Salinity and Drainage in San Joaquin Valley, California

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Salinity and Drainage in San Joaquin Valley, California

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Preface

Salinity and drainage are challenges of irrigated agriculture in semiarid and arid climates that transcend history and geography. Three thousand years before Christ, the Mesopotamia culture emerged and prospered, aided by domestication of crops and animals and employment of a water conveyance and irrigation network. When the civilization crumbled millennia later, it was broad-spectrum socio-economical turmoil, poor governance, and institutional weakness that led to societal decline and eventually resulted in dilapidated water delivery infrastructure, rising shallow groundwater tables, salinization of soils, and crop failures. When and wherever irrigated agriculture has ascended in history, the populace sooner or later has been forced to cope with the threat of soil salinization. Examples today include Egypt, Jordan, China, Peru, India, Pakistan, Australia, and California. While water movement, salt buildup in soils, and plant injuries are molecular-scale processes governed by the natural laws, over time, it has been failures in public policy, institutions, and management, which have culminated in wholesale crises in irrigated agriculture.

At different temporal and spatial scales, salinity and drainage issues would take distinctively different forms and shapes. In 1983, the reproductive failures and deformed embryos of shore birds appeared at the Kesterson National Wildlife Refuge, a wetland fed by subsurface tile drain effluents from farmlands in the western San Joaquin Valley. A looming ecological catastrophe caused by irrigated agriculture was unfolding. At the process level, as drainage waters congregated in the terminus water body, micro-quantities of waterborne selenium bio-accumulated unnoticed through the aquatic food chain and quickly reached levels toxic to biota occupying the top ecological echelon. Instantaneously, the ecosystem harm brought the sustainability of irrigated agriculture in the Valley into question, a crisis at the regional level. Basin-wide options to address the issues were constrained by water rights, special interests, public policies and legal mandates, and political actions at the local, statewide, and federal levels. On farms, if irrigated agriculture were to continue, the irrigation and cultivation practices had to be adjusted to contain and/or eliminate the release of selenium via drainage water discharge. There were technology gaps to be closed. “How to fix it?” was a multifaceted dilemma.

In 1985, the University of California (UC), Division of Agriculture and Natural Resources, in response to the environmental crises, launched the UC Salinity Drainage Research Program, mobilizing resources and personnel for a concerted effort to tackle problems associated with salinity, selenium, and drainage in the western San Joaquin Valley. UC researchers initiated a diverse range of research studies, worked with local special service districts, and participated in inter-agency review panels. It was a period of focused academic pursuits by students and faculty alike and intense interactions with public agencies, water management professionals, and individual growers. Research findings were disseminated in presentations at workshops and conferences, in written reports distributed among concerned public agencies, in proposals and plans for feasibility assessments, and in technical articles in professional journals. It was the first time salinity drainage problems of an irrigated crop production region were systematically and comprehensively investigated.

The UC Center for Water Resources asked selected participants in the Salinity Drainage Research Program to critically recapture findings that over the time span of two-plus decades had been scattered in the scientific literature of diverse disciplines. As the subject matter is revisited and updated, we all benefit from the perspective of time and experience, additional research findings, new technologies, and greater knowledge base, to view the material with wisdom.

This compendium of 15 chapters is a collection of independent treatises, each depicting a distinctive salinity drainage topic with fresh perspective. As environmental scientists, engineers, and biologists, we are cognizant of the multiple scales at which complex issues should be examined, and we recognize the need to integrate those scales to recommend viable solutions. At first, the subject matter covered in this collection may appear random and lacking in relationship, but when the scales are invoked and integrated, then a mosaic of irrigated agriculture in time and space emerges. The following are synopses of the chapters:

Time, Geography, and Scale

Chapter 1 provides background information and a water distribution map to familiarize readers with the San Joaquin Valley, setting a stage for events and issues that developed.

Chapter 2 delineates the evolution of irrigated agriculture in the San Joaquin Valley over the temporal scale. Water rights doctrines, state and federal water policies, and infrastructure building played decisive roles in how water was distributed and used then and now. Processes that facilitated irrigated agriculture to blossom also led to delays in solving salinity and drainage problems. Later, the constraints were set forth by federal mandates in the Clean Water Act and Endangered Species Act and by eco-toxicological crises of selenium.

Chapter 3 depicts the geochemical and hydrological processes that define the San Joaquin Valley, including the physics, chemistry, and biology attributes that impact water management policies and strategies in the Valley.

Chapter 4 provides a comprehensive discussion of how scales entered into the salinity drainage research and management in the San Joaquin Valley. Scaling, the tools of integrating data obtained at different scales, is imperative in accurately assessing impacts at the regional level.

Biogeochemistry of Selenium

Chapter 5 elaborates chemical reactions that transform selenium when irrigation water passes through the soil profile and facilitates its transport to subsurface tile drains.

Chapter 6 explains the biochemical roles of plants in absorbing selenium from soils and transforming and volatilizing it as gaseous methyl selenium. The processes have the potential to reduce and eliminate selenium from the drainage water.

Chapter 7 describes how microbial reductive processes to precipitate selenium species found in the drainage water are affected by environmental factors and demonstrates a path to optimize the reduction of selenium.

Chapter 8 describes the aquatic chemistry and biology of selenium in evaporation ponds that are employed to retain and concentrate dissolved salts in the drainage water. Again, the processes may be employed to reduce the selenium load of the drainage water stream.

Coping with the Salts

Chapter 9 shows that evaporation ponds, while acting as the repository for selenium and dissolved salts in the drainage water, might be a threat to the safety of foraging shore birds. However, providing alternative and compensatory habitats for the birds can mitigate the potential hazards. The evaporation pond systems operated by the Tulare Lake Drainage District are a successful example.

Chapter 10 documents on-farm and plot-level irrigation provisions that would reduce agricultural drainage outputs and examines their effects on plant performance. These meso-scale practices might be implemented on a basin-wide level to enhance irrigation efficiencies and reduce drainage and salt disposal requirements.

Chapter 11 explores the on-farm drainage water reuse potential and tests the integrated farm drainage management (IFDM) approach. Drainage water may be retained on-farm by collecting, blending, and reusing it for irrigation of a more salt-tolerant crop. The secondary drainage water, in turn, may be reused on an even more salt-tolerant crop. The system, if properly scaled and operated, would reduce the drainage volume and concentrate the salts for final disposal.

Chapter 12 thoroughly delineates the technical merits of the reverse osmosis technologies in desalting agricultural drainage water, with emphasis on examining mechanisms of membrane clogging and on preventing microbial and mineral fouling of membranes and extending membrane life and operation time.

Chapter 13 shows how the wetlands in the San Joaquin Valley may be operated and through monitoring data evaluates their performances in accommodating the salt discharges from irrigated fields.

The Real Game: Public Policy and Management

Chapter 14 is a realistic policy analysis of the water management options for irrigated agriculture in the San Joaquin Valley and their respective outcomes, if implemented. In this exercise, the findings at the micro- and meso-scales are integrated for a basin-wide assessment.

Chapter 15 provides an international perspective on the sustainability of irrigated agriculture and returns to the thesis from the outset.

As editors, we remind readers that at different temporal and spatial scales, salinity drainage issues would take distinctively different forms and shapes.

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