Browne's empirical relation for soil characteristics for the Upper Ballona Creek Watershed in Los Angeles. The heterogeneity of the watershed was quantified by dividing it into many small subareas and applying lumped parameters for each. Characterization of total pollutant load by land-use types to total loads was achieved through zeroth-order regularization and limited memory Broyden–Fletcher–Goldfarb–Shanno bound constrained optimization techniques. Relative form was used in the objective function to compensate for strong contributions of high magnitude variables. Model predictions showed reasonable agreement with pollutant loadings, using Zn as an example, measured at the mass emission site at watershed mouth. The predicted runoff volumes using the developed quantity model were in good agreement with the data and had R2 of 0.86. The RMS error of the quality model was 9 kg, which is low compared to the mean discharge of 77 kg/event.

Methods Applied in Studies of Benthic Marine Debris. Spengler, Angela and Monica F. Costa. 2008. Marine Pollution Bulletin. 56(2):226-230.

Abstract
The ocean floor is one of the main accumulation sites of marine debris. The study of this kind of debris still lags behind that of shorelines. It is necessary to identify the methods used to evaluate this debris and how the results are presented and interpreted. From the available literature on benthic marine debris (26 studies), six sampling methods were registered: bottom trawl net, sonar, submersible, snorkeling, scuba diving and manta tow. The most frequent method used was bottom trawl net, followed by the three methods of diving. The majority of the debris was classified according to their former use and the results usually expressed as items per unity of area. To facilitate comparisons of the contamination levels among sites and regions some standardization requirements are suggested.

Discriminating Sources of PCB Contamination in Fish on the Coastal Shelf Off San Diego, California (USA). Parnella, P. Ed, Ami K. Groceb,, Timothy D. Stebbins and Paul K. Dayton. 2008. Marine Pollution Bulletin. 56(12):1992-2002.

Abstract
Management of coastal ecosystems necessitates the evaluation of pollutant loading based on adequate source discrimination. Monitoring of sediments and fish on the shelf off San Diego has shown that some areas on the shelf are contaminated with polychlorinated biphenyls (PCBs). Here, we present an analysis of PCB contamination in fish on the shelf off San Diego designed to discriminate possible sources. The analysis was

complicated by the variability of species available for analysis across the shelf, variable affinities of PCBs among species, and non-detects in the data. We utilized survival regression analysis to account for these complications. We also examined spatial patterns of PCBs in bay and offshore sediments and reviewed more than 20 years of influent and effluent data for local wastewater treatment facilities. We conclude that most PCB contamination in shelf sediments and fish is due to the ongoing practice of dumping contaminated sediments dredged from San Diego Bay.

Monitoring

Heal the Bay End of Summer Beach Report Card. 2009. Heal the Bay.

Project Summary

Heal the Bay's End of Summer Beach Report Card provides beachgoers with essential water quality information by grading nearly 460 monitoring locations from Humboldt County through San Diego County from Memorial Day to Labor Day 2009.

The Beach Report Card is based on the routine monitoring of beaches conducted by local health agencies and dischargers. Water samples are analyzed for bacteria that indicate pollution from numerous sources, including fecal waste. The better the grade a beach receives, the lower the risk of illness to ocean users. The report is not designed to measure the amount of trash or toxins found at beaches. The Beach Report Card would not be possible without the cooperation of all of the shoreline monitoring agencies in the state.

Water quality data collected at California beaches this past summer showed that this was one of the cleanest summers on record. Southern California's third summer of drought likely contributed to the third consecutive year of excellent overall summer grades. Despite a few problem areas, statewide water quality was very good (and slightly better than last summer) with 92% A and B grades. There were only 37 locations (8%) throughout the state that received fair-to-poor water quality grades (10 Cs, 5 Ds and 22 Fs).

Overall, Los Angeles beach water quality grades were good and moderately improved from last year. Santa Monica Bay beaches showed a significant improvement from last summer with far more beaches receiving A or B grades. Overall, Santa Monica Bay beaches fared better than last summer, with 60 (91%) of 66 monitoring locations receiving A or B grades compared to 86% last year.

One of Santa Monica Bay's most polluted beaches is the Santa Monica Pier. This historic landmark, attracting over 3 million tourists each year, has been plagued by poor water quality for many years. In 2006, a study was conducted to determine the source of the chronic bacteria issues experienced on the south side of the pier. Consultants to Santa Monica determined that a stormdrain rehabilitation project was required to alleviate these water quality problems. The City completed the stormdrain project before Memorial Day 2009. Santa Monica is continuing work with UCLA and Heal the Bay to determine additional pollution sources and potential maintenance modifications.

The full End of Summer Beach Report Card can be found at www.healthebay.org/brc

Ecosystem Response to Regulatory and Management Actions: The Southern California Experience in Long-Term Monitoring. E.D. Stein and D.B. Cadien. 2009. Marine Pollution Bulletin. 59:91-100.

Abstract

Billions of dollars have been invested over the past 35 years in reducing pollutant emissions to coastal environments. Evaluation of the effectiveness of this investment is hampered by the lack of long-term consistent data. A rare opportunity exists in southern California to evaluate the effectiveness of management actions by analyzing long-term monitoring of effluent, sediment, benthos, and fish and comparing this trend data to periodic regional surveys of environmental condition. In this paper, we ask the question "have improvements in effluent quality in response to environmental regulation translated into improvements in the receiving environment?" Results indicate that management actions directed at reducing mass emissions from wastewater treatment plants (POTWs) have resulted in substantial improvement in aquatic communities. However, the magnitude and timing of response varies by indicator suggesting that use of multiple assessment endpoints is necessary to adequately interpret trends. Reductions in the effect of POTW effluent have allowed managers to shift resources to address other contaminant sources such as stormwater and resuspension of legacy pollutants.

The Extent and Magnitude of Sediment Contamination in the Southern California Bight. Maruya, K.A. and K. Schiff. 2009. The Geological Society of America Special Paper. 454:399-412.

Abstract

More than 30 million dollars are expended annually to assess environmental quality of the Southern California Bight, yet only 5% of the Bight area is surveyed on an ongoing basis. Because decision makers lacked the data to make regional assessments of ecosystem condition, multiple stakeholders collaborated to create a Southern California Bight Regional Monitoring Program. The third survey in this program was conducted in 2003. A primary goal of this regional monitoring program was to determine the extent and magnitude of sediment contamination in the Southern California Bight, and to compare these assessments among several different habitats. A stratified random design was selected to provide unbiased areal assessments of environmental condition; 359 surficial sediments were collected, representing 12 different habitats that extend from shallow embayments and estuaries to deep offshore basins. Each sample was analyzed for grain size, total organic carbon and nitrogen (TOC/TN), 15 trace metals, and a suite of

persistent organic constituents (total dichloro-diphenyltrichloroethane [DDT], total polychlorinated biphenyl [PCB], and total polynuclear aromatic hydrocarbon [PAH]). The greatest accumulated mass of these constituents (76% on average; range 70% to 87%) was located at depths >200 m, which was proportional to its relatively large area (67% of entire Southern California Bight). The greatest sediment concentrations of trace metals, total PAH, and total PCB were observed in embayments (e.g., marinas, estuaries draining urbanized watersheds, and industrialized port facilities). These shallow habitats also contained a disproportionately high mass of contaminants relative to their area. Despite the relatively widespread anthropogenic enrichment of Southern California Bight sediments, only 1% of the Southern California Bight was at a moderate to high risk of adverse biological effects based on empirically derived sediment quality guidelines. Risk, however, was not evenly distributed throughout the Southern California Bight. The greatest risk of adverse biological effects was found in sediments of marinas, Los Angeles estuaries, and large publicly owned treatment works (POTWs); these were the only habitats for which the mean effects range-median quotient (ERMQ) exceeded 0.5. The least risk was observed in sediments associated with the Channel Islands and small POTWs, for which all sites were considered to be at low risk of adverse biological effects.

Effects of Post-Fire Runoff on Surface Water Quality: Development of a Southern California Regional Monitoring Program with Management Questions and Implementation Recommendations. Stein, E.D. and J. Brown. 2009. Technical Report 598. Southern California Coastal Water Research Project. Costa Mesa, CA.

Executive Summary
Periodic wildfires are a natural component of southern California's forest and scrubland and essential to maintaining overall ecological health of these systems. However, the frequency and intensity of wildfires has increased in association with human activities in and near natural forest and foothill areas. The effects of fire on hydrologic response and sediment loads in southern California have been noted for over 80 years, yet no coordinated monitoring of water quality following fires currently occurs. The lack of coordinated monitoring is particularly problematic in southern California because watersheds affected by fire often drain to waterbodies that support sensitive resources or that have been designated as impaired under Section 303(d) of the Clean Water Act, often for the same constituents found in post-fire runoff. Consequently, the contribution of metals, nutrients, and organic contaminants from post-fire runoff to receiving waters is poorly understood in terms of both the magnitude and persistence of potential effects.

The lack of a coordinated post-fire monitoring program results from several factors. First, there is no procedure for post-fire water quality monitoring that identifies a standard set of constituents and monitoring protocols appropriate for assessing water quality following fires. Second, resources are often scarce following fires making it difficult for various entities to coordinate. Third, there is no regional entity responsible for coordinating post-fire sampling, compiling the resultant data, and disseminating the information back to mangers at the local and regional levels. Fourth, because fires occur unexpectedly, there is often insufficient available funding for conducting post-fire sampling.

This document describes a regional post-fire water quality monitoring program. The goal of the program is to help address the current information gaps by providing agreed upon regional post-fire water quality sampling procedures, including an implementation plan and a funding strategy. This plan was developed by a team of technical experts, stormwater managers, and regulators from academia, government, and the private sector. The plan provides a ready "off-the-shelf" response plan that can be quickly implemented after fires.

The post-fire monitoring program is organized around three priority management questions:

How does post-fire runoff affect contaminant flux?

What is the effect of post-fire runoff on downstream receiving waters?

What are the factors that influence how long post-fire runoff effects persist?

Status of Perennial Estuarine Wetlands in the State of California. Sutula, M., J.N. Collins, A. Wiskind, C. Roberts, C. Solek, S. Pearce, R. Clark, A.E. Fetscher, C. Grosso, K. O'Connor, A. Robinson, C. Clark, K. Rey, S. Morrissette, A. Eicher, R. Pasquinelli, M. May and K. Ritter. 2008. Final report to the Surface Water Ambient Monitoring Program, State Water Resources Control Board. Technical Report 571. Southern California Coastal Water Research Project. Costa Mesa, CA.

Executive Summary
Section 305(b) of the Federal Clean Water Act (CWA) requires each state submit biennial reports describing the health of its surface water, including wetlands, to the USEPA. This document reports on the health of California's perennial, saline estuarine wetlands.

Estuaries are partially enclosed bodies of water along the coast where freshwater runoff meets and mixes with salt water from the ocean. Based on the draft definition of wetlands for California, an estuarine wetland is an area within an estuary that is exposed at low tide and covered with rooted vegetation.

The health of the state's estuarine wetlands is estimated from a statewide survey of the distribution, abundance, and ambient condition of estuarine wetlands. The survey had three components: 1) landscape profile; 2) probability-based assessment of ambient condition; and 3) assessment of selected estuarine wetland restoration and mitigation projects. The results help answer four fundamental management questions: 1) where are the State's estuarine wetlands and how abundant are they; 2) what is the ambient condition of estuarine wetlands statewide and how does their condition vary by region; 3) what are the

major stressors and how do they vary among coastal regions; and 4) what is the condition of permitted restoration projects relative to ambient condition. This fourth question demonstrates how data could be used to evaluate policies and programs affecting the distribution, abundance, and condition of estuarine wetlands.

The landscape profile described the distribution and abundance of the State's estuarine wetlands relative to other estuarine habitats and explored the underlying causes through a detailed examination of trends in San Francisco Estuary. A probability-based survey was used to assess the ambient condition of saline, perennial estuarine wetlands. The statewide ambient survey involved 120 sites allocated equally among four regions: North Coast, San Francisco Estuary, Central Coast, and South Coast. An additional 30 sites were allocated to South Coast to test for a difference between large and small estuaries. The field survey was conducted in the Fall of 2007. The statewide ambient survey in turn served as a regional frame of reference for project assessments.

Extent and Magnitude of Copper Contamination in Marinas of the San Diego region, California, USA. Schiff, K. and J Brown, D Diehl, D Greenstein. 2007. Marine Pollution Bulletin. 54:322-328.

Abstract
Marinas are areas of special water quality concern because of the potential for pollutant accumulation within their protected waters. Perhaps the largest contaminant source to marinas is antifouling paints that leach copper to prevent the growth of encrusting organisms on vessel bottoms. Very little monitoring of marinas is typically conducted despite the potential environmental risk, particularly in the San Diego region of California, USA where as many as 17,000 recreational vessels are berthed. The objective of this study was twofold: (1) determine the extent and magnitude of dissolved copper concentrations in marinas throughout the San Diego region, and (2) determine if elevated copper concentrations in marinas of the San Diego region are resulting in adverse biological impacts. A probabilistic study design was used to sample water column copper concentrations and toxicity (using *Mytilus galloprovincialis*) at 30 stations. Results indicated that exceedence of state water quality objectives was widespread (86% of marina area), but that toxicity was much less prevalent (21% of marina area). Toxicity identification evaluations (TIEs) conducted at the most toxic sites indicated that toxicity was largely due to trace metals, most likely copper. Toxicity was reduced using TIE treatments that chelated trace metals such as cation exchange column, ethylenediaminetetraacetic acid (EDTA), and sodium thiosulfate (STS). Moreover, increasing dissolved copper concentrations correlated with increasing toxicity and these copper concentrations were high enough to account for virtually all of the observed toxicity.

Design of Storm Water Monitoring Programs. Lee, H, X. Swamikannu, D. Radulescu, S-J Kim and M.K. Stenstrom. 2007. Water Research. 41(18):4186-4196.

Abstract
Stormwater runoff is now the leading source of water pollution in the United States, and stormwater monitoring programs have only recently been developed. This paper evaluates several stormwater monitoring programs to identify ways of increasing the likelihood of identification of high-risk dischargers and increasing data reliability for assisting in the development of total maximum daily loads. No relationship was found between various types of industrial activity or land use and water quality data. Stormwater data collected with grab samples has much greater pollutant concentration variability than in potable water or wastewater monitoring programs. Industrial land use is an important source of metals. For grab samples, sampling time during the storm event will affect results. Data from California, which has distinct dry periods, showed a seasonal first flush, whereas data from areas with more uniform rainfall throughout the year did not show a seasonal first flush. Selecting a subset of sites from each monitored category using a flow-weighted composite sampler is an alternative strategy, and may result in lower overall cost with improved accuracy and variability in mass emissions, but may not be less successful in identifying high-risk dischargers.

Calibration and Evaluation of Five Indicators of Benthic Community Condition in Two California Bay and Estuary Habitats. Ranasinghe, J.A., S.B. Weisberg, R.W. Smith, D.E. Montagne, B. Thompson, J.M. Oakden, D.D. Huff and K.J. Ritter. 2009. Marine Pollution Bulletin. 59(1-3):5-13.

Abstract
Many types of indices have been developed to assess benthic invertebrate community condition, but there have been few studies evaluating the relative performance of different index approaches. Here we calibrate and compare the performance of five indices: the Benthic Response Index (BRI), Benthic Quality Index (BQI), Relative Benthic Index (RBI), River Invertebrate Prediction and Classification System (RIVPACS), and the Index of Biotic Integrity (IBI). We also examine whether index performance improves when the different indices, which rely on measurement of different properties, are used in combination. The five indices were calibrated for two geographies using 238 samples from southern California marine bays and 125 samples from polyhaline San Francisco Bay. Index performance was evaluated by comparing index assessments of 35 sites to the best professional judgment of nine benthic experts. None of the individual indices performed as well as the average expert in ranking sample condition or evaluating whether benthic assemblages exhibited evidence of disturbance. However, several index combinations outperformed the average expert. When results from both habitats were combined, two four-index combinations and a three-index combination performed best. However, performance differences among several combinations

were small enough that factors such as logistics can also become a consideration in index selection.

Die Off and Current Status of Southern Steelhead Trout (*Oncorhynchus mykiss*) in Malibu Creek, Los Angeles County, USA. Dagit, Rosi, Stevie Adams and Sabrina Drill. 2009. Bulletin, Southern California Academy of Sciences. 108(1):1-15.

Abstract
A die-off of native and exotic fish and invertebrate species, including the endangered southern steelhead trout (*Oncorhynchus mykiss*) was observed in Malibu Creek, Los Angeles County, during the summer and fall of 2006. Death was preceded by a period of illness during which trout in particular exhibited a noticeable yellow coloration. Physical, chemical and biological variables, including temperature, dissolved oxygen, a variety of chemical contaminants, presence of toxin producing algae, and direct pathology were examined but results remain inconclusive. The first day of a 12-day high temperature event occurred on the same date yellow trout were first observed. This sustained event is different from shorter term temperature spikes recorded in other years. Recovery monitoring documented recolonization by all exotic fish species and crayfish, but limited numbers of southern steelhead trout in 2007. Surveys in summer 2008 documented a record number of anadromous adults (five silvery fish over 50 cm total length) and young of the year (over 2,200 under 10 cm).

Restoration

Alien Invasions, Ecological Restoration in Cities and the Loss of Ecological Memory. Schaefer, Valentin. 2009. Restoration Ecology. 17(2):171-176.

Abstract
After a community or ecosystem is lost, it may leave behind an ecological memory. The site history, soil properties, spores, seeds, stem fragments, mycorrhizae, species, populations, and other remnants may influence the composition of the replacement community or ecosystem to varying degrees. The remnants may also hold the site to a trajectory that has implications for ecological restoration. This is true in urban situations in particular where repeated disturbance has masked the history of the site. The ecological memory remaining may be insufficient for a site to heal itself; restoration activities are required to direct the future of the site. Conversely, in light of climate change and other rapidly changing environments, the existing ecological memory may be poorly suited to the new conditions and restoration projects need to create new and perhaps novel ecosystems. The loss of ecological memory facilitates the establishment of foreign invasive species. These invasives may eventually create a new stability domain with its own ecological memory and degree of resilience. To be successful, invasive species control must address both internal within patch memory of invasives and external between patch memory. Further research is necessary to document and conserve ecological memory for ecological restoration in response to future ecosystem changes.

A Method for Evaluating Outcomes of Restoration When No Reference Sites Exist. Brewer, J. Stephen and Timothy Menze. 2009. Restoration Ecology. 17(1):4-11.

Abstract
Ecological restoration typically seeks to shift species composition toward that of existing reference sites. Yet, comparing the assemblages in restored and reference habitats assumes that similarity to the reference habitat is the optimal outcome of restoration and does not provide a perspective on regionally rare off-site species. When no such reference assemblages of species exist, an accurate assessment of the habitat affinities of species is crucial. We present a method for using a species by habitat data matrix generated by biodiversity surveys to evaluate community responses to habitat restoration treatments. Habitats within the region are rated on their community similarity to a hypothetical restored habitat, other habitats of conservation concern, and disturbed habitats. Similarity scores are reinserted into the species by habitat matrix to produce indicator (I) scores for each species in relation to these habitats. We apply this procedure to an open woodland restoration project in north Mississippi (U.S.A.) by evaluating initial plant community responses to restoration. Results showed a substantial increase in open woodland indicators, a modest decrease in generalists historically restricted to floodplain forests, and no significant change in disturbance indicators as a group. These responses can be interpreted as a desirable outcome, regardless of whether species composition approaches that of reference sites. The broader value of this approach is that it provides a flexible and objective means of predicting and evaluating the outcome of restoration projects involving any group of species in any region, provided there is a biodiversity database that includes habitat and location information.

The Restoration of Fishing Services and the Conveyance of risk information in the Southern California Bight. Breffle, William S. and Kristen K. Maroney. 2009. Marine Policy. 33(4): 561-570.

Abstract
Southern California's marine areas are heavily contaminated with dichloro-diphenyl-trichloroethane (DDT) and polychlorinated-biphenyls (PCBs), and fish consumption advisories (FCAs) have been issued throughout the region. Between 2002 and 2003, the Montrose Angler Survey, a large-scale survey of subsistence anglers, was developed and implemented on site in Orange and Los Angeles counties. This survey was intended to assist natural resource trustees in the development of restoration programs that will address injuries to natural resources and restore lost economic services for anglers, but the data were never fully analyzed. The trustees have shown a clear preference for ecological restoration programs that may take years to improve fishing services. In contrast, this analysis, which includes a random-parameter fishing site choice model, demonstrates that simple, inexpensive programs such as better signage to

warn of FCAs and transportation to clean sites have the potential to yield substantial benefits quickly. This paper also focuses on how different ethnic minority groups are affected by FCAs, and determines how best to communicate risk information and change fishing behavior through outreach programs.

Ballona Wetlands Restoration: Planning for Sea Level Rise. Garrity, Nicholas J., Jeremy P. Lowe and Jeffrey Haltiner. 2009. Phillip Williams & Associates.

Project Summary

The Ballona Wetlands Restoration seeks to restore and enhance diverse wetland habitats within the 600 acres owned by the State of California. Philip Williams & Associates and the Santa Monica Bay Restoration Commission have led the preparation of a restoration feasibility report for the California State Coastal Conservancy (www.ballonarestoration.org). One planning consideration is to accommodate recent projections of sea level rise, per the Conservancy's Climate Change Policy (June 2009).

Fine sediment from the Ballona Creek watershed and the ocean is limited; accretion rates are expected to be low and the restored wetlands may not keep pace with sea level. Inundation frequency will increase with rising tide levels, and vegetated wetland may convert to mudflat, and upland may convert to wetland, in the process of "transgression."

The restoration alternatives developed restore initially large areas of upland and upland-transition habitats that are expected to convert to wetlands as sea level rises. Long gradually sloping transitions (approximately 100:1 to 300:1) would be graded from mudflat to upland habitat elevations. Figure 1 shows a conceptual cross-section of the restored grade and expected habitat types for today and the end of the 21st century. As sea level rises, the broad areas of high marsh, transition zone, and upland habitats may be converted to a mix of mudflat, low marsh, and mid marsh. Upland acreage would decrease over time, mudflat and low marsh area would increase, and mid marsh would stay roughly constant. Restored upland and transition habitats are expected to provide interim habitat benefits, act as high tide refugia, and serve as buffers from human activity. Restoring upland habitats also avoid the cost of grading these areas to intertidal elevations.

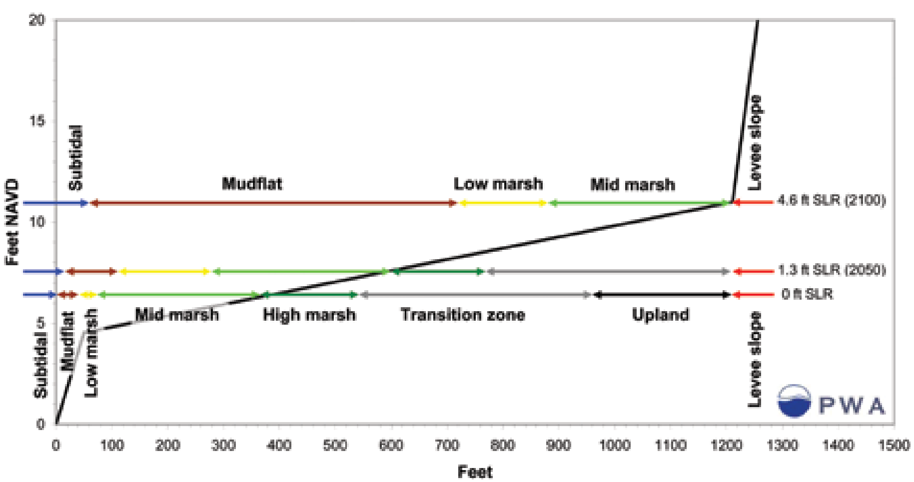


Figure 1. Conceptual Cross-section Showing Habitat Transgression with Sea Level Rise

The Nature of Urban Soils and Their Role in Ecological Restoration in Cities. Pavao-Zuckerman, Mitchell A.. 2008. Restoration Ecology. 16(4):642-649.

Abstract

Current and predicted trends indicate that an increasing proportion of the world's population is living in urban and suburban places. The nature of the urban environment becomes an important factor if we are concerned with the restoration and preservation of biodiversity and ecosystems in and around cities. This article highlights the varied impacts of cities on soils and their implications for restoration planning and expectations of restoration "success." Urban soils exist in different historical and formational trajectories than their local nonurbanized counterparts due to direct anthropogenic disturbance and indirect environmental impacts from urbanization. Therefore, urban soils often exhibit altered physical, chemical, and biological characteristics in comparison to local nonurbanized soils. Several unique features of urban soils and urban ecosystems pose particular issues for ecological restoration or the improvement of degraded soil conditions in cities. The creation of novel soil types, conditions that promote invasion by non-natives, the strong influence of past land use on soil properties, and the presence of strong interactions and alternative stable states set up unique difficulties for the restoration of urban soils. Soils in urban restorations are a medium that can be deliberately manipulated to improve site conditions or in the monitoring of soil conditions as indices of ecosystem status. Including an explicit role for strong manipulations of soils in urban ecosystems changes how we approach baselines, management, and reference conditions in urban ecological restoration. With an understanding of urban soil ecological knowledge, we can guide aspects of urban ecological restoration toward successful outcomes.

Rehabilitation of Stream Ecosystem Functions through the Reintroduction of Coarse Particulate Organic Matter. Aldridge, Kane T., Justin D. Brookes and George G. Ganf. 2009. Restoration Ecology. 17(1):97-106.

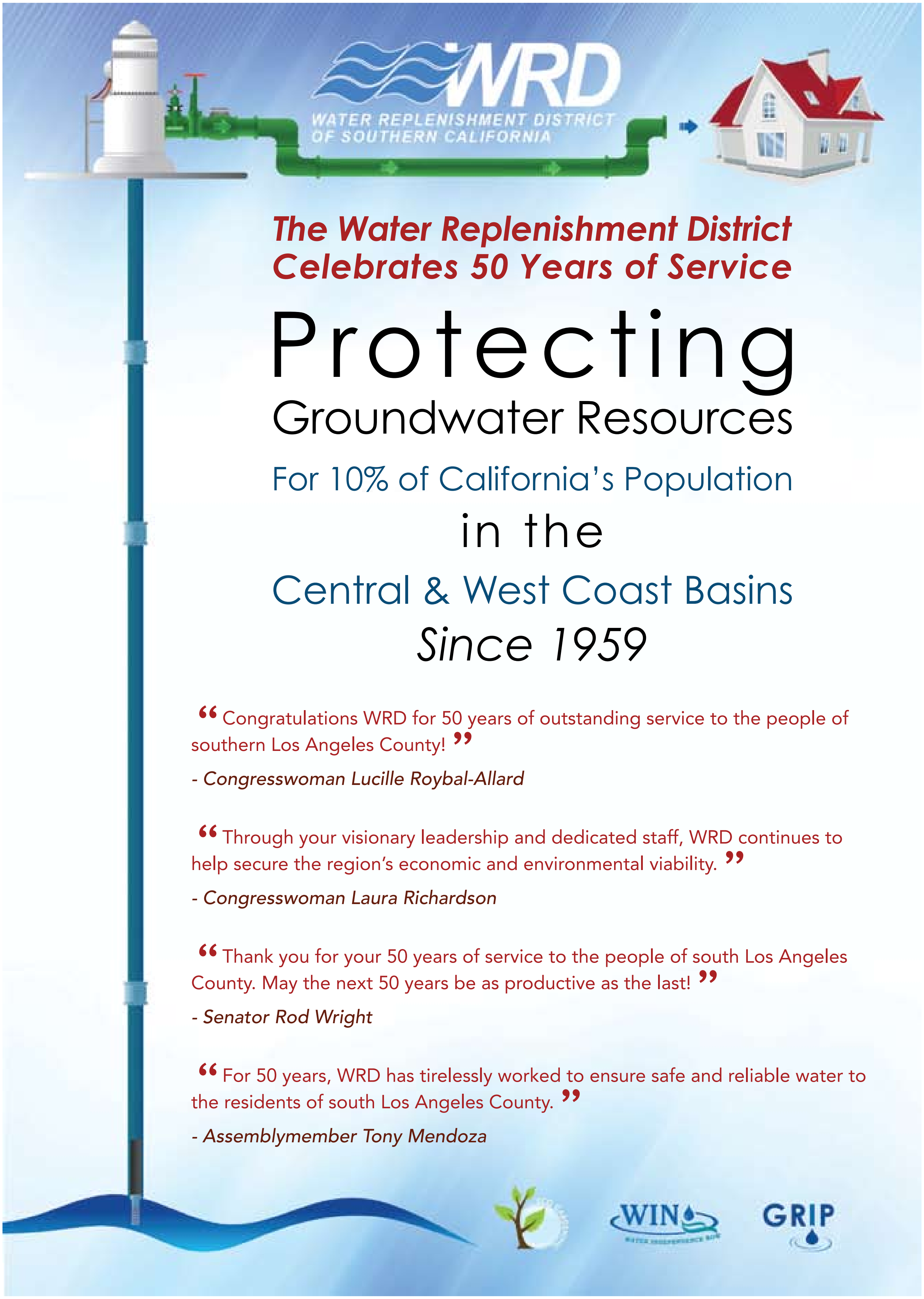
Abstract
In streams, coarse particulate organic matter (CPOM) acts as a substrate for microbial activity, which promotes nutrient retention. However, in urban areas, increased peak flows within streams lead to decreased retention of CPOM. The aim of this study was to investigate whether the reintroduction of CPOM, in the form of leaf litter, into a degraded urban stream would increase biofilm activity and phosphorus retention, two ecosystem functions that reflect the integrity of the ecosystem. Stream metabolism and nutrient retention were assessed in treated (T) and control (C) channels of the Torrens River Catchment, South Australia, before and after CPOM addition. Gross primary production and community respiration (CR) were measured as oxygen production and consumption within benthic chambers. Phosphorus retention was measured through a series of short-term filterable reactive phosphorus (FRP) addition experiments. Before CPOM addition, there were no differences in CR, but C retained 6.8% more FRP than T. After CPOM addition, CR was greater in T than in C (572 and 276 mg O2·m−2·day−1, respectively), and T retained 7.7% more FRP than C. The increase in FRP retention in T compared to C was attributed to phosphorus limitation of the CPOM and increased demand for phosphorus of the attached microbial heterotrophic community. The reintroduction of CPOM into degraded streams will be an important step in the restoration of stream metabolism and nutrient retention. Maintenance of CPOM may be achieved through restoration of riparian vegetation, a reduction in the increased peak flows, and rehabilitation of stream morphology.

Seed Dispersal and Seedling Emergence in a Created and a Natural Salt Marsh on the Gulf of Mexico Coast in Southwest Louisiana, U.S.A. Elsey-Quirk, Tracy, Beth A. Middleton, and C. Edward Proffitt. 2009. Restoration Ecology.17(3):422-432.

Abstract
Early regeneration dynamics related to seed dispersal and seedling emergence can contribute to differences in species composition among a created and a natural salt marsh. The objectives of this study were to determine (1) whether aquatic and aerial seed dispersal differed in low and high elevations within a created marsh and a natural marsh and (2) whether seedling emergence was influenced by marsh, the presence of openings in the vegetation, and seed availability along the northern Gulf of Mexico coast. Aerial seed traps captured a greater quantity of seeds than aquatic traps. Several factors influenced aquatic and aerial seed dispersal in a created and a natural salt marsh, including distance from the marsh edge, cover of existing vegetation, and water depth. The natural marsh had a high seed density of *Spartina alterniflora* and *Distichlis spicata*, the low-elevation created marsh had a high seed density of *S. alterniflora*, and the high-elevation created marsh had a high seed density of *Aster subulatus* and *Iva frutescens*. The presence of adult plants and water depth above the marsh surface influenced seed density. In the natural marsh, openings in vegetation increased seedling emergence for all species, whereas in the low-elevation created marsh, *S. alterniflora* had higher seedling density under a canopy of vegetation. According to the early regeneration dynamics, the future vegetation in areas of the low-elevation created marsh may become similar to that in the natural marsh. In the high-elevation created marsh, vegetation may be upland fringe habitat dominated by high-elevation marsh shrubs and annual herbaceous species.

Effects of Stream Restoration on Denitrification in an Urbanizing Watershed. Kaushal, Sujay S., Peter M. Groffman, Paul M. Mayer, Elise Striz and Arthur J. Gold. 2008. Ecological Applications. 18(3):789-804.

Abstract
Increased delivery of nitrogen due to urbanization and stream ecosystem degradation is contributing to eutrophication in coastal regions of the eastern United States. We tested whether geomorphic restoration involving hydrologic "reconnection" of a stream to its floodplain could increase rates of denitrification at the riparian-zone–stream interface of an urban stream in Baltimore, Maryland. Rates of denitrification measured using in situ 15N tracer additions were spatially variable across sites and years and ranged from undetectable to >200 μg N·(kg sediment)−1·d−1. Mean rates of denitrification were significantly greater in the restored reach of the stream at 77.4 ± 12.6 μg N·kg−1·d−1 (mean ± SE) as compared to the unrestored reach at 34.8 ± 8.0 μg N·kg−1·d−1. Concentrations of nitrate-N in groundwater and stream water in the restored reach were also significantly lower than in the unrestored reach, but this may have also been associated with differences in sources and hydrologic flow paths. Riparian areas with low, hydrologically "connected" streambanks designed to promote flooding and dissipation of erosive force for storm water management had substantially higher rates of denitrification than restored high "nonconnected" banks and both unrestored low and high banks. Coupled measurements of hyporheic groundwater flow and in situ denitrification rates indicated that up to 1.16 mg NO3−-N could be removed per liter of groundwater flow through one cubic meter of sediment at the riparian-zone–stream interface over a mean residence time of 4.97 d in the unrestored reach, and estimates of mass removal of nitrate-N in the restored reach were also considerable. Mass removal of nitrate-N appeared to be strongly influenced by hydrologic residence time in unrestored and restored reaches. Our results suggest that stream restoration designed to "reconnect" stream channels with floodplains can increase denitrification rates, that there can be substantial variability in the efficacy of stream restoration designs, and that more work is necessary to elucidate which designs can be effective in conjunction with watershed strategies to reduce nitrate-N sources to streams.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