Appendix A – *Technical Memorandum: San Jacinto Watershed Existing Data Summary*

To: Pat Boldt, San Jacinto Basin Resource Conservation District
From: Tetra Tech, Inc.
Date: December 30, 2007
RE: Technical memorandum concerning existing data for the San Jacinto Watershed

Funding for this project has been provided in full or in part through an agreement with the California State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. (Gov. code 7550, 40 CFR 31.20).

Dairy Management Plan Elements

Stakeholders involved in the San Jacinto Integrated Regional Watershed Management Plan (IRWMP) process submitted 93 resource management projects to be considered for inclusion in the IRWMP (San Jacinto River Watershed Council, 2007). Control of dairy runoff is a key component of the IRWMP and *Implementation of the Integrated, Regional Dairy Management Plan Recommendations* is one of the 93 stakeholder projects. The principal objective of the Integrated Regional Dairy Management Plan (IRDMP) is to identify specific ways to solve water quality issues (nutrients, salts, and pathogens) associated with the dairy industry. Specific topics of concern include surface and ground water quality, air quality and salts in the basin. Aspects of dairy management associated with these water quality issues include solid and liquid manure application, dairy wash water runoff, and management of storm water runoff. Additional areas of concern that will be addressed in the IRDMP are importation of manure, frequency of flushings, manure manifest system improvements, revised requirements for the General Waste Discharge Permit, total maximum daily load (TMDL) requirements, changes in the flow patterns or understanding of gap related issues, and the identification for future development of any additional best management practices (BMPs) of merit. The IRDMP approaches the problems on a regional and individual basis using sites at multiple dairy locations, and will provide a guidance document necessary to plan and integrate the specific needs of dairy operators in the San Jacinto Watershed.

IRDMP Objectives Requiring Data

Development of the IRDMP depends heavily upon the availability of accurate information concerning a wide range of watershed characteristics, water quality and other environmental problems in the watershed, the causes and sources of identified problems, the management of activities and land in the watershed, and the cost and effectiveness of potential solutions to the water quality and other environmental problems. To serve as a viable plan for the dairy industry in the San Jacinto watershed, the IRDMP must set forth reliably effective management strategies and actions that can be implemented by dairies while maintaining the sustainability of the dairy industry.

The following are IRDMP objectives that are dependent upon accurate, current, and readily accessible data:

- Characterize the role of dairy operations in determining the quality of surface and ground water in the watershed
- Collect monitoring data on and around surrounding dairies and the Mystic Lake area to address an existing data gap associated with the current TMDL plan
- Characterize the role of dairy operations in determining the air quality in the region
- Characterize the role of dairy operations in causing and solving problems associated with salts in the watershed
- Identify solutions to water quality and air quality problems that maintain the sustainability of dairy agriculture in the watershed
    - Improve watershed manure balance
        - Improve system to track manure import, distribution, and applications in the watershed (manure manifest program)
        - Identify areas needing improved dairy storm water and wastewater management
        - Identify potential application of dairy BMPs, including those being evaluated by ARS on the Scott Brothers Dairy and the resulting reductions in N & P, indicator bacteria, and salts
        - For dairies that include cropland, identify areas needing nutrient management plan (NMP) implementation and improved irrigation management
        - Develop effective strategies to deal with Gap area
        - Evaluate relationship of dairy management to air quality regulatory requirements
    - Identify pathogen sources for which improved management can result in measurable reductions in pathogen levels
    - Identify opportunities to reduce reliance on imported water
        - Identify opportunities to use reclaimed or desalter water
        - Address dairy was water runoff and frequency of flushings
    - Identify opportunities to reduce total dissolved solids and nitrogen concentrations in groundwater
    - Develop effective salt offset program
    - Develop implementation plan for General Permit that provides an offset for discharges associated with process wastewater and manure
    - Identify opportunities to preserve critical habitat, linkages and aquatic resources for species either currently on or at risk of being added to, the federal and state endangered and threatened species lists
- Develop an implementation timeline that is feasible and will result in achieving TMDL and other environmental goals for the watershed

This technical memo reviews available data against these objectives and assesses data sources in terms of their accuracy, currency, and accessibility.

Physical and Natural Features

Available data (as GIS data layers) appear to be adequate and are useful for characterization of the watershed and its physical and natural resources. Topography (digital elevation model), soils, vegetation, stream network, and meteorological data are all useful as input parameters for models applied to the watershed. Ground water inventory data are available (CA Bulletin 118), but do not appear to be at a detailed scale that would be useful in addressing issues with specific dairies in the San Jacinto watershed. [*Note: GIS data for dairies is expected in early 2008 and will be incorporated into final IRDMP*]

GIS Data Layers
Digital Elevation Models (EPA BASINS)
Ecoregions, Level 3 (EPA BASINS)
Soils (USDA STATSGO, RCFC&WCD, SARWQCB, USGS Riverside Co.)
Vegetation (WRCOG, Riverside Co.)
Stream network (BASINS reach files, USGS NHD Reach Files)
Watershed boundaries (BASINS)
USGS quadrangles (USGS)
Meteorologic station locations (BASINS, NOAA-NCDC, RCFC&WCD, Earth Info)
Monitoring station locations (BASINS, RCFC&WCD, STORET)

Ground water resources
CA DNR. 2003. California's Ground Water. Bulletin 118, Update 2003.
http://www.groundwater.water.ca.gov/bulletin118/update2003/index.cfm

Hydrologic Region South Coast, San Jacinto Groundwater Basin, update 2006
http://www.dpla2.water.ca.gov/publications/groundwater/bulletin118/basins/pdfs_desc/8-5.pdf

Hydrology
Sonderegger, A. L. Hydrology of the San Jacinto Valley

Climate/Weather data
Precipitation, temperature, dew point, humidity, cloud cover, wind speed (NOAA-NCDC, RCFC and WCD)

Land Use and Demographic Information

Land use and demographic data are ordinarily useful in watershed characterization, assessment of pollutant loads and sources, design of monitoring networks, and planning for implementation of pollution management measures. However, land use data for the San Jacinto watershed appears to be largely inadequate for these purposes. Available data appear to be substantially out of date, especially considering the rapid pace of development and land use change in the region. Furthermore, existing data lack detail on agricultural land uses that would permit effective prioritization of watershed regions or activities for pollutant load reduction efforts or to make meaningful estimates of load reductions anticipated from implementation of management

measures. Furthermore, there is also a lack of systematic information concerning the current status of management on dairies and associated cropland in the watershed.

- **It is recommended that land use/land cover in the San Jacinto watershed be updated as soon as possible based on recent satellite imagery and professional photointerpretation and classification, as well as appropriate ground-truthing.** Particular emphasis should be given to agricultural land use, other watershed land where manure is or may be spread, and contemporary land development patterns**.**

Population data specific to the San Jacinto do not appear to be readily available, although population data by county and city are readily available from the 2000 U.S. Census (http://www.census.gov/census2000/states/ca.html)

Because growth, development, and land use change is a major issue in the watershed, knowledge of current and forecast population and development patterns is essential to any planning process. Applications of such data are numerous. For example, good population data would be useful to project future water demand Some data for both population and water demand projections exist for portions of the San Jacinto watershed (e.g., from the Eastern Municipal Water District). Additional near-current population, land use, and water supply data for the San Jacinto River watershed are published in the EVMWD 2006 Watershed Sanitary Survey (MWH 2006). Information on the spatial distribution of residential development could help assess possible conflicts between residential land use and dairies as growth and development continue. An analysis of impervious cover associated with land development could improve understanding of watershed hydrology and contribute to the assessment of pollutant sources across the watershed.

- **It is recommended that current population data for the San Jacinto watershed be assembled from available sources, along with any available forecasts (spatial as well as numerical) and that the data be incorporated into GIS and other useful formats.**

- **It is recommended that information concerning municipal growth management plans, zoning regulations, etc. be compiled.**

- **It is recommended that information be compiled on land development requirements for builders/developers that pertains to water quality, air quality, salinity, or other issues that also involve dairies.**

GIS Data Layers
City Boundaries (BASINS, US Census)
County Boundaries (BASINS)
Land Use (based on SCAG) (EMWD, 1999)
Land Use (based on MRLC) (USGS, 1993)
Roads (BASINS)
Location of mines (BASINS)
Location of dams (FEMA, USACE, BASINS)

Location of septic systems (Tetra Tech)
Permitted Sources Locations (USEPA PCS, 2002)

Database of permitted dairies (Santa Ana Regional Water Quality Control Board)

Eastern Municipal Water District. 2007. Water Supply Assessment for Emerald Acres. September 19, 2007, EMWD, Perris, CA. [Publication evaluates water supply for one specific proposed residential development, but contains EMWD projections for population and water supply within its service area to 2030]

Pollutant Sources

Assessment of pollutant sources requires both basic information concerning the types and locations of potential sources and information concerning land management and current management activities. The 2006 supplemental environmental project (SEP) report sought to identify the sources of nutrients and salts in the San Jacinto watershed through surveys of agricultural and dairy producers, model the results of the survey data to determine if nutrient management techniques could prove effective at reducing the impact of these nutrients and salts, and assess the feasibility of practices or controls to accomplish the goal of improving water quality in the watershed. The assessment of pollutant sources was confounded by the poor resolution of the land use data and by the relatively poor response of producers in the watershed to the surveys. Although similarly limited by lack of solid data requiring numerous assumptions, the 2004 *San Jacinto Nutrient Management Plan, Final Report* provides a rough assessment of nonpoint source nutrient sources, both geographically and by land use. Until a new analysis can be conducted on new land use/land cover data (see above), these resources are the only basis available for assessing nutrient sources across the San Jacinto watershed.

In terms of dairies alone, the dairy database maintained by the Santa Ana Regional Water Quality Control Board for purposes of permitting (Order No. R8-2007-0001) provides the location and some basic characteristics of permitted dairies in the watershed. This database may also include some information on dairy facilities, an engineered waste management plan (if any), and results of any inspections or monitoring. Data concerning the locations and characteristics of dairies in the San Jacinto Watershed are available from the Santa Ana Regional Water Quality Control Board as an Access database. For planning and analysis purposes, it would be useful if this database could be mapped as a GIS coverage.

- **It is recommended that the RWQCB dairy database be searched and compiled to assemble information on locations of permitted dairies in the San Jacinto watershed and that this information be incorporated into a GIS data layer.**

- **It is recommended that information on the current status of dairy and land management be developed, e.g., through review of existing dairy permit information such as *Engineered Waste Management Plans*, permit inspections, and other records, as well as field surveys.**

In general, data on pollution sources can be applied to several aspects of the watershed planning process, including assessment of CAFO discharges and other dairy issues, development of a salt offset program, and a pathogen source assessment.

Tetra Tech, Inc. 2006. *Supplemental Environmental Project (SEP) - Source Identification for Phosphorous, Nitrates and Salts in the San Jacinto Watershed and Identification of Technologies and Alternate Control Measures Report*. Final report prepared for Western Riverside County Agricultural Coalition.

Tetra Tech, Inc. 2004. *San Jacinto Nutrient Management Plan, Final Report.* Submitted to Santa Ana Watershed Project Authority, Riverside, CA.

Western Riverside County Agriculture Coalition. No date. *Dairy Survey.* Prepared as part of the 2006 SEP report identified above; includes short- and long-term plans and current and predicted herd inventories, as well as data on milk production data, cropping, grain commodities used, manure generation, manure transportation costs, and acres farmed for all San Jacinto dairies.

Waterbody Monitoring Data

Lakes. A wealth of data exist from monitoring of Canyon Lake and Lake Elsinore, the two principal surface waterbodies in the San Jacinto watershed. These data include most recently TMDL monitoring reports and analyses, as well as historical data on the physical, chemical, and biological aspects of in-lake water quality. These data contribute to the characterization of the two waterbodies and document their water quality impairments. Many of these data were instrumental in developing the nutrient TMDL (CRWQCB 2004), supporting the evaluation of nutrient cycling in the lakes, characterizing spatial and temporal trends in water quality, and modeling the lakes' response to nutrient loads from the watershed. It is expected that continued collection of waterbody monitoring data would support evaluation of trends in nutrient loads and lake water quality in response to application of the TMDL and other pollution control programs implemented in the watershed.

The 2007 Mystic Lake and Agricultural Runoff Monitoring Plan (WRCAC 2007) will provide data that fill important gaps in knowledge about surface water quality in the San Jacinto watershed.

- **It is recommended that existing waterbody data be examined for temporal and spatial trends that would shed light on the possible influence of dairies on observed levels of nutrients and bacteria.**

SJBRCD 2007. Mystic lake and Agricultural Runoff Monitoring Plan

Tetra Tech, Inc. 2005. The Lake Elsinore and Canyon Lake TMDL Monitoring Plan. (LESJWA)

CRWQCB. Lake Elsinore/Canyon Lake Nutrient TMDL Monitoring Reports 2001, 2002

Numerous QAPP documents for specific monitoring activities

Canyon Lake

- Nutrient and Pathogen Data; 1/25/2005 - 12/29/2005
- Nutrient Data; 5/15/2001 - 4/21/2004
- Bacteria data at 5 in-lake stations; 1/2002 - 11/24/2003 and 1/2003 - 12/2004
- 1 station; nutrients, TSS, turbidity, others; 5/22/2003
- 1 station; nutrients, TSS, turbidity, others; 4/22/2003
- 2 stations; nutrients, TSS, turbidity, others; 3/27/2003
- 4 stations; nutrients, TSS, turbidity, others; 1/22/2003-2/4/2003
- Bathymetry data; 1/14/2002
- Assessment of the Occurrence and Distribution of Indicator Organisms in and Near Canyon Lake Quarterly Monitoring Reports, UC Riverside, 2001-2002
- Depth profile data; bacteria, temp, DO, turbidity, ORP, and Chlorophyll a; 8/14/2001-8/13/2002
- 15 stations; bacteria; 8/8/2001-7/16/2002
- Water quality monitoring data; 5/2000 - 6/2001
- Elevation data; 1990-2002
- Bacteria data at 6 in-lake stations, includes data for 2001 sewage spill; 12/14/1990 - 11/20/2002
- Various TMDL Data for the SJ watershed for 4 lake stations
- Historical record of purchased water stored in Canyon Lake; EVMWD

Lake Elsinore

- Anderson, M.A. and R. Lawson. 2005. Continuation of Recycled Water and Aeration Monitoring at Lake Elsinore: July 1, 2004 - June 30, 2005. (SAWPA)
- Nutrient data; 5/15/2001 - 6/25/2002 and 6/2002 - 6/2005
- Chlorophyll A monitoring data; 9/18/2002
- Water quality monitoring data; 5/2000 - 6/2001
- Bathymetry data; 7/2000 - 8/2000

Rivers and streams. Considerable data also exist for the San Jacinto River and streams in the San Jacinto watershed, including nutrient data collected for the TMDL, pathogen data, and discharge data. In addition to the obvious application of some of these data to the TMDL for Canyon Lake and Lake Elsinore, the nutrient data could contribute to assessment of the spatial distribution of both sources and impacts of nonpoint source nutrients in the watershed. Furthermore, pathogen data could be applied to the pathogen source assessment.

- **It is recommended that this watershed water quality database be more closely examined to determine its utility for these purposes and to identify any gaps (spatial and temporal) that should be addressed by additional monitoring in the future.**

San Jacinto River and other surface waters
Bacteria data for 21 stations in SJR watershed; 2/2003, 2/2004, 10/2004, 1/2005; SARWQCB

CRWQCB. San Jacinto River Watershed Nutrient TMDL Monitoring Reports 2001/2002, 2002/2003, 2003/2004, 2004/2005

Bacteria data for 8 stations in Canyon Lake watershed; 3/3/2004 - 10/22/2004; City of Canyon Lake

Pathogen data at channels/drains in San Jacinto Watershed; 2/12/2003 - 2/25/2003; SARWQCB

USGS flow data for gages 11070465 and 11070365; 1983 – 2003

LESJWA. 2002. Citizen monitoring plan for the San Jacinto River Watershed.

Various TMDL data for the SJ watershed for in-stream 15 stations - includes minimal pathogen data; 1/3/1992 - 6/19/2001

Montgomery Watson. 1995. EVMWD San Jacinto River Watershed Sanitary Survey

Peak Flows, Avg Daily Flows; USGS

Ground water. Compared to surface waters, relatively little data appear to exist for ground water quality in the San Jacinto watershed. Data from a USGS assessment of ground water quality in the Santa Ana Watershed provide a snapshot of conditions and patterns in concentrations of major ions, nutrients, pesticides, and volatile organic compounds from 1999 to 2001; however information on ground water flow paths is limited, except at the regional scale. Other work has also helped characterize TDS and nitrogen levels in regional groundwater. While these studies provide a valuable regional scale picture of ground water quality, it is unlikely that the data would be helpful in addressing specific cases of interactions between dairies and ground water or in tracking trends in groundwater quality associated with changes in dairy management.

Current work evaluating the performance of CNMP measures on environmental issues, transport pathways, and potential treatments associated with the reuse of CAFO wastewater on agricultural lands at the field scale in the San Jacinto watershed will have direct application on implementation of management measures on cropland receiving dairy wastewater in the watershed.

Bradford et al. USDA-ARS. Spatio-Temporal Assessment of Nutrient Management Plan (NMP) Performance for Field-Scale Lagoon Water Application at Scott Brothers Dairy Farms [work in progress; numerous interim progress reports available]

Hamlin et al. 2002. *Ground-Water Quality in the Santa Ana Watershed, California: Overview and Data Summary*. U.S. Geological Survey, Water-Resources Investigations Report 02-4243, Sacramento, California . http://pubs.usgs.gov/wri/wri02-4243/text.html

Wildermuth Environmental, Inc. 2000. TIN/TDS Study - Phase 2A Technical Memorandum: Development of Groundwater Management Zones Estimation of Historical and Current TDS and Nitrogen Concentrations in Groundwater.

Fett, John D. and Associates. Geophysical Investigation of SJ Valley

Management/Planning

A number of important management and/or planning studies have been reported that are relevant to dairy management in the San Jacinto watershed. While many of these reports (e.g., the 2004 *San Jacinto Nutrient Management Plan*, and the *Lake Elsinore and Canyon Lake Nutrient TMDL*) provide a broad perspective on nutrient sources in the watershed, there is little that is directly germane to dairy management in 2007. The 1996 EVMWD *San Jacinto Watershed Sanitary Survey* identifies dairies as high risk sources of pathogens in the watershed, identifies some specific problem areas, and makes some general recommendations about management measures for CAFOs; however this information is largely outdated and of little direct use today.

An exception is the 2006 SEP report that included a central objective to provide a list of recommended dairy management technologies and practices for further consideration. Although that list may not be exhaustive, it is a useful starting point for making recommendations on ways to address major dairy issues such as managing dairy wastewater and land application of manure.

Results of two current pilot projects (when reported) should yield important information directly applicable to managing dairy impacts on water quality in the San Jacinto watershed:

- *Spatio-Temporal Assessment of Nutrient Management Plan (NMP) Performance for Field-Scale Lagoon Water Application at Scott Brothers Dairy Farms, San Jacinto, CA* (see above under ground water);
  The project is designed to test current best management practices for waste disposal. Specifically, this project examines the assumption that a well-executed NMP is protective of groundwater and addresses potential weaknesses in the land application design and operation processes. An assessment of the performance and long-term sustainability of a NMP for field-scale dairy lagoon water application will be conducted.

- *Innovative Treatment System for Quality Improvement of CAFO Wastewater Using Vibratory Shear Enhanced Processing (VSEP)*
  This project examines the use of a state-of-the-art treatment process to clean dairy wastewater. On-site treatment and recycling of liquid waste, and subsequent use in-lieu of groundwater, would reduce the dependency upon local groundwater. The reduction in groundwater production, in addition to the reduction of salt and nutrient loading, would also free up assimilative capacity for recycled water use. The pursuit of cost-effective alternatives

for nutrient removal of dairy waste would provide significant water benefits to the San Jacinto Watershed and its communities. The demonstration technologies and multi-dairy plan approach offer a wide range of benefits to dairymen and agriculture within the state and across the country.

"An Analysis of Dairy Waste Management Alternatives for Southern California" by University of California, Riverside 1973 [U-20 06/09/92 SAWPA library]

"Impacts of Animal Confinement Policies on Water Qualify in the City of Norco" by Albert A. Webb Associates January 1978. [A-119 02/18/93 SAWPA library]

"Sources and Sinks of Nitrogen and other Inorganic Constituents in the Santa Ana River above Prado Dam Draft Final Report" by Lanny J. Lund May 1, 1992 [L-85. SAWPA library]

"Bureau of Reclamation on Multi-Constructed Wetlands Research and Demonstration Study" June 1994. EMWD

"Water Quality Control Plan Santa Ana River Basin- Region 8 1995" by CAWQCB January 24, 1995. [C-602. SAWPA library]

"Manure Management Strategy Report for the Chino Basin, Santa Ana River Watershed" by Santa Ana River Watershed Group October 1999. [S-677. SAWPA library]

"Dairy Washwater Pilot Project – Job No. SP2000-70 Specifications and Plans" by Orange County Sanitation District November 2000. [O-117. SAWPA library]

Husing, J.E. 2005. Water and the Santa Ana Watershed's Economy. (SAWPA)

SAWPA. 2005. Santa Ana Integrated Watershed Plan, 2005 Update. Santa Ana Watershed Project Authority, Riverside, CA

CRWQCB. 2004. Resolution No. R8-2004-0037. Resolution Amending the Water Quality Control Plan for the Santa Ana River Basin to Incorporate Nutrient TMDLs for Lake Elsinore and Canyon Lake.

Tetra Tech, Inc. 2004. *San Jacinto Nutrient Management Plan, Final Report.* Submitted to Santa Ana Watershed Project Authority, Riverside, CA.

Xinyu. Li, 2004. *Lake Elsinore and Canyon Lake Nutrient TMDL Technical Report*. Santa Ana Region CRWQCB.

County of Riverside. 2003. Western Riverside County Multi-Species Habitat Conservation Plan

Tetra Tech, Inc. 2003. *Lake Elsinore and Canyon Lake Nutrient Source Assessment, Final Report.* Submitted to Santa Ana Watershed Project Authority, Riverside, CA.

SAWPA. 2002. Santa Ana Integrated Watershed Plan, Volume 1 Water Resources Component. Santa Ana Watershed Project Authority, Riverside, CA.

SAWPA. 2002. Santa Ana Integrated Watershed Plan, Volume 2 Environmental and Wetlands Component, Santa Ana Watershed Project Authority, Riverside, CA.

HEC-1 and HEC-RAS models of SJR (RCFC and WCD)

Montgomery Watson. 1996. EVMWD San Jacinto Watershed Sanitary Survey (SAWPA)

MWH. 2006. *San Jacinto River Watershed Sanitary Survey Update and Canyon Lake Reservoir Senate Bill 979 Compliance Report.* Prepared for Elsinore Valley Municipal Water District, Lake Elsinore, CA.

Bradford et al. 2007 Reuse of CAFO Wastewater on Agricultural Lands: Potential Environmental Contaminants, Transport Pathways, and Treatments. Draft ms submitted to JEQ [also numerous interim progress reports]

Lake Restoration/Remediation

Considerable data exist concerning in-lake approaches to restoration or remediation of Canyon Lake and Lake Elsinore. The studies reported are important because internal loading represents a significant component of the nutrient budget of both water bodies and without some in-lake treatment, response of these water bodies to load reductions from the watershed may be quite slow. The data associated with these studies, however, are not directly relevant to the dairy management planning effort.

Canyon Lake

- Anderson et al. 2007. Canyon Lake Nutrient Monitoring Study: June 2006 – June 2007, Final Report. Submitted to San Jacinto River Watershed Council, Norco, CA. [20 samples from 5 stations to provide data for the determination of compliance with the interim and final nitrogen, phosphorus, chlorophyll a and dissolved oxygen numeric targets. Also for estimation of net sediment nutrient flux and hypolimnetic oxygen demand in the main body of the lake using the hypolimnetic mass balance approach. Comparison with 2001-2002 data.]
- Anderson, M.A., C. Paez and S. Men. 2007. *Sediment Nutrient Flux and Oxygen Demand Study for Canyon Lake with Assessment of In-Lake Alternatives.* Final Report submitted to the San Jacinto River Watershed Council. 24 pp.
- HDR. 2004. Final Environmental Impact Report Canyon Lake Improvement Project. (LESJWA)
- Anderson, M.A. and H. Oza. 2003. *Internal Loading and Nutrient Cycling in Canyon Lake.* Final Report submitted to the Santa Ana Regional Water Quality Control Board. 69 pp.
- HDR. 2002. Canyon Lake East Bay Sediment Characterization. (LESJWA)

- Anderson, M.A. Internal Loading And Nutrient Cycling In Canyon Lake Quarterly Reports. (SAWPA)
- Horne, A.J. 2002. Restoration of Canyon Lake and Benefits to Lake Elsinore Downstream. (SAWPA)
- Anderson, M.A., K. Davis, and M.V. Yates. 2002. The Occurrence and Distribution of Indicator Bacteria in Canyon Lake UC-Riverside.
- Fast, A. W. 2002. Lake Aeration System for Canyon Lake. (LESJWA)
- Horne, A.J. 2002. Restoration of Canyon Lake and benefits to Lake Elsinore downstream. (LESJWA)

Lake Elsinore

- "Compilation of Information on Surface & subsurface Water Studies in Lake Elsinore" by Various Sources December 199x . 20.452 . EVMWD
- Anderson, M.A., 2006. Predicted Effects of Restoration Efforts on Water Quality in Lake Elsinore: Model Development and Results. (SAWPA)
- MWH. 2006. Feasibility Study Report: Nutrient Reduction Alternatives for Regional Water Reclamation Facility Effluent Discharge to Lake Elsinore. (SAWPA)
- Anderson, M.A. and R. Lawson. 2005. Continuation of Recycled Water and Aeration Monitoring at Lake Elsinore: July 1, 2004 - June 30, 2005. (SAWPA)
- Anderson, M.A., 2005. Aeration Monitoring at Lake Elsinore June 2003 - December 2004 (SAWPA)
- EIP Associates. 2005. Fisheries Management Plan for Lake Elsinore. Final Report to LESJWA.
- Kirby, Anderson, Lund, and Poulsen. 2005. Developing a baseline of natural lake-level/hydrologic variability and understanding past versus present lake productivity over the late-Holocene: a paleo-perspective for management of modern Lake Elsinore, Final Report. (LESJWA)
- MWH. 2005. Lake Elsinore Final Stabilization and Enhancement Project Final PEIR. (LESJWA)
- Professional Service Industries, Inc. 2005. Geotechnical exploration report, proposed aeration project. (LESJWA)
- Wildlands, Inc. 2005. Lake Elsinore fish habitat construction project.
- Wildlands, Inc. and Strange Aquatic Resources. 2005. Lake Elsinore Fish Production Pond Design and Management Plan. (SAWPA)
- Anderson, M. 2004. Removal of dissolved phosphorus using calcium amendment. (LESJWA)
- CH2M Hill. 2004. Lake Elsinore Nutrient Removal Study. (SAWPA)
- Nascimento, R.A.V. and M.A Anderson. 2004. Zooplankton Monitoring Report at Lake Elsinore Final Report. (SAWPA)
- Nascimento, R.A.V. and M.A.. Anderson. 2004. Lake Elsinore Recycled Water Monitoring Project Final Report (SAWPA)
- PACE. 2004. Lake Elsinore and Canyon Lake Preliminary Aeration System Report. (SAWPA)
- Anderson, M.A. 2002. Impacts of Alum Addition on Water Quality in Lake Elsinore. (SAWPA)

- Anderson, M. 2002. Evaluation of Calcium Treatment for Control of Phosphorus in Lake Elsinore (LESJWA)
- Cooke, G. D., 2002. Alum Application to Lake Elsinore, California: Questionnaire Update (LESJWA)
- EVMWD. 2002. Pilot Project of Tertiary Treated Wastewater Discharge into Lake Elsinore (SAWPA)
- Fast, A.W. 2002. Proposed Lake Aeration and Biomanipulation for Lake Elsinore, California. (SAWPA)
- Montgomery Watson. 2002. Final Report Engineering Feasibility Study NPDES Permit for Discharge to Lake Elsinore, (LESJWA)
- Prepas. E.E. 2002. Report on Evaluation of Potential Calcium Treatment to enhance Water Quality in Lake Elsinore (LESJWA)
- Tetra Tech, Inc. 2002. Lake Elsinore Replenishment Level Study Alternative Analysis. (SAWPA)
- Anderson, M.A. 2001. Internal Loading and Nutrient Cycling in Lake Elsinore. (SAWPA)
- Cooke, G. D., 2001. Alum Application to Lake Elsinore, California: Responses to Questionnaire (LESJWA)
- Dangermond Group. 2001. Investigation of Potential Funding Sources to Support Environmental and Recreation Projects for Lake Elsinore and the San Jacinto River. (SAWPA)
- HDR, Inc/City of Lake Elsinore. 2001. Lake Elsinore In-Lake Water Quality Treatment Program Draft EIR. (SAWPA)
- 2001 Lake Elsinore Toxics TMDL Monitoring Program Report
- Anderson, M. 2000. Laboratory and limnocosm-scale evaluations of restoration alternatives for Lake Elsinore, Final Report. (LESJWA)
- Montgomery Watson. 1997. Lake Elsinore NPDES Permit Feasibility Study. (SAWPA)
- Black and Veatch. 1995. Lake Elsinore Water Quality Management Plan (SAWPA)
- Noble Consultants. 1994. Lake Elsinore Master Plan Economic Feasibility Study 1995 – 2015. (SAWPA)

Water Supply

Several reports exist concerning water supply issues in the San Jacinto watershed, focusing mainly on water reclamation issues. Information such as the 2004 USGS report on concentrations of dissolved salts in water sources may be relevant to the salt offset component of the Dairy Management Plan.

California Potable Reuse Committee. A Proposed Framework for Regulating Indirect Potable Reuse of Advanced Treated Reclaimed Water by Surface Water Augmentation

Lee, T-C; A. Williams, and C. Wang. An Artificial Recharge Experiment in the San Jacinto Basin

Edwards, Kenneth L. Analysis of Spreading Operations and Stream Flow Perc. in SJ River

Biehler, S., and T-C. Lee. Basin Structures in Central SJ River Watershed

Boyle Engineering, Inc. Brackish Groundwater Reclamation Study Vol 1 Rep1
Dunbar, Keith S., and Assoc. Ca RWQCB Waste Discharge and Producer Reclamation Requirements for EMWD/Draft EIR SJ Water Reclamation Prog.

Belitz, K. (USGS) 2004. Concentrations of Dissolved Solids and Nutrients in Water Sources and Selected Streams of the Santa Ana Basin, Calif., Oct. 1998-Sept. 2001, Water Resources Investigations Report 03-4426, National Water Quality Assessment Program.

Sonderegger and Hincks Conditions of SJ Watershed Water Supply

Boehm, J.C. Considerations for a Project at Lake Perris to put Seepage Water into the EMWD System

HydroScience and Technology, Inc. Evaluation of Feasibility and Requirements for a Reclaimed Water Recovery Well, Moreno Valley

Fritz, J., and F. Rosell Maximum Safe Yield of Water from Hemet-San Jacinto Valley

Ground Water Management

Ground water management plans and reports for the San Jacinto provide mainly regional overviews of ground water characteristics and conditions; as such they have limited utility to the dairy management plan. Synoptic surveys of ground water quality (such as the 2006 EMWD report of the Groundwater Management Plan for the West San Jacinto Groundwater Basin and the USGS overview of ground water quality data (Hamlin et al. 2002)), however, may be useful in generally identifying areas of significant ground water quality problems deserving additional investigation if the problems appear to be associated with dairies.

“Final Report on Representative Water Quality Problems: Early Action on Mineral Pollution in Groundwater, Water Quality Management from Liquid Wastes, and Solid Waste Streams of Dairy Industry in Chino-Corona Area” by Pomeroy, Johnston and Baily October 1977 [P-20 12/21/92 SAWPA library]

"A Groundwater Model and the Hydrogeology of the San Jacinto Valley with Emphasis on the Soboba Indian Reservation" by Fliegner, Julianne F. December 1978 . . . EMWD

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Other

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San Jacinto Watershed Resource Data List

http://www.sawpa.org/lesjwa/documents/misc/SJWR%20Data%20List.pdf

Note: most items on this list are general references, not specific to the San Jacinto watershed; many are outdated. Those judged potentially useful and relevant to the IRDMP have been included on the lists above.

References

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Appendix B – Mystic Lake and Watershed Monitoring Quarterly Report #2

Mystic Lake and Watershed Monitoring

Quarterly Report #2

January – May 2008

Final
July 17, 2008

Submitted to
San Jacinto Basin Resource Conservation District

Submitted by
Tetra Tech

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Funding for this project has been provided in full or in part through an agreement with the California State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. (Gov. code 7550, 40 CFR 31.20).

Background

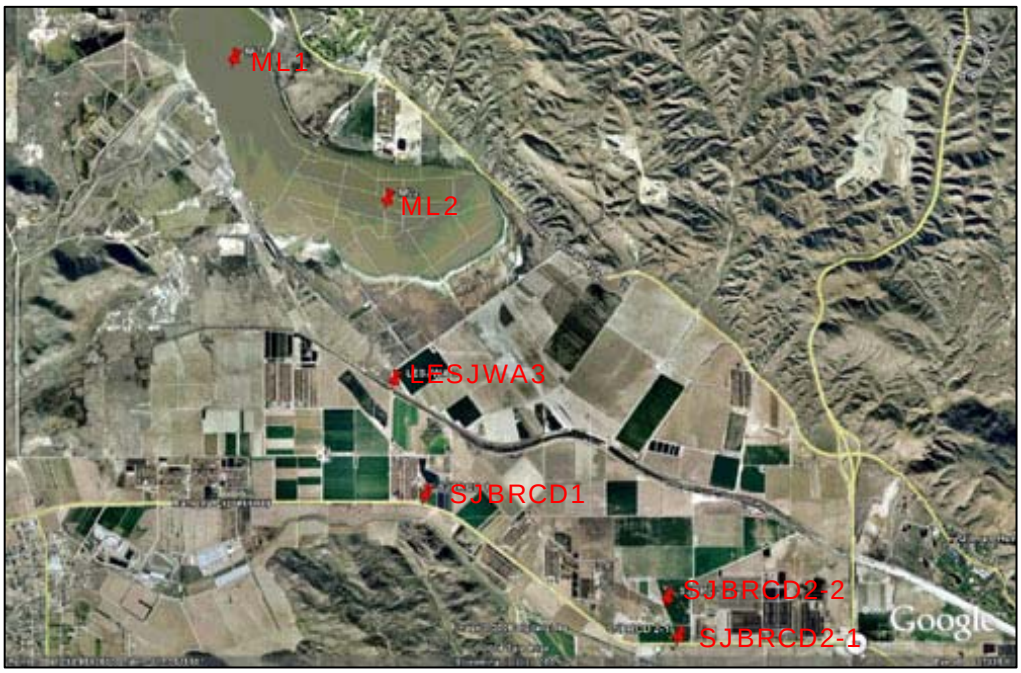
To address implementation of Total Maximum Daily Loads (TMDLs) for Lake Elsinore and Canyon Lake and to provide information for future management and planning, the San Jacinto Basin Resource Conservation District (SJBRCD) is conducting monitoring in Mystic Lake and in key areas within the San Jacinto River watershed. Monthly sampling is conducted at two stations on Mystic Lake. Flow monitoring and water quality sampling of one storm event over each storm season (September 1 to April 30) are conducted at three locations in the San Jacinto Watershed. Monitoring site locations are described in Table 1 and Map 1. Data are collected by Weston Solutions, Inc. and are reported quarterly by Tetra Tech, Inc.

Table 1. Description of Monitoring Sites

Site Name	Location (Long/Lat)	Station Type	Type of Sampling
ML1	-117.0909, 33.8906 North end of Mystic Lake	Lake	Grab
ML2	-117.0694, 33.8742 South end of Mystic Lake	Lake	Grab
SJBRCD 1	-117.0640, 33.8398 Ramona Expy near Bridge St., Te Velde property	Culvert under bridge crossing	Continuous flow monitoring and time weighted grabs
SJBRCD 2-1	-117.0284, 33.8233 Ramona Expy east of Warren Rd., Bert Lauda property	Culvert under bridge crossing	Continuous flow monitoring and time weighted grabs
SJBRCD 2-2	-117.030036, 33.827732 near Ramona Expressway and Warren Road 0.5 km N of SJBRCD2-1	Agricultural irrigation ditch	Continuous flow monitoring and time weighted grabs
LESJWA 3	-117.0684, 33.8531 San Jacinto R. at Bridge St.	Culvert under bridge crossing	Continuous flow monitoring and time weighted grabs

Monitoring Status

Monitoring was completed in May, 2008. Monitoring was conducted according to the Quality Assurance Project Plan (QAPP) dated September 27, 2007. Flow data were collected at the three channel stations (SJBRCD1, SJBRCD2, and LESJWA 3) during several storm events through April, but no water quality samples were taken. A small storm event in late May, 2008 was sampled. Station SJBRCD2-1 (previously monitored) was relocated in late February; that new station is subsequently identified as SJBRCD2-2. Some technical flow measurement issues continued to be encountered, as discussed below. Samples were collected from both Mystic Lake stations (ML1 and ML2) in January, February, March, and April.



Map 1. Location of monitoring stations.

Precipitation and Flow Data

Daily precipitation data were obtained from Weston Solutions. Because all available weather stations had substantial missing data, Weston assembled a "best professional judgment" precipitation record using data from several gauges: San Jacinto, Hemet, Winchester, and Perris. Rainfall was relatively frequent over the reporting period. A total of 4.82 inches of rain was recorded from January 1, 2008 through May 31, 2008 when monitoring was completed; the largest storm of the period occurred over January 27 – 29, when 0.74 inches of rain were recorded. Daily rainfall totals over this period are plotted in Figure 1.

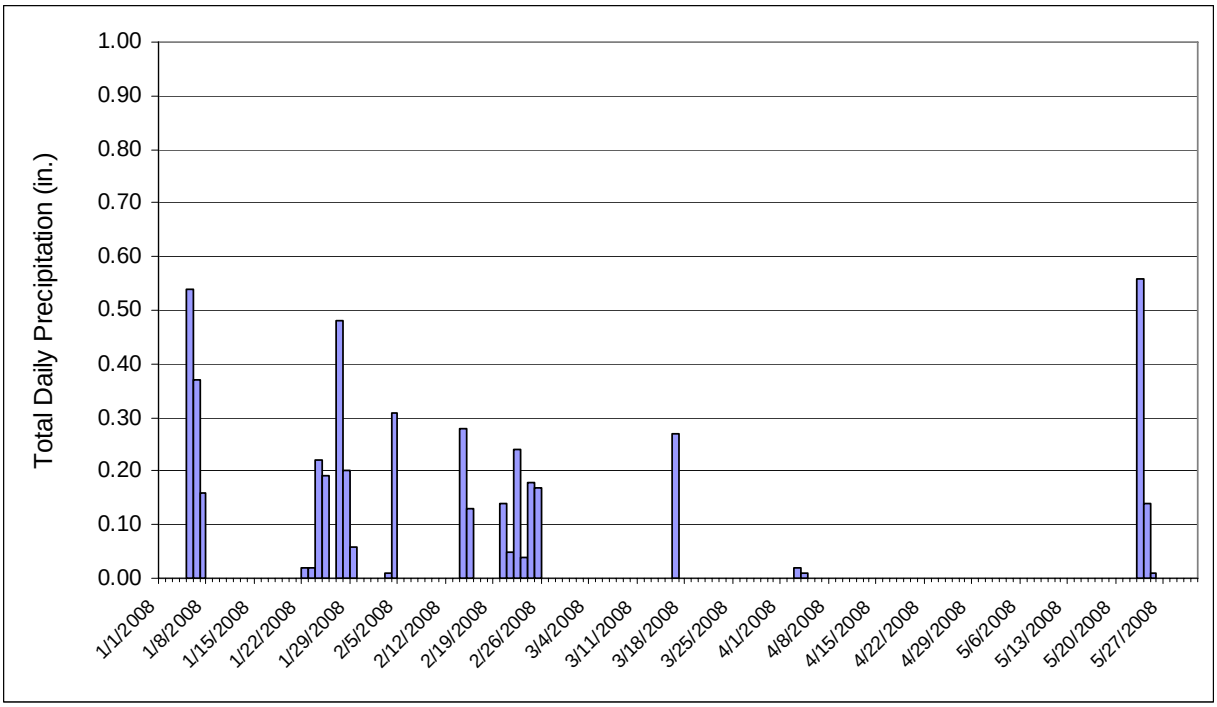


Figure 1. Daily total precipitation January 1 – May 31, 2008 (Weston Solutions).

During this reporting period, Weston made efforts to correct the technical difficulties in flow measurement experienced in the last quarter. At SJBRCD1, the sensor was repositioned in the culvert to permit more accurate low flow measurement. Because of backwater issues that could not be corrected at the site, station SJBRCD2 (now designated SJBRCD2-1) was abandoned on February 21, 2008. On the same day monitoring began at a new location designated SJBRCD2-2 approximately 0.5 km north of SJBRCD2-1. This site was selected because it appeared to be better drained and did not appear to be subject to ponding. Unfortunately, shortly after this relocation, it was discovered that the City of San Jacinto, in order to alleviate some severe erosion issues in the area, has diverted some of the flows that normally would have been captured at SJBRCD2. The current flow is apparently not captured at any of the SJBRCD2 locations nor is it captured at SJBRCD1. The City of San Jacinto has indicated that the flow will be returned to its original path; however, at the time of the sampled storm event, the flow was still diverted.

The frequent rainfall during the period led to numerous and extended periods of flow at the monitoring stations. Seven significant flow events were monitored at SJBRCD1; hydrographs for these events are plotted in Figures 2 through 8.

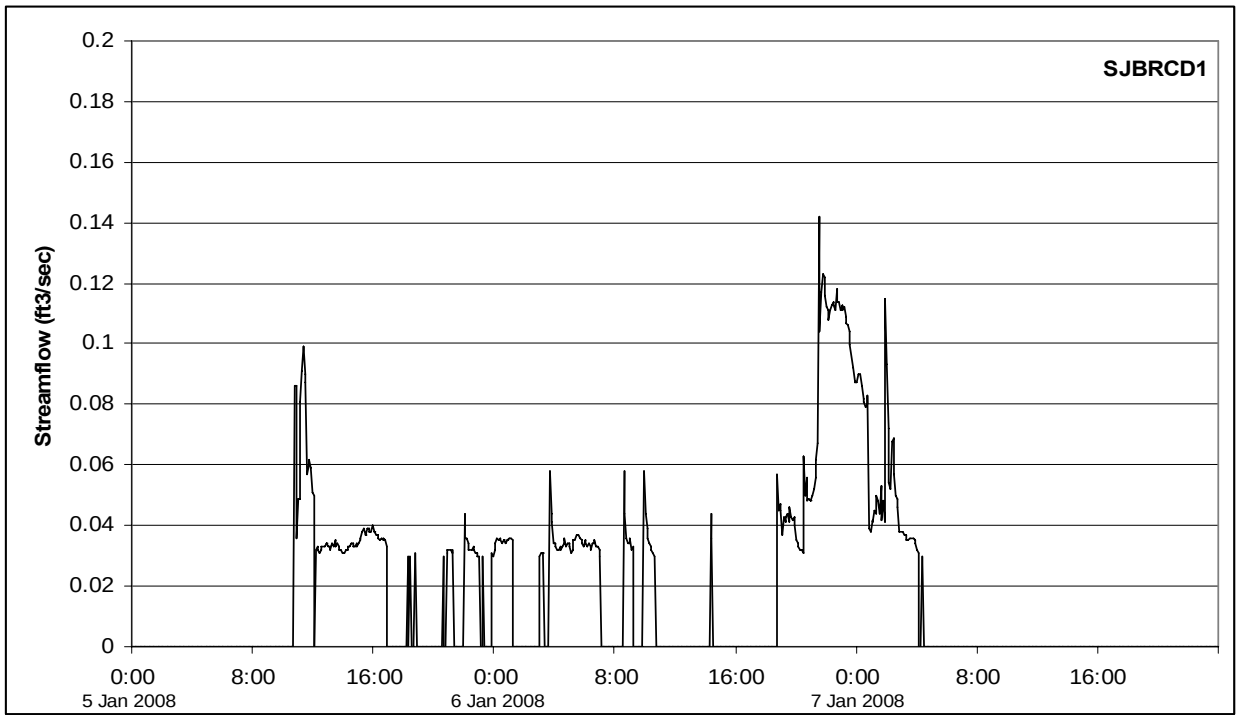


Figure 2. Hydrograph for Station SJBRCD1, January 5 – 7, 2008.

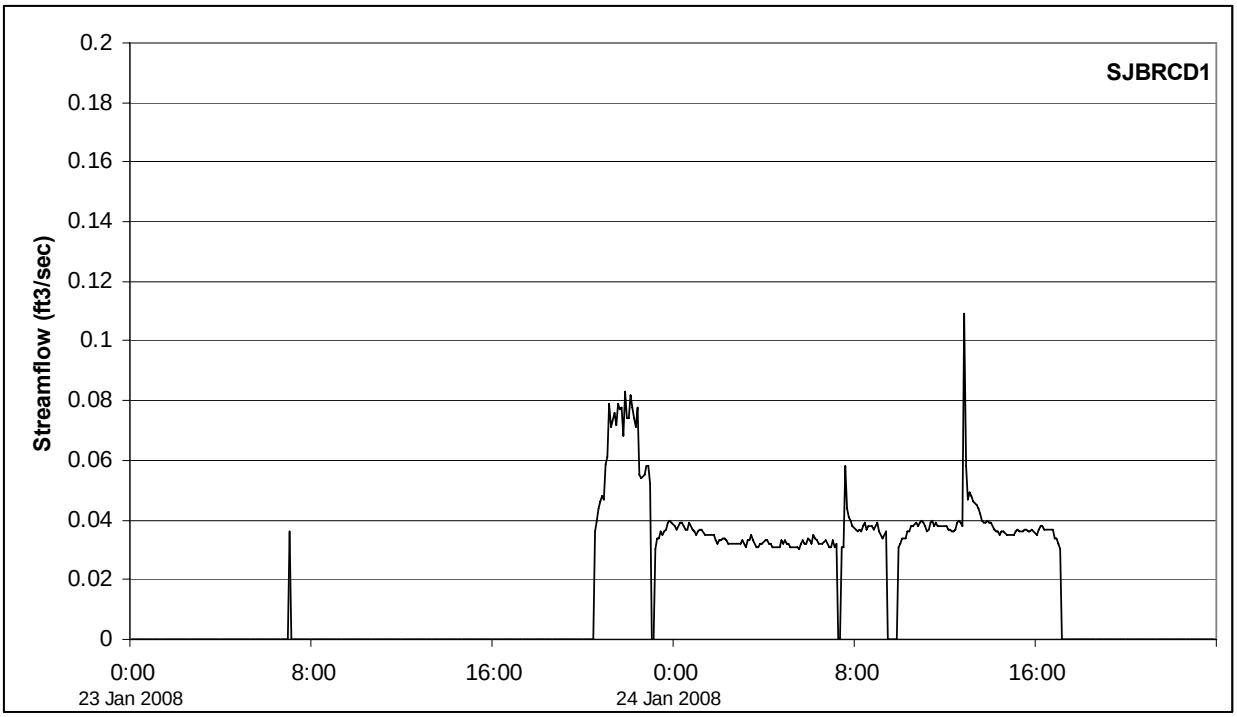


Figure 3. Hydrograph for Station SJBRCD1, January 23 - 24, 2008.

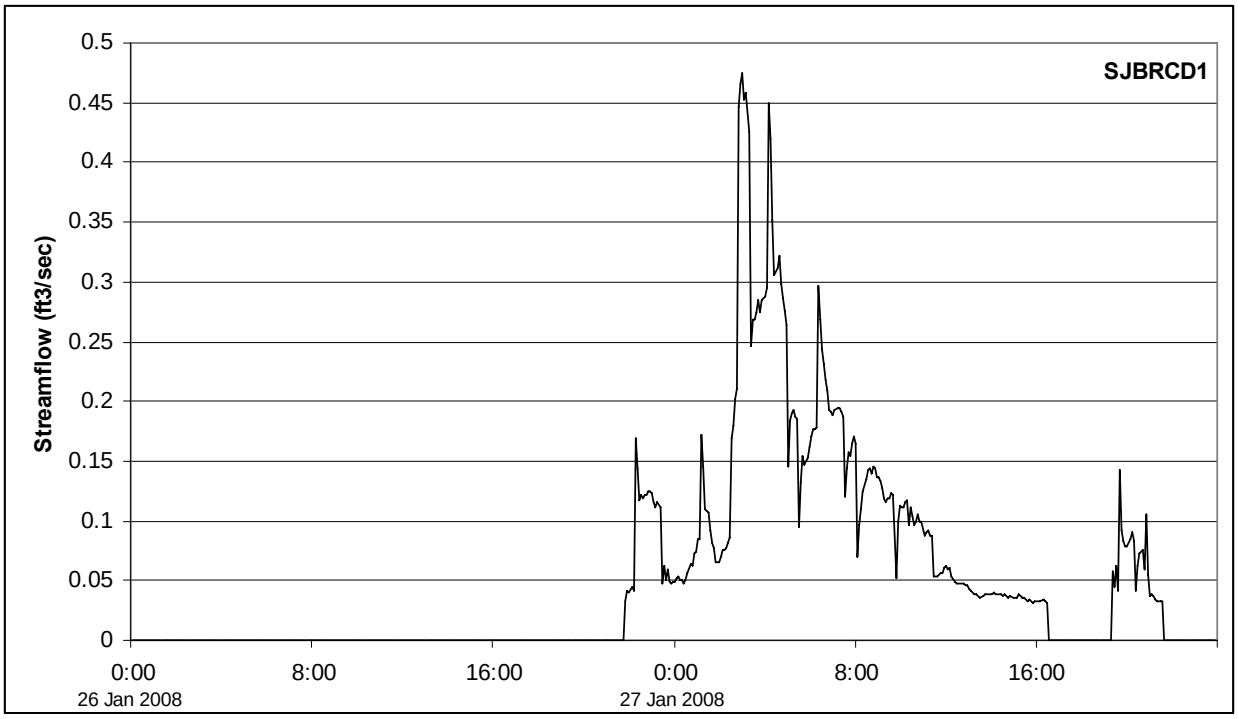


Figure 4. Hydrograph for Station SJBRCD1, January 26 – 27, 2008.

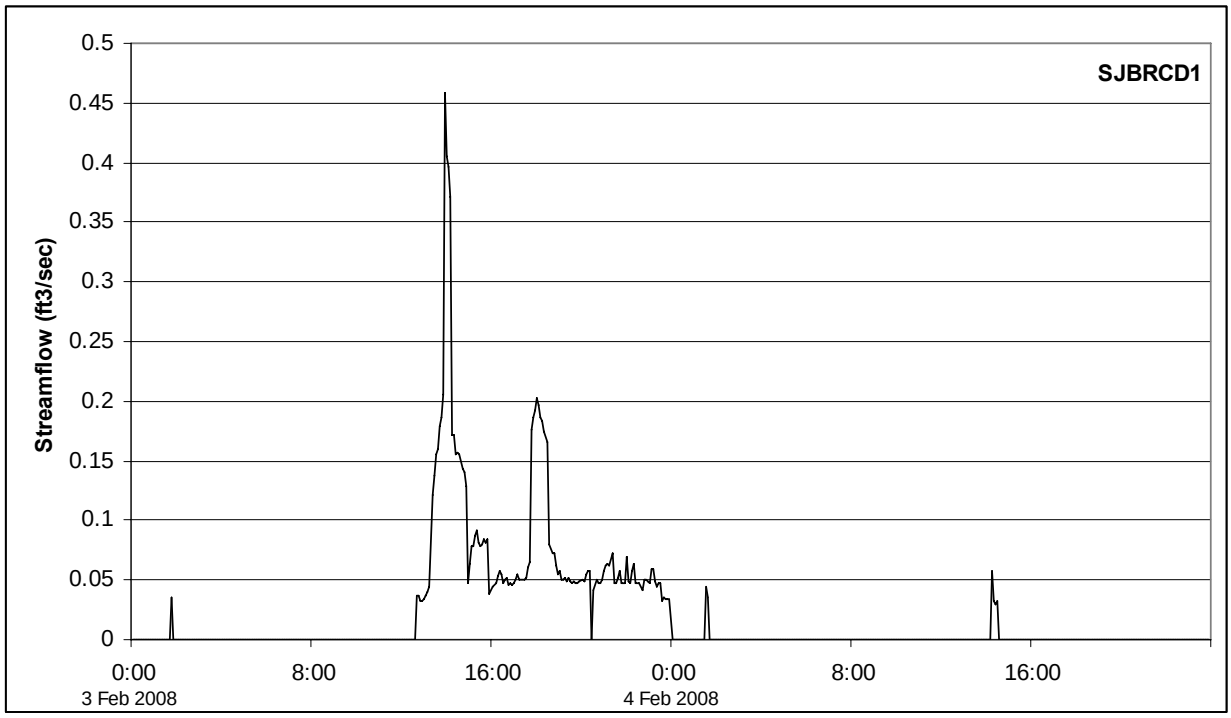


Figure 5. Hydrograph for Station SJBRCD1, February 3 – 4, 2008.

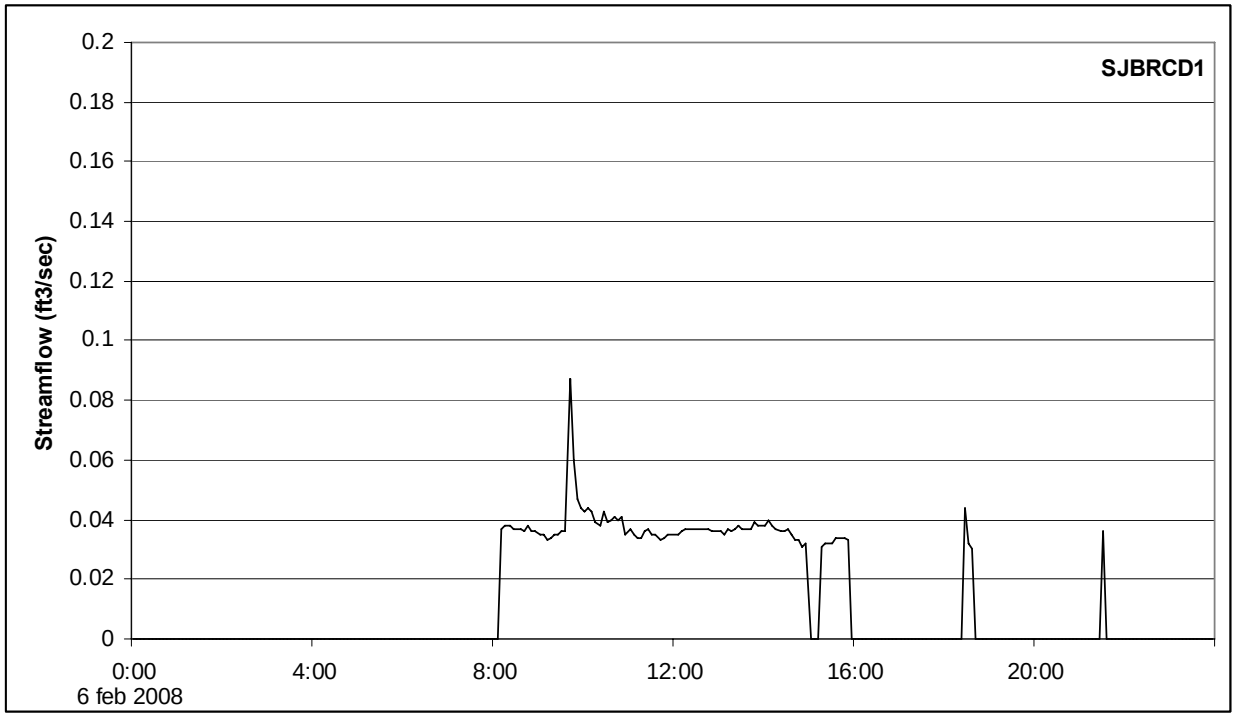


Figure 6. Hydrograph for Station SJBRCD1, February 6, 2008.

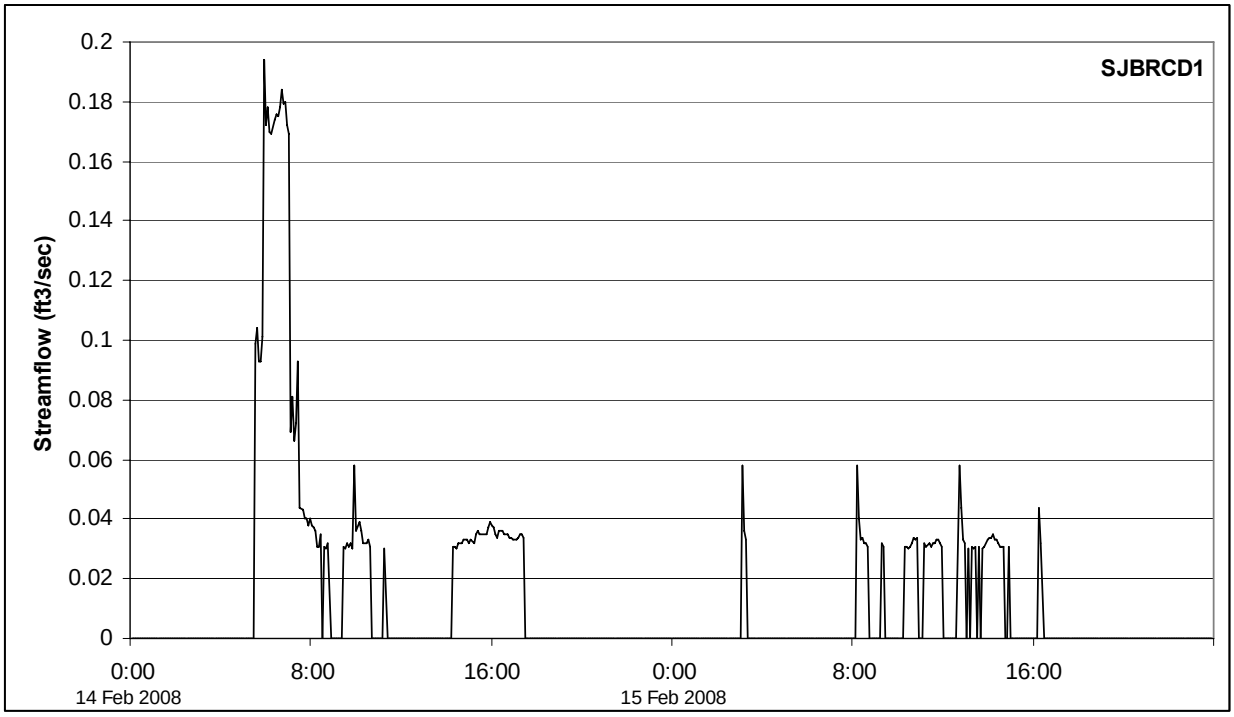


Figure 7. Hydrograph for Station SJBRCD1, February 14 – 15, 2008

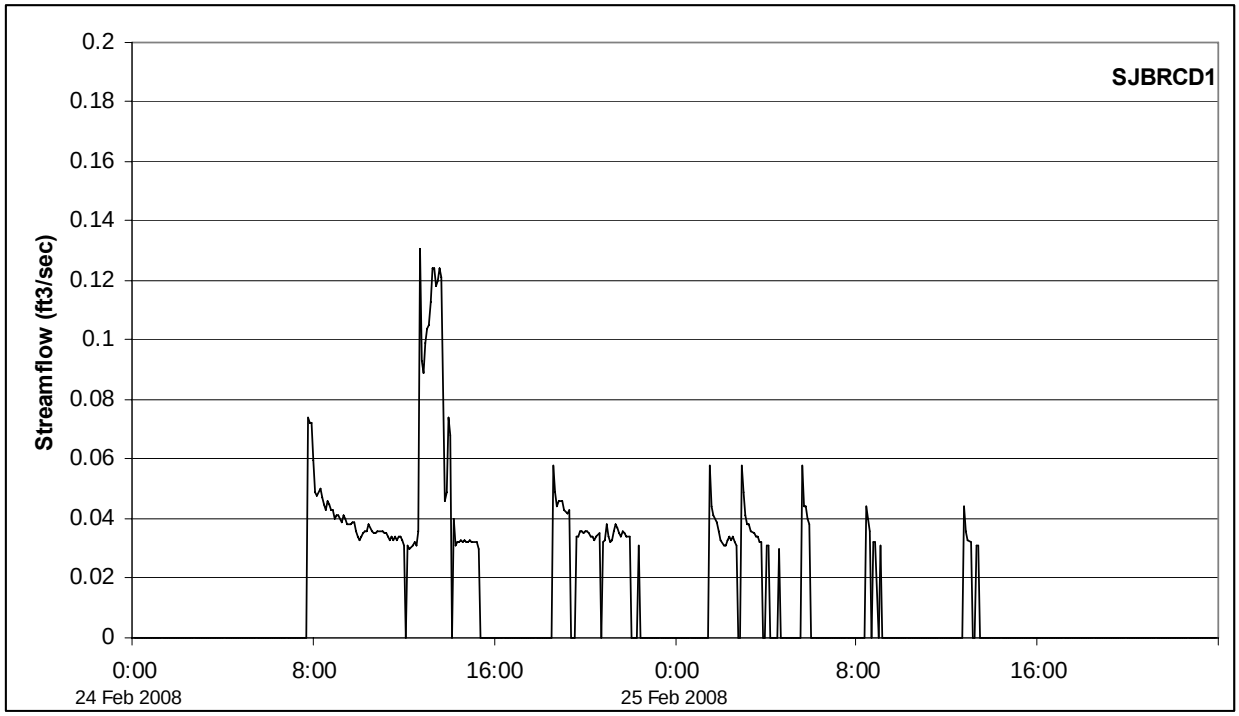


Figure 8. Hydrograph for Station SJBRCD1, February 24 – 25, 2008

Although frequent, flows at SJBRCD1 were generally small; peak flow rate during the period was less than 0.5 ft^3/s (January 27, 2008). The choppiness in the hydrographs at very low flows (e.g., Figures 2, 7, and 8) appears to be an artifact of a threshold for measuring very low water depths in the culvert. It appears that water must be >0.6 inches deep for non-zero stage (and flow) to be recorded; before this threshold is achieved, the system detects a stage and flow of zero. As flow recedes, a similar abrupt transition from a small stage/flow to zero is also recorded as the water drops below the threshold. This threshold may represent either the depth of the corrugation or the thickness of the sensor itself.

An extended hydrograph for station SJBRCD2-1 prior to the change in monitoring location is shown in Figure 9.

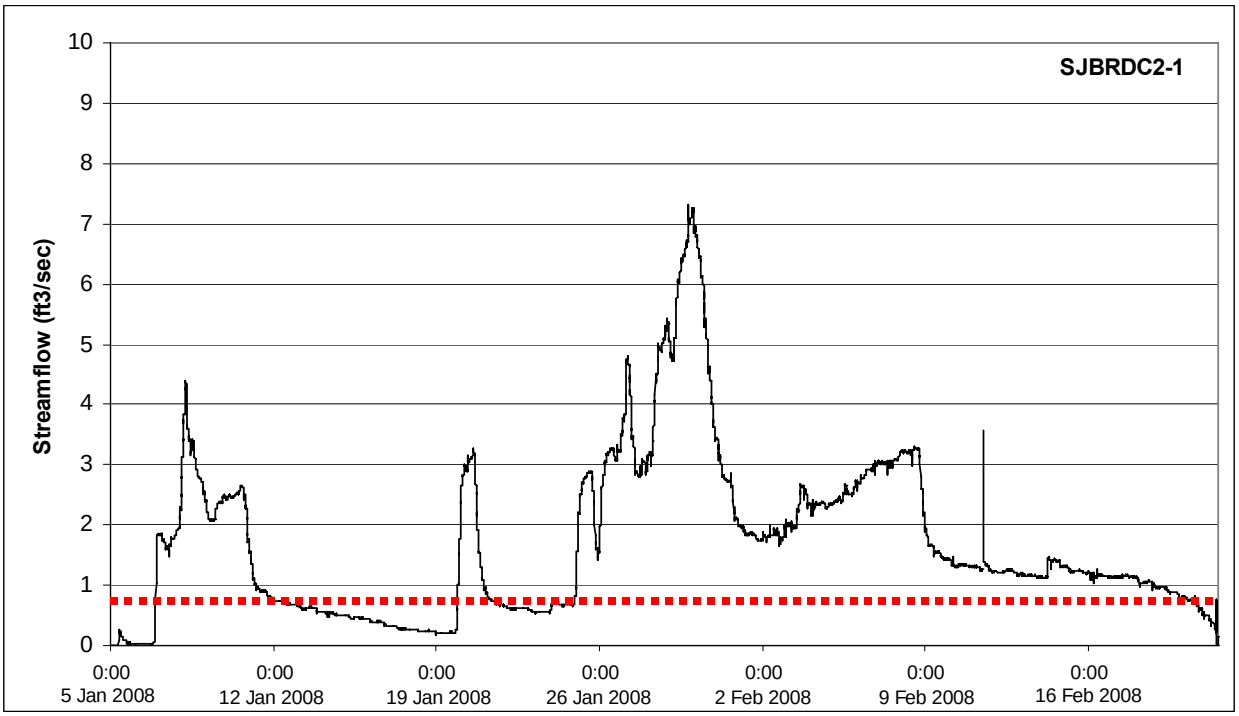


Figure 9. Hydrograph for Station SJBRCD2-1, January 5 – February 21, 2008. Horizontal dashed line represents backwater threshold.

Flows above the horizontal dashed line in Figure 9 are not valid, as stage in the culvert was controlled by backwater during these periods. While spikes in apparent flow over the period can be seen reflecting the frequent rain events, flows at this station cannot be meaningfully interpreted due to the backwater effect.

Following station relocation, six significant flow events were monitored at SJBRCD2-2; hydrographs for these events are plotted in Figures 10 through 15.

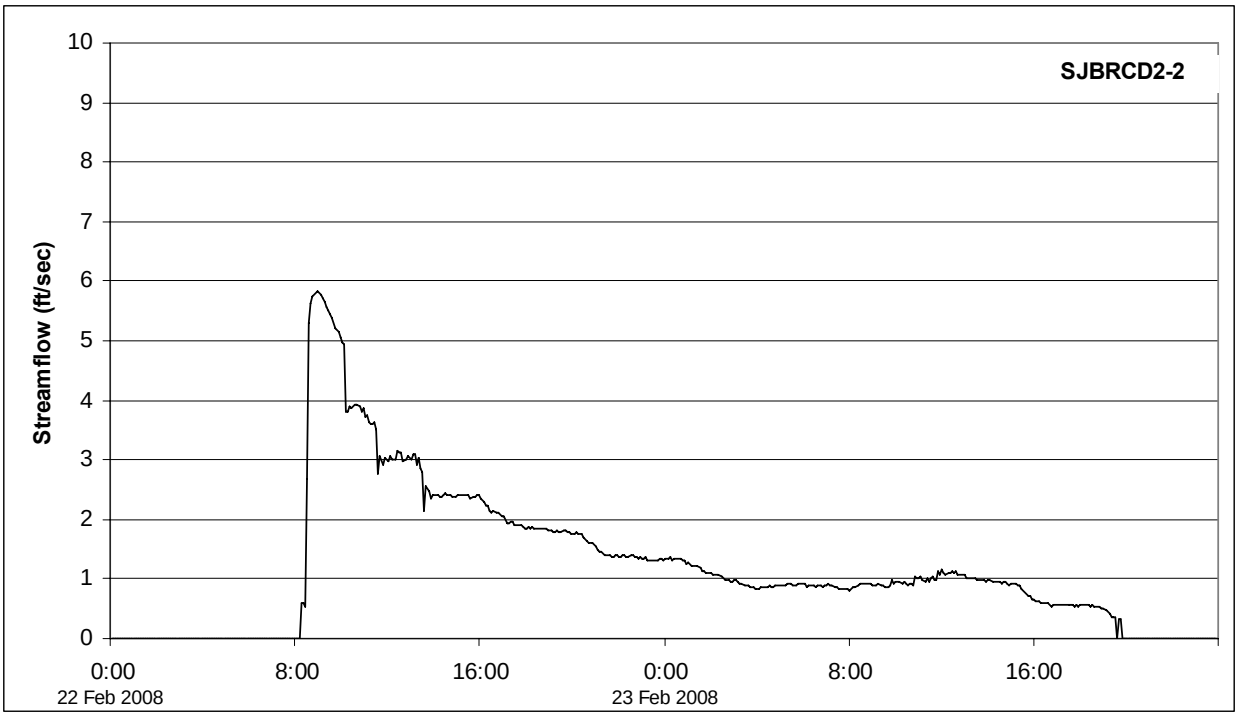


Figure 10. Hydrograph for Station SJBRCD2-2, February 22 – 23, 2008.

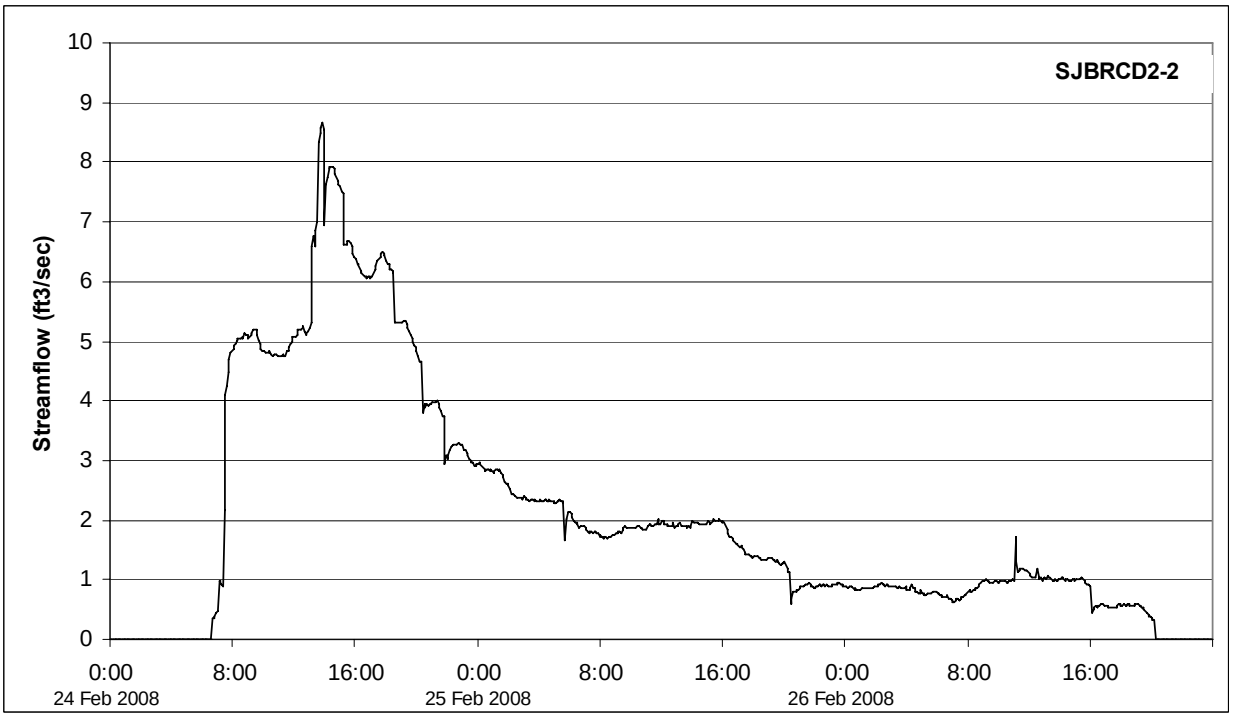


Figure 11. Hydrograph for Station SJBRCD2-2, February 24 – 26, 2008.

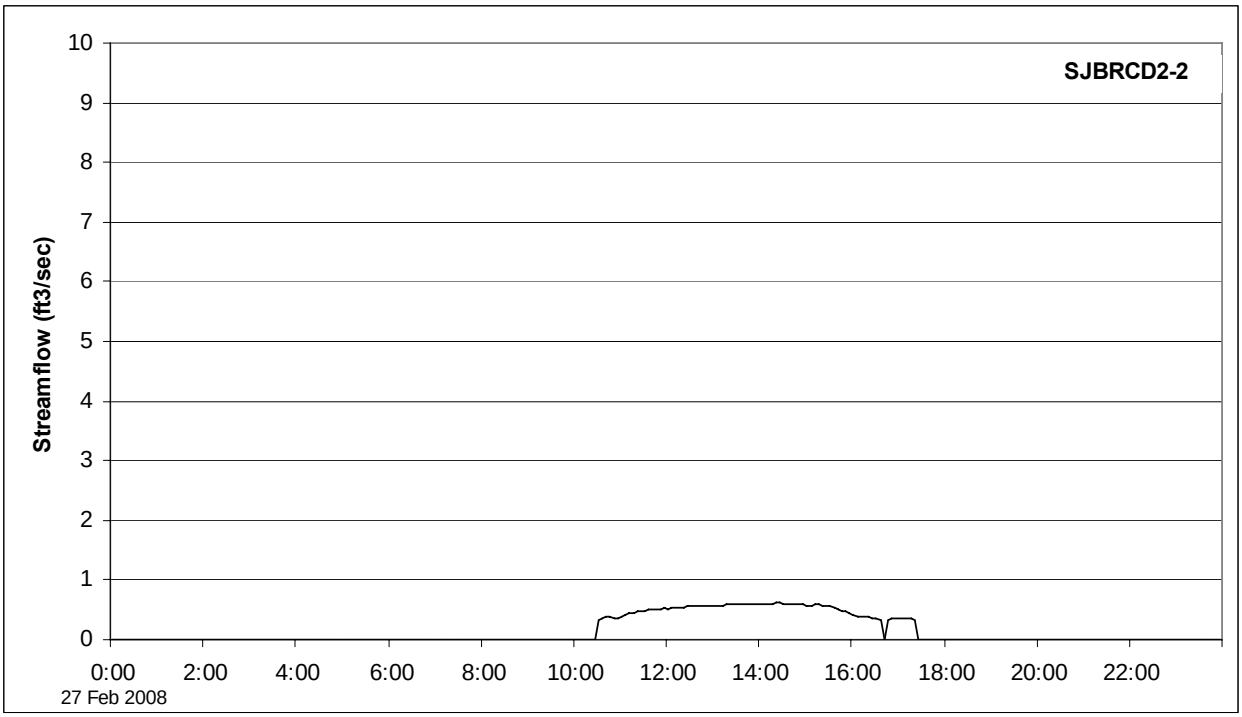


Figure 12. Hydrograph for Station SJBRCD2-2, February 27, 2008.

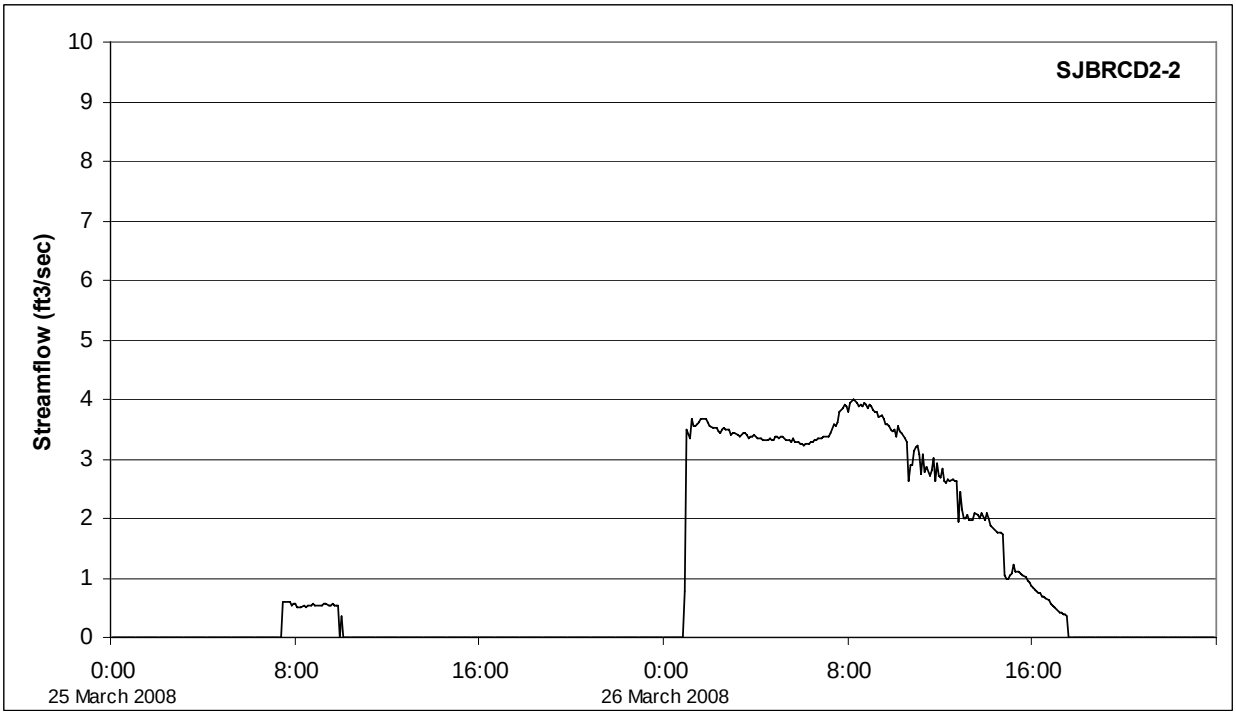


Figure 13. Hydrograph for Station SJBRCD2-2, March 25 – 26, 2008.

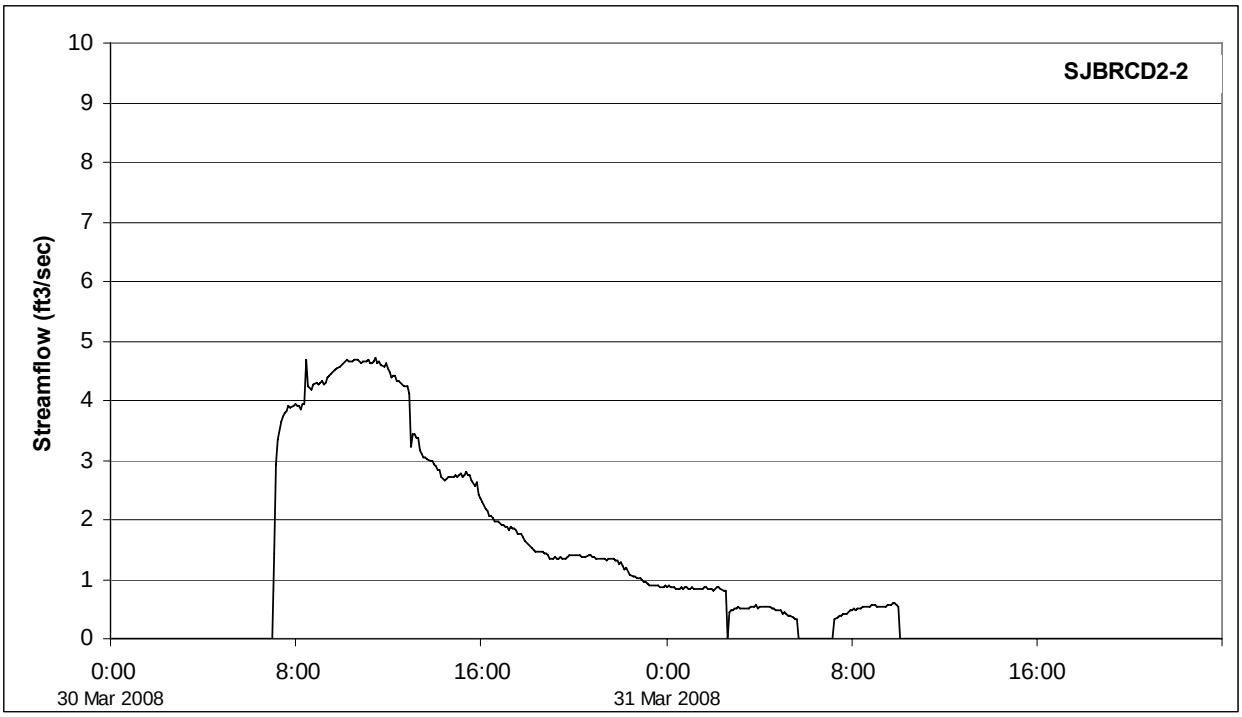


Figure 14. Hydrograph for Station SJBRCD2-2, March 30 – 31, 2008.

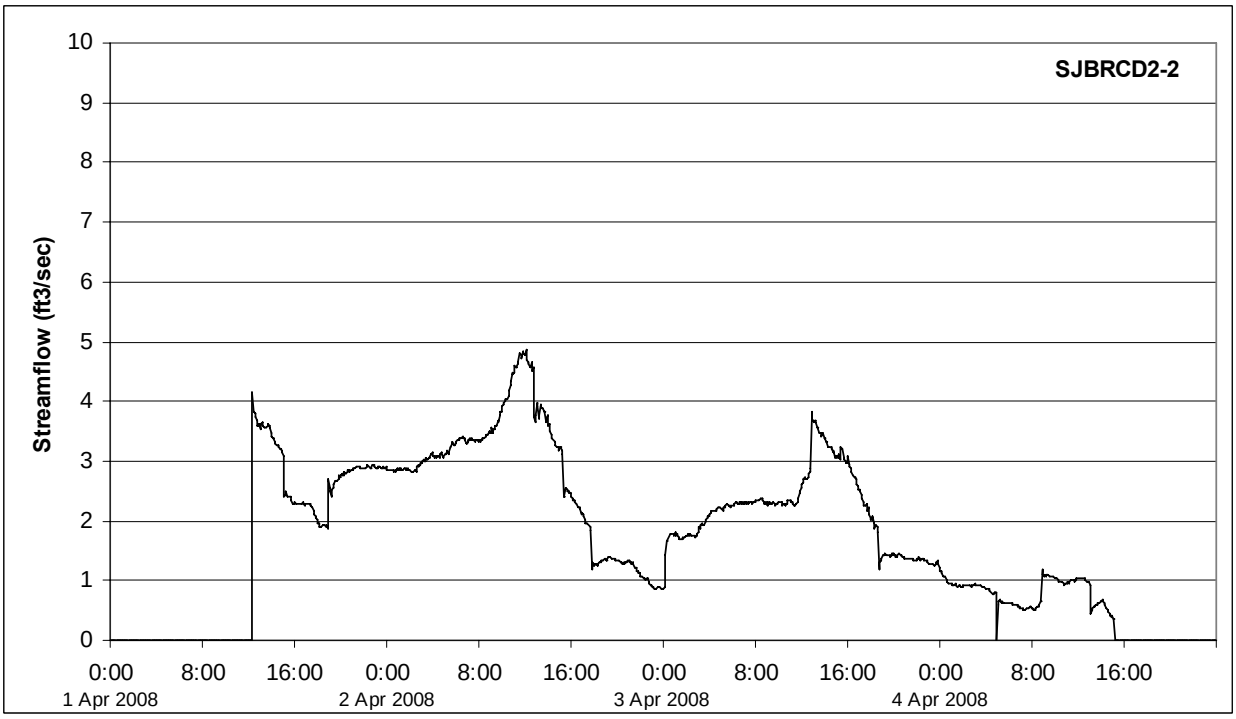


Figure 15. Hydrograph for Station SJBRCD2-2, April 1 – 4, 2008.

Flows at SJBRCD2-2 were moderate and exceeded those recorded at SJBRCD1 by one to two orders of magnitude; peak flow rate during the period was 8.7 ft^3/s (February 24, 2008). The choppiness seen in SJBRCD1 hydrographs was generally absent from SJBRCD2-2 except at the beginning and end of the event because the stage and flow were so much higher at SJBRCD2-2.

Flow occurred during two extended events at LESJWA3, as shown in Figures 16 and 17. Flow was continuous at this station from January 26 through March 12, 2008 (Figure 17) and showed periodic spikes reflecting individual rainfall events. Flows at LESJWA3 were quite high compared to those at the other two stations; peak flow rate during the period was 177 ft^3/s (January 31, 2008).

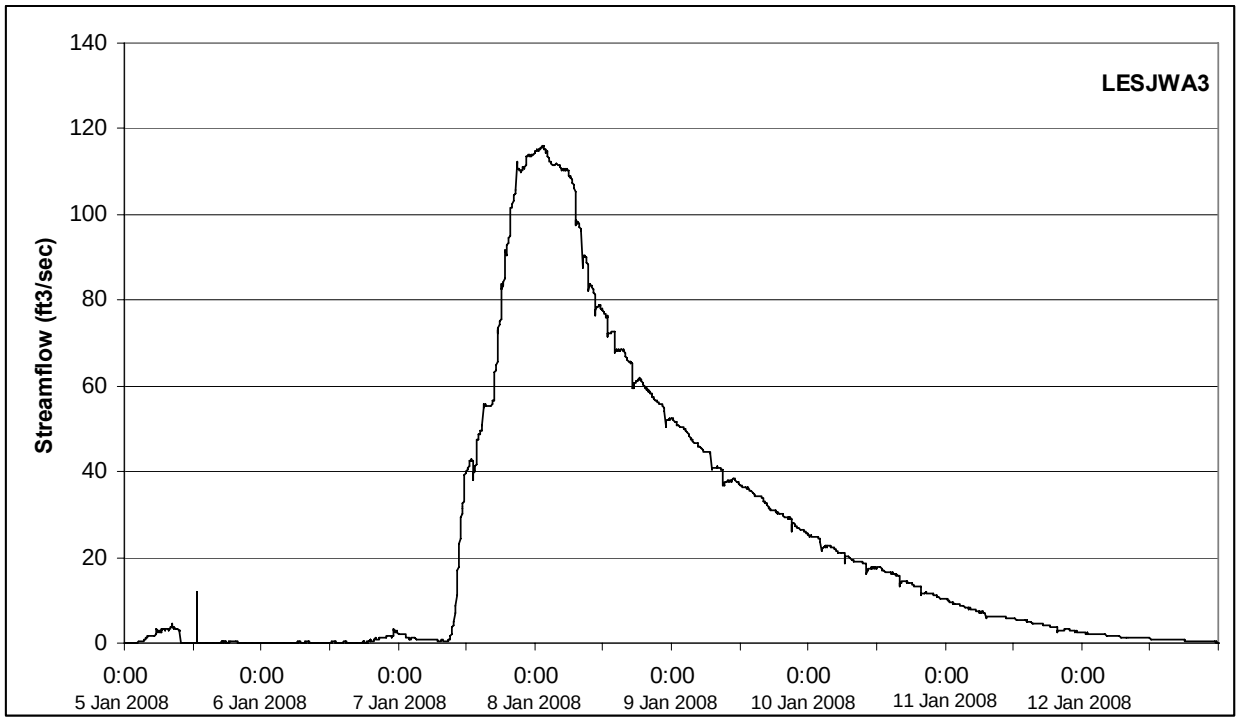


Figure 16. Hydrograph for Station LESJWA3, January 5 - 12, 2008

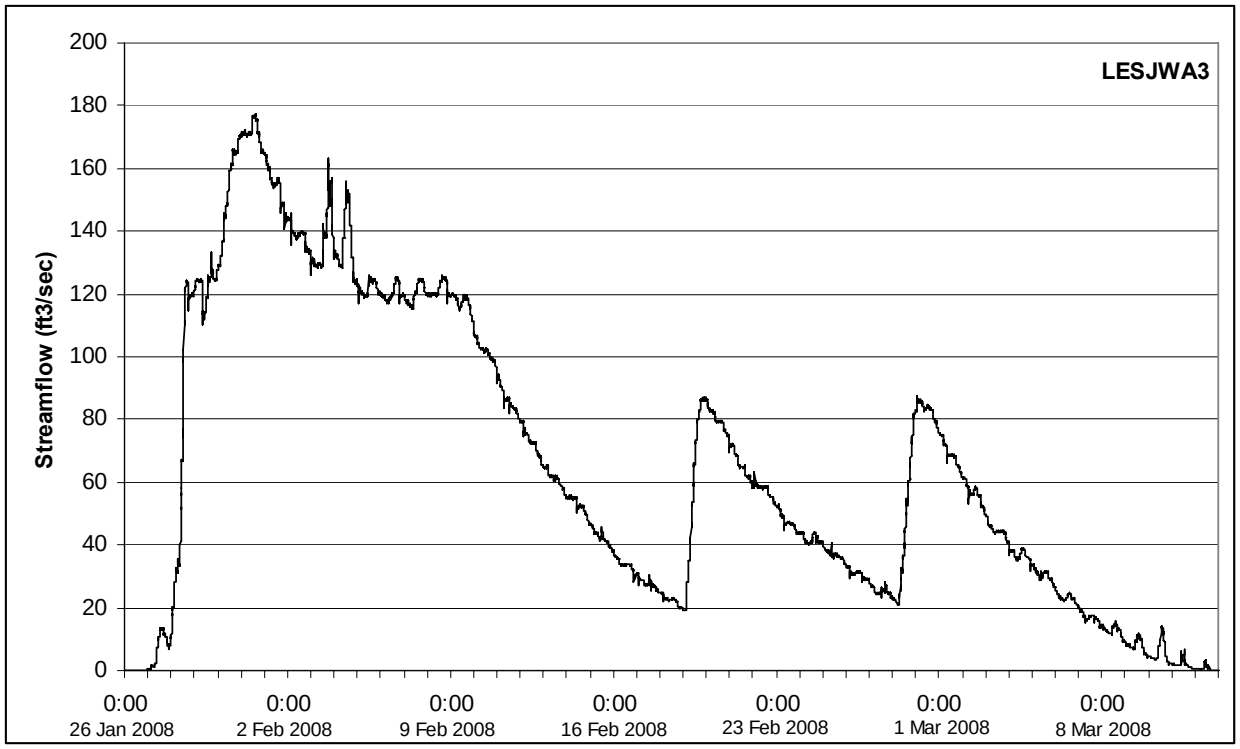


Figure 17. Hydrograph for Station LESJWA3, January 26 – March 12, 2008

Total discharge from the three monitored stations recorded during the period is summarized in Table 2. Flow did not occur simultaneously at the three stations, probably due to differences in drainage area size and hydrology and possibly due to variations in precipitation distribution. The relative magnitude of flow at the three stations is clearly shown.

Table 2. Summary of event discharge from monitoring stations, January – April, 2008.

SJBRCD1		SJBRCD2-2[1]		LESJWA3	
Date	**Discharge (ft^3)**	**Date**	**Discharge (ft^3)**	**Date**	**Discharge (ft^3)**
Jan 5–7	4,270			Jan 5–13	1.62×10^7
Jan 23–24	2,848				
Jan 26-27	8,890			Jan 26–Mar 12	2.66×10^8
Feb 3–4	3,526				
Feb 6	1,052				
Feb 14–15	2,281	Feb 22–23	206,370		
Feb 24–25	2,278	Feb 24–26	531,337		
		Feb 27	12,292		
		Mar 25–26	170,540		
		Mar 30–31	182,170		
		Apr 1–4	583,719		
Period Total	**2.51×10^4**		**1.69×10^6**		**2.82×10^8**

[1] Discharge data from monitoring station SJBRCD2-1 are not included as the backwater issue at this station prevents meaningful interpretation of the data.

Storm Event Samples

On May 22, 2008, a small storm event was monitored at the three watershed stations. Runoff began the evening of May 22 and lasted only a few hours at the SJBRCD1 and LESJWA3 stations; flow at the SDBRCD2-2 station lasted from May 22 into May 24.

Precipitation

The monitored event occurred in response to about 0.70 in. of precipitation that occurred on May 22 – 23, 2008. Unfortunately, only daily rainfall totals are available, so information on flow timing relative to rain does not exist.

Flow

Flow at the SJBRCD1 station lasted less than one hour, beginning at 19:05 on May 22 and ending at 19:50 (Figure 18). Maximum flow rate during the event was 0.044 ft^3/sec (1.25 L/sec), representing a water depth of less than one inch. Total discharge for the event was 113 ft^3 (3,203 L).

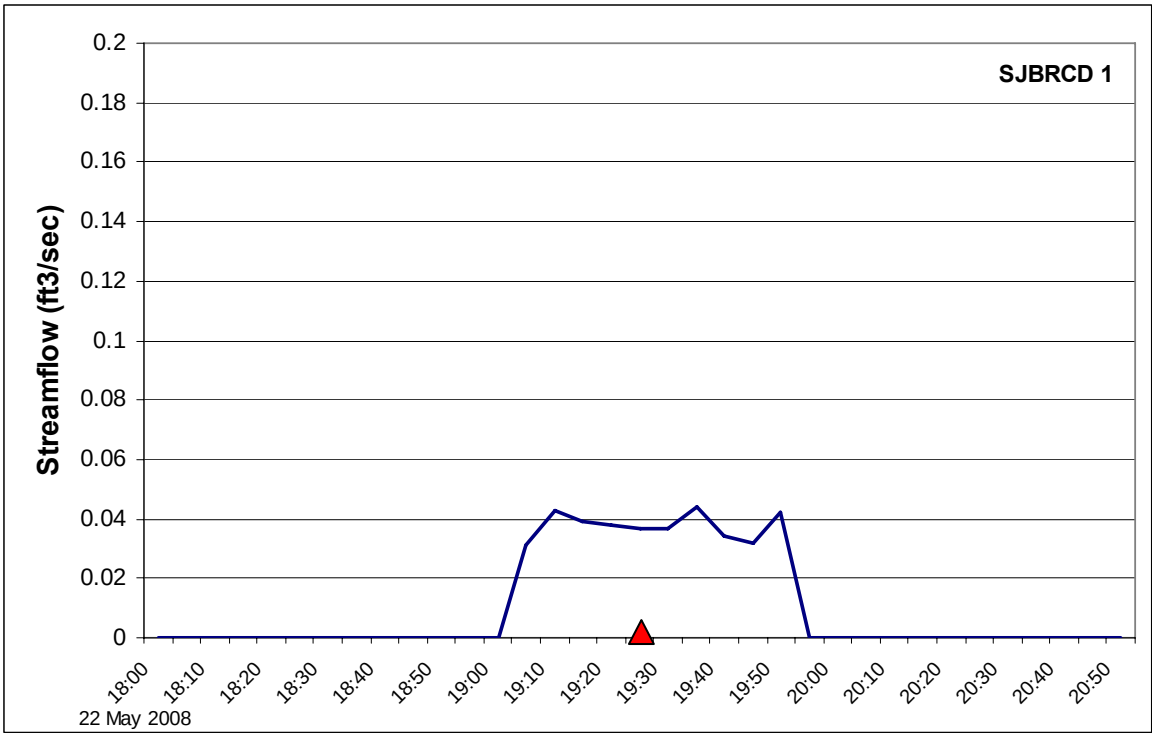


Figure 18. Hydrograph for May 22, 2008 storm event at station SJBRCD1. Triangle represents time water sample was collected.

Flow at the SJBRCD 2-2 (new location) station lasted 42.5 hours, beginning at 17:555 on May 22 and ending at 12:23 on May 24 (Figure 19). Maximum flow rate of 1.98 ft^3/sec (56 L/sec) occurred early in the event, representing a water depth of about 2 inches. Total discharge for the event was 209,866 ft^3 (5.94×10^6 L).

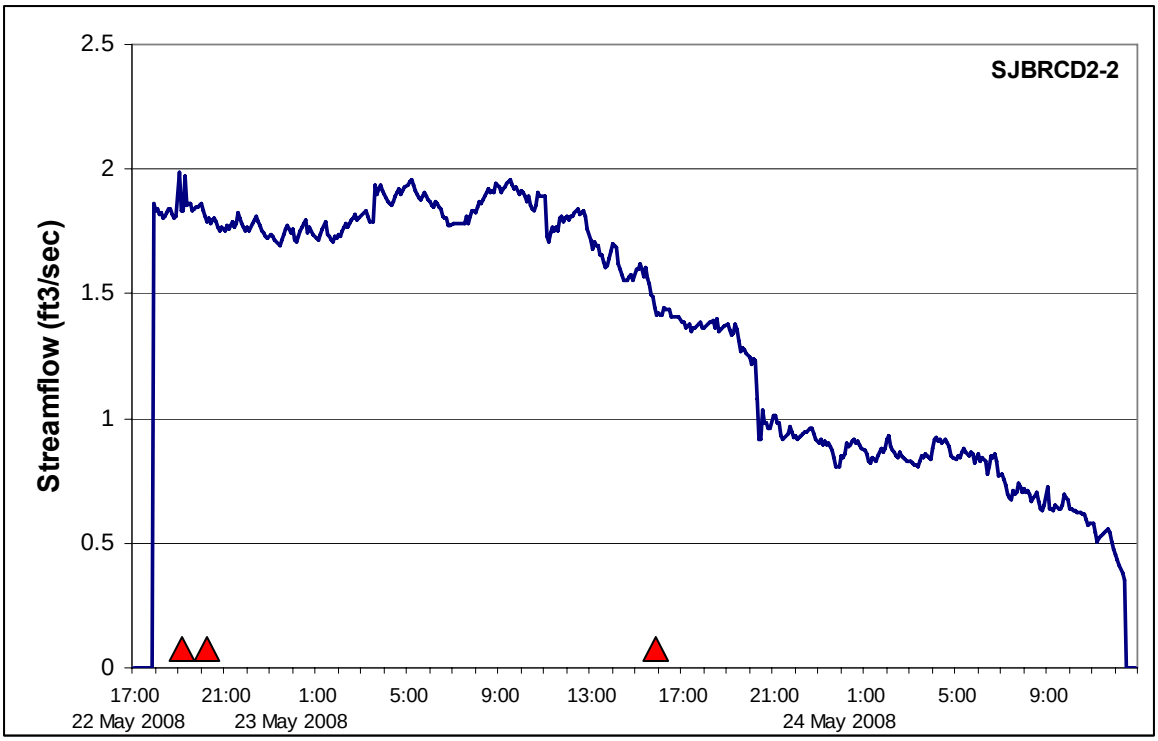


Figure 19. Hydrograph for May 22-24, 2008 storm event at station SJBRCD2-2. Triangles represent time water samples were collected.

Flow at the LESJWA3 station lasted just 35 minutes, beginning at 19:10 on May 22 and ending at 19:45 (Figure 20). Maximum flow rate during the event was 1.95 ft^3/sec (55 L/sec), representing a water depth of 3.5 inches. Total discharge for the event was 3,158 ft^3 (89,437 L).

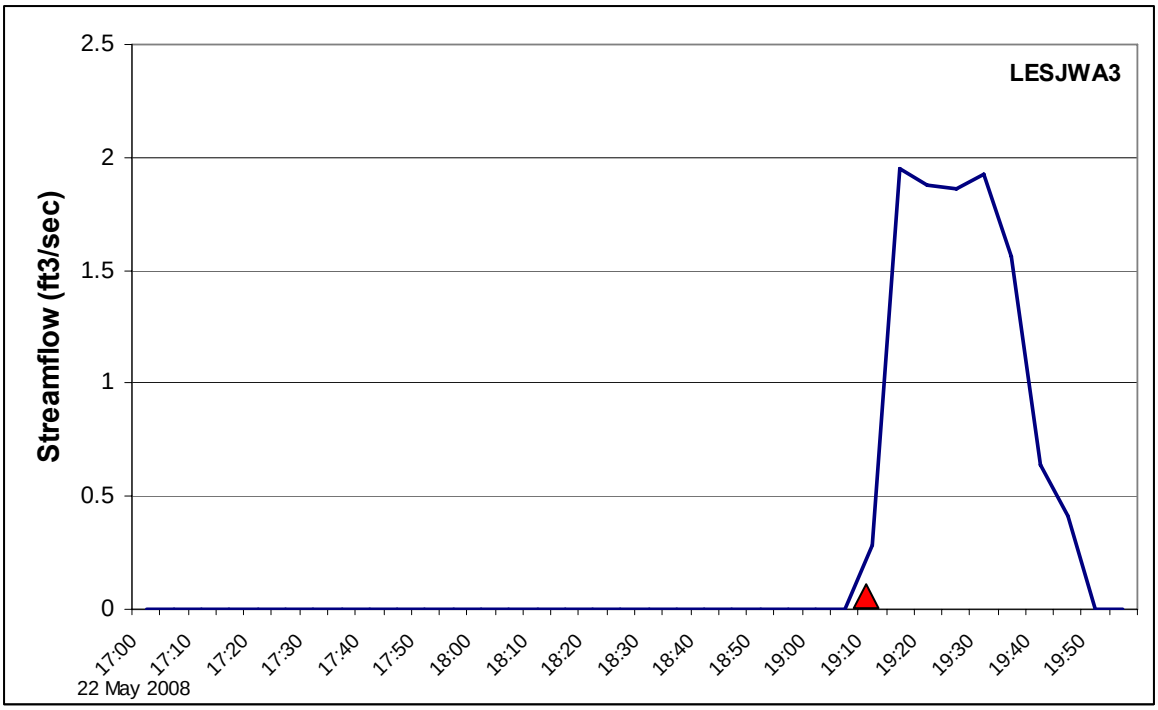


Figure 20. Hydrograph for May 22, 2008 storm event at station LESJWA3. Triangle represents time water sample was collected.

Water Quality

Grab samples were collected manually at each of the stations during the event. Because event flow was so brief, a single sample was collected at the SJBRCD1 and LESJWA3 stations; each of these samples was collected in duplicate. Three samples were collected at the SJBRCD2-2 station; only the first sample was collected in duplicate.

Data for field measurements and bacteria analyses are shown in Table 3. Note that in this and subsequent data tables for the event, "event mean" reported for SJBRCD2-2 is the flow-weighted mean, where the result of each discrete sample is weighted by the proportion of flow that occurred during the time interval that sample represents in computing the mean value for the event.

Table 3. Field measurements and bacteria counts in event samples, May 22-24, 2008.

Station	pH	Temp	COND	TC	FC	EC
SJBRCD1(1)	8.84	15.5	183.6	17,000	13,000	12,963
duplicate	8.81	15.5	182.9	17,000	3,500	10,860
mean[1]	**8.82**	**15.5**	**183.2**	**17,000**	**8,250**	**11,912**
SJBRCD2-2 (1)	8.92	16.9	1,765	280,000	5,000	5,291
duplicate	8.86	16.9	1,766	170,000	17,000	7,116
mean[1]	**8.89**	**16.9**	**1,766**	**225,000**	**11,000**	**6,204**
SJBRCD2-2 (2)	8.99	15.6	1568	110,000	8,000	4,881
SJBRCD2-2 (3)	9.06	20.2	1611	170000	2,800	821
event mean[2]	**9.03**	**18.6**	**1607**	**154,511**	**4,913**	**2,410**
LESJWA3 (1)	8.33	15.4	168.1	17,000	11,000	4,884
duplicate	8.32	15.4	168.4	23,000	8,000	5,172
mean[1]	**8.32**	**15.4**	**168.2**	**20,000**	**9,500**	**5,028**

[1] mean of duplicate samples
[2] flow-weighted mean for event

Data for chemistry analyses are shown in Table 4. It should be noted that for the SJBRCD2 (1), the relative percent difference (RPD) for TP between the field duplicate samples was 100%, suggesting that one or both of the analyses failed QA/QC criteria. However, the QAPP does not call for rejection of the involved data, only notation that the QC target was exceeded.

Table 4. Chemistry results for event samples, May 22-24, 2008.

Station	SRP	TP	NH_3	NO_2	NO_3	TKN	TSS	TOC
SJBRCD1(1)	1.193	8.168	3.46	0.18	4.5	11	1924	40.6
duplicate	1.140	10.072	3.65	0.17	4.53	9.7	1660	40.2
mean[1]	**1.166**	**9.120**	**3.56**	**0.18**	**4.5**	**10.4**	**1792**	**40.4**
SJBRCD2-2 (1)	2.246	3.148	2.82	0.27	1.41	11	26.5	65.2
duplicate	2.289	6.31	3.2	0.27	1.37	12	26	65.2
mean[1]	**2.268**	**4.729[2]**	**3.0**	**0.27**	**1.39**	**11.5**	**26.2**	**65.2**
SJBRCD2-2 (2)	2.599	3.28	3.4	0.28	1.44	8.7	41	65.5
SJBRCD2-2 (3)	2.842	3.35	3.22	0.24	0.44	11	25	61.4
event mean[3]	**2.732**	**3.410**	**3.26**	**0.25**	**0.81**	**10.3**	**30**	**62.9**
LESJWA3 (1)	1.087	5.663	2.99	0.14	0.94	7.7	1856	31.4
duplicate	1.016	5.3	2.9	0.13	0.94	8.7	2057.8	28.1
mean[1]	**1.052**	**5.48**	**2.95**	**0.14**	**0.94**	**8.2**	**1957**	**29.8**

[1] mean of duplicate samples
[2] RPD of field duplicates = 100%
[3] flow-weighted mean for event

Event Loads

Nutrient and sediment loads from the monitored event were calculated as the product of concentration and discharge. For stations SJBRCD1 and LESJWA3 the estimated load was simply the product of total event discharge and measured concentration (mean of duplicate samples) because the entire event was represented by a single sample. For station SJBRCD2-2, event flow was attributed to the water quality sample closer to it in time than to other samples. Loads for each of the three flow intervals were calculated as the product of the measured concentration and the flow attributed to that sample. Event load was then computed as the sum

of these loads. This division is illustrated in Figure 21. This process is equivalent to simply multiplying the event mean concentration times the total event discharge.

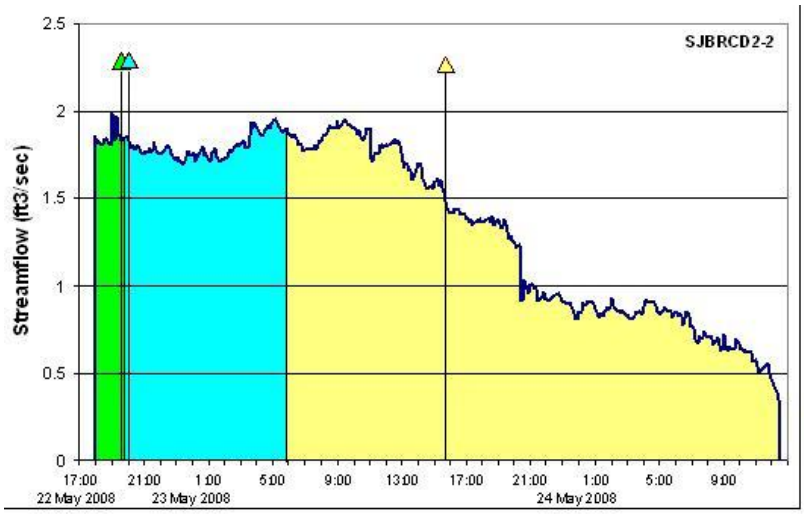


Figure 21. Schematic of load estimation for SJBRCD2-2 for event of May 22 – 24, 2008. Triangles represent water quality samples. Shaded areas represent event discharge associated with each water quality sample.

Event loads calculated in this manner are given in Table 5.

Table 5. Estimated chemical loads for May 22-24, 2008 runoff event.

Station	Discharge	SRP	TP	NH_3	NO_2	NO_3	TKN	TSS	TOC
	(L)	(kg)							
SJBRCD1	3203	0.004	0.029	0.011	0.001	0.014	0.033	5.7	0.13
SJBRCD2-2	5.94×10^6	16.237	20.3	19.4	1.5	4.8	61.3	178.7	373.9
LESJWA3	89437	0.094	0.490	0.264	0.013	0.084	0.733	175.0	2.7
Total	**6.04×10^6**	**16.335**	**20.786**	**19.67**	**1.52**	**4.91**	**62.0**	**359.5**	**376.7**

Discussion of Storm Event Monitoring Data

It is difficult to draw firm conclusions from the results of monitoring this small event. Event discharge at the SJBRCD1 and LESJWA3 stations was very small and very brief; discharge from SJBRCD2-2 was higher and more prolonged. Peak flow rates and total event discharge from all three stations during the event were substantially lower than for other events recorded earlier in 2008.

Temperature and pH were similar among all three stations during the event. Conductivity at SJBRCD2 was an order of magnitude higher than at the other two stations, indicating that, coupled with the high event discharge, the SJBRCD2 drainage area carried a substantially higher dissolved solids load to Mystic Lake than that from the other two drainage areas.

Bacteria levels in discharge measured during the event were several orders of magnitude higher than levels measured in Mystic Lake over the past year (Table 8). This is not surprising, given

that fecal bacteria die off rapidly in fresh water. Bacteria in event flow were likely to be of fairly recent origin in land runoff, compared to those in the waters of Mystic Lake. Recall also that pH and high ammonia concentrations in Mystic Lake may have an inhibitory effect on bacteria in the water column.

Total P concentrations in event samples from all three stations were comparable to those observed in Mystic Lake, whereas SRP, NH_3, NO_2, and NO_3 concentrations were substantially higher than those in Mystic Lake. This is not surprising, given the dilution of incoming nutrient loads in the lake and the rapid uptake of these dissolved nutrients by algae growth. In contrast, both TOC and TKN concentrations were lower in event discharge than in Mystic Lake. This is also probably a result of algal production that would fix atmospheric carbon into organic carbon and convert inorganic N into organic N, resulting in higher concentrations of both TOC and TKN in lake water. TSS in event discharge—probably mostly inorganic sediment particles—were higher in event discharge than in Mystic Lake, except in SJBRCD2-2, which showed very low TSS concentrations during the event. Sediment particles introduced into Mystic Lake in event discharge would tend to settle out over time, although direct comparison is difficult as TSS in Mystic Lake are likely predominantly of algal origin, while TSS in event discharge is probably composed mainly of inorganic soil particles.

Comparison of event water quality among the three stations is not conclusive because of the small data set. Total P and NO_3 concentrations appeared to be highest in flow at the SJBRCD1 station, suggesting that that drainage area may be a significant source of P and N. N concentrations appeared to be lowest in the event sample taken at LESJWA3. Suspended sediment concentrations seem to be substantially lower in event discharge at SJBRCD2-2, possibly suggesting lower erosion and soil loss in that drainage area compared to the other stations. Again, it must be cautioned that inferences drawn from a single event and from a single sample during the event cannot be made with confidence.

It is clear that most of the sediment and nutrient loads during the event came from the area drained by the SJBRCD2-2 station; loads from the other two stations were essentially negligible by comparison.

Mystic Lake Data

Field Data

Data collected in the field from the two Mystic Lake sampling stations are shown in Table 6.

Samples appear to have been collected in accordance with procedures specified in the QAPP. Data quality objectives with respect to completeness, accuracy, and precision have been met.

The waters of Mystic Lake appear to be quite alkaline, with high concentrations of dissolved solids, as indicated by the conductance values. The high dissolved oxygen levels at both stations in January and February were considerably above saturation concentration and are indicative of oxygen supersaturation, probably due to algal production. Field observations made at the time of sampling reported dense algae blooms and highly turbid water.

Table 6. Field data from Mystic Lake samples.

Station	Date	Depth (ft)	pH	Temperature (°C)	Conductance (µS/cm)	Dissolved Oxygen (mg/L)
ML 1	11/29/07	2	9.41	8.6	18,141	3.68
	12/17/07	1.33	9.51	13.5	14,251	20.88
	1/10/08[1]	2.0	9.62	17.2	12,653	36.84
	2/11/08	3.0	9.97	15.9	5,205	26.15
	3/11/08	2.5	9.67	23.3	5,553	17.40
	4/8/08[1]	2.0	9.58	18.3	6,820	10.88
ML 2	11/29/07[1]	0.42	9.46	19.1	11,116	20.20
		0.67	9.15	16.3	17,744	19.62
	12/17/07	0.42	9.66	12.2	14,809	28.08
	1/10/08[1]	0.5	9.60	12.7	12,688	41.86
	2/11/08	2.0	10.26	20.6	4,998	42.16
	3/11/08	1.5	9.64	19.9	5,563	15.60
	4/8/08[1]	1.0	9.66	18.0	6,906	11.28

[1] Values represent mean of duplicate measurements in the field.

Chemistry Data

Chemical analysis data for the sampling events through April 2008 are shown in Table 7.

Table 7. Chemistry data from Mystic Lake samples.

Station	Date	TSS	TP	SRP	NO_2-N	NO_3-N	NH_3-N	TKN	TOC
		mg/L							
ML 1	11/29/07[1]	470	7.012	<0.01	<0.05	<0.05	19.2	130	1,658.0
	12/17/07	260	7.508	0.854	<0.05	<0.05	11.5	100	888.6
	1/10/08[1]	230[2]	6.372	2.405[3]	<0.05[3]	<0.05	0.97	85	912.8
	2/11/08	134	1.964	0.123	<0.05[3]	<0.05	0.28	36	242.7
	3/11/08	102	2.26	0.472	<0.05[3]	<0.05[3]	0.18	29	225.7
	4/8/08	170	2.934	0.412	<0.05[3]	<0.05	0.37	39	324.8
ML 2	11/29/07	3,700	8.649	<0.01	<0.05	<0.05	13	110	1,076
	12/17/07	360	7.105	0.819	<0.05	<0.05	13.5	120	895.3
	1/10/08	510	9.9	2.885[3]	<0.05[3]	<0.05	1.11	82	869.5
	2/11/08	166	2.363	0.161	<0.05[3]	<0.05	0.28	29	269.1
	3/11/08	92	2.29	0.647	<0.05[3]	<0.05[3]	0.17	29	239.5
	4/8/08	164	3.023	0.358	<0.05[3]	<0.05	0.36	42	338.9

[1] Values represent mean of duplicate samples.
[2] RPD of duplicate samples = 52%
[3] Spike recovery failed lab QC

Samples appear to have been collected in accordance with procedures specified in the QAPP. Data quality objectives with respect to completeness, accuracy, and precision have been met for the most part, although there were several QA/QC issues to be noted. The Relative Percent Difference (RPD) for the TSS analysis of ML 1 field duplicate samples was 52%. This exceeds the laboratory QC criterion of 30% and the target RPD of 25% noted in the project QAPP. However, the QAPP does not call for rejection of the data, only notation that the QC target was exceeded. Also, spike recoveries failed lab QC limits for the January samples for the SRP and NO_2-N analyses and in February for the NO_2-N analysis. The laboratory did not judge this

failure sufficient to reject the data, although it should be noted that the SRP values reported in January for both stations appear to be considerably higher than values reported in other months.

Phosphorus concentrations were quite high; most of the P was in the particulate form. It is also worth noting that both ammonia and total Kjeldahl nitrogen concentrations at both stations were an order of magnitude lower in 2008 than in November and December 2007. Total Organic Carbon concentrations appeared to be declining over the monitoring period.

Bacteria

Indicator bacteria data from the two Mystic Lake sampling stations are shown in Table 8.

Table 8. Bacteria data from Mystic Lake samples.

Station	Date	Total Coliform	Fecal Coliform	*E. coli*
		MPN/100 ml		
ML 1	11/29/07	500	≤220[1]	91
	12/17/07	4	2	6
	1/10/08[2]	<2	<2	<2
	2/11/08	2,300	<2	2
	3/11/08	90	26	24[3]
	4/8/08	170	30	17
ML 2	11/29/07	170	≤110[1]	96
	12/17/07	2	2	4
	1/10/08	130	130	40
	2/11/08	50	2	<2
	3/11/08	50	14	15
	4/8/08	80	50	32

[1] Results only reportable as "≤" due to technician error
[2] Values represent mean of duplicate measurements
[3] Lab duplicate failed QC

Data quality objectives with respect to completeness, accuracy, and precision have been largely met, although a lab duplicate failed QC for the ML 1 sample in March. Indicator bacteria counts tended to be somewhat higher in January through April than previously observed, although counts continued to be low relative to water quality standards.

Discussion of Mystic Lake Monitoring Data

Mystic Lake appears to have received a significant input of water over the period, as seen in the precipitation and flow measured in the tributaries. The effects of this water input can be seen in the increasing depth and lower conductance (dilution) noted in samples collected in February, March, and April, 2008 (Figure 22). Dissolved oxygen levels in Mystic Lake continue to be considerably above saturation, indicating supersaturation from photosynthesis, as noted in observations of high algal production. As shown in Figure 18, DO levels tended to be higher at the ML-2 station, compared to ML-1.

Concentrations of P, N, and TOC in the samples collected from February through April appear to be lower than previous levels, consistent with the notion of dilution of Mystic Lake by new water input (Figure 23). Sediment and nutrient concentrations appeared to be quite similar between the two lake monitoring stations, except at the January 2008 sampling when TSS was substantially

higher at ML-2. It is unknown if this was due to inorganic sediment, algal production, or both. There was also a slight increase in TP at ML-2 on the same sampling date; this could be due either to P in elevated suspended sediment or to higher algal production.

Indicator bacteria counts in Mystic Lake continue to be low and showed no obvious trend over the monitoring period. The *E. coli* counts reported in this monitoring effort have been considerably below the geometric means of 231 – 703 MPN/100 ml reported by the RWQCB in 2007 from samples collected at three locations in Mystic Lake. No explanation for this difference is available at this time.

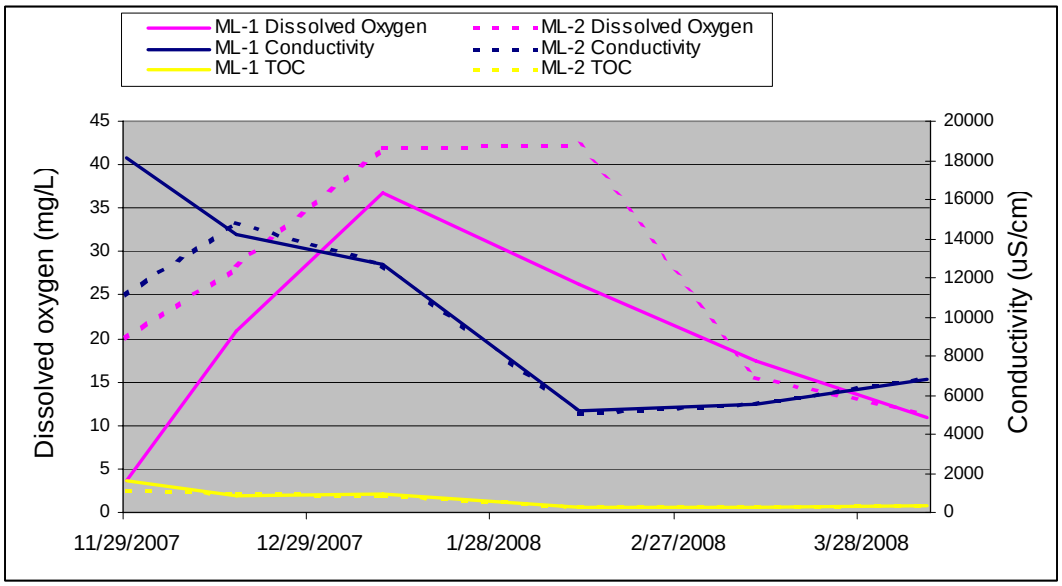


Figure 22. Dissolved oxygen and TOC concentrations and conductivity values observed at Mystic Lake sampling stations, November 2007 – April 2008.

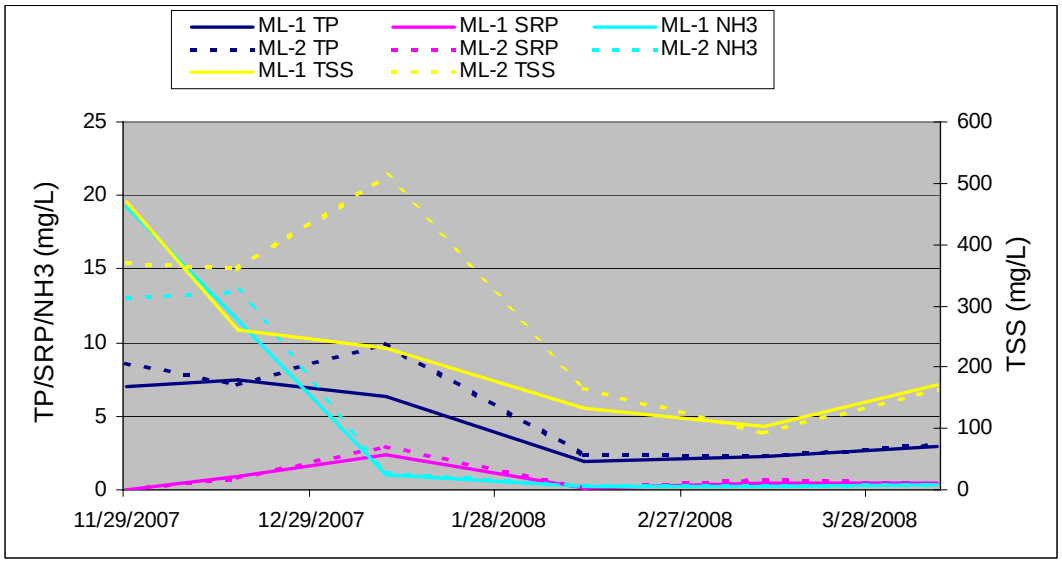


Figure 23. Phosphorus, ammonia, and total suspended solids concentrations observed at Mystic Lake sampling stations, November 2007 – April 2008.

Appendix C – Spatio-Temporal Assessment of Nutrient Management Plan Performance for Field-Scale Lagoon Water Application at Scott Brothers Dairy, San Jacinto, CA

State Water Resources Control Board Agreement No. 06-279-558-1

FINAL REPORT

for

Spatio-Temporal Assessment of Nutrient Management Plan Performance for Field-Scale Lagoon Water Application at Scott Brothers Dairy, San Jacinto, CA

December 24, 2009

United States Department of Agriculture - Agricultural Research Service
United States Salinity Laboratory
450 West Big Springs Road
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EXECUTIVE SUMMARY

The USDA, ARS, U.S. Salinity Laboratory conducted a three-year study on the performance of a nutrient management plan (NMP) on the Scott Brothers Dairy in San Jacinto, CA. The current study followed an ongoing research funded by the USEPA, which tested the performance of NMP on a small scale site and served as the foundation for the field scale pilot. The USEPA project served to match the funds. The application of dairy wastewater (DWW) and recycled water to agricultural soils under NMP conditions could provide a beneficial solution for the disposal of these marginal waters by using water and excess nutrients for crop production. However, improper application poses a potential environmental threat to surface and ground water sources, and a potential impairment of soil quality. Specifically, the benefits of using DWW and recycled water in NMPs may be partially offset by accumulation of salts in the root zone, with deleterious effects on plant growth and yield, and by the leaching of salts, nutrients and microorganisms towards ground water. Impacts to ground water are especially important because San Jacinto dairies and most cropland in the San Jacinto Watershed overlie Groundwater Management Zones that lack assimilative capacity for TDS. Challenges to efficient NMP implementation in the San Jacinto Watershed include

- Inadequate information on soil properties, climatic data, wastewater constituents or crop water and nutrients uptake rates;
- Spatial and temporal variability of soil, wastewater, and crop properties;
- Management constraints related to water and wastewater application amounts and timing;
- Management-induced changes that influence soil properties over time.

The overall objective of this study was to assess the performance and long-term sustainability of a NMP for field-scale wastewater application. The study included intensive data collection on soils, wastewater, and crops and had these elements:

- Characterization of the soil spatial variability at the field site, using apparent soil electrical conductivity (ECa) survey that guided the soil sampling locations.

- Monitoring the spatio-temporal changes in transport-related soil properties and temporal changes in wastewater constituents and crop performance.
- Development of a field-scale NMP based upon findings from a plot-scale study and addressing potential weaknesses in the NMP design and operation processes.
- Measurement of the fate of nitrogen, salts and indicator microorganisms under a well-designed and implemented NMP.

Study results were intended to lead to the development of science-based recommendations to improve NMP performance and sustainability, thereby protecting groundwater under a wastewater-irrigated site from nutrients, salts, and pathogens.

The study site was an 80 ac (33 ha) field located on the Scott Brothers Dairy Farm in San Jacinto. A rotation of Wheat-Rye, Barley and Sorghum as implemented on this field. Intensive geospatial measurements of apparent soil electrical conductivity (ECa) were taken at the beginning of the project (May, 2007) to characterize the spatial variability of soil chemical and physical properties influencing soil quality and to temporally monitor changes in soil quality across this field. Nearly 600 soil samples were collected from 70 locations and 7 depth increments across the study field. Soils were re-sampled at the same locations at the end of the project to evaluate temporal changes in soil properties and salt and nutrient concentrations. Water flow and retention characteristics were developed by integrating detailed data on soil particle size distribution and bulk density with predictive models developed to estimate soil hydraulic parameters from simple physical properties. Following the first ECa survey, infiltration measurements were initiated to study the spatial and temporal changes of infiltration properties.

Frequent information on water and *N* mass balances in the root zone required for the implementation of the NMP were obtained from four instrumented sampling sites on the field that measured soil volumetric water content over depth, soil temperature, salts and nutrients in and below the root zone, and plant biomass and *N* content. The *N* mass balance was calculated over the upper 30 cm for the Wheat-Rye and Barley crops and 60 cm for the sorghum crop, where roots are most active in water and nutrient uptake under irrigated conditions.

A full chemical analysis (major anions and cations, EC, macro- and micro-nutrients, and pH) of wastewater and soil profiles at each sampling location was conducted at the beginning of the project. During the growing seasons, salt content in the wastewater and the root zone was estimated from sequential measurements of EC. TDS was assumed to be correlated to the EC (1 $dS \cdot m^{-1}$= 640 $mg \cdot L^{-1}$). At mid-project time (July 2008), the salinity of the upper soil profile (0-30 cm) was measured after water application of 9 to 15 cm that was applied to leach excess salts. A second full chemical analysis (major anions and cations, EC, macro- and micro- nutrients, and pH) of the soil profiles at each sampling location was conducted on November 2008.

The transport and fate of several fecal indicator microorganisms (*Enterococcus*, fecal coliforms, somatic coliphage, and *E. coli*) was monitored under ponded infiltration and redistribution of fresh DWW. These conditions were selected to mimic a worst-case transport scenario of saturated conditions that would enable DWW and microorganisms to move rapidly through the soil in macropores.

Three sources of water were used in this study: well water, recycled water and DWW. The recycled water and DWW contained macro- and micro - nutrients for plant growth. The amounts of nutrients need to be taken into consideration when developing a recommendation for commercial fertilizer or manure application based on soil tests before each growing season. The inorganic *N* content of the various sources was integrated and embedded into the *N* mass balance. Significant seasonal variations measured in NO_3-N levels in the DWW and recycled water suggested that an efficient NMP will require frequent information on the inorganic *N* content of this sources. Sampling of irrigation source water showed that the TDS of recycled water and DWW was double that of local well water, indicating that use of recycled water and/or DWW will require frequent leaching of salts to avoid yield effects due to increased soil salinity.

A NMP was implemented on winter (Wheat-Rye and Barley) and summer (sorghum) crops during 2007-2009. During 2009, a rotation of three crops was tested, where a short growing season of Barley was added between the Wheat-Rye and the sorghum. Whereas all the water was supplied through the irrigation system during summer, only 57% in average was supplied as irrigation water during winter due to seasonal rainfall and low ET rates. Therefore, only a fraction of the *N* removed by the

crop was supplied during winter. The missing water and *N* was supplied by depleting the soil inorganic N and converting soil organic N to plant available inorganic forms (mineralization).

The high evaporative demands throughout summer required frequent water application for plant growth. Despite similar quantities of water application during summer 2007, 2008 and 2009, different salt loads occurred due to the use of different water sources with varying salt content. Summer 2008 and 2009 loaded 3 times more salts then summer 2007. Similarly, utilizing recycled water during winter 2009 increased the total salt per water application unit. Leaching of salts below the root zone occurred due to seasonal rainfall (20.95cm) during fall 2008 and winter 2009. The salts were leached from the upper 60 cm and accumulated in a lower layer (-60 to -90cm).

Nitrogen application to the crops was based on the mass balance of *N* in the root zone. Subsequent measurements of each component in the *N* mass balance were used to calculate the plant available *N* at the beginning and during the growing seasons. The three principal *N* sources were inorganic forms (NH_4-N and NO_2+NO_3-N) in the DWW, recycled water and soil, and organic forms in the soil and the supplied wastewater. Crop uptake was the major sink for N; volatilization, denitrification, immobilization and drainage were the major losses. Leaching of NO_3 was restricted to the upper 90 cm, where it is still available for crops with deep root system (i.e. corn, sorghum and alfalfa). Changes in soil NH4-N were limited to the upper 30 cm of the soil profile.

Measured concentrations of fecal indicator microorganisms in fresh and stored DWW significantly exceeded the recommended U.S. standards for unrestricted irrigation (USEPA, 2004). Indicator microorganisms were not detected in the soil below the depth of 20 cm. Batch survival experiments revealed much more rapid die-off rates for the bacterial indicator microorganisms in native than in sterilized soil, suggesting that the biotic factors played a dominant role in survival behavior.

The main lessons learned from the study include:

- Develop a “hydrological sensitivity index” based on the soil and groundwater properties (depth, quality, hydraulic properties, and mineralogy of the vadose zone and aquifer). This index should categorize high and low potential zones of

contamination from agricultural activity. Application of liquid and solid dairy wastes in low sensitivity zones would be more flexible than in other zones.

- Improve measurements of water and nutrient requirements by the crop to obtain accurate information on the required timing and quantities for application.
- Increase the water and *N* use efficiency by irrigating to meet plant uptake requirements using a high uniformity application system. Minimize runoff and ponding conditions by matching the water application rate to the soil infiltration rate.
- Regulations should be more specific and not based solely on TDS. Chloride is one potential indicator for salinity.
- Blending of high quality water (well water) and degraded water will decrease significantly the salt load; due to the order of magnitude difference in chloride concentrations.
- Growing salt tolerant crops will minimize the yield reduction due to salt accumulation in the root zone and will increase the uniformity of water and nutrients uptake from the soil.
- The timing of salt leaching may be a crucial management decision in NMPs because organic soil *N* continues to be converted to inorganic *N* forms (NH_4, NO_2 and NO_3) during periods of low *N* plant removal (fallow season). A pre-irrigation at the beginning of a new growing season, or seasonal rains during the fallow season may result in migration of inorganic *N*, especially NO_3, below the root zone towards groundwater, therefore leaching salts is preferred following harvests rather than prior to planting.
- Minimize application of dairy solid manure by matching to agronomic uptake rates of the crops. Alternative treatments (composting and biogas production) do not remove salts, however composting stabilizes the fresh manure to a balance fertilizer with lower potential for groundwater contamination and biogas production is a feasible bio-energy source to handle excess dairy solid manure at specific sites.

Special caution is warranted in coarse textured and structured soils and during water flow transients where enhanced microorganism transport potential has been reported in the literature.

- Timing of water application should allow for adequate die-off of microorganisms before leaching the root zone by irrigation or natural precipitation.
- The potential for groundwater contamination will increase with shorter travel times and distances. The water table depth is therefore another important consideration for environmentally protective NMPs.
- The transport potential of microorganisms can be significantly reduced by minimizing water leaching below the root zone and surface water runoff. This can be achieved by:
    - Precise estimation of the ET rate.
    - Uniform application of wastewater.
    - Selecting water application timing and quantities based on considerations of soil permeability and ET.

BACKGROUND

Concentrated animal feeding operations (CAFOs) have been identified as potential point sources of pollutants to surface and groundwater. Dairy wastewater (DWW) contains high levels of plant nutrients, organic compounds, and inorganic salts. Excess amounts of these constituents can adversely impact soil and water quality. On the other hand, DWW and manure may be valuable fertilizers and soil amendments that improve soil physical conditions for plant growth, reduce energy required for tillage, and increase the organic matter content of soil. In semi-arid and arid environments the reuse of DWW for irrigation reduces demand for high quality water, a scarce resource.

Many pathogenic microorganisms have also been found in animal wastes and water-and food-borne disease outbreaks have frequently been linked to a farm animal source. A study by Macler and Merkle (2000)[1] estimated that pathogenic microorganisms in groundwater cause between 750,000 to 5 million illnesses per year in the United States. Drinking and irrigation water standards to protect human health, however, are largely based on measured concentrations of fecal indicator microorganisms. Recent concentration measurements of several fecal indicator microorganisms in select lagoon water samples from dairy, beef, poultry, and swine CAFOs, were found to significantly exceed the recommended U.S. standards for unrestricted irrigation.

Currently, the USEPA requires that application of wastewater generated by CAFOs to agricultural lands follow approved Nutrient Management Plans (NMPs). NMPs are designed to meet the water and nutrient needs of crops, while ensuring that all the contaminants in CAFO's wastewater (salts, nutrients, and pathogens) are retained or taken up in the root zone, so that groundwater is inherently protected. However, recent research by the EPA has observed significant migration of pollutants towards surface and groundwater bodies at NMP sites. These observations suggest that implementing a NMP based on current agronomic practices may not always protect the environment.

[1] Macler, B.A., and J.C. Merkle. 2000. Current knowledge on groundwater microbial pathogens and their control. Hydrogeol. J. 8:29–40.

Effective NMPs should accurately quantify both water and nutrient balances. Water balance information should include characterization of soil hydraulic properties, frequent determination on soil water status in and below the root zone, and analyzing the uniformity of applied irrigation. NMPs should include comprehensive and periodic (temporal) information on all the relevant nutrient forms in soils, DWW, and plant tissues and seasonal changes on reaction rates. NMPs involve mass balance considerations for a limiting nutrient for plant growth or a nutrient that is the primary environmental concern. Nitrogen (*N*) and phosphorus (*P*) are two of the most limiting nutrients affecting plant production in semi-arid environments. Plant uptake of *N* is typically higher than *P*, hence, NMPs based on *P* will use smaller quantities of DWW than a NMP based on *N*, and will also require additional *N* fertilizer. Conversely, NMPs based on *N* will tend to over apply *P*. Semi-arid soils are characterized by high pH and abundant *Ca* and *Mg* that contribute to *P* precipitation. Furthermore, potential transport of *P* in soils was found to decrease in the presence of manure. All of these considerations indicate that it is reasonable to develop NMPs based on *N* for mineral soils in semi-arid environments. Moreover, most NMP sites employ DWW with high organic loads. Efficient implementation of a NMP is more difficult when there is a high ratio of organic to inorganic *N*, because organic *N* forms are not available for plant uptake until after mineralization into inorganic forms.

Benefits of using DWW as water and fertilizer may be partially offset by accumulation of salts in the root zone. Plant uptake of salts is typically very minimal and concentration of salts in the root zone by evapotranspiration (ET) is known to deteriorate plant growth and yield. Two conventional practices to minimize the adverse effects of salt accumulation are growing salt tolerant crops and periodic leaching of salts below the root zone. Leaching of salt, however, may also transport nutrients below the root zone toward groundwater resources. The groundwater contamination potential by leaching will depend on the nutrient species and concentration, leaching fraction, depth to groundwater, and preferential water flow that can accelerate the migration rate of nutrients and salts that bypass the soil matrix.

NMPs implicitly assume that pathogenic microorganisms in DWW will be retained and inactivated and/or degraded in the root zone, so that food and water supplies are

protected. This assumption has not yet been thoroughly tested at the field scale. The human health risks that pathogens pose at NMP application sites are expected to be highly dependent on their survival and transport potential. Pathogen survival in soils is reported to be a complex function of temperature, moisture content, soil solution and solid phase chemistry, soil texture, organic matter, microbial activity, and pathogen type. Given the right environmental conditions in soils it is also possible that bacterial pathogens can grow in the root zone.

The advective transport potential of pathogens in the root zone is dependent on the water flow regime, which varies with initial soil water status, water application method, application timing and amount, ET, soil hydraulic properties and structure, and surface topography. Pathogen retention processes are known to be a function of many physical (grain size distribution, pathogen size, pore scale hydrodynamics, surface roughness, colloid concentration, and water content), chemical (soil solution and interface chemistry), and microbiological (pathogen type and metabolic activity, motility, bio-films, and microbial community) variables. Furthermore, infiltration and drainage of water in the root zone create transients in water content and soil solution composition that are known to influence these pathogen retention mechanisms.

Maintaining soil and groundwater quality is the key to the successful use of NMPs on dairy farms. The application of dairy wastewater (DWW) to cropped soils provides a means to dispose of an unwanted waste, but poses a potential environmental threat to groundwater resources and a potential impairment of soil quality. Potential problems with efficient NMP implementation need to be identified and overcome. For example, NMPs may not adequately quantify water and nutrient mass balances due to inadequate information on soil properties, climatic data, wastewater constituents or crop water and nutrients uptake rates. Other potential difficulties associated with efficient NMP implementation include the inherent spatial and temporal variability in NMP properties, management constraints related to the water and wastewater application amounts and the timing, and management-induced changes that occur to edaphic (soil) properties over time. Osmotic effects of salinity and ion specific toxicity could restrict crop establishment and growth. Furthermore, salt accumulation might change the soil physical structure, infiltration and soil water holding capacity.

Selective actions can be taken to minimize the potential negative effects of DWW on soil, groundwater quality and crop production (i.e., pretreatment of DWW, gypsum application, leaching schedule, growing salt tolerant crops, timing of DWW application under a site-specific management regime).

OBJECTIVES

The overall objective of this study was to assess the performance and long-term sustainability of a NMP for a field-scale DWW application site.

This goal can be achieved by:

- Characterizing the spatial variation of soil properties influencing the transport and fate of DWW contaminants using apparent soil electrical conductivity (EC_a) to direct soil sampling.
- Developing a field-scale NMP based upon findings from a plot-scale study and address potential weaknesses in the NMP design and operation processes.
- Monitoring the spatio-temporal changes in transport-related soil properties and temporal changes in DWW constituents and crop performance.
- Measuring the fate of nitrogen, salts and pathogenic microorganism under a well-designed and implemented NMP.

Collectively, this information should lead to the development of science-based recommendations to improve NMP performance and sustainability, thereby protecting groundwater under DWW sites from nutrients, salts, and pathogens.

MATERIALS AND METHODS

The on-farm research site used for the study is an 80-acre field (33 ha) located on the Scott Brothers Dairy Farm in San Jacinto in southern California's Riverside County (33°50'32" N, 117°00'30" W). The site location and its aerial photo are showed in Figure 1. This location was chosen due to:

- Proximity to a heavily instrumented experimental plot established by the USEPA funds (IAG # DW-12-92189901-0), studying the fate and transport of salts, macro-nutrients and indicator microorganisms under NMP conditions at a dairy

water application site (Fig.1- 25 x 25 meters). The experimental plot will be used as a basis for the development of the NMP to be used at the large field site.

- High variability in soil properties and crop performance during the past seasons. These conditions turn the field into a case study for implementation of NMP under precision agriculture management.

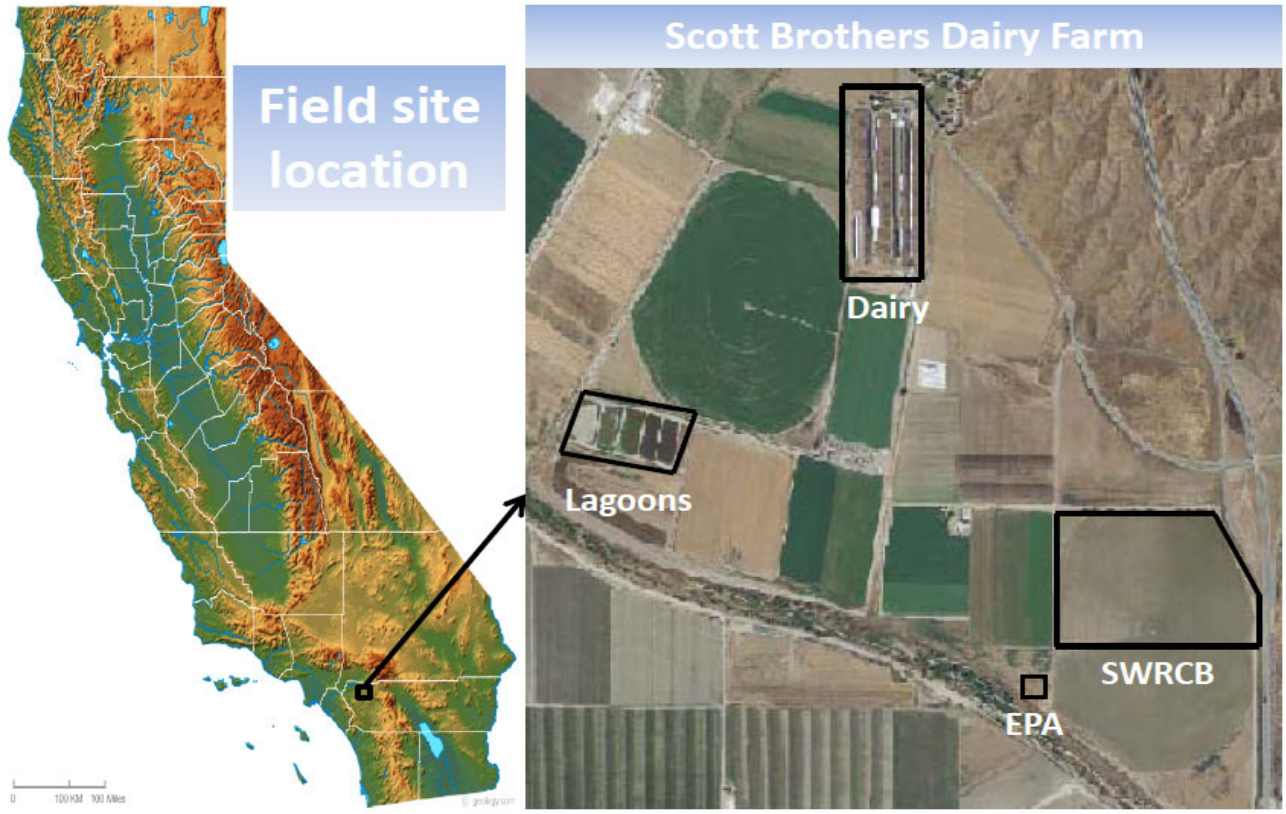

Figure 1. Location and Aerial photo of the experimental sites.

Statistical analysis was performed using the SigmaPlot software (Version 11,Systat. Software, Inc). Geospatial analysis and presentation was conducted using the ArcGIS Desktop software (Version 9.3, ESRI) in conjunction with an inverse distance weighting geo-spatial algorithm.

Soil survey

A flowchart of the measurements, sampling, analysis and monitoring program is depicted in Figure 2. Geospatial analysis of the apparent soil electrical conductivity (EC_a) survey identified 70 soil sampling sites and four monitoring stations. The 70 sites were used to characterize the physical, chemical and infiltration properties of the field

site. The same sites were served for yield monitoring as well. Frequent information on DWW and recycled water constitutes, soil and plant from the four monitoring stations and yield monitoring served to implement NMP on the experimental site. The study on the transport and fate of indicator microorganisms was based on infiltration properties and concentrations in the DWW. A second soil sampling at the same 70 sites was employed to evaluate the spatial and temporal effects of NMP on soil properties. Detailed description of each phase is given below.

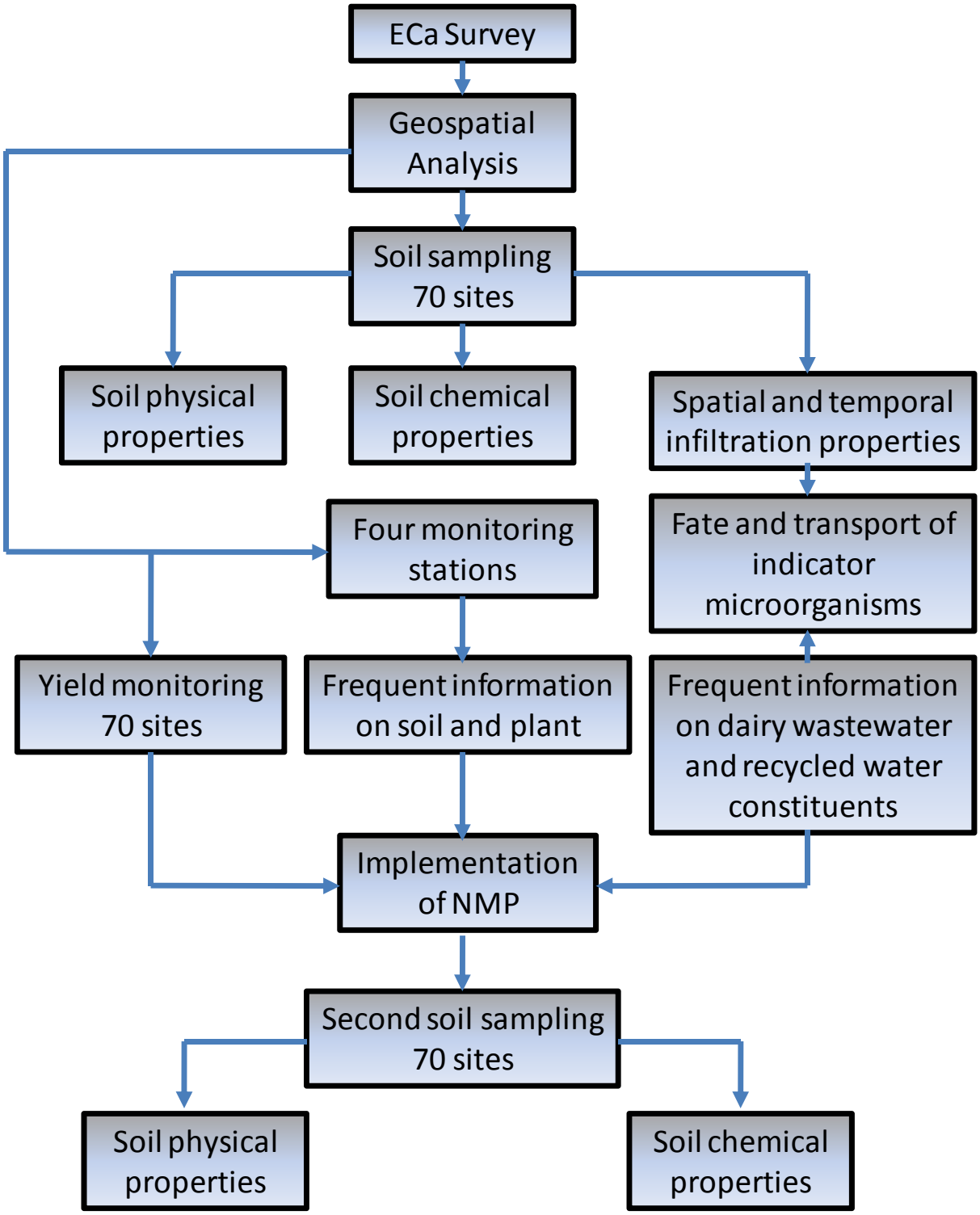

Figure 2. A flowchart of the measurements, sampling, analysis and monitoring program

Electromagnetic induction

Intensive geospatial measurements of apparent soil electrical conductivity (EC_a) were taken at the beginning of the project (May, 2007) to provide a means of spatially characterizing the spatial variability of soil chemical and physical properties influencing soil quality and of spatially and temporally monitoring changes in soil quality. Mobile GPS-based electromagnetic induction (EMI) equipment developed at the U.S. Salinity Laboratory was used to take the geospatial measurements of EC_a (Fig. 3). Electromagnetic induction measurements of EC_a were taken in the horizontal (EM_h) and vertical (EM_v) coil configurations at 16191 locations, with each location approximately 5 m apart.

Figure 3. Mobile GPS-based electromagnetic induction equipment.

The initial EC_a survey was used to direct soil sampling using a response surface sample design (RSSD) and stratified random sample design (SRSD). Forty sites were selected from the RSSD and 30 sites from the SRSD (Fig. 4). The RSSD characterizes the spatial variation in EC_a measurements while minimizing clustering; thus, characterizing the spatial variability of soil properties correlated with EC_a. The SRSD will characterize the spatial variability of any soil properties that do not correlate with EC_a. The protocols used for the EC_a survey and soil sampling are those developed by

Corwin and Lesch (2003, 2005a, 2005b)[2]. Aside from soil samples, the depth to the water table at 7 sites randomly selected throughout the field was investigated. In all cases, the water table was deeper than 9 m, which was the deepest depth to which the Giddings drill could penetrate.

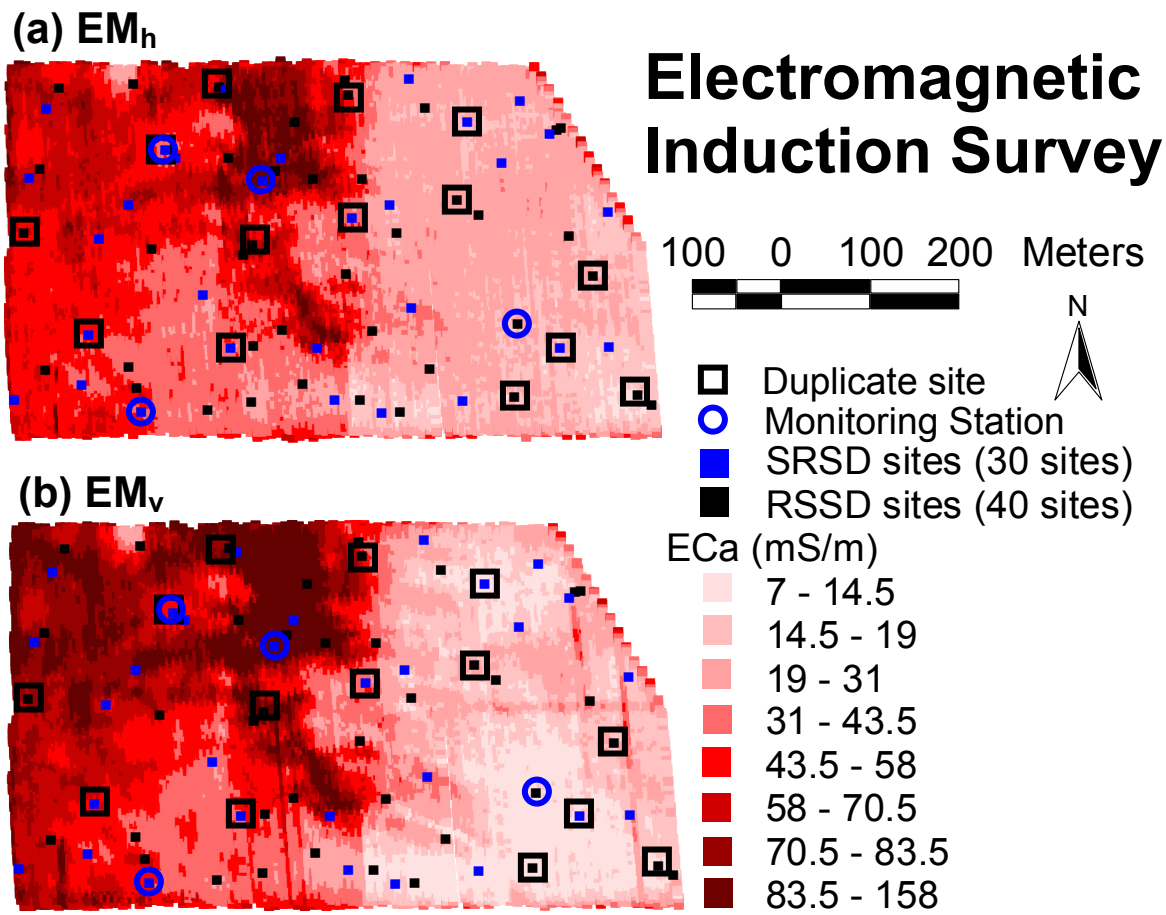

Figure 4. Electromagnetic induction (EMI) survey of apparent soil electrical conductivity (EC_a) at 16191 locations: (a) EMI horizontal coil configuration (EM_h) and (b) EMI vertical coil configuration (EM_v). Response surface sample design = RSSD and stratified random sample design = SRSD.

[2] Corwin, D.L., and S.M. Lesch.2003. Application of soil electrical conductivity to precision agriculture: Theory, principles, and guidelines. Agron. J. 95:455–471.
Corwin, D.L., and S.M. Lesch.2005a.Apparent soil electrical conductivity in agriculture. Comput. Electron. Agric. 46:11-43.
Corwin, D.L., and S.M. Lesch.2005b.Characterizing soil spatial variability with apparent soil electrical conductivity I. Survey protocols. Comput. Electron. Agric. 46:103-133.

Soil sampling

Soil samples were taken from each of the 70 locations at 7 depth increments: 0-15, 15-30, 30-60, 60-90, 90-120, 120-150, and 150-180 cm. At 14 randomly selected sites duplicate samples were taken within 1 m of the original location to establish the local-scale variability (Fig. 4). A total of 588 soil samples were collected using a Giddings drill rig. All soil samples were air-dried, sieved to pass a 2-mm sieve, and ground. Soil saturation pastes were prepared and saturation extracts of all soil samples were obtained.

A second set of soil samples (November 2008) were collected at the same sample locations to study the temporal changes in soil properties and contaminant concentrations (salts and nutrients). To assure pin-point accuracy in locating the sample sites, sub-meter GPS equipment was used (Pro-XR, Trimble, Sunnyvale-CA).

Chemical and physical analysis

The soil samples, representing the initial conditions of the field, were analyzed for a complete spectrum of soil properties that potentially influence the function of soil as a crop-producing system. The physical and chemical properties included: gravimetrical water content (GWC), bulk density (BD), particle size distribution (PSD), saturation percentage (SP), salinity (ECe), pH, major cations (Ca, Na, K, and Mg) and anions (Cl, HCO_3, PO_4, and SO_4), NO_2+NO_3-N, NH_4-N, total N and C, inorganic and organic C, trace elements, total exchangeable cations (TEC), sodium adsorption ratio (SAR). Methods and protocols for analyzing each constituent are presented in Table 1.

Table 1. Analytical constituents and method requirements.

Soil Property	Method†
Physical properties	
Bulk density	Grossman and Reinsch pp.207-209 (2002)[7]
Water content	Topp and Ferre, pp. 422-424 and Hignett and Evett, pp. 501-521 (2002)[7]
Texture	Gee and Or, pp. 255-283 (2002)[7] and Segal et al., (2009)[8]
Infiltration rate (Ks)	Reynolds, Elrick, and Youngs, pp.821-843 (2002)[7]
Chemical properties	
Soil prep and saturation extract	Rhoades (p. 167-179) [1]
Analysis of saturation extract	
Salinity- Electrical conductivity (EC_e)	Rhoades (p. 167-179) [1]
pH and alkalinity (HCO_3^-)	Rhoades (p. 167-179) [1]
Saturation percentage (SP)	Rhoades (p. 167-179) [1]
Anions:	
Cl	Rhoades (p. 167-179) [1,2]
SO_4	Rhoades (p. 167-179)[1,3]
PO_4	Rhoades (p. 167-179)[1,3]
NO_2+NO_3-N	Rhoades (p. 167-179)[1,4]
Cations:	
NH_4-N	DIN Method Number 38 406[6]
Na	Rhoades (p. 167-179)[1,3]
K	Rhoades (p. 167-179)[1,3]
Ca	Rhoades (p. 167-179)[1,3]
Mg	Rhoades (p. 167-179)[1,3]
Trace elements:	
Se, Zn, Cu, As, Mo, B, Cd, Fe	Rhoades (p. 167-179)[1,3]
Total, organic, and inorganic C	Nelson and Sommers (p. 539-579)[1]
Total N	Nelson and Sommers (p. 539-579)[1]

† Method described by author(s) and page numbers with reference book footnoted.

[1]Page, A.L., R.H. Miller, and D.R. Keeney (eds.). 1982. Methods of soil analysis. Part 2 – Chemical and microbiological properties. 2nd edition. Agronomy Monograph No. 9. ASA-CSSA-SSSA, Madison, WI.

[2]Analysis by Automatic Coulometric/Amperometric Cl Titrator.

[3]Analysis by inductively coupled argon plasma (ICP) using 3300 Dual Systeem (UV detector covers range from 165-403 nm and VIS detectore covers range from 404-782 nm.

[4]Analysis by UV-visible spectrophotometer.

[5]Rhoades, J.D., and M. Clark. 1978. Sampling procedures and chemical methods in use at the U.S. Salinity Laboratory for characterizing salt-affected soils and waters. P. 116-151. In: Mansur Aba-Hussayn (ed.) Proc. Soil, Water and Plant Analyses Workshop. Ministry of Agric. And Water, Riyadh, Suadi Arabia, Oct. 1977.

[6]German Standard Methods for the Examination of Water, Wastewater and Sludge, "Determination of Ammonium-Nitrogen by Flow Analysis (E23)," DIN Method Number 38 406, December 1991.

[7]Dane, J.H. and G.C. Topp (eds). 2002. Methods of Soil Analysi. Part 4—Physical Methods. Soil Science Society of America Book Series: 5. Soil Science Society of America, Inc. Madison, WI.

Hydraulic properties

Characterization of water flow and retention parameters in the field site was attained by integrating detailed information on PSD and BD from each sampling location and prediction models. Those models were developed to predict the soil hydraulic parameters from simple physical properties. Nevertheless, in order to conserve the precision of the process, these indirect methods needed to be supported by direct measurements.

Particle size distribution

Soil samples, collected after the survey, were analyzed for the PSD by the laser diffraction method. Briefly, 4 g of soil sample was ground, sieved (< 2mm), and oven dried (105°C) overnight. After cooling down, 5 cm^3 of 0.02 M NaCl was added per g of soil and shaken for 1 h. The soil suspension was then centrifuged on 850 times gravity for 20 minutes. After decanting, the samples were shaken overnight with 5 cm^3 of sodium hexametaphosphate solution per g of soil. A laser diffractometry device (LA 930, Horiba LTD, Kyoto, Japan) was used to determined the PSD according to Mie theory. Wet sieving with a 50 μm sieve was used to separate the soil suspension into two size fractions, sand and silt-clay. A sub-sample (0.5 cm^3) of the silt-clay suspension was analyzed immediately with the laser diffractometer using values of 1.5 and 0.1 for the real and imaginary parts of the refractive index, respectively. In contrast, the sand fraction (>50μm) was oven dried (105°C) overnight and weighed. Any remaining organic matter was removed before analysis. Then, the sand was re-suspended in the sodium hexametaphosphate solution, equilibrated for 1 hour, and analyzed with the laser diffractometer, using 1.5 and 0.1 as refractive indices. The PSD of the silt-clay and sand analyses, made with the laser system, were merged based on the relative weight of each fraction. Following the manufacturer recommendation, obscuration levels of the soil solutions in the laser diffractometer were kept between 7 and 13%. Maintaining these obscuration levels in soils with high clay content (>20%) compelled us to use small volumes due to the high optical density of clay. The silt-clay fraction of these samples was diluted with sodium hexametaphosphate (1:10 ratio) so that the same volume of suspension could be used, but containing low concentration of particles.

Predictive models

The Arya-Paris model[3] was employed to predict the relation between the PSD and BD to the soil water retention curve (WRC). The model assumes the pore size distribution curve mimics the soil WRC. However, a scaling factor, α, was used to correlate between the pore size to the pore length, which affects the tortuosity of the soil. The predicted WRC was fitted to the van Genuchten (1980)[4] hydraulic model, using the RETC computer code (van Genuchten et al., 1991), which describes the nonlinear relations in porous media between the effective water saturation (*Se*), soil water pressure head (*h*), and hydraulic conductivity (*K*) .

The saturated hydraulic conductivity (K_s) of the soil samples was predicted based on the Kozeny-Carmen model[5], which relates the geometrical particle surface area (A_s) to water permeability and hence K_s. The geometrical surface area ($cm^2 \cdot cm^{-3}$) was calculated from the PSD information.

The effective vertical saturated conductivity (K_s^{eff}) of the soil profiles consist of multiple layers of different texture, was calculated based on the harmonic mean of the K_s for the individual layers (K_{sb}).

Infiltration

Following the first ECa survey, infiltration measurements were initiated to study the spatial and temporal changes of infiltration properties. Infiltration was measured at only 61 sites identified in Fig. 4, due to technical problems. An automatic apparatus for measuring ponded (5 cm head) infiltration was developed – Figure 5. An Odyssey water level logger (ODYWL30, Dataflow Systems Ltd, Christchurch, New Zealand) was inserted into a large (150 cm tall x 10 cm diameter) Marriotte bottle to measure the water level over time and thus the infiltration rate. A large single disc, 30 cm diameter, was used to avoid biased results due to disc size.

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[3] Arya L.M., and J.F. Paris. 1981. A physicoempirical model to predict the soil moisture characteristic from particle-size distribution and bulk density data. Soil Sci. Soc. Am. J. 45:1023–1030.

[4] van Genuchten, M. Th. 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44:892-898.

[5] Lagerwerff, J.V., F.S. Nakayama, and M.H. Frere. 1969. Hydraulic Conductivity Related to Porosity and Swelling of Soil. Soil Sci. Soc. Am. J. 33:3-11.

The disc was inserted 13 cm deep to the soil and was connected to a Marriotte bottle through a 20 mm tube, while leveling the Marriotte bottle outlet to the disc inlet. Priming the system included: i) filling the Marriotte bottle with water, ii) starting data acquisition every 1 min., and consecutively iii) filling the disc up to 5 cm of water head in a short time (1 to 2 sec), iv) open the Marriotte bottle water outlet and air inlet valves. The Marriotte bottle was refilled after 5 hours (while the water outlet valve was close) to get a maximum cumulative infiltration of 50 cm, which continued up to 24 h. The water level data was transformed into volume and then infiltration depth over time. The water flow pattern from the inflitrometer changed from one dimensional infiltration to three-dimensional flow when water reached the edge of the disc at a depth of 13 cm. However, the actual infiltration rate was controlled mainly by the saturated hydraulic conductivity (K_s) of the upper soil layer (0-20 cm), which was under saturation during most of the experiment (>2 h). Therefore, the quasi-steady state infiltration rate (i_f) was used to estimate the K_s of this upper soil layer.

While the infiltration data from the 61 sites served for studying the spatial variability of the field hydraulic properties, only fourteen sites were used to study the temporal variations in infiltration properties of the field during a wheat-sorghum rotation. These sites represent the entire range of EC_a values measured in the field. The infiltration experiments were repeated at these 14 sites on 2 occasions after deep (100 cm) coarse soil ripping (October 2007) and after shallow (20 cm) plowing (December 2007). The July 2007 data was collected right after harvesting the wheat, when the root zone was intact.

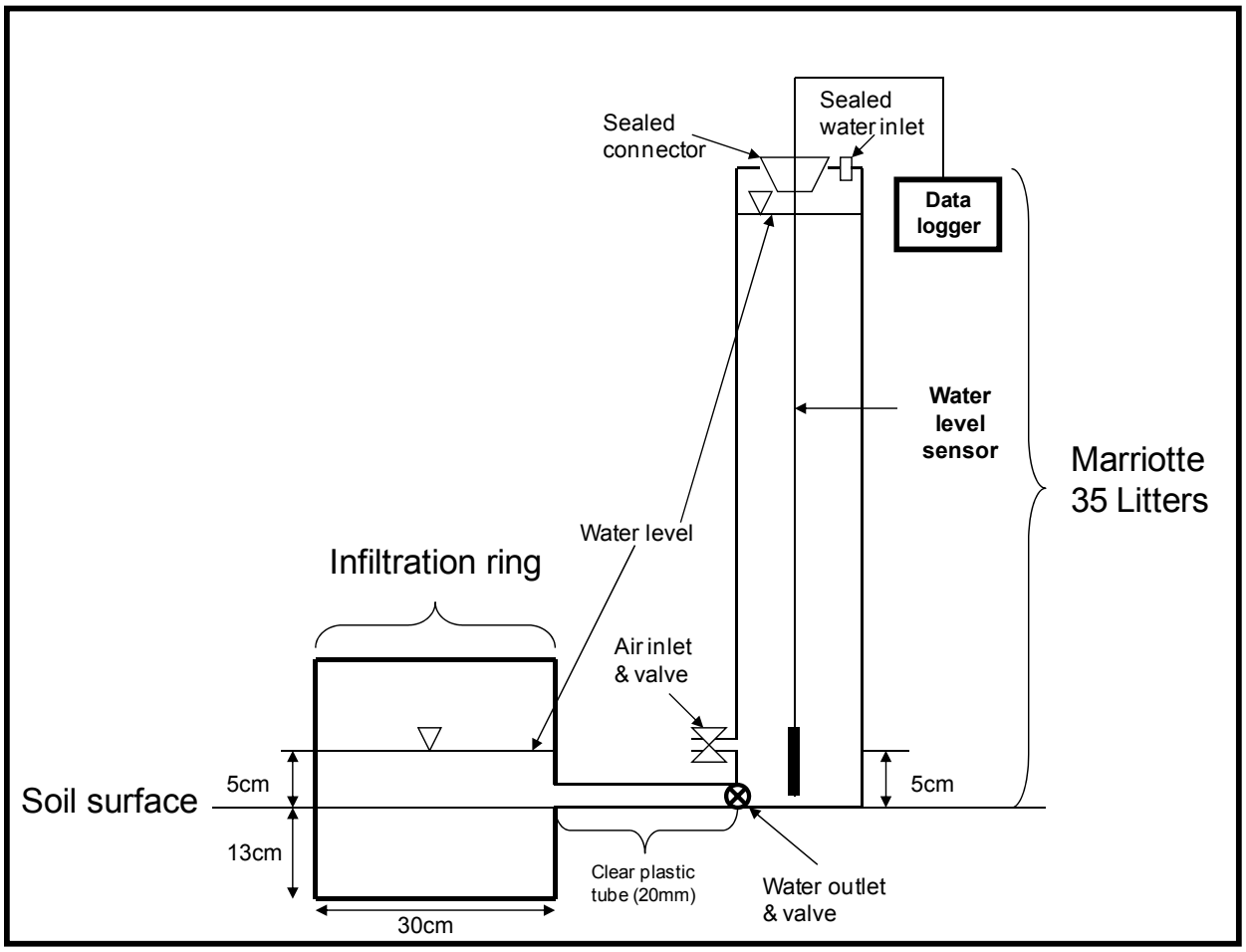

Figure 5. An automatic apparatus for measuring ponded infiltration under constant head of 5 cm. The apparatus consists of Marriotte bottle, infiltration ring, water level sensor with datalogger, water and air valves.

Nutrient Management Plan

Accurate implementation of the NMP in the field site requires frequent information on water and N mass balances in the root zone. The mass balances are calculated from a wide spectrum of measurements that cannot be obtained from each sampling location (Fig. 4). Therefore, four sampling sites, two extremes (7424 as high and 13747 as low) and two averages values (3790 and 4824) of measured ECa obtained in the initial soil survey were selected to represent different growing zones in the field (Fig. 4). Monitoring stations (Figure 6) were installed at these locations and used to implement the NMP. The 3×3 m stations were comprised from:

- A 3 m long neutron probe access tube for measuring the distribution of volumetric water content (VWC) over depth.
- Two water potential sensors at depths of 30 and 90 cm for measuring the soil water status at and below the root zone (MPS-1, Decagon devices Inc.).
- Two ECa probes (four probes) at depths of 30 and 90 cm for measuring the soil salinity at and below the root zone (Self made).
- Two solution samplers at depths of 30 and 90 cm for monitoring salts and nutrients in the soil solution at and below the root zone (25 mm Swinnex filter holder with 45μm filter paper, Millipore Inc.).
- Thermometers at depths of 5 and 30 cm for monitoring soil temperature (Copper-Constantan thermocouple, Campbell Scientific).
- A precipitation gauge for monitoring rain and irrigation amounts (RAINEW111-RainWise Inc.).
- A data logger and solar panel (CR10X-Campbell Scientific).

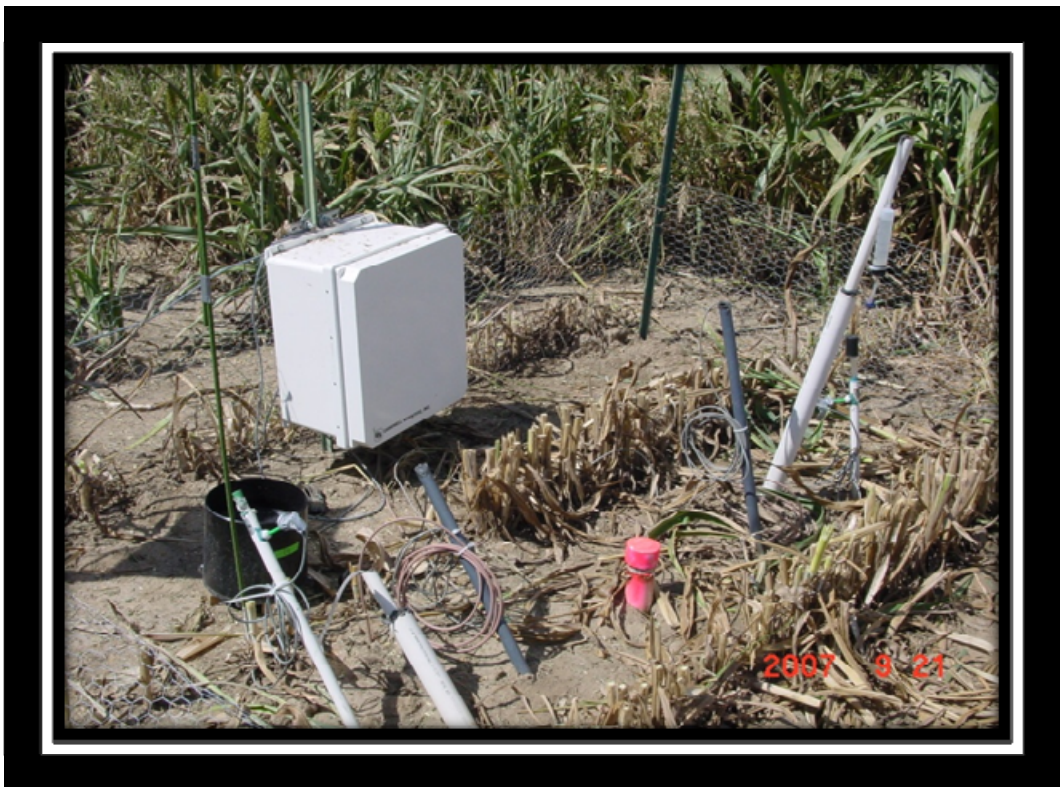

Figure 6. Monitoring station at the field site.

Evapotranspiration

Field scale water balance information in the root zone over a given time interval was used to determine the amount of applied irrigation water, I ($ML^{-3}\Delta T^{-1}$) to meet crop ET ($ML^{-3}\Delta T^{-1}$) at the end of this interval as:

$$I = ET + D + \Delta W - P_w \quad \textbf{[1]}$$

where D ($ML^{-3}\Delta T^{-1}$) is water loss due to drainage, P_w ($ML^{-3}\Delta T^{-1}$) is the water input due to precipitation, and ΔW ($ML^{-3}\Delta T^{-1}$) is the change in soil water storage (final – initial).

Water balance parameters in Eq. [1] were measured as described below. Potential ET (ET_p), with a resolution of 0.1 mm, was estimated from weather station data (Penman, 1948) located at the nearby experimental plot. Temperature, relative humidity, solar radiation, wind speed and rain gauge were recorded every 15 min. Actual ET (ET_{actual}) was calculated by multiplying ETp with the crop coefficient (K_c) during a given time period. Crop coefficients were estimated from literature values (Allen et al., 1998). For comparison, ET_{actual} values were calculated also from bi-monthly measurements of VWC over depth at each station. The value of P_w (resolution of 0.25 mm) was measured using the rain gauges located at each station and a gauge (CS700, Campbell scientific Inc.) installed at the adjacent plot. The values of D and ΔW were determined from the VWC readings. The value of I was verified from flow meter readings.

Nitrogen

In this study the following inorganic N mass balance equations for the root zone were employed:

$$N^I_{application} + E_{OI} = N^I_{plant} + N^I_{drainage} + N^I_{atmosphere} + \Delta N^I_{soil} \quad \textbf{[2]}$$

where $N^I_{application}$ is the inorganic N applied to the soil surface ($ML^{-3}\Delta T^{-1}$),. N^I_{plant} ($ML^{-3}\Delta T^{-1}$) is the inorganic N uptake by the plant, $N^I_{drainage}$ ($ML^{-3}\Delta T^{-1}$) is the inorganic N drained below the root zone, $N^I_{atmosphere}$ ($ML^{-3}\Delta T^{-1}$) is the inorganic N lost to the atmosphere during irrigation, and ΔN^I_{soil} is the difference in inorganic N storage in the root zone (final-initial). E_{OI} ($ML^{-3}\Delta T^{-1}$) stands for the net gain/loss of inorganic N in the root zone and include the mineralization, denitrification, surface volatilization and immobilization.

The *N* mass balance was calculated over the upper 30 cm for the Wheat-Rye crop and 60 cm for the Sorghum crop, where roots are most active in water and nutrient uptake under irrigated conditions. Nitrogen balance parameters were quantified as described below. Total *N* and *C* in the solid phase of the DWW, soil, and plant tissues were measured using the combustion method (Flash EA 1112, Thermo-Finnigan, Waltham, MA). Measurement of NH_4-N and combined NO_2+NO_3-N concentrations in soil solution and DWW were performed using a colorimetric system (O.I. Analytical, Flow Solution IV, College Station, Texas) after filtering the sample through a 0.22 μm filter.

Values of $N^I_{application}$ were determined from the concentrations of NH_4-N, NO_2+NO_3-N in the DWW multiplied by the irrigation depth. The value of ΔN^I_{soil} was determined from sequential measurements of soil inorganic *N* concentrations in the root zone. The value of $N^I_{drainage}$ was determined from drainage fluxes and inorganic *N* concentrations in soil solution below the root zone.

$N^I_{atmosphere}$ accounts for volatilization of NH_4-N during application. Nitrogen as ammonium loss during irrigation was measured using the concentration ratio of NH_4-N in the irrigation water at the emitter outlet and at the soil surface. Nitrogen as ammonium volatilization from the soil surface was measured following DWW wastewater application for a period of one week during the 2007 winter crop season on the nearby EPA plot using a standard chamber and acid-trap technique[6] to capture NH_3 emissions. The volatilized NH_4-N from the soil after irrigation was measured to be three orders of magnitude smaller than NH_4-N losses to the atmosphere during irrigation (5-30% losses). These findings are consistent with other data presented in the literature[7].

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[6] Black, A.S., Sherlock, R.R., Smith, N.P., Cameron, K.C., Goh, K.M., 1985. Effects of form of nitrogen, season and urea application rate on ammonia volatilization from pastures. New Zealand Journal of Agricultural Research 28, 469-474.

[7] Cameron, K.C., Di, H.J., Reijnen, B.P.A., Li, Z., 2002. Fate of nitrogen in dairy factory effluent irrigated onto land. New Zealand Journal of Agricultural Research 45, 207-216.
Sharpe, R.R., Harper, L.A., 1997. Ammonia and nitrous oxide emissions from sprinkler irrigation applications of swine effluent. J. Environ. Qual. 26, 1703-1706.

The atmospheric loss of NH_4-N during irrigation was measured and taken into account in the *N* balance.

N^I_{plant} was determined from measurements of dry phytomass and its *N* content. During the growing seasons, three repetitions of a known area (0.1- 0.3 m^2) of plants of the Wheat-Rye and Sorghum were collected for *N* analysis from the vicinity of each monitoring station. At the end of the 2007 and 2008 growing seasons, yield was monitored at the 70 sampling sites (summer 2007, winter 2008, summer 2008, winter 2008). At the end of 2009 growing seasons (summer and winter) yield was monitored only at 14 sampling sites that were chosen based on ECa values from the initial survey and accounted for the full range of measured ECa. A 3×3 m plot around the sampling sites was manually harvested and weighed for fresh biomass. A sub-sample of 4-5 plants was weighed separately and oven dried in 60°C for 7 days. After weighing the dry biomass, the whole subsample was ground, mixed well and was used to measure the total C and N content with the combustion method. Since the root system was not removed during the harvesting, it was not considered as an *N* sink.
The value of E_{OI} was determined from measurements of N^O_{soil} and the calculated mineralization rates at the nearby EPA plot.

In practice, $N^I_{application}$ was calculated from Eq. [2] to meet the projected N^I_{plant} during the subsequent time interval. The projected plant uptake for each time interval was determined from potential *N* uptake curves for crops under optimum growth conditions[8]. The blending ratio before each application was determined by matching simultaneously $I_{application}$ and $N^I_{application}$, where $I_{application}=I_{DWW} + I_{well/recycled}$ and $N^I_{application}= N^I_{well}\, I_{well/recycled} + N^I_{DWW}\, I_{DWW}$. $I_{application}$ is the total supplied water, comprises from I_{DWW} and $I_{well/reccycled}$, which are the water amounts supplied by DWW and by well water or recycled water. Similarly, $N^I_{application}$ is the total supplied inorganic N, comprises from N^I_{well} *and* N^I_{DWW}, which are the inorganic N amounts supplied by the DWW and by the

[8] Karow, R.., Marx, E., Morrow, K., Bohle, M., Dovel, R., Eldredge, E., Hayes, P., James, S., Peterson, J., Reed, G., Shock, C., Smiley, D., 199. Spring Wheat Varities for 1999. Special Report 986; Oregon State University: Corvallis, OR.
Rahman, M., Fukai, S., Blamey. F.P.C., 2001. Forage production and nitrogen uptake of forage sorghum, grain sorghum and maize as affected by cutting under different nitrogen levels. In: Proceedings of the 10th Australian Agronomy Conference, Hobart, Australia (http://www.regional.org.au/au/asa/2001/1/c/rahman.htm).

well water or recycled water. In order to maintain the required blending ratio over time, a blending system consists of two flow meters (Stainless steel paddle wheel 2540, GF-Signet), adjustable valve (4" motorized butterfly valve, Crane Energy) and a controller/ datalogger (CR21, Campbell Scientific Inc.) were installed in the field site prior to the application of DWW. A scheme of the blending system is given in Figure 7.

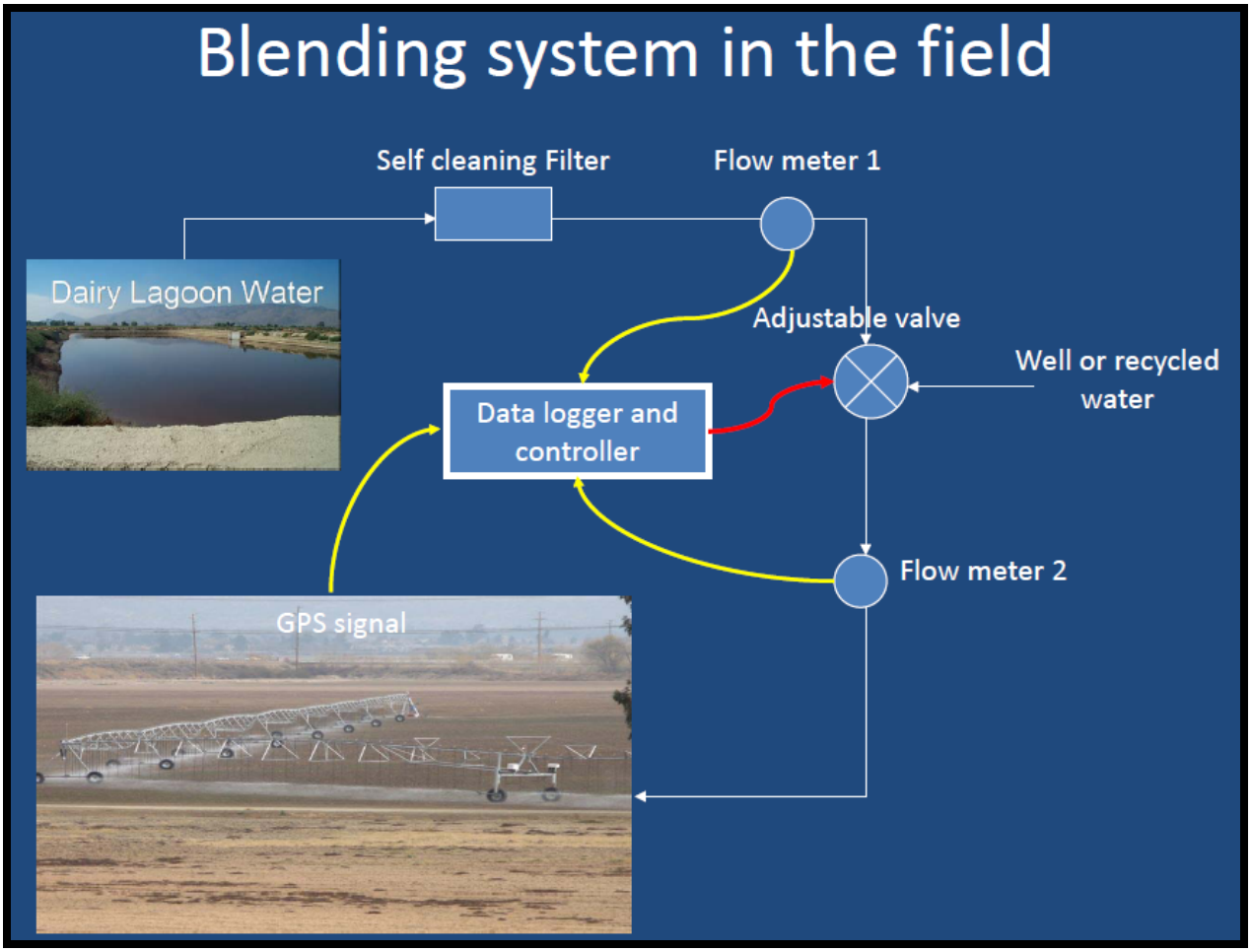


Figure 7. A scheme of the blending system in the field site.

Initially, the desire blending ratio was programmed into the controller. The flow meters connected to the controller measured the actual blending ratio in 10 sec intervals. The controller opens or closes the adjustable valve where difference between measured and desired blending ratio was/less more than one. Additionally, the blending system was design to address future needs of precise agriculture. A signal from the GPS system located on the Pivot will allow different application amounts of DWW by adjusting the blending ratio for each section of the field.

Suspended sediments concentration (SSC) of the DWW were measured by centrifuging a known volume at 2040 times gravity for 20 min, decanting the liquid phase and measuring the remaining solid after drying at 60ºC for 48 hour (ASTM D 3977-97 - Method A).

Salts

A full chemical analysis (major anions and cations, EC, macro- and micro-nutrients, and pH) of DWW and soil profiles at each sampling location was conducted at the beginning of the project (May, 2007). During the growing seasons, salt content in the DWW and the root zone was estimated from sequential measurements of EC and ECe. The TDS was assumed to be correlated to the EC (1 $dS \cdot m^{-1}$=640 $mg \cdot L^{-1}$) and was measured with an EC meter (M33.1, Agricultural electronics, Montclair, CA). At mid-project time (July 2008), the ECe of the upper soil profile (0-30cm) was measured right after water application of 9 to 15 cm, that was applied to leach excess of salts. A second full chemical analysis (major anions and cations, EC, macro- and micro- nutrients, and pH) of the soil profiles at each sampling location was conducted at the end of the project (November, 2008). During 2009, soil salinity of the upper profile (0-60 cm and 0-90 cm) was monitored at the four monitoring stations.

Microorganisms

The transport and fate of several fecal indicator microorganisms (*Enterococcus*, fecal coliforms, somatic coliphage, and total *E. coli*) was monitored under ponded infiltration and redistribution of fresh DWW. These conditions were selected to mimic a worst case transport scenario of saturated conditions which enable DWW and microorganisms to move rapidly through the soil in macropores.

In this case, DWW was instantaneously added to the soil surface to a depth of 10-20 cm and allowed to infiltrate into the profile. Following application and infiltration of the wastewater, 2 cm diameter and 65 cm long soil cores were collected vertically from the column surface at selected times (0, 1, 3 and 7 days) and analyzed for concentrations of indicator microbes. Subsequently to core sampling, a capped PVC tube with similar dimensions was plugged in the bore. Due to the time, labor, and costs associated with such an experiments, four sampling sites (two extremes and two

averages values of measured soil hydraulic conductivity of the upper soil profile – infiltration experiments) served for this study. The concentration of each microorganism in the fresh DWW was determined prior to the application. For microbial analysis, the soil cores were divided into 5 to 10 cm depth increments. A 5-10 g sample of the field soil from each depth increment was placed in a 50 mL sterile polypropylene centrifuge tube (Thermo Fisher Scientific, Waltham, NJ) containing 20 mL of 3.5% beef extract solution with its pH adjusted to 9, phosphate buffer solution, or de-ionized water. The solution was vortexed for 1-2 minutes and then the soil solution was allowed to settle. These solutions were subsequently be analyzed for microbial concentrations using the outlined procedures described below. Subsamples of the soil core were analyzed for water content (difference in weight of field and oven dry samples), and the microorganism concentrations were corrected for the amount of soil and solution in each depth increment.

The concentration of the somatic coliphage in the soil solution and lagoon water was determined using the double agar overlay method with bacterial host *Escherichia coli* CN-13 (ATCC 700609) (USEPA, 2001). The Colilert and Enterolert methods (Erkner, 1998) were used to determine concentrations of total *E. coli*, fecal coliform, and *Enterococcus* in the soil solution and lagoon water according to the manufacturer's instructions. Alternatively, concentrations of total E. coli, fecal coliforms, and Enterococcus were sometimes determined using the conventional spread plating method[9]. In this case, a 100 μl sample was plated on Chromagar ECC (CHROMagar Microbiology, Paris, France) plates for total E.Coli, on mFC agar (BD Diagnostic Systems, Sparks, MD) plates for fecal coliforms, and on KF agar (EM Science, Gibbstown, NJ) plates for *Enterococcus*. The plates were inverted and incubated at 37°C for total *E. Coli* (24 hours) and *Enterococcus* (24-48 hours), and at 44.5^{o}C for fecal coliform (24 hours). The bacterial colony forming units (CFU) were then counted. All bacterial assays were run in duplicate and diluted as necessary.

[9] Clesceri, L. S., A. E. Greenberg, and R. R. Trussell. 1989. *Standard Methods for the Examination of Water and Wastewater, 17th edition*, American Public Health Association, Washington, D.C.

RESULTS

Soil physical characterization

The soil texture of the upper profile is cataloged as a sandy loam (Grangeville Fine Sandy Loam, a Coarse-loamy, mixed, superactive, thermic Fluvaquentic Haploxeroll). However, the sub soil (<65cm) is heterogeneous due to the fact that part of the field is located above the course of an old river bed, where coarse sand layers and fine texture lenses due to flooding events were found.

A typical example of PSD and BD over depth and the predicted hydraulic parameters is given in Figure 8, for sampling site 10049. PSD and BD varied over depth. While finer soil layers were found at 0-30 cm and 90-120 cm, coarser soil layers were found at 30-60cm and 120-150 cm. Measured BD generally corresponded to the PSD data, with finer soil layers characterized by lower BD. In the upper profile, farm traffic increases the BD due to compaction. Detailed PSD and BD information with depth for site no. 10049 are presented in Figure 8, as well as the predicted hydraulic properties for the profile.

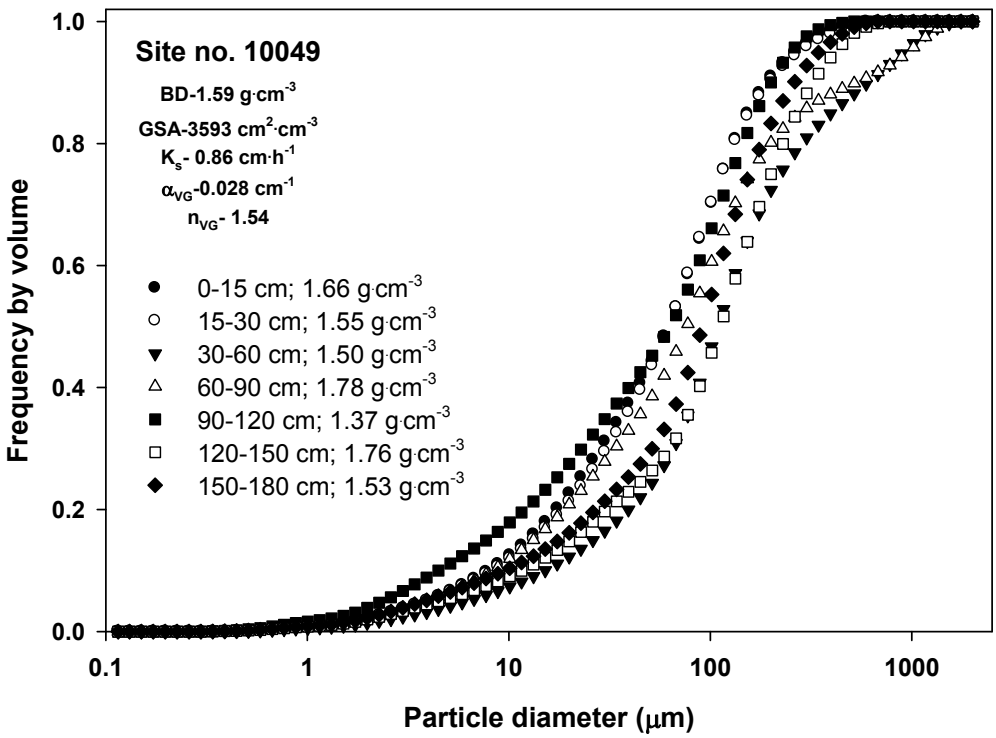
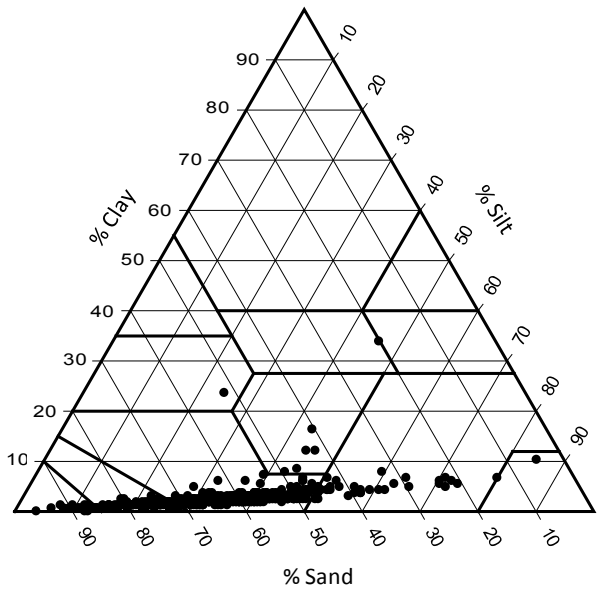


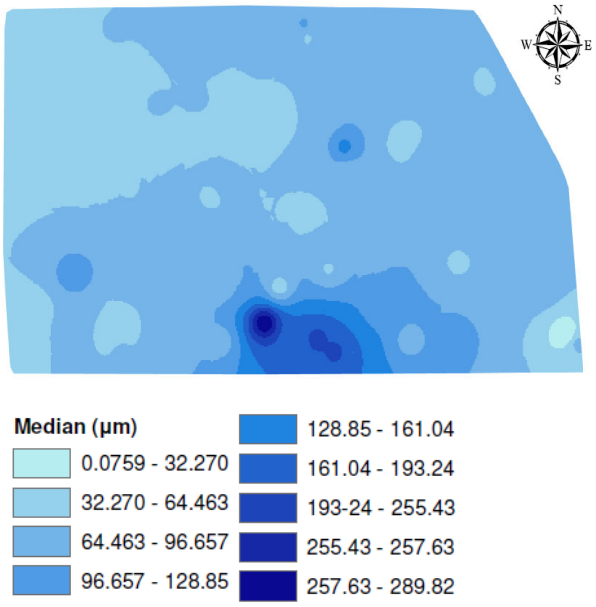
Figure 8. Particle size distribution and bulk density of seven soil layers at sampling site 10049, and predicted hydraulic properties of the soil profile.

Textural characterization of the soils in the field and the spatial data of average physical and hydraulic properties of the soil profile at each sampling site are presented in Figure 9. Maps present the arithmetic means over depth of median particle size (d_{50}), BD, GSA, α_{VG} , n_{VG}, harmonic mean of K_s^{eff} and measured i_f. Data sources are the 70 soil sampling sites and 61 sites of infiltration experiment in June 2007.

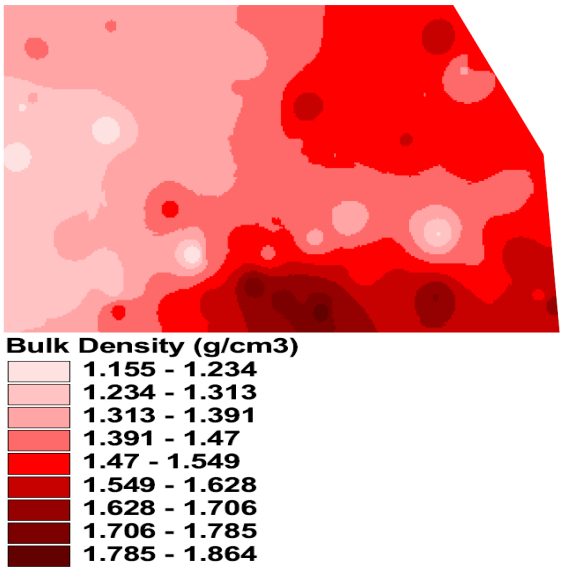
Texture



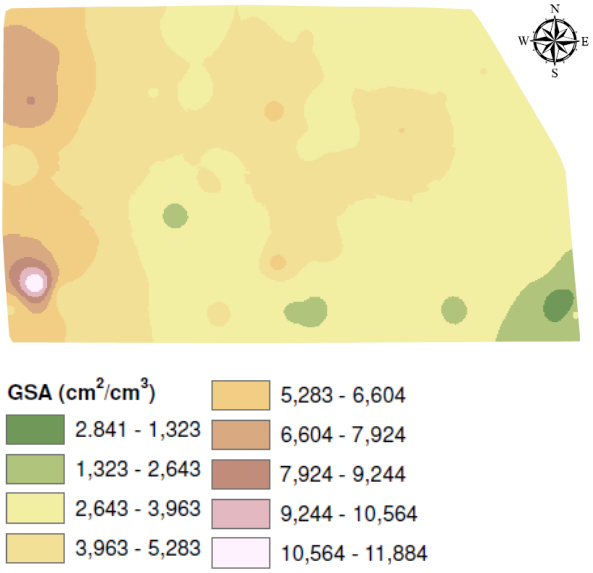
Median particle size



Bulk Density



Geometrical Surface Area



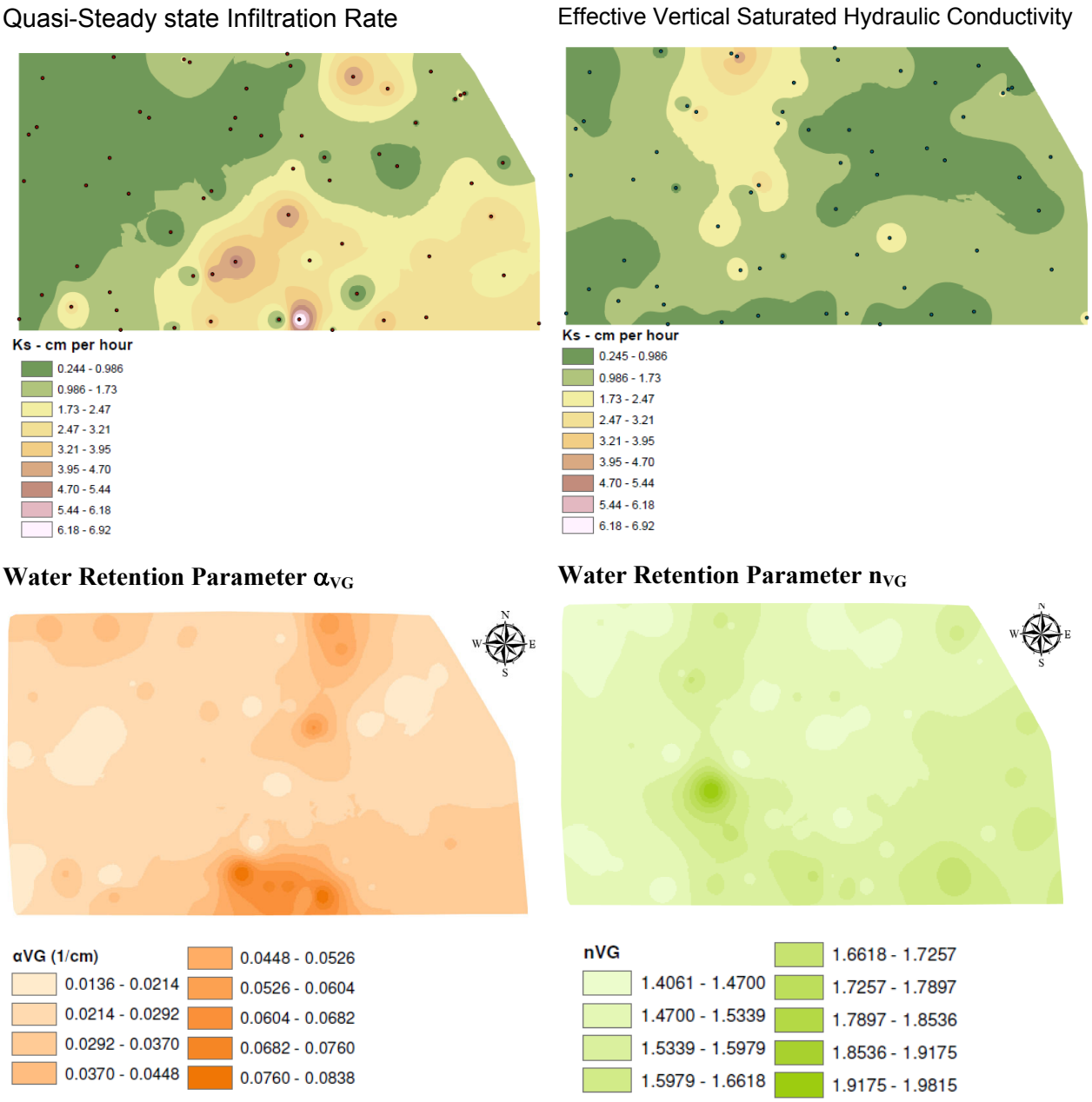


Figure 9. Textural distribution of soil sample and spatial data average physical properties of the soil profile (0-180 cm) at each sampling site. Median particle size, bulk density, geometrical soil surface area, measured quasi-steady state infiltration rate, calculated effective vertical saturated hydraulic conductivity, soil water retention curve parameters of the van-Genuchtan hydraulic model, α_{VG} and n_{VG}. Data sources are the 70 soil sampling sites and 61 sites of infiltration experiment in June 2007.

The field soil texture mainly comprised from sandy and loam soils: sand, loamy sand, sandy loam, loam and silt loam. The sand content varied between 20% to 95%, silt varied between 5% to 75%, and clay between 0 to 7%. The spatial pattern of soil texture, based on d_{50}, ρ_b and GSA show a transition from finer textural soil (silt loam and loam) to coarser soils (loamy sand and sand) from west to east. The spatial pattern of measured i_f was similar to the textural pattern and ranged between 0.25 to 6 $cm \cdot h^{-1}$, typical values for sandy loam soils. The extreme values of d_{50}, BD, GSA and i_f reflect the soil heterogeneity of the lower profile, where coarse sand layers and fine texture lenses were found and mainly affected values presented as arithmetic means. In contrast, the harmonic mean is less affected by a single layer or lens and therefore the range of K_s^{eff} values is relative small. The spatial pattern of soil water retention parameters partly matched the textural and infiltration patterns. The parameters n_{VG} and α_{VG} correspond to the slope and air entry of the soil water retention curve, respectively, and higher values typically characterize coarser soils. The n_{VG} and α_{VG} values ranged between 1.47 to 1.98 and 0.01 to 0.08 (cm^{-1}), which and are typical values for loam and sandy soils, respectively. The variation between soil texture and the water flow and retention parameters may be attributed in part to soil structure which is not characterized by textural parameters.

Predicted K_s^{eff} based on PSD and BD information was found to be significantly different from measured i_f , which served as an alternative estimate of K_s of the upper soil layer. Predicted K_s^{eff} (0-30cm) versus measured i_f are shown in Figure 10. Horizontal error bars represent the maximum and minimum values of measured i_f over time. Measured K_s of the upper soil layer usually was found to be higher than the predicted value. This is due to the fact that the Kozney-Carmen model for K_s prediction only accounts for the matrix, while actual field condition are influenced by soil structure effect due to the tillage practice, soil consolidation and root growth.

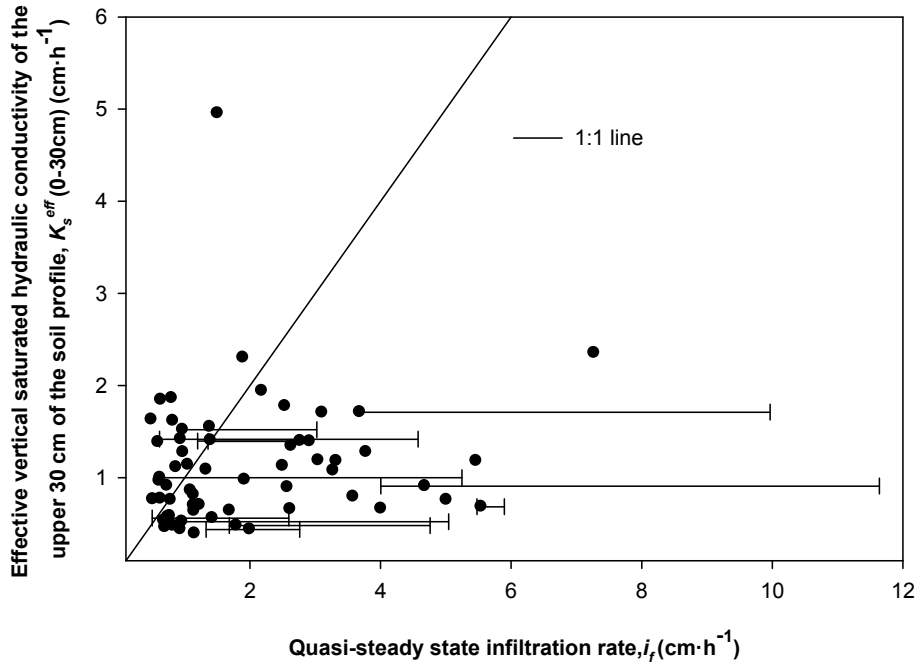


Figure 10. Effective vertical saturated hydraulic conductivity of the upper 30 cm of the profile, K_s^{eff} (0-30cm) versus quasi-steady state infiltration rate, i_f. Horizontal error bars represent maximum and minimum values of measured i_f.

Temporal variability of infiltration properties across the field was measured at 14 locations on three occasions, June, October and December 2007. A typical example of the cumulative infiltration curve as a function of time is presented in Figure 11, for sampling site 8481. Different initial soil properties (moisture, structure and existence of roots) yielded temporal variability in the cumulative infiltration curves. The quasi-steady state infiltration rate, i_f for each occasion is given in the figure as well.

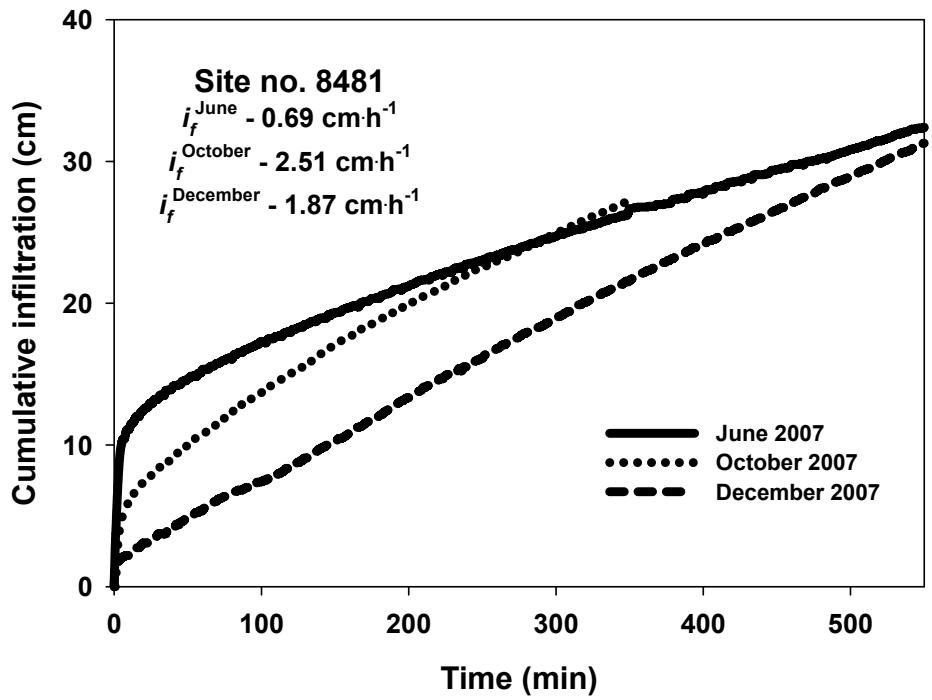


Figure 11. Cumulative infiltration versus time for sampling site 8481 at three occasions

Data on the temporal variability of infiltration properties across the field is presented in Figure 12 by using box plots. Measured i_f across the field at three occasions, June, October and December 2007, is presented in Figure 12A-C. Field average, STD and CV of each occasion is given on the figure as well. Letter in brackets next to the average is a statistical group of TTEST at significant level of 0.05. Data sources are the 14 sites of infiltration experiment (12A-C). Arithmetic means of the average i_f , STD and CV values of each infiltration location (14 sites) is presented in Figure 12D. Field average values of i_f and its STD from the 61 infiltration sites (1.95±1.48 cm·h^{-1}, Fig. 9) and the sub-population of 14 sites, that served to study the temporal variations in the field (2.02±1.40 cm·h^{-1}, Fig. 12A), were found similar with high correlation (P_{TTEST} -0.89). Consequently, we assume that the 14 sites in June 2007 represent adequately the entire field. Field average values of i_f and its STD varied significantly after the deep (100 cm) coarse ripping in October 2007 (3.99±3.15 cm·h^{-1}, Fig. 12B). Intermediate values were found after shallow (20cm) plowing and planting in December 2007 (2.53±1.59 cm·h^{-1}, Fig. 12C). This measured variability in i_f due to soil tillage practices (October and December 2007) and the intact root system (June 2007)

have been formally identified in the literature. However, most of the studies had found that temporal variations were more significant then spatial ones. In contrast to these findings, the spatial variability of i_f was found to be larger than temporal variability, where the average spatial CV ($CV_{spatial}$= 0.72, Fig. 12A-C) was higher than the average temporal CV ($CV_{temporal}$=0.55, Fig. 12D).

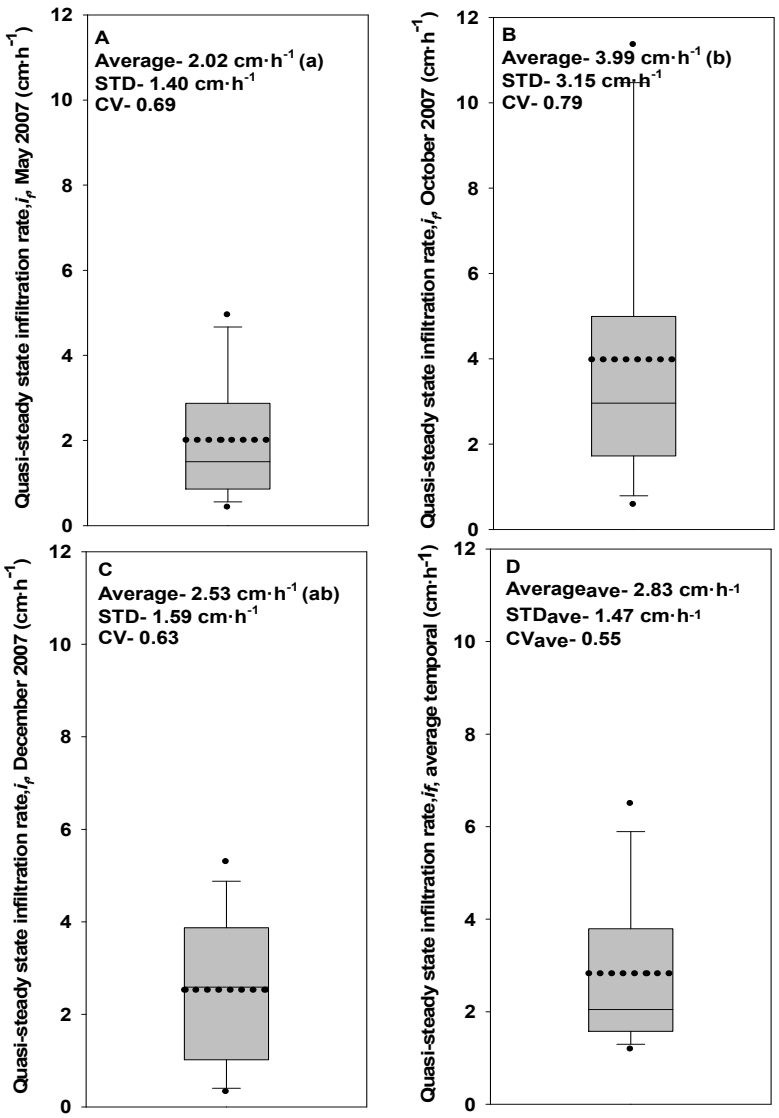


Figure 12. Field average, standard deviation (STD) and coefficient of variance (CV) of quasi-steady state infiltration rate, i_f (A-C) at three occasions (June, October and December 2007). Data represents the 14 sites of infiltration experiment. Arithmetic means of the average i_f , STD and CV values of each sampling location (D). Letter in brackets next to the average values are statistical group of TTEST at significant level of 0.05.

Initial conditions

The initial conditions of the field prior to land application of DWW were the direct result from past management and soil properties. In-situ and laboratory analysis of the soil samples, collected after the first EMI survey (May 2007), were used to measured the spatial initial conditions of each constituent. The ECa map generated by the EMI was highly correlated to the soil moisture (R^2=0.70) and soil salinity (R^2=0.72), Fig. 13.

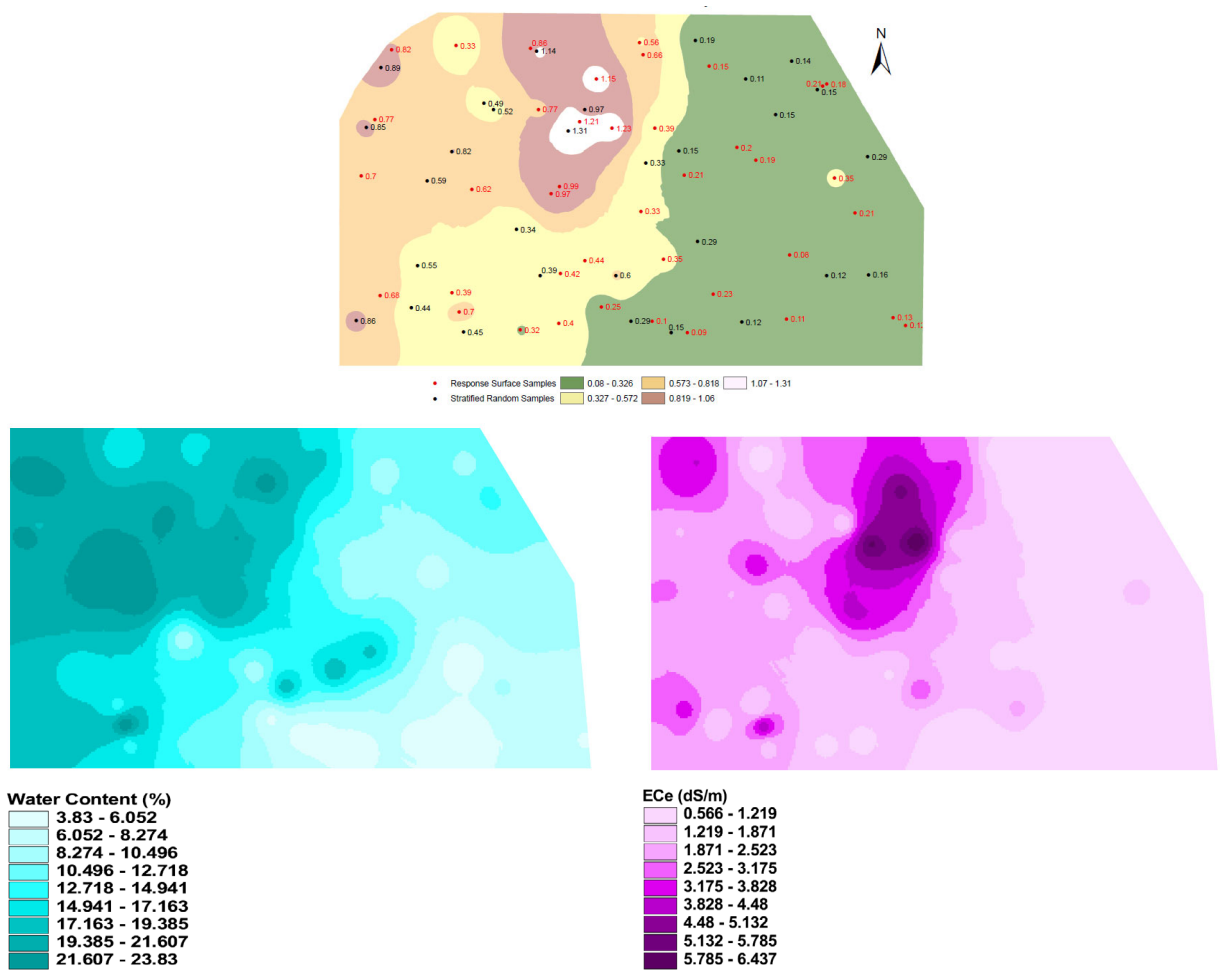


Figure 13. ECa map generated by the EMI technique on May 2007 and corresponded maps of soil moisture and soil salinity.

The gravimetric water content (GWC) and ECe maps are influenced by the soil texture, application of water and crop performance. Assuming uniform application of water, the GWC map reflects the water holding capacity of the soil profile. Lower GWCs were measured in the east side of the field that is associated with coarser soils,

whereas higher GWCs were found in the west part with finer soils. The high salt content in the upper middle section of the field may restricted plant growth and decreased water uptake, therefore higher GWC were measured. The textural characterization of the soils in the field found mainly sandy and loam soils (sand, loamy sand and sandy loam) with silt content that vary between 5 to 70%. Loam soils with high silt content suffer from lack of drainage and intensive runoff. These conditions inhibit salts accumulation in the upper profile and poor crop performance. Support for this hypothesis is provided on the high upper middle section of the field shown in Figure 14, where comparison between GWC, saturation percentage (SP) and yield is presented. The SP is a better prediction parameter of the soil water holding capacity. The yield map was generated on Oct. 2007 after a full growing season of Sorghum.

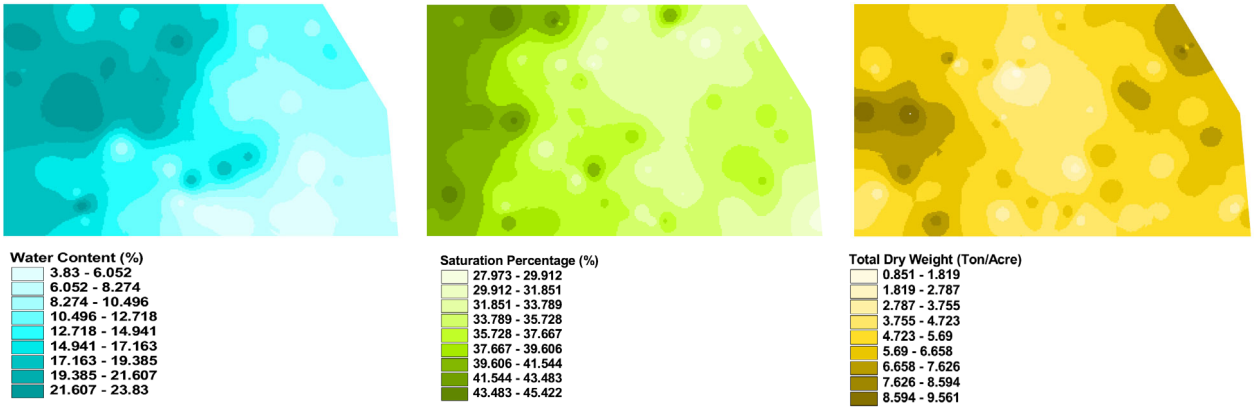
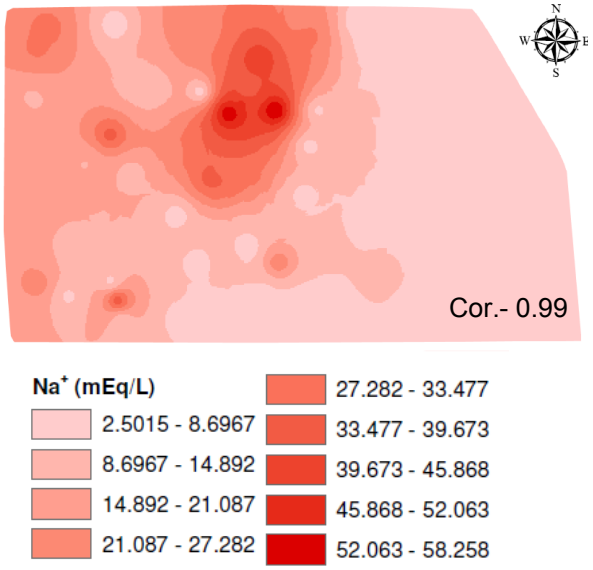


Figure 14. Maps of soil moisture (gravimetrical water content) and saturation percentage as measured on May 2007, and dry biomass of sorghum measured on Oct. 2007.

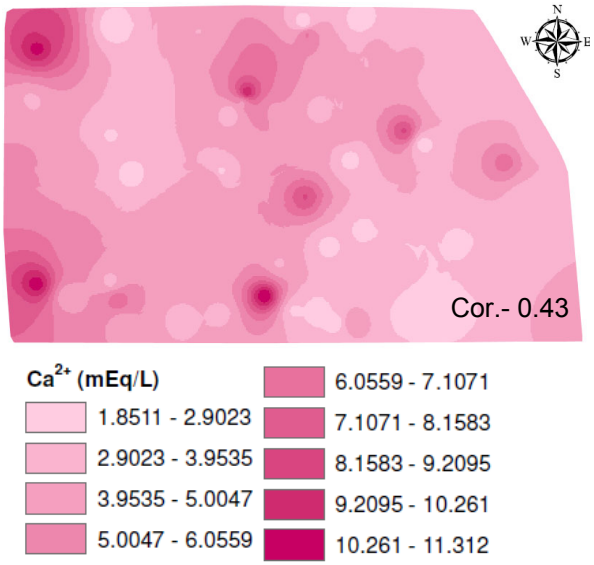
The comparison revealed that the measured high GWC in the upper middle of the field were not due to finer texture soils, but due to high salinity levels that inhibited poor crop performance and caused a corresponding sharp reduction in plant water uptake.

The electrical conductivity of the soil was found to be strongly correlated to the concentration of major cations and anions. A profile view of the major cations and anions, measured from a saturation paste, and their correlation coefficients are given in Figure 15:

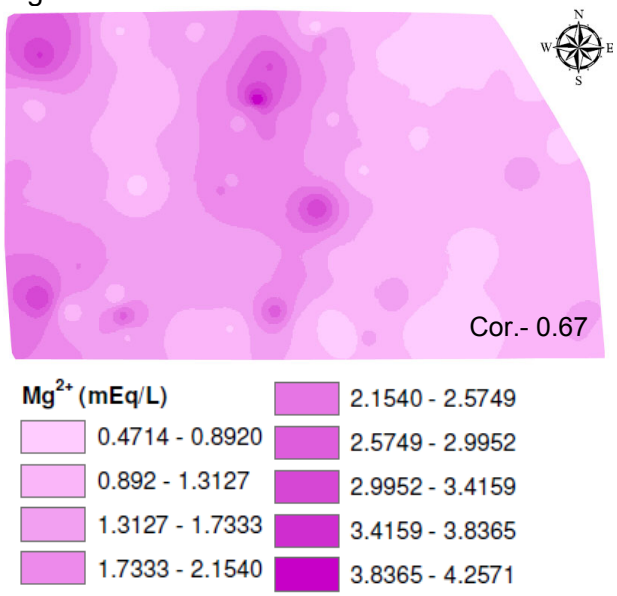
Na


N
W
E
S
Cor.- 0.99
Na+ (mEq/L)
2.5015 - 8.6967
8.6967 - 14.892
14.892 - 21.087
21.087 - 27.282
27.282 - 33.477
33.477 - 39.673
39.673 - 45.868
45.868 - 52.063
52.063 - 58.258

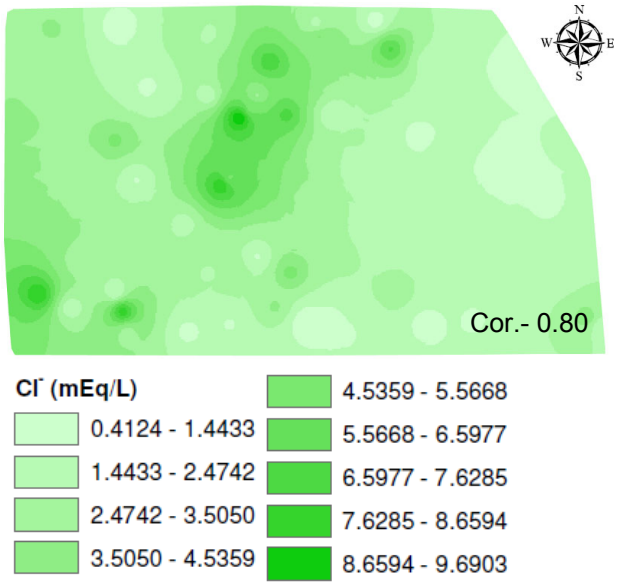
Ca


N
W
E
S
Cor.- 0.43
Ca2+ (mEq/L)
1.8511 - 2.9023
2.9023 - 3.9535
3.9535 - 5.0047
5.0047 - 6.0559
6.0559 - 7.1071
7.1071 - 8.1583
8.1583 - 9.2095
9.2095 - 10.261
10.261 - 11.312

Mg


N
W
E
S
Cor.- 0.67
Mg2+ (mEq/L)
0.4714 - 0.8920
0.892 - 1.3127
1.3127 - 1.7333
1.7333 - 2.1540
2.1540 - 2.5749
2.5749 - 2.9952
2.9952 - 3.4159
3.4159 - 3.8365
3.8365 - 4.2571

Cl


N
W
E
S
Cor.- 0.80
Cl- (mEq/L)
0.4124 - 1.4433
1.4433 - 2.4742
2.4742 - 3.5050
3.5050 - 4.5359
4.5359 - 5.5668
5.5668 - 6.5977
6.5977 - 7.6285
7.6285 - 8.6594
8.6594 - 9.6903

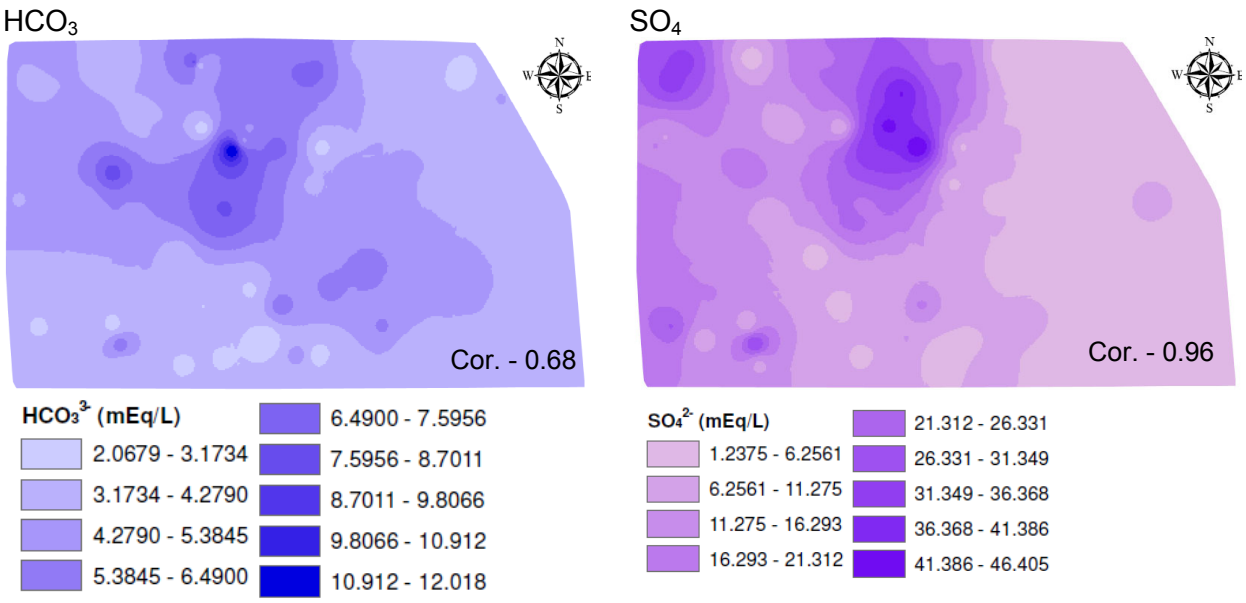
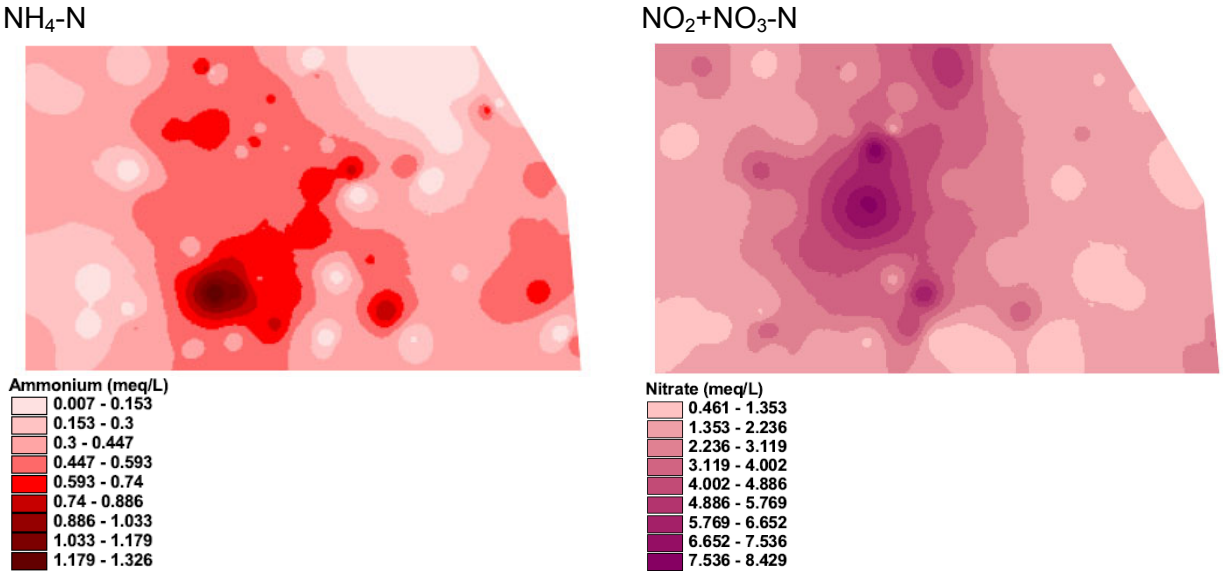


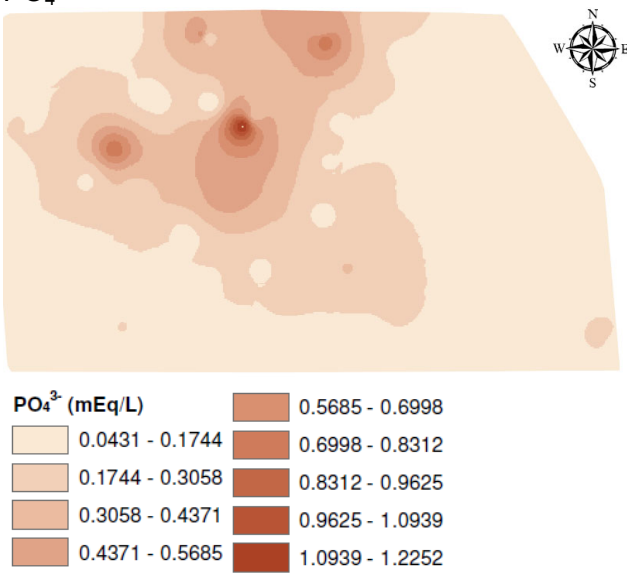
Figure 15. A profile view of the major cations and anions and their correlation coefficients to the soil electrical conductivity.

The spatial pattern of Na, Mg, Cl, SO_2 and HCO_3 followed the spatial pattern of the EC, reflected by the high coerrelation (Cor.). The spatial distribution of Ca was relatively uniform (2-5 meq·L^{-1}) with few sites of higher concentrations.

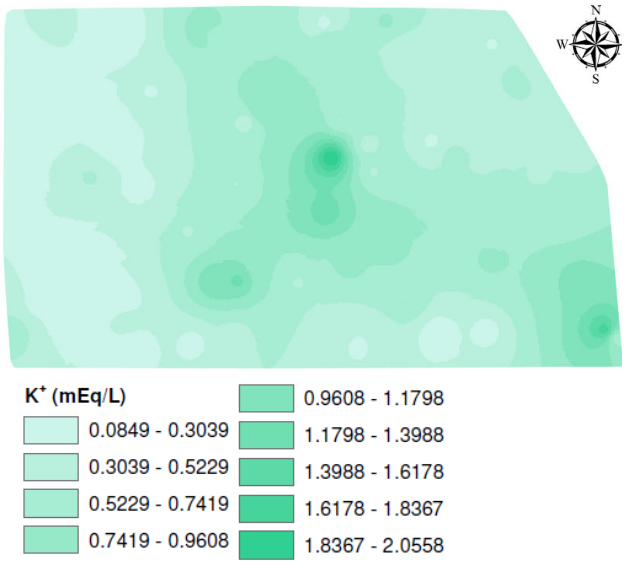
Similarly, profile views of the macro- and micro- nutrients and total C and N are given in Fig. 16:



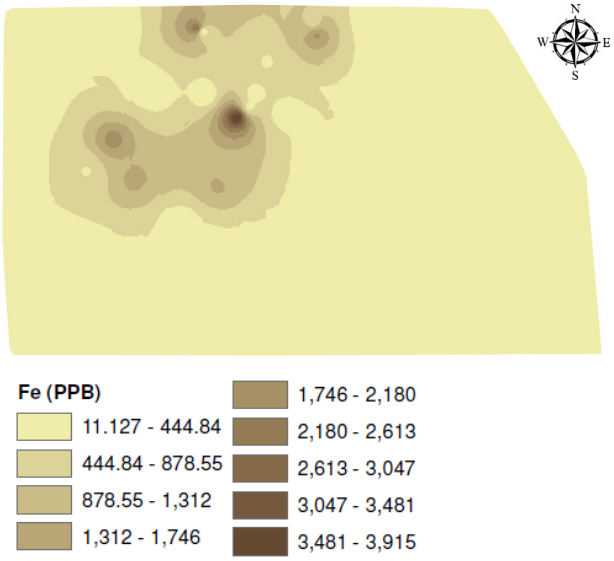
PO_4


N
W
E
S
PO_4^{3-} (mEq/L)
0.0431 - 0.1744
0.1744 - 0.3058
0.3058 - 0.4371
0.4371 - 0.5685
0.5685 - 0.6998
0.6998 - 0.8312
0.8312 - 0.9625
0.9625 - 1.0939
1.0939 - 1.2252

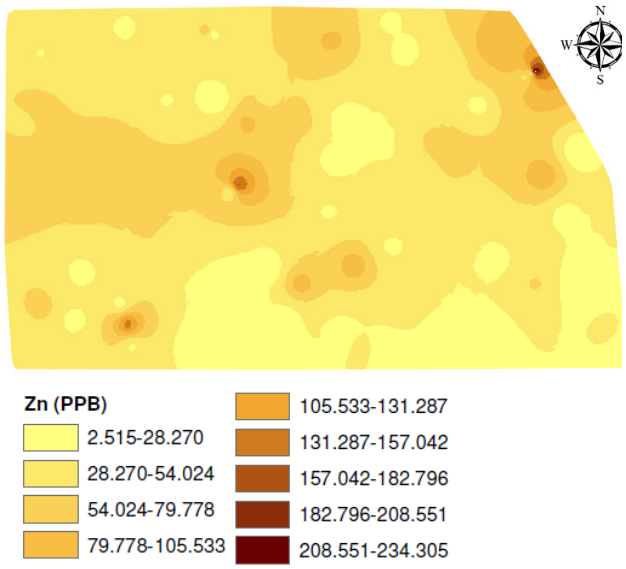
K


N
W
S
K^+ (mEq/L)
0.0849 - 0.3039
0.3039 - 0.5229
0.5229 - 0.7419
0.7419 - 0.9608
0.9608 - 1.1798
1.1798 - 1.3988
1.3988 - 1.6178
1.6178 - 1.8367
1.8367 - 2.0558

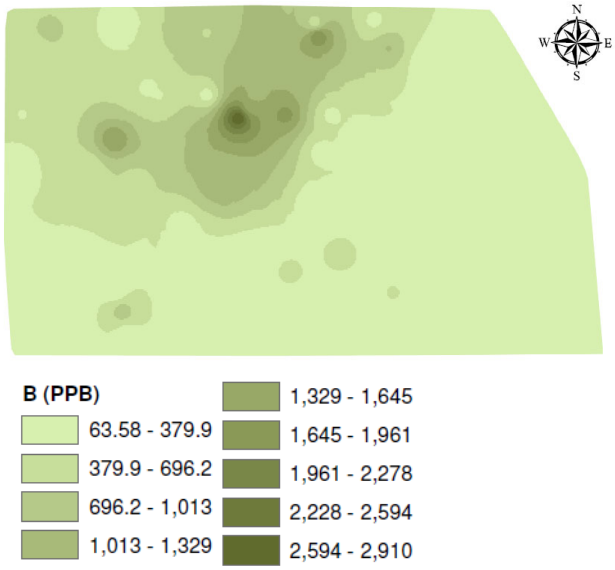
Fe


N
W
E
S
Fe (PPB)
11.127 - 444.84
444.84 - 878.55
878.55 - 1,312
1,312 - 1,746
1,746 - 2,180
2,180 - 2,613
2,613 - 3,047
3,047 - 3,481
3,481 - 3,915

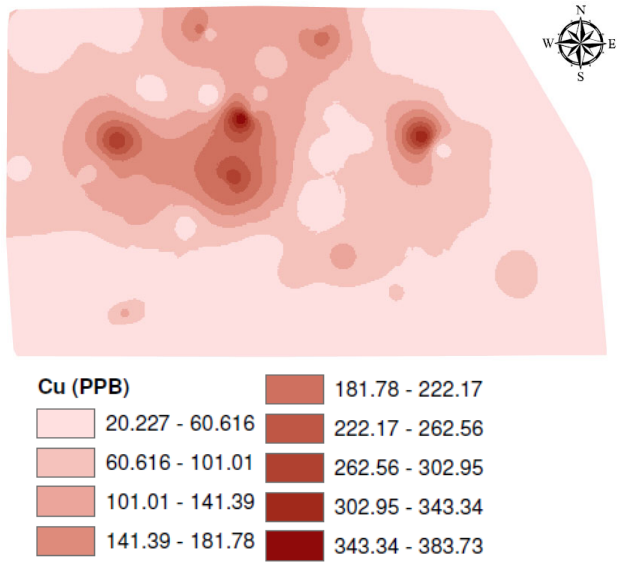
Zn


N
W
S
Zn (PPB)
2.515-28.270
28.270-54.024
54.024-79.778
79.778-105.533
105.533-131.287
131.287-157.042
157.042-182.796
182.796-208.551
208.551-234.305

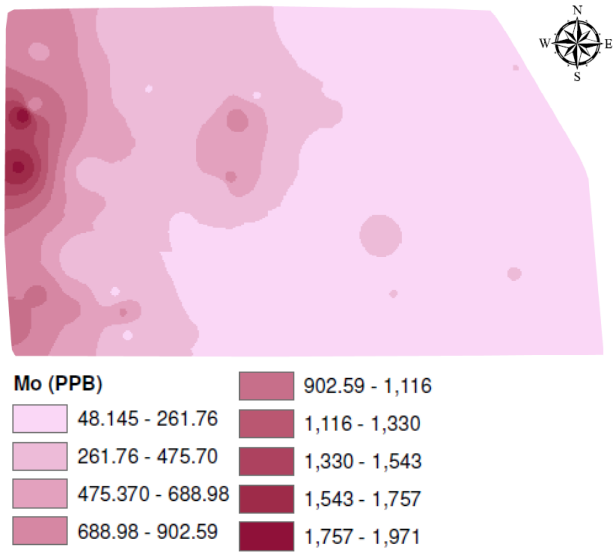
B


N
W
E
S
B (PPB)
63.58 - 379.9
379.9 - 696.2
696.2 - 1,013
1,013 - 1,329
1,329 - 1,645
1,645 - 1,961
1,961 - 2,278
2,228 - 2,594
2,594 - 2,910

Cu


N
W
E
S
Cu (PPB)
20.227 - 60.616
60.616 - 101.01
101.01 - 141.39
141.39 - 181.78
181.78 - 222.17
222.17 - 262.56
262.56 - 302.95
302.95 - 343.34
343.34 - 383.73

Mo


N
W
E
S
Mo (PPB)
48.145 - 261.76
261.76 - 475.70
475.370 - 688.98
688.98 - 902.59
902.59 - 1,116
1,116 - 1,330
1,330 - 1,543
1,543 - 1,757
1,757 - 1,971

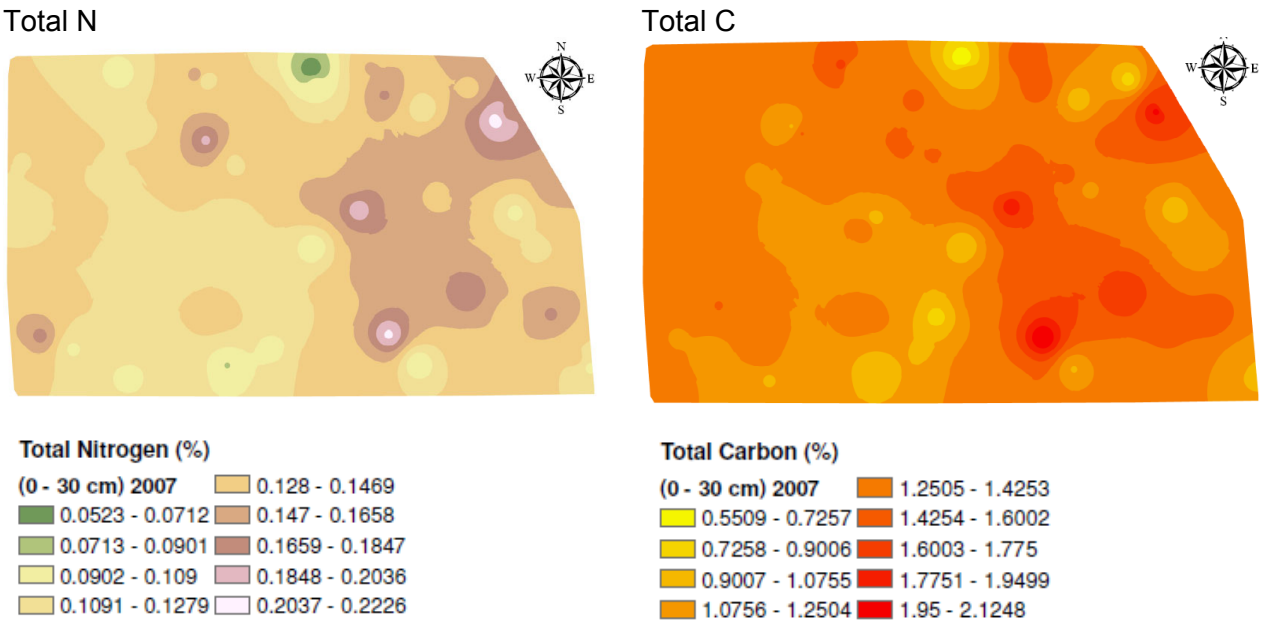


Figure 16. A profile view of macro- and micro- nutrients and total C and N.

In general, a similar spatial patter was found for the macro- and micro- nutrients, where high concentration were measured in the middle upper part of the field and relatively uniform concentration elsewher. The high residuals concentrations can be attributed to the poor crop performance in this part of the field due to the elevated salinity levels (Fig. 13). An exceptional is the spatial pattern of the Molybdenum (Mo) that follows the soil texture pattern rather than that of crop performance one. Total C and N were found to be strongly correlated (correlation coefficient- 0.87) due to the fact that organic N is the dominant N form in the soil. Total N ranged between 0.05-0.22% and total C 0.5-2.1%. The average C to N ratio was 9.8, a typical value for organic matter in soils.

Water sources and water application method

Three water sources were used during the period of the study. Initially, DWW was blended with well water before application. The DWW was treated in two stages before use:

1. A series of notched weirs along the canal, which channeled the DWW from the dairy to the lagoon, removed most of the solids before entering the lagoon.

2. A self cleaning filter (SAF-3000, Amiad filtration systems, Israel) with 200 mesh screen was installed before blending with the well/recycled water to remove solids that could clog the emitters.

Seasonal variation in the concentrations of each constituent in the DWW is expected due to seasonal fluctuations in the herd's diet, storage time in the lagoons and temperatures.

The average concentrations of salts, macro- and micro- nutrients of treated DWW (summer 2009), recycled water (summer 2009) and well water (winter 2007) are presented in Table 2.

Table 2- Salts and macro-nutrients of treated dairy wastewater. Treatment included notched weirs, sedimentation in the lagoon and a screen filter.

Category	component	lagoon DWW	Recycled water	Well water
General	EC ($dS \cdot m^{-1}$)	2.6	1.1	0.5
	TDS ($mg \cdot L^{-1}$)	NA	600	320
	SSC ($mg \cdot L^{-1}$)	199.1	196	NA
	pH	8.6	7.38	8.7
Salts ($mg \cdot L^{-1}$)	Na	293.2	201.1	61.5
	Ca	134.3	115.3	50
	Mg	69.1	22.1	2.3
	Cl	304.4	188.8	17.4
	$S\text{-}SO_4$	107.8	68.6	43.8
	HCO_3	493.8	105.8	59.5
Macro-Nutrients ($mg \cdot L^{-1}$)	NH_4-N & NO_2+NO_3-N	37.9	17.9	1.15
	Organic N	7.05	6.9	NA
	K	289.5	17.7	2.2
	Total P	29.1	4.3	0.06
Micro-Nutrients ($\mu g \cdot L^{-1}$)	B	64.4	17.1	40
	Fe	43.8	12.8	82
	Cu	13.5	1.7	NA

On May 2008 the irrigation water system in the farm was switched from well water to recycled water from a nearby water plant. The transition to recycled water has three aspects:

1. Utilizing marginal water as water and nutrient sources to crop production solves the disposal problem back to the environment.

2. Macro- and micro- nutrients in the recycled water reduce the need for commercial fertilizers.
3. Salts that accompanied the nutrients can accumulate in the upper soil profile and have a negative effect on soil fertility. Rigorous management of salts in the root zone is therefore required.

On one hand, the TDS of the recycled water was double that of the local well water (600 versus 320 $mg \cdot L^{-1}$), meaning frequent leaching of salts is required to avoid yield reduction due to enhanced soil salinity in the root zone. On the other hand, the considerable inorganic *N* in the recycled water needs to be accounted for in the *N* mass balance. Recycled water has seasonal variations as well, due to the multiple sources, storage time and treatment efficiency. Frequent measurements of total inorganic N (NO_2+NO_3-N and NH_4-N) and EC of the recycled water during 2009 (DOY- day of the year) are presented in Figure 17.

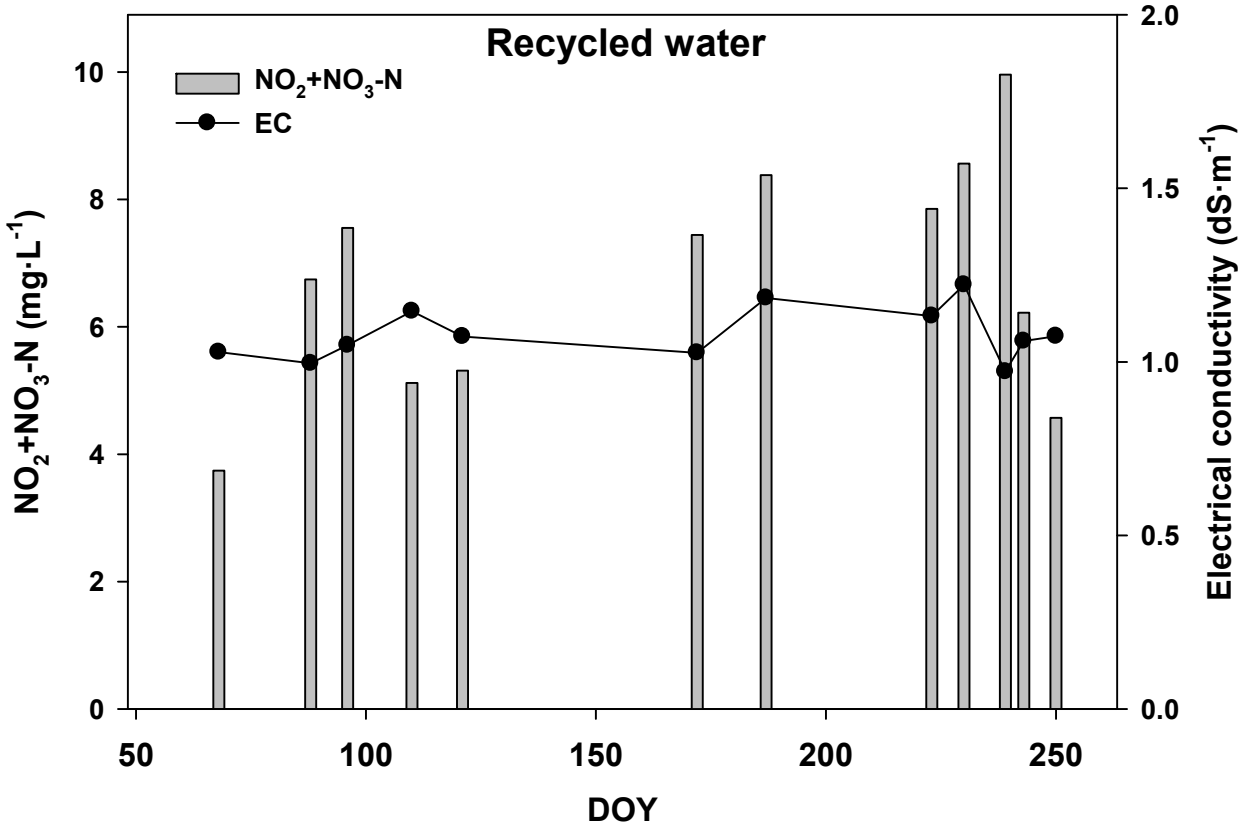


Figure 17. Nitrate-N and EC of the recycled water during three months period in 2009.

While minor seasonal variations were found in EC, significant variations were measured in NO_2+NO_3-N (4 versus 10 mg·L^{-1}) in the recycled water. Meaning, an efficient NMP that utilizes recycled water will require frequent information on the inorganic N content of this source.

A central pivot (Reinke, Nebraska) irrigation system was installed in the field site on Nov. 2006. During the previous 25 years, the field was irrigated with sprinklers and furrows. The irrigation uniformity of the pivot was tested prior to the application of DWW by employing the catching cups technique on March 2007, under typical wind conditions for this season (average day time wind speed-1.85 m·s^{-1}). Seventy two, 300 ml / 95 cm^2, catching cups were placed at 5 m intervals along the pivot. The pivot was programmed to apply 9.4 mm of water. After the pivot passed the measured area, the volume of water was measured for each cup. The depth of water as a function of the radial distance from the pivot is presented in Figure 18.

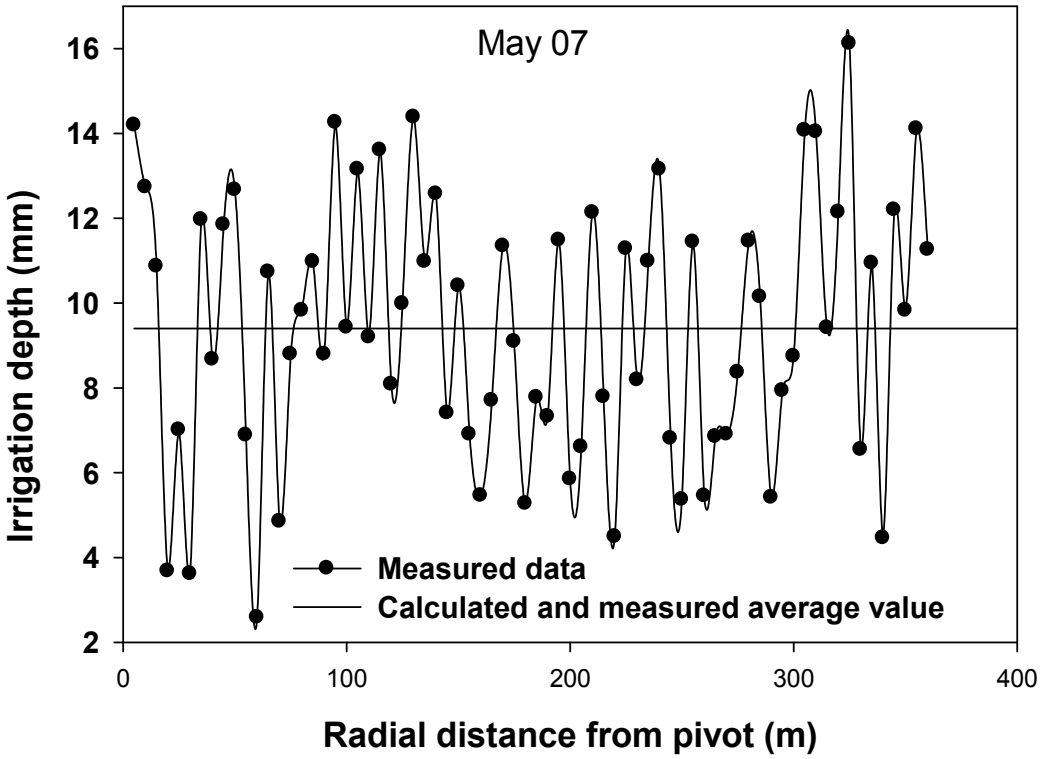


Figure 18. Application rate as a function of the radial distance.

The results indicate that measured and calculated average application rates were similar, however the coefficient of uniformity was only 72% due to the cyclic pattern in the irrigation water application.

Nutrient management plan

A NMP was implemented on winter and summer crops during 2007-2009. Wheat-Rye hybrid (Triticale, Resource Seeds, Inc.) served as the winter crop and forage Sorghum served as summer crop (NK 300 in 2007-2008 and SorgoMax in 2009). During 2009, a rotation of three crops was tested, where a short growing season of barley was added between the Triticale and the Sorghum. Although the experimental system was installed and was ready to apply DWW and to implement the NMP starting June 2007, high levels of plant available *N* was found in the root zone. Therefore, no DWW was applied during the summer 2007 growing season. The planting and harvesting dates of the crops at each growing seasons are given in Table 3. The delayed schedule of winter 2008 was due to extensive damage to the pivotfrom strong winds on Oct. 15th 2007.

Table 3. Planting and harvesting dates of the crops for each growing season

Growing season	Planted	harvested
Summer 2007- Sorghum	10th of June	20th of Sep.
Winter 2008- Triticale	7th of Dec.	28th of April
Summer 2008- Sorghum	7th of June	20th of Sep.
Winter 2009- Barley	1st of Oct.	2nd of Jan.
Winter 2009- Triticale	15th of Jan.	5th of May
Summer 2009- Sorghum	1st of June	21th of Sep.

Water balance

Water balance information for the 2007-2009 winter and summer growing seasons was based on measured precipitation (P), irrigation (I) and potential evapotranspiration (ET_p). Maximum crop ET (ET_{max}) was estimated using the crop coefficient (K_c) method, where $ET_{max}= K_c*ET_p$. Literature values (FAO publication-Allen et al., 1998) of K_c as a function of day after planting (AP) for Wheat, Barley and Sorghum and P, I and ET_p are presented in Table 4.

Table 4. Estimated crop coefficients (K_c) for each crop, measured precipitation (P), irrigation (I) and potential evapotranspiration (ET_p), and calculated maximum crop ET (ET_{max}) for each growing season.

Crop coefficient, K_c				
DAP	Sorghum		DAP	Wheat/Barley
0-20	0.4		0-20	0.3
20-50	0.75		20-60	0.75
50-90	1.1		60-110	1.15
90-110	0.75		110-130	0.8
Before harvesting	0.5		Before harvesting	0.3/0.25
Actual Evapotranspiration, ET_a				
Growing season	P	I	ET_p	ET_{max}
	cm			
Summer 2007- Sorghum	0.41	54.56	96.1	74.6
Winter 2008- Triticale	12.7	11.69	61.7	51.9
Summer 2008- Sorghum	0	57.89	100.12	79.9
Fall 2008- Barley	12.24	17.78	44.47	31.9
Winter 2009- Triticale	8.69	20.3	47.42	26.6
Summer 2009- Sorghum	0	69.92	111.8	85.1

Rainfall occurred during winter and was absent during summer. Potential ET was significantly lower during winter than during summer. Average supplied water amounts were 76% and 77% of ET during summer and winter, respectively. Whereas all the water was supplied through the irrigation system during summer, only 57% was supplied as irrigation water during winter. The balance was completed by depleting water from the soil profile, which was recharged by rainfall and pre-irrigations during fallow periods.

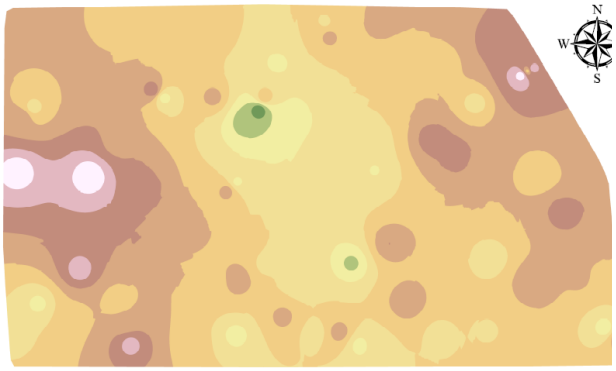
Actual crop water uptake (T_a) could not be measured directly in the field, and therefore was estimated from the verified ratio between relative transpiration to relative yield, where T_{max} was assumed to be equal to ET_{max}:

$$\frac{T_a}{T_{\max}} = \frac{Y_a}{Y_{\max}} \qquad [3]$$

Where Y_a is actual yield and Y_{max} is the maximum yield.

A map of actual crop water uptake for each growing season is presented in Figure 19:

Summer 2007- Sorghum

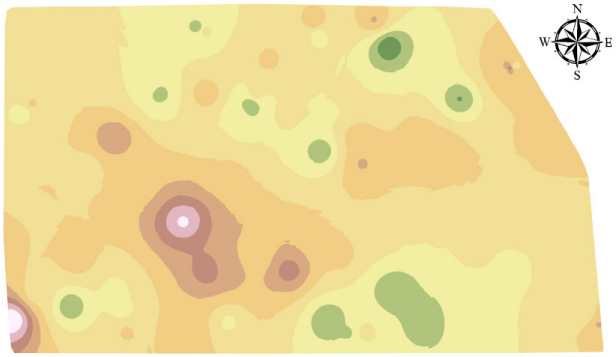


Transpiration(T_a) (cm)

Summer 2007

- 6.545 - 14.105
- 14.105 - 21.665
- 21.665 - 29.225
- 29.225 - 36.784
- 36.784 - 44.344
- 44.344 - 51.904
- 51.904 - 59.464
- 59.464 - 67.023
- 67.023 - 74.583

Winter 2008- Triticale

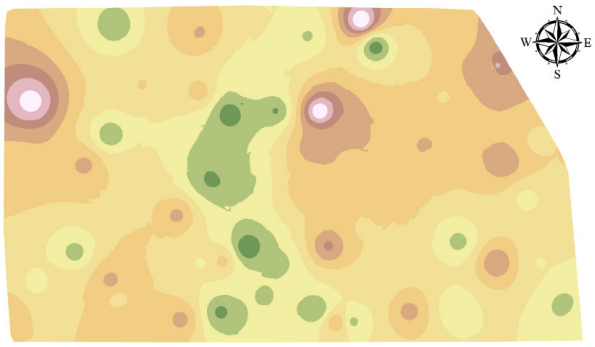


Transpiration(T_a) (cm)

Winter 2008

- 17.165 - 20.857
- 20.857 - 24.549
- 24.549 - 28.241
- 28.241 - 31.933
- 31.933 - 35.625
- 35.625 - 39.317
- 39.317 - 43.009
- 43.009 - 46.701
- 46.701 - 50.393

Summer 2008- Sorghum

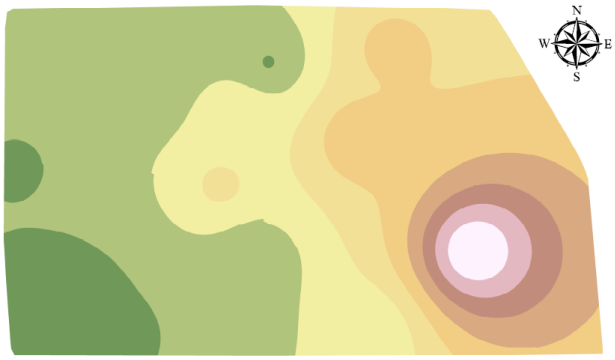


Transpiration(T_a) (cm)

Summer 2008

- 17.514 - 24.441
- 24.441 - 31.369
- 31.369 - 38.296
- 38.296 - 45.224
- 45.224 - 52.151
- 52.151 - 59.078
- 59.078 - 66.006
- 66.006 - 72.933
- 72.933 - 79.861

Winter 2009- Triticale



Transpiration(T_a) (cm)

Winter 2009

- 8.115 - 10.168
- 10.168 - 12.222
- 12.222 - 14.276
- 14.276 - 16.329
- 16.329 - 18.383
- 18.383 - 20.437
- 20.437 - 22.490
- 22.490 - 24.544
- 24.544 - 26.597

Summer 2009- Sorghum

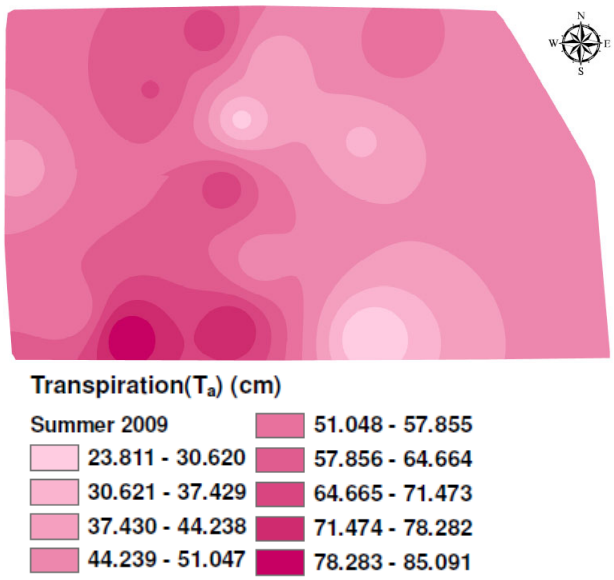
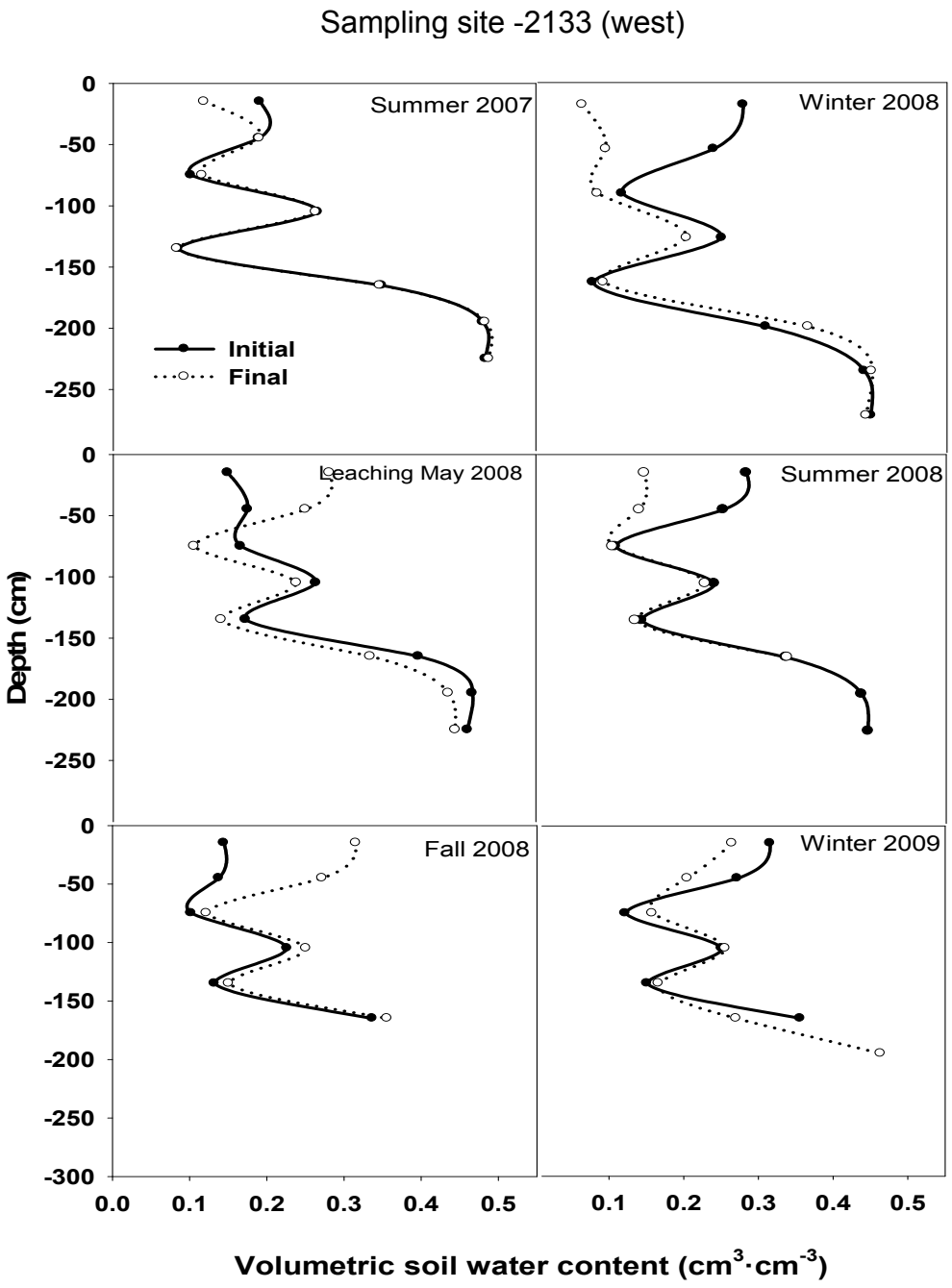
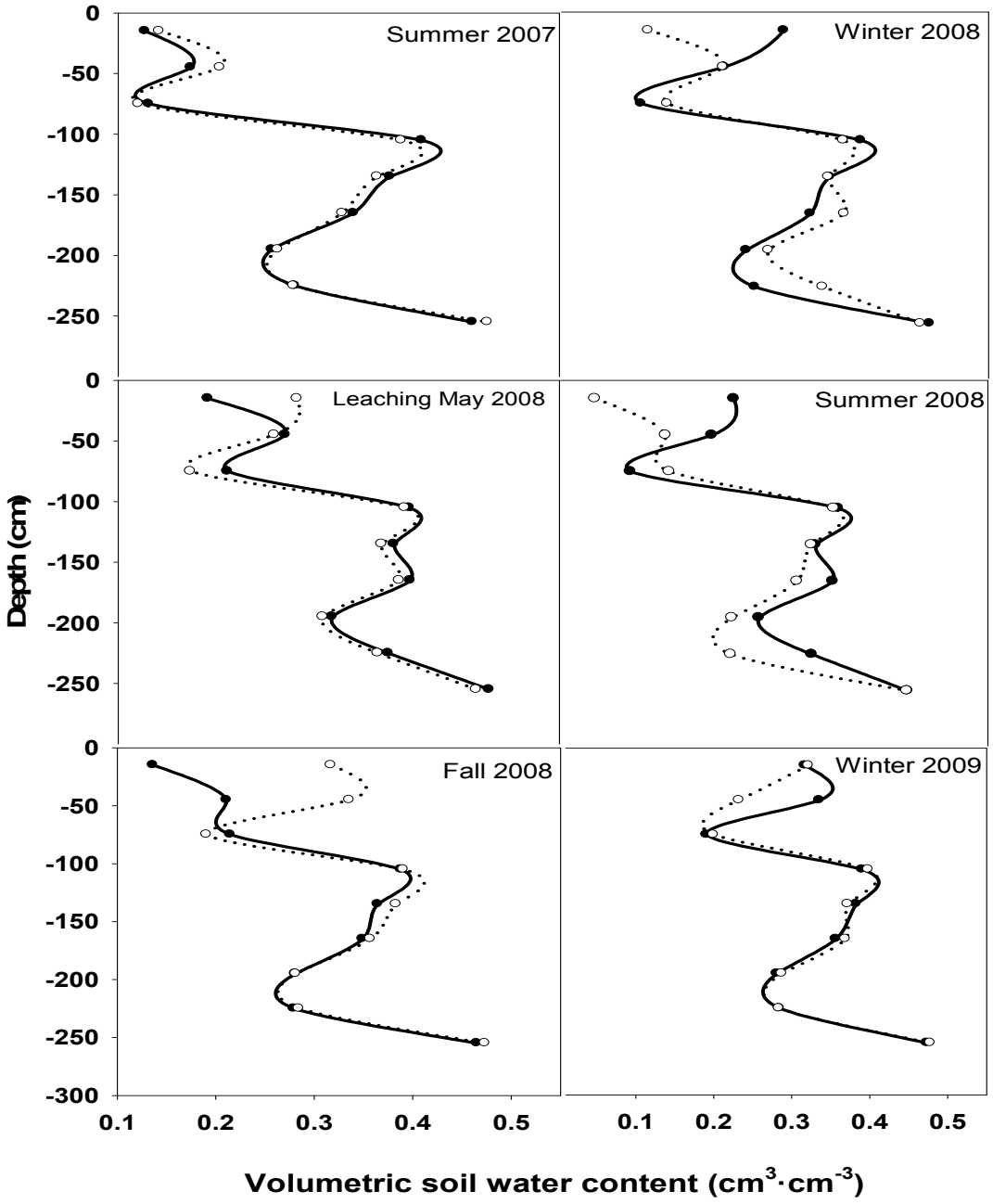


Figure 19. Actual crop water uptake for each growing season.

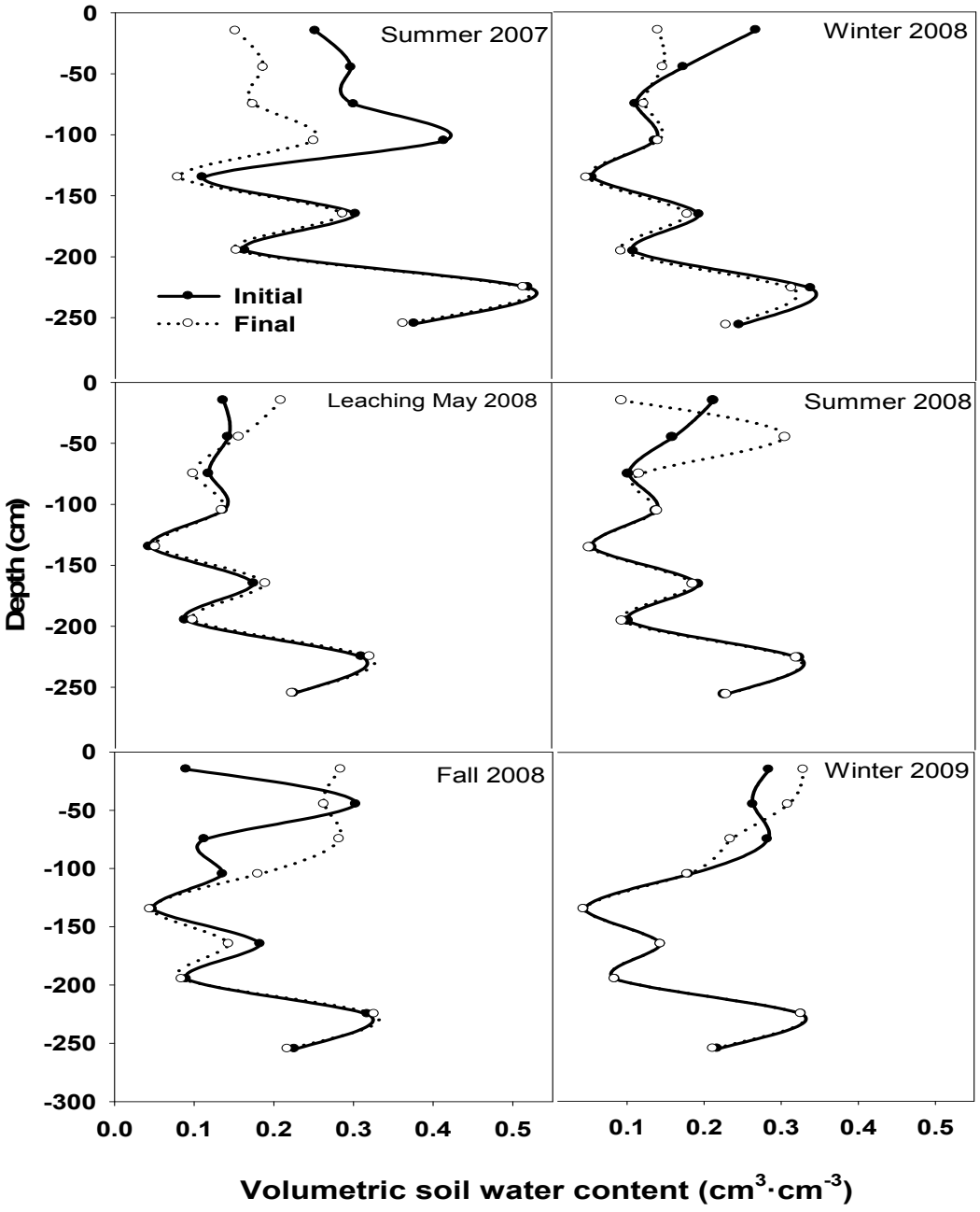
Initial and final values of volumetric soil water content (VWC) in the soil profile at four sampling locations for each growing season are presented in Figure 20. The four sites represent different zones of the field, varying in soil type and salt load. The sub soil of the east part is sand and loamy sand and on the west part is sandy loam and loam. Deficit irrigation during the summer 2007, winter 2008, summer 2008 and winter 2009 growing seasons resulted in depletion of the soil water content. In contrast, the extra irrigation (14.7 cm to the upper center and 8.9 cm to the rest of the field) for salts leaching on May-June 2008, and high rainfall (12.24cm) during fall 2008 increased the VWC in the upper soil profile. In general, the soil VWC below the root zone (i.e. <-100 cm) was generally steady throughout the growing seasons. Due to the difference in soil texture, changes in VWC were measure only in the upper 75 cm of the soil profile on the west side (sites 2133 and 6823) and 100 cm on the east side (sites 10721 and 13474).


Sampling site -2133 (west)
Summer 2007
Winter 2008
Leaching May 2008
Summer 2008
Fall 2008
Winter 2009
Initial
Final
Depth (cm)
0
-50
-100
-150
-200
-250
-300
0.0
0.1
0.2
0.3
0.4
0.5
Volumetric soil water content (cm3·cm-3)

Sampling site – 6823 (west-center)



Sampling site -10721 (east-center)



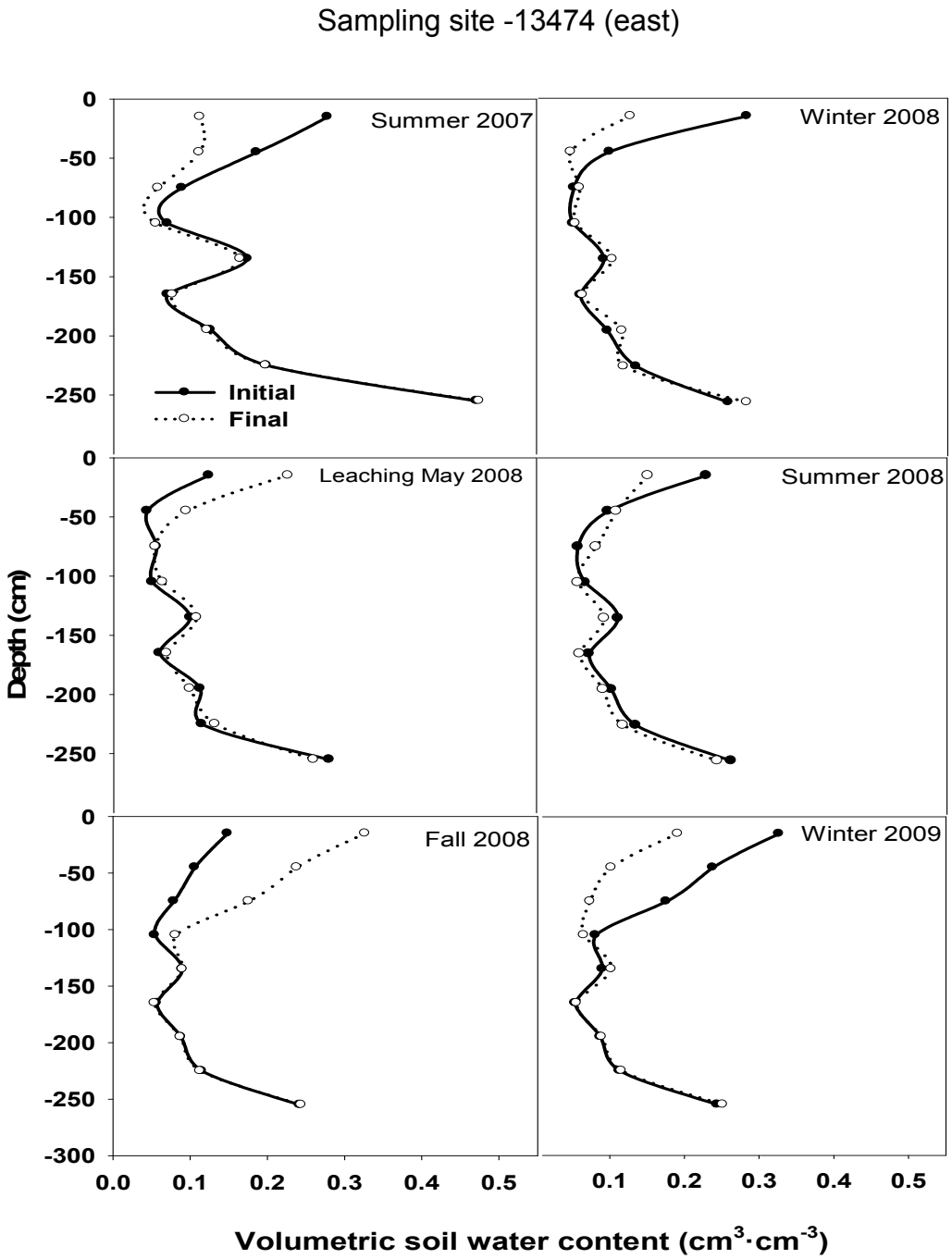


Figure 20. Initial and final values of volumetric soil water content (VWC) in the soil profile at four sampling locations for each growing season.

Nitrogen balance

Nitrogen application to the crops was based on the mass balance of N in the root zone. Subsequent measurements of each component in the N mass balance were used to calculate the plant available N at the beginning and during the growing seasons. While crop uptake was the major sink for N, Nitrogen volatilization, denitrification, immobilization and drainage were the major loses. The two major N sources were:

1. Inorganic forms (NH_4, NO_2 and NO_3) in the soil, supplied DWW and recycled water.
2. Organic forms in the soil and in the supplied DWW. However, actual mineralization rates were difficult to predict under field conditions, due to its dependency on variable environmental soil properties (temperature, moisture, carbon content and more).

Dry phytomass and N removal by the crop was measured bi-monthly at the four monitoring stations during the growing season and throughout the field (60 sampling sites) at the end of it. While, the information from the monitoring stations was used to manage the application of DWW, the whole field data was used to study the spatial variability of yield and N removal across the field.

Typical curves of relative cumulative N removal by the crops as a function of time (DAP, day after planting) are presented in Figure 21, as measured at two monitoring stations. Similar to literature curves, the plants uptake about 10% of the total N in the first 40 days, the rest is removed in a relative constant higher rate throughout the growing season.

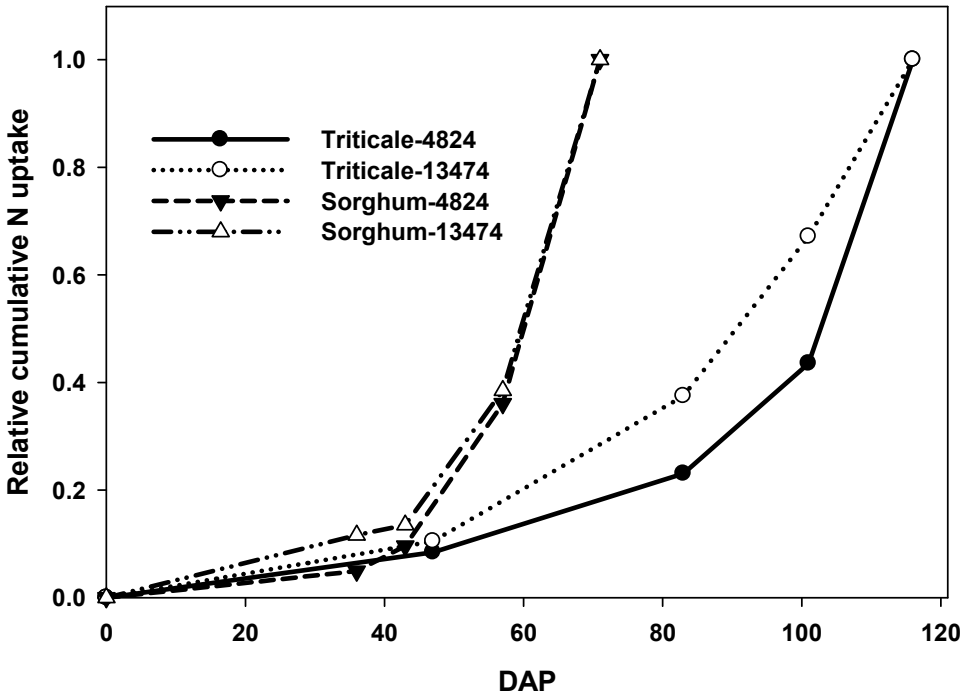
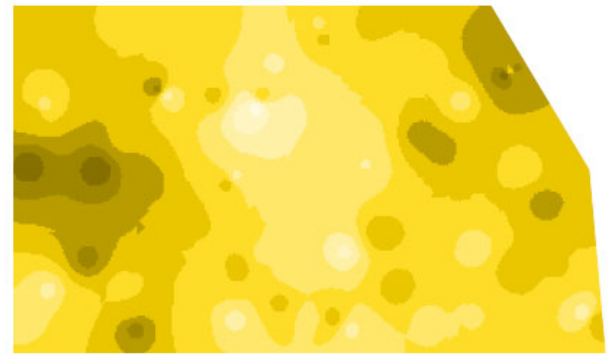


Figure 21. Relative cumulative N removal by the crops as a function of time.

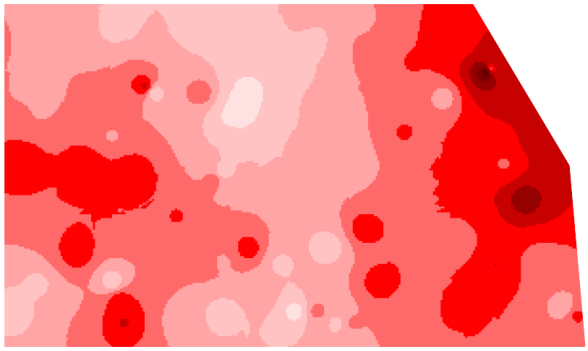
Spatial data on dry yield and N removal by the crops is presented in Figure 22. Average, standard errors and coefficient of variance are presented on the maps as well. As NMP is design to replenish the soil with nutrients based on the removal rates of the crop, accurate quantification of N removal is vital. The spatial information allows one to estimate the variability in N removal rates and potentially to adjust DWW application throughout the field.



Total Dry Weight (Ton/Acre)
- 0.851 - 1.819
- 1.819 - 2.787
- 2.787 - 3.755
- 3.755 - 4.723
- 4.723 - 5.69
- 5.69 - 6.658
- 6.658 - 7.626
- 7.626 - 8.594
- 8.594 - 9.561

Summer 2007-Yield

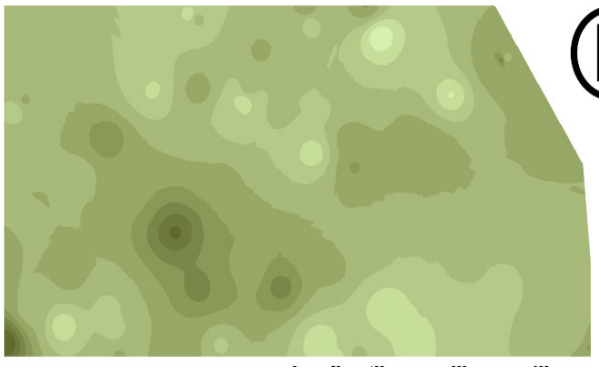
Average- 1.33
Std-0.44
CV-0.33



Nitrogen (Kg/Acre)
- 16.696 - 30.101
- 30.101 - 43.506
- 43.506 - 56.911
- 56.911 - 70.316
- 70.316 - 83.721
- 83.721 - 97.127
- 97.127 - 110.532
- 110.532 - 123.937
- 123.937 - 137.342

Summer 2007-N uptake

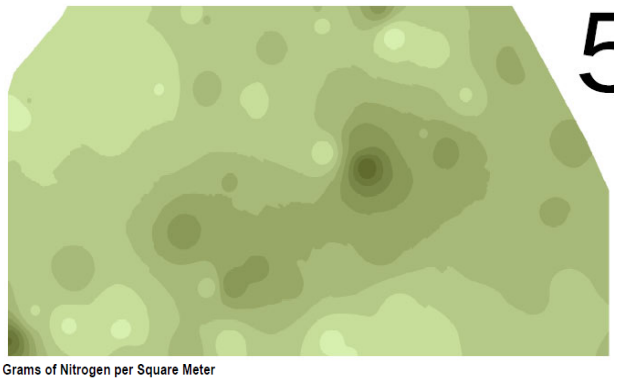
Average- 14.56
Std-5.44
CV-0.37



Dry Yield (Kg per Square Meter)
- 0 - 0.675
- 0.675 - 0.795
- 0.795 - 0.914
- 0.914 - 1.034
- 1.034 - 1.153
- 1.153 - 1.272
- 1.272 - 1.392
- 1.392 - 1.511
- 1.511 - 1.631

Winter 2008-Yield

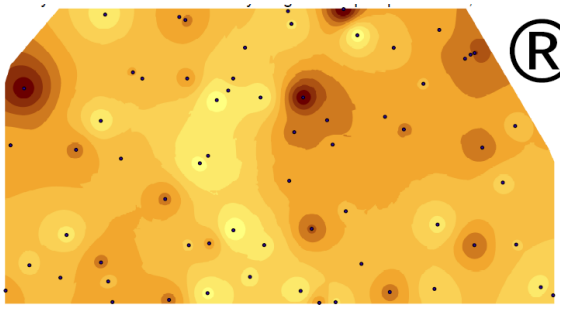
Average- 0.99
Std-0.55
CV-0.21



Grams of Nitrogen per Square Meter
- 7.184 - 9.691
- 9.691 - 12.197
- 12.20- 14.70
- 14.70 - 17.21
- 17.21 - 19.72
- 19.72 - 22.23
- 22.23 - 24.73
- 24.73 - 27.24
- 27.24 - 29.75

Winter 2008-N uptake

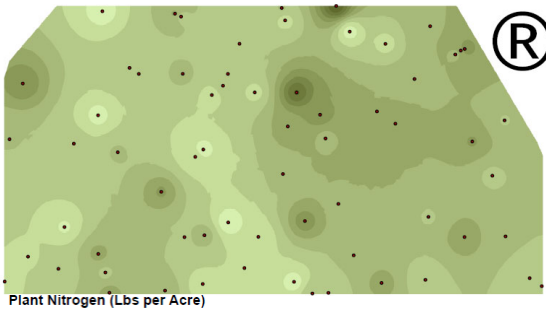
Average- 14.58
Std-7.17
CV-0.31



Dry Yield (Kg/Sq m)
- Sample Locations
- 0.57 - 0.79
- 0.79 - 1.01
- 1.01 - 1.24
- 1.24 - 1.46
- 1.46 - 1.69
- 1.69 - 1.91
- 1.91 - 2.13
- 2.13 - 2.36
- 2.36 - 2.58

Summer 2008-Yield

Average- 1.39
Std- 0.46
CV-0.33



Plant Nitrogen (Lbs per Acre)
- Sample Locations
- 51.09 - 80.44
- 80.44 - 109.8
- 109.8 - 139.1
- 139.1- 168.5
- 168.5 - 197.8
- 197.8 - 227.2
- 227.2 - 256.5
- 256.5 - 285.9
- 285.9 - 315.2

Summer 2008-N uptake

Average- 15.83
Std-5.76
CV-0.33

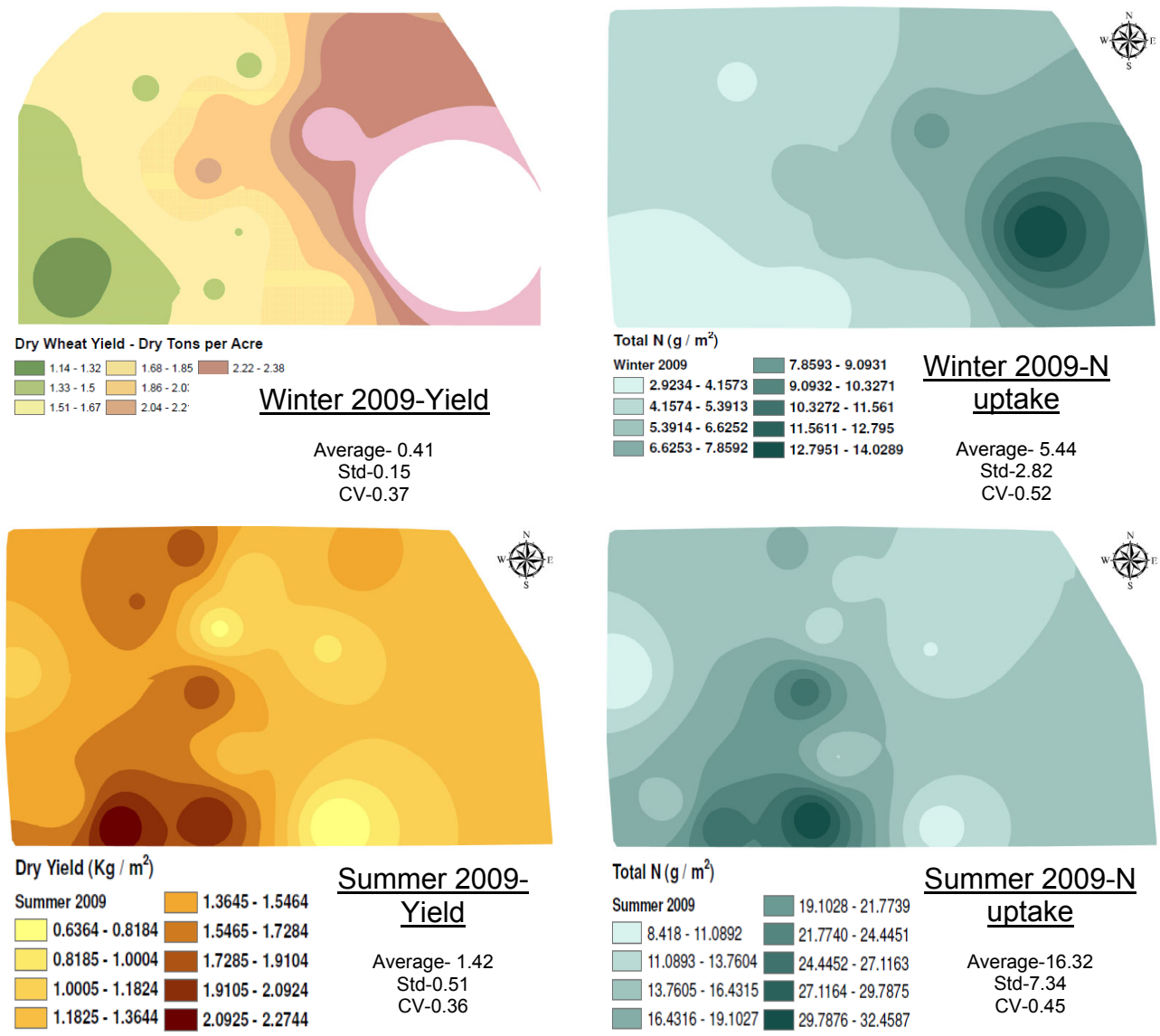


Figure 22. Field maps of dry yield and N removal by the crops. Average, standard deviations and coefficient of variance are presented as well.

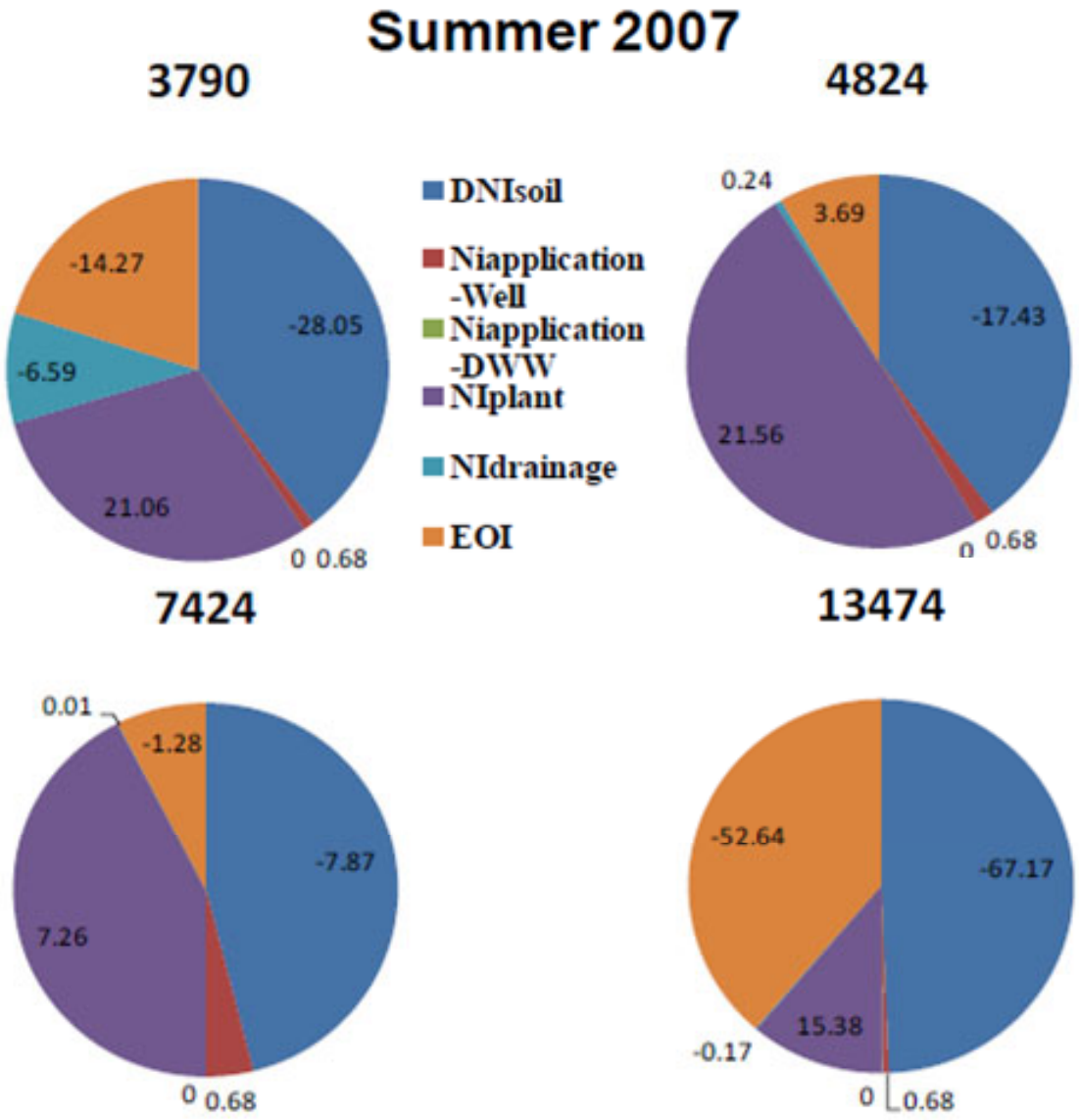
Spatial and temporal analysis of crop yield and N removal rates revealed no significant change in summer crop performance during the three years of the study. Average yield of summer crops ranged between 1.33 to 1.42 Kg·m^2, with a coefficient of variance (CV) of 0.33 to 0.37. Similarly, average N removal by summer crops ranged between 14.56 to 15.83 g of N ·m^2, with a CV of 0.33 to 0.37. A significant difference was measured in winter crop performance during the two years of the study. Average yield of winter crops ranged between 0.41 to 0.99 Kg·m^2, with CV of 0.21 to 0.37. Similarly, average N removal by winter crops ranged between 5.44 to 14.58 g of N ·m^2,

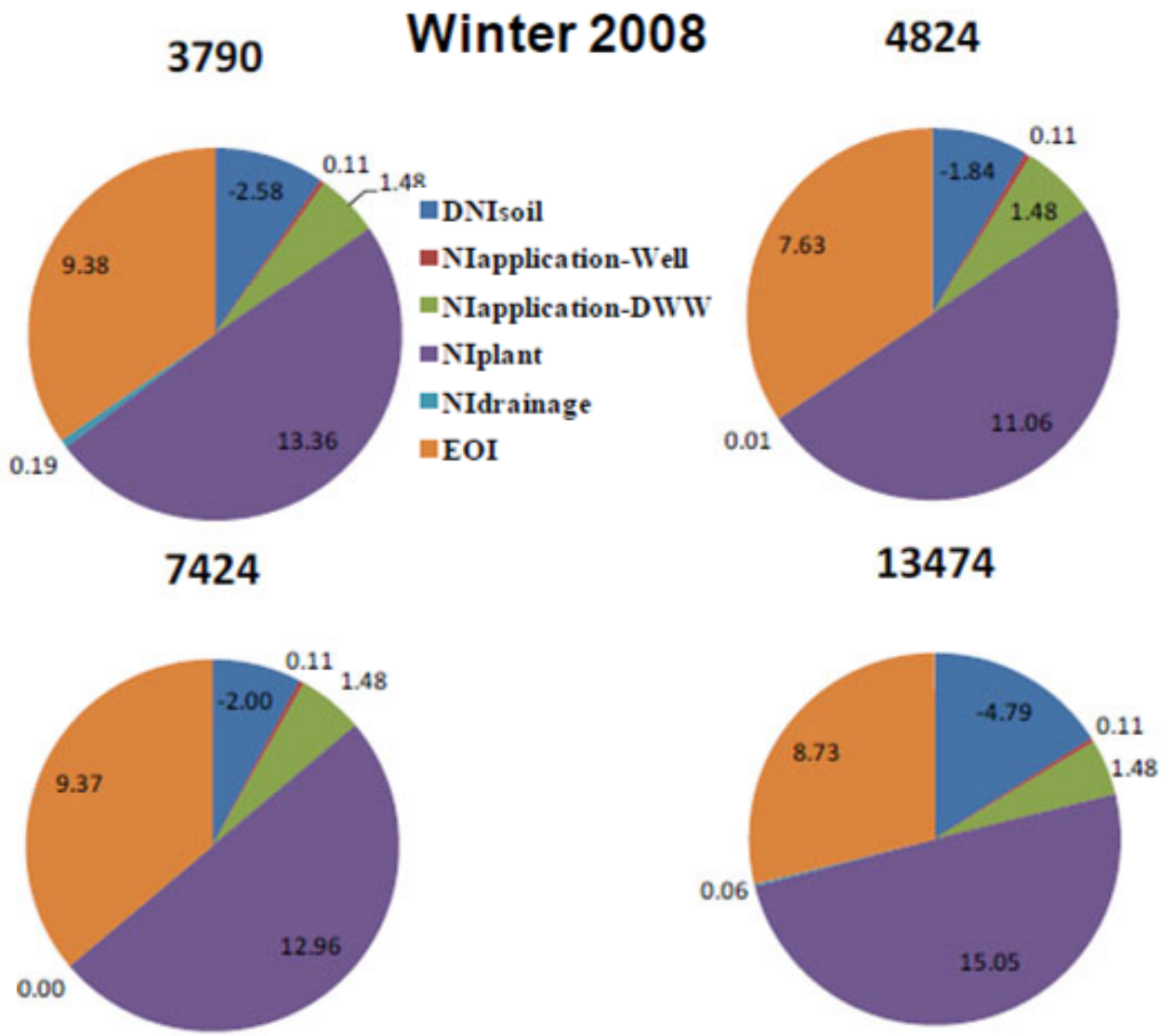
with a CV of 0.31 to 0.52. This significant difference can be explained by several factors:

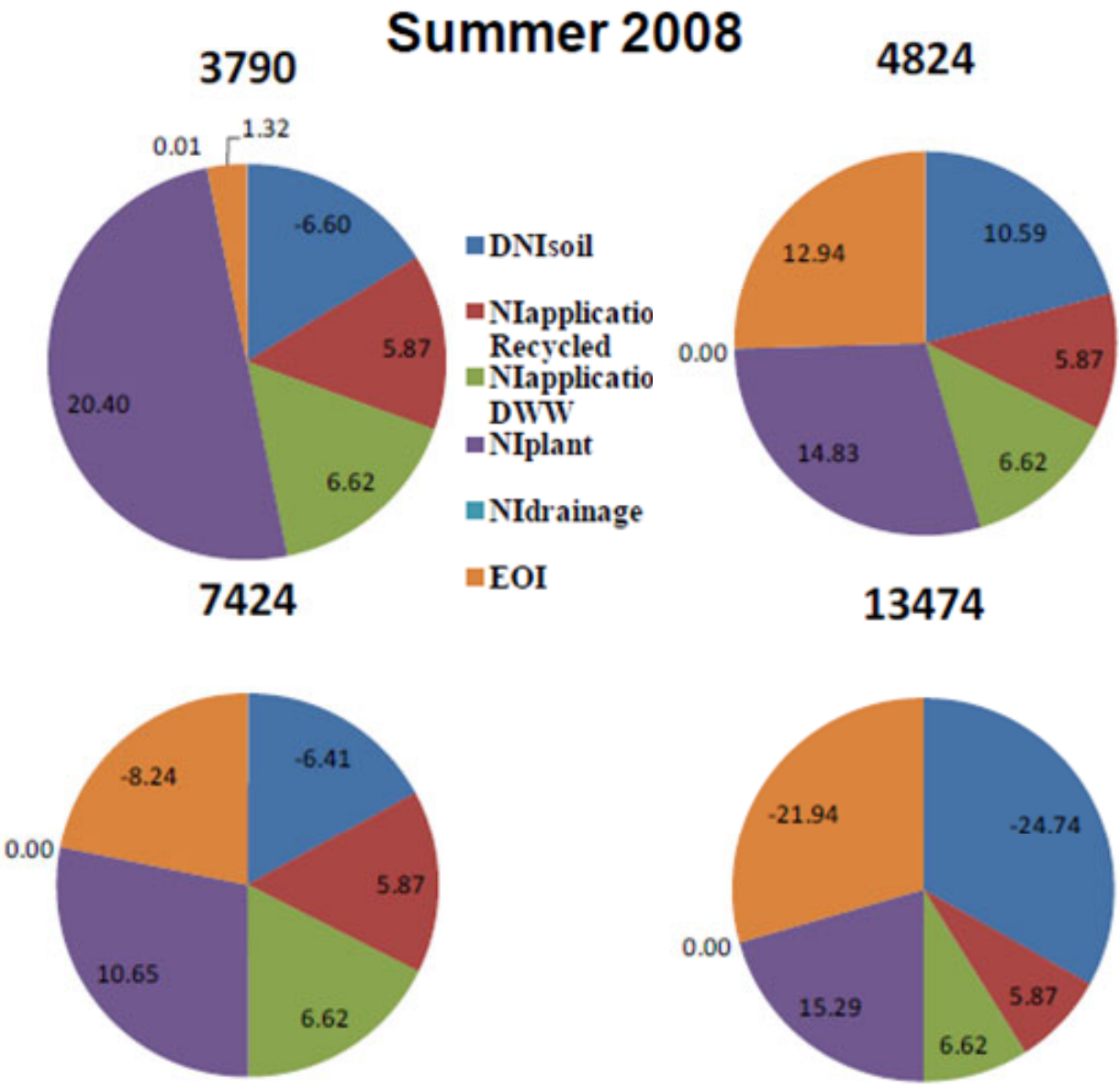
1. The winter 2008 crop was planted after a fallow season of two months, whereas in 2009 the fallow season was replaced with a fall 2008 crop.
2. The lack of DWW application during fall 2008 and winter 2009, due to seasonal precipitation.
3. Leaching of nutrients, due to seasonal precipitation.

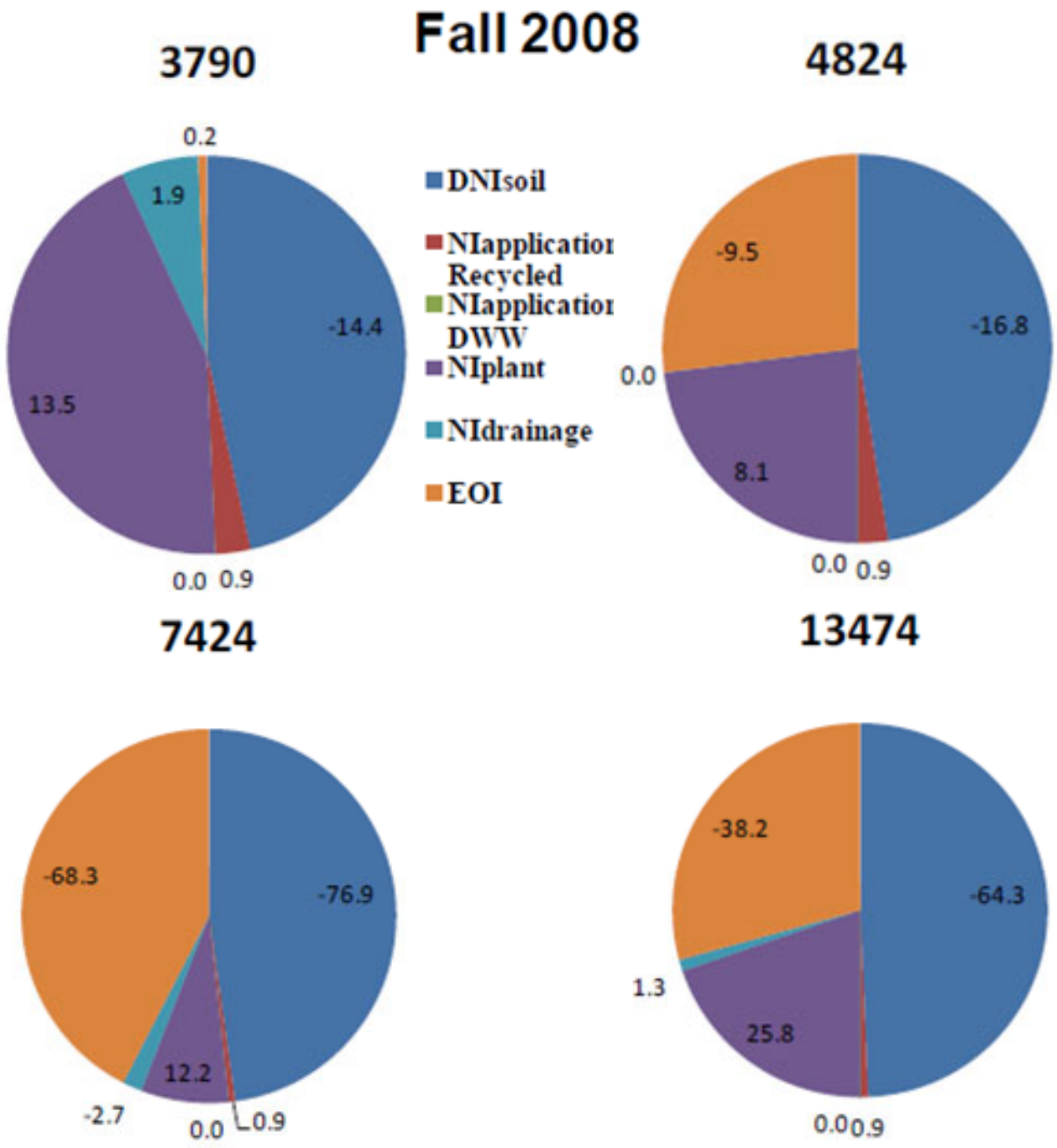
By combining the yield and N removal rates of the fall 2008 crop and the winter 2009 crop, a better comparison can be made between winter 2008 and 2009 is accomplished. Average yield of the combined winter crops was 1.18 $Kg \cdot m^2$ with a CV of 0.27 and the average N removal was 21.23 g of N $\cdot m^2$ and CV of 0.49. The higher CV of N removal can be attributed to the high variability in soil inorganic N and the organic N reservoir, which served as the dominant N sources.

The N mass balance components for each growing season at the four monitoring stations, represented different growing zones are presented in Figure 23. The 7424 station is characterized with high soil salinity and moisture, lack of aeration due to poor drainage and poor crop performance. The 13747 station is characterized with low soil salinity and moisture, good aeration due to proper drainage and good crop performance. The 4824 and 3790 stations corresponded to intermediate EC_a values, yet differences were found in soil properties. The 4824 station had higher water holding capacity and lower salinity, therefore better crop performance.


Summer 2007
3790
-14.27
-28.05
-6.59
21.06
0
0.68
DNIsoil
Niapplication -Well
Niapplication -DWW
NIplant
NIdrainage
EOI
4824
0.24
3.69
-17.43
21.56
0
0.68
7424
0.01
-1.28
-7.87
7.26
0
0.68
13474
-52.64
-67.17
15.38
-0.17
0
0.68


Winter 2008
3790
-2.58
0.11
1.48
9.38
0.19
13.36
DNIsoil
NIapplication-Well
NIapplication-DWW
NIplant
NIdrainage
EOI
4824
-1.84
0.11
1.48
7.63
0.01
11.06
7424
-2.00
0.11
1.48
9.37
0.00
12.96
13474
-4.79
0.11
1.48
8.73
0.06
15.05


Summer 2008
3790
0.01
1.32
-6.60
5.87
6.62
20.40
4824
12.94
10.59
0.00
5.87
14.83
6.62
DNIsoil
NIapplicatio Recycled
NIapplicatio DWW
NIplant
NIdrainage
EOI
7424
-8.24
-6.41
0.00
5.87
10.65
6.62
13474
-21.94
-24.74
0.00
15.29
5.87
6.62


Fall 2008
3790
0.2
1.9
-14.4
13.5
0.0
0.9
DNIsoil
NIapplicatior Recycled
NIapplicatior DWW
NIplant
NIdrainage
EOI
4824
-9.5
-16.8
0.0
8.1
0.0
0.9
7424
-68.3
-76.9
12.2
-2.7
0.0
0.9
13474
-38.2
-64.3
1.3
25.8
0.0
0.9

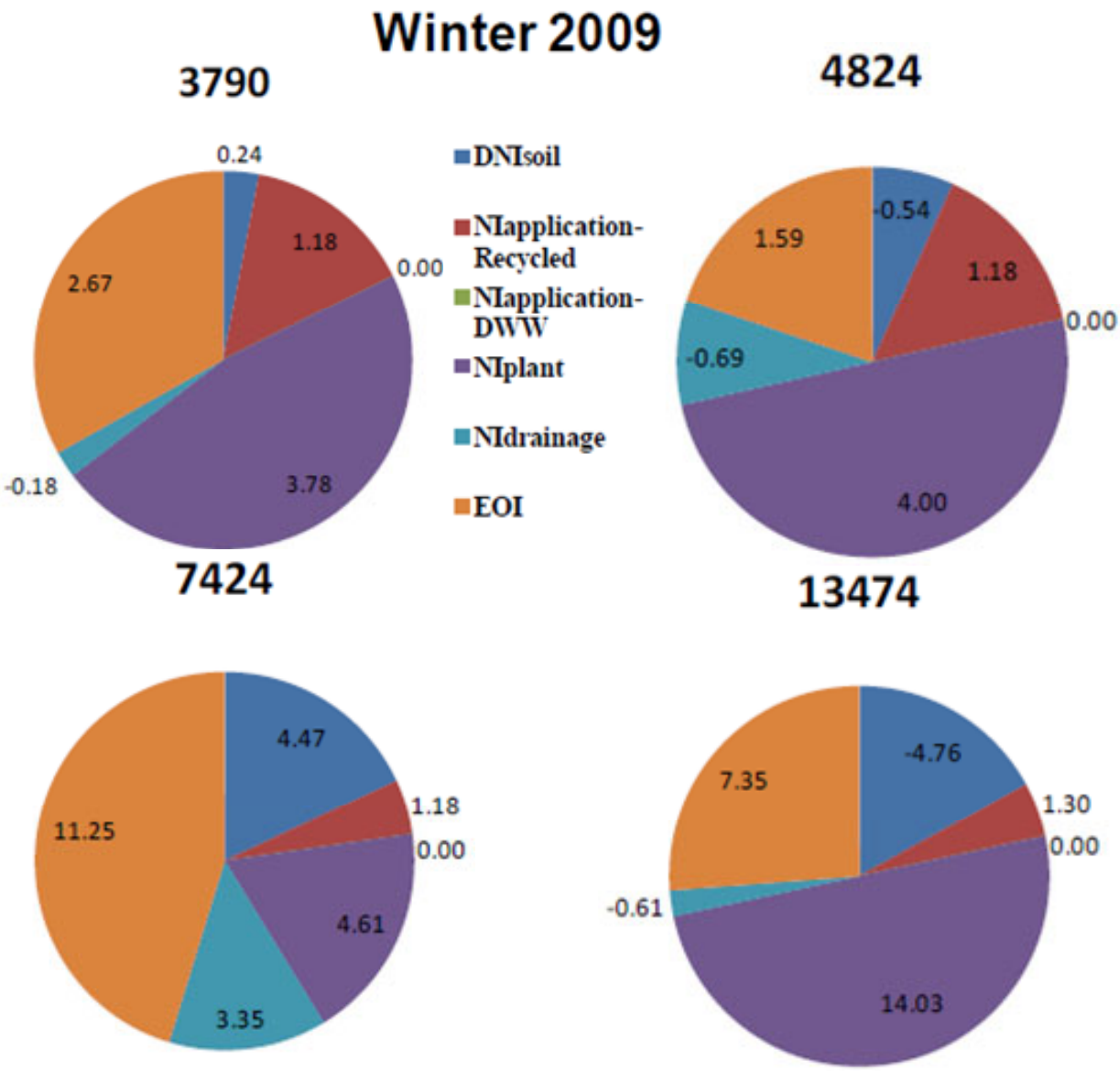


Figure 23. Components of the N mass balance for each growing season at the four monitoring stations.

The reduced application of water during winter time, due to seasonal precipitation, sharply decreased the supply of N added through the irrigation system. This implies that the supplied N matched crop removal rates only during the summer season. Moreover, similar quantities of N were supplied by the continuous application of recycled water and DWW. Due to the accurate application of water relative to ETa, losses of N below the root zone were minor. The negative numbers of drainage are

associated with a reverse in the water flow direction (due to a dry root zone) that caused soil water with inorganic N from deeper layers to migrate into the root zone. The soil inorganic N and organic N reservoir plays a major role in supplying plant available N. Whereas, positive values of E_{OI} were attributed to mineralization of organic N, negative values reflect losses to the atmosphere due to dentrification and volatilization, or conversion of inorganic N to organic forms (immobilization). Dentrification is associated with anaerobic conditions; these conditions are likely to occur right after application, when the soil is under saturated conditions. Loam soils are more susceptible to lack of aeration, especially when irrigated with the central pivot at application rates that are above the soil infiltration rate. In addition, ponding DWW may volatilize NH_4 as NH_3. The contribution of organic matter to the soil by application of DWW and recycled water may also enhance the microbial activity, and associated immobilization of inorganic N. The quantification of dentrification, volatilization and immobilization are very challenging under field conditions due to the complexity of each process and the field spatial variability. Therefore, these processes were combined with mineralization to generate a value (E_{OI}) that stands for the net gain/loss of inorganic N in the root zone. Positive E_{OI} were measured during winter 2008 and 2009, and negative values were measured during fall 2008. During summer, 7424 and 13474 exhibited negative values and 4824 positive ones. These observations suggest that mineralization was the dominant process in the soil during winter time, due to the continuous high water content, mild temperatures and the small application amounts of DWW that reduced volatilization and immobilization. During summer time, the 7424 site is characterized with poorly drained and aerated soil and poor crop performance, which might increase volatilization and denitrification. In contrast, the 4824 site is characterized with well-drained and aerated soil and high crop performance, which might decrease volatilization and enhanced mineralization.

Depletion of the organic reservoir in the soil can serve as a quantifying tool for the net exchange rate (mineralization and immobilization) between the organic and inorganic N reservoirs in the root zone.

Salts accumulation

Salts accompany the macro and micro- nutrients in the well water, DWW, and recycled water. Excess salts and specific ion toxicity in the root zone inhibits crop production. However, flushing these salts toward groundwater may deteriorate water quality. The total salt load, expressed as total dissolved solids (TDS), for each growing season is presented in Figure 24. Calculations were based on the common ratio, TDS ($mg \cdot L^{-1}$) = 640×EC ($dS \cdot m^{-1}$). The high evaporative demands throughout summer required frequent water application for plant growth. Despite similar quantities of water application in during summer 2007, 2008 and 2009, different salt loads occurred due to the use of different water sources with varying salt content. Summer 2008 and 2009 loaded 3 times more salts then summer 2007. Similarly, utilizing recycled water during winter 2009 increased the total salt per water application unit.

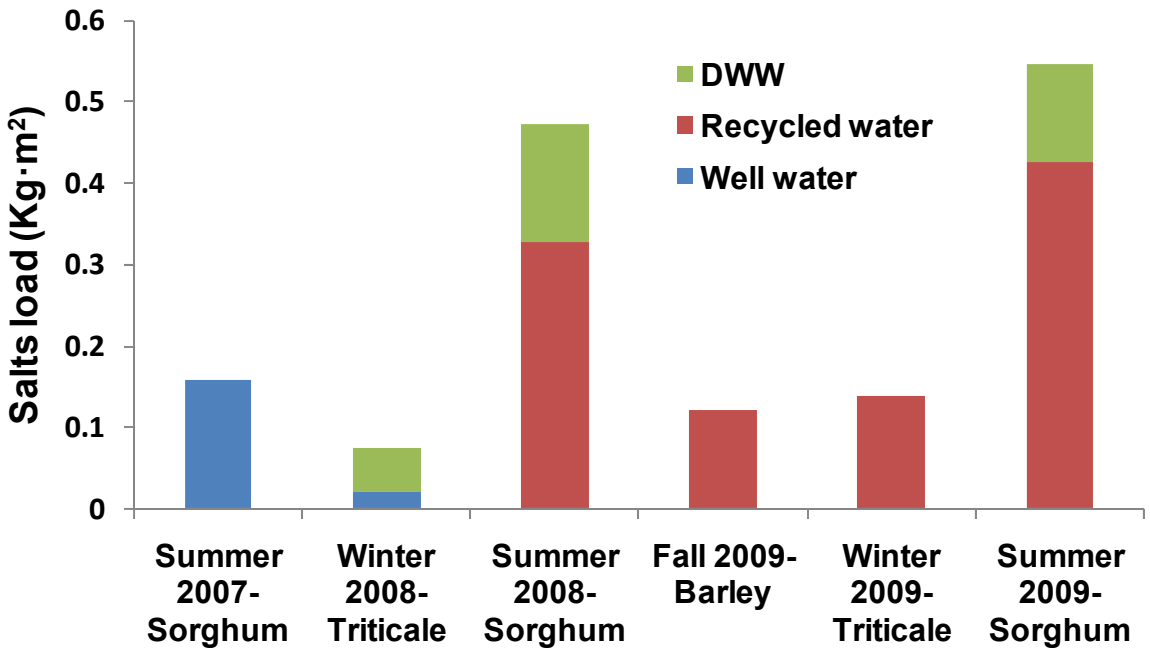


Figure 24. Total salt load, expressed as total dissolved solids (TDS), for each growing season.

The increase in the ECe of the upper root zone (0 to -15cm) during 2008, due to the use of irrigation water with high TDS, a low leaching factor, and concentration of salts by *ET* is presented in Figure 25. The average EC_e of the upper root zone

increased from 1.5 to 2.9 $dS \cdot m^{-1}$ during winter 2008, and to 4.1$dS \cdot m^{-1}$ at the end of summer 2008.

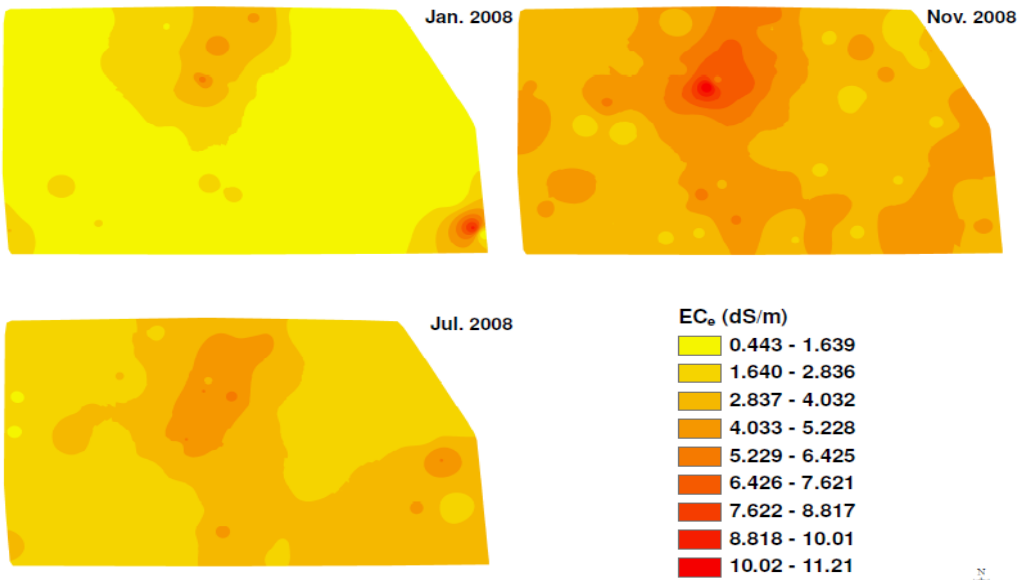


Figure 25. ECe of the upper root zone during 2008.

Leaching of salts below the root zone, due to seasonal rainfall (20.95cm) during fall 2008 and winter 2009 are presented in Figure 26. The salts were leached from the upper two layers (0 to -30cm and -30 to -60cm) and accumulated in the lower layer (-60 to -90cm).

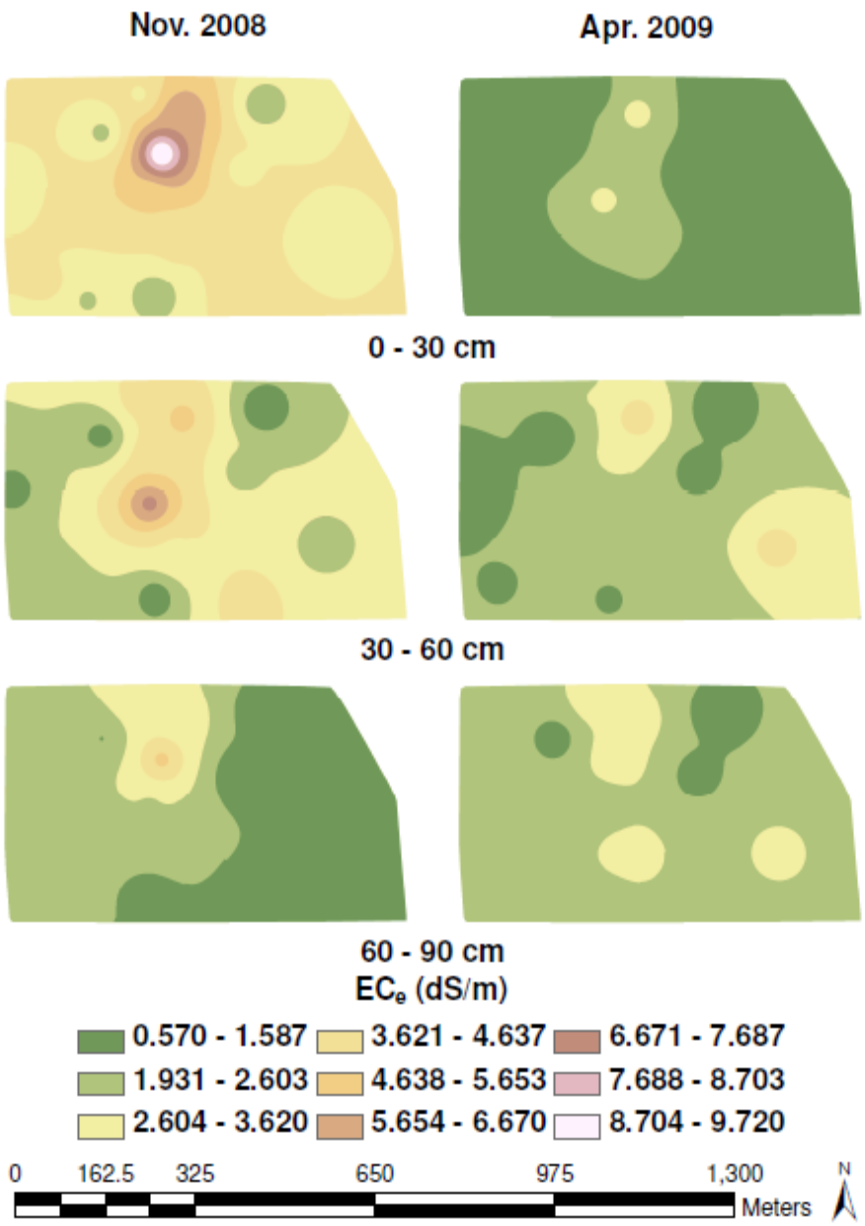


Figure 26. ECe of three soil layers (0 to -30, -30 to -60 and -60 to -90 cm) at the beginning and end of the rainy season.

Indicator microorganisms

The potential transport and survival of several fecal indicator microorganisms that are commonly associated with fecal contamination and are typically found in high concentrations in animal wastes were studied. The experiment was designed to mimic a worst-case transport scenario of ponded infiltration and redistribution of fresh DWW. The concentration of representative viral (somatic coliphage) and bacterial (total *E. coli*,

fecal coliforms, and *Enterococcus*) indicator microorganisms in fresh and stored DWW are given in Table 5:

Table 5. Average concentration of somatic coliphage, total *E. coli*, fecal coliforms, and *Enterococcus* in fresh DWW and lagoon water.

Microorganisms	Fresh DWW	Stored DWW
	Nos. per ml	
Enterococcus	1.9×10^{8}	1×10^{6}
Fecal coliforms	1.8×10^{6}	1×10^{4}
Somatic coliphage, ϕx	3.2×10^{4}	2.5×10^{3}
Total *E. coli*	1.1×10^{6}	NA

The measured concentrations of fresh and stored DWW significantly exceeded the recommended U.S. standards for unrestricted irrigation[10].

Representative results from two experimental sites with large differences in texture and hydraulic properties are discussed below. The 16138 site is characterized by a high hydraulic permeability and a lower water holding capacity relative to the 567 site. Since microorganisms are transported with the irrigation water, measured water contents over depth and time (Figure 27) provide estimation for the infiltration depth of the DWW at each site.

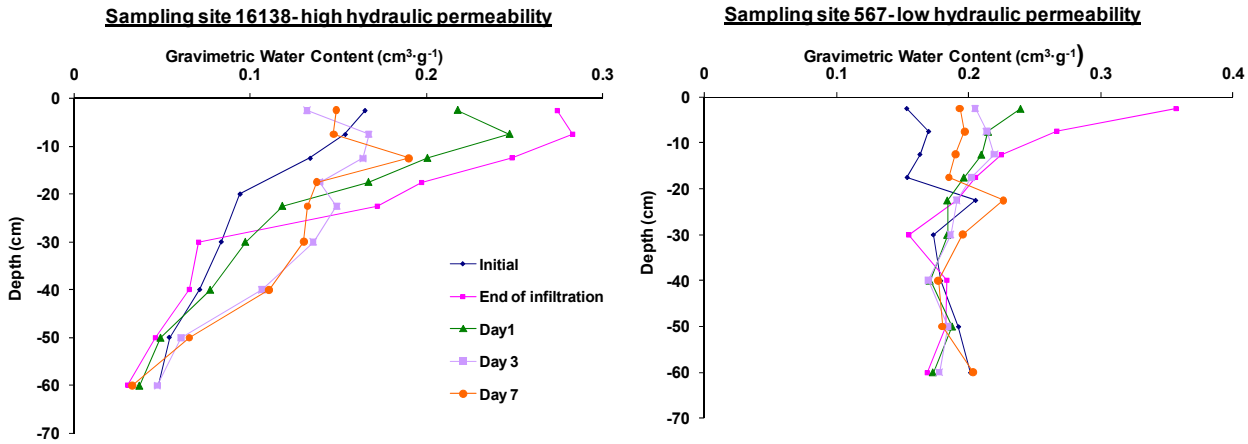
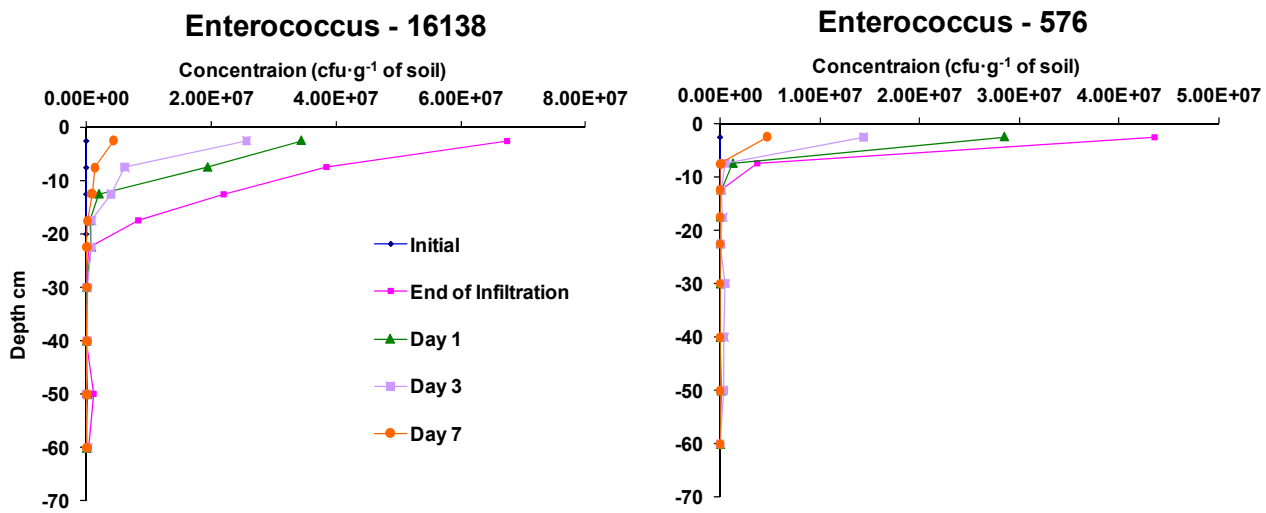


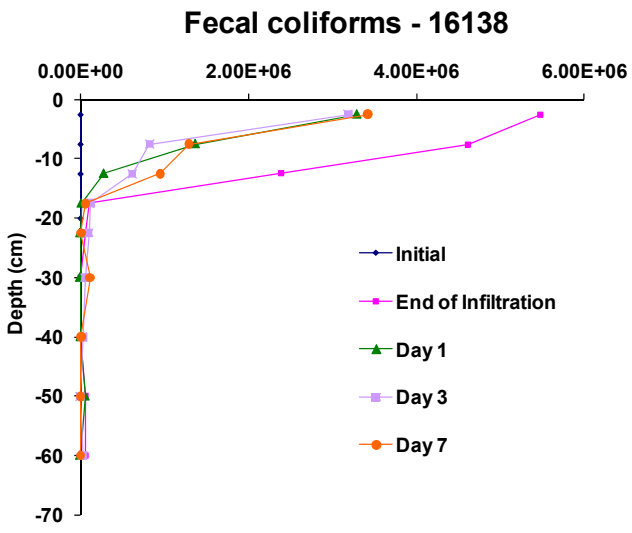
Figure 27. Gravimetric water contents over depth and time.

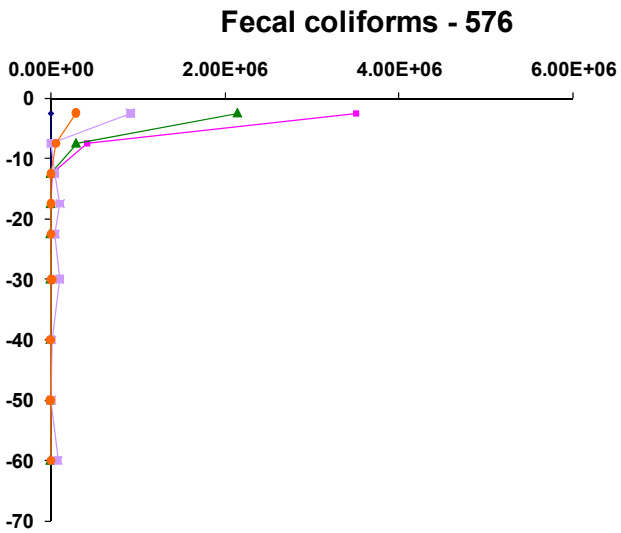
Lower soil water contents were measured at the 16138 site relative to the 567 site. Due to the higher water content the wetting front at site 16138 was deeper (-20 to -

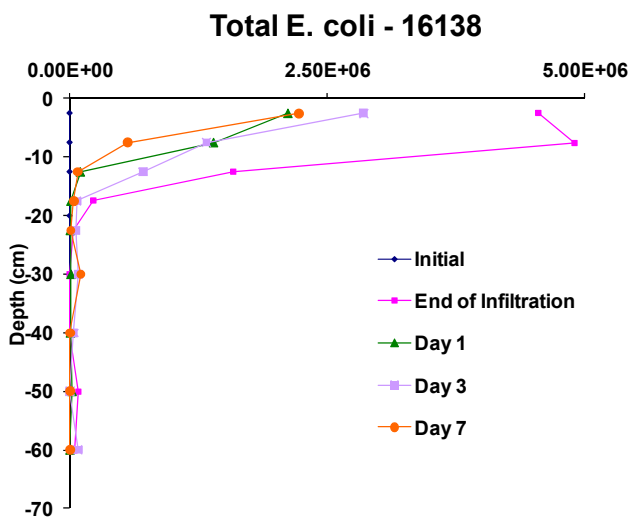
[10] United States Environmental Protection Agency. 2004. Guidelines for water reuse. EPA 625/R-04/108. USEPA, Cincinnati, OH.

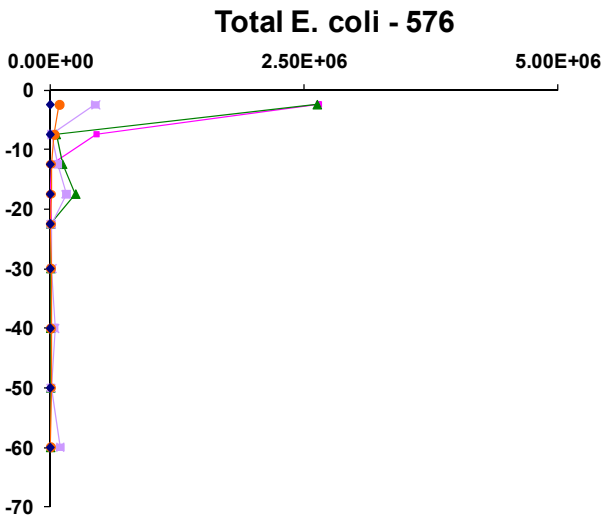
25 cm) than site 567 (-10-to -15 cm). The maximum depth affected by the DWW application was -50cm at the 16138 site and -30cm at the 567 site. All these measured values indicated that DWW transported deeper and faster at the 16138 site. Moreover, the fast drained soil at the 16138 site maintains the profile well ventilated for microbial respiration. The concentration of each indicator microorganisms over depth and time is presented in Figure 28 for both sites. Absence of indicator microorganisms in the soil profile was confirmed prior to DWW application (Initial). Maximum concentrations were detected in the upper profile right after infiltration ceased. The maximum transport depth corresponded to the water front depth of each site, -20 cm at 16138 and around -10 cm at 567. Consecutive data displayed decline in concentrations over time at both sites due to die-off or inactivation of microorganisms. After 7 days, microorganisms survived only in the upper 5 cm of the profile at site 567 and 10cm at site 16138 (beside Fecal Coliforms that were detected at -12.5 cm at site 16138). Comprehensive batch survival experiments in the laboratory with the field soil from the EPA site and fresh DWW revealed much more rapid die-off rates for the bacterial indicator microorganisms in native than in sterilized soil, suggesting that biotic factors controlled survival.




Fecal coliforms - 16138
0.00E+00
2.00E+06
4.00E+06
6.00E+06
Depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
Initial
End of Infiltration
Day 1
Day 3
Day 7


Fecal coliforms - 576
0.00E+00
2.00E+06
4.00E+06
6.00E+06
0
-10
-20
-30
-40
-50
-60
-70


Total E. coli - 16138
0.00E+00
2.50E+06
5.00E+06
Depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
Initial
End of Infiltration
Day 1
Day 3
Day 7


Total E. coli - 576
0.00E+00
2.50E+06
5.00E+06
0
-10
-20
-30
-40
-50
-60
-70

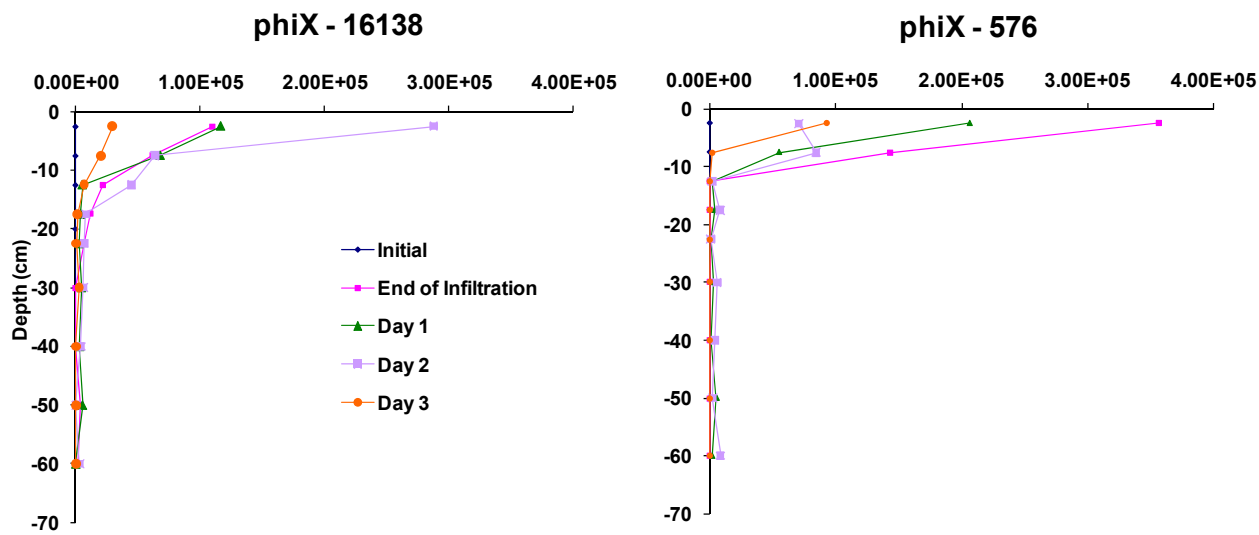
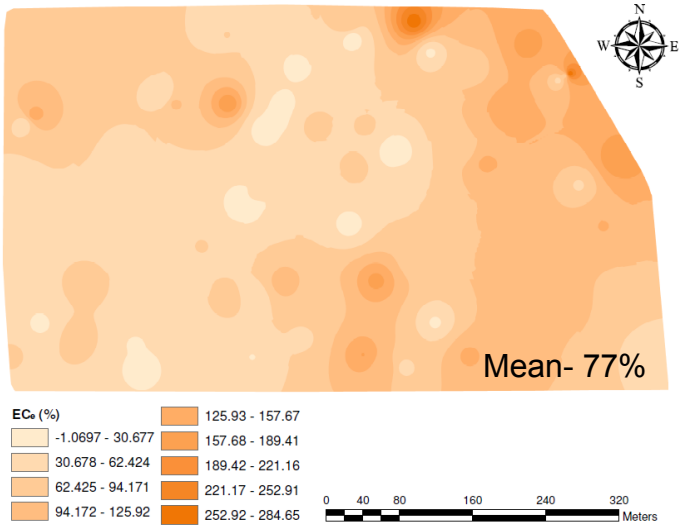


Figure 28. The concentration of each indicator microorganisms over depth and time at both experimental sites.

Final conditions

Due to the shortened schedule of the project based upon the December 2008 through August of 2009 State grant freeze, and the long duration required for analyzing numerous soil samples, final conditions in the soil profiles of the field were measured at the end of October 2008. Since no DWW was applied in the summer of 2007, the changes in the soil account for one winter and one summer growing season only. Spatial relative changes (in percent) of ECe and major cations and anions are depicted in Figure 29. Arithmetic means of change and coefficients of correlation (to EC_e) are presented as well:



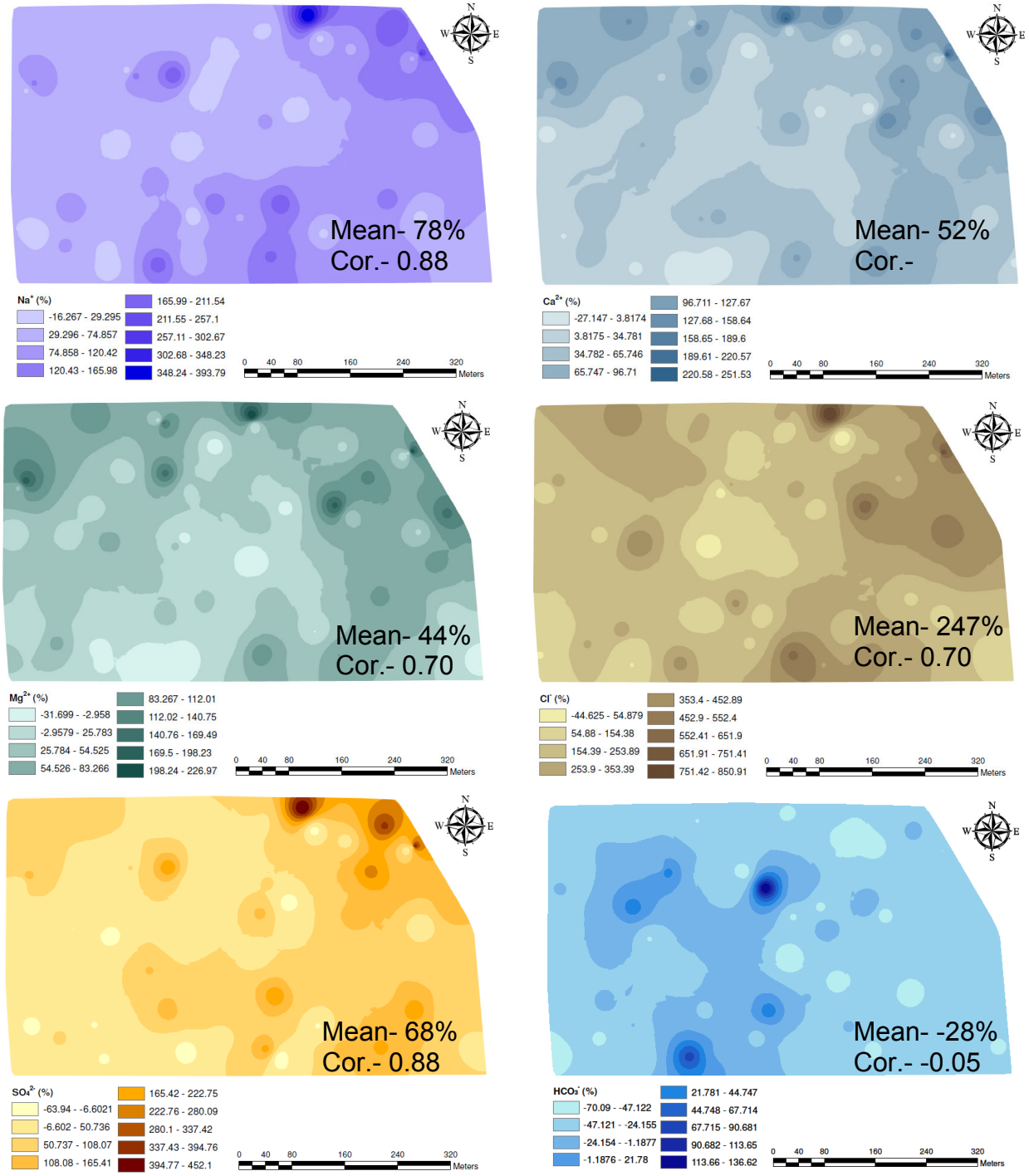


Figure 29. Relative changes of ECe and major cations and anion.

The electrolytes concentrations in soil solution increased throughout the field. Averages changes increased up to 250% (Cl). Positive high coefficients of correlation (>0.70) were calculated for Na, Ca, Mg, SO_2 and Cl. These high values indicate a

uniform spatial pattern of these ions in the field. In contrast, HCO_3 had low mean and negative correlation to the EC_e, meaning that HCO_3 was depleted and was not affected by the same process. Bicarbonate (HCO_3) is part of a chain of reactions that includes CaCO3, Ca, HCO_3, CO_2 in the soil and pH. Dynamic equilibrium is maintained in the soil and the system can be shifted due to change in one or more components. In our case, excess application of Ca and HCO_3 and possible elevated CO_2 in the soil, due to increased microbial activity, decreased the average pH from 7.78 to 7.36.

An overview map of initial and final EC_e with depth is presented in Figure 30. The set of maps revealed no changes at the upper 15 cm and accumulation at lower depths. Whereas salts accumulation on the east side was restricted to the next 2 layers (-15 to -60 cm), an increase in EC_e was observed at all the layers on the west side. These differences are associated with poor crop performance at the edge of the field that enhances the migration of irrigation water below the root zone. The low water uptake rate maintains high water contents that induced high fluxes of water below the root zone. The poor crop performance was attributed to the ponded conditions in this section of the field due to the low infiltration rate of the soil and the high water application rates at this part of the field (inherent design of the Pivot).

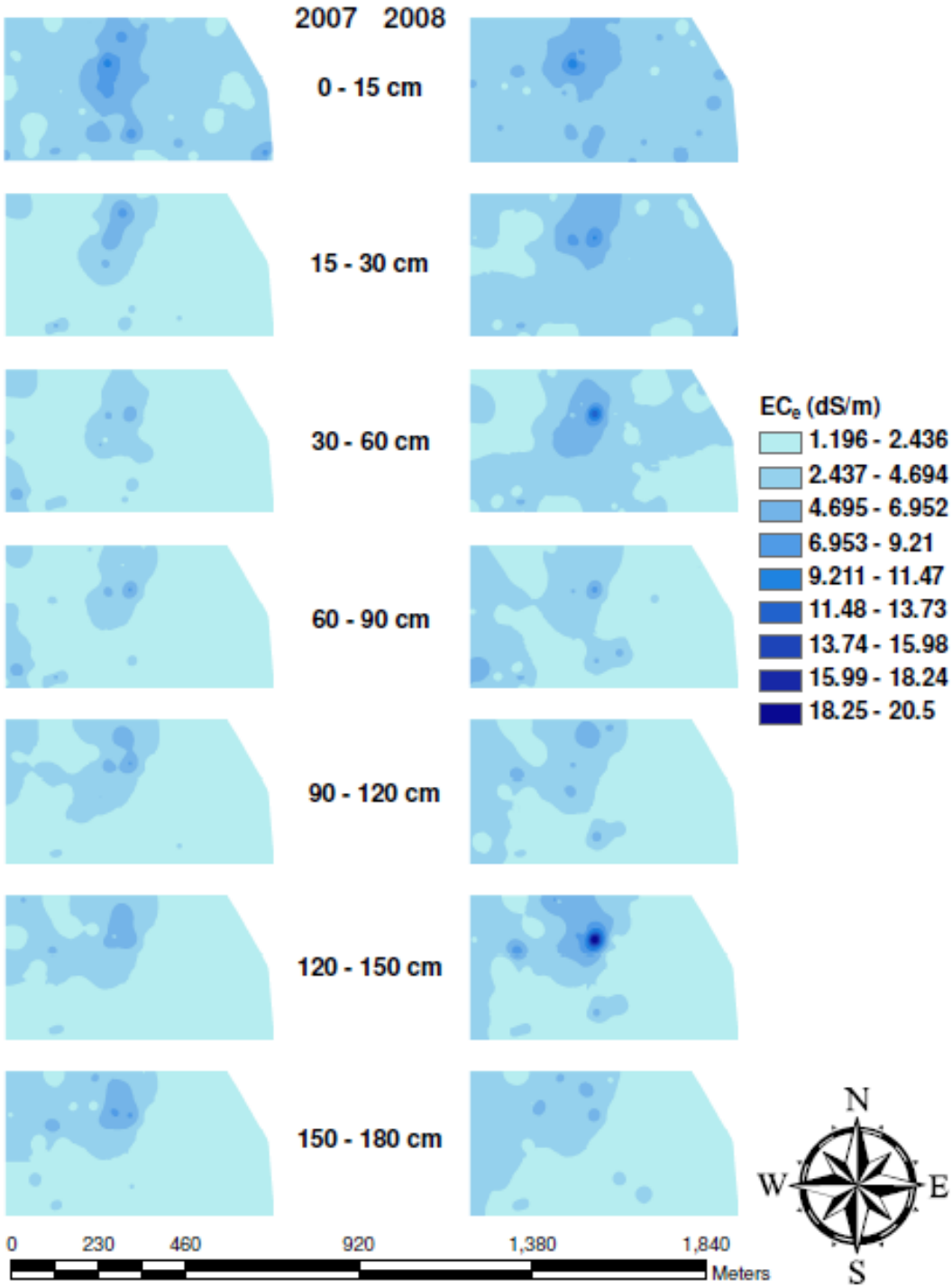
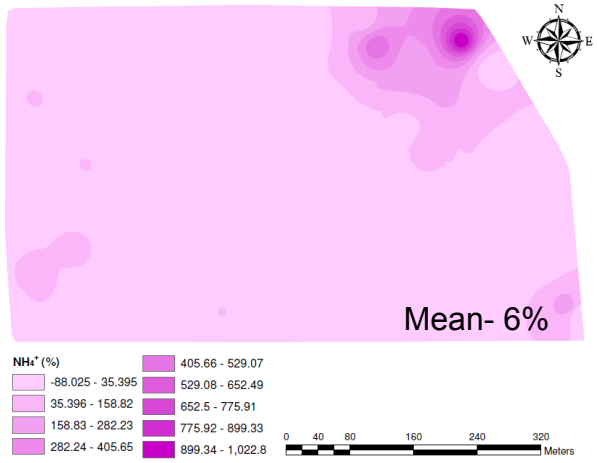


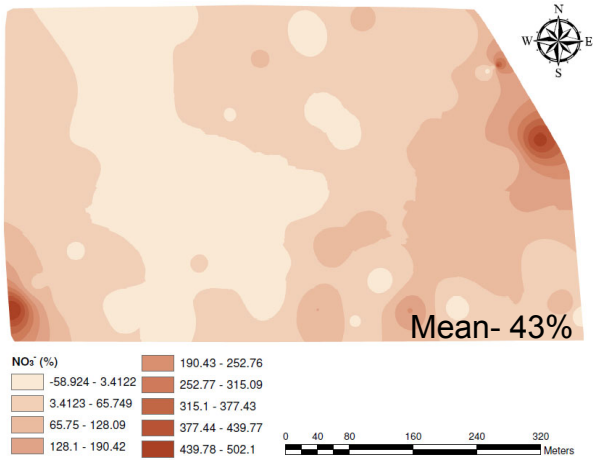
Figure 30. Initial and final EC_e over depth.

Spatial relative changes (in percent) of macro- and micro- nutrients and total C and N are depicted in Figures 31. Arithmetical means of the change are presented on figures as well.

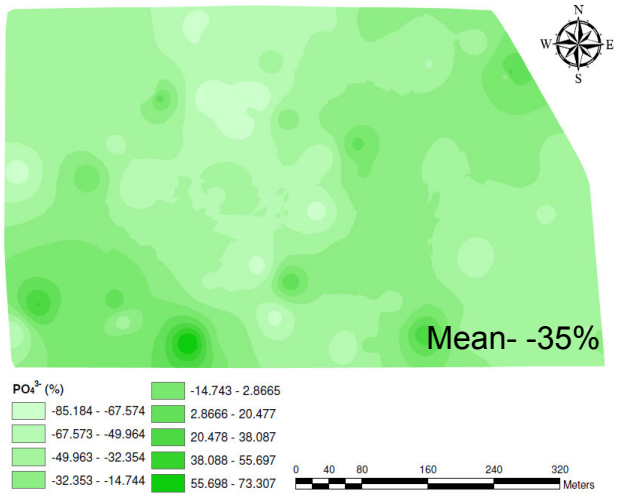
NH_4-N



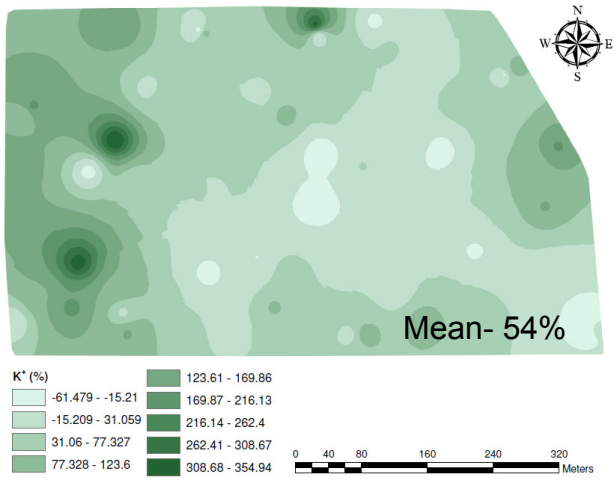
NO_2+NO_3-N



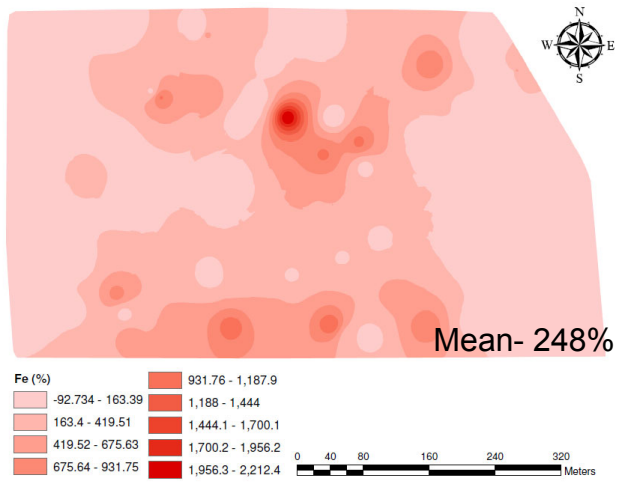
PO_4



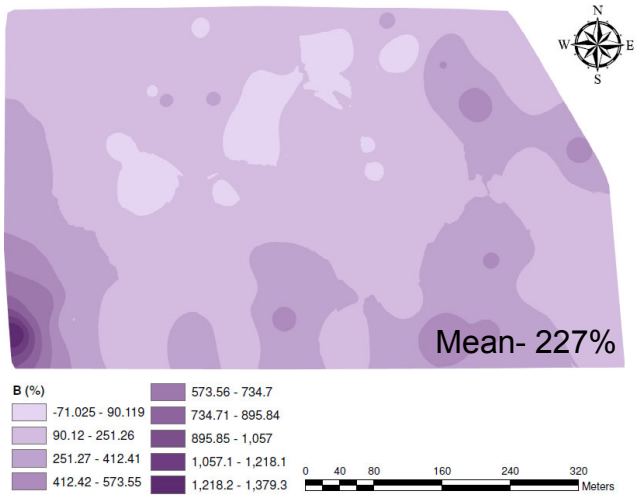
K



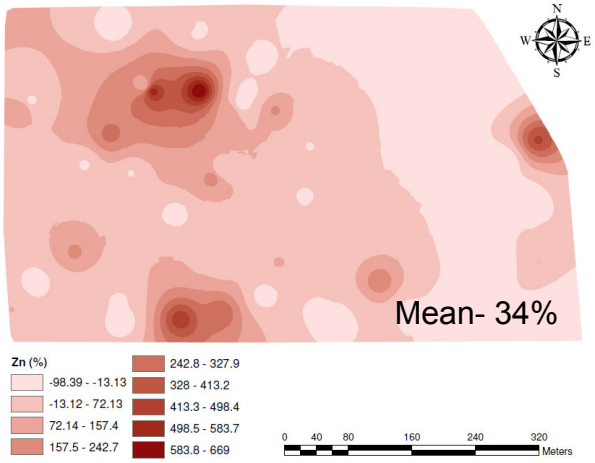
Fe


N
W
E
S
Mean- 248%
Fe (%)
-92.734 - 163.39
163.4 - 419.51
419.52 - 675.63
675.64 - 931.75
931.76 - 1,187.9
1,188 - 1,444
1,444.1 - 1,700.1
1,700.2 - 1,956.2
1,956.3 - 2,212.4
0 40 80 160 240 320
Meters

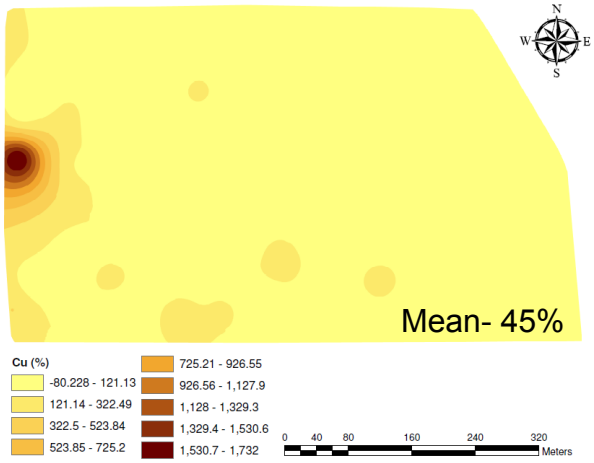
B


N
W
E
S
Mean- 227%
B (%)
-71.025 - 90.119
90.12 - 251.26
251.27 - 412.41
412.42 - 573.55
573.56 - 734.7
734.71 - 895.84
895.85 - 1,057
1,057.1 - 1,218.1
1,218.2 - 1,379.3
0 40 80 160 240 320
Meters

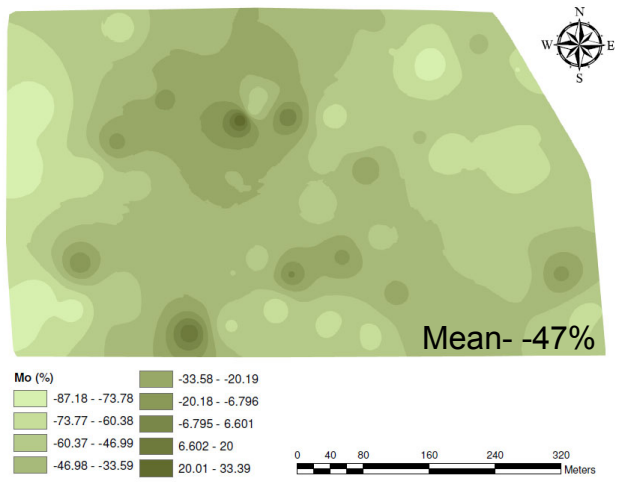
Zn


N
W
E
S
Mean- 34%
Zn (%)
-98.39 - -13.13
-13.12 - 72.13
72.14 - 157.4
157.5 - 242.7
242.8 - 327.9
328 - 413.2
413.3 - 498.4
498.5 - 583.7
583.8 - 669
0 40 80 160 240 320
Meters

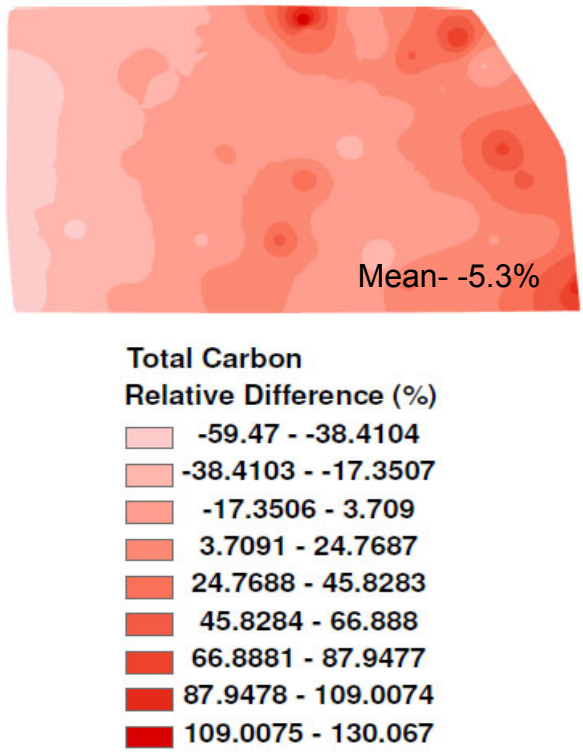
Cu


N
W
E
S
Mean- 45%
Cu (%)
-80.228 - 121.13
121.14 - 322.49
322.5 - 523.84
523.85 - 725.2
725.21 - 926.55
926.56 - 1,127.9
1,128 - 1,329.3
1,329.4 - 1,530.6
1,530.7 - 1,732
0 40 80 160 240 320
Meters

Mo



Total N



Total C

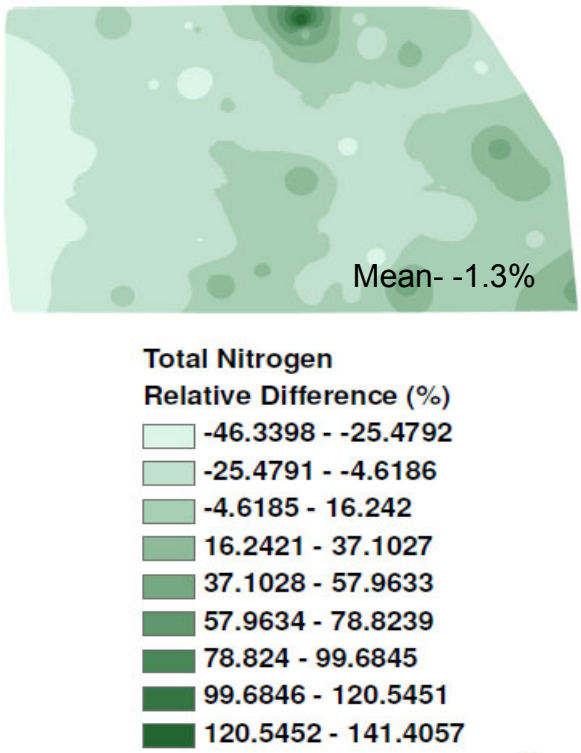
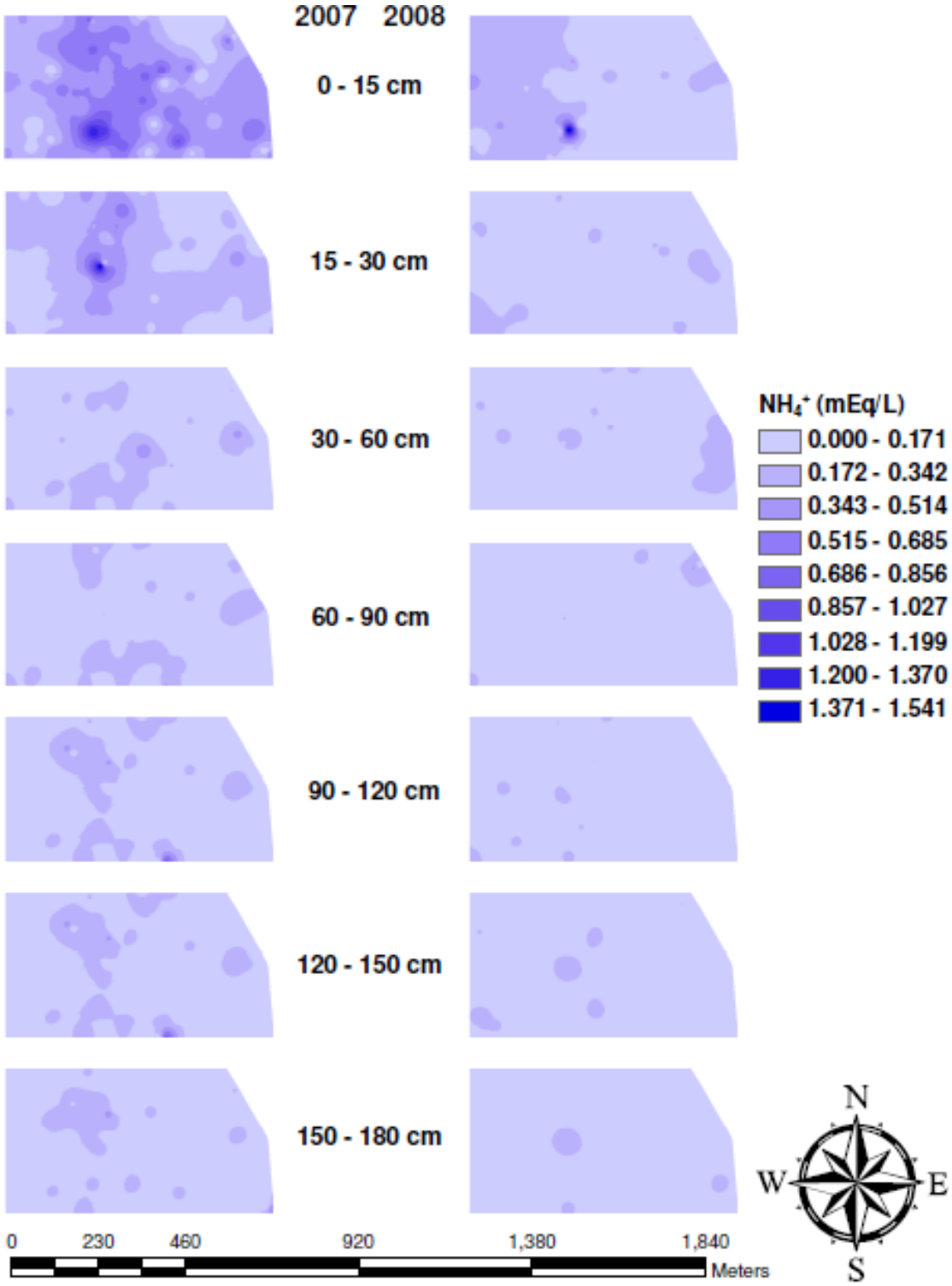


Figure 31. Relative changes of macro- and micro- nutrients. Arithmetical means of the change are presented as well.

Unlike the mechanisms of the major cations and anions that depend mainly on equilibrium processes in the soil, macro- and micro-nutrients are also dependent on crop performance and uptake rates. While N and K increased in the soil profile (around 50%), P was depleted due to its low concentrations in the recycled water (Table 2) and the deficit application of DWW (Figure 23). The micro-nutrients Fe and B increased markedly (>200%) due to its high concentrations in the recycled water and DWW and low uptake rate. Zn and Cu increased and Mo decreased. Depletion of the organic reservoir in the soil can serve as a quantifying tool for the net exchange rate (mineralization and immobilization) between the organic and inorganic N reservoirs in the root zone. Total C and N were depleted from the upper 30 cm of the soil profile during 2008, meaning a positive net exchange rate due to mineralization. Yet, no change was found in the correlation between total N and total C (Corr. Coeff.- 0.87) and their ratio (C/N ratio-10.0), implying that mineralized inorganic N was not accumulated in soil but was utilized by the crop.

An overview map of initial and final of NH_4-N and NO_2+NO_3-N with depth is presented in Figure 32. The set of maps revealed that changes in NH_4-N were limited to the upper 30 cm of the soil profile. Accumulation of NO_2+NO_3-N was observed in the upper 15 cm as well and down to -90 cm on the east side. Leaching or uptake of NO_2+NO_3-N from the lower profile -90 to -150 cm was observed on the east side of the field. These differences are associated to the spatial pattern of soil textural, where coarser soils enhance the leaching of NO_2+NO_3-N on the east side of the field.


2007 2008
0 - 15 cm
15 - 30 cm
30 - 60 cm
60 - 90 cm
90 - 120 cm
120 - 150 cm
150 - 180 cm
NH4+ (mEq/L)
0.000 - 0.171
0.172 - 0.342
0.343 - 0.514
0.515 - 0.685
0.686 - 0.856
0.857 - 1.027
1.028 - 1.199
1.200 - 1.370
1.371 - 1.541
0 230 460 920 1,380 1,840
Meters
N
W
E
S

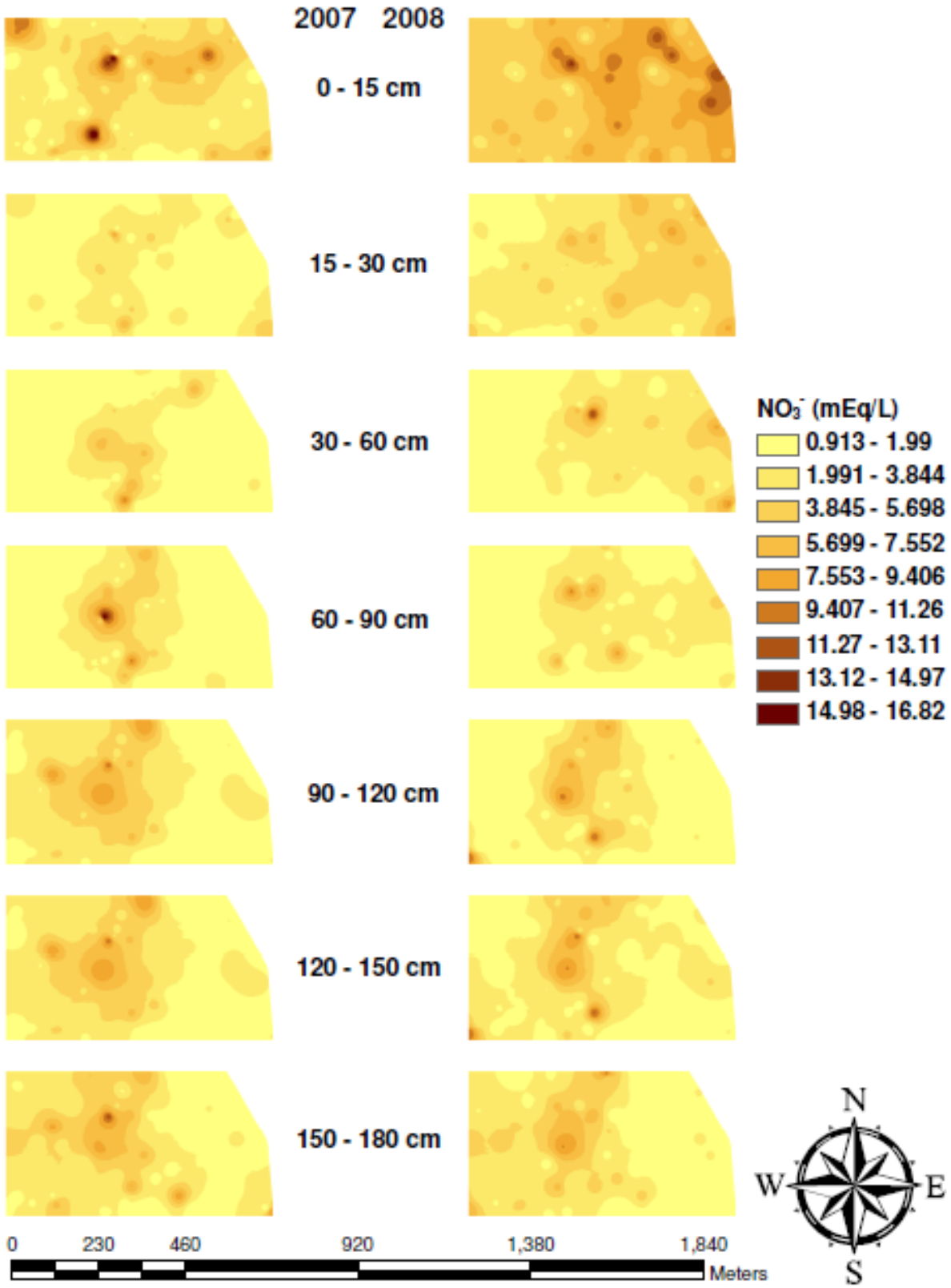


Figure 32. Initial and final NH_4-N and NO_2+NO_3-N over depth.

CONCLUSIONS AND RECOMMENDATIONS

The BMP was well underway in December of 2008, when all funds were frozen by the State. This grant was not reinstated until September of 2009 and we were unable to restart this BMP within the requested 3 month window. The shortened nature of this study must therefore be considered when conclusions are drawn and recommendations are adopted. A longer term study is needed to more fully assess the sustainability and performance of the field-scale NMP. Nevertheless, we still believe that key management issues that have been identified in this work are not time depended and only the magnitude of these processes will change.

A detailed characterization of the field physical and hydraulic properties was conducted. The soil texture (based on d50, BD, and GSA) was mainly comprised of sandy and loam soil, that spatially transitioned from finer textural soil (silt loam and loam) to coarser soils (loamy sand and sand) from the west to east. The spatial pattern of measured infiltration rate was similar to the textural pattern and ranged between 0.25 to 6 $cm \cdot h^{-1}$, typical values for sandy loam soils. The water retention parameters were within the common range of values for loam and sandy soils. These physical and hydraulic have several implications for NMPs:

- The some locations in the field were associated with low infiltration rates. Ponding and runoff may occur when the high application rate of the irrigation system is higher than the soil infiltration rate. Ponded DWW may enhance water evaporation and nutrient volatilization. Runoff would likely decrease the uniformity of water application by diverting water and nutrients to other locations in the field.
- On the other hand, regions with low hydraulic conductivity slows down drainage below the root zone and increase the availability of water and nutrients for plant uptake between successive DWW applications.
- The high water holding capacity of the root zone can serve as a storage volume for water and nutrients, and minimize the need for frequent water applications.

- Loam soils are susceptible to a lack of aeration, which can have an effect on microbial activity and nutrient transformation rates.
- Higher infiltration rates occurred following deep tillage. These high rates may accelerate the water flow through the root zone. Therefore, timing and quantities of DWW should accounts for tillage practice. Specifically, application of DWW should not follow immediately after deep tillage.

Accurate water application was found to be a key factor restricting the migration of contaminants below the root zone. The deficit irrigation practice limited the water flow and water uptake to the upper 100 cm of the soil profile. The high water holding capacity of the soil enables the storage of seasonal precipitations and pre-irrigations in the root zone for later crop use, without affecting the plant water availability. An irrigation system with a high degree of uniformity is desirable when applying marginal water to ensure high water use efficiency by the crop.

Three sources of water were used in this study: well water, recycled water and DWW. The recycled water and DWW contained macro- and micro-nutrients for plant growth. The amounts of nutrients in each water source need to be taken into consideration when developing a recommendation for commercial fertilizer or manure application based on soil tests before each growing season. The inorganic N content of the various sources was integrated and embedded into the N mass balance. Even though only minor seasonal variations were found in the EC of the recycled water, significant variations were measured in NO_2+NO_3-N (4 versus 10 mg·L^{-1}). Similarly, DWW exhibited seasonal fluctuations (data is not shown) due to changes in herd diet, storage time in the lagoons and temperatures. Frequent information on the N content in the recycled water and DWW is therefore useful at NMP sites.

The N mass balance in the root zone validated that N removal by the crop is the dominant N sink in the root zone. However, supplied N only matched the crop N requirements during the summer. Only a fraction of the N removed by the crop was supplied during winter due to seasonal rainfall and low ET rates that limited the amounts of DWW application. The missing N was supplied by depleting the soil inorganic N and converting soil organic N to plant available inorganic forms (mineralization). Significant

losses of N to the atmosphere and through immobilization were measured mainly during summer and fall, and were attributed to the specific properties of the field site (i.e. irrigation method, soil properties, climate and DWW constituents). Losses of N during application events (as water drops) and subsequent ponding conditions were attributed to evaporation and volatilization of N. Moreover, the persistent high soil water content at several sites in the field (due to the ponded condition and poor crop performance), yielded insufficient ventilation in the soil which may limit the bacterial activity and induce denitrification. In contrast, only minor loss of N as drainage was measured due to the deficit irrigation practice. Leaching of NO_2+NO_3 was restricted to the upper 90 cm, where it is still available for crops with a deep root system (i.e. corn *** I though corn had a shallow root system, sorghum and alfalfa). General recommendations for this NMP site are:

- Develop a “hydrological sensitivity index” based on the soil and groundwater properties (depth, quality, hydraulic properties, and mineralogy of the vadose zone and aquifer). This index should categorize high and low potential zones of contamination from agricultural activity. Application of liquid and solid dairy wastes in low sensitivity zones would be more flexible than in other zones.
- Improve measurements of water and nutrient requirements by the crop to obtain accurate information on the required timing and quantities for application.
- Increase the water and *N* use efficiency by irrigating to meet plant uptake requirements using a high uniformity application system. Minimize runoff and ponding conditions by matching the water application rate to the soil infiltration rate.

The average increase of electrolytes in the soil profile after one year of implementing a NMP at the field site was 75%. However, salts were accumulated mainly in the upper 60 cm at most of the field and at deeper layers, where poor crop performance accelerated the drainage process. In order to maintain a fertile soil, leaching of salts below the root zone is a common practice. In semi-arid and arid environments, recharge to groundwater will be minimal if the water table is deep and precipitation+irrigation are equal to or less than evapotranspiration. In this case, storing

salts below the root zone (in the vadose zone) can serve minimize the impact of agricultural activities on groundwater.

Few recommendations that provide guidance to minimize the potential risks of salt contamination of water resources at NMP sites are currently available. The secondary maximum contaminant level (sMCL) in drinkwater for total dissolved solids (TDS) is 500 $mg \cdot L^{-1}$, which is equal to about 0.8 $dS \cdot m^{-1}$. Typical TDS of DWW and recycled water are 500-2000 $mg \cdot L^{-1}$, however part of the cations and anions that contribute to the TDS interact with the soil particle or are uptaken by the crop, especially in wastewater rich with nutrients. Hence, it may be useful to consider alternative indicators for salinity such as chloride, as the dominant anion, due to its high mobility in the soil and very low uptake rate by crops. A few operational recommendations that will lead to a decrease of salt load by DWW application and timing of leaching are summarized below:

- Regulations should be more specific and not based solely on TDS. Chloride is one potential indicator for salinity.
- Blending of high quality water (well water) and degraded water will decrease significantly the salt load; due to the order of magnitude difference in chloride concentrations.
- Growing salt tolerant crops will minimize the yield reduction due to salt accumulation in the root zone and will increase the uniformity of water and nutrients uptake from the soil.
- The timing of salt leaching may be a crucial management decision in NMPs because organic soil *N* continues to be converted to inorganic *N* forms (NH_4, NO_2 and NO_3) during periods of low *N* plant removal (fallow season). A pre-irrigation at the beginning of a new growing season, or seasonal rains during the fallow season may result in migration of inorganic *N*, especially NO_3, below the root zone towards groundwater, therefore leaching salts is preferred following harvests rather than prior to planting.
- Minimize application of dairy solid manure by matching to agronomic uptake rates of the crops. Alternative treatments (composting and biogas production) do not remove salts, however composting stabilizes the fresh manure to a balance

fertilizer with lower potential for groundwater contamination and biogas production is a feasible bio-energy source to handle excess dairy solid manure at specific sites.

Measured concentrations of fecal indicator microorganisms in fresh DWW significantly exceeded the recommended U.S. standards for unrestricted irrigation (USEPA, 2004). However, in practice fresh DWW are generally treated (removal of solids) and stored in lagoons for some period prior to application. Consequently, lower concentrations are expected in irrigation water (Table 5). A worst case transport scenario of ponded infiltration was initiated at two sites in the field, representing the two extremes of soil hydraulic properties. Indicator microorganisms were not detected in the soil below the depth of 20 cm. Additional experiments were conducted in the laboratory with soil from the EPA site to better quantify microorganism survival in the field soil. Batch survival experiments revealed much more rapid die-off rates for the bacterial indicator microorganisms in native than in sterilized soil, suggesting that the biotic factors played a dominant role in survival behavior.

Although transport and survival of microorganisms in NMP soils are likely to be site specific, a few recommendations to provide guidance to minimize the potential risks of pathogen contamination of water resources at NMP sites can be developed.

- The transport potential of microorganisms can be significantly reduced by minimizing water leaching below the root zone and surface water runoff. This can be achieved by:
    - Precise estimation of ET rate.
    - Uniform application of wastewater.
    - Selecting water application timing and quantities based on considerations of soil permeability and ET.

Special caution is warranted in coarse textured and structured soils and during water flow transients where enhanced microorganism transport potential has been reported in the literature.

- Timing of water application should allow for adequate die-off of microorganisms before leaching the root zone by irrigation or natural precipitation.

The potential for groundwater contamination will increase with shorter travel times and distances. The water table depth is therefore another important consideration for environmentally protective NMPs.

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Appendix D – CAFO Dairy Wastewater Treatment, VSEP L/P Filtration System Laboratory & Pilot Test Project Pilot BMP

CAFO Dairy Wastewater Treatment, VSEP L/P Filtration System Laboratory & Pilot Test Project Pilot BMP part of Integrated Regional Dairy Management Plan

Performed for the San Jacinto Basin Resource Conservation District

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Field Testing Dates: March 24, 2008 – April 14, 2008
Report Date: October, 2008

Location of Field Test: Abacherli Dairy, Menifee, CA

"Funding for this project has been provided in full or in part through an agreement with the State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of the trade names or commercial products constitute endorsement or recommendation for use." (gov.code 7550, 40 CFR 31.20).

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Executive Summary:

Dairy operators in the San Jacinto basin of California have identified a number of issues of concern regarding surface water and ground water quality, air quality, and compliance with regulatory requirements. The General WDR's prohibit the discharge of waste containing total dissolved solids and/or nitrogen concentrations in excess of the underlying groundwater management zone objectives for those constituents, unless adequately offset to the satisfaction of the Regional Board. Because groundwater management zones in the San Jacinto River Basin lack assimilative capacity for TDS and nitrate nitrogen discharges, salt inputs, including the discharge of corral manure and other animal wastes, such as process wastewater, and their application on cropland, can only be allowed if the impacts of the salt discharges are offset. The General WDR's will require dairies in the San Jacinto River Basin to cease the discharge of process wastewater and the land application of manure if a work plan to offset the impacts has not been approved and implemented by September 6, 2012.

This BMP project was performed to demonstrate the liquid/solids separation capabilities of a patented VSEP membrane filtration system for the separation and removal of suspended and dissolved nutrients (primarily salts and nitrates) from dairy wastewater. Improvement in the quality of wastewater from CAFO's is critical for the region and the successful operation of all farms in the future. The primary goal for the VSEP system was to provide liquid/solid separation of farm wastewater to produce clean safe water for reuse as cattle wash and possibly drinking water. The project results provide the operating parameters to size a full-scale system as well as performance data from the BMP pilot system to be used for cost-effectiveness evaluation. The results of the BMP pilot project will be used to assess the potential for application of VSEP technology at San Jacinto dairies to meet the requirements and goals of the General WDR's and nutrient TMDL. This information will be incorporated into the IRDMP facility-level recommendations to address dairy issues of concern.

An initial lab test on a dairy wastewater sample enabled the selection of a RO membrane to be used for the field pilot test. Operating parameters were confirmed for pressure to operate the VSEP system along with the estimated percent recovery rate and chemicals required for membrane cleaning. Lab analysis confirmed VSEP/RO permeate quality, as well as a second (pass) RO permeate quality, as additional polishing in case this was required. A series of pilot test batches were run in the field to confirm average flux and recovery rates for VSEP system sizing and samples were obtained for analysis. The results provided confirmation that permeate from the VSEP system is of suitable quality for reuse and shows that the system concentrated solids and dissolved salts and nutrients while obtaining 80% recovery of the water from the feed volume.

Introduction:

Wastewater and run-off from dairies in this region rely on settling basins for the separation of solids with the water being land applied. Dissolved nutrients in the wastewater, is of immediate concern for the groundwater basin and percolation of waste and run off. The Vibratory-Sheer-Enhanced-Processing (VSEP) system utilizes reverse osmosis (RO) membrane to separate and concentrate all suspended solids as well as most of the dissolved solids in the waste stream. Pathogens, virus and bacteria are too large to pass through the membrane and would be separated with the solids. RO membranes have long been used in water treatment systems to provide high quality water to municipalities and for bottled water production. Used in conjunction with VSEP technology, wastewater from dairy farms can also be used to provide safe high quality water.

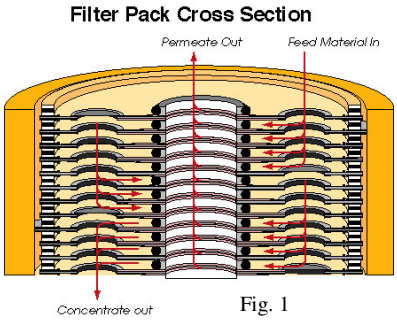


Fig. 1

The VSEP membrane filter pack contains hundreds of sheets of membrane, which are arrayed as parallel disks contained in a fiberglass reinforced plastic cylinder (FRP). This entire assembly is vibrated in torsional oscillation, similar in principle to the agitation

of a washing machine. VSEP can produce extremely high shear energy at the surface of the membrane with the filter attached to a spring assembly that moves at amplitude of 3/4" peak-to-peak displacement. This shear energy allows the VSEP RO system to handle high solids concentration without fouling or requiring extensive pretreatment systems associated with conventional RO membrane systems.

The wastewater is gently pumped through the VSEP filter module while a highly focused shear zone at the surface of the membrane is created by resonating oscillation. Rejected solids at the membrane surface are repelled by the shear waves and are washed away becoming more and more concentrated until the reject exits the module. An AC motor controlled by a variable frequency speed controller provides the resonant excitation that produces the vibration. The motor spins an eccentric weight coupled to the heavy seismic mass. Since the eccentricity of the weight induces a wobble, the seismic mass begins to move as the motor speed increases. Thus energy is transmitted up the torsion spring inducing the same wobble in the filter pack, however 180^0 out of phase. As the motor speed approaches the resonance frequency, the amplitude of moving filter pack reaches a maximum. The resonant frequency vibration employed by VSEP is extremely energy efficient. VSEP systems are completely automated, compact and reliable. The system is a complete integration requiring only process in and process out connections during installation. The system is controlled using as Allen Bradley industrial computer that monitors data and implements the program functions in a seamless automatic process.

The VSEP systems are module and can be expanded for future capacity by adding additional units to the system. Several VSEP module sizes are available to fit application requirement flows a full range of flow requirements to fit any farm size. It is expected, that up to ~80% of the wastewater can be recovered from the feed stream as high quality water for reuse.

VSEP Test Plan:

The BMP demonstration project was divided into two parts:

1) **Lab Testing-** Performed at New Logic Research's Laboratory in Emeryville, CA:

   In preparation for on-site pilot testing, the membrane to be used for the pilot demonstration must be established along with other operating parameters for operation.

2) **Field Pilot Testing-** Performed at Abacherli Dairy in Menifee, CA:

   Pilot scale VSEP systems use a membrane filter pack containing the selected membrane, having the same flow configurations as a full-scale VSEP system. Performance data can then be easily scaled to size a full-scale system. Samples obtained from the pilot test can be used to verify separation and permeate quality results.

VSEP Series L Test Protocol:

The following test protocol was followed in New Logic's research lab located in Emeryville, CA lab to establish the parameters for the pilot demonstration test. All test work for this research was completed in accordance with New Logic's Quality Assurance Project Plan (QAPP). The Series L test provides a summary of the developmental test work performed at our research center.

The initial lab test work included the testing of several kinds of polymeric membranes to find the one best suited for the application based on the objectives that have been laid out.

Application Information:

Customer:	San Jacinto Basin Resource Conservation District
Application:	CAFO Dairy Wastewater
Process Temperature:	20º C

Process Objectives:

Dairies in the San Jacinto region of Southern California will face regulatory restrictions on how they will dispose of wastewater in the future. The normal practice of percolating excess water from dairy operations will be restricted in the future to control contamination to ground water and surface water flows. Therefore, it is inevitable that action must be taken to look for ways that large volumes of waste water could be reused within the dairy operation such as hosing for floor wash down and possible use as livestock drinking water for the dairy, thus reducing the potential for contamination and regulatory mandates that could force existing dairy operation to close. Reuse of the treated water on dairies may depend on current local regulations as quality of the treated water is compared to current farm fresh water quality. Using technology that exists today will enable dairies to meet the objectives of pending regulations by reducing the waste stream by as much as 80% and leaving the remaining stream much easier to handle and dispose of as a condensed volume of high solids material.

Dairy livestock drinking water is one of the largest uses of water for dairy operations so recovered water with a high quality objective will be the primary use of any reclaimed water generated by this VSEP demonstration project. We will demonstrate that the VSEP treatment process is capable of consistently providing water quality at palatable drinking water standards during the demonstration period. These results may later lead to other approved water reuses on a dairy facility such as cattle washing in prior to entering the milking barn area. Currently rules clearly state that water of a secondary use can't be used for washing of milk cows regardless of water quality or treatment standards achieved.

The outcome of this initial lab test will provide information to develop requirements for a full-scale VSEP wastewater treatment system to recovery dairy wastewater and reuse and provide guidelines for the quality of "reuse" dairy wastewater and the solids and nutrient concentration disposal characteristics. Permeate sample analysis will determine if this water is of a quality to allow for reuse for farm operations as livestock drinking water. Collectively, this information should lead to the development for recommendations to CAFO's for wastewater and nutrient reduction and water reuse, thereby protecting groundwater under CAFO waste application site from nutrients, salts, and pathogens.

Desired VSEP Performance:

Process Flow Rate:	To be determined to size a full scale VSEP system

Test Protocol:

A test procedure was developed based on the feed material, process conditions and separation goals for the project. The test work was set up so that performance can be measured against for each of the process steps shown below. The process of filtration is dynamic and involves many variables. This test was conducted by isolating as many of these variables as possible to determine the

optimum in each case. These variables include: Membrane Selection, Temperature, Pressure, Concentration Factor, and Fouling. These variables were tested as follows:

In preparation for the Test, the sample material was pre-screened using a 60-mesh screen to remove large particles and then placed into a feed tank connected to the VSEP system. The membranes were installed and feed was introduced and pumped into the VSEP machine. Once settings were made on the VSEP machine, the Lab Technician records the measurements.

STEP 1 MEMBRANE SELECTION

Step 1 was used to evaluate a variety of membranes on the sample material to determine the best membrane in terms of flux and/or permeate quality. The performance was measured in what is referred to as re-circulation mode. This simply means returning the separated streams back to the feed tank and only measuring the relative performance of each membrane under the same conditions. This step was used to determine the most appropriate membrane. A Membrane Comparison Graph is included to the report to illustrate the performance of the membranes tested.

STEP 2 PRESSURE STUDY

Step 2 was used to determine the best operating pressure of the chosen membrane on the feed material. The permeate rate was measured as incremental increases in pressure are made to the system. A pressure was chosen at the point before there is a decrease in the ratio of permeate flux to pressure, to obtain an economical balance between this variable. This test determines if this is the case and at what pressure this begins to occur. A Pressure Study Graph is included to illustrate the performance of the membrane at the various pressure increments.

STEP 3 SHORT TERM LINE-OUT STUDY

Step 3 was used to measure the flux versus time to "condition" the membrane until the flux became stable. The membrane was run for a set time at the selected pressure. The time interval can vary and depends on the behavior of the feed material. A Flux versus Time (Line-Out Study) Graph is included to the report to illustrate the performance of the membrane over time.

STEP 4 CONCENTRATION STUDY

Step 4 is designed to measure flux vs. concentration or recovery. The test was completed in batch mode, as the membrane area is only 0.5 square feet. Permeate was continually removed from the system while the concentrated material was returned to the feed tank. This data was used to determine the average flux over the concentration/recovery range and was used to calculate the required membrane area and system size. A Flux versus Recovery Graph is included to illustrate the performance of the membrane during the concentration step.

STEP 5 CLEANING STUDY

Step 5 was used to develop a preliminary cleaning routine if one is necessary. Various cleaners were tested and the performance of each was measured. In this way, the optimum cleaning procedure can be developed.

TEST CONDITIONS:

Temperature:	25º C
Operation Mode:	L-Mode
Membrane Area:	0.5 ft2
Feed Solids:	0.40 %

MEMBRANE SELECTION:

Based on the Test Objectives, the following membranes were chosen for study:

Table 1 Membrane Selection

Membrane	Size Rating	Pressure	Max Temp	Water Flux	Composition
FE	93.5% NaCl rej	300 psi	60º C	66 GFD	TFC Polyamide
LFC	98.0% NaCl rej	300 psi	60º C	49 GFD	Thin-film Composite
ESPA	97.4% NaCl rej	300 psi	60º C	85 GFD	Composite Polyamide
BW-30	96.7% NaCl rej	300 psi	70º C	46 GFD	TFC Polyamide

- Average Batch Cell Test Results in GFD on new membrane @ 25º C
- GFD = Gallons of permeate produced per square foot of membrane per day

The relative performance of each of the selected membranes was tested. The feed tank was prepared with the sample feed material and the system was configured in "Re-circulation Mode". Each of the membranes shown above was installed and a 2-4 hour "Line-Out Study" was conducted. The membranes are compared based on flux and permeate quality.

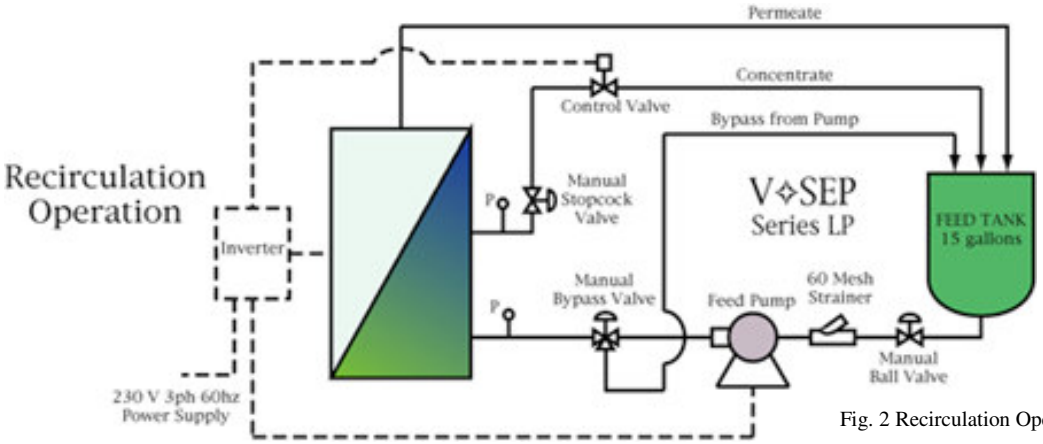


Fig. 2 Recirculation Operation

The following table shows relative performance of each membrane:

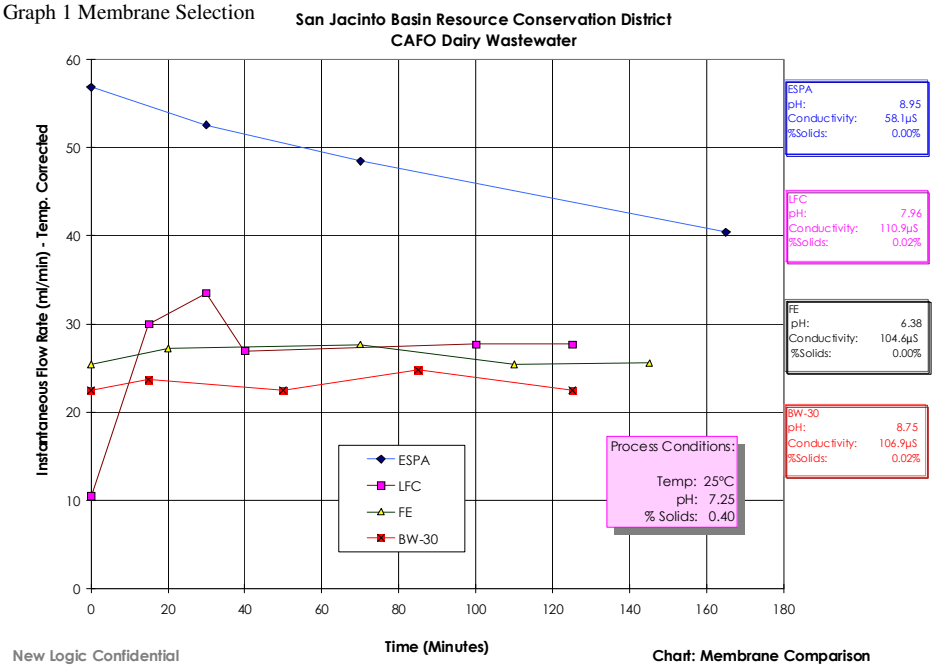
Table 2 Membrane Performance

Membrane	Type	Initial Flow*	Ending Flow*	Pressure	% Solids
FE	RO	25.4	25.6	300 psi	0.00 %
LFC	RO	16.5	27.7	300 psi	0.02 %
ESPA	RO	56.9	40.4	300 psi	0.02 %
BW-30	RO	22.5	22.5	300 psi	0.00 %
				Feed:	0.40 %

•Flow rates are in ml/min and are temperature corrected to 25º C

The **ESPA** membrane was chosen for further study because of the economical flux rates and the permeate quality. Grab samples of each permeate were collected for analysis. The results of this study are shown in the Graph: **Membrane Selection**.

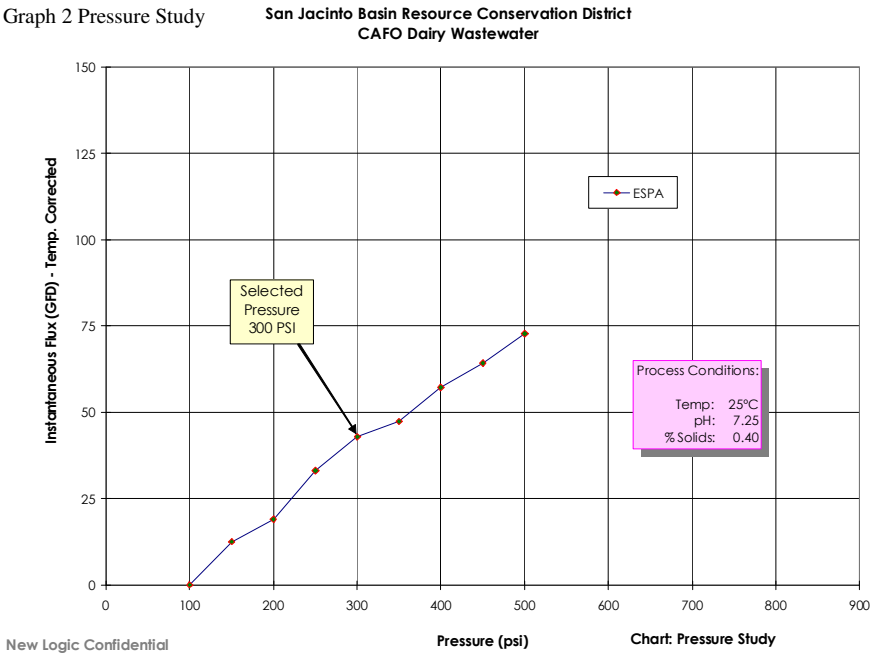
Graph 1 Membrane Selection



PRESSURE SELECTION:

The Selected Pressure was determined by measuring the flux at various pressures. The Selected Pressure for this application was determined to be **300 psi**. The results of this study are shown in the Graph: **Flux vs. Pressure**

Graph 2 Pressure Study



FLUX VS. CONCENTRATION:

The system was started up first in "Re-circulation" mode and also set to the Selected Pressure and expected process temperature. The system was run for a few hours to verify that the flux was stable and the system had reached equilibrium. Then the permeate line was diverted to a separate container for "Batch" mode. The permeate flow rate was measured at timed intervals to determine flow rate produced by the system at various levels of concentration. The sample becomes more concentrated as permeate was removed and the relationship between flux and concentration can be seen as the flux decreases as concentration increases. The concentration study is ended once the flux drops below 5-10 GFD and is considered uneconomical or if the feed is no longer able to be pumped. The average flux rate was calculated from these numbers and is used to size the full-scale equipment.

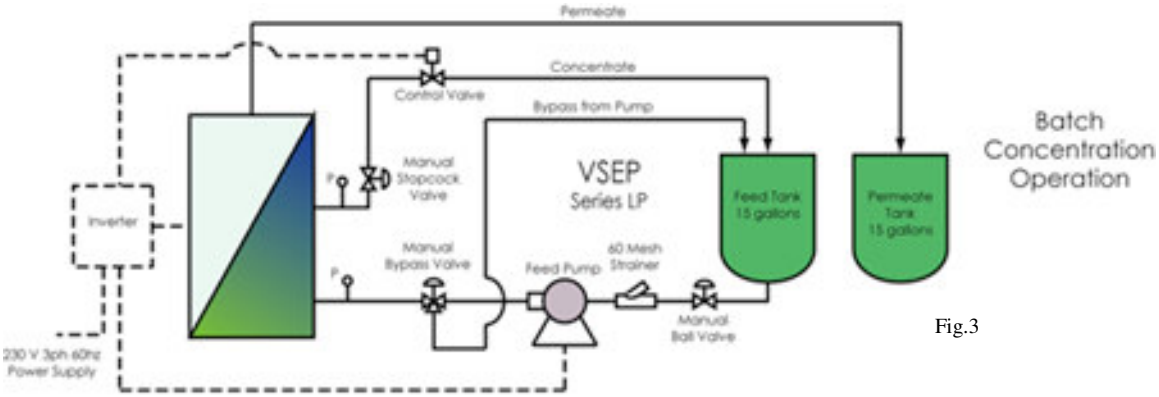


Fig.3

The results of the Line Out run are shown in the Graph: **Flux vs. Time (Line Out Study)**

Graph 3 Line Out

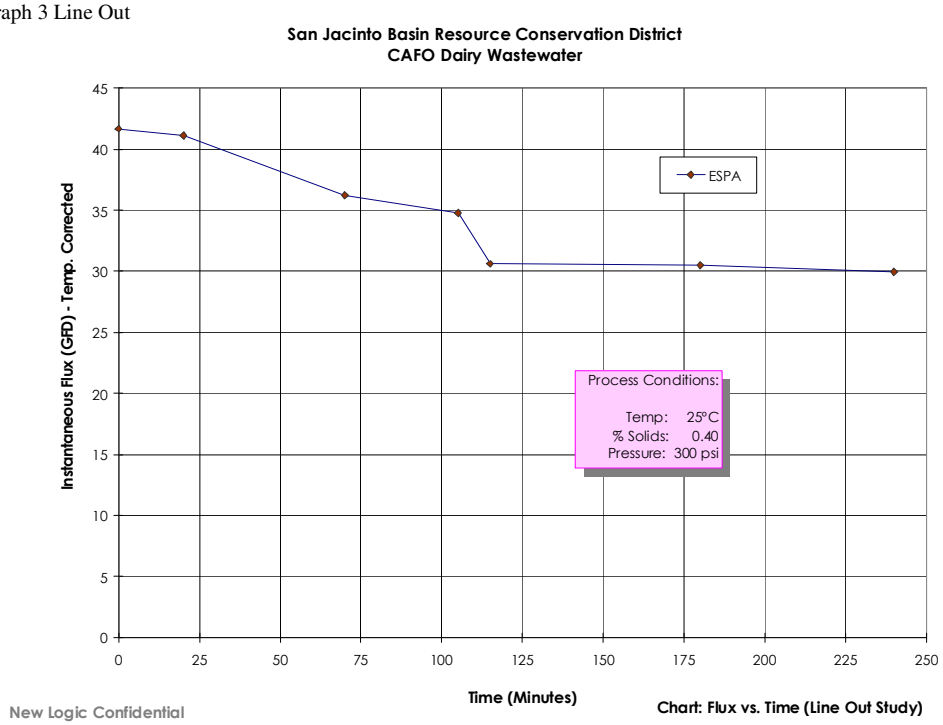


Table 3 shows the performance during the "Concentration Study":

Table 3 Concentration Study

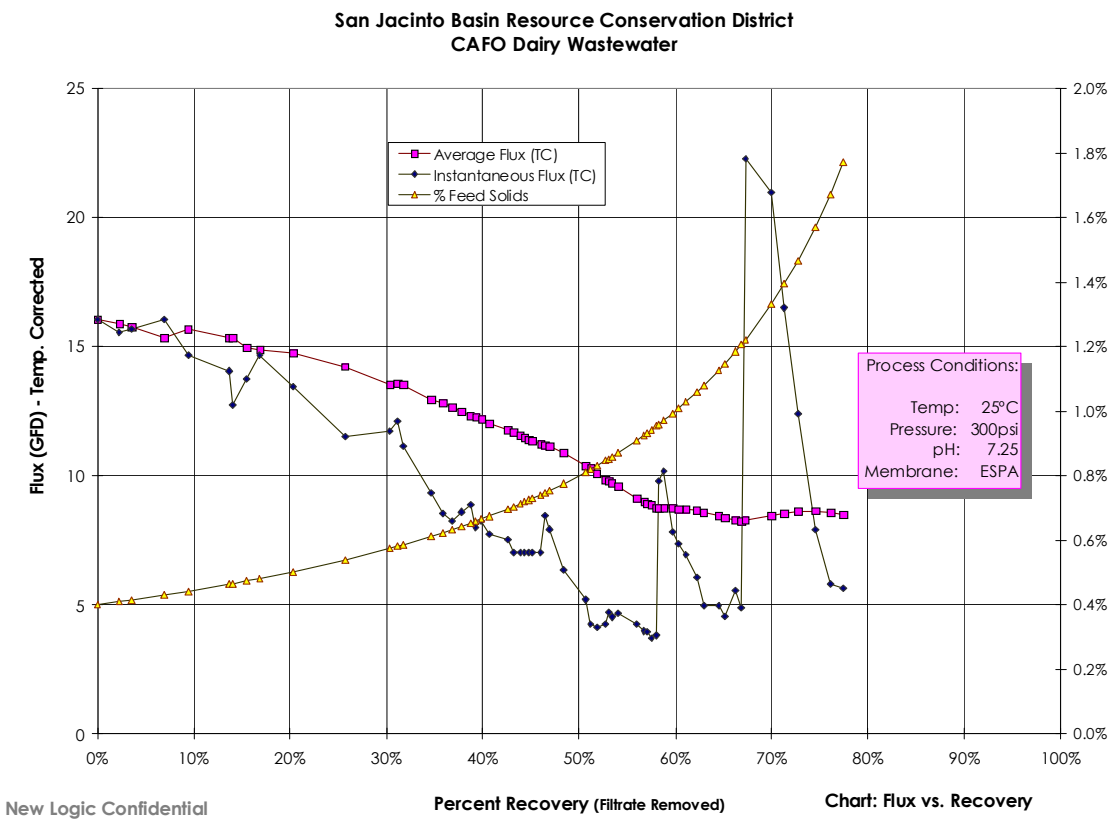
Ave Flux	Initial Flux*	Ending Flux*	Pressure	Initial Solids	Ending Solids	% Recovery
8.5 GFD	16.1 GFD	5.6 GFD	300 psi	0.40 %	1.77 %	77.40 %

- Flow Rates are gfd and are corrected to 25º C

Based on this Series L Data, **ESPA** Membrane was found to be suitable because it provided an acceptable permeate flux and demonstrated good performance over time. In this case, the maximum % recovery achieved was **77.40%**, which yielded an average flux of **8.5 GFD**.

This flux is the number used for sizing calculations. The results of this study are shown in the Graph: **Flux vs. % Recovery**

Graph 4 Flux vs. Recovery



CLEANING STUDY PROCEDURE:

At the end of the concentration study, a cleaning study was conducted to determine if the flux was recoverable. The system was flushed with warm water and the flux was recorded. A chemical cleaning was performed with NLR 404 acidic cleaning solution using 45º C water and pH adjusted to 2.5 using HCl, if needed. The system was run for 30-60 minutes at 50 psi and flushed with water. A second chemical cleaner NLR 505 at 45º C water and pH adjusted to 11.5 using NaOH was performed for 30-60 minutes at 50 psi and flushed with water. Other chemical cleaners are available and are tested when flux is not able to be recovered using this standard cleaning method.

CLEANING RESULTS:

Table 4 Shows the Results of Cleaning:

Table 4 Cleaning Results

Membrane	Membrane Condition	Cleaner Temp	pH	Flow Rate	% of New Flow
ESPA	New Membrane	-	-	85 GFD	100%
	Warm Water Flush	45º C	-	36 GFD	42%
	After NLR 404	45º C	2.5	57 GFD	64%
	After NLR 505	50º C	11.5	95 GFD	111%

* Flow rates on water and are temperature corrected to 25º C and are given in terms of GFD

Based on these results, it can be said that these cleaners were effective at cleaning the membrane and recovering flux rates. Warm water and pH adjusting are critical to the success of the cleaning.

Note: The new membrane flux was obtained from multiple batch cell tests and is an average value. During Series P (pilot) testing, a water flux for the individual filter pack will be used.

.

NLR 404 is an acidic liquid cleaner designed to provide superior and rapid mineral scale cleaning of wide range of RO, NF and UF membranes. It removes metallic salts such as iron, aluminum, barium and strontium sulfate, calcium sulfate, calcium carbonate, as well as dyes and polymers.

NLR 505 is a caustic liquid membrane cleaner designed to provide superior and rapid soil removal properties. It contains a combination of ingredients, which provide cleaning actions that include lifting, dispersing, emulsifying, sequestering, dissolving and suspending. It removes biological and organic materials, silt, particulates, colloids, silica and emulsified oil from a wide range of RO, NF, UF and MF membranes.

SUMMARY RESULTS:

The Laboratory Testing of the dairy wastewater test sample was completed and the optimum process variables to be used for pilot testing were obtained.

Table 5 shows the final analytical results of testing:

Table 5 Analytical Results

Membrane	% Solids	Conductivity	pH*	Volume
Initial Feed	0.40 %	4,660 µS	7.25	100 %
Final Permeate	0.00 %	185.6 µS	7.25	77 %
Final Concentrate	1.77 %	12,200 µS	7.75	23 %

*pH was held constant by adding H2SO4 (Sulfuric Acid) to the feed to maintain stable flux rates during the concentration study

The system design recommendations based on this lab test work are as follows:

Most Suitable Membrane:	**ESPA**
Selected Pressure:	**300 psi**
Design Basis Temperature:	**25º C**
% Recovery:	**77.40% Recovery**
Actual Average Flux:	**8.5 GFD**

LAB TEST SAMPLES:

During the testing, small grab samples were taken for the purposes of analysis. The following samples were collected:

Table 6 Sample Analysis

Stage 1

Sample Name	Color	pH	Conductivity	% Solids
Initial Feed	Brown	7.25	4,660 µm	0.54%
LFC Permeate	Clear	7.96	110.9 µm	0.02%
ESPA Permeate	Clear	8.95	58.1 µm	0.00%
FE Permeate	Clear	6.38	104.6 µm	0.00%
BW-30 Permeate	Clear	8.75	106.9 µm	0.02%
Composite Permeate	Clear	7.25	185.6 µm	0.00%
Final Concentrate	Brown	7.75	12,200 µm	17.20%

Descriptions:

Initial Feed:	Some of the actual original sample delivered to us for testing
Initial Permeate:	Sample collected during initial membrane selection
Composite Permeate:	A composite sample of all permeate taken during concentration
Final Concentrate:	The ending sample left (reject) after concentration

SAMPLE PHOTOGRAPHS:

Initial Feed, Composite Permeate and Final Concentrate

Photo 1

Photo 2

LFC, ESPA, FE, BW-30 Initial Permeate – Membrane Selection Samples

LAB TEST SAMPLE QUALITATIVE RESULTS:

Table 7 Lab Test Qualitative Results

	Stage 1 Feed	Stage 1 Concentrate	Stage 1 Permeate	Stage 2 Permeate
Total Hardness			23	ND
Calcium			ND	730*
Magnesium			ND	ND
Sodium			6,500	2,100
Potassium			4,200	ND
Total Alkalinity			23	ND
Carbonate			ND	ND
Bicarbonate			10	ND
Chloride			3.4	ND
Sulfate			1.2	ND
Nitrate as N			ND	ND
Fluoride			0.38	ND
Unionized Ammonia Nitrogen			ND	ND
pH			6.2	4.9
Conductance			99	4,280*
TDS	3,500	11,300	20	46*
TSS	4,240	3,350	ND	ND
TS			40	ND
Volatile Solids			40	ND
BOD			28	24*
COD			34	26
Turbidity			1.9	0.70
Sulfide			ND	ND
Ammonia-Nitrogen	130	230	4.5	1.5
Nitrogen TKN			3.9	ND
T Phosphorus			0.30	ND
Aluminum			ND	ND
Antimony			ND	ND
Arsenic			ND	ND
Barium			ND	ND
Beryllium			ND	ND
Chromium			ND	ND
Copper			ND	ND
Iron			ND	ND
Manganese			ND	21*
Mercury			ND	ND
Nickel			ND	ND
Selenium			ND	ND
Thallium			ND	ND
Zinc			ND	ND
Total Coliform			$1.6 \times 10^{3**}$	<20**
E. Coli			$1.6 \times 10^{3**}$	<20**

* * Values shown are suspicious since they should be lower than Stage 1 permeate

** Obvious lab contamination, since these organisms can not pass through an RO membrane

Important Note:

The purpose of this test is to be used as an initial feasibility study. These results are preliminary and were conducted on a small amount of aged feed sample. The effects of aging and the limited quantity of potential membrane foulants can skew results. Additional pilot testing is recommended and the results from that could vary from these results. The effect of this is that the number of VSEP modules required for a specific installation could change and affect any budgetary capital costs that may be quoted. Phase Two trials done in P mode using a larger filter pack will more closely simulate the full-scale operation. In addition, running a number of batches with an unlimited volume of feed material will provide reliable data upon which firm VSEP proposals can be offered for full scale implementation.

VSEP Series P (pilot) Testing:

The conclusion of the initial Series L VSEP (lab) test has provided the information required to set up and run a BMP pilot test in the field. Operating parameters, membrane selection and expected performance goals were determined during the lab test providing a reasonable starting point for pilot equipment runs. Past experience in testing other manure wastewater streams has confirmed that operation of the VSEP system will obtain a higher recovery rate if operated in batch mode. Therefore, the VSEP pilot test will be set up to run a series of batch runs.

VSEP Series P (pilot) Test Information:

New Logic Research (NLR) conducted a P-Mode VSEP test (pilot mode) at Abacherli Dairy as part of the test plan designed to demonstrate the ability of VSEP to treat dairy wastewater. The VSEP system is able to generate a clean permeate steam of water and a volume reduce concentrated waste. This test showed that clean permeate stream can be generated for reuse on dairies. The volume reduction of the waste stream by as much as 80% will result in a waste stream that can be more easily land applied.

This report details the BMP pilot testing phase of the project.

BMP Pilot Test Objectives:

The primary objectives of this P mode test are:

- Generate permeate samples for analysis so that separation quality can be documented to show that permeate from system can be reused at the dairy.
- Generate throughput data and operating parameters so that system sizing estimates can be calculated to provide full-scale systems for economic analysis.

Pilot Test Equipment and Set-Up:

NLR provided VSEP membrane filtration unit and periphery equipment to the Abacherli Dairy site in Menifee California. A second stage polishing Spiral RO unit was also provided. This secondary unit was used to further treat the VSEP permeate in order to maximize the separation and permeate quality for sample production. The VSEP unit was used in batch mode for the all of the VSEP testing. Figure 4 illustrates the basic set up for a single VSEP Series LP as used during this study. Figure 4 does not include any of the pre-treatment equipment being used such as the pre-filtration system. The Spiral RO unit operates with the same set up and equipment.

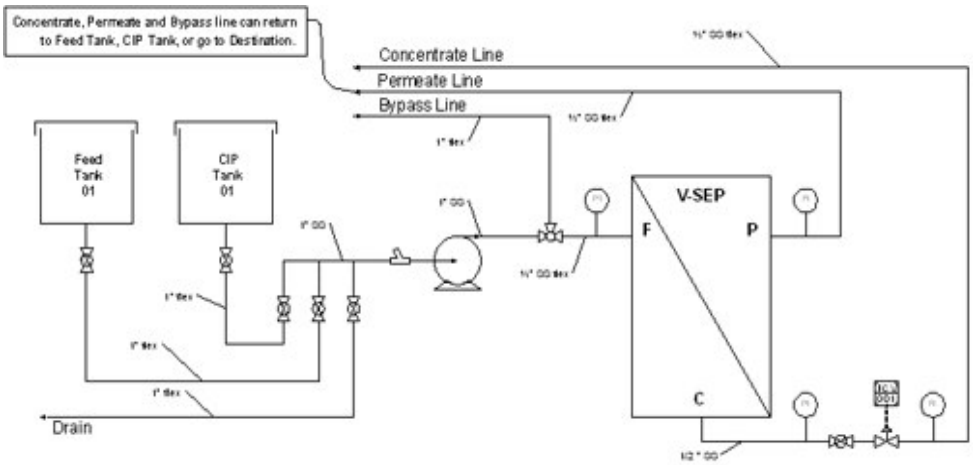


Fig. 4:

Standard VSEP Setup

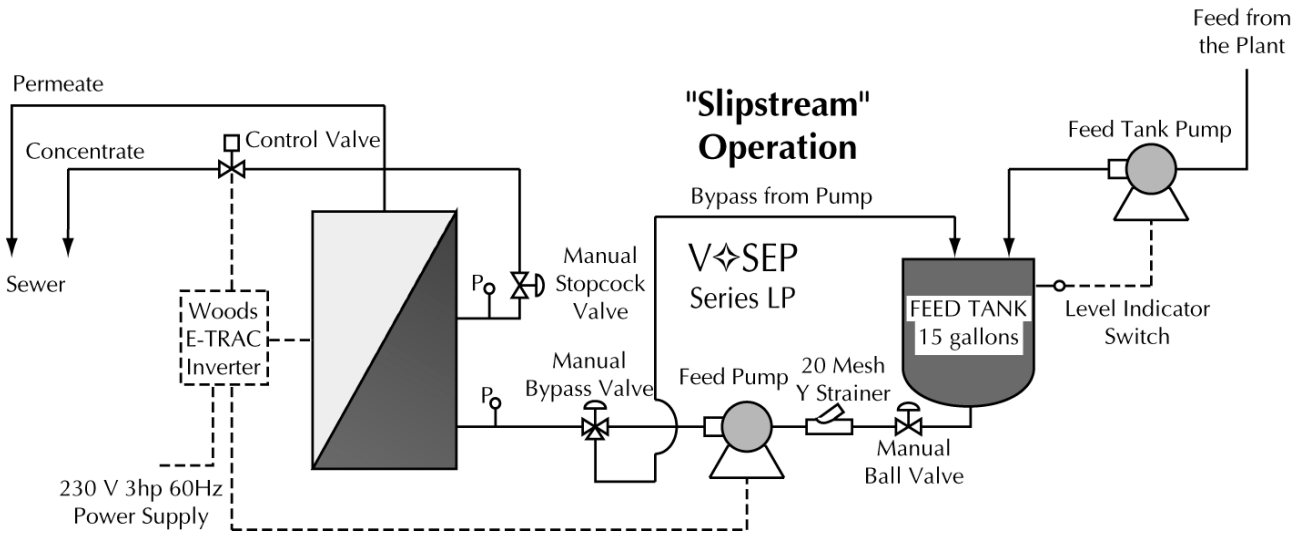


Fig. 5: "Slipstream" VSEP Setup

The VSEP pilot system was tested using a Reverse Osmosis (RO) membrane called ESPA. This membrane was selected based on previous studies conducted by NLR including an in house L mode test that was completed as part of this project. The Spiral RO system was tested using a similar RO membrane called LFC.

The standard system shown in Figure 1 can be run in two ways. First, it can be run in 'slipstream' shown in Figure 5. During slipstream operation, new feed material is continuously added to the feed tank while the Permeate and Concentrate lines are allowed to leave the system. This mode is not effective on high solids streams. The second method (used during this test) is referred to as 'batch' mode shown in Figure 6. In batch mode, the feed tank is filled with a limited volume of feed material and the concentrate line is returned to the feed tank. Permeate is allowed to leave the system thus concentrating the feed tank.

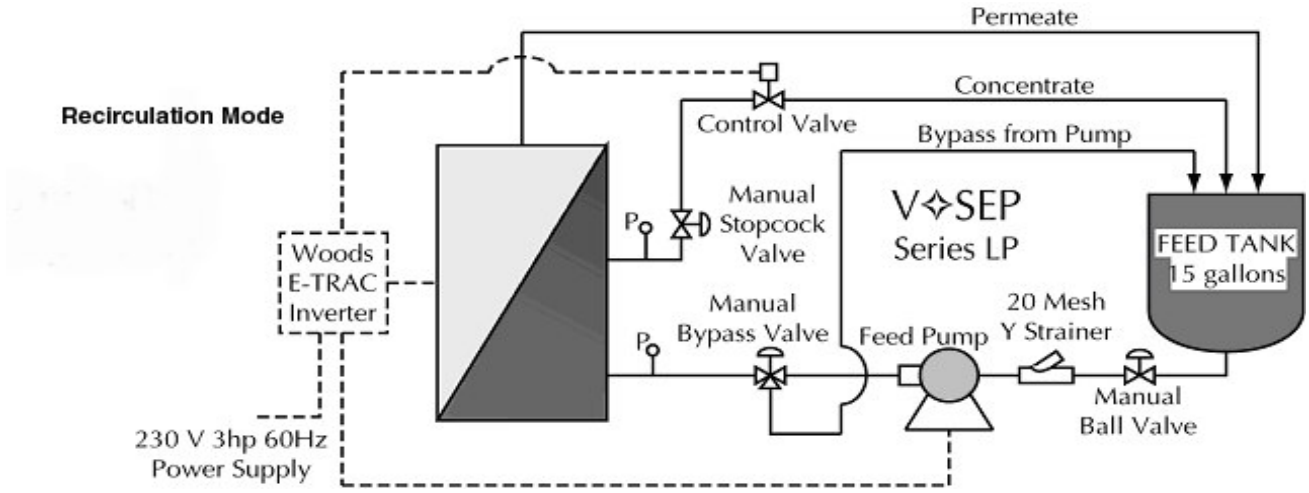


Fig. 6: "Batch" VSEP Setup

The accuracy of the flux readings and the calculated flux data can be estimated based on the error equation in Figure 7. Flow rates were measured using a graduated cylinder and a stopwatch. Volume readings in the cylinder were measured to the nearest 10 ml marker. The error of the volume recorded was +/- 5 ml for every reading. The error in the use of the stopwatch is estimated at +/- 0.3 seconds. Typical readings during testing ranged from 900 ml/min to 5000 ml/min. The error associated with each would be +/- 6.7 ml/min and +/- 25.5 ml/min respectively. This can also be expressed as 0.74% and 0.51% respectively. The indication is that a maximum error of +/- 0.74% exists for flux data reported and calculated. Recovery rate data is based on two separate flow rate readings, permeate and concentrate. However, an error in flow rate of 0.74% does not lead to an equal error in recovery calculated. As an example, a system with a permeate flow rate of 90 ml/min and a concentrate rate of 10 ml/min would have a recovery rate of 90%. Introduction of 0.74% error to both flow rates leads to a permeate rate of 90.7 ml/min and 10.1 ml/min of concentrate. These flow rates represent a recovery rate of 89.98% recovery. This is only an error of 0.02%. Therefore it can be said that recovery rates reported are accurate to +/- 0.02%.

$$s_x = x \cdot \sqrt{\left(\frac{s_a}{a}\right)^2 + \left(\frac{s_b}{b}\right)^2}$$

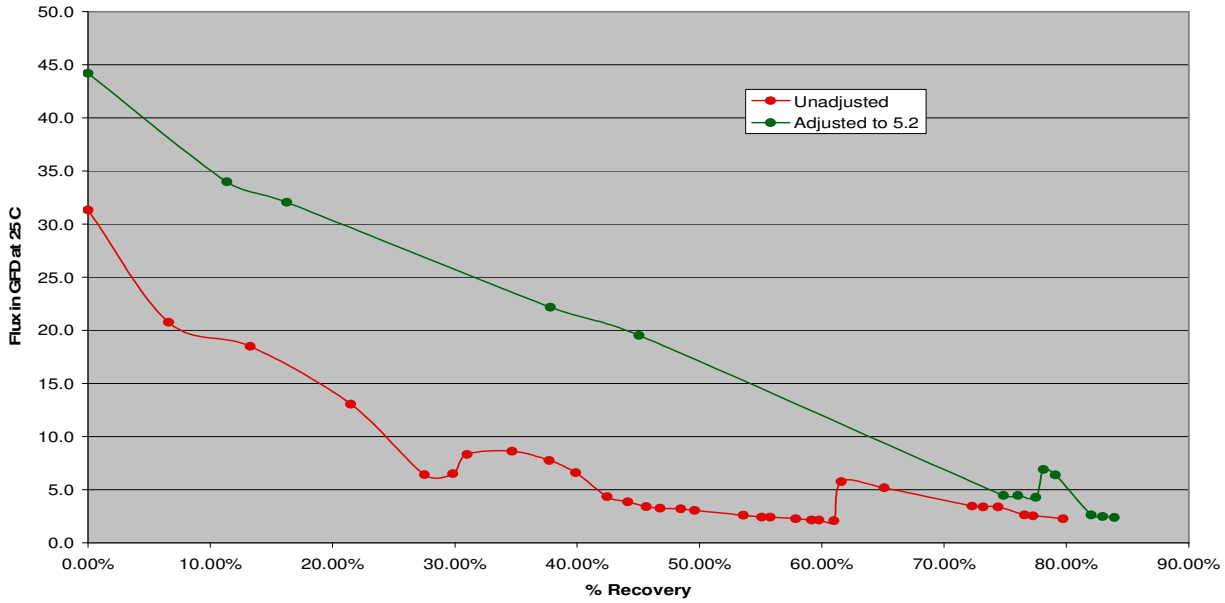
Fig. 7: Equation Used for Error Calculations

VSEP Pilot Test Results:

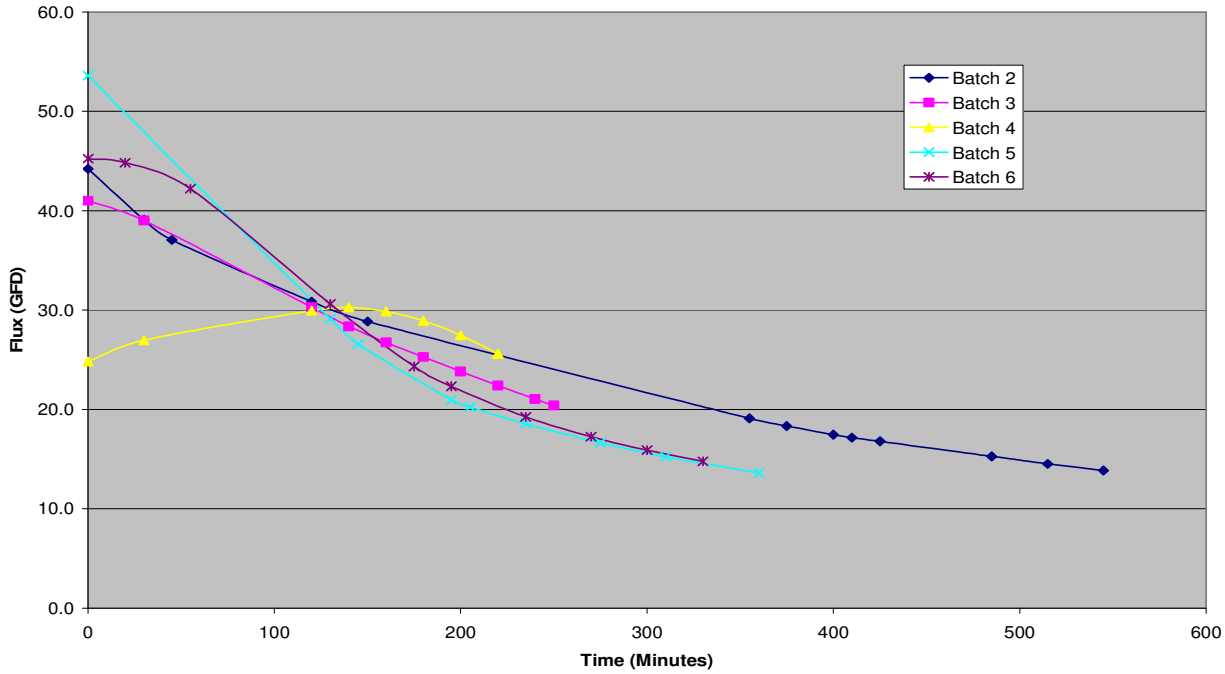
During testing multiple batch concentrations were completed. Several variables are set as constants based on quick optimization studies. For example, the operating pressure was maximized at 350 psi in order to maximize throughput. Vibration was maximized at ¾" of vibration in order to maximize fouling resistance of the VSEP system. Ideally, temperature would also be maximized in order to maximize throughput, however, temperature control was not available. Temperature will be discussed in greater deal at the end of this section.

The final, and perhaps most important variable that can be (and should be) optimized on this type of VSEP system is pH. Two batch studies were conducted at the beginning of the study in order to demonstrate the improved performance at lower pH levels. This comparison is illustrated in Graph 5. As Graph 5 suggests, running at the lower pH of 5.2 increases the flux rate of the system throughout the batch concentration, resulting in a higher average flux rate. This in turn will result in fewer full scale VSEP units needed for a given process flow rate. The lower pH of the feed also increases the rejection of ammonium (NH_4).

It should be noted that the decline flux rate seen during these batch concentrations is normal. As clean water is removed from the system as permeate, the feed material in the tank becomes more concentrated. This material becomes more and more difficult to process until an end point has been reached. In this case 80% volumetric recovery was achieved. The two batch concentrations shown in Graph 5 had average flux rates of 5.2 GFD (pH 6.6) and 13.9 GFD (pH 5.2). This higher average flux rate by a factor of 2.7 means that 2.7 times more equipment would be needed to process a given flow rate if the feed material were not pH adjusted.



Graph 5: ESPA, pH Study



Graph 6: ESPA, pH Adjusted Batch Concentrations

Graph 6 shows all of the batch concentrations that were completed at the adjusted pH range of 5.2 to 5.6. The flux rate, starting volume and ending recovery rate will all affect the time it takes to process a given

batch. The important data to extract from this figure is the ending average flux of each batch concentrations. These average flux rates can then be averaged themselves to give an estimated average flux to be used on system sizing calculations. The result of this averaging calculation is a design flux rate of 17.6 GFD at 25˚ C and 350 psi.

Permeate from several batches were collected in order to further process the material on the pilot scale Spiral RO system in order to generate samples for qualitative analysis. Sizing of a Spiral RO system would be done through simulation software readily available from all membrane manufacturers. Table 1 presents the full qualitative results of both stages.

E. Coli and Coliform values shown for the Stage 1 permeate are suspect. With an RO membrane, these numbers should have been zero or below testing limits. It is physically impossible for E. Coli or Coliform to pass through an RO membrane. The testing conditions at the farm were rather difficult in terms of eliminating sample contamination and we suspect that these samples were in fact contaminated. Dust and waste particulates were blowing around the testing area at all times.

Table 8: Qualitative Results

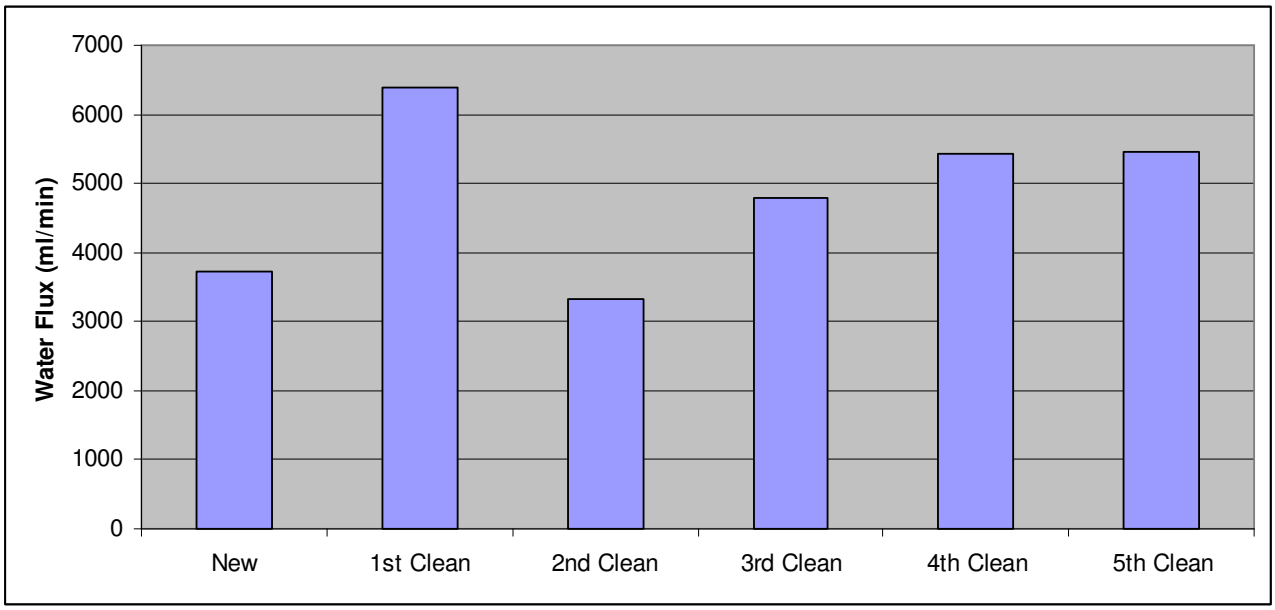
	Stage 1 Feed	Stage 1 Concentrate	Stage 1 Permeate	Stage 2 Permeate
Total Hardness	N/A	N/A	ND	ND
Calcium	N/A	N/A	ND	ND
Magnesium	N/A	N/A	ND	ND
Sodium	N/A	N/A	23	8.4
Potassium	N/A	N/A	22	6.9
Sodium Adsorption Ratio	N/A	N/A	6.6	7.8
Total Alkalinity	N/A	N/A	110	30
Hydroxide	N/A	N/A	ND	ND
Carbonate	N/A	N/A	ND	ND
Bicarbonate	N/A	N/A	130	37
Chloride	N/A	N/A	21	8.3
Sulfate	N/A	N/A	4.8	ND
Nitrate as N	N/A	N/A	ND	ND
Fluoride	N/A	N/A	ND	ND
Total Anions	N/A	N/A	2.89	9.83
pH	N/A	N/A	5.4	6.3
Conductance	N/A	N/A	380	110
TDS	1760*	5377*	210	44
TSS	N/A	ND	ND	ND
TS	N/A	N/A	230	66
Volatile Solids	N/A	N/A	100	64
BOD	N/A	N/A	170	44
COD	N/A	N/A	190	59
TOC	N/A	N/A	70	18
Turbidity	N/A	N/A	7.3	ND
Cyanide	N/A	N/A	ND	ND
Sulfide	N/A	N/A	55	ND
Ammonia-Nitrogen	23*	66.4*	4.3	5.0
K Nitrogen	N/A	N/A	20	7.5
Organic Nitrogen	N/A	N/A	16	ND
T Phosphorus	N/A	N/A	0.28 as P2O5	< 0.11 as P2O5
Aluminum	N/A	N/A	ND	ND
Antimony	N/A	N/A	ND	ND
Arsenic	N/A	N/A	ND	ND
Barium	N/A	N/A	ND	ND
Beryllium	N/A	N/A	ND	ND
Boron	N/A	N/A	380	460**
Chromium	N/A	N/A	ND	ND
Copper	N/A	N/A	ND	ND
Iron	N/A	N/A	ND	ND
Manganese	N/A	N/A	ND	ND
Mercury	N/A	N/A	ND	ND
Nickel	N/A	N/A	ND	ND
Selenium	N/A	N/A	ND	ND
Total Silica	N/A	N/A	ND	ND
Thallium	N/A	N/A	ND	ND
Zinc	N/A	N/A	ND	ND
Fluorine	N/A	N/A	ND	0.16**
Total Coliform	N/A	N/A	> 2400 mpn/100 ml	99 mpn/100 ml
E. Coli	N/A	N/A	> 2400 mpn/100 ml	< 1 mpn/100 ml

*** Calculated values based on typical RO membrane rejection efficiency**
**** These values as suspect based on typical RO rejections**

Membrane Cleaning:

Chemical cleaning of the membrane is used to restore the flux rate. While VSEP can prevent colloidal fouling of the membrane and can reduce the polarization of rejected materials at the membrane surface, like other membranes, it cannot avoid chemical bonding type fouling that will occur. For this reason, chemical cleaners are used to solubilize the foulants and restore the membrane. During chemical cleaning, cleaners are recirculated through the membrane system and then flushed out. Multiple cleaning cycles using different cleaners are used.

The cleaning procedure used was a two-part process. The steps in sequence were: NLR 404 acid cleaning followed by NLR 505 caustic cleaning. The procedure was based on previous experience with similar applications. The cleaners were used in a 3% by volume solution. Graph 7 shows the water flux after cleaning. These numbers indicate that the cleaning procedure used is effective in restoring the membrane system after exposure to concentrated waste. Cleaning frequency is estimated to be once per batch concentration, and therefore we suggest batch volumes that correspond to 1 or 2 batches per day. Hot water will need to be available for fully effective cleaning.



Graph 7: ESPA, Water Flux after Cleaning

NLR 404 is an acidic liquid cleaner designed to provide superior and rapid mineral scale cleaning of wide range of RO, NF and UF membranes. It removes metallic salts such as iron, aluminum, barium and strontium sulfate, calcium sulfate, calcium carbonate, as well as dyes and polymers.

NLR 505 is a caustic liquid membrane cleaner designed to provide superior and rapid soil removal properties. It contains a combination of ingredients, which provide cleaning actions that include lifting, dispersing, emulsifying, sequestering, dissolving and suspending. It removes biological and organic materials, silt, particulates, colloids, silica and emulsified oil from a wide range of RO, NF, UF and MF membranes.

BMP Pilot Test Summary:

Based on the objectives and results presented in this report it can be said that we were successful in demonstrating the ability of VSEP to treat the dairy waste stream generated at Abacherli Dairy. The following is a list of process recommendations/results.

Test Results:

Best VSEP Membrane:	ESPA - RO
Number of Stages:	1 (2nd Spiral RO stage recommended for highest quality water if required or desired)
Recovery:	80%
Average Flux Rate at 80% Recovery:	17.6 GFD at 25° C
Temperature:	25º C (Heating recommended to maximize flux)
Pressure:	350 psi
Cleaners Needed:	NLR 404 / NLR 505
Cleaning Frequency:	Once per Batch estimate.

BMP VSEP Series P (pilot) Test Conclusions:

Both lab and pilot tests were completed successfully and show the ability of the VSEP membrane filtration system to process dairy wastewater, producing high quality permeate water for possible reuse or discharge at the dairy operations. Operating data from these tests confirmed the ability of the VSEP to separate 80% of the feed volume as clean permeate while concentrating feed solids, both suspended and dissolved solids, to a significantly reduced volume of high value concentrated nutrients. Test sample analysis show that first-stage permeate from the VSEP/RO may well be satisfactory for reused. If necessary, a second stage of spiral RO can polish permeate generated from the VSEP system to a much higher quality.

Of most importance was the reduction of total dissolved solids (TDS) and nitrogen components from the feed. TDS levels were 210 mg/L from stage 1 VSEP/RO and 44 mg/L from stage 2 Spiral RO permeate. Nitrogen levels were reduced to <5 mg/L. Nitrates were completed separated from water produced from the test unit.

During the tests, pH was intentionally reduced which helped to increase the flux rate as illustrated in the report. Processing at a lower pH also improves the RO membrane rejection of ammonium (NH_4). Ammonium is ionized, (it has a plus charge), and is very soluble in water. Because the ammonium is ionized it will associate with a negatively charged anion such as carbonate or nitrate. This attraction keeps and holds the ammonium in solution. Even if concentrated, the ammonium will remain in solution and be rejected by the membrane. Ammonia, however, is non-charged and has a limited solubility in water as a gas. If the pH or temperature changes or the solution is concentrated shifting the concentrations of ammonia past its solubility, then it will evolve as a gas and leave the liquid rather than convert to ammonium. Therefore, maintaining the pH in the feed to the RO membrane was important to capture the ammonium inorganic nitrogen.

In order to determine what size or how many Series i Filter Packs are needed for a project, calculations are made from the pilot data shown above. The number used as a basis is the Actual Average Flux at the desired % recovery obtained from pilot testing in batch mode. With this number, we can ascertain the amount of membrane area that will be necessary to process a desired flow rate.

Based on the results of this pilot test a VSEP membrane system can be estimated for implementation. The calculations for system capacity are made using the recovery rate, average flux rate, known membrane area of a VSEP filter pack and allowance for membrane cleaning (2 hours per day) are as follows:

Given:

% Recovery:	**77.40% Recovery**
Actual Average Flux:	**8.5 GFD**
Membrane Area:	**1500 ft2**

Permeate: Gallons per Day = (1500 ft2)*(8.5 GFD)*(22/24 hour/day) = **11,687 GPD**

Feed: Gallons per Minute = (11,687 GPD) ÷ (77.40%) ÷ (1440 min/day) = **10.49 GPM**

By evaluating the data from pilot testing and long term needs, we can determine a safe degree of over-design. Thirty percent (30%) is generally recommended. The exact amount of over-design depends on the application. We recommend that there be some level of over-design which assists in the overall life of the equipment. By not using the system at its limit as far as throughput, you will extend the life and reduce the frequency of cleaning and thereby reduce your filter pack replacement costs and also allow for variations in the amount processed. The amount of over-design is critical to ensure that the system meets the processing requirements.

The calculations for the capacity of one (1) VSEP modules are as follow:

Given:

Permeate Flow Rate:	**11,687 GPD**
Actual Average Flux:	**8.5 GFD @ 25º C**
Membrane Area:	**1500 ft2.**

One 1) Series i VSEP 1500 ft2 Unit: **10.49 GPM * 70% = 7.34 GPM (permeate)**

One (1) Series i 84" VSEP module with ~ 1500 ft2 of membrane area unit can process a feed flow rate of 7.34 GPM, which includes a 30% Safety Factor. Multiple VSEP modules would be added to a system to provide the total capacity required for an installation.

Glossary

Average Flux: The time weighted average flux measured over a particular concentration range.

Batch Concentration: The machine configuration where a fixed amount of feed slurry is progressively concentrated by removal of permeate from the system. The concentrate from the system is returned to the feed tank.

BMP: Best Management Practice.

CAFO: Concentrated Animal Feeding Operations.

Concentrate: The part of the fluid solution, which does not permeate through the membrane.

Concentration Factor: The ratio of feed flow rate to the concentrate flow rate.

ESPA: A reverse osmosis membrane produced by Hydranautics.

Feed: Also called feed slurry. It is the raw solution, which is offered for filtration. It typically has suspended solids, bacteria, or molecules, which are to be segregated from a clear filtrate, and reduced in size making a concentrate solution of feed slurry.

Filter Pack: The filtering module, which contains the membrane, layers and is housed by a fiberglass enclosure.

Fouling: The accumulation of materials on the membrane surface or structure, which results in a decrease in flux.

Flux: Not the same as flow rate. Flux is a measurement of the volume of fluid, which passes through the membrane during a certain time interval for a set area of membrane, ie GFD, LMH.

GFD: Gallons per square foot per day.

GPM: Gallons per minute.

Instantaneous Flux: Flux measured at a given moment in time.

IRWMP: Integrated Regional Water Management Plan

L Mode: The configuration where a single piece of membrane is used and supported by clamshells on a Series L or LP Machine. This also means that the Feed slurry enters the filter pack from below and the permeate exits from the top.

Line Out Study: The procedure of measuring the membrane flux over time in order to determine eventual stability.

Microfiltration: Filtration of particles suspended in solution, which are ≥ 0.1 µm or 500,000 daltons in size or weight.

Micron: A unit of measurement. 1 Micron is equal to one-millionth of a meter (10^{-6}). 1 Micron also equals 12,000 mesh or .0000394". The limit of human visibility is 40 Microns.

Molecular Weight: The number that expresses the average mass of the molecules of a compound to the mass of an atom of Carbon 12 at a value of exactly 12.

MSDS: Material Safety Data Sheet.

Nanofiltration: Filtration of particles suspended in solution which are ≥ 0.01 µm or 1000 daltons in size or weight.

NLR-404: An acidic membrane chemical cleaner manufactured by New Logic Research, Inc.

NLR-505: A caustic membrane chemical cleaner manufactured by New Logic Research, Inc.

Optimum Pressure: The value of maximum pressure at which above that pressure is detrimental to performance.

Over Design: The additional membrane area provided in a system as a design safety factor.

P Mode: The configuration where 19 layers of membrane are used as a filter pack on a Series LP Machine. This also means that the Feed slurry enters the filter pack from the top and permeate also exits from the top. The actuated valve is typically used in "P Mode".

PSI: Pressure per square inch.

Percent Recovery: The ratio of permeate flow rate to the feed flow rate.

Permeate: Is also called filtrate. It is the part of the solution, which is able to or allowed to filter through the membrane. The particle size of solids still suspended is determined by the pore size of the discriminating membrane.

Retentate: The part of the solution, which is rejected by the membrane pores, also known as concentrate.

Reverse Osmosis: Filtration of particles suspended in solution, which are ≥ 0.001 µm or 100 daltons in size or weight.

SJBRCD: San Jacinto Basin Resource Conservation District.

VSEP: Vibratory Shear Enhanced Processing.

WDR: Waste Discharge Requirements

Ultrafiltration: Filtration of particles suspended in solution which are 0.01 to 0.1 µm or 1000 to 500,000 daltons in size or weight.

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CHAIN OF CUSTODY

Page _____ of _____

C & T LOGIN #: 202430

Sampler:

Project No.:

Report To: Angie DeSchutter

Project Name: San Jacinto

Company: New Logic Research

Project P.O.:

Telephone: 510-655-7305

Turnaround Time: Standard

Fax: 510-655-7307

Analysis

Lab No.	Sample ID.	Sampling Date Time	Matrix: Soil	Matrix: Water	Matrix: Waste		# of Containers	Preservative: HCL	Preservative: H_2SO_4	Preservative: HNO_3	Preservative: ICE		TDS, TSS	Ammonia	TDS, TSS, turb, pH, EC, TS, Alk, Sulfite	TVS, BOD, Sulfate, nitrate, Fluoride	Chloride, Asbestos	Ammonium, COD, TKN, total Phosp.	Metals, Hardness						
-1	Feed	10:00am 4/4/08		X			1						X												
	Feed			X			1		X					X											
-2	Concentrate			X			1						X												
	Concentrate			X			1		X					X											
-3	Permeate			X			5								X	X	X								
	Permeate			X			4		X									X							
	Permeate			X			1			X									X						
	Permeate			X			1		X					X						[redacted]					

Notes:

SAMPLE RECEIPT
☐ Intact ☐ Cold
☐ On Ice ☐ Ambient

Preservative Correct?
☐ Yes ☐ No ☐ N/A

RELINQUISHED BY:

Angie DeSchutter 4/4/08 12:00pm DATE / TIME

DATE / TIME

DATE / TIME

RECEIVED BY:

[signature] 4/4/08 12:00pm DATE / TIME

DATE / TIME

DATE / TIME

SIGNATURE

COOLER RECEIPT CHECKLIST

Curtis & Tompkins, Ltd.

Login # 202430 Date Received 4/4/08 Number of coolers 2
Client New Logic Project San Jacinto

Date Opened 4/4/08 By (print) KHellbock (sign) K Hellbock
Date Logged in ↓ By (print) KHellbock (sign) K Hellbock

1. Did cooler come with a shipping slip (airbill, etc)?..... YES (NO)
   Shipping info _____

2A. Were custody seals present? .... ☐ YES (circle) on cooler on samples ~~☐ NO~~
   How many _____ Name _____ Date _____
2B. Were custody seals intact upon arrival? ..... YES NO (N/A)
3. Were custody papers dry and intact when received?..... (YES) NO
4. Were custody papers filled out properly (ink, signed, etc)?..... (YES) NO
5. Is the project identifiable from custody papers? (If so fill out top of form)..... (YES) NO
6. Indicate the packing in cooler: (if other, describe) paper

   ☒ Bubble Wrap ☒ Foam blocks ☐ Bags ☐ None

   ☐ Cloth material ☐ Cardboard ☐ Styrofoam ☐ Paper towels
7. If required, was sufficient ice used? Samples should be < or = 6°C .....YES NO N/A

   Type of ice used: ☐ WET ☐ BLUE ☒ NONE Temp(°C) 5, 7 – only 1/2 coolers had ice

   ☐ SAMPLES RECEIVED ON ICE DIRECTLY FROM FIELD. COOLING PROCESS HAD BEGUN.
8. Were soil Encore sampling devices present? .....YES (NO)
   If YES, what time were they transferred to freezer? _____
9. Did all bottles arrive unbroken/unopened?..... (YES) NO
10. Are samples in the appropriate containers for indicated tests? ..... (YES) NO
11. Are sample labels present, in good condition and complete? ..... (YES) NO
12. Do the sample labels agree with custody papers? ..... (YES) NO
13. Was sufficient amount of sample sent for tests requested? ..... (YES) NO
14. Are the samples appropriately preserved? ..... (YES) NO N/A
15. Are bubbles absent in VOA samples?..... YES (NO) (N/A)
16. Was the client contacted concerning this sample delivery?..... YES NO
   If YES, Who was called? _____ By _____ Date: _____

COMMENTS
~~Bubbles/headspace in ALL VOAs~~

SOP Volume: Client Services
Section: 1.1.2
Page 1 of 1

Rev: 4 Number 1 of 3
Effective: 06 March 2008
F:\qc\forms\checklists\Cooler Receipt Checklist_rv4.doc

Curtis & Tompkins, Ltd.
Analytical Laboratory Since 1878
2323 Fifth Street
Berkeley, CA 94710
(510) 486-0900 Phone
(510) 486-0532 Fax

CHAIN OF CUSTODY

Page _____ of _____

C & T LOGIN #: 202894

Sampler: Sommer Carter
Report To: Sommer Carter
Company: New Logic Research
Telephone: 510-655-7305
Fax: 510-655-7307

Project No.:
Project Name: San Jacinto
Project P.O.:
Turnaround Time: Standard

Lab No.	Sample ID.	Sampling Date Time	Matrix: Soil	Matrix: Water	Matrix: Waste	# of Containers	Preservative: HCL	Preservative: H_2SO_4	Preservative: HNO_3	Preservative: ICE	TDS, TSS.	Ammonia	TDS, TSS, Turb, pH, EC, TS, Alk, Sulfite	TVS, BOD, Sulfate, Nitrate, Flouride	chloride, Asbestos	Ammonium COD, TKN, Total Phosphorus	Metals, Hardness
				X													
1	Concentrate	3:15 PM/4/29/8		X		1					X						
	Concentrate			X		1		X				X					
2	Stage 2 permeate			X		1		X				X					
	Stage 2 permeate			X		1			X								X
	Stage 2 permeate			X		IIII		X								X	
	Stage 2 permeate			X		~~IIII~~							X	X	X		
3	Stage 1 permeate			X		1		X								X	
	Stage 1 permeate			X		[redacted] 1		X				X	[redacted]				
	Stage 1 permeate			X		1							X		-		
	Stage 1 permeate			X		1									X		

Notes:

SAMPLE RECEIPT
☒ Intact ☒ Cold
☐ On Ice ☐ Ambient

Preservative Correct?
☐ Yes ☐ No ☐ N/A

RELINQUISHED BY:
4/29/8 3:20 DATE / TIME
DATE / TIME
DATE / TIME

RECEIVED BY:
4/29/08 3:20pm DATE / TIME
DATE / TIME
DATE / TIME

SIGNATURE

COOLER RECEIPT CHECKLIST

Curtis & Tompkins, Ltd.

Login # 202894 Date Received 4-29-08 Number of coolers 1
Client NLI Project San Jacinto

Date Opened 4-29-08 By (print) E Nichols (sign) [signature]
Date Logged in 4-29-08 By (print) E Nichols (sign) [signature]

1. Did cooler come with a shipping slip (airbill, etc)?..... YES (NO)
   Shipping info _____

2A. Were custody seals present? .... ☐ YES (circle) on cooler on samples ☒ NO
   How many _____ Name _____ Date _____
2B. Were custody seals intact upon arrival? ..... YES NO (N/A)
3. Were custody papers dry and intact when received?..... (YES) NO
4. Were custody papers filled out properly (ink, signed, etc)?..... (YES) NO
5. Is the project identifiable from custody papers? (If so fill out top of form)..... (YES) NO
6. Indicate the packing in cooler: (if other, describe) _____

   ☒ Bubble Wrap ☐ Foam blocks ☐ Bags ☐ None

   ☐ Cloth material ☐ Cardboard ☐ Styrofoam ☐ Paper towels
7. If required, was sufficient ice used? Samples should be < or = 6°C ..... YES (NO) N/A

   Type of ice used: ☐ WET ☐ BLUE ☒ NONE Temp(°C) 14.5°C

   ☐ SAMPLES RECEIVED ON ICE DIRECTLY FROM FIELD. COOLING PROCESS HAD BEGUN.

8. Were soil Encore sampling devices present? ..... YES (NO)
   If YES, what time were they transferred to freezer? _____
9. Did all bottles arrive unbroken/unopened?..... (YES) NO
10. Are samples in the appropriate containers for indicated tests? ..... (YES) NO
11. Are sample labels present, in good condition and complete? ..... (YES) NO
12. Do the sample labels agree with custody papers? ..... (YES) NO
13. Was sufficient amount of sample sent for tests requested? ..... (YES) NO
14. Are the samples appropriately preserved? ..... (YES) NO N/A
15. Are bubbles absent in VOA samples?..... YES NO (N/A)
16. Was the client contacted concerning this sample delivery?..... YES NO
   If YES, Who was called? _____ By _____ Date: _____

COMMENTS

_____

Curtis & Tompkins, Ltd.

Metals Analytical Report

Lab #:	202430	Project#:	STANDARD
Client:	New Logic Research	Location:	San Jacinto
Field ID:	PERMEATE	Sampled:	04/04/08
Lab ID:	202430-003	Received:	04/04/08
Matrix:	Water	Prepared:	04/07/08
Units:	ug/L	Analyzed:	04/07/08
Diln Fac:	1.000		

Analyte	Result	RL	Batch#	Prep	Analysis
Aluminum	ND	100	136808	EPA 3010A	EPA 6010B
Antimony	ND	10	136808	EPA 3010A	EPA 6010B
Arsenic	ND	6.1	136808	EPA 3010A	EPA 6010B
Barium	ND	5.0	136808	EPA 3010A	EPA 6010B
Beryllium	ND	2.0	136808	EPA 3010A	EPA 6010B
Calcium	ND	500	136808	EPA 3010A	EPA 6010B
Chromium	ND	5.0	136808	EPA 3010A	EPA 6010B
Copper	ND	5.0	136808	EPA 3010A	EPA 6010B
Iron	ND	100	136808	EPA 3010A	EPA 6010B
Magnesium	ND	500	136808	EPA 3010A	EPA 6010B
Manganese	ND	5.0	136808	EPA 3010A	EPA 6010B
Mercury	ND	0.20	136810	METHOD	EPA 7470A
Nickel	ND	5.0	136808	EPA 3010A	EPA 6010B
Potassium	4,200	500	136808	EPA 3010A	EPA 6010B
Selenium	ND	10	136808	EPA 3010A	EPA 6010B
Sodium	6,500	500	136808	EPA 3010A	EPA 6010B
Thallium	ND	10	136808	EPA 3010A	EPA 6010B
Zinc	ND	20	136808	EPA 3010A	EPA 6010B

ND= Not Detected
RL= Reporting Limit

Curtis & Tompkins, Ltd.

Batch QC Report

Metals Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	EPA 3010A
Project#:	STANDARD	Analysis:	EPA 6010B
Type:	BLANK	Diln Fac:	1.000
Lab ID:	QC436396	Batch#:	136808
Matrix:	Water	Prepared:	04/07/08
Units:	ug/L	Analyzed:	04/07/08

Analyte	Result	RL
Aluminum	ND	100
Antimony	ND	10
Arsenic	ND	6.1
Barium	ND	5.0
Beryllium	ND	2.0
Calcium	ND	500
Chromium	ND	5.0
Copper	ND	5.0
Iron	ND	100
Magnesium	ND	500
Manganese	ND	5.0
Nickel	ND	5.0
Potassium	ND	500
Selenium	ND	10
Sodium	ND	500
Thallium	ND	10
Zinc	ND	20

ND= Not Detected
RL= Reporting Limit

Curtis & Tompkins, Ltd.

Batch QC Report

Metals Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	EPA 3010A
Project#:	STANDARD	Analysis:	EPA 6010B
Matrix:	Water	Batch#:	136808
Units:	ug/L	Prepared:	04/07/08
Diln Fac:	1.000	Analyzed:	04/07/08

Type: BS Lab ID: QC436397

Analyte	Spiked	Result	%REC	Limits
Aluminum	2,000	1,747	87	80-120
Antimony	500.0	465.9	93	80-120
Arsenic	100.0	102.3	102	80-120
Barium	2,000	1,941	97	80-120
Beryllium	50.00	52.02	104	80-120
Calcium	20,000	17,980	90	80-120
Chromium	200.0	192.3	96	80-120
Copper	250.0	234.6	94	80-120
Iron	1,000	892.2	89	80-120
Magnesium	20,000	17,550	88	80-120
Manganese	50.00	50.83	102	80-120
Nickel	500.0	474.9	95	80-120
Potassium	10,000	8,607	86	80-120
Selenium	100.0	104.7	105	80-120
Sodium	20,000	17,200	86	80-120
Thallium	100.0	101.7	102	80-120
Zinc	500.0	489.7	98	80-120

Type: BSD Lab ID: QC436398

Analyte	Spiked	Result	%REC	Limits	RPD	Lim
Aluminum	2,000	1,709	85	80-120	2	20
Antimony	500.0	457.0	91	80-120	2	20
Arsenic	100.0	99.16	99	80-120	3	20
Barium	2,000	1,902	95	80-120	2	20
Beryllium	50.00	51.33	103	80-120	1	20
Calcium	20,000	17,330	87	80-120	4	20
Chromium	200.0	189.0	95	80-120	2	20
Copper	250.0	232.1	93	80-120	1	20
Iron	1,000	867.8	87	80-120	3	20
Magnesium	20,000	17,280	86	80-120	2	20
Manganese	50.00	49.93	100	80-120	2	20
Nickel	500.0	466.9	93	80-120	2	20
Potassium	10,000	8,285	83	80-120	4	20
Selenium	100.0	102.9	103	80-120	2	20
Sodium	20,000	16,550	83	80-120	4	20
Thallium	100.0	99.63	100	80-120	2	20
Zinc	500.0	483.8	97	80-120	1	20

RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Batch QC Report

Metals Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	EPA 3010A
Project#:	STANDARD	Analysis:	EPA 6010B
Field ID:	PERMEATE	Batch#:	136808
MSS Lab ID:	202430-003	Sampled:	04/04/08
Matrix:	Water	Received:	04/04/08
Units:	ug/L	Prepared:	04/07/08
Diln Fac:	1.000	Analyzed:	04/07/08

Type: MS Lab ID: QC436399

Analyte	MSS Result	Spiked	Result	%REC	Limits
Aluminum	20.34	2,000	1,524	75 *	77-120
Antimony	4.074	500.0	445.5	88	78-120
Arsenic	<2.042	100.0	97.12	97	80-126
Barium	1.773	2,000	1,866	93	80-120
Beryllium	<0.04231	50.00	50.44	101	80-120
Calcium	359.0	20,000	16,420	80	67-128
Chromium	0.3209	200.0	185.1	92	80-120
Copper	1.792	250.0	229.0	91	80-120
Iron	7.503	1,000	795.8	79	72-123
Magnesium	169.4	20,000	15,870	79	71-123
Manganese	0.6046	50.00	49.09	97	79-123
Nickel	0.8189	500.0	458.6	92	79-120
Potassium	4,183	10,000	11,630	75	74-120
Selenium	<1.469	100.0	100.5	101	80-125
Sodium	6,523	20,000	21,190	73	68-125
Thallium	<1.616	100.0	96.30	96	77-120
Zinc	8.408	500.0	482.8	95	78-122

Type: MSD Lab ID: QC436400

Analyte	Spiked	Result	%REC	Limits	RPD	Lim
Aluminum	2,000	1,601	79	77-120	5	20
Antimony	500.0	458.4	91	78-120	3	20
Arsenic	100.0	100.7	101	80-126	4	20
Barium	2,000	1,902	95	80-120	2	20
Beryllium	50.00	51.25	102	80-120	2	20
Calcium	20,000	17,110	84	67-128	4	20
Chromium	200.0	188.8	94	80-120	2	20
Copper	250.0	232.4	92	80-120	2	20
Iron	1,000	821.9	81	72-123	3	20
Magnesium	20,000	16,490	82	71-123	4	20
Manganese	50.00	49.92	99	79-123	2	20
Nickel	500.0	466.9	93	79-120	2	20
Potassium	10,000	12,170	80	74-120	4	20
Selenium	100.0	101.8	102	80-125	1	20
Sodium	20,000	22,440	80	68-125	6	20
Thallium	100.0	98.68	99	77-120	2	20
Zinc	500.0	488.7	96	78-122	1	20

*= Value outside of QC limits; see narrative
RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Batch QC Report

Metals Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	EPA 7470A
Analyte:	Mercury	Diln Fac:	1.000
Type:	BLANK	Batch#:	136810
Lab ID:	QC436419	Prepared:	04/07/08
Matrix:	Water	Analyzed:	04/07/08
Units:	ug/L		

Result	RL
ND	0.20

ND= Not Detected
RL= Reporting Limit

23.0

Curtis & Tompkins, Ltd.

Batch QC Report

Metals Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	EPA 7470A
Analyte:	Mercury	Batch#:	136810
Matrix:	Water	Prepared:	04/07/08
Units:	ug/L	Analyzed:	04/07/08
Diln Fac:	1.000		

Type	Lab ID	Spiked	Result	%REC	Limits	RPD	Lim
BS	QC436420	5.000	5.080	102	80-120		
BSD	QC436421	5.000	5.100	102	80-120	0	20

RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Batch QC Report

Metals Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	EPA 7470A
Analyte:	Mercury	Batch#:	136810
Field ID:	ZZZZZZZZZZ	Sampled:	04/04/08
MSS Lab ID:	202445-001	Received:	04/04/08
Matrix:	Filtrate	Prepared:	04/07/08
Units:	ug/L	Analyzed:	04/07/08
Diln Fac:	1.000		

Type	Lab ID	MSS Result	Spiked	Result	%REC	Limits	RPD	Lim
MS	QC436423	<0.04502	5.000	5.170	103	77-126		
MSD	QC436424		5.000	5.160	103	77-126	0	20

RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Hardness (Total)

Lab #:	202430	Project#:	STANDARD
Client:	New Logic Research	Location:	San Jacinto
Analyte:	Hardness as CaCO3	Matrix:	Water
Field ID:	PERMEATE	Sampled:	04/04/08
Lab ID:	202430-003	Received:	04/04/08

Result
NA

NA= Not Analyzed

9.0

Curtis & Tompkins, Ltd.

Curtis & Tompkins Laboratories Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	EPA 300.0
Field ID:	PERMEATE	Diln Fac:	1.000
Matrix:	Water	Sampled:	04/04/08 10:00
Units:	mg/L	Received:	04/04/08

Type: SAMPLE Lab ID: 202430-003

Analyte	Result	RL	Batch#	Analyzed
Fluoride	0.38	0.10	136776	04/05/08 14:33
Chloride	10	0.20	136738	04/04/08 13:33
Nitrogen, Nitrate	ND	0.05	136738	04/04/08 13:33
Sulfate	1.2	0.50	136738	04/04/08 13:33

Type: BLANK Batch#: 136738
Lab ID: QC436119 Analyzed: 04/04/08 09:34

Analyte	Result	RL
Chloride	ND	0.20
Nitrogen, Nitrate	ND	0.05
Sulfate	ND	0.50

Type: BLANK Batch#: 136776
Lab ID: QC436271 Analyzed: 04/05/08 13:40

Analyte	Result	RL
Fluoride	ND	0.10

ND= Not Detected
RL= Reporting Limit

Curtis & Tompkins, Ltd.

Batch QC Report

Curtis & Tompkins Laboratories Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	EPA 300.0
Matrix:	Water	Diln Fac:	1.000
Units:	mg/L	Batch#:	136738

Type: BS Analyzed: 04/04/08 09:52
Lab ID: QC436120

Analyte	Spiked	Result	%REC	Limits
Chloride	4.000	3.903	98	80-120
Nitrogen, Nitrate	1.000	0.9597	96	80-120
Sulfate	10.00	9.751	98	80-120

Type: BSD Analyzed: 04/04/08 10:09
Lab ID: QC436121

Analyte	Spiked	Result	%REC	Limits	RPD	Lim
Chloride	4.000	3.902	98	80-120	0	20
Nitrogen, Nitrate	1.000	0.9436	94	80-120	2	20
Sulfate	10.00	9.699	97	80-120	1	20

RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Batch QC Report

Curtis & Tompkins Laboratories Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	EPA 300.0
Field ID:	PERMEATE	Diln Fac:	1.020
MSS Lab ID:	202430-003	Batch#:	136738
Matrix:	Water	Sampled:	04/04/08 10:00
Units:	mg/L	Received:	04/04/08

Type: MS Analyzed: 04/04/08 13:54
Lab ID: QC436177

Analyte	MSS Result	Spiked	Result	%REC	Limits
Chloride	10.28	2.040	12.03	86 NM	80-120
Nitrogen, Nitrate	<0.01169	0.5100	0.4943	97	80-120
Sulfate	1.224	5.100	6.041	94	80-120

Type: MSD Analyzed: 04/04/08 14:12
Lab ID: QC436178

Analyte	Spiked	Result	%REC	Limits	RPD	Lim
Chloride	2.040	12.03	86 NM	80-120	0	20
Nitrogen, Nitrate	0.5100	0.4986	98	80-120	1	20
Sulfate	5.100	6.092	95	80-120	1	20

NM= Not Meaningful: Sample concentration > 4X spike concentration
RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Batch QC Report

Curtis & Tompkins Laboratories Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	EPA 300.0
Analyte:	Fluoride	Diln Fac:	1.000
Matrix:	Water	Batch#:	136776
Units:	mg/L		

Type	Lab ID	Spiked	Result	%REC	Limits	RPD	Lim	Analyzed
BS	QC436272	2.000	2.007	100	80-120			04/05/08 13:58
BSD	QC436273	2.000	1.964	98	80-120	2	20	04/05/08 14:15

RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Batch QC Report

Curtis & Tompkins Laboratories Analytical Report

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	EPA 300.0
Analyte:	Fluoride	Diln Fac:	1.020
Field ID:	PERMEATE	Batch#:	136776
MSS Lab ID:	202430-003	Sampled:	04/04/08 10:00
Matrix:	Water	Received:	04/04/08
Units:	mg/L		

Type	Lab ID	MSS Result	Spiked	Result	%REC	Limits	RPD	Lim	Analyzed
MS	QC436274	0.3777	1.020	1.387	99	69-120			04/05/08 14:50
MSD	QC436275		1.020	1.398	100	69-120	1	20	04/05/08 15:07

RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Alkalinity

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM2320B
Field ID:	PERMEATE	Batch#:	136794
Matrix:	Water	Sampled:	04/04/08
Units:	mg/L	Received:	04/04/08
Diln Fac:	1.000	Analyzed:	04/07/08

Type: SAMPLE Lab ID: 202430-003

Analyte	Result	RL
Alkalinity, Bicarbonate	23	1.0
Alkalinity, Carbonate	ND	1.0
Alkalinity, Hydroxide	ND	1.0
Alkalinity, Total as CaCO3	23	1.0

Type: BLANK Lab ID: QC436340

Analyte	Result	RL
Alkalinity, Bicarbonate	ND	1.0
Alkalinity, Carbonate	ND	1.0
Alkalinity, Hydroxide	ND	1.0
Alkalinity, Total as CaCO3	ND	1.0

ND= Not Detected
RL= Reporting Limit

Curtis & Tompkins, Ltd.

Batch QC Report

Alkalinity

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM2320B
Analyte:	Alkalinity, Total as CaCO3	Units:	mg/L
Type:	LCS	Diln Fac:	4.000
Lab ID:	QC436341	Batch#:	136794
Matrix:	Water	Analyzed:	04/07/08

Spiked	Result	%REC	Limits
200.0	194.8	97	90-110

Curtis & Tompkins, Ltd.

Batch QC Report

Alkalinity

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM2320B
Analyte:	Alkalinity, Total as CaCO3	Diln Fac:	4.000
Field ID:	ZZZZZZZZZZ	Batch#:	136794
MSS Lab ID:	202380-004	Sampled:	04/02/08
Matrix:	Water	Received:	04/02/08
Units:	mg/L	Analyzed:	04/07/08

Type	Lab ID	MSS Result	Spiked	Result	%REC	Limits	RPD	Lim
MS	QC436342	561.3	200.0	758.4	99	80-120		
MSD	QC436343		200.0	755.2	97	80-120	0	25

RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Ammonia Nitrogen

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	SM4500NH3-B
Project#:	STANDARD	Analysis:	SM4500NH3-D
Analyte:	Ammonia-N	Sampled:	04/04/08 10:00
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Analyzed:	04/11/08 14:40
Batch#:	136970		

Field ID	Type	Lab ID	Result	RL	MDL	Diln Fac
FEED	SAMPLE	202430-001	130	2.0		20.00
CONCENTRATE	SAMPLE	202430-002	200	2.0		20.00
PERMEATE	SAMPLE	202430-003	4.5	0.10		1.000
	BLANK	QC437083	ND	0.10		1.000

ND= Not Detected
RL= Reporting Limit
MDL= Method Detection Limit

34.0

Curtis & Tompkins, Ltd.

Batch QC Report

Ammonia Nitrogen

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	SM4500NH3-B
Project#:	STANDARD	Analysis:	SM4500NH3-D
Analyte:	Ammonia-N	Diln Fac:	1.000
Field ID:	ZZZZZZZZZZ	Batch#:	136970
MSS Lab ID:	202370-001	Sampled:	04/02/08 09:00
Matrix:	Water	Received:	04/02/08
Units:	mg/L	Analyzed:	04/11/08 14:40

Type	Lab ID	MSS Result	Spiked	Result	%REC	Limits	RPD	Lim
LCS	QC437084		5.000	4.060	81	61-120		
MS	QC437087	0.8410	5.000	4.110	65	54-120		
MSD	QC437088		5.000	4.120	66	54-120	0	51

RPD= Relative Percent Difference

35.0

Curtis & Tompkins, Ltd.

Biochemical Oxygen Demand

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM5210B
Analyte:	Biochemical Oxygen Demand	Batch#:	136754
Field ID:	PERMEATE	Sampled:	04/04/08 10:00
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Prepared:	04/04/08 15:00
Diln Fac:	1.000	Analyzed:	04/09/08 16:00

Type	Lab ID	Result	RL
SAMPLE	202430-003	28	5.0
BLANK	QC436193	ND	5.0

ND= Not Detected
RL= Reporting Limit

42.0

Curtis & Tompkins, Ltd.

Batch QC Report

Biochemical Oxygen Demand

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM5210B
Analyte:	Biochemical Oxygen Demand	Batch#:	136754
Field ID:	PERMEATE	Sampled:	04/04/08 10:00
MSS Lab ID:	202430-003	Received:	04/04/08
Matrix:	Water	Prepared:	04/04/08 15:00
Units:	mg/L	Analyzed:	04/09/08 16:00
Diln Fac:	1.000		

Type	Lab ID	MSS Result	Spiked	Result	RL	%REC	Limits	RPD	Lim
BS	QC436194		198.0	189.3		96	85-115		
BSD	QC436195		198.0	200.8		101	85-115	6	20
SDUP	QC436196	27.76		24.82	5.000			11	25

RL= Reporting Limit
RPD= Relative Percent Difference

43.1

Curtis & Tompkins, Ltd.

Chemical Oxygen Demand

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM5220D
Analyte:	Chemical Oxygen Demand	Batch#:	136749
Field ID:	PERMEATE	Sampled:	04/04/08 10:00
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Prepared:	04/07/08 17:10
Diln Fac:	1.000	Analyzed:	04/08/08 10:00

Type	Lab ID	Result	RL
SAMPLE	202430-003	34	10
BLANK	QC436167	ND	10

ND= Not Detected
RL= Reporting Limit

14.0

Curtis & Tompkins, Ltd.

Batch QC Report

Chemical Oxygen Demand

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM5220D
Analyte:	Chemical Oxygen Demand	Batch#:	136749
Field ID:	ZZZZZZZZZZ	Sampled:	03/25/08 11:51
MSS Lab ID:	202189-001	Received:	03/26/08
Matrix:	Water	Prepared:	04/07/08 17:10
Units:	mg/L	Analyzed:	04/08/08 10:00
Diln Fac:	1.000		

Type	Lab ID	MSS Result	Spiked	Result	%REC	Limits	RPD	Lim
LCS	QC436168		75.00	76.59	102	90-110		
MS	QC436169	<10.00	150.0	157.2	105	60-125		
MSD	QC436170		150.0	161.2	107	60-125	3	20

RPD= Relative Percent Difference

15.0

Curtis & Tompkins, Ltd.

Conductivity

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM2510B
Analyte:	Specific Conductance	Batch#:	136759
Field ID:	PERMEATE	Sampled:	04/04/08 10:00
Matrix:	Water	Received:	04/04/08
Units:	umhos/cm	Analyzed:	04/04/08 15:15
Diln Fac:	1.000		

Type	Lab ID	Result	RL
SAMPLE	202430-003	99	1.0
BLANK	QC436208	ND	1.0

ND= Not Detected
RL= Reporting Limit

26.0

Curtis & Tompkins, Ltd.

Batch QC Report

Conductivity

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM2510B
Analyte:	Specific Conductance	Diln Fac:	1.000
Field ID:	ZZZZZZZZZZ	Batch#:	136759
MSS Lab ID:	202432-003	Sampled:	04/04/08 11:50
Matrix:	Water	Received:	04/04/08
Units:	umhos/cm	Analyzed:	04/04/08 15:15

Type	Lab ID	MSS Result	Spiked	Result	RL	%REC	Limits	RPD	Lim
LCS	QC436209		1,000	1,003		100	90-110		
SDUP	QC436210	2,800		2,750	1.000			2	20

RL= Reporting Limit
RPD= Relative Percent Difference

27.0

Curtis & Tompkins, Ltd.

pH

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	EPA 9040B
Analyte:	pH	Diln Fac:	1.000
Field ID:	PERMEATE	Batch#:	136758
Lab ID:	202430-003	Sampled:	04/04/08 10:00
Matrix:	Water	Received:	04/04/08
Units:	SU	Analyzed:	04/04/08 15:15

Result	RL
6.2	1.0

RL= Reporting Limit

Curtis & Tompkins, Ltd.

Batch QC Report

pH			
Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	EPA 9040B
Analyte:	pH	Units:	SU
Field ID:	ZZZZZZZZZZ	Diln Fac:	1.000
Type:	SDUP	Batch#:	136758
MSS Lab ID:	202432-003	Sampled:	04/04/08 11:50
Lab ID:	QC436207	Received:	04/04/08
Matrix:	Water	Analyzed:	04/04/08 15:15

MSS Result	Result	RL	RPD	Lim
6.890	6.870	1.000	0	20

RL= Reporting Limit
RPD= Relative Percent Difference

33.0

Curtis & Tompkins, Ltd.

Total Phosphorous

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	SMWW18:4500P-B
Project#:	STANDARD	Analysis:	SM4500P-E
Analyte:	Phosphorous	Batch#:	136852
Field ID:	PERMEATE	Sampled:	04/04/08
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Prepared:	04/07/08
Diln Fac:	1.000	Analyzed:	04/08/08

Type	Lab ID	Result	RL
SAMPLE	202430-003	0.032	0.030
BLANK	QC436584	ND	0.030

ND= Not Detected
RL= Reporting Limit

18.0

Curtis & Tompkins, Ltd.

Batch QC Report

Total Phosphorous

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	SMWW18:4500P-B
Project#:	STANDARD	Analysis:	SM4500P-E
Analyte:	Phosphorous	Batch#:	136852
Field ID:	ZZZZZZZZZZ	Sampled:	04/02/08
MSS Lab ID:	202372-001	Received:	04/02/08
Matrix:	Water	Prepared:	04/07/08
Units:	mg/L	Analyzed:	04/08/08
Diln Fac:	1.000		

Type	Lab ID	MSS Result	Spiked	Result	%REC	Limits	RPD	Lim
LCS	QC436585		0.1980	0.2104	106	64-138		
MS	QC436586	1.574	0.1980	1.882	155 NM	31-151		
MSD	QC436587		0.1980	1.566	-4 NM	31-151	18	30

NM= Not Meaningful: Sample concentration > 4X spike concentration
RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Sulfite

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Analysis:	SM4500SO3-B
Project#:	STANDARD		
Analyte:	Sulfite	Batch#:	136751
Field ID:	PERMEATE	Sampled:	04/04/08 10:00
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Analyzed:	04/04/08 15:00
Diln Fac:	1.000		

Type	Lab ID	Result	RL
SAMPLE	202430-003	ND	2.0
BLANK	QC436181	ND	2.0

ND= Not Detected
RL= Reporting Limit

2.0

Curtis & Tompkins, Ltd.

Batch QC Report

Sulfite

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Analysis:	SM4500SO3-B
Project#:	STANDARD		
Analyte:	Sulfite	Diln Fac:	1.000
Field ID:	PERMEATE	Batch#:	136751
MSS Lab ID:	202430-003	Sampled:	04/04/08 10:00
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Analyzed:	04/04/08 15:00

Type	Lab ID	MSS Result	Spiked	Result	%REC	Limits	RPD	Lim
LCS	QC436182		17.80	18.50	104	80-120		
MS	QC436183	<2.000	17.80	19.50	110	70-130		
MSD	QC436184		17.80	20.00	112	70-130	3	30

RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Total Dissolved Solids (TDS)

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM2540C
Analyte:	Total Dissolved Solids	Sampled:	04/04/08
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Analyzed:	04/08/08
Batch#:	136842		

Field ID	Type	Lab ID	Result	RL	Diln Fac
FEED	SAMPLE	202430-001	3,500	100	10.00
CONCENTRATE	SAMPLE	202430-002	7,040	100	10.00
PERMEATE	SAMPLE	202430-003	20	10	1.000
	BLANK	QC436543	ND	10	1.000

ND= Not Detected
RL= Reporting Limit

28.0

Curtis & Tompkins, Ltd.

Batch QC Report

Total Dissolved Solids (TDS)

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM2540C
Analyte:	Total Dissolved Solids	Batch#:	136842
Field ID:	V-4 PERM	Sampled:	04/04/08
MSS Lab ID:	202458-008	Received:	04/07/08
Matrix:	Water	Analyzed:	04/08/08
Units:	mg/L		

Type	Lab ID	MSS Result	Spiked	Result	RL	%REC	Limits	RPD	Lim	Diln Fac
BS	QC436544		104.0	96.00		92	74-132			1.000
BSD	QC436545		104.0	88.00		85	74-132	9	29	1.000
SDUP	QC436546	13,000		14,300	500.0			10	20	50.00

RL= Reporting Limit
RPD= Relative Percent Difference

29.0

Curtis & Tompkins, Ltd.

Total Kjeldahl Nitrogen

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	SMWW20:4500-NORG
Project#:	STANDARD	Analysis:	SM4500NH3-C
Analyte:	Nitrogen, Total Kjeldahl	Batch#:	136818
Field ID:	PERMEATE	Sampled:	04/04/08
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Prepared:	04/07/08
Diln Fac:	1.000	Analyzed:	04/08/08

Type	Lab ID	Result	RL
SAMPLE	202430-003	3.9	1.0
BLANK	QC436451	ND	1.0

ND= Not Detected
RL= Reporting Limit

21.0

Curtis & Tompkins, Ltd.

Batch QC Report

Total Kjeldahl Nitrogen

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	SMWW20:4500-NORG
Project#:	STANDARD	Analysis:	SM4500NH3-C
Analyte:	Nitrogen, Total Kjeldahl	Batch#:	136818
Field ID:	ZZZZZZZZZZ	Sampled:	03/28/08
MSS Lab ID:	202269-001	Received:	03/28/08
Matrix:	Water	Prepared:	04/07/08
Units:	mg/L	Analyzed:	04/08/08
Diln Fac:	1.000		

Type	Lab ID	MSS Result	Spiked	Result	%REC	Limits	RPD	Lim
LCS	QC436452		10.00	9.860	99	64-120		
MS	QC436453	8.740	10.00	16.63	79	42-132		
MSD	QC436454		10.00	15.34	66	42-132	8	36

RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Total Solids

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Analysis:	SM2540B
Project#:	STANDARD		
Analyte:	Total Solids	Batch#:	136976
Field ID:	PERMEATE	Sampled:	04/04/08
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Prepared:	04/11/08
Diln Fac:	1.000	Analyzed:	04/14/08

Type	Lab ID	Result	RL
SAMPLE	202430-003	40	10
BLANK	QC437116	ND	10

ND= Not Detected
RL= Reporting Limit

36.0

Curtis & Tompkins, Ltd.

Batch QC Report

Total Solids

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Analysis:	SM2540B
Project#:	STANDARD		
Analyte:	Total Solids	Batch#:	136976
Field ID:	PERMEATE	Sampled:	04/04/08
MSS Lab ID:	202430-003	Received:	04/04/08
Matrix:	Water	Prepared:	04/11/08
Units:	mg/L	Analyzed:	04/14/08
Diln Fac:	1.000		

Type	Lab ID	MSS Result	Spiked	Result	RL	%REC	Limits	RPD	Lim
LCS	QC437117		1,058	986.0		93	80-120		
SDUP	QC437118	40.00		42.00	10.00			5	30

RL= Reporting Limit
RPD= Relative Percent Difference

37.0

Curtis & Tompkins, Ltd.

Total Suspended Solids (TSS)

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM2540D
Analyte:	Total Suspended Solids	Sampled:	04/04/08
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Analyzed:	04/09/08
Batch#:	136885		

Field ID	Type	Lab ID	Result	RL	Diln Fac
FEED	SAMPLE	202430-001	4,240	150	30.00
CONCENTRATE	SAMPLE	202430-002	1,930	170	33.00
PERMEATE	SAMPLE	202430-003	ND	5	1.000
	BLANK	QC436712	ND	5	1.000

ND= Not Detected
RL= Reporting Limit

30.0

Curtis & Tompkins, Ltd.

Batch QC Report

Total Suspended Solids (TSS)

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Prep:	METHOD
Project#:	STANDARD	Analysis:	SM2540D
Analyte:	Total Suspended Solids	Diln Fac:	1.000
Field ID:	V-1 FEED	Batch#:	136885
MSS Lab ID:	202458-001	Sampled:	04/04/08
Matrix:	Water	Received:	04/07/08
Units:	mg/L	Analyzed:	04/09/08

Type	Lab ID	MSS Result	Spiked	Result	RL	%REC	Limits	RPD	Lim
BS	QC436713		50.00	48.00		96	80-120		
BSD	QC436714		50.00	51.00		102	80-120	6	20
SSPIKE	QC436715	19.00	50.00	63.00		88	37-153		
SDUP	QC436716	19.00		21.00	5.000			10	32

RL= Reporting Limit
RPD= Relative Percent Difference

31.0

Curtis & Tompkins, Ltd.

Turbidity

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Analysis:	SM2130B
Project#:	STANDARD		
Analyte:	Turbidity	Diln Fac:	1.000
Field ID:	PERMEATE	Batch#:	136757
Lab ID:	202430-003	Sampled:	04/04/08 10:00
Matrix:	Water	Received:	04/04/08
Units:	NTU	Analyzed:	04/04/08 15:15

Result	RL
1.9	0.20

RL= Reporting Limit

38.0

Curtis & Tompkins, Ltd.

Batch QC Report

Turbidity

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Analysis:	SM2130B
Project#:	STANDARD		
Analyte:	Turbidity	Units:	NTU
Field ID:	PERMEATE	Diln Fac:	1.000
Type:	SDUP	Batch#:	136757
MSS Lab ID:	202430-003	Sampled:	04/04/08 10:00
Lab ID:	QC436206	Received:	04/04/08
Matrix:	Water	Analyzed:	04/04/08 15:15

MSS Result	Result	RL	RPD	Lim
1.860	1.830	0.2000	2	20

RL= Reporting Limit
RPD= Relative Percent Difference

Curtis & Tompkins, Ltd.

Total Volatile Solids

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Analysis:	SM2540E
Project#:	STANDARD		
Analyte:	Total Volatile Solids	Batch#:	136978
Field ID:	PERMEATE	Sampled:	04/04/08
Matrix:	Water	Received:	04/04/08
Units:	mg/L	Prepared:	04/11/08
Diln Fac:	1.000	Analyzed:	04/15/08

Type	Lab ID	Result	RL
SAMPLE	202430-003	40	10
BLANK	QC437120	ND	10

ND= Not Detected
RL= Reporting Limit

40.0

Curtis & Tompkins, Ltd.

Batch QC Report

Total Volatile Solids

Lab #:	202430	Location:	San Jacinto
Client:	New Logic Research	Analysis:	SM2540E
Project#:	STANDARD		
Analyte:	Total Volatile Solids	Batch#:	136978
Field ID:	PERMEATE	Sampled:	04/04/08
MSS Lab ID:	202430-003	Received:	04/04/08
Matrix:	Water	Prepared:	04/11/08
Units:	mg/L	Analyzed:	04/15/08
Diln Fac:	1.000		

Type	Lab ID	MSS Result	Result	RL	RPD	Lim
SDUP	QC437122	40.00	40.00	10.00	0	20

RL= Reporting Limit
RPD= Relative Percent Difference

BioVir Laboratories, Inc.

NELAC #05234CA
EPA ID #01401, CA-ELAP # 1795

685 Stone Road, Unit 6 · Benicia, CA 94510 · (707) 747-5906 · 1-800-GIARDIA · FAX (707) 747-1751 · WEB: www.biovir.com

REPORT OF SAMPLE EVALUATION

REPORT NO.: 080867-1 and 080867-2

PAGE NO.: 1 of 1

CLIENT ADDRESS: New Logic Research, Inc
1295 67th St
Emeryville, CA 94608

CLIENT NO.: NEW011

SAMPLE INFORMATION:

Name of Contact: Sommer Carter
Name of Sampler: Sommer Carter
Sample Volume: 120 mL Each

Sample Date: 04/22/08
Sample Matrix: Filtered Wastewater

Sample Received Date: 04/22/08
Sample Received time: 16:40
Check-in Temp: 9.3 C

ASSAY RESULTS:

1. Coliform, Total, and *E. Coli* Assay:
(SM 9221B&E) Analysis Begun Date: 04/22/08 Time: 17:05 Analyst Initials: MAP

BIOVIR ID	SAMPLE ID	Sample Time	TOTAL COLIFORM MPN / 100 mL	*E. COLI* MPN / 100 mL
080867-1	San Jacinto Composite Permeate L-mode	15:30	1.6×10^3	1.6×10^3
080867-2	San Jacinto Spiral Permeate S-Mode	15:30	< 20	< 20

"Less than" results represent the lowest detection limit for this assay.

SAMPLE EVALUATION PERFORMANCE CRITERIA: The precise rates of recovery of organisms from environmental samples cannot be determined. BioVir Laboratories has analyzed your sample(s) in accordance with the method described with each analyte above, however, due to inherent limitations of these methods organisms may avoid detection. For additional information regarding the limitations of the method(s) referred to above please call us at 1-800-GIARDIA.
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COPY

04-24-08
COMPLETION DATE

Richard E Daniel
SIGNATURE/DATE
05-07-08 new

F:\WP\REPDIR\NEW011 New Logic Research, Inc\080867-1-2.wpd

COPY

080867 1-2
NEW01

BioVir LABORATORIES ®

SAMPLE DATA SHEET

SHIPPING ADDRESS: BIOVIR LABORATORIES, INC., 685 STONE ROAD, UNIT 6, BENICIA CALIFORNIA 94510
1-800-GIARDIA (442-7342) FAX: 707-747-1751

Business Hours: Monday through Friday - 8:30 AM to 5:00 PM 93

COMPANY OR UTILITY: New Logic Research

TELEPHONE# 510-655-8305 EXT# 234 FAX# 510-655-8307

NAME OF SAMPLER: (Please print and sign - REQUIRED)
Shannon Carter

DATE OF SAMPLING: 4/22/08

PURCHASE ORDER #:

Matrix: Drinking Water (Wastewater) Biosolid OTHER: filtrate/permeate

Regulatory Drinking Water Sample(s) Yes ☐ No ☐

CA DHS Contact Person and Phone Number:

SAMPLE ID#	TIME	VOLUME	TREATMENT	SAMPLING LOCATION	ANALYSIS REQUESTED
San Jacinto Composite Permeate	3:20pm	120ml		L-mode Composite Permeate	E. Coli & Total Coliform MPN
San Jacinto Spiral Permeate	3:30pm	120ml		S-mode Composite Permeate	E. Coli & Total Coliform MPN

RELINQUISHED BY (SIGNED)	DATE/TIME	RECEIVED BY (SIGNED)	DATE/TIME
	4/23/08 1440	William Kenn	4/22/08 c

~~1440~~ 1640 MP 4-23-08

William Kenn

9.3°C

F:\WP\FORMS\Datasheets\DATASHT.General1.19.08wpd.wpd

Forensic Analytical Laboratories

ANALYSIS REPORT
ASBESTOS IN DRINKING WATER
Transmission Electron Microscopy*

Client:	Curtis & Tompkins Ltd	Page:	1 of 1
Contact:	Robert Butler	Client Number:	1137
Street:	2323 Fifth St	Report Number:	T014633
City/state/zip:	Berkeley CA 94710	Date/time Received:	4/30/08 1328

Project Name:	San Jacinto	Date/time filtered:	4/30/08 1450
Project#:	202894	Analyst(s):	RE
Reference#:		Date Analyzed:	5/7/08
Date/time collected:	4/29/08 1515	Date Reported:	5/7/08
Hold time, hrs	<48		
Filter type:	25mm Mixed Cellulose Ester		
Pore size	0.22 μm		

ANALYTICAL RESULTS

Client Sample Number	Stage 2 Permeate	Stage 1 Permeate			
C&T Lab#:	202894-002	202894-003			
Lab Sample Number	20056045	20056046			
Volume Filtered, mL	1	10			
Filter Area, mm^2	190	190			
Grid Opening Area, mm^2	0.0086	0.0086			
Number of GOs Analyzed	10	10			
Area Analyzed, mm^2	0.086	0.086			
# Asbestos Fibers ≥10μm	0	0			
Analytical Sensitivity, MFL	2.2	0.2			
Asbestos Concentration, ≥10μm in length, MFL	**<2.2**	**<0.2**			
Asbestos Type(s) Detected**	**ND**	**ND**			
Water Blank Conc., MFL	n/a	n/a			
95% Upper Conf. Limit	8.2	0.8			
95% Lower Conf. Limit	0	0			

Mark S. Floyd, Analytical Microscopy Supervisor

* Method 100.2 (EPA/600/R-94/134). Results are reported in Millions of Fibers per Liter (MFL) over 10 μm in length.

** Asbestos types: CH=chrysotile; AM=amosite; CR=crocidolite; AC=actinolite; TR=tremolite; AN=anthophyllite; ND=none detected.

3777 Depot Road, Suite 409, Hayward, California 94545 Phone: 510-887-8828 Fax: 510-887-4218 www.forensica.com

Series P (Pilot) Test
Chain of Custody and Analytical Forms Reports

E.S.BABCOCK&Sons,Inc.
Environmental Laboratories est 1906

Client Name: New Logic Research, Inc.
Contact: Roger Torres
Address: 1295 67th Street
Emeryville, CA 94608

Report Date: 08-Aug-2008

Analytical Report: Page 1 of 5
Project Name: New Logic - Dairy Wastewater
Project Number: Dairy Wastewater

Work Order Number: A8G1844
Received on Ice (Y/N): Yes Temp: 4 °C

Attached is the analytical report for the sample(s) received for your project. Below is a list of the individual sample descriptions with the corresponding laboratory number(s). Also, enclosed is a copy of the Chain of Custody document (if received with your sample(s)). Please note any unused portion of the sample(s) may be responsibly discarded after 30 days from the above report date, unless you have requested otherwise.

Thank you for the opportunity to serve your analytical needs. If you have any questions or concerns regarding this report please contact our client service department.

Sample Identification

Lab Sample #	Client Sample ID	Matrix	Date Sampled	By	Date Submitted	By
A8G1844-01	Stage I Permeate - San Jacinto	Liquid	07/21/08 15:48	Frazier Glenn	07/21/08 16:35	Frazier Glenn

The following samples were split from an unpreserved container at the laboratory after submittal and then preserved.
Federal guidelines (40CFR Parts 136 and 141) instruct preservation be performed on a separate container collected at site:

A8G1844-01 A8G1844-01

E.S.BABCOCK&Sons,Inc.
Environmental Laboratories est 1906

Client Name: New Logic Research, Inc.
Contact: Roger Torres
Address: 1295 67th Street
Emeryville, CA 94608

Report Date: 08-Aug-2008

Analytical Report: Page 2 of 5
Project Name: New Logic - Dairy Wastewater
Project Number: Dairy Wastewater

Work Order Number: A8G1844
Received on Ice (Y/N): Yes Temp: 4 °C

Laboratory Reference Number
A8G1844-01

Sample Description	Matrix	Sampled Date/Time	Received Date/Time
Stage 1 Permeate - San Jacinto	Liquid	07/21/08 15:48	07/21/08 16:35

Analyte(s)	Result	RDL	Units	Method	Analysis Date	Analyst	Flag
Cations							
Total Hardness	ND	3.0	mg/L	SM 3120B	07/25/08 16:45	lmt	
Calcium	ND	1.0	mg/L	EPA 200.7	07/25/08 16:45	lmt	
Magnesium	ND	1.0	mg/L	EPA 200.7	07/25/08 16:45	lmt	
Sodium	23	1.0	mg/L	EPA 200.7	07/25/08 16:45	lmt	
Potassium	22	1.0	mg/L	EPA 200.7	07/25/08 16:45	lmt	A-01
Total Cations	1.6	0.05	me/L	Calculation			
Sodium Adsorption Ratio	6.6	0.20	N/A	EPA 200.7	07/25/08 16:45	lmt	
Adjusted Sodium Adsorption Ratio	2.8	0.20	N/A	EPA 200.7	07/25/08 16:45	lmt	
Anions							
Total Alkalinity	110	3.0	mg/L	SM 2320B	07/25/08 16:30	je	
Hydroxide	ND	3.0	mg/L	SM 2320B	07/25/08 16:30	je	
Carbonate	ND	3.0	mg/L	SM 2320B	07/25/08 16:30	je	
Bicarbonate	130	3.0	mg/L	SM 2320B	07/25/08 16:30	je	
Chloride	21	1.0	mg/L	EPA 300.0	07/21/08 23:15	SBD	
Sulfate	4.8	0.50	mg/L	EPA 300.0	07/21/08 23:15	SBD	
Nitrate as N	ND	0.20	mg/L	EPA 300.0	07/21/08 23:15	SBD	
Fluoride	ND	0.1	mg/L	SM 4500F C	07/22/08 14:30	sda	
Total Anions	2.89	0.05	me/L	Calculation			
Aggregate Properties							
pH	5.4	1.0	pH Units	SM 4500H+ B	07/21/08 20:17	jc	
Specific Conductance	380	1.0	umhos/cm	SM 2510 B	07/21/08 20:17	jc	
Solids							
Total Dissolved Solids	210	20	mg/L	SM 2540C	07/28/08 13:56	ctl	
Total Suspended Solids	ND	5	mg/L	SM 2540D	07/22/08 10:55	sda	
Total Solids	230	20	mg/L	SM 2540B	07/24/08 11:45	jma	
Volatile Solids	100	20	mg/L	EPA 160.4	07/24/08 11:45	jma	

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NELAP no. 02101CA
CA ELAP no. 1156
EPA no. CA00102

E.S.BABCOCK&Sons,Inc.
Environmental Laboratories est 1906

Client Name: New Logic Research, Inc.
Contact: Roger Torres
Address: 1295 67th Street
Emeryville, CA 94608

Report Date: 08-Aug-2008

Analytical Report: Page 3 of 5
Project Name: New Logic - Dairy Wastewater
Project Number: Dairy Wastewater

Work Order Number: A8G1844

Received on Ice (Y/N): Yes Temp: 4 °C

Laboratory Reference Number
A8G1844-01

Sample Description	Matrix	Sampled Date/Time	Received Date/Time
Stage 1 Permeate - San Jacinto	Liquid	07/21/08 15:48	07/21/08 16:35

Analyte(s)	Result	RDL	Units	Method	Analysis Date	Analyst	Flag
Aggregate Organic Compounds							
Biochemical Oxygen Demand	170	100	mg/L	SM 5210B	07/21/08 20:51	sbd	
Chemical Oxygen Demand	190	10	mg/L	SM 5220D	07/31/08 13:00	sda	
Total Organic Carbon	70	3.5	mg/L	SM 5310B	08/06/08 20:17	lmt	
General Physical							
Turbidity	7.3	0.20	NTU	SM 2130 B	07/22/08 21:06	sbd	
General Inorganics							
Cyanide	ND	0.005	mg/L	SM 4500CN E	07/25/08 14:03	sll	N_pScr
Sulfide	55	1.0	mg/L	SM 4500S2 D	07/21/08 21:00	jc	
Nutrients							
Ammonia-Nitrogen	4.3	0.10	mg/L	SM4500NH3H	07/22/08 19:03	mds	
Kjeldahl Nitrogen	20	1.0	mg/L	EPA 351.2	07/29/08 15:24	sll	
Organic Nitrogen	16	1	mg/L	Calculation			
Total Phosphorus	0.28 as P2O5	0.05	mg/L	SM 4500P B E	07/30/08 14:40	mds	
Metals and Metalloids							
Aluminum	ND	100	ug/L	EPA 200.7	07/25/08 16:45	lmt	
Antimony	ND	10	ug/L	EPA 200.8	07/24/08 11:31	ap	
Arsenic	ND	5.0	ug/L	EPA 200.8	07/24/08 11:31	ap	
Barium	ND	20	ug/L	EPA 200.8	07/24/08 11:31	ap	
Beryllium	ND	10	ug/L	EPA 200.8	07/24/08 11:31	ap	
Boron	380	100	ug/L	EPA 200.7	07/25/08 16:45	lmt	
Total Chromium	ND	20	ug/L	EPA 200.8	07/24/08 11:31	ap	
Copper	ND	10	ug/L	EPA 200.8	07/24/08 11:31	ap	
Iron	ND	50	ug/L	EPA 200.7	07/25/08 16:46	lmt	
Manganese	ND	10	ug/L	EPA 200.8	07/24/08 11:31	ap	
Mercury	ND	0.50	ug/L	EPA 200.8	07/24/08 11:31	ap	
Nickel	ND	20	ug/L	EPA 200.8	07/24/08 11:31	ap	

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NELAP no. 02101CA
CA ELAP no. 1156
EPA no. CA00102

E.S.BABCOCK&Sons,Inc.
Environmental Laboratories est 1906

Client Name: New Logic Research, Inc.
Contact: Roger Torres
Address: 1295 67th Street
Emeryville, CA 94608

Report Date: 08-Aug-2008

Analytical Report: Page 4 of 5
Project Name: New Logic - Dairy Wastewater
Project Number: Dairy Wastewater

Work Order Number: A8G1844
Received on Ice (Y/N): Yes Temp: 4 °C

Laboratory Reference Number
A8G1844-01

Sample Description	Matrix	Sampled Date/Time	Received Date/Time
Stage 1 Permeate - San Jacinto	Liquid	07/21/08 15:48	07/21/08 16:35

Analyte(s)	Result	RDL	Units	Method	Analysis Date	Analyst	Flag
Metals and Metalloids							
Selenium	ND	5.0	ug/L	EPA 200.8	07/24/08 11:31	ap	NMout
Total Silica	ND	5.0	mg/L	EPA 200.7	07/25/08 16:45	lmt	
Thallium	ND	200	ug/L	EPA 200.8	07/24/08 11:31	ap	
Zinc	ND	10	ug/L	EPA 200.8	07/24/08 11:31	ap	
Halogens							
Fluorine	ND	0.10	mg/L*	EPA 340.2	08/01/08 17:05	hga	

* NELAP does not offer accreditation for this analyte/method/matrix combination

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Client Name: New Logic Research, Inc.
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Address: 1295 67th Street
Emeryville, CA 94608

Report Date: 08-Aug-2008

Analytical Report: Page 5 of 5
Project Name: New Logic - Dairy Wastewater
Project Number: Dairy Wastewater

Work Order Number: A8G1844

Received on Ice (Y/N): Yes Temp: 4 °C

Notes and Definitions

pH:	Regulatory 15 minute holding time exceeded (A8G1844-01)
A-01	Result = 26mg/L as K2O.
N_pScr	Sample screened for interference and preserved upon receipt at the laboratory.
NMout	The matrix spike and/or matrix spike duplicate performed on this sample did not meet laboratory acceptance criteria.
ND:	Analyte NOT DETECTED at or above the Method Detection Limit **(if MDL is reported)**, otherwise at or above the Reportable Detection Limit (RDL)
NR:	Not Reported
RDL:	Reportable Detection Limit
MDL:	Method Detection Limit

* / (Non-NELAP): NELAP does not offer accreditation for this analyte/method/matrix combination

Approval

Enclosed are the analytical results for the submitted sample(s). Babcock Laboratories certify the data presented as part of this report meet the minimum quality standards in the referenced analytical methods. Any exceptions have been noted. Babcock Laboratories and its officers and employees assume no responsibility and make no warranty, express or implied, for uses or interpretations made by any recipients, intended or unintended, of this report.

Lorenzo Rodriguez

☒ Lorenzo Rodriguez, Project Manager
☐ Allison Mackenzie, General Manager
☐ Lawrence J. Chrystal, Laboratory Director

cc:

ESB_Short_.Report

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Chain of Custody & Sample Information Record

Client: NEW LOGIC RESEARCH Contact: ROGER TORRES Fax No.

Phone No. 612-875-0102 email:

Project Name: SAN JACINTO

Project Location: MENIFEE, CA

Turn Around Time: Routine *72 Hour Rush *48 Hour Rush *24 Hour Rush

*Lab TAT Approval: By: *Additional Charges Apply

Additional Reporting Requests
Include QC Data Package: ☐ Yes ☐ No
FAX Results: ☐ Yes ☐ No
Email Results: ☐ Yes ☐ No
State EDT: ☐ Yes ☐ No
(Include Source Number in Notes)

Sampler Information

Name: Frazier Glenn

Employer:

Signature: Frazier Glenn

Sample ID	Date	Time	Unpreserved	H_2SO_4	HCl	HNO_3	$Na_2S_2O_3$	NaOH	NaOH/Zn Acetate	NH_4Cl	MCAA	Total # of Containers	Routine	Resample	Special	Hardness	Metals	Ammonia	COD/Phos./TKN	Chloride/Ashes.	TVS/BOD/Nit./Flow	TDS/TSS/Turb./pH	ECL/Alk./Fol.	TSS	QT Bact 7/21/08	Matrix	Notes
Stage 1 Permeate	7/21	3:48				1										1	1									WW	Bacti poured off unp. quart
Stage 1 Permeate		3:48	1			1											1			1						WW	
Stage 1 Permeate		3:49		1														1								WW	
Stage 1 Permeate		3:50		1															1							WW	
Stage 1 Permeate		3:50	1																			1				WW	
Stage 1 Permeate	↓	3:51	1																		1					WW	

Matrix: DW = Drinking Water, WW = Waste Water, GW = Ground Water, S = Soil, SG = Sludge, L = Liquid, M = Miscellaneous

Notes: see attachment for remaining tests

Relinquished By (sign)	Print Name / Company	Date / Time	Received By (sign)	Print Name / Company
Frazier Glenn		7/21/08 16:35	Angie Brown	Angie Brown/ESBC

(For Lab Use Only) Sample Integrity Upon Receipt

Sample(s) Submitted on Ice? Yes No

Custody Seal(s) Intact? Yes No NA

Sample(s) Intact? Yes No

Temperature 4 °C

☐ Cooler Blank

Lab Notes

Lab No. ABG1844 AB

Page 1 of 1

E.S.BABCOCK&Sons,Inc.
Environmental Laboratories est 1906

Client Name: New Logic Research, Inc.
Contact: Roger Torres
Address: 1295 67th Street
Emeryville, CA 94608

Report Date: 07-Aug-2008

Analytical Report: Page 1 of 5
Project Name: New Logic - Dairy Wastewater
Project Number: Dairy Wastewater

Work Order Number: A8G2194
Received on Ice (Y/N): Yes Temp: 1 °C

Attached is the analytical report for the sample(s) received for your project. Below is a list of the individual sample descriptions with the corresponding laboratory number(s). Also, enclosed is a copy of the Chain of Custody document (if received with your sample(s)). Please note any unused portion of the sample(s) may be responsibly discarded after 30 days from the above report date, unless you have requested otherwise.

Thank you for the opportunity to serve your analytical needs. If you have any questions or concerns regarding this report please contact our client service department.

Sample Identification

Lab Sample #	Client Sample ID	Matrix	Date Sampled	By	Date Submitted	By
A8G2194-01	Stage 2 Permeate - San Jacinto	Liquid	07/24/08 13:20	Frazier Glenn	07/24/08 14:25	Frazier Glenn

The following samples were split from an unpreserved container at the laboratory after submittal and then preserved.
Federal guidelines (40CFR Parts 136 and 141) instruct preservation be performed on a separate container collected at site:

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NELAP no. 02101CA
CA ELAP no. 1156
EPA no. CA00102

E.S.BABCOCK&Sons,Inc.
Environmental Laboratories est 1905

Client Name: New Logic Research, Inc.
Contact: Roger Torres
Address: 1295 67th Street
Emeryville, CA 94608

Report Date: 07-Aug-2008

Analytical Report: Page 2 of 5
Project Name: New Logic - Dairy Wastewater
Project Number: Dairy Wastewater

Work Order Number: A8G2194
Received on Ice (Y/N): Yes Temp: 1 °C

Laboratory Reference Number
A8G2194-01

Sample Description	Matrix	Sampled Date/Time	Received Date/Time
Stage 2 Permeate - San Jacinto	Liquid	07/24/08 13:20	07/24/08 14:25

Analyte(s)	Result	RDL	Units	Method	Analysis Date	Analyst	Flag
Cations							
Total Hardness	ND	3.0	mg/L	SM 3120B	07/31/08 15:35	lmt	
Calcium	ND	1.0	mg/L	EPA 200.7	07/31/08 15:35	lmt	
Magnesium	ND	1.0	mg/L	EPA 200.7	07/31/08 15:35	lmt	
Sodium	8.4	1.0	mg/L	EPA 200.7	07/31/08 15:35	lmt	
Potassium	6.9	1.0	mg/L	EPA 200.7	07/31/08 15:35	lmt	A-01
Total Cations	0.5	0.05	me/L	Calculation			
Sodium Adsorption Ratio	7.8	0.20	N/A	EPA 200.7	07/31/08 15:35	lmt	
Adjusted Sodium Adsorption Ratio	> 4.1	0.20	N/A	EPA 200.7	07/31/08 15:35	lmt	
Anions							
Total Alkalinity	30	3.0	mg/L	SM 2320B	07/31/08 12:29	ctl	
Hydroxide	ND	3.0	mg/L	SM 2320B	07/31/08 12:29	ctl	
Carbonate	ND	3.0	mg/L	SM 2320B	07/31/08 12:29	ctl	
Bicarbonate	37	3.0	mg/L	SM 2320B	07/31/08 12:29	ctl	
Chloride	8.3	1.0	mg/L	EPA 300.0	07/25/08 00:12	SBD	
Sulfate	ND	0.50	mg/L	EPA 300.0	07/25/08 00:12	SBD	
Nitrate as N	ND	0.20	mg/L	EPA 300.0	07/25/08 00:12	SBD	
Fluoride	ND	0.1	mg/L	SM 4500F C	08/06/08 15:20	hga	
Total Anions	0.83	0.05	me/L	Calculation			
Aggregate Properties							
pH	6.3	1.0	pH Units	SM 4500H+ B	07/24/08 21:10	adb	
Specific Conductance	110	1.0	umhos/cm	SM 2510 B	07/24/08 21:10	adb	
Solids							
Total Dissolved Solids	44	10	mg/L	SM 2540C	07/31/08 09:00	jma	
Total Suspended Solids	ND	5	mg/L	SM 2540D	07/30/08 12:39	je	
Total Solids	66	20	mg/L	SM 2540B	07/31/08 09:00	jma	
Volatile Solids	64	20	mg/L	EPA 160.4	07/31/08 09:00	jma	

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Client Name: New Logic Research, Inc.
Contact: Roger Torres
Address: 1295 67th Street
Emeryville, CA 94608

Report Date: 07-Aug-2008

Analytical Report: Page 3 of 5
Project Name: New Logic - Dairy Wastewater
Project Number: Dairy Wastewater

Work Order Number: A8G2194
Received on Ice (Y/N): Yes Temp: 1 °C

Laboratory Reference Number
A8G2194-01

Sample Description	Matrix	Sampled Date/Time	Received Date/Time
Stage 2 Permeate - San Jacinto	Liquid	07/24/08 13:20	07/24/08 14:25

Analyte(s)	Result	RDL	Units	Method	Analysis Date	Analyst	Flag
Aggregate Organic Compounds							
Biochemical Oxygen Demand	44	20	mg/L	SM 5210B	07/24/08 21:35	rmc	
Chemical Oxygen Demand	59	10	mg/L	SM 5220D	07/31/08 13:00	sda	
Total Organic Carbon	18	0.70	mg/L	SM 5310B	07/29/08 02:02	krv	
General Physical							
Turbidity	ND	0.20	NTU	SM 2130 B	07/25/08 16:15	fmm	
General Inorganics							
Cyanide	ND	0.005	mg/L	SM 4500CN E	07/25/08 14:22	sll	N_pScr
Sulfide	ND	0.10	mg/L	SM 4500S2 D	07/24/08 19:35	adb	
Nutrients							
Ammonia-Nitrogen	5.0	1.0	mg/L	SM4500NH3H	07/28/08 12:19	sll	
Kjeldahl Nitrogen	7.5	4.0	mg/L	EPA 351.2	07/28/08 16:18	sll	
Organic Nitrogen	ND	4.0	mg/L	Calculation			
Total Phosphorus	<0.11 as P2O5	0.05	mg/L	SM 4500P B E	07/30/08 14:40	mds	
Metals and Metalloids							
Aluminum	ND	100	ug/L	EPA 200.7	07/31/08 15:35	lmt	
Antimony	ND	10	ug/L	EPA 200.8	07/29/08 18:32	ap	
Arsenic	ND	5.0	ug/L	EPA 200.8	07/29/08 18:32	ap	
Barium	ND	20	ug/L	EPA 200.8	07/29/08 18:32	ap	
Beryllium	ND	10	ug/L	EPA 200.8	07/29/08 18:32	ap	
Boron	460	100	ug/L	EPA 200.7	07/31/08 15:35	lmt	
Total Chromium	ND	20	ug/L	EPA 200.8	07/29/08 18:32	ap	
Copper	ND	10	ug/L	EPA 200.8	07/29/08 18:32	ap	
Iron	ND	50	ug/L	EPA 200.7	07/31/08 15:35	lmt	
Manganese	ND	10	ug/L	EPA 200.8	07/29/08 18:32	ap	
Mercury	ND	0.50	ug/L	EPA 200.8	07/29/08 18:32	ap	
Nickel	ND	20	ug/L	EPA 200.8	07/29/08 18:32	ap	

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Environmental Laboratories est 1906

Client Name: New Logic Research, Inc.
Contact: Roger Torres
Address: 1295 67th Street
Emeryville, CA 94608

Report Date: 07-Aug-2008

Analytical Report: Page 4 of 5
Project Name: New Logic - Dairy Wastewater
Project Number: Dairy Wastewater

Work Order Number: A8G2194

Received on Ice (Y/N): Yes Temp: 1 °C

Laboratory Reference Number
A8G2194-01

Sample Description	Matrix	Sampled Date/Time	Received Date/Time
Stage 2 Permeate - San Jacinto	Liquid	07/24/08 13:20	07/24/08 14:25

Analyte(s)	Result	RDL	Units	Method	Analysis Date	Analyst	Flag
Metals and Metalloids							
Selenium	ND	5.0	ug/L	EPA 200.8	07/29/08 18:32	ap	
Total Silica	ND	5.0	mg/L	EPA 200.7	07/31/08 15:35	lmt	
Thallium	ND	200	ug/L	EPA 200.8	07/29/08 18:32	ap	
Zinc	ND	10	ug/L	EPA 200.8	07/29/08 18:32	ap	
Halogens							
Fluorine	0.16	0.10	mg/L*	EPA 340.2	08/01/08 17:05	hga	

* NELAP does not offer accreditation for this analyte/method/matrix combination

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Report Date: 07-Aug-2008

Analytical Report: Page 5 of 5
Project Name: New Logic - Dairy Wastewater
Project Number: Dairy Wastewater

Work Order Number: A8G2194
Received on Ice (Y/N): Yes Temp: 1 °C

Notes and Definitions

pH:	Regulatory 15 minute holding time exceeded (A8G2194-01)
A-01	Result = 8.3mg/L when expressed as K2O.
N_pScr	Sample screened for interference and preserved upon receipt to the laboratory.
ND:	Analyte NOT DETECTED at or above the Method Detection Limit **(if MDL is reported)**, otherwise at or above the Reportable Detection Limit (RDL)
NR:	Not Reported
RDL:	Reportable Detection Limit
MDL:	Method Detection Limit

* / (Non-NELAP): NELAP does not offer accreditation for this analyte/method/matrix combination

Approval

Enclosed are the analytical results for the submitted sample(s). Babcock Laboratories certify the data presented as part of this report meet the minimum quality standards in the referenced analytical methods. Any exceptions have been noted. Babcock Laboratories and its officers and employees assume no responsibility and make no warranty, express or implied, for uses or interpretations made by any recipients, intended or unintended, of this report.

Lorenzo Rodriguez

☒ Lorenzo Rodriguez, Project Manager
☐ Allison Mackenzie, General Manager
☐ Lawrence J. Chrystal, Laboratory Director

cc:

ESB_Short_Report

mailing: P.O. Box 432, Riverside, CA 92502-0432
location: 6100 Quail Valley Court, Riverside, CA 92507-0704
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Chain of Custody & Sample Information Record

Client: NEW LOGIC RESEARCH
Contact: ROGER TORRES
Fax No.
Phone No. 612-875-0102
email:
Project Name: SAN JACINTO
Project Location: MENIFEE, CA
Turn Around Time: Routine *72 Hour Rush *48 Hour Rush *24 Hour Rush
*Lab TAT Approval: By: *Additional Charges Apply

Additional Reporting Requests
Include QC Data Package: ☐ Yes ☐ No
FAX Results: ☐ Yes ☐ No
Email Results: ☐ Yes ☐ No
State EDT: ☐ Yes ☐ No
(Include Source Number in Notes)

Sampler Information
Name: Frazier Glenn
Employer: NEW LOGIC RESEARCH
Signature: Frazier Glenn

Sample ID	Date	Time	Unpreserved	H_2SO_4	HCl	HNO_3	$Na_2S_2O_3$	NaOH	NaOH/Zn Acetate	NH_4Cl	MCAA	Total # of Containers	Routine	Resample	Special	SEE ATTACHED SHEET	Matrix	Notes
Stage 2 Permeate	7/24	1:20pm	2	3		1	1	1				9				X	WW	
" " "																	WW	
" " "																	WW	
" " "																	WW	
" " "																	WW	12 07/24/08

Matrix: DW = Drinking Water; WW = Waste Water; GW = Ground Water; S = Soil; SG = Sludge; L = Liquid; M = Miscellaneous

Relinquished By (sign)	Print Name / Company	Date / Time	Received By (sign)	Print Name / Company
Frazier Glenn	Frazier Glenn / NEW LOGIC	07/24/08 1425	Lorenzo Rodriguez	LORENZO RODRIGUEZ / ESB

(For Lab Use Only) Sample Integrity Upon Receipt

Sample(s) Submitted on Ice? Yes No
Custody Seal(s) Intact? Yes No NA
Sample(s) Intact? Yes No
Temperature 1 °C
☐ Cooler Blank

Lab Notes

Lab No. A8G2194
Page 1 of 1
Rev. 6/07

Appendix E – A Forage Crop Irrigation Demonstration Project

A Forage Crop Irrigation Demonstration Project

Final Report

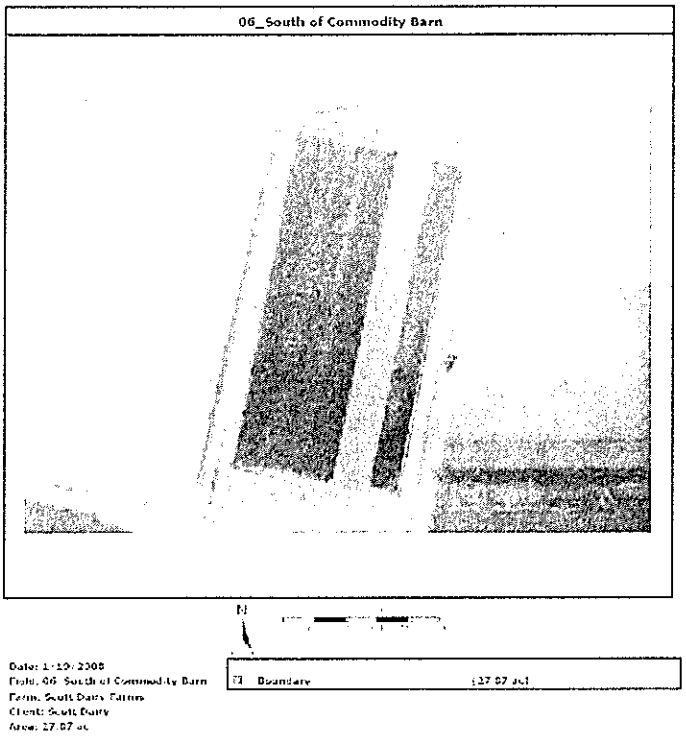
Report period:
June 1, 2006 - June 30, 2008

Project end date:
June 30, 2008

Agreement no.: 06SF350186

Introduction

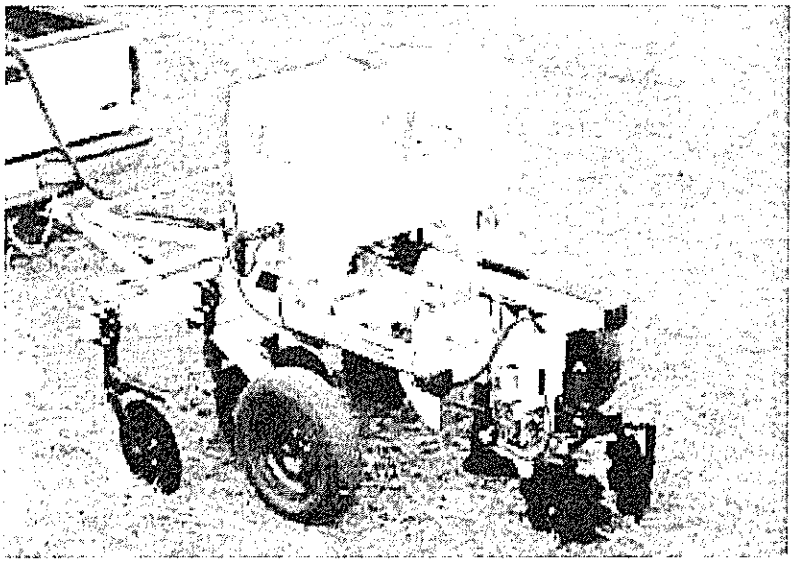
The Forage Crop Irrigation Demonstration Project took place on property located in San Jacinto, California bordered by Gilman Springs Road and Highway 79. The primary field used in this study was the 27-acre field known as '06 South of the Commodity Barn'. The purpose of this project was to demonstrate how the use of modern technology—such as a Veris machine and Ech2o soil moisture monitoring irrigation systems—could improve the efficiency of the crop production. During the course of this project, water application was monitored. By using Ech2o technology to manage it and apply it when necessary. A Veris machine was also used to determine the soil types present in the field. Using various computer programs like SST Summit, the soil types were then analyzed in order to gain a better understanding of how soil types, water application, and nutrient management all affect the yield of a crop. At the end of the project, computations were performed to determine the application efficiency of the irrigation, and crop yield data was gathered to examine improvements in crop quantity and quality.



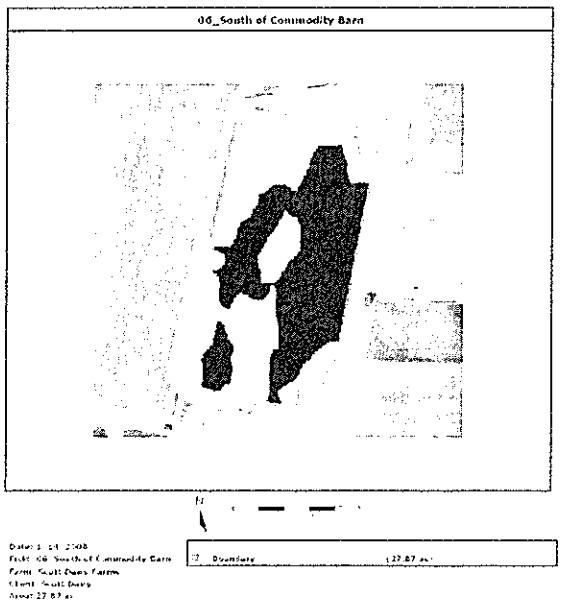
SST

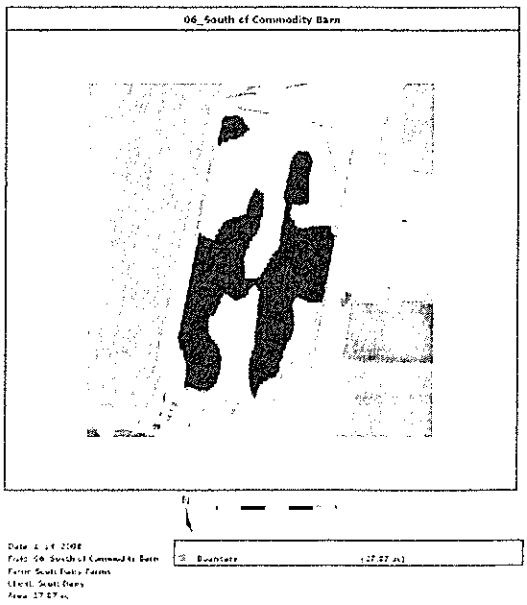
A. Soil Maps/Field Electrical Conductivity Maps

A Veris machine was used to analyze the types of soil within the project field. Using the concept of electrical conductivity, the soil is evaluated at a depth of one foot and three feet, GPS points and electrical conductivity values are recorded simultaneously on a digital media. This data is then transferred and analyzed in the office to be used to create a map showing the differences in the soil properties at the tested depths.



http://www.veristech.com/





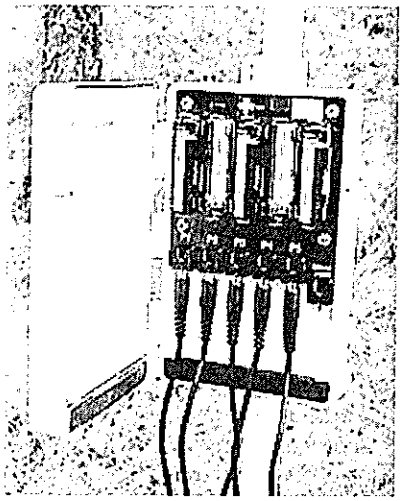
SST

SST

The results of the Veris testing (shown in the figures above) show a field made of heavier soils (dark reds), medium soils (salmon), and lighter soils (light pink). With this knowledge of the soil types present, these areas can be further tested by irrigation monitoring technology, aerial photography, and soil sampling to gain a better understanding of managing the irrigation and nutrient needs of the soil to optimize crop yield.

B. Irrigation System Evaluation Reports

The Ech2o irrigation monitoring system records and stores information which is then collected every two weeks for analyzing. The logged data is downloaded from the receiver and then the resulting reports are reviewed with the grower for adjustments in irrigation timing. During the duration of the project, two instances of time were not recorded due to damage to the equipment located in the field. Repairs were made as quickly as possible to facilitate the continued collection of data.



http://www.decagon.com/ag_research/soil/em50.php

C. Seasonal Water Use Reports

From June 2007 to June 2008, water application and soil moisture was monitored on the field using the Ech2o electronic instrumentation, measuring at three depths-6, 12, and 24 inches. The moisture level in the soil was continuously recorded, logging data on a pre-programmed frequent interval. The objective of the project was to develop a scheduled irrigation application to accommodate efficient irrigation practices at a low soil moisture level of 10% and to continue irrigating the crop until reaching a soil moisture level not to exceed 30%. The resulting soil moisture irrigation schedule also takes into consideration temperature, evapotransporation and other weather related influences.

In the following charts, average, minimum, and maximum moisture content are shown for probes at three different depths. The soil moisture for December 2007 to June 2008 was monitored, but no data was recorded for those months because there were no irrigations being done during that time.

The resulting test tables show that the moisture totals for the three probes (P1, P2 & P3) remained fairly consistent within a range of +/- 5 inches throughout the six month testing period.

	P1 Minimum (6" depth)	**P2 Minimum (12" depth)**	**P3 Minimum (24" depth)**
June	27.4"	21.5"	12.5"
July	20.5"	18.0"	10.7"
August	21.4"	16.9"	8.4"
September	18.1"	13.8"	9.2"
October	18.6"	14.4"	9.6"
November	17.0"	13.0"	8.5"

	P1 Maximum (6" depth)	**P2 Maximum (12" depth)**	**P3 Maximum (24" depth)**
June	40.5"	37.7"	29.1"
July	39.9"	35.7"	37.5"
August	39.5"	35.2"	40.1"
September	40.6"	36.9"	39.7"
October	30.1"	23.0"	16.4"
November	18.8"	14.4"	9.6"

	P1 Average (6"depth)	**P2 Average (12" depth)**	**P3 Average (24" depth)**
June	32.1"	23.9"	15.6"
July	31.6"	24.1"	17.7"
August	28.1"	22.5"	16.3"
September	26.6"	19.9"	14.7"
October	22.9"	18.7"	12.5"
November	17.9"	13.7"	9.0"

D. Seasonal Soil Moisture Graphs by Field, Moisture Level

The data from the three different probes was translated into graphs showing the moisture level in the field as well as the dates and times at which the field was watered. The soil moisture graphs for the months of June through December of 2007 are attached (see Appendix A).

E. Irrigation Efficiency and Application Uniformity Computations

The evaluation of the Ech2o technology has proved to be an effective tool for managing and improving appropriate application rates and scheduling of crop irrigation, thus achieving optimum water efficiency for the farmer. The soil moisture graphs showed that the water traveled an average of 34 inches out of the possible 48 inch root depth (average root depth of alfalfa), meaning that the average irrigation efficiency from June 2007-December 2007 was 70%.

F. Nitrate Test Summaries

Nitrogen content is an important component in both the growth of alfalfa and in water quality. Nitrates were tested in order to determine how frequently nitrate fertilizers should be applied to the soils; to both substantiate the plant, by providing enough nitrates and protecting the water quality by not applying more than is necessary. There are two quick, field friendly ways to test for the nitrate content in alfalfa: a Cardy meter, and the use of quick test strips to test for the positive content of nitrate. The Cardy meter was this projects tool of choice, due to its ease of use, to test for nitrate in this project as well as the desire of the project group to evaluate its accuracy. Sending samples out to the lab is not only expensive, but it's also time consuming creating a delay in the results. The Cardy meter allowed for immediate results giving a much quicker reporting period.

As stated above, one method to test for nitrate content in alfalfa is the use of a Cardy meter. Samples of alfalfa are gathered from the field in the different soil type zones (see Appendix B). The sampled alfalfa is then cut into small pieces and the sap is extracted. Once the sap is extracted, that sampling is placed onto the Cardy meter sensor and the nitrate is then measured and reported in parts per million.

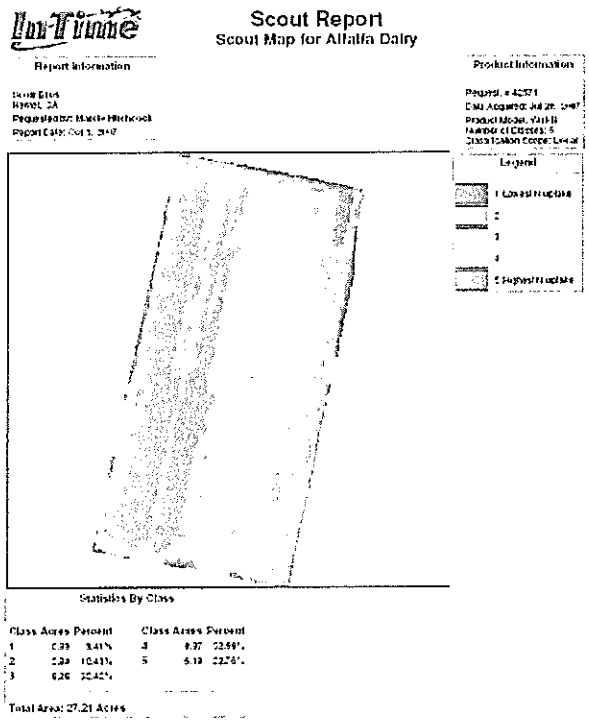
	Light Soil	**Medium Soil**	**Heavy Soil**
Reading 1	2 x 1 ppm	10 x 1 ppm	6 x 1 ppm
Reading 2	2 x 1 ppm	10 x 1 ppm	5 x 1 ppm
Reading 3	3 x 1 ppm	12 x 1 ppm	7 x 1 ppm
Reading 4	2 x 1 ppm	12 x 1 ppm	7 x 1 ppm
Reading 5	2 x 1 ppm	14 x 1 ppm	7 x 1 ppm
Average Reading	2.2 x 1 ppm	12. 2 x 1 ppm	6.4 x 1 ppm

According to historical data, light soils should have a nitrate level reading around 6 x1 ppm, medium soils around 12 x 1 ppm, and heavy soils around 20 x 1 ppm. The readings revealed that the medium soils were in the proper range, however the heavy and light soils had very low indicated levels. These low levels could be

due to the fact that the alfalfa shoots tested were somewhat dry and a sufficient amount of sap was not obtained for an accurate reading. However when further tests were done on other samples, the readings were also very low. It was determined that even though the Cardy meter was a less time consuming method, it was not as accurate as the project group had hoped for.

G. Infrared Field Maps

In order to further understand the vigor and stressed areas of the crop and the affects of the nutrients and water provided to it, aerial infrared photos are obtained of the field.



As shown in the picture above, the areas in red have the lowest nitrogen uptake while the areas in green have the highest nitrogen uptake. The green areas have received irrigation, while the red areas have yet to receive irrigation. When this information is compared with the soil maps, it shows that the areas that are green are those in the light soil region. The heavy and medium soil regions are mostly red and orange.

Conclusion

In the past forage producers enjoyed an abundant and affordable water supply. Due to this historical abundance, many forage crop producers have not been the most efficient users of water. Until recently water conservation was not a high priority in the cost of production and their sustainability. Now, with water supply and costs conservation has taken on a more important role in their production management. We felt and proposed this project as a timely and relevant study with a high potential for achieving water conservation by using and demonstrating modern monitoring technologies. Since little accurate data on water use or application from the producers was available at the start of this project it was not possible to quantify the water savings within the projects time-line. Because of declining water supplies and increasing costs, we feel confident that the forage producers will embrace, and continue to use, the demonstrated tools and technologies to better utilize water resources while maximizing their yields.

The goal of this project was to implement irrigation instrumentation and monitoring technologies on field crops while evaluating their benefits, and to determine whether maximum water efficiency was achieved while maintaining an industry standard for yield and the quality of the crop.

The first objective was to monitor the traditional irrigation practices and implement new irrigation technology. Over the course of this project, the Ech2o irrigation technology was implemented into the field, and the irrigation practices were monitored continuously. Soil maps and aerial maps were also obtained to determine the amount of water and nutrients that should be applied to the various soil types. The soil moisture was closely monitored and the data was recorded in the graphs included in Appendix A. This data was then used to determine if the irrigation technology was efficient. The average irrigation efficiency of 70% was within the expected irrigation efficiency range.

The second objective asked whether the technology used improved crop yield and quality. The technology used for this project was very beneficial in improving crop yield and quality. By using a Veris machine to analyze soil types and create a soil map, growth of the crop can be better understood. By knowing what type of soil is beneath the crop, the amount of supplements (including soil amendments, mineral treatments, chemicals as well as fertilizer and water) applied to the crop can be adjusted according to the characteristics of the soil type. Understanding that lighter soils hold less water, while heavier soils hold more water, the types of soil also need differing amounts of supplements in order to be most productive. Therefore, if the types of soil are understood, the application of nutrients and water can be more efficient. With this knowledge, a correct amount of irrigation was applied to the crops. For this one season, the yield of alfalfa for the '06 South of the Commodity Barn' field was 634 tons.

During the process of testing different technologies and equipment, we have recognized some issues that need to be addressed. The nitrate testing by a Cardy meter proved to be a tedious process that did not deliver consistent accurate results. In future work on similar projects, if nitrate is to be tested, it should be accomplished by a different method.

Several of the local forage producers involved in this process have expressed an interest in continuing to use the methodologies in their daily management practices. The SJBRCD along with several of the vendors have expressed an interest in correcting the shortfalls discovered during this evaluation and to continue with development of several of the technologies utilized. For these reasons, we feel that this was a highly successful and very relevant project.

Acknowledgements

San Jacinto Basin Resource Conservation District would like to acknowledge and thank the following participants who provided funding, match funding or in-kind services for this project.

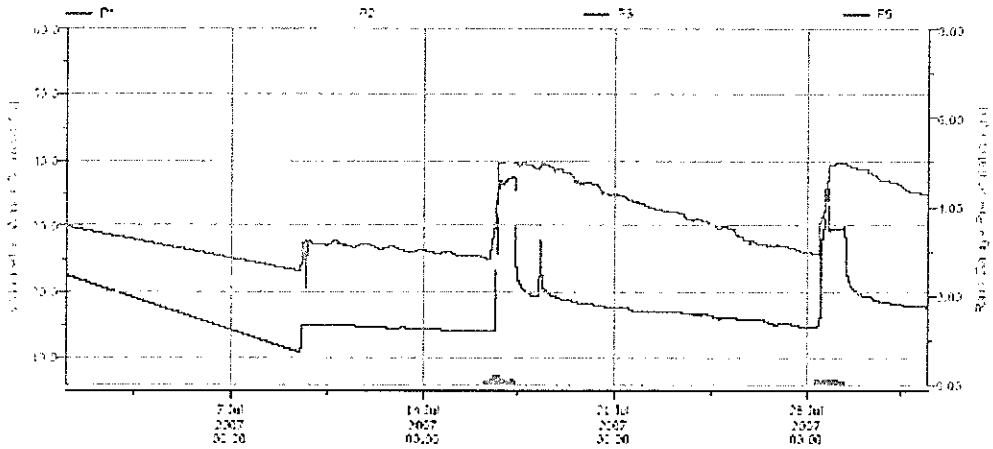
Bureau of Reclamation
Santa Ana Watershed Association
Helena
InTime
Ech2o
SST
Participating local forage producers

Appendix A (Soil Moisture Graphs)

AlfDr07

Farm: My Farm **Field:** None

Start: 07/01/2007 1:34:51 **Stop:** 08/01/2007 10:24:26



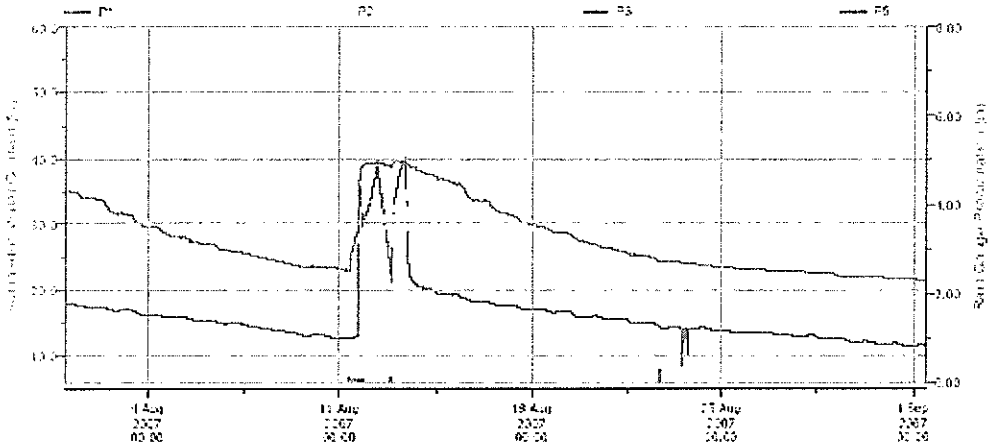
	P1	P2	P3	P5
	%	%	%	in
Avg:	31.63	24.08	17.65	------
Min:	20.5	18	10.7	------
Max:	39.9	35.7	37.5	------
Total:	------	------	------	8.51
Events:	------	------	------	100

Created 10/26/2007 12:28:22 by DC I-O DataTrac version 2.70

AlfDr07

Farm: My Farm **Field:** None

Start: 08/01/2007 1:34:51 **Stop:** 09/01/2007 10:24:26



	P1	P2	P3	P5
	%	%	%	in
Avg:	28.13	22.47	16.33	------
Min:	21.4	16.9	8.4	------
Max:	39.5	35.2	40.1	------
Total:	------	------	------	3.02
Events:	------	------	------	51

AlfDr07

Farm: My Farm **Field:** None

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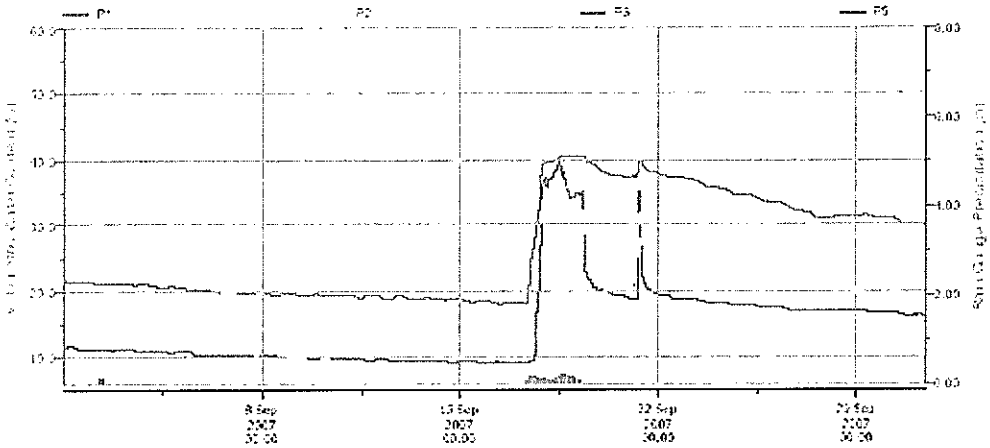

	P1	P2	P3	P5
	%	%	%	in
Avg:	26.63	19.91	14.66	------
Min:	18.1	13.8	9.2	------
Max:	40.6	36.9	39.7	------
Total:	------	------	------	8.37
Events:	------	------	------	105

AlfDr07

Farm: My Farm **Field:** None

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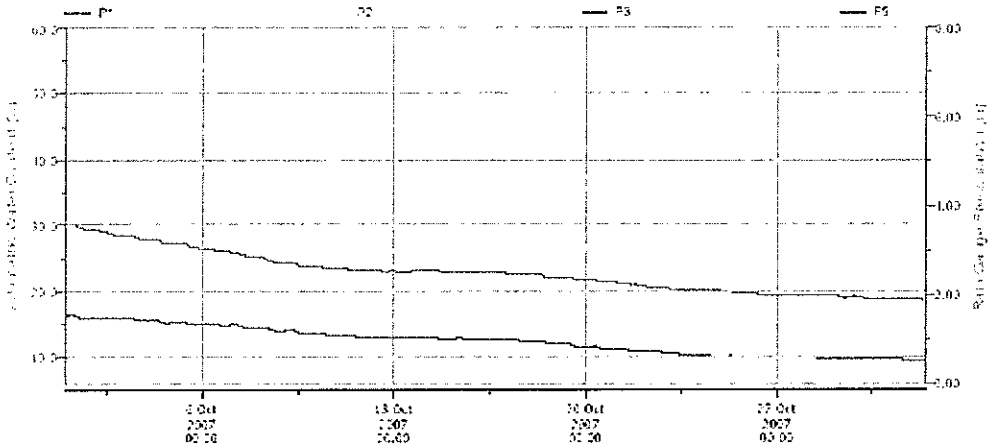
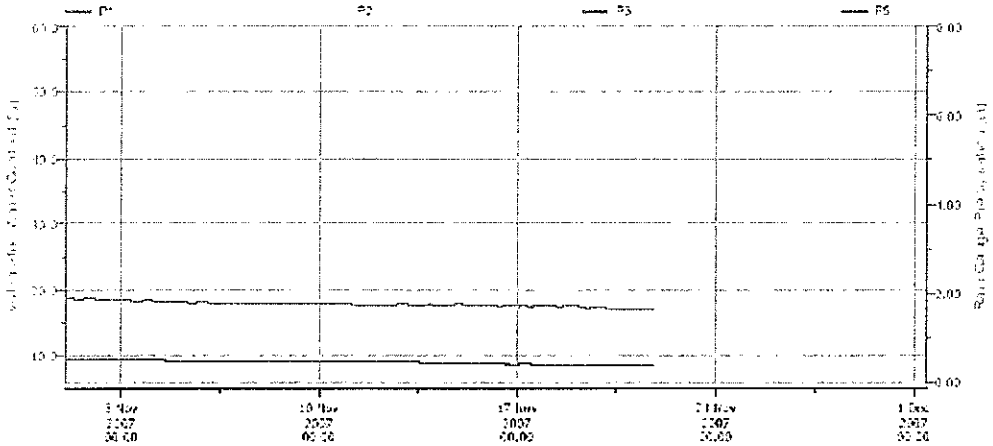


	P1	P2	P3	P5
	%	%	%	in
Avg:	22.91	18.66	12.47	------
Min:	18.6	14.4	9.6	------
Max:	30.1	23	16.4	------
Total:	------	------	------	0.04
Events:	------	------	------	1

AlfDr07

Farm: My Farm **Field:** None

Start: 11/01/2007 1:34:51 **Stop:** 12/01/2007 10:24:26



	P1	P2	P3	P5
	%	%	%	in
Avg:	17.85	13.7	9.02	------
Min:	17	13	8.5	------
Max:	18.8	14.4	9.6	------
Total:	------	------	------	0
Events:	------	------	------	0

Appendix B (Tissue Sample Points)

Appendix F – Salt Offset Options for the San Jacinto River Basin Dairies

Errata Sheet

for the document titled:

Salt Offset Options for the San Jacinto River Basin Dairies, October 30, 2008

(Appendix F of the San Jacinto Watershed Integrated Regional Dairy Management Plan)

Page	Erratum
1	Add: *Funding for this project has been provided in full or in part through an agreement with the California State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. (Gov. code 7550, 40 CFR 31.20).*
21	The response provided for Comment No. 15 is incorrect. The response indicates that areas that do not overlie a groundwater management zone but are tributary to a groundwater management zone lacking assimilative capacity for TDS or nitrate may not be used for land application of dairy waste, even at agronomic rates. This statement is false. The prohibition of land application over a groundwater management zone lacking assimilative capacity for TDS or nitrate applies only to croplands that overlie such groundwater management zones.

WILDERMUTH™
ENVIRONMENTAL INC.

October 30, 2008

Ms. Jennifer Ferrando
Tetra Tech
350 Indiana Street
Golden, CO 80401

SUBJECT: Salt Offset Options for the San Jacinto River Basin Dairies

Dear Ms. Ferrando:

Tetra Tech, Inc. retained the services of Wildermuth Environmental, Inc. (WEI) to prepare a set of salt offset options for the dairies located in the San Jacinto River Basin, represented by the Western Riverside County Ag Coalition (WRCAC). The region's dairies need to explore salt offset options in order to comply with the waste discharge requirements set forth in Regional Board Order R8-2007-0001. This report summarizes the methods used to estimate the salt loads produced by San Jacinto dairies and outlines potential options for mitigating the impact of salt loads to the underlying groundwater management zones.

BACKGROUND

In September 2007, the Santa Ana Regional Water Quality Control Board (Regional Board) issued order number R8-2007-0001: *General Waste Discharge Requirements for Concentrated Animal Feeding Operations (Dairies and Related Facilities) within the Santa Ana Region*. Two of the discharge prohibitions of interest to dairies operating in the San Jacinto River Basin read as follows:

> Disposal of manure to land is prohibited. The application of manure, process wastewater, and/or storm water runoff from manured areas, on cropland outside of the Chino Basin that overlie groundwater management zones lacking assimilative capacity for TDS and/or nitrate-nitrogen is also prohibited unless a plan, acceptable to the Executive Officer, is implemented that offsets the effects of that application on the underlying groundwater management zone. (Section IV. B.)

> The discharge of waste containing TDS and/or Nitrogen concentrations in excess of the underlying groundwater management zone objectives for those constituents is prohibited, unless adequately offset to the satisfaction of the Executive Officer. (Section V. B.)

The discharge prohibitions and limitations outlined in R8-2007-0001 are, in effect, the same as those outlined in the preceding dairy permit (Adopted Order 99-11). However, in the time between the adoption of these two discharge permits, an important change was made to the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) that affects the San Jacinto region dairies.

Under the 1995 Basin Plan, all of the San Jacinto groundwater subbasins, with the exception of the Canyon Subbasin, possessed assimilative capacity for planned salt waste loads, including those produced by dairy operations. Because no dairies in the San Jacinto region were located in the Canyon Subbasin, the discharge of dairy wastewater and the application of corral manure to cultivated croplands were not prohibited by Order 99-11. In January 2004, the Regional Board amended the Basin Plan to incorporate an updated total dissolved solids (TDS) and nitrogen management plan (Adopted Order R8-2004-0001). This amendment included revised groundwater subbasin boundaries (now called "management zones") and revised TDS and nitrate-nitrogen quality objectives for groundwater. Figure 1 shows the groundwater management zones in the San Jacinto region and the updated TDS and nitrate-nitrogen water quality objectives set forth in the Basin Plan Amendment. For a management zone to have assimilative capacity, the ambient TDS and/or nitrate-nitrogen concentrations must be below the water quality objectives. The Regional Board mandates the recalculation of ambient groundwater quality on a triennial basis to allow for continual assessment of a region's compliance with the State of California's antidegradation policies.

In total, there are 28 dairies operating in the San Jacinto region, overlying four of the region's eight management zones: San Jacinto Lower Pressure (SJLP), San Jacinto Upper Pressure (SJUP), Lakeview/Hemet North, and Menifee. Figure 2 shows the locations of all San Jacinto dairies in relation to these management zones.

The TDS and nitrate-nitrogen concentrations in all San Jacinto Groundwater Management Zones, with the exception of Canyon Management Zone, are in excess of the updated water quality objectives set forth in the Basin Plan Amendment. Tables 1 and 2 summarize the most recent assessment (2006) of ambient groundwater quality for each basin in comparison to the water quality objectives. Because there is no assimilative capacity for TDS or nitrate-nitrogen in any of the management zones underlying the San Jacinto dairies, all dairy operations in the San Jacinto region are now subject to the discharge prohibitions outlined in the 2007 dairy permit.

Under Order R8-2007-0001, any dairy overlying a groundwater basin that lacks assimilative capacity for TDS or nitrate-nitrogen and plans to continue to apply manure and other dairy process wastes to croplands, pastures, and ponds must design a work plan to offset its salt load by September 2012.

OBJECTIVES

The objective of this analysis is to present the San Jacinto dairies with a set of potential offset options to mitigate their impacts to the underlying groundwater basins. This requires an initial understanding of the TDS and nitrogen loading caused by dairy operations. In scoping out this analysis, the decision was made to estimate TDS loading alone. Nitrate loading was not estimated because the nitrogen cycle is far too complex and a thoughtful evaluation of nitrogen in the context of this analysis is beyond the budget of this investigation. However, the salt offset options discussed later in this report, can address both TDS and nitrate loading.

Please note that "TDS" and "salt" are often used interchangeably. In the Dairy Permit, the Regional Board refers to TDS and nitrate collectively as salts. Accordingly, a salt offset program (which may be made up of multiple offset strategies) needs to address both nitrate and TDS.

The question has been raised as to which TDS constituent is of primary concern to the Regional Board. TDS is defined as the sum of all inorganic and organic constituents in water that are present in suspension. In general, the primary contributors to TDS from agricultural related activities (*e.g.* runoff and soil leachate) are calcium, chloride, sodium, sulfate, nitrates, and phosphates. Compliance with the TDS objectives is evaluated by the TDS concentration of discharge waters as measured by an analytical laboratory and not by the concentrations of the individual constituents. In other words, the Regional Board is not necessarily more concerned about chloride than sodium: they are only concerned whether the sum of all dissolved salts results in a TDS concentration in excess of a management zone objective. The only exception to this is nitrate, for which the Regional Board has established a separate objective for evaluating compliance. Therefore, the offset options presented in this analysis are only aimed at mitigating TDS and nitrate contributions to groundwater.

In addition, please note that the term "offset", as used in this analysis, refers to strategies for implementing operational changes that physically reduce the salt loads being discharged by the dairies as well as strategies to implement groundwater quality improvement programs that will remove or mitigate, ton for ton, the salt loads added to underlying groundwater basins through dairy operations.

DATA COLLECTION

Before salt offset options could be recommended for the San Jacinto dairies, it was necessary for WEI staff to understand the TDS load added to the groundwater system through daily dairy operations. Even when operating according to their existing permits, dairies can impact the underlying groundwater basin in two ways: through the application of corral manure to cultivated cropland and through the disposal and/or application of process wastewater to land (e.g. percolation ponds, pastures, or cropland). To estimate the TDS load produced by these activities, the following data were needed for each dairy:

- Total number and type of cows
- Total manure production by cow type
- Daily operations water use
- Operations source water supply and quality

All available dairy operations data on file with the Regional Board were collected and reviewed. Data specific to each dairy in the San Jacinto region were acquired from the Engineered Waste Management Plans (EWMPs) and the 2007 Annual Reports of Animal Waste Discharge (Annual Reports). Additional dairy data were acquired from the 2004 Dairy Survey produced by the WRCAC.

Information on dairy source water supply was obtained with the help of the Eastern Municipal Water District (EMWD). The majority of the dairies in the San Jacinto River Basin, with the exception of those located in the Menifee Management Zone, obtain their milk parlor operations water supply from local groundwater, produced from their own private wells. The EMWD serves water to the dairies located in the Menifee Management Zone because the TDS content of

groundwater in this region is too high for use as the sole water source for dairy operations. In addition, the EMWD provided water quality results for dairies that participate in its annual water quality monitoring program. Groundwater quality data were available for the wells of 18 of the 28 regional dairies.

ASSUMPTIONS

EWMPs, Annual Reports, water supply, and water quality data were not available for all 28 dairies in the region. Additionally, the review of each dairy's EWMP and 2007 Annual Report revealed that a variety of methods were used to estimate total manure production, how much of the manure ends up as solid or liquid waste, and daily wash water volumes. Uncertainty also exists as to how the Regional Board will calculate the amount of salt that needs to be offset by any given dairy. In the interest of producing a set of consistent TDS loading estimates and subsequent offset options, the following assumptions were applied in this analysis.

TDS Estimation Assumptions:

- TDS loading is directly linked to the number of cows on a dairy. All loading estimations were made based on the number and type of cows reported in each dairy's 2007 Annual Report. If the 2007 Annual Report was not available, the number of and type of cows listed in the EWMP was used.

- To calculate a dairy's total manure production, the manure production factors recommended by the Regional Board in their Annual Report template were applied (see Attachment B, of R8-2007-0001). These production factors are presented in Table 3.

- Attachment D of R8-2007-0001 estimates that 90% of the manure produced by a milk cow is excreted in the corral and that the remaining 10% is excreted in the milk barn and, thus, ends up in the process wastewater stream. It is assumed that the increase in final wastewater volume caused by the addition of the manure to process wash water is negligible.

- Because non-dairy cows do not spend time in the milk barn, it is assumed that 100% of the manure produced by all other cow types is excreted in the corral.

- One ton of manure contains 8.1% salt by mass (WRCAC, 2004) [1].

- Salts typically remain in solution in dairy process wastewater even after solids separation because they are dissolved or are associated with the finest particle sizes in suspension (University of California, 2005). It is therefore assumed, for the purpose of this analysis, that 100% of the manure's TDS content is dissolved into solution in the process wastewater stream.

- Where groundwater quality data were available, the source water TDS concentration was assumed to be the average of the concentration measured by the EMWD between 2002 and

[1] The TDS loading estimations yield the same results by applying a manure salt content of 160 pounds of salt per ton of manure (R8-2007-0001).

2006. Where data were not available for a dairy, the source water TDS concentration was assumed to be equivalent to that of neighboring dairies. Where data for a neighboring dairy were not available, the source water concentration was assumed to be equal to the 2006 ambient water quality of the underlying management zone.

Dairy Operations Assumptions:

- When provided in the EWMP, daily wash water use data (expressed as gallons per cow per day) were used to calculate the daily volume of wastewater produced. If an EWMP was not available, a value of 100 gallons of water per cow per day was assumed as recommended in the Regional Board's guidelines for producing an EWMP.

Regulatory Assumptions:

- To comply with the discharge prohibition under R8-2007-0001 that states "the application of manure […] on cropland outside of the Chino Basin that overlie groundwater management zones lacking assimilative capacity for TDS and/or nitrate-nitrogen is also prohibited," the dairies will need to mitigate the entire mass of TDS contained in corral manure.

- To comply the discharge prohibition under R8-2007-0001 that states "the discharge of waste containing TDS and/or Nitrogen concentrations in excess of the underlying groundwater management zone objectives for those constituents is prohibited," the dairies will need to mitigate the entire mass of TDS that contributes to wastewater TDS concentration in excess of the groundwater objectives for the underlying management zones—even if their source water concentrations are already in excess of the groundwater objectives.

DAIRY OPERATIONS SUMMARY AND TDS LOAD ESTIMATION

Sufficient data were available such that TDS load estimates could be made for 24 of 28 dairies in the San Jacinto Region. Estimates could not be made for the dairies in the Menifee Management Zone in particular because the proportion of groundwater and municipal water that contributes to the total source water volume used in this management zone for dairy operations is unknown. As such, the TDS load summary for the region will only represent the activities of the north San Jacinto dairies located in the SJLP, the SJUP, and the Lakeview/Hemet North Management Zones.

A summary of the total number of cows, the estimated manure production, and subsequent TDS loads produced by each of the San Jacinto dairies in the SJLP, the SJUP, and the Lakeview/Hemet North Management Zones is presented in Table 4. According to the 2007 Annual Reports, these dairies are home to a total of 54,946 cows, 29,383 of which are milking cows. This corresponds to an annual corral manure production of more than 152,000 tons. An additional 12,000 tons of manure ends up in the 577 million gallons of process wastewater produced each year. Based on the assumptions of this analysis, the northern San Jacinto dairies produce more than 13,000 tons of TDS annually.

Approximately 12,000 tons of TDS are potentially added to local groundwater systems through the application of corral manure to cropland. Assuming that 100% of the manure produced by any given

dairy is applied to croplands in the San Jacinto region, the estimated mitigation requirement ranges from a low of 54 tons per year (tons/yr) to a high of 1,332 tons/yr (see Table 4).

An additional 1,000 tons of TDS are added to the groundwater system through the disposal of process wastewater to ponds, pastures, and cropland. Based on the assumptions of this analysis, there are no dairies in the San Jacinto region that discharge wastewater with a TDS concentration below their respective underlying groundwater management zone objective. All dairies will therefore have to mitigate their wastewater discharges to some degree. The estimated TDS mitigation requirement for process wastewater ranges from a low of 10 tons/yr to a high of 75 tons/yr (see Table 4).

SALT OFFSET OPTIONS

As previously stated, dairy operations contribute salts to underlying groundwater basins in two ways: through the application of corral manure to cultivated croplands and through the disposal and/or application of process wastewater to ponds, pastures, or cropland. The following details the salt offset options recommended to address the loading produced by these activities.

Eliminate Application of Corral Manure to Croplands

Recall that under Section IV. B. of R8-2007-0001, the application of manure to croplands that overlie groundwater management zones lacking assimilative capacity for TDS or nitrate-nitrogen is prohibited—even at agronomic rates. A 1990 study conducted by the Regional Board in the Chino Basin found that the use of manure as fertilizer results in two to four times more salt reaching groundwater and up to 10 times more non-nitrate salts than the use of non-manure commercial fertilizer, thus providing a strong rational for this prohibition.

As reported in the 2007 Annual Reports, 24 of the region's dairies either applied corral manure to cropland on their own property or exported it locally to neighboring San Jacinto farms. The application of manure in this manner contributes to more than 90% of each dairy's TDS and nitrate loading problems. Accordingly, 90% of the problem could be solved by eliminating the use of corral manure as fertilizer in the San Jacinto River Basin. Chino Basin dairies followed this logic in 1999 when faced with the same land application prohibitions under the previous dairy permit (Order 99-11). To reduce their overall salt offset requirements under the permit, the Chino Basin dairies began exporting a large portion of their manure to the San Jacinto Basin—a practice that at the time was acceptable given the assimilative capacity status of the San Jacinto subbasins (prior to the 2004 Basin Plan Amendment and the 2007 Dairy Permit).

The export of manure from Chino Basin to San Jacinto continues to this day. The 2006 Annual Reports produced by Chino Basin dairies calculated that more than 196,000 tons of manure was exported to San Jacinto that year alone. The dairies in San Jacinto are not responsible for the loading caused by Chino Basin exports; however, this loading will still need to be accounted for and offset.

The difficulty of discontinuing the use of manure as fertilizer is that an appropriate location must be found for the disposal of more than 150,000 tons of manure—nearly 400,000 tons including manure imported from the Chino Basin. And, the elimination of this local fertilizer resource may be considered an economic loss for the region. However, the degradation of local groundwater

resources through the continued application of salt waste loads poses an even greater threat to the groundwater dependent region.

The WRCAC should consider partnering with other Santa Ana Region dairies to eliminate the use of manure as fertilizer in the Santa Ana River Basin. Solutions to consider include, but may not be limited to: transporting the manure out of the Santa Ana River basin to a location capable of accommodating this loading; transporting the manure to a local composting facility to process the waste; or constructing a local, centralized manure-to-energy facility that has the potential to provide economic benefits to the region while solving the solid manure loading problem.

The elimination of corral manure application to local croplands is an offset option considered viable for dairies located in all management zones.

Reduce TDS Concentration of Process Wastewater

It is assumed that compliance with the discharge prohibitions of R8-2007-001 will require the dairies to mitigate the entire mass of TDS that contributes to wastewater TDS concentrations in excess of the underlying groundwater management zone. Even in the event where source water TDS exceeds the TDS objective for a given underlying groundwater management zone, a dairy would need to offset that difference in addition to their TDS contribution. Options for reducing the final TDS concentration of dairy wastewater are provided below.

- *Reduce the TDS Concentration of Operations Source Water*. Many of the dairies in the San Jacinto region have elevated salt concentrations in their local water supplies. In some cases, it may be possible to reduce the final wastewater TDS concentration by reducing the source water concentration. Reductions in source water TDS concentrations can be achieved through the purchase of alternative, low TDS source waters, such as State Water Project (SWP) water, or through the pretreatment of local groundwater. The feasibility of purchasing SWP waster is limited by several factors: the increasing cost of imported water (due to increasing energy costs for transporting water from Northern California), the availability of pipelines to deliver imported water to San Jacinto, and limitations on deliveries from the SWP in the midst of a statewide drought and regulatory cutbacks. An additional option for reducing the TDS concentration of a dairy's source water supply involves the installation of a well head treatment system. However, because TDS requires the use of advanced treatment technology, such as reverse osmosis (RO), this option could prove to be very expensive for an individual dairy to execute. Furthermore, if the TDS load produced by milk parlor operations exceeds the underlying groundwater management objective, the treatment of source water alone will not be enough to comply with discharge prohibitions.

- *On-site Wastewater Treatment*. Given that identifying and procuring improved source water may prove challenging and may not in and of itself result in compliance with discharge prohibitions, dairies should consider the option of implementing an on-site wastewater treatment system. As with source water, the removal of TDS from wastewater is expensive because it requires the use of RO or other advanced treatment technologies in addition to primary, secondary, and tertiary treatment (for the complete removal of particles that can damage the RO membranes). The capital cost for such a system—even on a small scale of 100,000 gallons per day—can be as high as $11 to $15 per gallon of treatment capacity

needed. Operations and maintenance (O&M) costs can range from $1 to $2 per gallon treated. Recent advances in industry technology may however provide additional solutions. The WRCAC is testing the possibility of an on-site treatment technology known as Vibratory Shear Enhanced Processing or VSEP. Should the final VSEP research show that this technology is effective at reducing wastewater TDS and nitrate-nitrogen to required levels and that it can be implemented in a cost effective matter, it will represent a promising offset option that the dairies should consider implementing.

- *Regional Wastewater Treatment*. Given the high capital and operation/maintenance costs associated with the removal of TDS from wastewater, a centralized regional facility would be more cost effective than several individual on-site treatment systems. This cooperative opportunity would also reduce the time and money spent by the dairies and the Regional Board in evaluating, approving, and implementing this strategy.

A dairy's optimal strategy for the reduction of salts in process wastewater may be dependent upon their location relative to other dairies in the region. For example, those dairies located in the Menifee Management Zone are not likely candidates for a centralized wastewater treatment facility given their isolation relative the rest of the dairies in the region. In general, on-site treatment solutions will be better for dairies that are more isolated in location. An additional consideration for the use of wastewater treatment options, whether on-site or regional, is that such options also effectively treat nitrate loading from dairy operations.

Implement a Salt Management Plan

If a dairy wishes to continue the application of process wastewater as irrigation for pastures or croplands, a detailed salt management plan that demonstrates the fate of TDS as it moves from source to sink will be needed. Site specific data and computer models are required to demonstrate that no TDS reaches the groundwater table. In the absence of locally derived data and modeling demonstrations, the Regional Board will assume that 100% of TDS added to the system from manure and process wastewater reaches the groundwater table.

Similar to a salt management plan, a nutrient management plan, specifically targeting nitrate, can be implemented to demonstrate nitrogen loss through uptake and assimilation by crops. And though it is recommended that all corral manure be exported from the basin, if a dairy wishes to continue the application of corral manure as fertilizer to croplands, a salt and/or nutrient management plan can be designed to address this loading factor as well.

The USDA is carrying out a pilot project on one of the San Jacinto region dairies to investigate the efficacy of implementing a nutrient management plan, that includes a salt component. One benefit that has come from creating such a plan is the amount of data that has been generated regarding local conditions. The study showed that if process wastewater is applied at local evapotranspiration (ET) rates, very little leaching of salt occurs below the root zone. Because it is likely that 100% of the TDS will not be utilized by crops, there may be a small amount of mitigation required to account for the TDS that is transported to the groundwater aquifer. Upon completion of this pilot project, the WRAC should work closely with the Regional Board to demonstrate the impact of implementing a salt and/or nutrient management plan on the underlying groundwater basin to determine the resultant salt offset that may still be required.

The use of salt and/or nutrient management plans to reduce overall salt offsets can be implemented by any dairy, regardless of location.

Participate in Local Groundwater Improvement Projects

Another option involves the implementation of a groundwater quality improvement program that will remove, ton for ton, the TDS loads added to underlying groundwater basins through dairy operations, so long as the salt offset occurs within the same management zone as the loading.

Under current and previous dairy permits, the Regional Board found the implementation of a groundwater desalter facility in the Chino North Management Zone to be an acceptable salt offset for waste loads (TDS and nitrate) produced by dairies that discharge to this management zone. This offset was allowed under the condition that the desalter facilities were constructed according to the proposed schedule and that all corral manure continued to be exported from the basin.

While a regional groundwater desalination facility would have high costs, similar to a centralized wastewater treatment facility, this option presents the possibility of sharing costs with other local entities and creating economies of scale savings through partnerships. Dairy operations are not the only activities in the San Jacinto region affected by limitations imposed by a lack of assimilative capacity in the San Jacinto region. Local water supply agencies are also limited in their ability to implement groundwater management strategies, such as recycled water recharge. As such, these agencies are exploring their own salt offset options that will allow them to improve local water supply reliability within the constraints of the TDS and nitrate-nitrogen objectives.

One such program being explored in the San Jacinto region by the EMWD focuses on the SJUP Management Zone. The EMWD is seeking a Basin Plan amendment to increase the management zone TDS and nitrate-nitrogen objectives, which will require the EMWD to implement a groundwater desalter. While this proposed plan has yet to be reviewed and approved by the Regional Board, it presents an opportunity for San Jacinto dairies to propose a partnership that can achieve the goals of both parties. It is important to note that if the EMWD were to receive an increase in groundwater quality objectives through a Basin Plan amendment, these objectives would only apply to the EMWD. In order for the regional dairies to benefit from such a program, they would have to engage the EMWD to become a partner, both financially and with regard to regulatory accountability.

One obstacle to participating in local groundwater quality improvement programs relates to the implementation schedules for such projects. The dairies are working under a timeline that requires salt offset options to be in place by 2012. A project like the SJUP desalter, on the other hand, may not be slated for construction and operation until 2020. Nevertheless, even if the groundwater improvement project is not planned to be in place for several years beyond the dairy permit deadline, it may still be possible to design a program that offsets current loading at a future date. A payment penalty schedule could be arranged to raise the funds needed from the dairies for the overall project. An analysis of the amount of capacity needed in the desalter system to mitigate the dairies' waste loads will be needed in order to create a reasonable fee schedule. Such a program is desirable because not only will the overall cost be shared with other regional entities, but it allows the dairies to raise the funds over time and reduce the immediate financial stress of a project such as a centralized wastewater treatment plant.

As previously noted, a dairy's ability to participate in a desalter program may be limited by their location. The primary requirement of this type of salt offset is that the offset must occur within the same management zone as the loading. For example, should a groundwater desalter be implemented in the SJUP, only those dairies discharging to that management zone could benefit from the offset provided by the desalter. Nonetheless, if the dairies were able to engage EMWD early enough in the process and provide financial backing, it may be possible to explore a regional desalter that targets two adjacent management zones.

EVALUATING SALT OFFSET OPTIONS

The realistic salt offset options available for any one dairy are largely dependent on location. To recap the discussion above, Table 5 summarizes the options likely to be the most feasible in each management zone.

RECOMMENDATIONS

In reality, no one offset option is going to bring the San Jacinto dairies into compliance with the discharge prohibitions enforced under R8-2007-0001. As discussed herein, the realistic salt offset options available for any one dairy are largely dependent on location. Furthermore, depending on a dairy's operation plans, more than one strategy may be required to achieve said dairy's full offset requirement.

One thing, however, is certain: there is a dearth of data on actual manure production, water use, and the resulting TDS and nitrate loads produced by dairies in the San Jacinto region. The estimates provided within this analysis were made using a variety of assumptions and will not be sufficient for the Regional Board to determine the salt offset requirement for each dairy. To more effectively evaluate the options that are both technologically and economically feasible for dairy operators, further research and analysis will be required. To improve the potential success of a salt offset workplan, WEI recommends that the WRCAC consider the following:

- The implementation of a monitoring program that will quantify the actual salt impacts of the San Jacinto dairies, including the analysis of manure salt content, water usage and quality monitoring, and measuring the general water quality of process wastewater.

- In order to produce "a plan, acceptable to the Executive Officer," it is necessary for the WRCAC to meet regularly with the Regional Board to discuss the salt offset options proposed for implementation. This will help to bring forward any questions about what type of monitoring or analyses will be required for approval of the strategy and how compliance with the offset will be evaluated.

- It is strongly recommended that the WRCAC explore the option of eliminating the use of corral manure as fertilizer. The best chance the San Jacinto dairies have to continue operating in the future is to entirely remove the primary loading factor from the region, as is evidenced by the experience of the Chino Basin.

- It is also recommended that the WRCAC engage the EMWD as soon as possible to consider the regional groundwater management strategies being implemented. There may be a multitude of groundwater quality improvement programs in the making or possibly in existence that could help the dairies meet their offset needs.

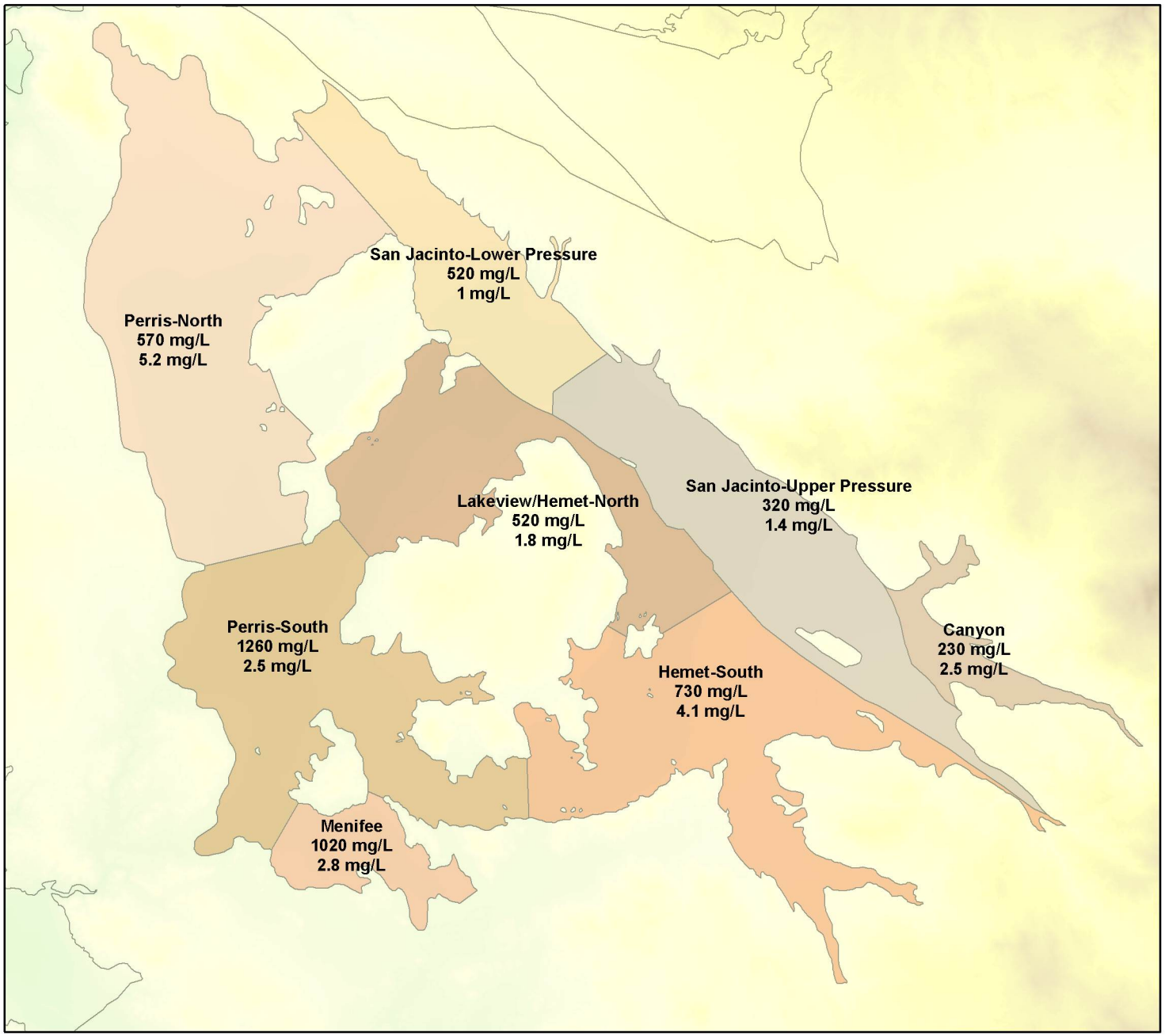
While there are many questions that still need to be addressed, it is our hope that the dairies represented by the WRCAC have the information necessary to take the next steps towards complying with the waste discharge requirements set forth in R8-2007-0001. WEI is pleased to have assisted Tetra Tech with this analysis. Please contact me or Samantha Stevens if you have any questions.

Respectfully,

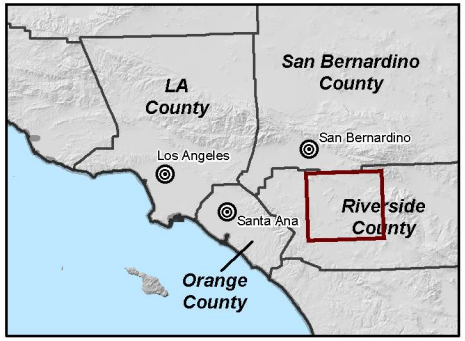
Mark Wildermuth
Chairman

Samantha Stevens
Senior Scientist

Enclosures:
Figures 1-2; Tables 1-5; References; Comments and Responses



Menifee — Management Zone
1020 mg/L — TDS Objective
2.8 mg/L — NO3-N Objective



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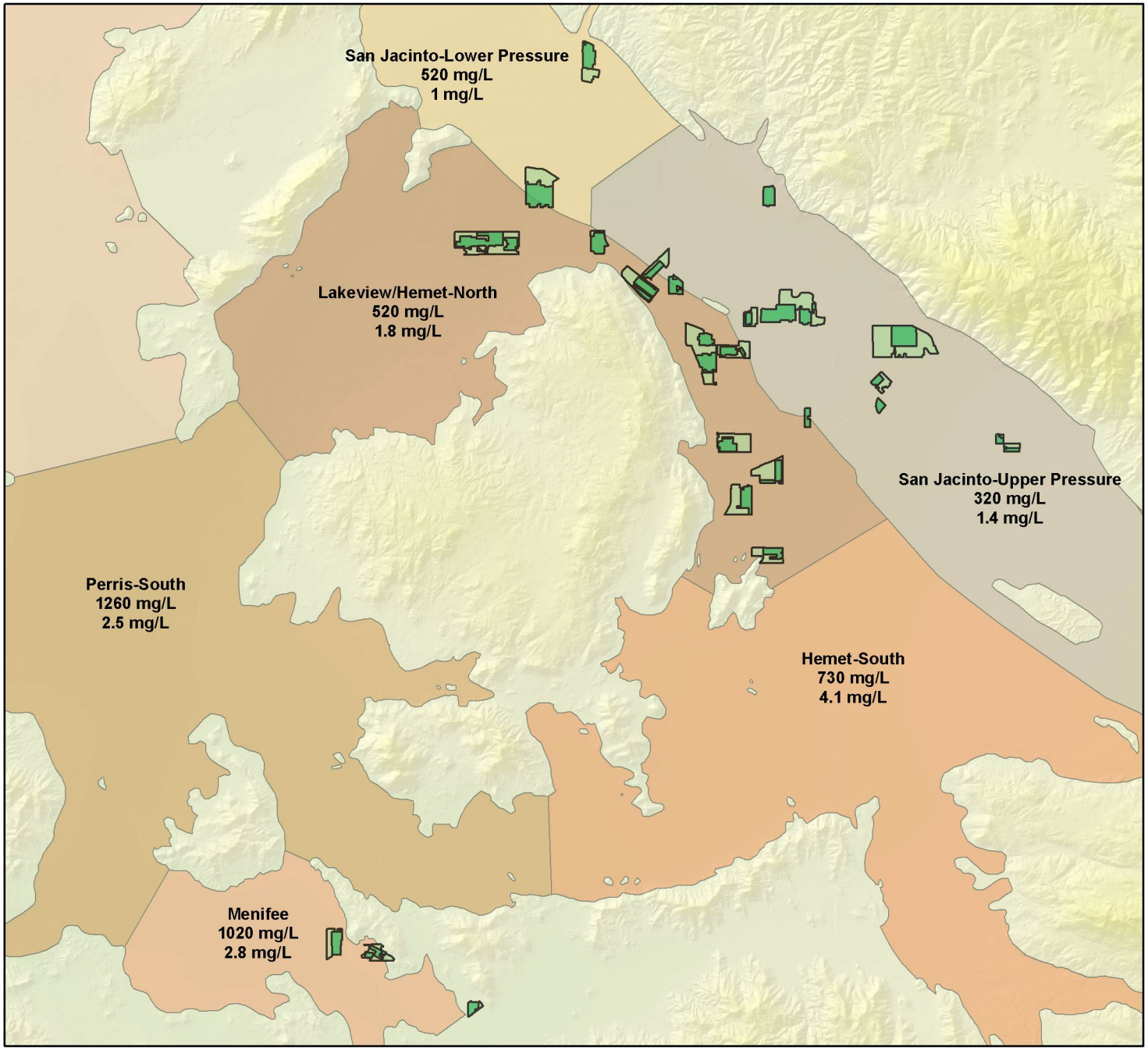
WRCAC Dairy Permit
San Jacinto Salt Offset Options

San Jacinto River Basin
Groundwater Management Zones

Figure 1



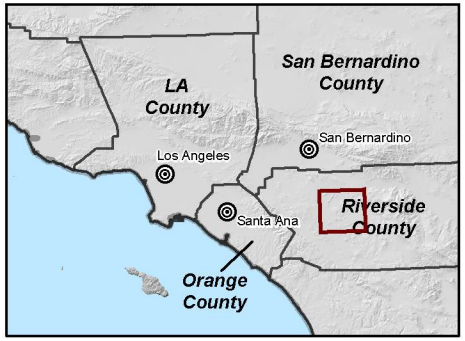
Menifee — Management Zone
1020 mg/L — TDS Objective
2.8 mg/L — NO3-N Objective

San Jacinto Land Use Classification
*Dairy Specific Uses**

Dairy Corrals and Milk Parlors

Dairy Pastures and Wastewater Ponds

**Land use data provided by AIS*



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San Jacinto Salt Offset Options

San Jacinto River Basin
Dairy Locations

Figure 2

Table 1
Groundwater Quality Objectives for Total Dissolved Solids

Management Zone	TDS Objective (mg/L)	2006 Ambient TDS (mg/L)	Assimilative Capacity?
San Jacinto Upper Pressure	320	350	No
San Jacinto Lower Pressure	520	810	No
Lakeview/Hemet North	520	880	No
Menifee	1020	2140	No

Table 2
Groundwater Quality Objectives for Nitrate as Nitrogen (NO_3-N)

Management Zone	NO3-N Objective (mg/L)	2006 Ambient NO_3-N (mg/L)	Assimilative Capacity?
San Jacinto Upper Pressure	1.4	1.6	No
San Jacinto Lower Pressure	1	1.2	No
Lakeview/Hemet North	1.8	2.7	No
Menifee	2.8	4.7	No

Table 3
Manure Production Factors

Cow Type	Manure Production (tons/yr)
Milking Cow	4.1
Dry Cow	4.1
Heifer	1.5
Calf	0.6
Other	4.1

Table 4
Total Dissolved Solids Production by Dairy Operations in the San Jacinto Region

Facility Name	Total # Cows[1]	# Milking Cows[1]	Annual Manure Hauling Requirement[2] (tons/yr)	TDS Mitigation Requirement for Corral Manure[3] (tons/yr)	Wastewater Production[4] (gal/day)	Source Water TDS[5] (mg/L)	Manure Contribution to Wastewater TDS[6] (mg/L)	Wastewater TDS[7] (mg/L)	TDS Mitigation Requirement for Process Wastewater[8] (tons/yr)
San Jacinto Upper Pressure Management Zone (TDS Objective = 320 mg/L)									
CBJ Dairy	3,234	1,453	8,257	661	145,300	223	215	438	**26**
Ed Vander Woude Dairy	660	354	1,829	146	8,673	224	879	1,103	**10**
Marvo Heifer Ranch	450	-	675	54	-	-	-	-	**-**
Hettinga Farms	4,944	1,009	6,794	544	100,900	530	215	745	**65**
John Oostdam and Son Dairy	1,050	700	3,143	251	16,100	245	936	1,181	**21**
Mira Vista Dairy	1,830	925	5,049	404	37,897	514	525	1,039	**42**
Pico Dairy????									
R&J Haringa Dairy	2,920	2,500	10,817	865	110,000	245	489	734	**70**
Ramona Farms	6,249	3,036	16,652	1,332	197,340	224	331	555	**71**
Sid Sybrandy Dairy	1,499	757	4,153	332	52,990	565	308	873	**45**
Scott Bros. Dairy	2,450	1,000	5,843	467	62,360	300	345	645	**31**
Sub Totals	***25,286***	***11,734***	***63,212***	***5,057***	***731,560***				***381***
San Jacinto Lower Pressure Management Zone (TDS Objective = 520 mg/L)									
Jim Bootsma Jr. Dairy	2,650	1,500	7,650	612	150,000	610	215	825	**70**
Marvo Holsteins Dairy	2,520	1,550	7,877	630	40,688	611	820	1,431	**57**
Moreno Valley Dairy (E&J Maqueda)	2,014	1,215	6,048	484	78,975	810	331	1,141	**75**
Sub Totals	***7,184***	***4,265***	***21,575***	***1,726***	***269,663***				***201***
Lakeview/Hemet North Management Zone (TDS Objective = 520 mg/L)									
Boersma Dairy	1,910	1,100	5,375	430	110,000	615	215	830	**52**
Dick Van Dam Dairy	2,125	1,350	6,769	542	56,700	520	513	1,033	**44**
Ferreira Dairy	1,175	995	4,410	353	17,005	510	1,260	1,770	**32**
John Bootsma Dairy	2,678	1,895	9,004	720	34,982	493	1,166	1,659	**61**
John&Margie Oostdam Dairy	1,745	810	4,562	365	32,238	444	541	985	**23**
Offinga Dairy	1,514	850	4,533	363	85,000	488	215	703	**24**
Peter Dotinga Jr. Dairy	1,490	734	4,118	329	24,229	520	652	1,172	**24**
Art Oostdam and Son Dairy	2,150	1,350	6,432	515	35,100	450	828	1,278	**41**
Pastime Lakes Dairy	3,958	2,160	11,400	912	75,859	533	613	1,146	**72**
Sunnydale Farm	2,080	1,080	6,005	480	43,632	520	533	1,053	**35**
Matson Dairy	1,651	1,060	4,976	398	65,720	773	347	1,120	**60**
Sub Totals	***22,476***	***13,384***	***67,583***	***5,407***	***580,465***				***469***
Total	***54,946***	***29,383***	***152,370***	***12,190***	***1,581,688***				***1,051***

[1]Data obtained from 2007 Annual Reports of Animal Waste Discharge

[2]Values represent estimated mass of manure to be hauled from the Dairy (90% of milking Cow production; 100% production from all other cow types) and are calculated using manure production factors provided by the Regional Board

[3]One ton of manure contains 8% salt by mass (per 2004 WRAC Dairy Survey)

[4]Data obtained from each dairy's Engineered Waste Management Plan. Where EWMP was not available, Regional Board recommended washwater requirement of 100 gal/cow/day was used

[5]Source water data obtained from EMWD. Values represent average TDS concentration from 2002-2006. Where data was unavailable, source water concentration was assumed to be identical to neighboring Dairies

[6]Wastewater TDS contribution from manure assumes 100% dissolution of salt (UC Davis 2005)

[7]Value represents the sum of Source Water TDS and Manure Contribution to Wastewater TDS and assumes 100% of washwater volume becomes wastewater

[8]The entire mass of TDS contributing to a wastewater TDS concentration in excess of the management zone objective needs to be mitigated

Table 5
Recommended Salt Offset Options by Management Zone

Management Zone	Eliminate use of Corral Manure as Fertilizer	Reduce TDS Concentration of Source Water	On-site Wastewater Treatment Facility	Regional Wastewater Treatment Facility	Implement Salt or Nutrient Management Plans	Participate in Regional Groundwater Quality Improvement Programs
San Jacinto Upper Pressure	X			X	X	X
San Jacinto Lower Pressure	X	X	X	X	X	?
Lakeview/Hemet North	X			X	X	X
Menifee	X	X	X		X	X

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APPENDIX -- COMMENTS AND RESPONSES

Comment Number	Reference Topic	Comment	Response
1	TDS	What specific salts? Are we are using salts and TDS interchangeably?	The definition of salts and TDS are addressed in the objectives section of the report.
2	Nitrate	The discussion switches here from the background/setup showing that the permit prohibits TDS and nitrate-nitrogen loading in all of the management zones underlying dairies to a data discussion that focuses only on TDS. Does the report assume that an offsetting TDS to the Basin Plan objectives will sufficiently offset nitrate-nitrogen to its corresponding objective? It seems there should be some discussion of the reasoning/basis for the focus on TDS in light of the requirement that applies to both parameters.	The objectives section of the report addresses why an analysis of estimated nitrate loads could not be performed.
3	Data Collection	All isn't factually correct as a few are all or part on EMWD metered palatable water source.	The original statement that all dairies rely on groundwater for operations has been updated to reflect that the dairies in the Menifee Management Zone also rely upon municipal water sources.
4	Assumptions	Provide a basis/justification for all of the assumptions – those identified in the list of assumptions as well as those discussed in the text. This will allow for the next step of refining the assumptions to get a better picture of the TDS load that really needs to be offset.	Assumptions have been elaborated and references are now provided where necessary.

Comment Number	Reference Topic	Comment	Response
5	Assumptions	It would be nice to see the methods that were used (in the EWMPs) and how they compare to the method(s) chosen for this report.	This discussion is out of the scope of the report. In general, it appeared that some of the estimates made in the EWMP reports were not reliable and would result in overestimations of TDS loading for some dairies. Accordingly assumptions were used in place of all EWMP derived data.
6	Assumptions	For those assumptions based on Regional Board assumptions, it would be nice to see the original basis for the Regional Board's assumptions.	This is beyond the scope of the analysis.
7	Assumptions	It would be interesting to say how the EWMP values compared to the assumption of 100 gal/cow/day	This was not discussed in the report, but in general, it appears that the assumption of 100 gal/cow/day is an overestimate. Metering of wells is needed to determine actual use.
8	Assumptions	Are there data on TDS/NO3 content of manure/wastewater to use as a basis for, or to ground-truth assumptions?	There are limited data available specific to TDS content of dairy wastes. Some research has been done in the Central Valley with regards to particular salts, such as sodium and chloride, however, because the Regional Board only regulates the sum of all dissolved inorganic and organic constituents (as TDS), these studies were not considered informative in estimating TDS loading for this analysis.
9	Assumptions	Do these numbers assume that the entire mass of TDS generated eventually makes it to ground water? If so, what is the basis for this assumption? Has there been research that can be used to refine the assumption? For example, Scott Bradford's research on wastewater movement through the soil profile.	These questions are addressed in the report. Refer to the offset discussion for: *Implement a Salt and/or Nutrient Management Plan*

Comment Number	Reference Topic	Comment	Response
10	Assumptions	100% effectiveness of any transfer or process is not the norm.	While 100% transfer is often not the norm, in the absence of supporting data, a conservative approach is preferred.
11	Offset Options	Provide a more robust set of options. In particular, some possible options for solid manure disposal/utilization seem to be missing (e.g., waste-to-energy technologies, composting, etc.).	The scope of the analysis was to present a set of salt offset options regarded as likely to be acceptable to the Regional Board. More detail was added to the salt offset options proposed, particularly as it relates to the elimination of manure application. However, specific details on how to achieve this recommendations was out of the scope of this analysis.
12	Offset Options	Please provide some idea of how the TDS load reductions play out in terms of meeting the nitrate objectives.	Within the discussion of each offset option, it is noted if the strategy will address TDS and/or nitrate.
13	Offset Options	If other options (for both solid manure and wastewater) were considered and dismissed, a discussion of what those options are and why they were not considered to be viable would be useful for future development of the salt offset program.	All options considered during the analysis are included in the report. No options were dismissed.
14	Offset Options	A decision framework (criteria, analysis of each option vs criteria, mechanics of moving manure from source to destination, etc.) would help the development of creative solutions because the why/why not will be documented and it may be possible to identify opportunities to stitch things together in new ways.	A decision framework was out of the scope of this analysis. There are too many unknown variables to design a realistic set of criteria for such a framework.

Comment Number	Reference Topic	Comment	Response
15	Offset Options	It appears, based on the figures, that there are areas in the region that do not overlie one of the management zones in question – can these be used for land application?	If these areas are tributary to any of the groundwater management zone lacking assimilative capacity, this is not an option.
16	Offset Options	It would be helpful to show a list of which specific dairies might consider each option.	Because specific dairies did not want to be named in the text, this was not done. However, a more direct discussion describes where each offset option may be applicable. See Table 5.
17	Offset Options	Discuss possibility of strategic placement of desalter to treat two management zones.	This is addressed in the report in the offset discussion for: *Participate in Local Groundwater Improvement Projects*
18	Offset Options	Is it possible to give examples of costs?	Because it is unclear as to how much TDS and nitrate are in dairy process wastewater, more accurate or detailed costs estimations are not possible.

Appendix G – Design and Implementation of a Salt Load Tracking Database

Errata Sheet

for the document titled:

Design and Implementation of a Salt Load Tracking Database, December 10, 2009

(Appendix F of the San Jacinto Watershed Integrated Regional Dairy Management Plan)

Page	Erratum
1	Add: *Funding for this project has been provided in full or in part through an agreement with the California State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. (Gov. code 7550, 40 CFR 31.20).*

WILDERMUTH™
ENVIRONMENTAL INC.

December 10, 2009

Ms. Jennifer Ferrando
Tetra Tech
350 Indiana Street
Golden, CO 80401

SUBJECT: Design and Implementation of a Salt Load Tracking Database

Dear Ms. Ferrando:

In 2008, Tetra Tech, Inc. retained the services of Wildermuth Environmental, Inc. (WEI) to prepare a set of salt offset recommendations for the dairies located in the San Jacinto River Basin. A salt offset program is needed in order to comply with the waste discharge requirements set forth in Regional Board Order R8-2007-0001. Under R8-2007-0001, any dairy that overlies a groundwater basin that lacks assimilative capacity for TDS or nitrate-nitrogen and plans to continue to apply manure and other dairy process wastes to lagoons, disposal fields, and croplands must design a work plan to offset its salt load by September 2012. The 2008 salt offset recommendations study revealed that the calculation of salt loads on a dairy is a data intensive process and that insufficient data was available to make this calculation with reasonable precision. A critical step towards designing a salt offset program is establishing the ability to consistently compute and carefully track the salt load produced by each individual dairy and to be able to cleanly store and manage the copious amounts of data collected in support of the salt load and salt offset calculations. Thus, as a follow up to the 2008 report, Tetra Tech contracted WEI to design a conceptual salt load tracking database that could be used to store and manage the data collected by the San Jacinto dairies in support of a salt offset program. This report summarizes the scope and design of the conceptual salt load tracking database.

OBJECTIVES

This report provides a framework for designing a salt load tracking database that can be used in support of a salt load offset program. The two primary goals of the data collected for a salt offset program are (1) to calculate the salt load produced on a dairy and (2) to calculate the salt load offset requirement for that dairy. This report focuses only on the calculation of the TDS component of the total salt load. The nitrogen cycle is complex and a thoughtful evaluation of nitrogen is beyond the scope of this investigation. From this point forward, the term salt load will be used synonymously with TDS load.

Throughout this report, regular use is made of the terms *salt load* and *salt offset requirement*. It is important to distinguish the difference between these two terms. The *salt load* of a dairy is the entire mass of salt in the solid and liquid wastes generated by dairy operations. The *salt offset requirement* is

the total mass of salt that contributes to a TDS concentration in excess of the regulatory TDS objective defined for the underlying groundwater management zone.

The general equation for calculating the salt load of a dairy is:

Salt Load = Mass of Salt in Solid Manure + Mass of Salt in Wastewater

The method for calculating the salt load offset requirement has not been explicitly defined. However, Order R8-2007-001 specifies that "the discharge of waste containing TDS and/or Nitrogen concentrations in excess of the underlying groundwater management zone objectives for those constituents is prohibited."

The prohibition indicates that the volume of wastewater that ultimately percolates into the underlying groundwater aquifer should be quantifiable in order to use it as measure for determining regulatory compliance. Thus, the salt load offset requirement could be defined as:

Salt Offset Requirement =

[(Total Salt Load - Salt Removed)/ Percolation Volume] - TDS Objective) * Percolation Volume

Designing a flexible and functional salt load tracking database requires careful and thoughtful preparation to ensure that it will meet the needs of the program it is designed to support. The following sections describe (1) the methodology used in identifying the data needed to calculate salt loads and offset requirements, (2) the proposed methodology to calculate salt loads and offset requirements, (3) the design of the database and the identification of data collection limitations, and (4) the next steps towards conceptual database implementation.

IDENTIFYING THE DATA NEEDED TO CALCULATE SALT LOAD AND SALT OFFSET REQUIREMENT

A practical means of breaking down the salt load into a collection of quantitative variables is to track the salt from source to sink. A sink is any place, on or off the dairy, where liquid or solid waste is disposed of. The two principal sources of salt on a dairy are cattle manure and water. For any given time period, a certain mass of salt will be generated. In that same period, an equal mass of salt will be disposed of in solid (manure) or liquid (wastewater) form to one or many of the possible sinks, in essence, balancing the salt budget for that time period. Thus, being able to define a manure and water budget for a dairy will define the operation's salt load.

The Manure Budget on a Dairy

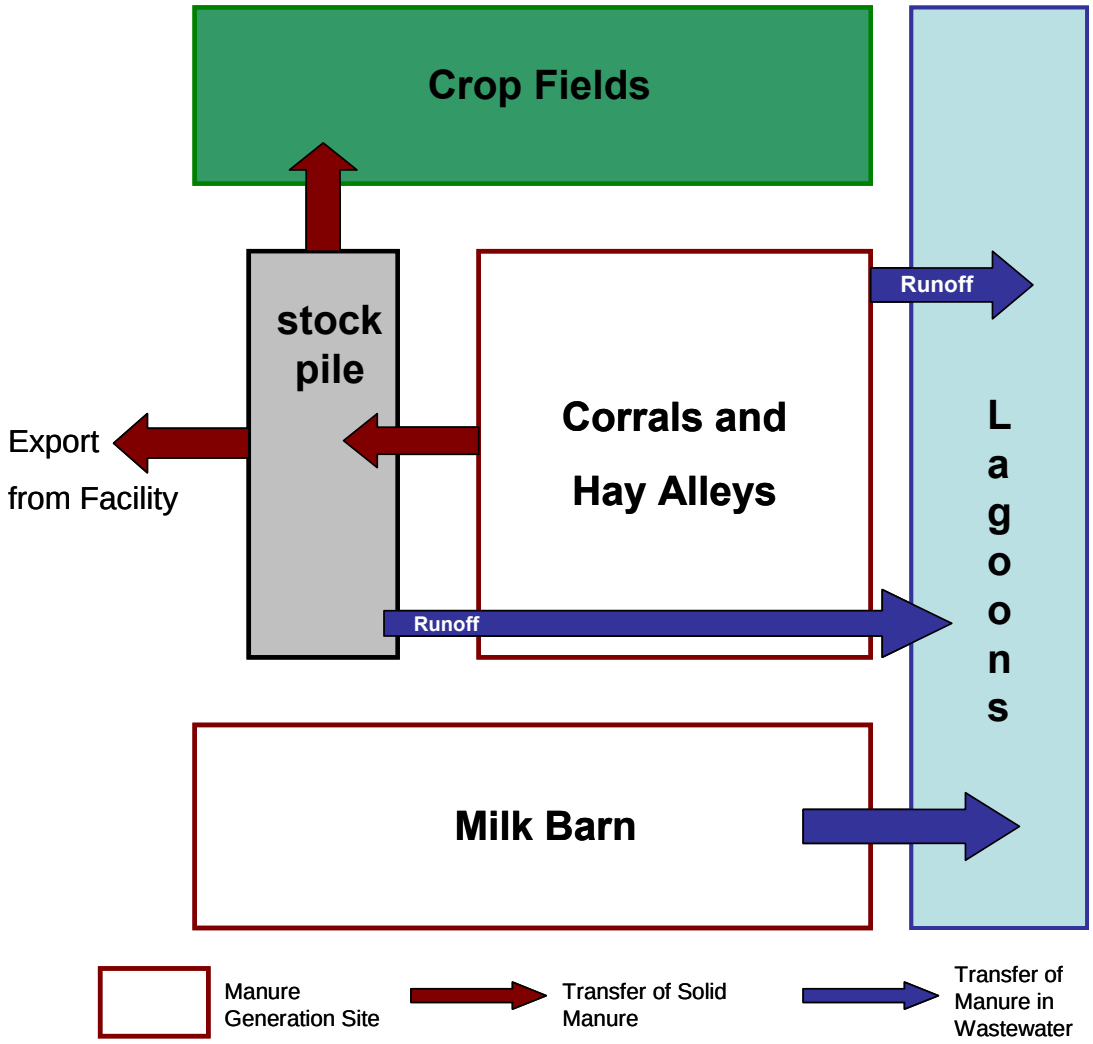
Figure 1 illustrates the generalized pathways that manure generated on a dairy travels from source to sink. Manure is generated by cattle in the two locations where they spend their time: the corral and the milk barn. Solid manure is removed from the corral and feeding areas and stored in utility areas, or stockpiles. Stored manure is then either exported from the property or used as a fertilizer for on-site crop fields. Manure generated in the milk barn becomes part of the wastewater stream generated during the milking process and is subsequently disposed of in wastewater lagoons or disposal fields. Manure can also be washed into lagoons from the corrals and utility areas (stockpiles) with runoff during precipitation events. The careful tracking of each transfer of manure will ensure that the salt

load can be tracked and calculated. The key variables that need to be quantified in order to calculate and balance the manure budget and the associated salt load for a given time period are described below.

Manure generation rates, by cattle type: the mass of manure an individual cow, by cattle type, can produce.

Cattle counts, by cattle type: the number of each cattle type present on the dairy during the defined time period.

Figure 1



Amount of time spent in each manure generation site, by cattle type: the percentage of time each cattle type spends in the corral/feeding area and the milk barn during an average day.

Mass of manure applied to on-site cropland: the mass of manure applied to each crop field that is growing during the defined time period.

Mass of manure exported from the dairy: the mass of manure hauled off-site during the defined time period..

Manure Hauling Location: the type and location of the hauling site will determine if the exported manure requires a salt offset. If the manure is hauled to a farm located within a management zone that lacks assimilative capacity for salt load the dairy will be required to offset the salt load of the manure hauled. If the manure is hauled to a management zone with assimilative capacity or to a location outside of the jurisdiction of the Santa Ana Regional Board, then the salt load of the manure will not need to be offset.

Mass of manure stored in on-site stockpile: the mass of manure stored in the stockpile at the end of the time period.

Manure salt content: the fraction of salt, by mass, contained in a ton of manure.

The Water Budget on a Dairy

Figure 2 illustrates the generalized pathways that water used on a dairy travels from source to sink. Balancing the water budget poses a greater challenge than balancing the manure budget because environmental factors come into play, such as evaporation, that remove water from the system but leave the salt behind. Furthermore, each dairy has a unique set of water supply sources (that may or may not be combined together before use) to meet water demands. In the San Jacinto region, the two primary sources of water are local groundwater pumped on-site at the dairy or water purchased from the Eastern Municipal Water District—who serves local groundwater and imported Colorado River water.

Water demands include the consumption needs of cattle, crop water requirements, and milking operations. Water applied to croplands is consumed by the crops by evapotranspiration (ET) and the remainder percolates to the underlying aquifer. The water lost through ET does not necessarily transfer salt. This is a crop specific transfer. If a crop does not have documented salt uptake rate, the mass of salt in the initial volume of water applied is assumed to be concentrated and left behind to percolate to groundwater. If a dairy has implemented an approved salt management plan that describes specific salt uptake rates for the crops grown on the dairy, then the dairy would get credit for a salt removal. Water used in the milk barn becomes wastewater and is disposed of in on-site lagoons. Runoff generated on the dairy during precipitation events also drains to the wastewater lagoons. Water delivered to the lagoons can evaporate, percolate, be transferred to croplands for irrigation, or be transferred to disposal fields. Water evaporating from the lagoons does not export salt from the system, thereby leaving a higher concentration in the lagoon. Water transferred to disposal fields is consumed by native vegetation (again, leaving salt behind) or percolated to the underlying aquifer.

The careful tracking of each transfer of water will ensure that the salt load can be tracked and calculated. The key variables that need to be quantified in order to calculate and balance the water budget and the associated salt load are described below.

Water use, by source: the total volume of water used from each supply source.

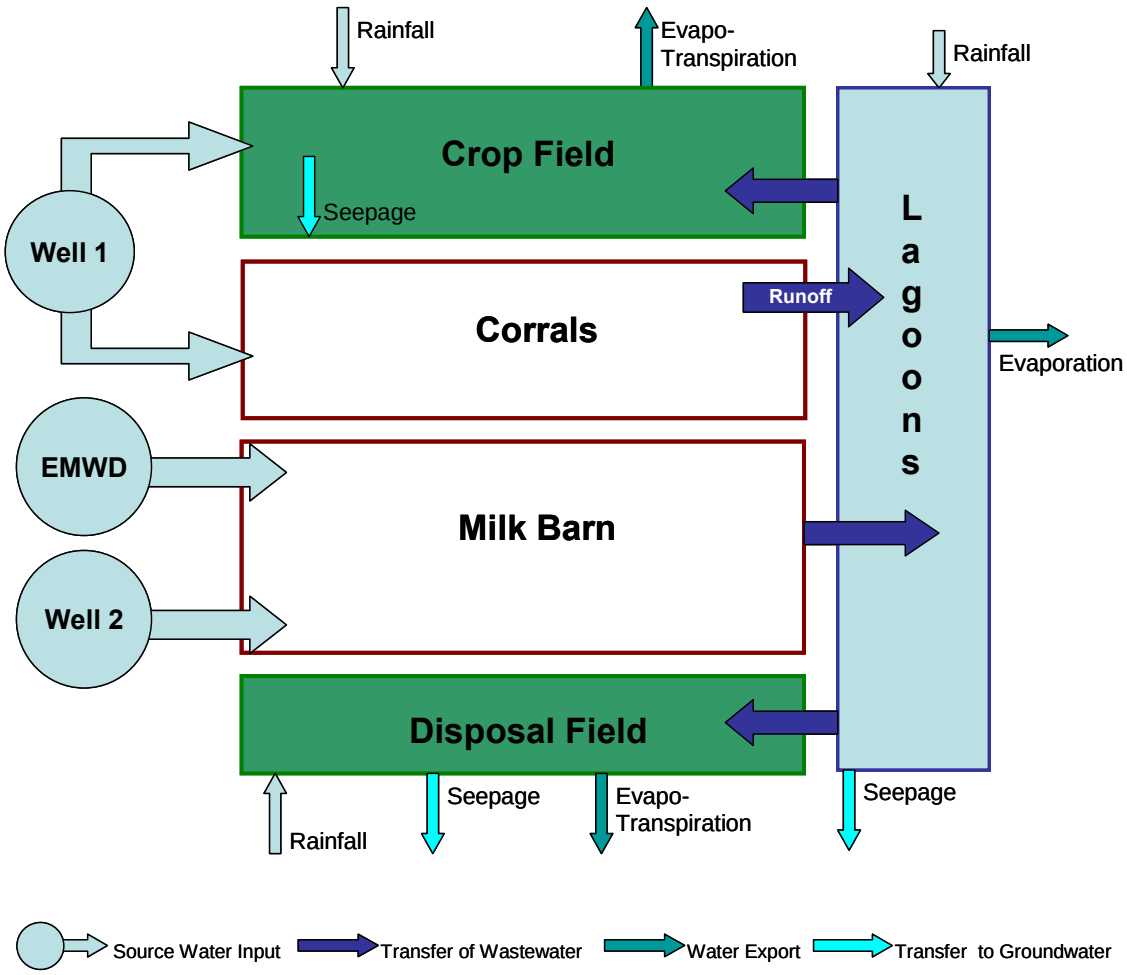
Cattle water consumption, by cattle type: the water requirements of each cattle type.

Milk barn water use: the volume of water used by the milk barn can be used to calculate how much wastewater is generated on the dairy, if the wastewater discharge is not measured.

Source water quality: the TDS concentration of each water supply source is used to calculate the mass of salt introduced to the wastewater stream.

Amount of time spent in the milk barn, by cattle type: the percentage of time each cattle type spends in the milk barn during an average day.

Figure 2



Wastewater quality: the concentration of TDS in wastewater leaving the milk barn can be used to calculate the wastewater salt load instead of relying on estimates of manure salt content and generation rates.

Distribution of wastewater among disposal areas: the volume of wastewater distributed to lagoons, disposal fields, and croplands.

Potential Lagoon Evaporation: the volume of water that can be evaporated in a lagoon during a specified time period.

Type of crop grown and duration of growth: the type of crop and duration of growth are necessary variables for calculating the water requirements of the subject crop.

Crop field area: The length and width of each cropland site that is under cultivation during the defined time period.

Reference Evapotranspiration: the evapotranspiration rate from a known surface (reference surface, e.g. standard grass) during a specified time period under the specific climate conditions of that time period (this data is available from the California Irrigation Management Information System).

Crop coefficient: a crop specific coefficient that is combined with reference evapotranspiration rates to calculate the total volume of water consumed per unit area of crop field.

Salt uptake by crop type: the rate of salt uptake for a specific crop type, per unit area of crop grown. This data would be specified in a dairy-specific salt management plan.

Volume of water added to lagoons from precipitation: the total volume of water from direct precipitation on disposal areas plus the volume of runoff generated elsewhere on the dairy.

IDENTIFYING DATA COLLECTION LIMITATIONS

It is prudent and necessary to evaluate the practicality and possibility of measuring or quantifying the variables identified for calculating the salt load. Moreover, it is important that the variables included in the calculations be realistically collectable or calculable for all dairies. Failure to identify data that are immeasurable or impractical to collect prior to designing the database could result in a fatal flaw in performing salt load calculations for all or some of the dairies. Table 1 evaluates the ability to measure or quantify the variables identified in the preceding analysis of manure, water, and salt budgets. All but one of the variables identified for the calculation of salt load were determined to be measurable or quantifiable; this variable is discussed below.

The volume of wastewater seepage to groundwater could most accurately be calculated if the volume of wastewater distributed to each disposal areas was known. However, this is the one variable, as identified in Table 1, that cannot be reasonably determined. A detailed review of the dairies' Engineered Waste Management Plans (EWMP) was performed to evaluate the practicality of defining a set of dairy-specific assumptions that would dictate how to distribute the wastewater among the disposal areas of the subject dairy. This revealed several factors that complicate such an estimation. First, every dairy has a unique set of disposal areas that are made up of some combination of lagoons, disposal fields, and cropland. Second, each dairy has a unique system for moving water to and between the disposal areas (underground pipelines, open trenches, etc.). Third, the determining factor of when and how much water is moved is not always based on measurable criteria, such as a maximum lagoon capacity. Thus, simulating the movement of wastewater around a

dairy would require the dairy operators to report exactly when they exercised various valves and pipes on a daily basis. From the standpoint of ensuring the quality assurance and quality control of the database inputs, this is not considered to be a practical variable for storage in a database. Because we cannot realistically monitor every aspect of the dairy operation on a daily basis, an alternative means for estimating the volume of wastewater seepage to groundwater will need to be developed from the other measurable terms. The alternative variables used to define wastewater seepage are presented in the following section.

METHODOLOGY TO CALCULATE SALT LOADS AND OFFSET REQUIREMENTS

Based on the analysis of the ability to measure or quantify each data variable, as presented in Table 1, the following are the proposed equations the salt load tracking database will use to calculate the salt load and salt offset requirement of a given dairy. Following each equation is a definition of the individual variables.

Recall that,

Total Salt Load = Mass of Salt in Solid Manure + Mass of Salt in Wastewater

And that,

Salt Offset Requirement =

[(Total Salt Load - Salt Removed)/ Percolation Volume] - TDS Objective) * Percolation Volume

Total Salt Load from Solid Manure

$$SL_{SM,t} = SF * [\sum(C_{i,t} * G_i * t * T_{c,i}) + M_{S,t-1}]$$

Where,

$SL_{SM,t}$ = the total mass of salt added from solid manure waste in time period *t*
SF = the fraction of salt, by weight, in one ton of manure at a specified moisture content
t = time period
$C_{i,t}$ = number of cows of type *i* on the dairy during time *t*
G_i = manure generation rate of cow type *i*
$T_{c,i}$ = the average percentage of time spent by cow type *i* in corrals and feeding areas
$M_{S,t-1}$ = the mass of manure stockpiled at the end of time the previous time period,*t-1*

Total Salt Load of Source Water

$$SL_{SW,t} = \sum(V_{j,t} * TDS_{j,t})$$

Where,

$SL_{SW,t}$ = the total salt load in source water produced during time period *t*
$V_{j,t}$ = the volume of the jth water supply produced during time period *t*
$TDS_{j,t}$ = the TDS concentration of the jth water supply produced during time period *t*

Total Salt Load of Manure Generated in Milk Barn Wastewater

$$SL_{MB,t} = SF^{*}\sum(C_i^{*}\ G_i\ ^{*}\ t\ ^{*}\ T_{mb,i})$$

Where,

$SL_{MB,t}$ = the total salt load added to wastewater from manure generated in the milk barn during time period *t*
$T_{mb,i}$ = the average percentage of time spent by cow type *i* in the milk barn

Salt Load Removed

$$SL_{R,t} = SF^{*}(M_{E,t} + M_{S,t}) + SL_{CU,c,t}$$

Where,

$SL_{R,t}$ = the mass of salt removed during time period *t*
$M_{E,t}$ = the mass of manure exported outside of the Santa Ana region during time period *t*
$M_{S,t}$ = the mass of manure stockpiled on-site at the end of time *t*
$SL_{CU,c,t}$ = the mass of salt removed through salt uptake by crop type *c* during time *t*

Salt Load Offset Requirement

$$SL_{offset,t} = \{[(SL_{SM,t} + SL_{SW,t} + SL_{MB,t} - SL_{R,t}) / V_{seepage,t}] - TDS_{obj,z}\} * V_{seepage,t}$$

Where,

$$V_{seepage,t} = V_{SW,t} + V_{P,t} - V_{WC,t} - V_{ET,t}$$

And,

$SL_{offset,t}$ = the salt offset requirement for time period *t*
$V_{seepage,,t}$ = the total volume of water that percolates to groundwater on the dairy during time period *t*
$TDS_{obj,z}$ = the TDS objective of underlying management zone *z*
$V_{SW,t}$ = the total volume of source water produced on the dairy during time period *t*
$V_{P,t}$ = the total volume of precipitation and runoff added to the disposal areas on the dairy during time period *t*
$V_{WC,t}$ = the total volume of water that was consumed by cattle during time period *t*
$V_{ET,t}$ = the total volume of water consumed by evaporation and transpiration during time period *t*

The salt load offset requirement assumes that all of the salt in solid manure applied to crops (on-site and at local farms) and all of the salt in wastewater used for irrigation (less any uptake by the crops) is percolated to groundwater. This is a conservative estimation. Provisions should be made in a final database design to store data that can be used to describe a defensible geochemical process for TDS reduction in transit to the saturated zone.

DESIGNING THE SALT LOAD TRACKING DATABASE

Designing a flexible and functional database requires careful and thoughtful preparation to ensure that it will meet the needs of the program it is intended to support. The key to implementing a successful database program lies in the ability to clearly articulate the objective, to understand all of the data needed to meet those objectives, and to recognize the limitations in collecting the requisite data. Accordingly, the discussion thus far has not focused on the database structure itself but on the methodology followed to develop a meaningful scope for implementing a salt load tracking database. In conceptualizing this database, the following questions have been explored:

1. What is the objective of the database?
2. What questions are the data meant to answer?
3. What calculations need to be performed?
4. What is the minimum set of variables needed to perform the calculations?
5. Can the required data be measured, estimated, or calculated?
6. What are the means for collecting the data?
7. What supplementary data can be collected and stored to support the required dataset?

The conceptual structure for the salt load tracking database was designed based on the consideration of these questions. Appendix A, included as an attachment to this report, contains an Entity Relationship Diagram (or ERD) that summarizes the set of tables (and their associated data fields) necessary to store data collected in support of a salt offset program. Appendix B, included as an attachment to this report, contains the data dictionary for the tables, columns, and fields included in the conceptual salt load tracking database. Note that more than just the minimum required data is included for storage in the database. The justification for collecting the supplemental information is to provide a means to verify that the data used in the salt load and salt offset calculation is realistic.

NEXT STEPS TOWARDS DATABASE IMPLEMENTATION

Verification of database design

Once the conceptual design for the salt load tracking database has been established, the next step is to confirm that the design meets the stated objectives of the database. This is accomplished with a trial data collection period. The goal of the trial data collection event is to attempt to collect all the requisite data from two to three dairies to confirm that the data can be collected as defined in Table 1 and that they can be used to calculate the salt load as defined in the salt load and offset calculations. The collected data will then be loaded into the database and the series of calculations tested for accuracy, compared to manual calculations of the results. This data trial will help finalize the database structure and the salt load calculations.

Data Collection Program

Having a well thought-out data collection program is essential to ensuring that a consistent set of data is collected from each dairy. It is important that the data collection program be designed to collect the minimum set of data needed to calculate salt loads and to capture as many site-specific operational details as possible at each individual dairy.

The data proposed for collection can be categorized into two data types. The first set of data defines the operational criteria of the dairy and is not likely to change from year to year (e.g. lagoon capacity). The second set includes data that are variable from year to year (e.g. number of milking cows). Accordingly, the data collection program should be treated as a two-part effort: (1) an initial audit of dairy operations and (2) an annual survey of dairy activities. Below, the recommended procedures for performing the initial dairy audit and the annual dairy survey are described. It is recommended that this methodology be tested as part of the database design verification efforts described above.

Initial Dairy Operations Audit: The objective of the initial dairy audit is to identify the operational variables that define each dairy's day-to-day manure and water budget and, thus, the overall salt budget. The manure, water, and salt transfers previously defined in Figures 1 and 2 were generalized portrayals of the pathways that occur on a dairy. The information gathered during the initial audit should include the level of detail needed to create site-specific manure and water budget diagrams, as shown in Figures 1 and 2.

The first step of the dairy operations audit is to review a dairy's EWMP to define all the operational units that generate and/or use water and manure (e.g. corrals, disposal fields, lagoons, etc.). A map of the delineated dairy operational areas can be overlaid on an aerial photograph and reviewed with the dairy operators to confirm that the operational units have not changed since the EWMP was created. Appendix C, included as an attachment to this report, is a map that shows the recommended level of detail. The second step of the dairy audit is to conduct a site visit with the dairy's operations managers to confirm that the data collected from the EWMP is accurate and to define the variables that are not available in the EWMP. Appendix C also contains a short survey form that can be filled out during the initial dairy audit to help define water uses on the dairy. Finally, during the site visit, an explanation of all the data that need to be collected and recorded as part of the annual data survey should be provided to dairy operators.

Annual Dairy Data Survey: The objectives of the annual dairy survey are (1) to confirm that the operational criteria defined during the initial dairy audit are still valid and (2) to collect the data needed to compute the dairy's annual salt load offset requirement for the preceding calendar year. Currently, each individual dairy reports to the Regional Board on an annual basis. The annual report contains an average annual cattle count, a list of the crops grown on the dairy property, the area of cropland cultivated, a manifest detailing the amount of manure applied to on-site cropland, and a manifest detailing the amount of manure hauled from the dairy during the calendar year. Appendix D, included as an attachment to this report, is a proposed survey form that can be used to report the data collected during the calendar year. The proposed survey was designed as a more detailed version of the existing annual report.

CONCLUSIONS AND RECOMMENDATIONS

The database described in this report represents a conceptual database design, not necessarily the final design that should be implemented. The conceptual design takes into consideration the current state of regulatory requirements and the ability to collect the data variables that are required to estimate dairy salt loads and salt load offset requirements. Clearly, data measured in the field, if done properly, will greatly improve the estimation of TDS loading and is preferred over using published

parameters to make the estimations. The design of the conceptual database is not meant to ignore this fact. However, it is difficult, and somewhat impractical, to design a database based on uncertain future monitoring program requirements. The complexity of implementing monitoring programs to collect data of the quality needed to make the estimations was discussed in Table 1. The key point noted in Table 1 is that in the absence of a mandatory dairy monitoring program that specifies a detailed data collection protocol (SAP), it is not practical to assume that the dairies will collect this information voluntarily. Thus, the salt load calculations presented in this report followed a methodology that allowed for estimation of the TDS in the absence of measured data. This approach is prudent and practical in the absence of a well-designed, robust, mandatory dairy metering program that can demonstrably produce useful data.

The following are recommendations for a mandatory monitoring program that will improve estimation of salt load and salt offset requirements, and thus a final database design:

1. As part of a dairy monitoring program, the Regional Board should require dairies to meter all of their water sources. Metering the movement of water on farms can be problematic and unreliable. To be useful, the metering program of water supplies that contribute to wastewater will require detailed specifications and periodic calibration and testing. Because there will be periods when the meter malfunctions or completely fails, a secondary method to estimate volume should not be dismissed. Thus, the data described in this report to make water supply estimations should still be collected and stored.

2. As part of a dairy monitoring program, the Regional Board should require dairies to meter the movement of wastewater on the facility (e.g. from lagoons to crop fields and from lagoons to disposal fields). Metering the movement of wastewater is likely to be even more problematic and unreliable than metering of water sources given the variety of means dairies can use to transport the water between disposal areas (e.g. pipelines and unlined ditches). To be useful, the metering program will require detailed specifications, such as meter type and installation procedure. It is important to note that a mandate to meter wastewater movement will require dairies to upgrade their facilities.

3. As part of a dairy monitoring program, the Regional Board should require dairies to implement a solid manure sampling program. All manure leaving the facility or being applied to the on-site cropland should be analyzed for solid and moisture content (i.e. % solids and % moisture) as well as salt content. At a minimum sampling should occur during each hauling event. Manure that is stockpiled for crop field application should be sampled quarterly.

4. As part of a dairy monitoring program, the Regional Board should require dairies to implement a water quality monitoring program. This program should include the collection of source water quality, wastewater quality, and stored lagoon water quality. Source waters should be sampled at least once per year. Wastewater quality is more difficult to characterize and should be sampled more frequently. It is recommended that an intensive monitoring program be implemented initially that can then be scaled back once an understanding of the variability of wastewater quality has been achieved. Intensive could mean anything from weekly to monthly sampling of wastewater. The goals of the intensive monitoring program would be to understand the average salt concentration of wastewater as it leaves the barn

(composite versus grab sampling) and the average salt concentration of wastewater stored in disposal lagoons.

In the event that a dairy monitoring program is not mandated, the conceptual database design presented in this report provides a practical approach for the collection and storage of dairy specific data and for the calculation of dairy salt load offset requirements.

It has been our pleasure to assist Tetra Tech with this important and timely analysis. Please call me at 949.420.3030 if you have any questions or concerns.

Wildermuth Environmental, Inc

Mark Wildermuth
Chairman

Samantha Stevens
Senior Scientist

Enclosures: Table 1
Appendix A – Salt Load Tracking Database Entity Relationship Diagram
Appendix B – Salt Load Tracking Database Dictionary
Appendix C – Map of Dairy Operations Areas and Initial Data Collection Form
Appendix D – Annual Dairy Survey Form
Appendix E – Comments and Responses

Table 1

Variables Needed to Calculate the Salt Load and Salt Offset	Is the Data Measurable?	Can the Values Be Estimated?	Notes on the Collection of the Data Needed to Calculate the Salt Load and Salt Offset
Cattle counts, by cattle type	Yes	No	Cattle counts are easily measurable and the numbers reported should reflect the average number of cattle present during the reporting period. If further refinement of manure generation assumptions is desired, it is recommended that a final database design allow the cattle counts to be further refined into size classes.
Manure salt content	Yes	Yes	The salt content of manure can be measured or estimated. Literature values on typical manure salt content are available. However, the salt content of manure is highly dependent on diet. A site specific ratio of salt content can be developed by analyzing manure collected from a dairy's utility areas and corrals. To develop a site-specific manure content ratio, it is recommended that manure content be analyzed four times during a one-year period to account for any seasonal variations.
Total weight of manure produced in corrals and feeding areas	No	Yes	It is not practical to directly measure the amount of manure produced by each cattle type. Literature values exist that can be used to estimate how much an individual cow produces in a given time period. Furthermore, by estimating the time spent by each cattle type in the corrals and feeding areas, the amount of manure that is disposed of as solid waste can be estimated. In cases where the amount of manure that is exported off-site, applied to crops, or stockpiled on-site cannot be directly measured, it is important to be able to estimate the total amount of solid manure waste generated.
Total weight of manure produced in the milk barn	No	Yes	It is not practical to directly measure the amount of manure produced in the milk barn. Literature values exist that can be used to estimate how much an individual cow produces in a given time period. Furthermore, by estimating the time spent by each cattle type in the milk barn, the amount of manure that is disposed of in wastewater can be estimated.
Weight of manure hauled off property	Yes	Yes	To avoid calculating solid manure salt loads from estimated values, the total weight and moisture content of manure hauled from the property should be directly measured during each hauling event.

Table 1

Variables Needed to Calculate the Salt Load and Salt Offset	Is the Data Measurable?	Can the Values Be Estimated?	Notes on the Collection of the Data Needed to Calculate the Salt Load and Salt Offset
Weight of manure applied to on-site crops	Yes	Yes	Given the requirement of applying manure to croplands (as fertilizer) at agronomic rates, the weight and moisture content at the time of each application should be measured and recorded.
Weight of manure stockpiled	Yes	Yes	To avoid calculating solid manure salt loads from estimated values, the total weight (and moisture content) of manure stockpiled on the property should be directly measured and tracked at the end of the year.
Water use for milk barn operations	Yes	Yes	To ensure the most accurate salt load calculations, this variable should be measured and not estimated. However, metering the movement of water on farms has always been problematic and unreliable. To be useful, the metering of water supplies that contribute to wastewater will require detailed specifications (meter type and installation) and periodic calibration and testing. There will be periods when the meter malfunctions or completely fails that will require a secondary method to estimate volume. In cases where a dairy cannot directly meter how much source water is distributed to its milk barn, the alternative is to calculate the volume of wastewater produced from the total water production of the dairy and the estimation of water use for consumption by cattle. Alternatively, a dairy can estimate the water use based on milk barn operational data, including the model of sprinklers used, the flow rates of sprinklers, the number of washes per day (in the winter and summer), the duration of washing events, and other milk barn washing requirements.

Table 1

Variables Needed to Calculate the Salt Load and Salt Offset	Is the Data Measurable?	Can the Values Be Estimated?	Notes on the Collection of the Data Needed to Calculate the Salt Load and Salt Offset
Total water use	Yes	No	Measuring the total volume of water used on a dairy is critical if it is not possible to meter the amount of water that is used in the milk barn. Dairies in the San Jacinto region use groundwater pumped on-site, water purchased from the EMWD, or both. In either case, the EMWD can provide the dairy operators with water production data. Purchased water volumes appear on monthly invoices. And, the EMWD will equip groundwater wells with meters and record production volumes on a monthly basis for dairies that volunteer to participate in its groundwater monitoring efforts. See discussion on "Water use for milk barn operations" for a review of the complications in metering water sources.
Water use for consumption by cattle	Yes	Yes	In cases where a dairy cannot directly meter how much water is distributed to the milk barn, it will be crucial to estimate what volume of the total water production on the dairy is consumed by cattle and, therefore, not included in the final wastewater discharge volume (or salt offset requirement). Literature values on cattle water consumption are available to make this estimation.
TDS concentration, by supply source	Yes	No	The quality of each source water should be measured annually. In the San Jacinto region, most dairies use groundwater that is pumped on-site or water purchased from the EMWD. In either case, the EMWD can provide this data to the dairies. Purchased water quality data is available in EMWD's annual consumer confidence reports. For on-site groundwater quality measurements, the dairy simply needs to volunteer to participate in the EMWD's annual groundwater sampling events, and the data will be collected by EMWD staff at no cost to the dairy.
Volume of wastewater generated	Yes	Yes	The volume of wastewater generated is assumed to be equal to the water produced for use in the milk barn.

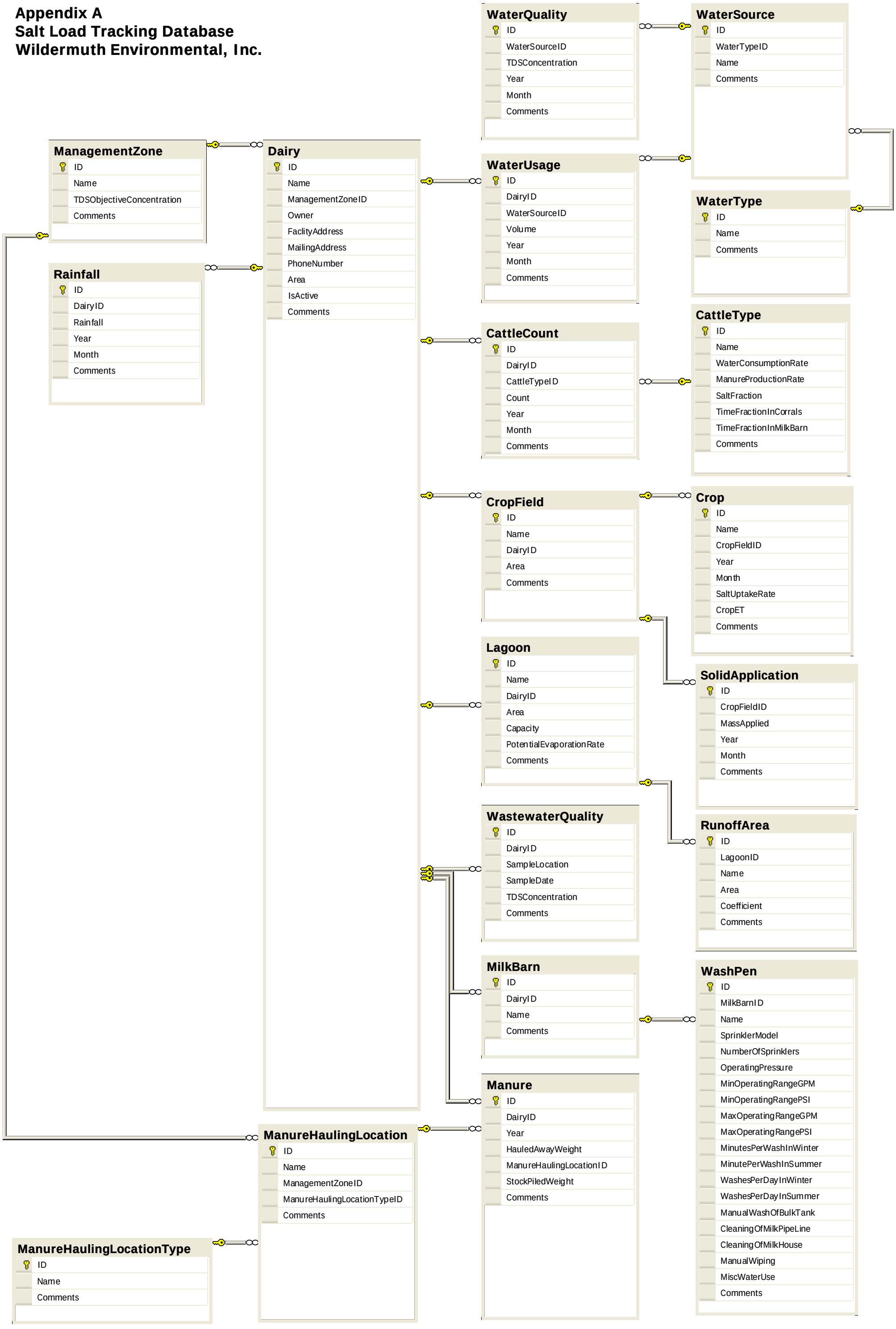
Table 1

Variables Needed to Calculate the Salt Load and Salt Offset	Is the Data Measurable?	Can the Values Be Estimated?	Notes on the Collection of the Data Needed to Calculate the Salt Load and Salt Offset
TDS concentration of wastewater (upon leaving milk barn)	Yes	Yes	The TDS concentration of dairy wastewater can either be measured or estimated. To ensure the most accurate salt load calculations, this variable should be measured directly and not estimated. However, water quality monitoring on dairies has been problematic, if not impossible, to implement in other regions without regulatory requirements. To be useful, the samples need to be collected frequently to account for a variety of seasonal and operational variations. And, ideally samples should be collected randomly (no warning given as to the date of the sampling). In the absence of measured data, the concentration can be estimated from source water concentrations and the amount of manure produced in the milk barn.
Distribution of wastewater among disposal areas (lagoons, disposal fields, and crop fields)	No	No	At present, no site-specific data exist on the volumes of wastewater distributed to the various disposal areas of a given dairy. The highly unique operational criteria of each dairy, which define how water is moved and distributed, also make this an unrealistic variable for data collection. The shortcomings of this variable are discussed in detail in the report text. It may be possible to meter the movement of the water between disposal areas, but this could be problematic as discussed in the "water use" section above. In the absence of a regulatory requirement to metered the data, it is not practical to expect the dairies to collect this level of detailed data.
Volume of water evaporated from wastewater lagoons	No	Yes	The EWMPs of the dairies provide potential evaporation rates (based on historical climate data and lagoon design specifications) that can be used to estimate the amount of water lost through evaporation.
Volume of water consumed by crops and disposal fields	Yes	Yes	The volume of water consumed by on-site crop fields and disposal fields is related to potential evapotranspiration, the specific vegetation type, the area of the crop field, and the duration of crop growth. All of these variables are collectible data. Dairies should keep detailed records of each crop they grow during the year. Reference evapotranspiration data are available from local CIMIS stations in Riverside, Winchester, and Temecula. These data can be collected annually. Literature values on crop-specific water requirements (e.g. crop coefficients) are also available for use in this estimation.

Table 1

Variables Needed to Calculate the Salt Load and Salt Offset	Is the Data Measurable?	Can the Values Be Estimated?	Notes on the Collection of the Data Needed to Calculate the Salt Load and Salt Offset
Salt uptake by crops	Yes	No	The salt uptake rate of a particular crop will factor into the mass of salt removed from the system by crop fields. A dairy must have a salt management plan that demonstrates site-specific uptake rates to take credit for this removal.
Volume of water added to dairy disposal areas from precipitation	No	Yes	The volume of water added by precipitation equals direct rainfall on the disposal areas of the dairy as well as runoff that is diverted to the wastewater lagoons. The EWMPs provide data on the size of all runoff generating surfaces on the dairy and associated runoff coefficients. Care should be taken not to double count precipitation/runoff from disposal fields that may divert water to disposal lagoons during precipitation events. Precipitation data are available from local CIMIS stations in Riverside, Winchester, and Temecula. These data can be collected annually. Given that precipitation in the San Jacinto Region is highly variable, a final database design might consider the incorporation of dairy-specific precipitation measurements to calculate the volume of water added to the disposal areas.

Appendix A
Salt Load Tracking Database
Wildermuth Environmental, Inc.



Appendix B
Salt Load Tracking Database Dictionary

Table	Column	Description
CattleCount	ID	Unique identifier and primary key.
CattleCount	DairyID	Link to Dairy.ID to which the cattle record belongs.
CattleCount	CattleTypeID	Link to CattleType.ID
CattleCount	Count	Number of the cattle of the respective cattle type [CattleTypeID] in the repective year [Year] and [Month] of the respective dairy [DairyID]
CattleCount	Year	Year, which the cattle record refers to. Year is expressed in yyyy, for example 2010.
CattleCount	Month	Month, which the cattle record refers to. Valid values are between 1 and 12.
CattleCount	Comments	Comments
CattleType	ID	Unique identifier and primary key.
CattleType	Name	Name of a type of cattle.
CattleType	WaterConsumptionRate	Water consumption per cattle per day [gal/day]
CattleType	ManureProductionRate	Dry weight of manure produced per cattle per day [lb/day].
CattleType	SaltFraction	Fraction of salt content of dry manure of the respective cattle type. Manure commonly contain 4 to 5% soluble salts (dry weight basis) and may run as high as 10%. refer to http://www.ecochem.com/t_manure_fert.html for details.
CattleType	TimeFractionInCorrals	Fraction of time (between 0 and 1) that particular cattle type would be held in corrals.
CattleType	TimeFractionInMilkBarn	Fraction of time (between 0 and 1) that particular cattle type would be held in milkbarn.
CattleType	Comments	Comments
Crop	ID	Unique identifier and primary key.
Crop	Name	Name of the crop
Crop	CropFieldID	Link to CropField.ID
Crop	Year	The year that the respective crop is grown. Year is expressed in yyyy format, for example 2010.
Crop	Month	The month that the respective crop is grown. Month is expressed in mm format, where mm ranges from 1 to 12.

Appendix B
Salt Load Tracking Database Dictionary

Table	Column	Description
Crop	SaltUptakeRate	Defines the rate of salt taking in or absorbing by living organism, such as crops. The rate is expressed in [lb/day/acre].
Crop	CropET	Crop evapotranspiration [ft/day]. See http://www.fao.org/docrep/X0490E/x0490e0a.htm or http://www.ipm.iastate.edu/ipm/icm/2000/5-29-2000/wateruse.html for details.
Crop	Comments	Comments
CropField	ID	Unique identifier and primary key.
CropField	Name	Name of a crop field
CropField	DairyID	Link to Dairy.ID to which the cropfield belongs.
CropField	Area	Area where salt-uptake takes place. The unit of area is [sq ft].
CropField	Comments	Comments
Dairy	ID	Unique identifier and primary key.
Dairy	Name	Name of the dairy
Dairy	ManagementZoneID	Link to ManagementZone.ID
Dairy	Owner	Name of the owner of the dairy.
Dairy	FaclityAddress	Address of the dairy
Dairy	MailingAddress	Mailing addrss of the dairy
Dairy	PhoneNumber	Phone number of the dairy
Dairy	Area	Area of the dairy in [acres]
Dairy	IsActive	Defines whether the dairy is in operation or closed.
Dairy	Comments	Comments
Lagoon	ID	Unique identifier and primary key.
Lagoon	Name	Name of the lagoon
Lagoon	DairyID	Link to Dairy.ID
Lagoon	Area	Area of the lagoon [acres]
Lagoon	Capacity	Design capacity of the lagoon in acre-ft.

Appendix B
Salt Load Tracking Database Dictionary

Table	Column	Description
Lagoon	PotentialEvaporationRate	Potential evaporation rate of the lagoon that is used in the design specification. The unit is ft/day.
Lagoon	Comments	Comments
Management Zone	ID	Unique identifier and primary key.
Management Zone	Name	Name of the respective management zone.
Management Zone	TDSObjectiveConcentration	Objective TDS concentration in the groundwater of the respective management zone.
Management Zone	Comments	Comments
Manure	ID	Unique identifier and primary key.
Manure	DairyID	Link to Dairy.ID
Manure	Year	Year that the record data pertain. Year is expressed in yyyy, for example 2010.
Manure	HauledAwayWeight	The weight of manure that is hauled away from the dairy to the specified hauling location. Weight is expressed in short tons.
Manure	StockPiledWeight	The weight of manure that is stockpiled on the dairy. Weight is expressed in short tons.
Manure	Comments	Comments
ManureHaulingLocation	ID	Unique identifier and primary key.
ManureHaulingLocation	Name	Name of manure hauling location
ManureHaulingLocation	ManagementZoneID	Link to ManagementZone.ID
ManureHaulingLocation	ManureHaulingLocationTypeID	Link to ManureHaulingLocationTyoe.ID
ManureHaulingLocation	Comments	Comments
ManureHaulingLocationTypeID	ID	Unique identifier and primary key.
ManureHaulingLocationTypeID	Name	Name of the manure hauling location type
ManureHaulingLocationTypeID	Comments	Comments
MilkBarn	ID	Unique identifier and primary key.
MilkBarn	DairyID	Link to Dairy.ID.
MilkBarn	Name	Name of the Milk Barn.
MilkBarn	Comments	Comments

Appendix B
Salt Load Tracking Database Dictionary

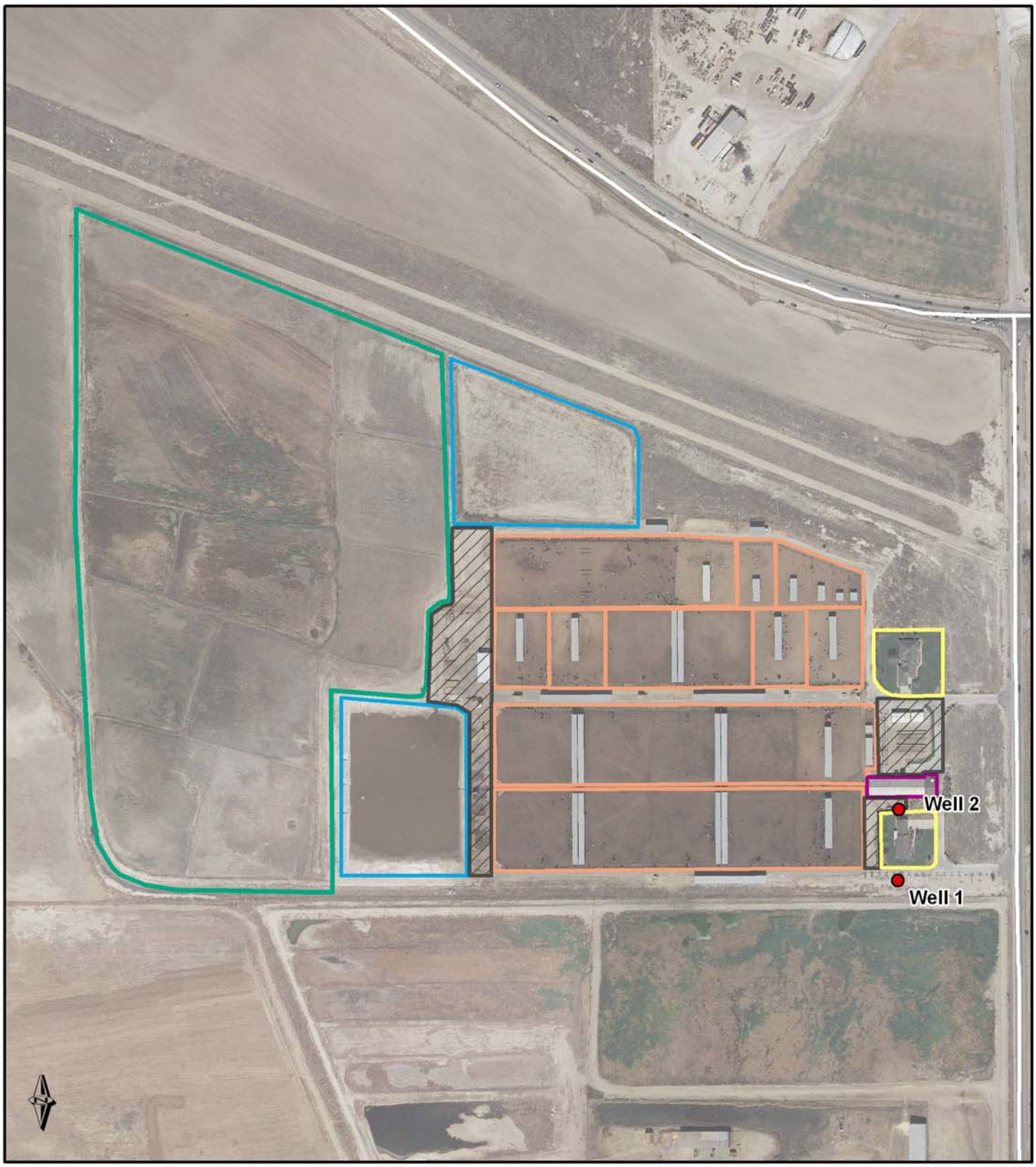
Table	Column	Description
Rainfall	ID	Unique identifier and primary key.
Rainfall	DairyID	Link to Dairy.ID
Rainfall	Rainfall	Total rainfall of the respective year and month. The unit of Rainfall is [in].
Rainfall	Year	Year to which the Rainfall pertains. Year is expressed in yyyy, for example 2010.
Rainfall	Month	Month to which the Rainfall pertains. Month is expressed in mm format, where mm ranges from 1 to 12.
RunoffArea	ID	Unique identifier and primary key.
RunoffArea	LagoonID	Link to Lagoon.ID where the runoff water is collected. If runoff area is linked to multiple lagoons, the runoff water is evenly distributed to the lagoons.
RunoffArea	Name	Name of the runoff area
RunoffArea	Area	Area of the runoff area in [acres].
RunoffArea	Coefficient	Runoff coefficient.
RunoffArea	Comments	Comments
SolidApplication	ID	Unique identifier and primary key.
SolidApplication	CropFieldID	Link to CropField.ID
SolidApplication	MassApplied	The weight of dry manure applied during the specific year. The unit is short tons.
SolidApplication	Year	Year to which MassApplied pertains. Year is expressed in yyyy, for example 2010.
SolidApplication	Month	Month to which MassApplied pertains. Month is expressed in mm format, where mm ranges from 1 to 12.
SolidApplication	Comments	Comments
WashPen	ID	Unique identifier and primary key.
WashPen	Name	Name of the wash pen.
WashPen	SprinklerModel	Model name of the sprinkler.
WashPen	NumberOfSprinklers	Number of sprinklers in the wash pen.
WashPen	OperatingPressure	Operating pressure of the sprinkler in psi.
WashPen	MinOperatingRangeGPM	Flow rate (in GPM) of the sprinklers at the lower bound of the operating range.
WashPen	MinOperatingRangePSI	Mininum Operating pressure of the sprinklers in PSI.

Appendix B
Salt Load Tracking Database Dictionary

Table	Column	Description
WashPen	MaxOperatingRangeGPM	Flow rate (in GPM) of the sprinklers at the upper bound of the operating range.
WashPen	MaxOperatingRangePSI	Maximum Operating pressure of the sprinklers in PSI.
WashPen	MinutesPerWashInWinter	Number of minutes per wash in Winter.
WashPen	MinutePerWashInSummer	Number of minutes per wash in Summer.
WashPen	WashesPerDayInWinter	Number of washes in per day in Winter.
WashPen	WashesPerDayInSummer	Number of washes in per day in Summer.
WashPen	ManualWashOfBulkTank	Water usage rate in gal/day used for manual wash of bulk tank.
WashPen	CleaningOfMilkPipeLine	Water usage rate in gal/day used for cleaning of milk pipelines.
WashPen	CleaningOfMilkHouse	Water usage rate in gal/day used for cleaning of milkhouse and parlor floors
WashPen	ManualWiping	Water usage rate in gal/day used for manual wiping of cows afer pre-wash.
WashPen	MiscWaterUse	Additional water usage rate in gal/day that is not account for.
WastewaterQuality	ID	Unique identifier and primary key.
WastewaterQuality	DairyID	Link to Dairy.ID.
WastewaterQuality	SampleLocation	Description of the sample location, e.g., lagoon #1.
WastewaterQuality	SampleDate	DateTime when the water sample is taken.
WastewaterQuality	TDSConcentration	[mg/L].
WastewaterQuality	Comments	Comments
WaterQuality	ID	Unique identifier and primary key.
WaterQuality	WaterSourceID	Link to WaterSource.ID
WaterQuality	TDSConcentration	TDS Concentration of the water source at given year/month. The unit of TDS concentration is [mg/L].
WaterQuality	Year	Year to which Volume and TDSConcentration pertain. Year is expressed in yyyy, for example 2010.
WaterQuality	Month	Month to which Volume and TDSConcentration pertain. Valid values are between 1 and 12.
WaterQuality	Comments	Comments
WaterSource	ID	Unique identifier and primary key.
WaterSource	WaterTypeID	Link to WaterType.ID

Appendix B
Salt Load Tracking Database Dictionary

Table	Column	Description
WaterSource	Name	Name of the water source
WaterSource	Comments	Comments
WaterType	ID	Unique identifier and primary key.
WaterType	Name	Name of a type of water
WaterType	Comments	Comments
WaterUsage	ID	Unique identifier and primary key.
WaterUsage	DairyID	Link to Dairy.ID
WaterUsage	WaterSourceID	Link to WaterSource.ID
WaterUsage	Volume	Amount of water usage of the respective water type and year. The unit of volume is [gal]
WaterUsage	Year	Year to which Volume and TDSConcentration pertain. Year is expressed in yyyy, for example 2010.
WaterUsage	Month	Month to which Volume and TDSConcentration pertain. Valid values are between 1 and 12.
WaterUsage	Comments	Comments



Dairy Features

Corral	Milkbarn
Lagoon	Concrete Utility Area
Field	Dairy Wells
Residence	

Dairy Operations Layout of Dairy X

Appendix C

Initial Dairy Audit

Facility Information

Facility Name:
Facility Address:
Mailing Address:
Telephone Number:

Figure 1 is a map describing the location and name of the operational units on this facility, including corrals, utility areas milk barns, wastewater lagoons, disposal fields, and crop fields. This map of the dairy was developed using the information available in the facility's Engineered Waste Management Plan (EWMP). Please review the figure and describe any changes that have been made since the creation of the EWMP below.

Water Supply Information

Water Sources & Capacity

List all water sources available on the dairy, including back-up sources. For each source indicate the capacity (e.g. well production rate).

	Sources	Capacity	Notes
1			
2			
3			
4			
5			

Water Use Prioritization

Identify all the water uses at the dairy. For each use please identify all sources that are used to meet the demand. If dairy wastewater is used for irrigation, please make sure to indicate so here, and note how the water is delivered to the crop fields.

	Water Use (Demand)	Water Supply	Notes:
D1		1	
		2	
		3	
D2		1	
		2	
		3	
D3		1	
		2	
		3	
D4		1	
		2	
		3	
D5		1	
		2	
		3	
D6		1	
		2	
		3	
D7		1	
		2	
		3	

Dairy Wash Water Requirements

Wash Pen Information

Sprinkler Model: _____

Operating Range: _____ gpm @ _____ psi

_____ gpm @ _____ psi

Operating Pressure at Wash barn: _____ psi

Sprinklers Per Wash Pen Area: _____

Cows Per Wash Pen: _____

Operating Time (Winter): _____ min/wash Operating Time (Summer): _____ min/wash

Washes Per Day (Winter) : _____ Washes Per Day (Summer): _____

Milk Barn Water Usage Less Wash Pen Sprinklers

Manual Wash of Bulk Tank _____ gal/day

Cleaning of Milk Pipelines _____ gal/day

Cleaning of Milkhouse/Parlor Floors _____ gal/day

Manual Wiping of Cows After Pre-Wash _____ gal/day

Other _____ gal/day

Total _____ gal/day

Notes:

Annual Dairy Survey

Reporting Period:

Survey Report Due Date:

Facility Information	
Operator's Name:	Dairy Operator 1 & Dairy Operator 2
Facility Name:	Dairy X
Facility Address:	1000 N. Ramona Expressway San Jacinto, CA 92582
Mailing Address:	1000 N. Ramona Expressway San Jacinto, CA 92582
Telephone Number:	(951) 000-0000

Has any of the facility information listed above changed since the last reporting period? Yes No

If yes, please make corrections directly on the form.

Has any of the dairy layout information in the attached figure changed? Yes No

If yes, please detail the changes here:

Water Supply Information

Water Sources & Capacity

List all water sources available on the dairy, including back-up sources. For each source indicate the capacity (e.g. well production rate).

	Sources	Capacity	Notes
1			
2			
3			
4			
5			

Water Use Prioritization

Identify all the water uses at the dairy. For each use please identify all sources that are used to meet the demand. If dairy wastewater is used for irrigation, please make sure to indicate so here, and note how the water is delivered to the crop fields.

	Water Use (Demand)	Water Supply	Notes:
D1		1	
		2	
		3	
D2		1	
		2	
		3	
D3		1	
		2	
		3	
D4		1	
		2	
		3	
D5		1	
		2	
		3	
D6		1	
		2	
		3	
D7		1	
		2	
		3	

Has the water supply and demand information listed on this page changed since the last reporting period? Yes No

If yes, please make corrections directly on the form, and detail changes in the notes.

Please review and confirm that the following operational criteria have not changed since the last annual survey.

Dairy Wash Water

Wash Pen Information

Sprinkler Model: _____

Operating Range: _____ gpm @ _____ psi

_____ gpm @ _____ psi

Operating Pressure at Wash barn: _____ psi

Sprinklers Per Wash Pen Area: _____

Cows Per Wash Pen: _____

Operating Time (Winter): _____ min/wash Operating Time (Summer): _____ min/wash

Washes Per Day (Winter) : _____ Washes Per Day (Summer): _____

Milk Barn Water Usage Less Wash Pen Sprinklers

Manual Wash of Bulk Tank _____ gal/day

Cleaning of Milk Pipelines _____ gal/day

Cleaning of Milkhouse/Parlor Floors _____ gal/day

Manual Wiping of Cows After Pre-Wash _____ gal/day

Other _____ gal/day

Total _____ gal/day

Has the wash pen and milk barn information listed above changed since the last reporting period? Yes No

If yes, please make corrections directly on the form, and detail changes here, and include date changes were made:

_____

_____

_____

_____

_____

_____

Cattle Counts

Enter the number of cattle, by cattle type, on the dairy property for each month.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Milking Cows												
Dry Cows												
Heifers												
Calves												
Other												

Crop Calendar

List the crop type grown on each field (C1 - C3) and indicated which months the crop was grown during the reporting period. (See Figure 1 for field layout).

	Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Field 1	C1												
	C2												
	C3												
Field 2	C1												
	C2												
	C3												
Field 3	C1												
	C2												
	C3												
Field 4	C1												
	C2												
	C3												
Field 5	C1												
	C2												
	C3												

Manure Calendar

Manure Spread to Crops (tons)

List the crop field name and enter the weight of manure spread at that location (in tons) for the corresponding month.

	Crop Field	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1													
2													
3													
4													
5													

Manure Hauled Offsite (tons)

List the name of each hauling location and enter the weight of the manure hauled to that location (in tons) for the corresponding month. Provide the hauling location address in the section below.

	Haul Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1													
2													
3													
4													
5													

Manure Hauling Location

List the manure hauling address and county.

	Haul Location	Address	County
1			
2			
3			
4			
5			

Manure Stockpiled (tons)

Enter the weight of manure that is stockpiled on site as of December 31st. _____

Water Usage

Monthly Water Use Volume (acre-feet)

Enter the volume of water in acre-feet used each month from all water sources on the property.

	Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1													
2													
3													
4													
5													
6													

Source Water Quality

Enter the total dissolved solids (TDS) value in mg/L, in the month the sampled was collected, for all water sources on the property.

	Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1													
2													
3													
4													
5													
6													

Wastewater Water Quality

Enter the average total dissolved solids (TDS) value in mg/L for all wastewater sampling events during the reporting period.

	Description of Sample Location	Sample Date	TDS mg/L	Comments
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				

A.1 ED KASHAK

Comment Number	Page Reference	Comment	Response
1.	8	Why is the mass of the stocked piled manure (MS,t) being subtracted from the mass of manure that was exported out of the Region (ME,t)? Seems like ME,t should be subtracted from MS,t.	There was a typographical error in the equation in the draft report. It should have read: $SL_{R,t} = SF*(M_{E,t} + M_{S,t}) + SL_{CU,c,t}$ It is intended to be the sum of all salt removed from the system in time period t. The mass of stockpiled manure and the mass of manure exported should be added together (and then multiplied by a conversion factor to obtain mass of salt). Also, $SL_{CU,c,t}$ should have been added to the salt load removed as solid manure. <u>The text will be modified to reflect this.</u>
2.	8	How can the mass of salt removed by crop uptake (SLCU,c,t) be subtracted from ME,t? The equation tells me that just the mass of salt, SLCU,c,t, is being subtracted from the mass of manure, ME,t & MS,t. In other words (for example) you could be subtracting 100 lb of salt from 100 tons of manure. That doesn't make sense to me. Seems like the equation is trying to subtract apples from oranges. Should there be a conversion factor for ME,t & MS,t to account for just the mass of salt in the mass of manure?	The equation was missing the conversion factor, SF, to convert the mass of manure to a mass of salt. <u>The text will be modified to reflect this.</u>

A.2 TETRA TECH

Comment Number	Page Reference	Comment	Response
G1.	n/a	We disagree with the dismissal of nitrogen at the beginning of the report. This goes to meeting the needs of the program the database is designed to support, as discussed on page 2 of the report. The utility of the database is in its ability to store and track information that will facilitate compliance with the salt offset requirement. The SJ dairies' compliance with the salt offset requirement includes offsetting the nitrate load as well as the TDS. While we agree that the nitrogen cycle is complex, for the project budget we would have expected at least a textbook sketch of the N mineralization - nitrification - denitrification cycle as it pertains to the NO3 issue in the watershed and how it would work on a dairy. We also expected recommendations for other variables to be tracked that would be important to a future evaluation of N issues, e.g., temperature (air, wastewater, manure, soil), moisture, oxygen, C.	Comment noted. Clearly there is communication breakdown between your expectations and what we proposed to do. That said our report presents a conceptual data base design and not a final design. To incorporate nitrogen would require the description of the nitrogen cycle and how it precisely works on a dairy, generalized to include all dairies in the San Jacinto area and be able to support the reporting requirements in a dairy permit.
G2.	n/a	There needs to be more emphasis on actual sampling and analysis of manure and wastewater, NOT estimation of TDS and salt contents. (see below)	Comment noted.

Comment Number	Page Reference	Comment	Response
S1.	n/a	There should be more emphasis on actual analysis of manure and water for salts and TDS and not give an option for estimation. A simple lab analysis is a lot easier to do than to try to figure out all the feed and management inputs that might affect the ww stream, plus our recent data show enough variation among dairies in ww TDS that we would not trust a textbook estimation applied to all dairies. Most important, our recent data show considerably higher TDS concentrations in ww than Wildermuth estimated in the previous report.	Comment noted. Our report presents a conceptual data base design and not a final design. Certainly the availability of frequent and representative analytical results would greatly improve the estimation of TDS loading. The salt load offset requirement calculations could be modified to incorporate these analytical data if these data are mandated for collection in a routine dairy monitoring program. The text will be modified to reflect this. (see Conclusions and Recommendations) That said, water quality monitoring on dairies has been problematic, if not impossible, to implement in other regions without regulatory requirements. To be useful, the samples need to be collected according to a detailed sampling and analysis plan (SAP) and ideally collected frequently and randomly (no warning given as to the date of the sampling). In the absence of regulation, the textbook data needed for estimation would need to be collected as well to continuously estimate TDS loading (or the loading of nutrients and other chemicals of interest). Finally, while some of the sampling results collected by Tetra Tech are considerably higher than the estimations made by WEI in 2008, it is important to note that a single sampling event on a dairy cannot be considered representative of the quality of the wastewater leaving the barn or in the lagoons. The dairies and the Regional Board need to develop a rigorous scientifically-based sampling and analysis plan and subsequently implement a monitoring program based on this SAP. The monitoring

Comment Number	Page Reference	Comment	Response
			program will need to initially include a high frequency sampling program followed by a less frequent sampling program.
S2	n/a.	We would like to see a clear recommendation to meter water supply that contributes to ww volume, rather than estimating based on sprinklers and milkbarn washing procedures or cow water consumption. As with chemical analysis, a meter is site-specific and seems much simpler than trying to collect all sorts of information to make an estimate.	Comment noted. Clearly metering, if done well, will improve the estimation of TDS loading. The salt load offset requirement calculations could be modified to incorporate these measured data if these data are mandated for collection in a routine dairy monitoring program. The text will be modified to reflect this. That said, metering the movement of water on farms has always been problematic and unreliable. To be useful, the metering of water supplies that contribute to wastewater will require detailed specifications (meter type and installation) and periodic calibration and testing. There will be periods when the meter malfunctions or completely fails that will require a secondary method to estimate volume. Metering information would need to be recorded as well as the other information as we have already described to continuously estimate TDS loading (or the loading of nutrients and other chemicals of interest).
S3.	n/a	If the focus is only on TDS (as in this report) then we see little reason to track movement of manure around within the dairy (except of course for land application). The report recommends, for example, that the quantities of manure stockpiled should be tracked in detail. It is not clear why this is important for conservative constituents like TDS because that manure eventually leaves the facility, along with all its salts. Of course, if this effort	See response to comment S16 for further explanation on the rational for tracking manure stockpiles.

Comment Number	Page Reference	Comment	Response
		were expanded to track N issues, then knowledge of size, age and other characteristics of manure stockpiles would be very important to collect data on variables influencing the N cycle.	
S4.	n/a	We recommend that all manure leaving the facility or being applied to facility cropland be analyzed for % dry matter (a.k.a. % solids, % moisture). This is a permit requirement for large CAFOs, but if you want to calculate salt loads with any accuracy, it needs to be done for all manure and more than once a year, ideally for each and every hauling event. It is reasonable to expect stockpiled manure to be lower moisture than corral manure and for % dm to vary with age in either type of manure. Knowledge of % dm is critical to convert any manure analytical results to dry weight basis, which allows you to know exactly how many tons of salts are moving with the manure and allows direct comparison of manures with different moisture contents.	Comment noted. The text will be modified to reflect this. (see Conclusions and Recommendations)
S5.	n/a	A meaningful salt balance calculation should include measurement/estimation/tracking of salts shipped off the dairy in milk and meat, as well as accumulation of salts in bovine tissues. This report (as well as our recent sampling project) assume that TDS in source water (+ spilled feed or cleaners, etc.) all goes into the wastewater. Some must be leaving in milk and either mortality or animals sold off the dairy. The Salt Load Removed equation seems an appropriate place to address this (with	Comment noted. We respectfully disagree.

Comment Number	Page Reference	Comment	Response
		a stipulation for mortalities that the salt load is not removed if the dead animal is disposed of on site or perhaps even within the SJ region).	
S6.	3	Figure 1 – should there be another blue arrow pointing from Lagoons to Crop Fields? (Possibly also from stockpile to lagoons)	An arrow was added to reflect that runoff from the stockpile/utility area can carry manure to the lagoons. An arrow was not added from the lagoons to the crop fields. Once the manure is mixed in the wastewater, it is not possible to track a mass of manure that ends up applied to the crop fields as irrigation water. This is salt transfer is discussed in the water budget.
S7.	4	Mass of manure exported to local farms: Add "during the defined time period"	Comment noted. The text will be modified to reflect this.
S8.	4	Mass of manure stored in on-site stockpile: Would you also need to know/account for the mass of manure stockpiled at the beginning of the time period?	This is assumed to be equal to the mass of manure stockpiled at the end of the previous time period and so there is no need to add an extra term to describe the mass of manure at the beginning of the time period. Refer to the discussion in *Methodology to Calculate Salt Loads and Offset Requirements* and explanation for the term $M_{S,t-1}$.
S9.	4	Mass of manure exported outside of the jurisdictional boundary of the Santa Ana Regional Board. This seems odd as there are no offset requirements that correspond to the regional board jurisdictional boundary. I'd prefer to see it as "Mass of manure exported outside the San Jacinto region to correlate to the description of Mass of manure exported to local farms or refer to San Jacinto watershed or the groundwater management zones or	The intent of this term was to account for the manure that is hauled from the facility that does not require a salt offset. The terminologies in the text and the database have been updated to make this issue clearer.

Comment Number	Page Reference	Comment	Response
		similar for both. Also, add "during the defined time period."	
S10.	4	Water Budget on a Dairy. Recommend expanding the discussion after "each dairy has a unique set of water supply sources" to describe the different sources used by SJ dairies.	Comment noted. The text will be modified to reflect this.
S11.	4.	Water Budget on a Dairy, "Water applied to croplands is consumed by the crops by evapotranspiration (ET) and the remainder percolates to into the underlying aquifer. The water lost through ET does not transfer salt. The mass of salt in the initial volume of water applied is concentrated and left behind to percolate to groundwater." We have a couple of problems with this: 1) some of the water taken up by the crops is assimilated into the crop tissue – not all is lost to ET, and 2) the crops also assimilate some nutrients, including some components of TDS, so it is not accurate to say that the entire mass of salt in the initial volume of water applied is left behind. We would like to see this modified, as it is in direct conflict with a section of our report that suggests phytoremediation (use of crops that are efficient at taking up salts) could be considered as part of a salt offset solution. This is also important if the discussion is modified to consider nitrate.	1) Comment noted. The amount water in the plant tissue is negligible compared to volume of water applied to the land and the volume lost to ET. 2) Comment noted. If a dairy implements a salt management plan, then they should be able to count this as a salt removal. The text will be modified to reflect this.

Comment Number	Page Reference	Comment	Response
S12.	6	Crop Coefficient – I'm not sure what this means – I think that crop water requirements are published/available – the "reference evapotranspiration rate" is confusing here – what does this do that can't be gained from the general crop water requirement?	Crop water requirements are not general, they are specific to the crop. In order for the reference evapotranspiration rate to be converted into a crop water requirement, you need to know the specific crop's "crop coefficient." For an explanation, please refer to: http://wwwcimis.water.ca.gov/cimis/welcome.jsp The inclusion of crop field water requirement AND the Crop Coefficient/ref. evapotranspiration was somewhat redundant. The text will be modified to reflect this.
S13.	6.	Salt uptake by crop type – this gets at the comments above but is inconsistent with the text in the preceding paragraph (see comment #11 above)	Comment noted. The text will be modified to reflect this.
S14.	6	Should you add volume of water transferred from lagoons to disposal/crop fields?	This is included as the term "distribution of wastewater among disposal areas" on page 6.
S15.	6 and Table 1	I'm not sure we necessarily agree that a dairy can't accurately measure distribution of wastewater among disposal areas. Where dairies are applying wastewater to croplands, they commonly install a flow meter so that they are able to control and record the amount of wastewater that is pumped to a particular field. It is unlikely that there would be more than a few pumping locations on a particular dairy; it doesn't strike us as particularly impractical to meter these pumping locations.	Comment noted. Clearly metering, if done well, will improve the estimation of TDS loading. The text will be modified to reflect this. Based on our experience in estimating impacts of dairies on groundwater we strongly disagree you're your last sentence. Metering the movement of water on farms has always been problematic and unreliable. To be useful, all water supplies used for crop irrigation crop would need to be metered and the metering will require detailed specifications (meter type and installation), periodic

Comment Number	Page Reference	Comment	Response
	6 and Table 1		calibration and testing. There will be periods when the meter malfunctions or completely fails that will require a secondary method to estimate volume. Dairy operation will continue after a dairy operator determines that his meter has failed and there will be period of time that the there will be no measurements. Metering information would need to be recorded as well as the other information as we have already described to continuously estimate TDS loading (or the loading of nutrients and other chemicals of interest). Furthermore, the dairy would need to meter more than just the water delivered to crops, it would also need to meter the water delivered to disposal fields. Our approach is prudent and practical in the absence of a well-designed, robust, mandatory dairy metering program that can demonstrably produce useful data.
S16.	7	Total Salt Load from Solid Manure, It might be more clear to add the following to the definition for MSt-1: "(the previous time period)." I had to re-read this before I understood that manure moved from corrals to stockpiles during time period t was not being double-counted. Also, I'm not sure about consideration of stockpiled manure here. If you're looking at a dairy's salt load at a point in time it makes sense, but it doesn't seem to make sense in looking at the salt offset requirement. The stockpiled	Comment noted. <u>The text will be modified to reflect this clarification.</u> The stockpiled manure needs to be tracked and is not being double counted. The salt offset requirement for a time period is the amount of salt added to the system; not necessarily the amount generated in that time period. More manure could be applied to crops than was generated because of the availability of stockpiled manure. The equations are set up so that if an amount of manure is

Comment Number	Page Reference	Comment	Response
		manure presumably was generated on the dairy–so it would seem that the salt offset requirement should only consider the manure generation–including stockpiled manure seems like double-counting (even though the salt offset equation is for time period t).	stockpiled in time period t, there is no offset requirement for that stockpiled amount in time period t. The salt offset (or salt removal) will be credited in the following time period (assuming the manure does not remain in the stockpile).
S17.	7	Salt Load Removed. This equation doesn't look correct: a. The SF is missing to convert the masses of manure to salt load b. Why would the mass of manure stockpiled be subtracted from the mass of manure exported? c. Shouldn't the SLCU,c,t be added to the ME,t? (But only with the stipulation that the crop is also removed from the area d. The geographic reference is not consistent with the salt offset requirement (see comment #9 above) e. Also see Ed Kashak's comments on this equation	a. Comment noted. The text will be modified to reflect this. b. This should be an addition, not a subtraction. The text will be modified to reflect this. c. This should be an addition, not a subtraction. The text will be modified to reflect this. d. See response to comment S9 e. See responses in E-1.1 and E-1.2.
S18.	8	Salt Load Offset Requirement. This assumes that all salt generated, except that which is exported or taken up by crops, percolates to groundwater. This might be fine as a conservative estimate (and may be the Regional Board's preference) but I would be more comfortable if the text highlighted that this is the assumption and pointed out that the entire mass of salt in solid manure generated during time period t is unlikely to leach from the manure and percolate through the soil profile. I believe the Regional Board will assume that the entire mass of salt will leach to groundwater eventually – this is perhaps	Comment noted. It is a conservative assumption and also reasonably accurate given the relative continuous nature of the salt loading. The text will be modified to say that provisions should be made in a final database design to store data that can be used describe a defensible geochemical process for TDS reduction in transit to the saturated zone.

Comment Number	Page Reference	Comment	Response
		another problem with calculating the offset requirement for a specific time period. I would also like to see the accompanying text acknowledge that there may be a certain amount of attenuation of some of the salt load in the soil profile (thereby leaving room for future refinement of this assumption based on new research)	
S19.	Table 1	Table 1, cattle counts by cattle type: Suggest adding a recommendation or suggestion to subdivide cattle types by size groups if further refinement of manure generation assumptions is desired.	Comment noted. Our report presents a conceptual data base design and not a final design. The table will be modified to reflect this as a recommended refinement for a final database design.
S20.	Table 1	Table 1, volume of wastewater added to dairy disposal areas. Should acknowledge that rainfall may be diverted to lagoons from disposal areas and this should not be counted twice. Would like to see recommendation to use dairy-specific precipitation measurements where possible since we have seen that precip can be highly variable from in different areas of the watershed during the same storm event.	Comments noted. The table and the database will be modified to reflect this. We recommend that Doppler Radar based precipitation estimates be considered as they have been proven to be highly accurate and easily downloadable.
S21.	Appendix A	Region – does this refer to a specific groundwater management zone? This is not defined in the Appendix B table	The Region table was re-named to Management Zone. See changes in Appendices A and B.
S22.	Appendix A	Water Usage/Water Type–Looks like these boxes are reversed–WaterUsage is the more specific and should be to the right of WaterType? Or the detail (TDS, Year, Month) should be moved to WaterType (and associated changes made in Appendix B)	The database tables were updated to more clearly define the relationships between water sources, water uses and water quality.

Comment Number	Page Reference	Comment	Response
S23.	Appendix A	Appendix A: I don't see anything in the database design that accounts for the salt content of solid manure	This term is located in the CattleType table as "SaltFraction."
E1 - E12	n/a	Editorial Comments and suggestions.	Thank you. Editorial suggestions were incorporated.

A.3 PAT BOLDT

Comment Number	Page Reference	Comment	Response
1.	n/a	Document is clean and easy to understand	Comment noted.
2.	n/a	Model appears to be fine but is not innovative	Clearly you are entitled to your opinion but we take strong exception to it. This is the first database design ever developed in the southern California area and perhaps the entire State. In that sense it is clearly innovative.
3.	5	Figure 2 shows EMWD but text does not mention in reference to diagram anything about them or EMWD water per se.	Comment noted. The text will be modified to reflect this.
4.	10	Initial dairy Operations audit: Isn't this the initial site visits on all of these dairies that Wildermuth was supposed to do? Would have been great with all that info completed.	Comment noted.
5.	11	This [conclusion] reads more like an introduction, doesn't really provide conclusions based on the content of the document	Comment noted. Please refer to the updated Conclusions and Recommendations section.
6.	n/a	There are no recommendations	Comment noted. Please refer to the updated Conclusions and Recommendations section.

A.4 BRUCE SCOTT

Comment Number	Page Reference	Comment	Response
1.	n/a	I found the document very clean and professional on needs for edits, I found couple simple typos, 1# use of diary instead of dairy on the bottom of page 9. 2# page 2# add the word "to" to the sentence below: "In that same period, an equal mass of salt will be disposed of in solid (manure) or liquid (wastewater) form to one or many of the possible sinks, in essence balancing the salt budget for that time period."	Thank you. Editorial suggestions were incorporated.

Appendix H – San Jacinto Watershed Dairy Sampling and Analysis for Salt Offset

San Jacinto Watershed Dairy Sampling and Analysis for Salt Offset

Funding for this project has been provided in full or in part through an agreement with the California State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. (Gov. code 7550, 40 CFR 31.20).

Introduction

The objective of the Dairy Sampling and Analysis Project was to improve the knowledge of dairy salt loads in the San Jacinto Watershed through measurement of TDS, NO_3-N, and other waste constituents at selected points in the dairy process. In order to collect data representative of the San Jacinto Watershed, dairies were selected for sampling and analysis based on a set of criteria that included:

- Range in herd size
- Location in different Ground Water Management Zones
- One flush dairy
- With and without own cropland where manure is applied

The willingness of dairy operators to participate in the sampling program, provide access to their facilities, and permit access to records of their water use was also an important selection factor. Ten dairies within the San Jacinto Watershed participated in the Project. Although each dairy gave written consent to collect and use data from their facility, this report refers to dairies and wells by arbitrary number to preserve confidentiality.

This project focused on collection of samples of alley, corral, and stockpiled manure; of wastewater as discharged from milk barns and as contained in lagoons; ground water quality and quantity data provided by EWMD, and operational data from the sampled facilities. It was beyond the scope of this effort to measure actual manure production from different types of dairy cows; this analysis relies on the assumptions of manure production recommended by the RWQCB in their annual dairy report template (Attachment B, of R8-2007-0001). Further, this Project accepted the RWQCB assumption that 90% of the manure produced by a milk cow is excreted in the corrals and that the remaining 10% is excreted in the milk barn and that 100% of the manure produced by all other cow types is excreted in the corrals. Thus, for this Project, manure quantities were estimated from 2008 Annual Dairy Report data on animal type and numbers. Sampling was conducted in November 2009 by Marvin McWaters of Walco International Environmental Services under contract with the SJBRCD.

Methods

Detailed sampling procedures are specified in a *San Jacinto Watershed Dairy Sampling and Analysis Plan for Salt Offset* (found at the end of this report). The herd size of selected dairies ranged from 870 to 2,500 milk cows, with an average of 1,584. Sampled dairies represent three GWMZs.

Manure sampling. Concentrations of nutrients and salts in dairy manure were determined by sampling and laboratory analysis of manure of different types depending on the management used on individual dairies. Samples were collected from corral manure, manure stockpiles (if any) and manure removed from the cattle feeding alleys if it is managed separately from corral manure. It was assumed that manure deposited in the milk barn is sampled as part of the wastewater stream. For each manure type, multiple grab samples were collected and combined into a single composite sample for the dairy.

Wastewater sampling. Because of the logistical challenges of collecting representative samples from an open lagoon, dairy wastewater generated from the milk barn was sampled for quality at a point just before it is discharged into the first containment lagoon, at a point where it is well-mixed. Samples were also collected from wastewater lagoons on four participating dairies in order to shed light on changes in quality with storage, although it is recognized that such samples were probably not completely representative of lagoon contents.

Operations water. Quantity and quality of source water extracted by sampled dairies was assessed using data reported on 26 wells by the EWMD. Rather than apply an assumption of 100 gal/cow/day of wash water, dairy-specific estimates of daily washwater used were obtained from dairy EWMPs or were calculated from information on sprinkler use and milk barn washing practices collected from dairies during sampling visits.

Quality assurance. During dairy sampling, two types of quality assurance samples were collected. One sample collected in the field for each medium (manure and water) and source were split by collecting a second subsample from the manure or wastewater composite sample and submitted to the laboratory as field duplicates. The purpose of these field duplicates was to assess the analytical precision of the laboratory. Secondly, on some dairies, true replicate samples were collected by repeating the full collection procedure of one sample type, including the full process of collecting individual grab samples, making up a composite, and subsampling the composite. The purpose of these replicate samples was to evaluate the consistency and repeatability of the field sampling procedures.

Laboratory analysis. Manure and wastewater samples were analyzed at Midwest Laboratories, Inc. (Omaha, NE) by standard methods, as given in Table 1.

All manure results were reported on a dry weight basis.
Ground water samples collected by EWMD were analyzed for an extensive list of constituents (Table 2).

Data analysis. All raw data collected in the Project have been reported to the SJBRCD under separate cover. Data reduction included averaging the results of duplicate and replicate samples to report a single value for each constituent for each sample. Censored data (values reported as below the detection limit) were replaced by a value equal to one-half the detection limit; for example, a NO_3-N result for water reported as "<0.2 mg/L" was entered as 0.1 mg/L. Because of extensive censored data in the EWMD data files, the following constituents were excluded from the analysis: NH_3-N, CO_3, Cu, OH, MBAS, NO_2-N, TKN, and TOC. Statistical analysis was conducted using JMP statistical software (version 7) (SAS Institute, 2008).

Table 1. Analytical methods and detection limits for manure and wastewater samples.

Manure			Wastewater		
Analysis	**Method**	**Detection Limit**	**Analysis**	**Method**	**Detection Limit**
NH_3-N	EPA 350.2	0.1 mg/Kg	NH_3-N	EPA 350.2	0.5 mg/L
TKN	SM 4500N	0.5 mg/Kg	TKN	EPA 351.3	2.5 mg/L
NO_3-N	EPA 353.2	1 mg/Kg	Nitrate	EPA 300.0	0.2 mg/L
Total P	SM 4500P	0.5 mg/Kg	Total P	SM 4500 P-F	10 mg/L
K	EPA 6010B	1 mg/Kg	K	ICAP	0.5 mg/L
Cl	EPA 6010B	1 mg/Kg	Chloride	EPA 300.0	10 mg/L
SO_4	EPA 300.0	1 mg/Kg	SO_4	EPA 300.0	1 mg/L
Ca	EPA 6010B	1 mg/Kg	Ca	ICAP	0.01 mg/L
Na	EPA 6010B	1 mg/Kg	Na	ICAP	0.01 mg/L
Mg	EPA 6010B	1 mg/Kg	Mg	ICAP	0.01 mg/L
% solids	SM 2540G	0.01	Conductance	SM 2510 B	2 μS/cm
			TDS	SM 2540C	10 mg/L

Table 2. Constituents reported by EWMD for sampled ground water.

NH_3-N	Hydroxide (OH)	Na
Bicarbonate (HCO_3)	Iron	SO_4
B	Mg	Total Alkalinity
Ca	Mn	TDS
Carbonate (CO_3)	MBAS	Total Inorganic N
Cl	NO_3-N	Total Kjeldahl N
Cu	NO_2-N	Total Organic C
Conductance	pH	Zinc
Fl	K	
Hardness	Si	

Results

Manure. Samples of corral manure were collected from all 10 participating dairies. Because of the timing of sample collection coincided with many dairies manure hauling schedules, there were only three manure stockpiles available for sampling; two samples of alley manure were collected. Descriptive statistics for corral manure samples are given in Table 3.

Corral manure ranged from 46 to 80% solids, equivalent to 20 to 54% moisture. As expected, about 90% of total N was in the organic form (TKN minus NH_3-N); very little NO_3-N was present as mineralization of organic N to ammonia and nitrification of ammonia to nitrate had not progressed. Variability among the dairies was low (C.V. $\leq$ 30%), suggesting that the quality of corral manure was fairly consistent across the different dairies. Nitrate was an exception, showing a higher variability among dairies, probably in response to variation in age of corral manure deposits.

Table 3. Descriptive statistics for corral manure, San Jacinto dairies sampled November 2009. All data except % solids in mg/Kg, dry weight basis.

	NH3-N	TKN	NO3-N	TP	K	Cl
Mean	3,386	25,016	43	5,367	35,804	18,906
Median	3,347	25,293	48	5,482	33,678	17,909
Range	2,069 – 5,453	19,611 – 29,733	<1 – 87	3,379 – 7,245	21,060 – 59,856	11,870 – 26,605
s.d. [1]	954.5	3378.5	32.2	1,221.0	10,588.9	5,582.9
C.V. [2]	0.28	0.14	0.75	0.23	0.29	0.30
n	10	10	10	10	10	10

	SO4	Ca	Na	Mg	% solids
Mean	7,954	21,207	10,143	8,208	63
Median	8,145	20,224	10,134	8,298	62
Range	5,068 – 12,061	17,689 – 27,829	6,700 – 14,230	6,916 – 9,774	46 – 80
s.d.	2,064.8	3490.9	2,225.0	959.8	10.3
C.V.	0.26	0.16	0.22	0.12	0.16
n	10	10	10	10	10

[1] Standard deviation
[2] Coefficient of variation = standard deviation/mean, a measure of variability in the data

Descriptive statistics for stockpiled manure are given in Table 4. Because it is older, stockpiled manure was drier than corral manure, ranging from 76 to 82% solids, equivalent to 18 to 24% moisture. As with corral manure, about 90% of total N was in the organic form and little NO_3-N was present. Total N (TKN + NO_3-N) in stockpiled manure averaged about 25% lower than that present in corral manure; loss of ammonia by volatilization is a likely cause. Variability among the dairies was again low (C.V. $\leq$ 35%), although a bit higher than for corral manure, possibly due to the low number of samples. The low variability suggests a consistent quality of stockpiled manure among the sampled dairies. Nitrate was again an exception, showing a higher variability among stockpiles, probably in response to variation in age or aeration of the stockpiles.

Descriptive statistics for alley manure are given in Table 5. As would be expected for fresh manure, % solids was less than 20% and about 30% of N was in the ammonia form.

Concentrations of measured constituents were compared among sampled manure groups by Analysis of Variance (ANOVA); results are summarized in Table 6.

Table 4. Descriptive statistics for stockpiled manure, San Jacinto dairies sampled in November 2009. All data except % solids in mg/Kg, dry weight basis.

	NH3-N	TKN	NO3-N	TP	K	Cl
Mean	2,099	18,438	57	4,825	33,198	15,293
Median	1,999	19,218	68	4,596	32,214	17,032
Range	1,778 – 2,520	14,955 – 21,140	3.3 – 101	4,406 – 5,472	24,578 – 42,803	10,165 – 18,681
s.d.	381.0	3,165.5	496	568.6	9,152.3	4516.6
C.V.	0.18	0.17	0.87	0.12	0.28	0.30
n	3	3	3	3	3	3

	SO4	Ca	Na	Mg	% solids
Mean	6,469	19,187	8,455	7,907	80
Median	5,417	18,130	8,474	8,570	80
Range	4,939 – 9,050	16,241 – 23,191	5,697 – 11,193	6,413 – 8,739	76 – 82
s.d.	2,248.2	3,593.6	2,748.0	1,296.9	3.0
C.V.	0.35	0.19	0.32	0.16	0.04
n	3	3	3	3	3

Table 5. Descriptive statistics for alley manure, San Jacinto dairies sampled in November 2009. All data except % solids in mg/Kg, dry weight basis. Sample numbers insufficient to calculate statistics other than mean.

	NH3-N	TKN	NO3-N	TP	K	Cl
Mean	10971	33590	30	6522	30023	17812
Median						
Range	10253 - 11689	31951 - 35228	<1 - 58	5947 – 7098	24404 - 35642	13823 - 21800
s.d.						
C.V.						
n	2	2	2	2	2	2

	SO4	Ca	Na	Mg	% solids
Mean	4254	17162	6531	7075	18
Median					
Range	3577 - 4932	15745 - 18578	5664 - 7398	6362 - 7788	15 - 20
s.d.					
C.V.					
n	2	2	2	2	2

Table 6. Comparison of mean concentrations within manure groups by Analysis of Variance. Within each row, means followed by the same letter(s) are not significantly different, P< 0.10.

	Alley	Corral	Stockpile
NH3-N	10,971**a**	3,385**b**	2,099**c**
TKN	33,590**a**	25,015**b**	18,438**c**
NO3-N	30**a**	43**a**	57**a**
TP	6,522**a**	5,367**a**	4,825**a**
K	30,023**a**	35,804**a**	33,198**a**
Cl	17,812**a**	18,906**a**	15,293**a**
SO4	4,254**b**	7,954**a**	6,469**ab**
Ca	17,162**a**	21,207**a**	19,187**a**
Na	6,531**b**	10,143**a**	8,455**ab**
Mg	7,075**a**	8,208**a**	7,907**a**
% solids	18**c**	63**b**	80**a**

As shown in Table 6, alley manure tended to be lower percent solids and have higher ammonia concentrations than either corral or stockpiled manure. Mean sulfate concentration was lower in alley manure than in other manure forms, probably because S had less opportunity to oxidize in fresher manure. Nitrate concentrations followed a similar pattern of increasing concentration with manure age. Concentrations of P, K, Cl, Ca, Na, and Mg did not differ significantly among the different manure groups. It should be cautioned that the number of alley manure samples is too low to assign high statistical confidence to comparisons across groups.

Some of these patterns are shown graphically in Figures 1 – 5. In these box plots, the lower and upper edges of the main box define the 25th and 75th percentiles, respectively. The horizontal line across the box represents the median. Where they appear, the lower and upper "whiskers" approximate the 10% and 90% confidence intervals around the median. For alley and stockpiled manure, data are insufficient to compute these features. The decline in ammonia concentration with increasing manure age is clearly shown in Figure 1, as is the tendency for increase in nitrate levels with age (Figure 2). Sodium concentrations were fairly stable across manure groups (Figure 3). The pronounced increase in % solids from alley to corral to stockpile is clearly illustrated in Figure 4.

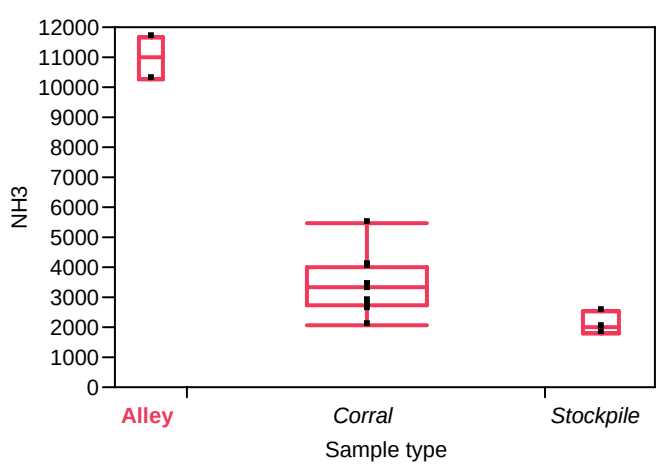


Figure 1. Box plot of NH_3-N concentrations by manure type.

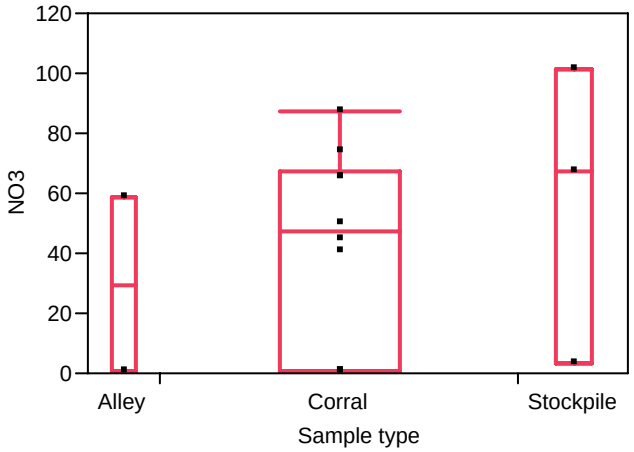


Figure 2. Box plot of NO_3-N concentrations by manure type.

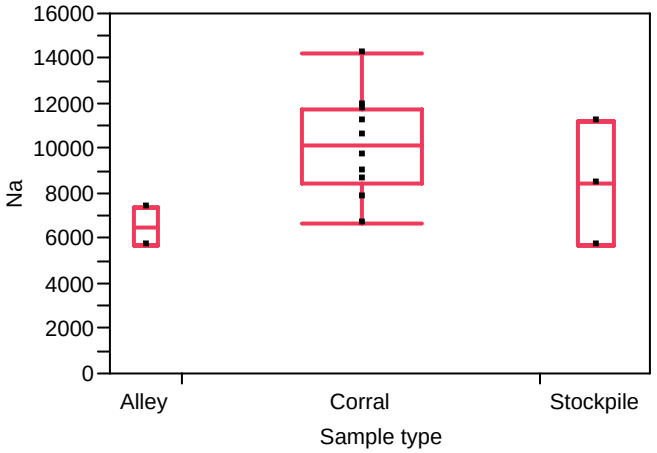


Figure 3. Box plot of Na concentrations by manure type

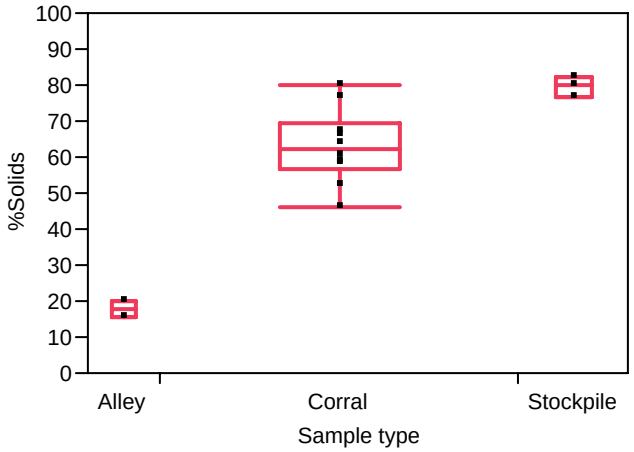


Figure 4. Box plot of % solids by manure type

Further confirmation of the effects of aging on manure ammonia content is shown in Figure 5. Within the group of corral manure, ammonia concentration declined as a function of increasing % solids, probably a reflection of ammonia volatilization with time.

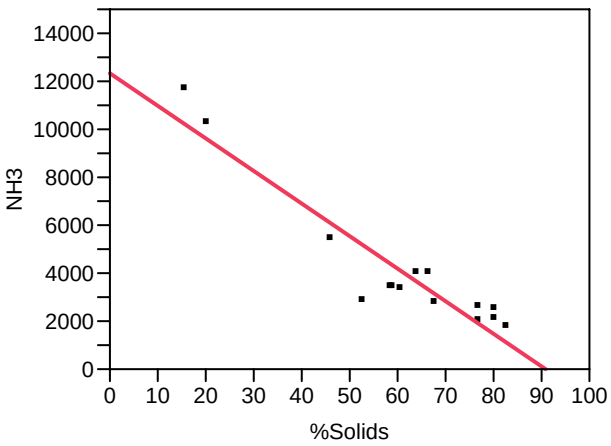


Figure 5. Manure NH_3-N concentration as a function of manure % solids. NH3 = 12317 - 135.7*(%Solids) $r^2 = 0.87$ $P<0.0001$

The mass of nutrients, salts, and other constituents contained in dairy manure was computed for each sampled dairy as the product of manure generated and the concentrations measured in corral manure for that dairy. It was assumed that 90% of milk cow manure goes into the corral, along with 100% of manure excreted by other animals on the dairy. It was further assumed that corral manure best represents the quality of manure from the dairy, although for an accurate N balance at any given time, corral manure and stockpiled manure should be considered separately because of ammonia losses over time. The mass of nutrients and salts contained in the manure of sampled dairies is summarized in Table 7.

Table 7. Calculated annual mass of manure constituents available in corral manure of sampled dairies based on 2009 samples and livestock numbers reported by dairy operators. Values for manure quantity represent 90% of annual milk cow manure production plus 100% of manure production of other facility livestock.

Dairy #	Manure	NH3-N	TKN	NO3-N	TP	K	Cl	SO4	Ca	Na	Mg
	t/yr	----kg/yr----									
1	7,056	21,842	161,518	474	38,564	211,051	106,802	51,952	118,840	74,823	54,435
2	7,083	21,177	125,982	263	26,547	190,804	76,250	59,997	120,820	43,041	47,811
3	10,275	25,628	196,051	5	58,116	300,028	155,447	47,231	167,022	83,958	82,365
4	9,881	18,539	227,160	587	30,279	188,743	106,643	48,634	233,344	70,099	77,161
5	7,705	17,961	172,330	349	38,057	187,394	133,679	57,104	123,619	78,263	48,330
6	10,440	32,168	244,594	616	45,160	325,529	208,809	80,575	218,071	112,648	66,778
7	4,973	12,858	129,527	392	19,255	190,686	62,616	29,702	125,535	38,857	44,088
8	10,327	37,692	203,907	422	51,696	383,104	249,205	112,974	196,367	90,737	87,009
9	6,249	30,909	168,536	3	41,067	339,283	141,334	39,701	110,442	59,971	42,864
10	5,645	20,655	144,492	3	34,024	193,983	129,684	47,423	111,303	72,860	41,422
kg/yr	MEAN	23,943	177,410	311	38,276	251,060	137,047	57,529	152,536	72,526	59,226
	MEDIAN	21,509	170,433	371	38,310	202,517	131,682	50,293	124,577	73,842	51,382
t/yr	MEAN	26.3	195.2	0.3	42.1	276.2	150.8	63.3	167.8	79.8	65.1
	MEDIAN	23.7	187.5	0.4	42.1	222.8	144.8	55.3	137.0	81.2	56.5

Based on the information in Table 7, corral manure from the average dairy among the sampled group produces about 196 tons of N, 42 tons of P, 80 tons of sodium, 151 tons of chloride, and 63 tons of sulfate annually.

Wastewater. Samples of wastewater as discharged from the milk barn were collected from all 10 participating dairies. One facility operated two separate milk barns which were sampled separately. Descriptive statistics for sampled dairy wastewater are shown in Table 8.

Table 8. Descriptive statistics for dairy wastewater, San Jacinto dairies sampled in November 2009. All values in mg/L except conductance in µS/cm.

	Cl	NO3	SO4	COND	TDS	TN	TP
Mean	350	2.8	224	3,781	2,984	399	51
Median	284	1.0	169	2,255	1,900	222	44
Range	93 – 1,051	<0.2 – 16.0	30 – 915	1644 – 7660	1,060 – 7,425	75 – 976	11 – 128
s.d.	279.8	4.5	244.6	2,384.4	2,180.9	316	36.8
C.V.	0.20	1.58	1.09	0.63	0.73	0.79	0.73
n	11	11	11	11	11	11	11

	NH3	Ca	Mg	K	Na	TKN
Mean	46	205	76	433	283	396
Median	28	144	53	291	291	221
Range	9 – 188	79 - 494	22 – 195	75 – 1,121	147 – 645	74 – 969
s.d.	52.8	139.7	60.6	389.1	151.6	313.7
C.V.	1.14	0.68	0.79	0.90	0.54	0.79
n	11	11	11	11	11	11

Dairy wastewater was high in TDS and conductance and in N and P. About 10% of N was in the NH_3-N form and less than 1% of total N was present as NO_3-N. This is expected for relatively fresh wastewater where substantial N mineralization and nitrification had not yet occurred. Variability among sampled dairies (as reflected in values of the C.V.) was substantially higher than was observed for manure. This higher variability may reflect differences in management among the sampled dairies or differences in the quality of source water used in the facility.

Wastewater lagoons were sampled on four dairies. Because of the sampling methods and the fact that the lagoons were not well-mixed, it cannot be claimed that these data are necessarily representative of the lagoon contents. Nevertheless, the data for lagoon wastewater (Table 9) are suggestive of processes affecting dairy wastewater quality. The data show total N concentrations in lagoon wastewater about 60% of those in fresh wastewater and that NH_3-N made up about 67% of total N. Both these changes are consistent with processes of mineralization converting organic N to NH_3-N and volatilization losses of NH_3-N.

Table 9. Descriptive statistics for dairy lagoons, San Jacinto dairies sampled November 2009
All values in mg/L except conductance in µS/cm.

	Cl	NO3*	SO4	COND	TDS	TN	TP
Mean	515	<0.2	66	4951	3090	238	40
Median	362	-	62	4500	2830	226	40
Range	324 – 1011	-	20 – 119	3735 – 7070	1775 – 7925	172 – 328	30 – 51
s.d.	331.3	-	41.2	164.8	1460.0	65.2	9.3
C.V.	0.64	-	0.63	0.30	0.47	0.27	0.23
n	4	4	4	4	4	4	4

	NH3	Ca	Mg	K	Na	TKN
Mean	161	160	86	444	366	238
Median	174	134	58	428	320	226
Range	121 – 176	124 – 246	38 – 191	213 – 709	256 – 567	172 – 328
s.d.	26.7	57.8	70.7	224.7	140.0	65.2
C.V.	0.17	0.36	0.82	0.51	0.38	0.27
n	4	4	4	4	4	4

*all results < detection limit of 0.2 mg/L

Differences in constituent concentrations between wastewater as discharged and wastewater in lagoons were tested using a standard t-Test (Table 10).

Table 10. Comparison of mean concentrations within manure groups by t-Test.
Within each row, means followed by the same letter(s) are not significantly different, $P \leq 0.10$.
All values in mg/L except COND (µS/cm).

Variable	Lagoon	Wastewater
Cl	515 **a**	350 **a**
NO3	<0.2 **a**	2.8 **b**
SO4	66 **a**	224 **b**
COND	4951 **a**	3781 **a**
TDS	3090 **a**	2984 **a**
TN	238 **a**	399 **a**
TP	40 **a**	51 **a**
NH3	161 **a**	46 **b**
Ca	160 **a**	205 **a**
Mg	86 **a**	76 **a**
K	444 **a**	433 **a**
Na	366 **a**	283 **a**
TKN	238 **a**	396 **a**

Statistically significant differences between fresh and stored wastewater were few, likely the result of the low sample size for lagoon wastewater. Mean NH_3-N concentration was significantly higher in lagoon compared to fresh wastewater, as noted earlier. Nitrate levels were negligible in lagoon wastewater, probably because the lagoons tended to be anaerobic (although no oxygen measurements were taken). Although not statistically significant, conductivity and concentrations of TDS, Cl, and Na were somewhat higher in lagoons than in fresh wastewater, possibly reflecting concentration of constituents due to evaporation of water during storage. An apparent decrease in total N concentration in lagoon wastewater may be due to ammonia volatilization losses.

Some of these patterns are illustrated in Figures 6 through 9. Figure 6 illustrates the sharply higher NH_3-N concentrations in lagoon wastewater; Figure 7 shows the tendency for declines in total N in storage. The tendency for conductivity and TDS to increase with storage (Figures 8 and 9) reflects concentration of wastewater constituents by evaporation.

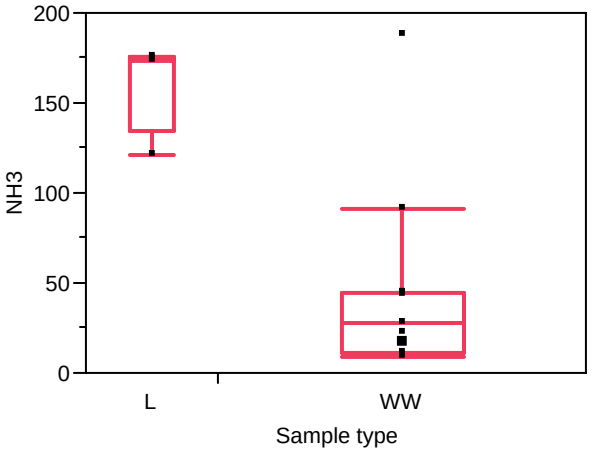


Figure 6. Box plot of NH_3-N concentrations in lagoons (L) vs. direct wastewater discharges (WW).

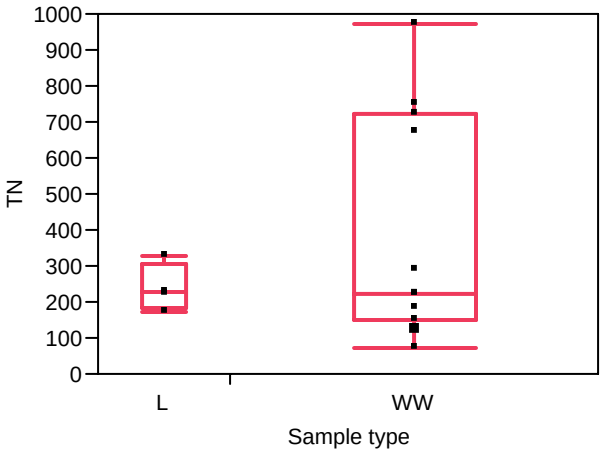


Figure 7. Box plot of total N concentrations in lagoons (L) vs. direct wastewater discharges

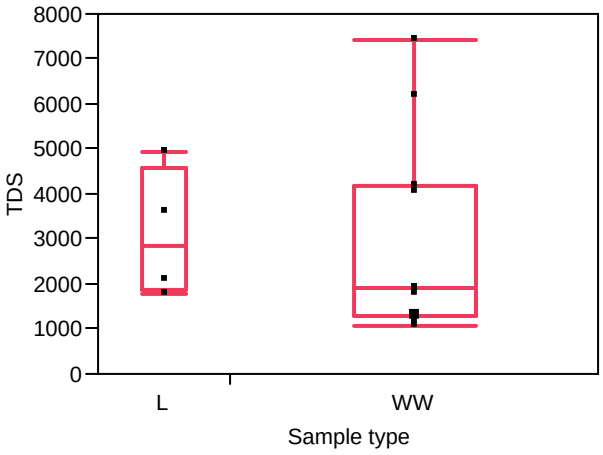


Figure 8. Box plot of TDS concentrations in lagoons (L) vs. direct wastewater discharges

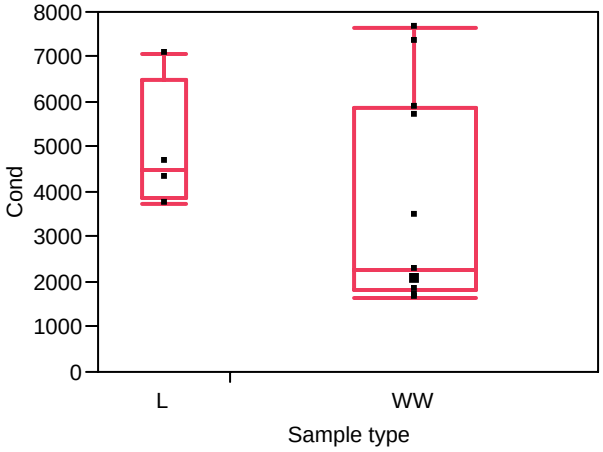


Figure 9. Box plot of conductivity in lagoons (L) vs. direct wastewater discharges

There were, of course, many strong correlations among wastewater constituents. Both conductivity and TDS, for example, were highly correlated ($r > 0.80$) with Ca, Mg, K, Na, Cl, total N, and total P. Total N and total P concentrations were also highly correlated ($r = 0.73$). Concentrations of Na and Cl were strongly correlated as well (Figure 10).

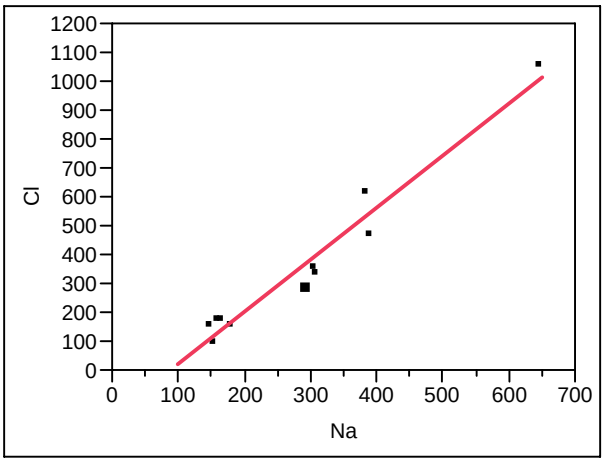


Figure 10. Wastewater Cl concentration as a function of Na concentration. Cl = -161.3485 + 1.806823*Na $r^2 = 0.95$ $P < 0.001$

As was done for manure, the mass of nutrients, salts, and other constituents contained in dairy wastewater as discharged from the milk barn was computed for each sampled dairy as the product of wastewater generated and the concentrations measured in wastewater for that dairy. Wastewater volume for each dairy was taken from site-specific calculations based either on EWMP data or data concerning wash water use reported in the 2009 sampling procedure. It should be noted that these wastewater volume estimates are substantially lower than the 100 gal/cow/day assumed in some facility EWMPs; the volumes used in this calculation range from 14 to 62 gal/cow/day, with a mean of 32 gal/cow/day. The wastewater volume and associated mass of nutrients and salts contained in the manure of sampled dairies is summarized in Table 11.

Based on the information in Table 11, wastewater discharged from the average dairy milk barn among the sampled group produce about 180 tons of TDS, 23 tons of N, 0.2 tons of NO_3-N, 3 tons of P, 20 tons of chloride, 16 tons of sodium, and 13 tons of sulfate annually.

Table 11. Calculated annual mass of manure constituents available in wastewater as discharged from milkbarn of sampled dairies based on 2009 samples and water use reported by dairy operators.

Dairy #	WW volume	Cl	NO3	SO4	TDS	TN	TP	NH3	Ca	Mg	K	Na	TKN
	gal/d	----kg/yr----											
1	36,280	52,678	777	45,861	372,154	37,666	3,859	2,203	24,760	9,774	50,598	32,303	36,890
2	30,835	6,518	53	7,178	75,784	7,913	1,321	954	6,390	1,779	6,305	7,519	7,860
3(1)	50,800	12,071	126	2,070	133,345	15,601	3,614	630	10,106	3,807	20,423	11,018	15,475
3(2)	50,800	24,844	119	5,544	435,125	50,861	8,983	3,172	28,073	11,861	78,673	21,195	50,741
4	28,000	23,635	147	11,605	156,007	37,631	1,973	3,501	6,963	2,979	34,582	14,777	37,484
5	33,000	12,811	55	6,018	59,678	5,617	775	761	3,588	1,003	5,334	13,267	5,562
6	31,388	14,527	56	5,464	80,959	12,458	1,084	1,843	5,464	1,843	13,052	13,313	12,402
7	37,832	8,101	57	11,864	55,402	7,897	1,202	502	6,795	2,749	9,147	7,683	7,840
8	30,930	19,955	43	9,358	179,468	28,758	4,230	8,033	14,571	5,555	20,425	16,579	28,715
9	59,240	7,611	74	2,946	155,499	18,161	3,601	2,308	9,821	2,619	12,276	12,522	18,087
10	62,250	15,136	77	20,210	98,900	6,416	946	937	7,895	1,901	6,441	14,018	6,338
kg/yr	MEAN	17,990	144	11,647	163,847	20,816	2,872	2,259	11,311	4,170	23,387	14,927	20,672
	MEDIAN	14,527	74	7,178	133,345	15,601	1,973	1,843	7,895	2,749	13,052	13,313	15,475
t/yr	MEAN	20	0.2	13	180	23	3	2	12	5	26	16	23
	MEDIAN	16	0.1	8	147	17	2	2	9	3	14	15	17

Dairy well water. Annual data from 2001 – 2008 for 26 wells among the 10 participating dairies were provided by EWMD. For this analysis, only data from 19 wells with samples collected in 2008 were included and only 2008 data were used. Because of possible long-term changes in ground water quality, the use of contemporary data was deemed appropriate. Descriptive statistics for sampled dairy wastewater are shown in Table 12.

Table 12. Descriptive statistics for EWMD data from dairy wells, San Jacinto dairies sampled in 2008. All values in mg/L except COND (μS/cm), Cu, Fe, Mn, and Zn (μg/L), and extraction (ac-ft/yr).

	HCO3	B	Ca	Cl	COND	Fl	HARD
Mean	175	1.0	77	175	1,118	5.5	263
Median	140	0.8	41	120	960	0.6	130
Range	100 – 420	<0.1 – 3.6	18 – 410	18 – 930	90 – 4,290	0.2 – 90	52 – 1,500
s.d.	86.7	0.99	118.2	249.3	1,062.0	20.5	437.6
C.V.	0.49	0.99	1.54	1.42	0.95	3.73	1.66
n	19	19	19	19	19	19	19

	Fe	Mg	Mn	NO3N	pH	K	Si
Mean	177	17.4	53	1.4	7.6	4.2	24
Median	65	6.4	6.5	0.7	7.8	3.8	17
Range	<5 – 1,300	1.6 – 120	5 – 330	<0.1 – 9.7	6.5 – 8.2	1.5 – 9.8	14 – 64
s.d.	314.5	36.6	96.1	2.3	0.50	2.2	14.4
C.V.	1.77	2.08	1.82	1.62	0.06	0.53	0.60
n	19	19	19	19	19	19	19

	Na	SO4	Alk	TDS	TIN	Zn	Extraction
Mean	140	175	144	690	2.0	20	63.4
Median	133	140	110	530	1.1	10	59
Range	27 – 360	12 – 770	86 – 340	210 – 2,760	<0.5 – 9.7	<5 – 79	4.5 – 214
s.d.	75.2	176.7	69.4	680.9	2.4	23.5	58.8
C.V.	0.54	1.01	0.48	0.99	1.16	1.19	0.93
n	19	19	19	19	19	19	18

It should be noted that the values shown in Table 12 are heavily skewed by very high values (e.g., TDS 2,400 – 2,700 mg/L, NO_3-N 5.2 – 9.7 mg/L) from two wells located on one dairy overlying the Menifee GWMZ. As shown in Table 13, wells sampled in the San Jacinto Upper Pressure and Lakeview-Hemet North GWMZs were generally consistent with management objectives for TDS and nitrate, although there were a few exceedances of those objectives in some wells. The two wells sampled in the Menifee GWMZ, however, greatly exceeded the TDS and nitrate objectives, even for the lower water quality of that ground water zone.

Table 13. Mean TDS and NO3-N concentrations in sampled wells vs. GWMZ management objectives.

GWMZ	TDS (mg/L)		NO3-N (mg/L)	
	Objective	Sampled wells	Objective	Sampled wells
SJ Upper Pressure	320	285 (210-370)	1.4	0.2 (<0.1-0.7)
Lakeview-Hemet North	520	524 (400-640)	1.8	0.9 (<0.1-2.3)
Menifee	1,020	2,585 (2,410-2,760)	2.8	7.4 (5.2-9.7)

Number of sampled wells: SJ-UP = 4 LHN = 13 Men = 2

As was done for manure and wastewater, the 2008 mass of nutrients, salts, and other constituents contained in dairy well water was computed for each sampled dairy as the product of recorded water extraction and the concentrations measured in the well. Note that the mass of nutrients, salts, and other constituents is already included in the mass estimated for dairy wastewater. The well water extractions and associated mass of nutrients and salts contained in the water are summarized in Table 14. Data for all constituents analyzed by EWMD are not reported. Also, note that chemistry data have not been reported for two wells and that lack of data may skew the reported means and medians.

Based on the information in Table 14, well water extracted from the average dairy well among the sampled group produces about 138 tons of TDS, 0.2 tons of NO_3-N, 32 tons of chloride, 33 tons of sodium, and 31 tons of sulfate annually. Note that these estimates for chloride, sodium, and sulfate exceed the estimated mass contained in dairy wastewater (Table 11). There are several possible explanations for this. First, not all well water extracted may contribute to dairy wastewater. Second, estimates of wastewater mass may be underestimates if wastewater volumes were underestimated. Third, comparison of data based on a single well sample analysis in 2008 with estimates based on a single wastewater sample in 2009 may introduce some discrepancy. Finally, some of the mass of nutrients and salts in the well water may be taken up by livestock and not excreted into the dairy waste stream.

Table 14. Calculated mass of constituents in water extracted from dairy wells in 2008 based on data provided by EWMD.

Dairy #	Well #	Extraction vol	Ca	Cl	Hard	Fe	Mg	Mn	NO3N	K	Na	SO4	TDS	TIN
		million gal/yr							kg/yr					
	1	1no data												
		2 37.2	57,775.4	112,732.4	211,373.3	183.2	16,909.9	0.9	732.8	1,240.1	33,819.7	67,639.5	339,606.5	775.0
	2NONE													
	3	3 64.8	4,663.0	41,721.3	14,479.7	10.6	638.1	3.9	12.3	368.1	44,666.3	31,904.5	157,068.4	171.8
	4	5 58.7	7,781.6	31,126.3	26,679.7	3.3	2,045.4	1.1	200.1	911.6	26,679.7	16,452.5	104,495.5	1,156.1
	5	7 14.2	2,358.2	6,431.5	7,503.4	1.2	348.4	0.3	37.5	305.5	8,092.9	9,647.2	28,405.7	59.0
		8 4.8	328.4	1,641.9	1,641.9	1.2	38.3	0.7	0.9	56.6	2,791.3	2,736.6	8,939.4	12.8
		9 4.5	378.0	876.4	1,099.8	2.6	41.2	0.4	1.7	51.6	2,044.9	2,062.1	6,873.6	8.6
	6	11 17.2	3,318.3	1,301.3	9,759.6	18.2	338.3	21.5	6.5	97.6	1,756.7	780.8	13,663.5	16.3
		12 95.6	18,812.1	6,873.6	54,265.5	43.4	1,700.3	101.3	18.1	1,121.5	10,129.6	5,064.8	94,060.3	506.5
	7	13 188.5	24,971.5	48,516.1	78,482.0	492.3	4,566.2	3.6	784.8	3,567.4	76,341.6	99,886.2	299,658.5	784.8
		14 59.2	8,520.5	14,574.5	26,906.8	0.6	1,435.0	1.1	358.8	1,031.4	23,543.5	31,391.3	94,173.8	358.8
	8	15 65.8	5,480.0	6,725.5	16,938.2	42.3	772.2	27.4	174.4	672.5	25,656.4	4,981.8	92,163.6	498.2
		17 75.3	14,816.6	5,128.8	39,890.9	23.4	740.8	37.0	14.2	427.4	15,956.3	14,246.7	85,480.4	199.5
		18 94.1												
	9	19 47.1	4,634.1	21,388.3	14,615.3	25.0	677.3	2.5	71.3	552.5	28,695.9	32,082.4	98,029.6	142.6
		20 80.0	12,408.6	36,317.8	39,344.3	10.9	2,209.3	1.5	302.6	1,150.1	42,068.2	48,423.8	160,403.8	332.9
		22 11.9	2,483.5	6,773.3	8,127.9	1.4	415.4	0.2	81.3	275.4	6,818.4	8,127.9	27,093.0	90.3
		23 214.0	14,577.8	145,777.8	42,113.6	15.4	1,295.8	8.1	40.5	2,753.6	162,785.2	97,185.2	494,024.6	202.5
	10	24 8.6	1,818.6	3,897.0	5,845.6	5.8	292.3	0.2	55.2	175.4	4,319.2	6,495.1	18,835.7	55.2
		25 no data												
		Mean	10,890	28,930	35,239	51.8	2,027	12.45	170.18	868	30,363	28,183	124,881	315.9
	kg/yr	Median	5,480	6,874	16,938	10.9	741	1.51	55.21	553	23,543	14,247	94,060	199.5
		Mean	12.01	31.89	38.85	0.06	2.24	0.01	0.19	0.96	33.47	31.07	137.68	0.35
	t/yr	Median	6.04	7.58	18.67	0.01	0.82	0.00	0.06	0.61	25.96	15.71	103.70	0.22

Because the annual EWMD well data go back as far as 2001, it is useful to look at changes in well water chemistry over time to see if any trends are apparent. Some examples are shown in Figures 11 through 14. As shown in Figures 11 – 13, TDS levels appear to be decreasing over time in several wells; this trend is by no means universal as some other wells show either no pattern or an increasing trend. Unfortunately, not all potential trends are good; Figure 14 shows an increasing trend in NO_3-N concentrations in a well; the same well showed a decreasing tendency for TDS. These suggestions of temporal patterns in well water quality suggest that a systematic evaluation of ground water quality trends in the region may be useful.

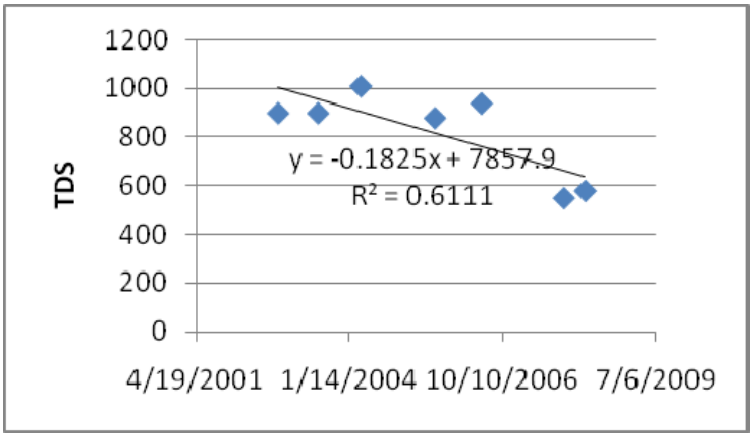


Figure 11. Time series of annual TDS values for a well in LHN GWMZ

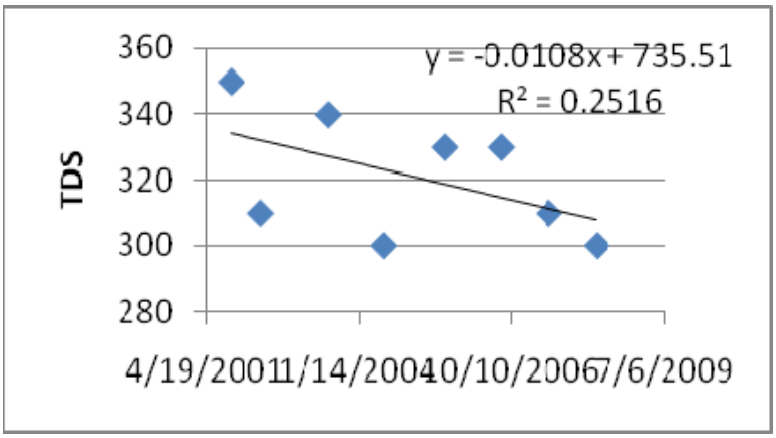


Figure 12. Time series of annual TDS values for a well in SJUP GWMZ

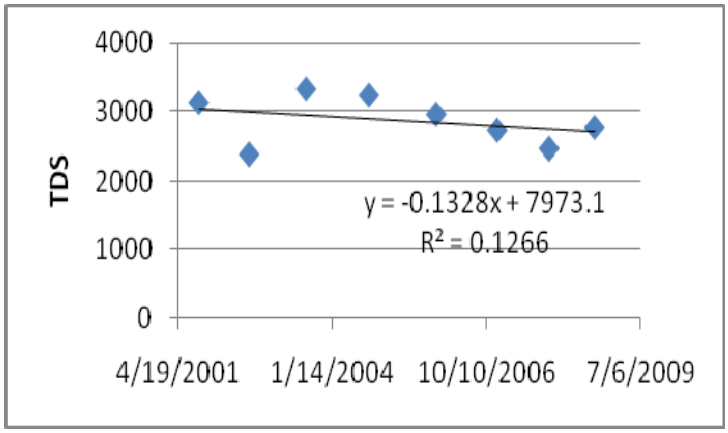


Figure 13. Time series of annual TDS values for a well in the Menifee GWMZ

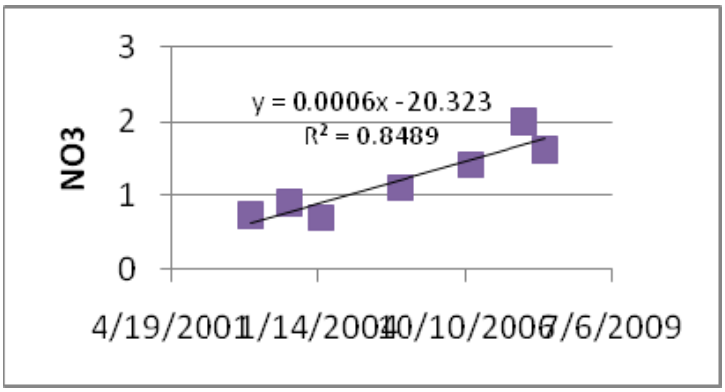


Figure 14. Time series of annual NO_3-N levels for a well in the LHN GWMZ

Discussion

Although there is no reason to suspect otherwise, it is not known if the nutrient and salt content of manure and wastewater sampled on the 10 participating dairies is typical of drylot dairies. In a review of CAFO wastewater reuse, Bradford et al. (2008) summarized representative values for some constituents in dairy wastewater (Table 15).

Table 15. Comparison of mean constituent concentrations in dairy wastewater from studies.

	K	TP	TKN	NH_3-N	COND
Bradford et al. 2008	178 mg/L	30 mg/L	185 mg/L	84 mg/L	3100 µS/cm
This project	466 mg/L	51 mg/L	396 mg/L	46 mg/L	3781 µS/cm

Dairy wastewater quality from this project appears to be reasonably similar to that reported in Bradford et al. (2008) with respect to conductivity, but substantially higher in total P, K, and TKN concentration and lower in NH_3-N. However, it should be noted that the data reported in Bradford et al. (2008) are from a dairy wastewater secondary treatment lagoon and are therefore not directly comparable with fresh dairy wastewater sampled in this project.

The dairy wastewater sampled in this project was substantially higher in TDS than was estimated in the recent *Salt Offset Options for the San Jacinto River Basin Dairies* analysis (Wildermuth, Inc., 2008). That study estimated wastewater TDS from source water TDS and assumed manure contribution to the waste stream to result in a mean TDS of 1,020 μS/cm (range 438 – 1,770 μS/cm). However, this project observed TDS more than double those values (Table 11): mean TDS 2,984 μS/cm (range 1,060 – 7,425 μS/cm). Thus, it appears that dairy wastewater in the San Jacinto may be a more potent source of salts and nitrate than previously believed.

However, dairy wastewater is only a small part of the total salt and nitrate load from dairies. As shown in Table 16, manure contributes the overwhelming majority of salts and other constituents to the overall dairy salt load. Manure contributes an average of 80 to 90% of N, P, and other constituents to the total annual mass load from sampled dairies. Nitrate, a relatively minor fraction of total N load, showed a higher proportional contribution in wastewater than other constituents, but manure still contributes two-thirds of the nitrate load. This pattern reinforces the importance of dealing with manure in the San Jacinto Watershed, because even a high level of treatment applied to wastewater would solve only about 20% or less of the TDS and nitrate problem.

Table 16. Estimated mean annual mass of nutrients and salts in manure and wastewater from sampled San Jacinto dairies. Numbers in parentheses in far right column represent the range observed on individual sampled dairies.

Constituent	Mean annual mass in manure (t)	Mean annual mass in wastewater (t)	Mean annual total mass (t)	% of annual load in manure	
NH_3-N	26.4	2.7	29.1	91%	(82-96%)
NO_3-N	0.34	0.17	0.51	66%	(2-92%)
TKN	195.6	25.1	220.7	89%	(75-96%)
P	42.2	3.5	45.7	92%	(82-98%
Ca	168.2	13.7	181.9	92%	(81-98%)
K	276.8	28.4	305.2	91%	(75-97%)
Mg	65.3	5.1	70.4	93%	(84-98%)
Na	80.0	18.1	98.1	82%	(70-89%)
Cl	151.1	21.8	172.9	87%	(67-95%)
SO4	63.4	14.1	77.5	82%	(53-94%)

Results of analysis of manure samples indicate that corral manure is of relatively consistent quality among the sampled dairies. This consistency could be a significant benefit in composting or other processing of manure into a marketable product for export out of the watershed. Dairy wastewater appears to be somewhat more variable in quality, perhaps at least partially reflecting

variations in management among the sampled dairies. This pattern suggests that the quality of dairy wastewater can be influenced by management, an important element in long-term salt offset planning.

The role of source water quality in wastewater quality is obvious in principle, but the data developed in this project do not support a clear conclusion. Obviously, source water high in TDS will produce wastewater high in TDS. The dairy overlying the Menifee GWMZ had the highest TDS source water and was among the highest TDS wastewater among those dairies sampled; however several other dairies with lower TDS source water produced wastewater higher in TDS. However, the estimated mass of TDS and salts contributed by well water exceeded the mass in dairy wastewater for a number of dairies and it is not known if this is due to data irregularities, or some other cause, as noted earlier.

Analysis of QA/QC sample data provides some guidance for future sampling of dairy manure and wastewater. In manure sampling, 95% of replicate analyses (73 of 77) showed less than a 20% relative percent difference (RPD) between paired samples, a commonly acceptable standard for laboratory quality assurance testing. For field duplicate samples, 94% (31 of 33) duplicate lab analyses showed less than 5% RPD, a very high level of agreement characteristic of excellent laboratory analysis. In wastewater sampling, replicate performance was even better, with 92% (24 of 26) of replicate analyses exhibiting less than 10% RPD. Analyses of field duplicate wastewater samples generally showed less than a 5% RPD. These results suggest that sampling procedures for manure and wastewater were highly repeatable and probably gave results reasonably representative of true manure and wastewater quality.

Conclusions and Recommendations

This dairy sampling and analysis project quantified the nutrient and salt loads associated with manure and wastewater on a group of San Jacinto dairies. These loads can be used for planning purposes in a salt offset program. Some specific conclusions are:

- Manure represents by far the dominant source of salt and nutrient loads from dairies; it is clear that any solutions to the salt offset issue must address manure export.
- The salt and nutrient content of manure in dairies was reasonably consistent among the sampled dairies; this consistency may be beneficial for the processing of manure into a uniform product for sale or export from the watershed.
- Salt and nutrient loads in dairy wastewater generally comprised 20% or less of total dairy loads.
- Estimated dairy wastewater volumes were substantially lower than the assumptions used in previous salt offset assessments, but measured TDS concentrations were substantially higher than previously estimates. As a result, wastewater TDS loads calculated in this project are substantially higher than those previously estimated.
- The quality of dairy wastewater was substantially more variable than manure quality among the sampled dairies. To some extent, this may be due to management variations, suggesting that opportunities might exist to reduce wastewater TDS and nitrate levels.

- Well water quality data provided by the EWMD suggest some trends toward declining ground water TDS; investigation and documentation of such trends should be an important part of a salt offset program.
- Quality assurance data suggest that the sample collection procedures used in this sampling program produced repeatable, representative results.

In future investigations of the dairy nutrient and salt issue, the following steps are recommended:

- Obtain more accurate data on dairy wastewater generation by metering source water at the point of use rather than relying on well extraction data.
- Collect detailed, site-specific data to support an analysis of N mineralization and nitrification rates in dairy wastewater management.
- Sample local ground water to assess actual delivery of TDS and nitrate to ground water.

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Appendix I – Analysis and Development of a Manure Manifest System for the San Jacinto River Watershed

Analysis and Development of a Manure Manifest System for the San Jacinto River Watershed

Final Report

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November 28, 2008

Funding for this project has been provided in full or in part through an agreement with the California State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. (Gov. code 7550, 40 CFR 31.20).

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Appendix B. Manure Manifest System Cost Model B-1

Acronyms and Abbreviations

BMP	Best management practice
CAFO	Concentrated animal feeding operation
EWMP	Engineered waste management plan
GIS	Geographic information system
IT	Information technology
LA	Load allocation
NMP	Nutrient management plan
NOI	Notice of intent
NPDES	National Pollutant Discharge Elimination System
PM_{10}	Particulate matter smaller than 10 micrometers
RWQCB	Regional Water Quality Control Board
SJBRCD	San Jacinto Basin Resource Conservation District
TDS	Total dissolved solids
TMDL	Total maximum daily load
VOC	Volatile organic compound
WLA	Wasteload allocation
WRCAC	Western Riverside County Agriculture Coalition

1. Executive Summary

Purpose and History

The purpose of this project was to develop a Manure Manifest System to track manure generation, transport, and utilization in the San Jacinto River watershed. The San Jacinto agricultural community, including the San Jacinto Basin Resource Conservation District (SJBRCD) and Western Riverside County Agriculture Coalition (WRCAC), requested technical assistance on nutrient management and salt reduction in the watershed. These groups are interested in developing a holistic tracking system to self-regulate transport and utilization of manure in the watershed.

Proper management of animal manure in the San Jacinto River Watershed is essential to meet a number of regulatory requirements, including surface water, ground water, and clean air regulations and local ordinances. These include the following:

- National Pollutant Discharge Elimination System (NPDES) Permit for Concentrated Animal Feeding Operations (CAFOs)
- Lake Elsinore and Canyon Lake Nutrient Total Maximum Daily Load (TMDL)
- Groundwater quality concerns outlined in the Water Quality Control Plan for the Santa Ana Region
- Riverside County Ordinance 427.2 governing manure transport and application
- South Coast Air Quality Management District's Rule 1127, Emission Reductions from Livestock Waste

Previous studies in the San Jacinto River watershed examined the dairy industry and quantified the amount of manure generated in the watershed. The studies identified a need for additional cropland beyond what is owned by dairies to spread manure at environmentally responsible rates. Because of this deficit, coordination between CAFO operators and crop producers is essential to ensure that a market exists for disposing of and utilizing manure.

The report outlines the current status of manure generation, transport, and utilization, including interactions among CAFO operators, haulers, and landowners as well as information that is and is not reported. The two existing programs that track manure—the NPDES Permit for CAFOs and Riverside County Ordinance 427.2—are each missing key features of a holistic tracking program because the former focuses on manure generation and transport and the latter focuses on land application. Tracking requirements are expected to increase, particularly for agricultural producers as a result of the future implementation of a best management practice-based waiver program for irrigated agriculture being considered by the Regional Water Quality Control Board (RWQCB).

The manifest program is expected to meet a variety of goals and produce the following benefits:

- Reduce groundwater contamination concerns by providing a mechanism to ensure prudent nutrient management by all manure users.
- Provide information on nutrient generation, transportation, and utilization to improve analyses for the Canyon Lake and Lake Elsinore TMDL, as well as information on best management practices implemented to mitigate nutrients.
- Address air quality concerns and reduce nuisance complaints from neighbors through guidance and site-specific limitations for manure application.
- Improve accountability for manure utilization and disposal and reduce dairy operators' risk of fines or litigation due to improper disposal outside of their control.
- Provide detailed spatial information on crop production and manure import, application, and export, which were identified as gaps in previous analyses.
- Improve communications and provide outreach to CAFO operators, haulers, and agricultural producers.

- Provide a head start for meeting irrigated agriculture waiver requirements.
- Provide an opportunity for funding regional implementation projects that benefit the entire watershed.

Manure Manifest Process

A multi-phase process is proposed for establishing and running the Manure Manifest System. The first phase involves recruiting participants through a notice of intent (NOI) process. Dairy operators will provide basic information about the business, including contact name and address, facility location, and manure product amount and condition. Haulers will provide basic information about the business, including contact name, address, business license number, number of trucks, and other relevant information. The owner of the property receiving manure will submit information about the property, including contact information, ownership, available acreage, crop history (past and current), soil information, groundwater management zone, and other site information.

Once applications are submitted, Manure Manifest System staff review and verify the information, conduct site visits, and enter participant data into a manifest system database (Phase 2). During Phase 3, Manure Manifest System staff will approve or deny applications and set any conditions for approval. Ongoing staff activities include processing manure transfers, conducting additional inspections, maintaining the manifest system database, and analyzing and synthesizing data for regulatory reporting. Ongoing activities for participants are to meet any conditions for approval, complete and submit paperwork for manure transfers, and renew their NOIs annually.

The report proposes series of steps and activities for each phase of the Manure Manifest System, and includes the following forms:

- NOI Forms (CAFO operator, hauler, and landowner)
- Landowner/Tenant Agreement Form
- Manure Transfer Form
- Annual Renewal Form (CAFO operator, hauler, and landowner)

Organization and Staffing

The SJBRCD has been identified as the organization best equipped to administer the Manure Manifest System. Three key staff positions have been identified to establish and run the Manure Manifest System: Program Manager, Ag Specialist, and Information Technology/Geographic Information System (IT/GIS) Specialist. The following levels of effort are expected for each staff position:

- Program Manager: 500 hours for Program start-up and 481 hours annually thereafter.
- Ag Specialist: 798 hours for Program start-up and 854 hours annually in subsequent years for ongoing tasks.
- IT/GIS Specialist: 168 hours for Program set-up and 30 hours annually in subsequent years for maintenance and upgrades.

Program Budget

One-time start-up costs (labor and capital costs) and ongoing, annual costs (labor and operation and maintenance) were estimated based on the assumptions presented in Appendix B. Start-up costs are estimated to be approximately $50,100 in labor and $12,500 in capital costs, yielding a total start-up cost of approximately $62,600. Annual costs, including renewal, manure transfer processing, and other program activities, is estimated at $49,900 ($4,000 in annual operation and maintenance costs can be avoided by billing these costs back to landowners). There are a number of options for allocating up-front and annual costs among the participants. Tetra Tech recommends a hybrid funding approach that combines annual membership fees with per-transfer fees and cost recovery for soil sample analysis to fund the program's operating expenses.

2. Introduction

The purpose of this project is to develop a Manure Manifest System to track manure generation, transport, and utilization in the watershed. The San Jacinto agricultural community, both CAFO operators and agricultural producers, requested technical assistance on nutrient management and salt reduction in the watershed. WRCAC has identified a holistic manure tracking system as a means to investigate reducing nutrients and salts in the watershed. Participation by stakeholders would be voluntary. A thorough analysis of issues and design of a refined manure manifesting system would assist the CAFO and agriculture operators in meeting TMDL nutrient reduction targets and NPDES permit requirements over the next several years.

Development of this Manure Manifest System involved working with WRCAC and other local stakeholders to identify the minimum requirements of the system and lay out details of administration, the nature of participating entities, economic factors driving manure utilization, and other issues that will shape the final Manure Manifest System. A list of start-up and ongoing activities was developed based on the overall plan for implementation and integrated into a cost model to estimate capital, labor, and operation and maintenance costs and help develop a fee structure to sustain the Program long-term.

3. Manure Management History in Watershed

Proper management of manure from dairy operations in the San Jacinto River Watershed is essential to meet a number of regulatory requirements, including those related to surface water, ground water, and clean air regulations and local ordinances. A manure tracking system will also address other, non-regulatory issues that have arisen as a result of manure hauling and land application activities. The following is a discussion of the applicable regulatory requirements that affect manure management, including the background and implementation requirements of each, as well as a brief discussion of the other issues that may benefit from a better system for tracking and managing manure.

3.1. Surface Water Quality Concerns and Regulations

NPDES Permit for CAFOs

In September 2007, the Santa Ana RWQCB issued order number R8-2007-0001 (NPDES No. CAG018001): *General Waste Discharge Requirements for Concentrated Animal Feeding Operations (Dairies and Related Facilities) within the Santa Ana Region* (Santa Ana RWQCB, 2007). All dairies in the San Jacinto River watershed are covered under the order, which includes requirements based on applicable federal and state regulations, the Water Quality Control Plan for the Santa Ana Region (Basin Plan), and the Lake Elsinore and Canyon Lake Nutrient TMDL. The discharge permit contains a number of requirements specific to the production areas at dairies (i.e., the areas where animals are confined and where manure, feed, commodities, and other by products and raw materials are stored). Production area requirements include:

- Dairies may not discharge process wastewater or storm water runoff from manured areas, except where (1) the discharge is caused by precipitation, (2) the facility is designed, constructed, operated, and maintained to contain manure, wastewater, and the runoff from a 25-year, 24-hour rainfall event and (3) the production area is operated in accordance with other permit requirements.
- Confined animals may not have direct contact with waters of the U.S.
- Dairies must develop and implement an Engineered Waste Management Plan (EWMP) that has been approved by the Regional Board.
- Wastewater holding structures must meet specific construction, operation, and maintenance requirements.
- Manure removed from corrals must be removed from the facility within 180 days.
- Surface drainage must be diverted away from manured areas and all drainage from manured areas must be contained.

- Chemicals and mortalities must be properly handled and disposed of.
- Containment structures and wastewater distribution lines must be inspected weekly.
- Water lines must be inspected daily.
- Deficiencies identified during facility inspections must be corrected promptly.
- Records of daily and weekly inspections and any discharges from the facility must be maintained.

The permit also contains specific requirements for land application of manure and wastewater.

- Disposal of manure to land is prohibited.
- Land application of manure and process wastewater in areas that overlie ground water management zones lacking assimilative capacity for total dissolved solids (TDS) and/or nitrate is prohibited, unless a plan is implemented to offset the impact of land application on the ground water management zone. In addition, the discharge of waste containing TDS and/or nitrogen concentrations in excess of the underlying ground water management zone objectives is prohibited, unless adequately offset. The permit includes a compliance schedule associated with these requirements:
    - Submit a Work Plan to offset the impacts of process wastewater discharge and manure land application to the Regional Board for approval. The final Work Plan was submitted to the Regional Board on August 21, 2008.
    - Fully implement the Work Plan or cease the discharge of process wastewater and land application of manure within the San Jacinto River Basin by September 6, 2012.
- Dairies that apply manure or process wastewater to their own croplands must develop a Nutrient Management Plan (NMP), in accordance with federal regulations and Natural Resources Conservation Services Conservation Practice Standards and submit it to the Regional Board by September 1, 2008. The NMP must be fully implemented by February 27, 2009.

The permit includes a compliance schedule of requirements specific to dischargers in the Lake Elsinore and Canyon Lake watershed. San Jacinto watershed dairies, through WRCAC, generally are complying with these requirements in cooperation with the TMDL Task Force, with exceptions identified below:

- Develop a watershed-wide, Canyon Lake in-lake and Lake Elsinore in-lake monitoring program to provide data to review and update the Lake Elsinore and Canyon Lake Nutrient TMDL. The SJBRCD is monitoring Mystic Lake and three watershed sites to provide data to validate some of the assumptions of the Nutrient TMDL.
- Develop an Agricultural NMP specific to CAFOs that includes steps to identify nutrient sources and develop nutrient reduction strategies. WRCAC submitted this plan to the Regional Board in September, 2007.
- Develop a plan and schedule for in-lake nutrient reduction for Lake Elsinore.
- Develop a plan for evaluating in-lake sediment nutrient reduction strategies for Canyon Lake.
- Develop a proposal and schedule for updating the existing Lake Elsinore/San Jacinto River Nutrient Watershed Model and the Canyon Lake and Lake Elsinore in-lake models.
- Develop a Pollutant Trading Plan.

Finally, the permit includes specific requirements related to manure transfers from dairies:

- Dairies must provide the manure recipients with information on the nutrient content of the transferred manure or wastewater.
- Dairies must complete a Manure Tracking Manifest Form for each manure hauling event identifying the manure source, hauler, destination, and quantity of manure involved.

Lake Elsinore and Canyon Lake Nutrient TMDL

The Lake Elsinore and Canyon Lake Nutrient TMDL (Santa Ana RWQCB, 2004) identified agriculture and CAFOs, including dairies, as significant sources of nutrients to the two impaired waterbodies. The TMDL distributes the portions of the waterbodies' modeled assimilative capacities to various pollution sources so that the waterbodies achieve their water quality standards. Table 1 summarizes the TMDL wasteload allocations (WLAs) and load allocations (LAs) relevant to agriculture and dairies that were assigned as a result of detailed modeling and technical analyses.

Table 1. Wasteload and load allocations for CAFOs and agriculture in the Lake Elsinore and Canyon Lake Nutrient TMDL (Santa Ana RWQCB, 2004).

Waterbody	Pollutant	Source	WLA/LA (kg/year)
Canyon Lake	Nitrogen	CAFO	132
		Agriculture	1,183
	Phosphorus	CAFO	1,908
		Agriculture	7,583
Lake Elsinore	Nitrogen	CAFO	0
		Agriculture	60
	Phosphorus	CAFO	0
		Agriculture	213

Note: Wasteload allocations apply to point sources, including CAFOs, and load allocations apply to nonpoint sources, which include crop agriculture

The TMDL Basin Plan amendment outlines a number of implementation activities for watershed stakeholders and sets December 31, 2020, as a final compliance date for the WLAs and LAs. For agricultural producers, the Basin Plan amendment requires development and implementation of an NMP that includes the following:

- Implementation of nutrient controls, BMPs and reduction strategies designed to meet LAs.
- Evaluation of effectiveness of BMPs.
- Development and implementation of compliance monitoring.
- Development and implementation of focused studies that will provide the following data and information;
- Inventory of crops grown in the watershed.
- Amount of manure and/or fertilizer applied to each crop with corresponding nitrogen and phosphorus amounts.
- Amount of nutrients discharged from croplands.

Additionally, watershed-wide monitoring and analyses are required of all stakeholders.

In 2006, to better coordinate implementation activities and meet WLAs, the San Jacinto dairies, represented by WRCAC, joined other watershed stakeholders to form the Lake Elsinore and Canyon Lake TMDL Task Force (Task Force). The Task Force is currently working to:

- Develop and implement a watershed-wide nutrient monitoring program.
- Develop and implement a Lake Elsinore and Canyon Lake nutrient monitoring program.
- Develop and implement a plan to reduce nutrients in Lake Elsinore sediments and develop a sediment nutrient treatment evaluation plan for Canyon Lake.
- Develop and implement a plan and schedule for updating the existing Lake Elsinore/San Jacinto River Watershed nutrient model and the Canyon Lake and Lake Elsinore in-lake models.
- Investigate, develop, and implement a pollutant trading plan.
- Investigate a long-term TMDL implementation structure, cost-sharing formula, and funding sources.

3.2. Ground Water Quality Concerns

The *General Waste Discharge Requirements for Concentrated Animal Feeding Operations (Dairies and Related Facilities) within the Santa Ana Region* addresses ground water concerns in addition to surface water concerns:

> Disposal of manure to land is prohibited. The application of manure, process wastewater, and/or storm water runoff from manured areas, on cropland outside of the Chino Basin that overlie ground water management zones lacking assimilative capacity for TDS and/or nitrate-nitrogen is also prohibited unless a plan, acceptable to the Executive Officer, is implemented that offsets the effects of that application on the underlying ground water management zone. (Section IV. B.)

In January 2004, the Regional Board amended the Basin Plan to incorporate an updated TDS and nitrogen management plan (Adopted Order R8-2004-0001). This amendment included revised ground water subbasin boundaries (now called "management zones"). In total, there are 28 dairies operating in the San Jacinto region, overlying four different management zones: San Jacinto Lower Pressure, San Jacinto Upper Pressure, Lakeview/Hemet North, and Menifee. The Basin Plan also included revised TDS and nitrate-nitrogen quality objectives for ground water. For a management zone to have assimilative capacity, the ambient TDS and/or nitrate-nitrogen concentrations must be below the water quality objectives. The Regional Board mandates the recalculation of ambient ground water quality on a triennial basis to allow for continual assessment of a region's compliance with the State of California's antidegradation policies.

The TDS and nitrate-nitrogen concentrations in all San Jacinto region ground water management zones, except the Canyon Subbasin, are in excess of the new water quality objectives laid out in the Basin Plan amendment. Because there is no assimilative capacity for TDS or nitrate-nitrogen in any of the management zones underlying the San Jacinto dairies, all dairy operations in the San Jacinto region are now subject to the discharge prohibitions outlined in the 2007 dairy permit.

Under Order R8-2007-0001, any dairy operating in a region that lacks assimilative capacity for TDS or nitrate-nitrogen and plans to continue to apply manure and other dairy process wastes to land must design a work plan to offset its salt load by September 2012. In 2008 an analysis was conducted by Wildermuth Environmental, Inc., to present San Jacinto dairy operators with a set of salt offset options to mitigate their impacts to the underlying ground water past this September 2012 deadline.

3.3. Riverside County Ordinance 427.2

Riverside County Ordinance 427.2 (Riverside County Board of Supervisors, no date) regulates the transportation and application of manure in certain Districts of the county. It requires that all farm and agricultural operations or landowners who wish to apply bulk manure register with the County Agricultural Commissioner. Such operators or landowners are required to report manure application, agreeing to a set of conditions described in the ordinance, to minimize impacts to neighboring properties, local waterways, underground water supplies, and soil resources. The ordinance states that landowners must apply for an exemption to utilize manure or allow manure transporters to apply manure to their land. Landowners also need to have demonstrated conformity with the "Standards for Manure Use at Approved Sites" in prior manure applications. Exemptions are granted for a period of one year.

The ordinance states the following prohibitions:

- No manure transporter shall deliver manure to a site for the purposes of disposal, land application or storage within the unincorporated portions of the area generally subject to regulation by the Santa Ana and San Diego RWQCBs and specifically defined and enclosed by the Riverside County Line ... unless the landowner of the site has a current and valid exemption as issued by the County Commissioner.

- No manure transporter shall deliver manure to a site within the regulated area without having in the possession of the driver of each of the following: (1) a copy of a valid exemption for the site issued by the County Commissioner, (2) the written permission from the landowner if not a part of the exemption and (3) a copy of the delivery contract between the transporter and the landowner or occupant.

- No landowner shall accept manure or knowingly allow manure to be deposited on land owned or controlled by him or her in areas prohibited by this ordinance.

- No manure transporter, manure applier, or landowner, including tenant or occupant, shall transport, apply, or allow the application of manure in a manner that may violate any conditions established through an exemption, the standards established by the ordinance, or other laws or regulations.

The following sites are not subject to the prohibitions:

- Agricultural sites operated in conjunction with a public school with a recognized agricultural training program or curriculum.

- Agricultural sites contiguous to and owned by the operator of, a facility operating as an Animal Feeding Operation under Waste Discharge Requirement issued by the RWQCB.

- A tree or vine farming operation considered active by the Commissioner.

- Operating farms registered with the County Agricultural Commissioner that have received approval to apply manure and meet the following conditions:

    - The site has a minimum of 5 acres of tillable soil or as otherwise accepted by the County Commissioner.

    - There is a distance not less than ¼ mile from all public schools in session during the time in which manure is to be applied and incorporated.

    - The manure application is conducted by or for the operating farm, at agronomic rates, using only quality manure, at application rates approved by the County Commissioner.

    - Crops are planted after manure application in a time frame approved by the County Commissioner.

According to two memoranda from WRCAC (Sybrandy, 2005) and the Riverside County Farm Bureau (Scott, 2006), not all local jurisdictions are complying with this ordinance, notably the City of Perris, resulting in untracked dumping of manure at a variety of sites. As of the date of this report, this situation remains unresolved.

3.4. Air Quality

Dairy operators in the San Jacinto Basin are subject to the South Coast Air Quality Management District's Rule 1127, Emission Reductions from Livestock Waste. The rule is intended to reduce emissions of ammonia, volatile organic compounds (VOCs), and particulate matter smaller than 10 micrometers (PM_{10}) from livestock waste. This rule applies to dairy farms and related operations, such as heifer and calf farms, and the manure produced on them. It also applies to manure processing operations, such as composting operations and anaerobic digesters. It specifies BMPs to reduce air emissions, including manure removal, minimization of excess water, paving, cleaning frequency, and stockpiling requirements. It limits disposal of manure to an approved manure processing operation and/or agricultural land within the South Coast Air Quality Management District approved by local

ordinance and/or the RWQCB for the spreading of manure. The rule also sets forth requirements for manure processing operations.

Dairy operators with 50 or more cows are required to submit notification of their operations to the South Coast Air Quality Management District and comply with the requirements set forth in the rule. Operators must submit an annual report specifying the number of animals present, the amount of manure removed during the year, and the destination(s) of the manure. Dairy operators can submit plans for review by the South Coast Air Quality Management District for alternate control options in lieu of implementing the BMPs outlined in the rule.

Large confined animal facilities are subject to additional requirements under the South Coast Air Quality Management District's Rule 223, Emission Reduction Permits for Large Confined Animal Facilities. The rule defines "large" facilities in detail; dairies with 1,000 or more milk-producing dairy cows are included in this definition. Facilities meeting this definition are required to obtain a permit to operate from the South Coast Air Quality Management District, and new facilities cannot operate without prior approval from the South Coast Air Quality Management District. The rule sets forth a set of mitigation measures with which operators must comply, including controls for feed and silage, milk parlor, freestall barns, corrals, handling of solid manure or separated solids, handling of liquid manure, and land application.

3.5. Other Issues to be Addressed by the Manure Manifest System

In addition to the requirements described above, the Manure Manifest System is expected to address other manure-related issues and concerns in the watershed. The first is that manure currently being land-applied in the San Jacinto Basin does not solely originate at San Jacinto dairies. Dairies in the Chino Basin are exporting manure and haulers are applying it at San Jacinto sites. Because the San Jacinto Basin has limited assimilative capacity for nutrients and salts, this additional manure from outside the Basin limits options for San Jacinto dairies to dispose of their manure.

Another issue is illegal dumping. When CAFO operators from within or outside the San Jacinto basin contract with haulers, a mechanism of accountability for the final destination of the manure is lacking. Many hauling events result in authorized land application on San Jacinto cropland, but anecdotal evidence suggests that some haulers are illegally dumping manure on non-authorized sites, posing a nuisance, increasing the risk of surface and ground water pollution, and violating conditions of the Riverside County Ordinance.

Finally, the Manure Manifest System offers the opportunity for land application sites to be reviewed in detail for soil and crop conditions, proximity to waterbodies and sensitive resources, and potential nuisance complaints based on neighboring land uses. For example, sites adjacent to schools or public parks might be less desirable for manure application during certain times of the year due to odor or public health concerns. The site visits afforded by the proposed Manure Manifest System can identify and address potential conflicts before they occur to eliminate discord and ensure communication between landowners and the public.

4. Quantity of Manure in Watershed

4.1. Manure Generation

According to a 2004 survey of 34 San Jacinto dairies, as summarized in the 2006 *Supplemental Environmental Project—Source Identification for Phosphorous, Nitrates and Salts in the San Jacinto Watershed and Identification of Technologies and Alternate Control Measures* report or "SEP Report" (Tetra Tech, Inc., 2006), dairy operators in the San Jacinto watershed reported a total of 229,346 tons of manure on their 2004 manifests submitted as a condition of the NPDES permit (Table 2). Calculations of manure generation based on the number and type of animals present at the facilities in 2004 estimates 224,861 tons of manure generated, based on the assumption that the manure is 75 percent dry. The reported vs. estimated values differ by 4,485 tons.

An assumption was made that 28,993 tons of manure were stored in lagoons in wet form. Total calculated manure generation was 695 tons per day or 253,882 tons per year. According to the 2004 Annual Reports submitted to the RWQCB, 241,026 tons of manure were used in the San Jacinto Basin, whereas 6,962 tons of manure (2.74 percent) were shipped out of the Basin. Note that 32 of the respondents collected 10 percent of manure in liquid form, whereas one CAFO operator collected 25 percent as liquid and one collected 50 percent as liquid.

Table 2. Manure Generation Statistics and Acres Needed for Land Application of Manure (Borges, 2005).

Manure Statistics	Tons
Dry Manure Reported on the 2004 Manifest	229,346
Generated Under Calculations 75% Dry	224,861
Difference in Tons	4,485
In Wet Form (in lagoons, assumed)	28,993
Total Manures Generated Daily (calculated)	695
Total Manures Generated Monthly (calculated)	21,157
Total Manures Generated Annually (calculated)	253,882
Manure Used in Basin Annually	241,026
Manure Shipped Out of Basin Annually	6,962

An analysis of the 2007 annual reports submitted by San Jacinto dairies in fulfillment of NPDES permit reporting requirements showed that there are now 28 dairy operators in the San Jacinto River Basin. Collectively the dairies reported 228,394 tons of manure spread at the facility, stockpiled, or shipped in 2007, which differs from the 2004 amount by 952 tons.

4.2. Land Available for Manure Application

According to the 2004 survey, 6,280 acres of land are under the direct control of dairy operators (owned or leased). Of these, 1,707 acres were used for the facility, roads, yards, or other uses that are not suitable for wastewater or manure application. Table 3 shows that a total of 1,604 acres were available for wastewater application, whereas 2,124 acres were needed, yielding a need for an additional 520 acres of farmland to dispose of all of the wastewater generated. For dry manure, 2,969 acres of farmland were available for application. Based on a single crop per year, 16,489 acres would be needed to apply all of the dry manure generated, resulting in a farmland deficit of 13,519 acres. Based on two crops per year, 10,993 acres would be needed to apply all of the dry manure, resulting in a need for 8,023 acres of additional farmland. A total of 8,543 acres would be needed to apply all of the liquid and dry manure generated. To address the deficit in dairy-owned land application areas, dairy operators contracted with haulers to remove manure to local cropland as reported in dairy manifests.

Table 3. Land Available and Needed for Wastewater and Manure Application

Land Application Statistics	Acres
Total Land Owned and Leased Under Direct Dairy Control	6,280
Land Used for Facility, Roads, Yards, etc.	1,707
Wastewater Analysis	
Land Needed for Generated Wastewater Application	2,124
Dairy-Owned Land Available for Generated Wastewater Application	1,604
Additional Farmland Needed For Wastewater Application	520
Dry Manure Analysis	
Farmland Needed for Dry Manure Application: Single Crop	16,489
Farmland Needed for Dry Manure Application: Double Crop	10,993
Dairy-Owned Farmland Available for Dry Manure Application	2,969
Additional Farmland Needed for Dry Manure Application: Double Crop	8,023
Total Farmland Deficit	
Additional Farmland Needed for Double Crop (Liquid and Dry Manures)	8,543

One of the challenges facing dairy operators is the persistent trend in the region of conversion of agricultural lands and open space to suburban and urban land uses. This has steadily reduced the land available for manure application in terms of overall cropland. It also has meant that existing cropland may now be located adjacent to an urban land use (e.g., housing development, school), which can pose nuisance concerns or lead to prohibitions on manure application during some parts of the year (e.g., when school is in session).

An effort is underway to collect spatial data on agricultural lands to address outdated and inaccurate parcel maps. These data were not available at the time of publication of this report, but they will provide the Manure Manifest System with highly accurate, up-to-date information about sites potentially available for land application of manure.

5. Summary of Activities Influencing the Manifest Project

Manure generation, transport, utilization, and disposal in the San Jacinto Basin involves relationships between manure generators, haulers, landowners, and regulators within and outside of the San Jacinto watershed (Figure 1). The environmental regulations and ordinance described above set the regulatory stage that guides the process and limits how much, when, and where manure can be applied to land. Challenges arise when certain parties do not follow guidelines regarding manure disposal, defeating the efforts of other individuals and groups who spend time, money, and effort ensuring that their practices are sound. Reports of illegal dumping, application of manure at non-agronomic rates, and application of manure to sites that might pose a neighborhood nuisance can draw negative attention from both regulators and the community.

A limited amount of manure tracking currently exists through Riverside County's ordinance governing land application of manure and the RWQCB's NPDES permit. The County maintains a list of approved land application sites and provides the authority to take enforcement actions against haulers or landowners for improperly transporting and/or applying manure. The RWQCB's Annual Report of Animal Waste Discharge captures the number and type of animals at a facility, information on manure spread and stockpiled onsite, and the amount of manure transported offsite. The current Manure Tracking Manifest required by the NPDES permit records details on the dairy operator, hauler, and destination for the manure, as well as total weight and a requirement to provide results of the most recent manure nutrient analysis to the recipient of the manure. The Manure Tracking Manifests are submitted annually with the Annual Report of Animal Waste Discharge.

These two programs do not provide the holistic tracking of manure generation, transport, and utilization/disposal that is needed to ensure true accountability. The RWQCB Manure Tracking Manifest only requires that haulers sign for the manure and provides no information about the specific land application site(s). The RWQCB focuses on generation and utilization at dairy operations and does not directly involve agricultural producers who take possession of the manure. In addition, anecdotal evidence, including Annual Report reviews and information supplied to dairy inspectors in the field, suggests that the data reported on the RWQCB manifest form are not of consistent quality from dairy to dairy. The County's ordinance focuses on agricultural producers and sets limits for manure use, but it does not directly involve haulers or CAFO operators. In addition, the County ordinance only applies in unincorporated areas; some jurisdictions within the County do not regulate manure disposal in a manner consistent with the County ordinance.

The RWQCB is considering implementation of a waiver of waste discharge requirements for irrigated agricultural operations, which would provide more stringent pollution prevention requirements for crop agriculture operations. An irrigated agriculture waiver system is already in place in the Central Coast RWQCB, where agricultural producers have been required to submit notices of intent to operate and prepare a farm plan that specifies BMPs that will be implemented to reduce discharges of pollutants to surface waters. The details of the Santa Ana RWQCB's approach to the irrigated agriculture waiver are not known, so the effect on manure tracking and application in the San Jacinto watershed cannot be determined yet. However, irrigated agriculture waiver requirements should be considered in future implementation of the Manure Manifest System.

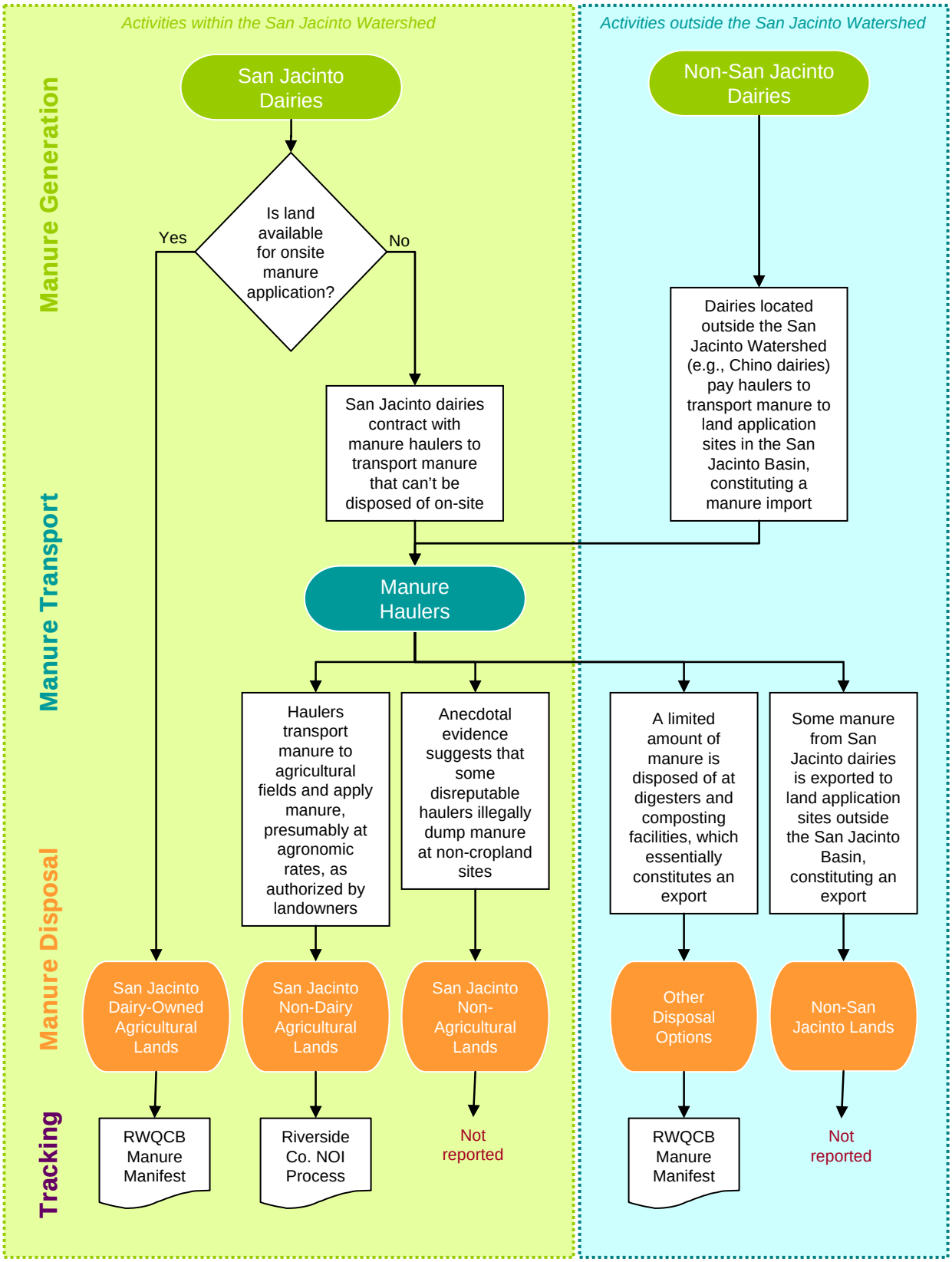

Figure 1. Interactions among parties dealing with manure generation, transport, and utilization/disposal.

6. Manifest System Benefits to the Watershed

The proposed Manure Manifest System offers a variety of benefits to the watershed and its stakeholders, including water and air quality improvements as well as improved accountability and communication among participating parties. The following is a more detailed discussion of individual benefits.

- The risk of groundwater contamination from manure overapplication has led to a pending prohibition of manure application in most of the watershed (see Section 3.2). The Manure Manifest System will address nutrient and salt loadings by specifying that manure be applied to land at rates consistent with cropping practices and groundwater conditions. This will prohibit over-application at sites with groundwater limitations, thereby protecting water quality and, when combined with other ongoing efforts to offset groundwater impacts, increasing the likelihood that regulatory agencies will continue to allow the judicious application of manure.

- The Manure Manifest System will provide better information to support the TMDL Task Force's efforts to model and mitigate nutrient sources to meet requirements of the Canyon Lake and Lake Elsinore TMDL (See Section 3.1). Both dairies and crop agriculture have been specifically identified as sources of nutrients in this TMDL, and the manifest program will allow for tracking of manure application on a site basis rather than on a county or whole watershed level, providing higher resolution modeling of impacts. The manifest program will also document management practices for which stakeholders can claim nutrient mitigation credit.

- Dairy operators are subject to air quality regulations to control ammonia, VOCs, and PM_{10} from livestock waste (see Section 3.4). The Manure Manifest System will address air quality concerns by providing guidance and/or prohibitions regarding where and when manure can be land-applied. During site visits to facilities where manure is generated, handled, processed, and/or land-applied, BMPs to reduce air emissions will be recommended or required. The manifest system will track disposal of manure, ensuring that it is transported to an approved manure processing operation or approved agricultural land, as required by the South Coast Air Quality Management District.

- Nuisance complaints from owners of property that neighbor land application sites can cause significant political fallout and lead to stricter local regulation or possibly prohibitions of manure disposal. The Manure Manifest System can mitigate this concern by evaluating land application sites for potential conflicts with neighbors and addressing them with odor-reducing and containment BMPs to alleviate nuisances before they become a problem.

- The Manure Manifest System will improve accountability for the generation, transport, and fate of manure. The program will establish a "chain of custody" for manure, which should reduce illegal dumping because a paper record will allow identification of any party that did not legitimately transfer or utilize the manure. This level of accountability will reduce the risk to CAFO operators of fines or litigation for improper disposal that is beyond their control.

- The manifest system will provide better data for modeling and analyses, particularly manure production rates and spatial data on crop production and manure application. The SEP Report stated that data regarding agricultural lands is lacking, outdated, and inaccurate, particularly with regard to crop types and rotation schedules, irrigation practices, and manure, fertilizer, and wastewater application rates/practices. Older datasets must be updated to reflect development patterns and conversion of cropland to suburban development. Also, better data on nutrient loading rates would allow actual values to be used in lieu of relying on literature values, more accurately reflecting local conditions.

- The Manure Manifest System will likely improve communication among landowners, haulers, and CAFO operators by providing a forum for outreach on voluntary and regulatory initiatives to improve manure management. Site visits by Manure Manifest System staff will allow direct, one-on-one communication with operators, allowing staff to offer solutions tailored to individual settings. The manifest program will also have access to a participant mailing list to disseminate information about program changes, new or revised regulations that will affect operations, new BMP technologies, and other pertinent information.

- The Manure Manifest System will provide a starting point for irrigated agriculture BMPs and farm plans that may be required as part of an irrigated agriculture waiver program, which is currently under consideration by the RWQCB. The work accomplished by the manifest program sets the stage for more streamlined compliance with future regulations concerning water and air quality.

- Fees from the manifest program will mainly cover operating expenses, though the Manure Manifest System offers a method by which future implementation projects may be funded to reduce manure impacts throughout the watershed. These non-site-level projects can offer another layer of mitigation when onsite BMPs are inadequate to meet stringent regulatory requirements, benefiting all watershed stakeholders and improving good will between the regulated community and state regulators.

7. Manifest System Recommendations

7.1. Summary of Other Manifest Systems

A number of other states have programs that regulate or create incentives to manage the transport of manure from CAFO operators to land application sites. Highlights of such programs in Delaware, Maryland, Pennsylvania, South Carolina, Texas, and West Virginia are presented below. Many of these programs include incentives and public/private partnerships that improve the cost-effectiveness of transporting manure—these types of practices might be considered for use in the San Jacinto Manure Manifest System if possible.

Delaware

Delaware offers a Manure Matching Service to enable Delaware poultry growers with excess poultry litter to relocate the litter to farmers in the need of nutrients for crop production or to approved alternative use projects (State of Delaware, 2007). The service provides contact information about manure providers, including the amount of manure and the date it will be available. It also provides contact information for manure receivers, including the amount and date of required manure. Finally, the service identifies brokers and transporters to relocate excess manure.

Maryland

Maryland sponsors a Manure Transport Program to provide financial assistance to CAFO operators to cover the cost of transporting manure to other areas (Maryland Department of Agriculture, no date). The state provides cost-share assistance of up to $20 per ton for transport of manure to other farms or alternative use facilities. Cost-share rates are higher for certain priority areas based on soil phosphorus levels. In 2004, the program provided farmers with $295,356 in state grant payments to transport 44,292 tons of manure away from areas with high soil phosphorus levels. Cost-share funds to transport poultry litter—comprising the bulk of the manure transported—were matched by Delmarva poultry companies, bringing the total amount of financial support to $581,162.

Maryland also has a Manure Matching Service that establishes a marketplace where farmers can sell their excess manure to buyers who need the valuable nutrients it contains for crop production or alternative use business ventures. The service is free and available to both sending and receiving operations.

Pennsylvania

Pennsylvania requires confined animal operators to maintain manure transfer records (Pennsylvania Nutrient Management Program, 2003). In some cases, such as transfers of manure to known landowners, the documentation does not need to be submitted to the Conservation District but must be maintained onsite for at least 3 years. In other cases, such as when transfers occur to brokers or to importers who use the manure for non-agricultural land application, manure transfer records must be submitted to the Conservation District within one year. The information can be submitted for each manure transfer, or it can be summarized annually for all manure transfers occurring that year. Information to be tracked includes destination, date, and amount of exported manure.

South Carolina

South Carolina has had a manure broker program since 2002, which is required by legislation (South Carolina Department of Health and Environmental Control, Ag Program, no date). The broker program defines brokers as those parties who accept or purchase animal manure and transfer it to a third party for land application or who spread it themselves; this includes landowners who apply manure purchased from CAFO operators to their crops. Brokers are required to apply for a permit from the South Carolina Department of Agriculture. Tracking of manure transfers is accomplished with manure balance sheets and manure transfer agreements. All parties—CAFO operators, brokers, and land applicators—have the same requirements for land application.

Texas

Texas focuses on regional composting of manure in phosphorus-limited watersheds, reducing the volume of manure to be transported longer distances by approximately half. The Texas State Soil and Water Conservation Board initiated the Dairy Manure Export Support project to create incentives for dairies to send manure to composting facilities, and the Texas Commission on Environmental Quality (2008) created the Composted Manure Incentive project to provide financial incentives for government entities to purchase the composted manure and to link composters to customers. Rebates were later offered to agricultural producers, compost dealers, and private users who purchased compost from participating facilities. The composting projects resulted in the export from phosphorus-limited watersheds of 468,000 cubic yards of manure compost, equivalent to 2 million pounds of phosphorus.

West Virginia

West Virginia experimented with a pilot transport subsidy program to move poultry litter to areas with nutrient-deficient soils (Collins and Basden, 2006). The pilot program met its short-term goals: it attracted first-time buyers of poultry litter, and the subsidy made the use of poultry litter economically feasible compared to commercial fertilizer use. The environmental protections used by manure purchasers were comparable to those used by poultry producers. However, continued participation was contingent upon continued use of the subsidy to ensure economic feasibility.

7.2. Manure Manifest System Recommendations

Tetra Tech envisions a multi-step process for establishing and running the Manure Manifest System. The first phase involves recruiting participants through an NOI process. Once applications are submitted, Manure Manifest System staff review and verify the information, conduct site visits, and enter participant data into a manifest system database (Phase 2). During Phase 3, Manure Manifest System staff will approve or deny applications and set any conditions for approval. Ongoing staff activities include processing manure transfers, conducting additional inspections, maintaining the manifest system database, and analyzing and synthesizing data for regulatory reporting. Ongoing activities for participants are to meet any conditions for approval, complete and submit paperwork for manure transfers, and renew their NOIs annually. The following is a detailed outline of the process, described graphically in Figures 2 and 3.

Phase 1: Initiation & NOI

CAFO operators, haulers, and landowners seeking manure who choose to participate will submit NOIs for initial registration into the Manure Manifest System. This registration is not a one-time-only registration period – new businesses can join at any time as desired. The initiation phase will be the most labor-intensive in terms of forms for the CAFO operators, haulers, and landowners to fill out and for the Manure Manifest Staff to review and process. The following responsibilities were identified for each party:

- CAFO operator responsibilities: Dairy operators will provide basic information about the business, including contact name and address, facility location, and number and type of animals, manure product amount and condition, and information about crops if applicable. This information is similar to that already collected by the RWQCB.

- Hauler responsibilities: Haulers will provide basic information about the business, including contact name, address, business license number, number of employees, number and type of equipment, and insurance information.

- Landowner responsibilities: A property owner who wishes to receive manure will submit information about the property including contact information, ownership, available acreage, crop history (past and current), soil information, ground water management zone, and other relevant information. If the land is occupied by a farm tenant, the landowner can authorize the farm tenant to submit an NOI on his or her behalf. This agreement must be documented as part of the NOI process.

Phase 2: Review and Verification

Manifest staff will review all NOIs for accuracy and completeness. Site visits will be scheduled with landowners planning to apply manure to gather additional site details. Staff will determine crop history, manure application history, planned land use, and neighboring land use to identify possible conflicts. Soil samples will be collected and analyzed unless the landowner has commissioned his or her own soil samples and has maintained complete records. The site will be assessed to determine drainage and runoff impacts and identify appropriate setbacks. Records will be augmented with a GPS-based field map and digital photos. GIS information will be used to determine the watershed and ground water management basin(s) that may be affected by manure application.

Where data gaps or inconsistencies exist in the NOI information, staff may request clarification from applicants to complete the review and approval process.

Staff will evaluate all available information and will either (1) approve the application outright, (2) approve the application with conditions, such as setbacks, land application limitations, or required BMPs, or (3) reject the application with a request for additional information if necessary.

At a later stage, additional considerations may be added to the review process, including a more detailed assessment of impacts, analysis of mitigation options for a particular site, or analysis of the cost-benefit of alternatives to land application at a particular site.

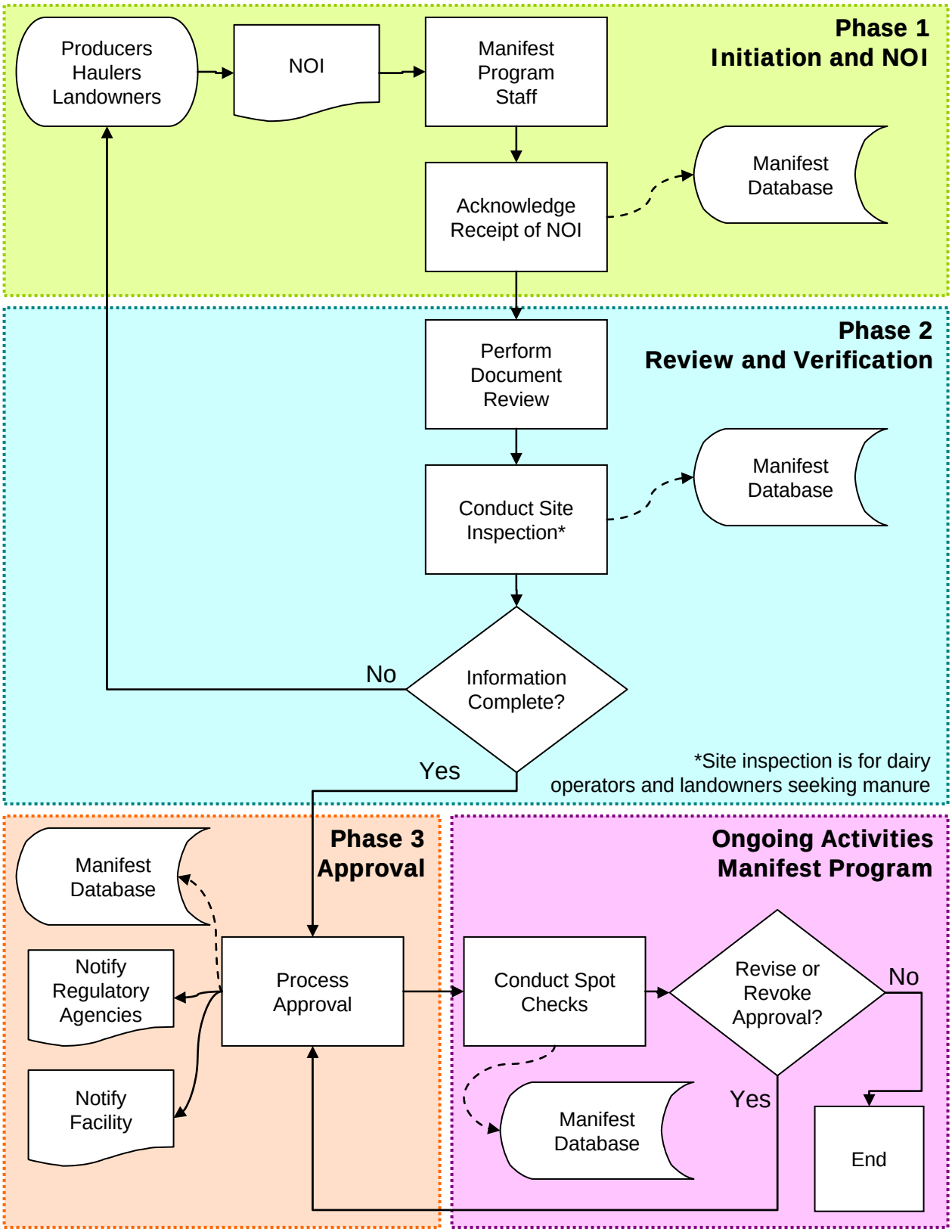

Figure 2. Manure Manifest System process diagram: Phases 1, 2, 3, and ongoing activities.

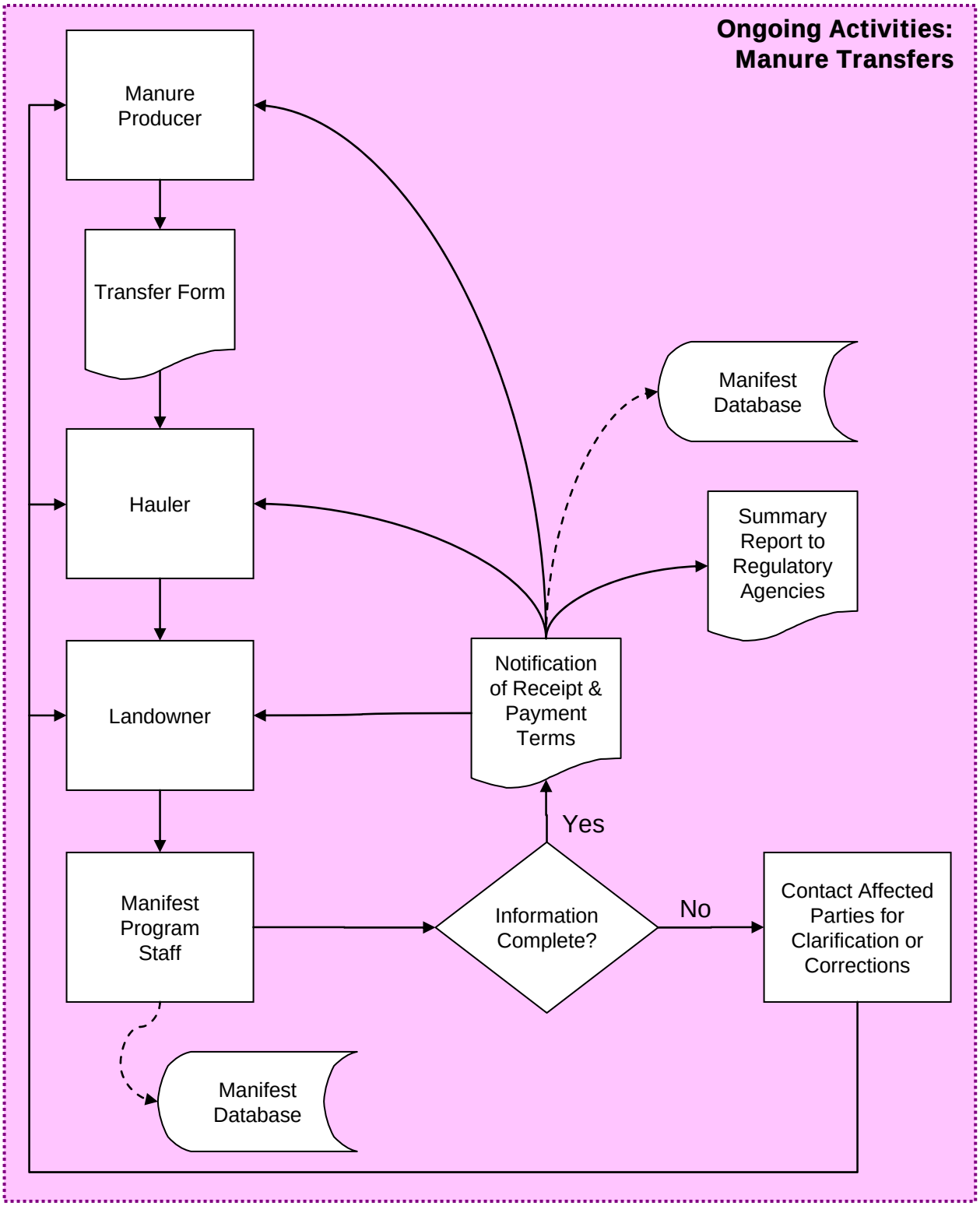

Figure 3. Manure Manifest System process diagram: manure transfers.

Phase 3: Approval

Manifest staff will notify applicants by mail of approval, conditional approval, or rejection, with copies provided to local and state regulatory agencies as required. Approval letters will include:

- CAFO Operators: Schedules for manure removal as specified in the application, condition or preparation of manure before hauling, manifest tracking numbers, approved hauler(s), location and conditions of manure application, membership and tipping fees, and mitigation offset for mileage, salts, and/or TMDL.

- Haulers: Approval for participation; requirement to maintain equipment and carry insurance; guidelines for manure loading, handling, transport, and application; requirement for staff training on guidelines; and membership and tipping fees.

- Landowners: Approved requirements and conditions for application, including guidelines on establishing application rates and schedule; record keeping requirements; setback area map; turn-down BMPs for incorporating manure into the soil; property signage and posting; required notification to neighbors; fees for and results of soil sample analyses if collected by Manure Manifest System Staff; membership and tipping fees; and mitigation offset for mileage, salts, and/or TMDL.

Ongoing Activities: Manure Manifest System Activities

Manure Manifest System staff would periodically notify local jurisdictions and regulatory agencies of participant approvals and conditions and summaries of manure transfer amounts and locations.

Manifest System staff would perform site visits to verify that approved conditions are being met by CAFO operators, haulers, and landowners. CAFO operators would be subject to site inspections, verification of site conditions, animals, etc. and collection of additional data, and verification of conditions of participation. Haulers would be required to show manifest paperwork, permits, licenses, and insurance and demonstrate any BMPs used or required. Visits to land application sites would involve verifying information collected during the review and verification phase, as well as looking for evidence of past, current, or potential discharges and identifying areas of impact if runoff were to occur. Records would be reviewed to verify that past land application was consistent with the conditions of approval and other guidelines.

Other tasks that may be performed by Manifest System staff or contractors as funding becomes available include an analysis of impacts to ground water, an analysis of alternative management strategies for sites that are limited in their ability to apply manure by groundwater or surface water concerns, and economic and logistical analyses.

The administrative burden for Manifest System staff, in summary, will be to:

- Receive/process NOIs.
- Verify field conditions and perform inspections (initial inspections and during/post-application inspections [i.e., spot checks]).
- Receive/process Transfer Forms.
- Respond to information requests and initiate required notifications.
- Prepare summary reports.
- Perform billing and collections.
- Perform or initiate a bid process for ongoing technical, financial, and logistical analyses.

Ongoing Activities: Manure Transfers

Manure transfer paperwork will be initiated by CAFO operators (quadruplicate forms will be provided in advance to CAFO operators). CAFO operators will fill out one form for each transfer (a transfer may be a single truckload

or multiple individual truckloads transported over several days) with information pertaining to the source, quantity, and condition of the manure as well as the date and the hauler that is contracted to transfer the load. The hauler will sign that they receive the load (verifying source, quantity, and condition) and will leave one copy of the form with the CAFO operator. The hauler will indicate the location(s) to which the load is transferred (using the landowner or business name or a manifest tracking number unique to the property authorized for land application). The landowner receiving the manure will sign that they received the load and that it has been applied as specified in their conditions for approval. One copy of the completed form will go to the hauler, one to the landowner, and the remaining copy will be sent to the Manure Manifest System Staff for processing and verification if necessary.

Manure Manifest System Staff will notify all parties of receipt of the completed form and will include payment details for all parties. If the forms are incomplete or inconsistent, Manifest System Staff will contact the relevant parties for clarification until the issues are resolved (note that this will delay processing and payment authorization).

8. Manure Manifest System Implementation Guidelines

Based on the process described above, the following individual steps should be taken to initiate and implement the Manure Manifest System.

Phase 1: Initiation & NOI

- Create a database to track all form data and internal Manure Manifest System activities. The software and details of the database should be consistent with other systems the managing agency uses so that the need for additional training is minimized.
- Create forms (described in the following section) and have Manure Transfer Forms printed in quadruplicate. Other forms can either be printed in-house or by a professional printer.
- Distribute NOI forms to CAFO operators, haulers, and landowners. Include a letter describing details of the program, benefits, etc. and specify deadlines if desired. Additional outreach to potential participants might be coordinated with outside entities to leverage resources.
- Distribute landowner/tenant agreement form if requested.
- Receive and process forms. This will be an on-going process as some participants will submit immediately and others will wait until they need to transfer or apply manure. Forms should be processed within a two-week period if possible.
- Notify parties of receipt of NOI.
- Enter form data into database, contacting applicants when additional information is needed.

Phase 2: Review and Verification

- Have an Ag Specialist review the NOI information.
- Have an IT Specialist/GIS Technician research GIS data (ownership, neighboring properties, watershed location, groundwater management zone, etc.) to augment landowner records.
- Conduct a site visit to verify NOI data (crop history, manure application history, etc.), verify site conditions (crop cover, storage areas, structures, waterbodies, etc.), create a site map and indicate setbacks, take digital photographs, and collect soil samples. Staff should consider using existing software, such as USGS's Web Soil Survey, to develop the field maps. Such software is available online and is free for use.
- Conduct a final review of the site visit information to determine application approval or rejection.

Phase 3: Approval

- Notify applicant in writing of approval status and describe conditions of approval (e.g., setbacks, phosphorus-based land application, etc.) or reasons for rejection if necessary, including schedules and fees. Include in the notification guidelines for calculating land application rates and record keeping requirements.
- Enter final site visit data into the database.
- Enter approval status information and conditions of approval (if any) into the database.
- Distribute Manure Transfer Forms with unique tracking numbers to approved parties.
- Enter the Manure Transfer Form tracking numbers into the database for each participant.
- Create and distribute lists of approved CAFO operators, haulers, and landowners with locations/conditions for manure application to all parties, including the RWQCB and Riverside County if necessary.

Phase 4: Annual Renewal

- Receive and process recertification forms annually.
- Determine tipping fees for the prior year and membership fees for the coming year.
- Perform billing and collections.

Ongoing Manure Manifest System Activities

- Create annual summaries of participating parties; the number, type, amount, and location of manure transfers; and any other data required by regulatory agencies or requested by program participants.
- Conduct periodic site visits of CAFO operators to verify site conditions, the number and type of animals, etc., collect additional data, and verify that the conditions of participation are being met.
- Meet with haulers to verify paperwork, permits, licenses, and insurance and have them demonstrate any BMPs that are used or required to be used.
- Conduct periodic site visits to land application sites to verify information collected during the review and verification phase and ensure compliance with approval conditions.
- Conduct maintenance and upgrades to the Manure Manifest database as needed.
- Collect periodic soil samples to verify conditions at land application sites (unless the landowner commissions his or her own soil samples, in which case the results can be reported to the Manure Manifest System).

Ongoing Manure Transfer Processing

- Receive and process Manure Transfer Forms with a goal of a 10-day administrative turnaround time to avoid delaying payments.
- Enter Manure Transfer Form information into the Manure Manifest System database.
- Notify all parties by mail that the Manure Transfer Forms have been received and whether they are complete. If they are complete, include payment terms, or if more information is needed, deny payment and follow up with relevant parties until discrepancies are resolved.

9. Example Manifest Forms

The following forms are recommended to allow the Manifest System to create and maintain a database of participants and to track manure transfers:

- CAFO Operator NOI Form
- Hauler NOI Form
- Landowner NOI Form
- Landowner/Tenant Agreement Form
- Manure Transfer Form
- Annual Renewal Form – CAFO Operators
- Annual Renewal Form – Haulers
- Annual Renewal Form – Landowners

Table 4 lists proposed fields for each of the forms listed above.

Table 4. Forms and form fields for the San Jacinto Manure Manifest System.

Form	Category	Fields
CAFO Operator NOI Form	CAFO Operator Information	Facility name Facility address (physical location, not mailing address) Operator name (primary contact) Contact address (mailing address) Contact phone, fax, e-mail
	Manure Production	Number of milking cows Number of dry cows Number of heifers Number of calves Number/type of other animals
	Facility Information	Total acreage Cropland acreage Corral acreage Containment pond capacity Wastewater disposal/pasture acreage Has an EWMP been prepared? Date Has an EWMP been approved? Date Has the plan been certified? By whom? date
	Product Condition	Results of nutrient and dry matter analyses Frequency of nutrient and dry matter analyses
	Other	Estimated frequency or timeline for manure/wastewater removal
Hauler NOI Form	Hauler Information	Business name Business address (physical location, not mailing address) Business license number Contact name Contact address (mailing address) Contact phone, fax, e-mail Number of trucks Truck capacity Proof of insurance

Table 4. Forms and form fields for the San Jacinto Manure Manifest System.

Form	Category	Fields
Landowner NOI form	Landowner Information	Facility name Property owner name Property address (physical location, not mailing address) latitude/longitude? Tenant name (if applicable – see also landowner/tenant agreement) Contact name Contact address (mailing address) Contact phone, fax, e-mail
	Facility Information	Acreage of land available for manure/wastewater application Current crops and associated acreage (per crop) • Crop(s) grown/expected rotation • Number of cropland acres • Number of plantings per year Crop history and associated acreage NMP prepared, approved, and/or implemented?
	Other	Estimated frequency or timeline for manure/wastewater application
Landowner/Tenant Agreement Form	Location Information	Property address (physical location)
	Property Owner Information	Property owner name Property owner address (mailing address) Property owner phone, fax, e-mail
	Tenant Information	Tenant name (if applicable) Tenant address (mailing address) Tenant phone, fax, e-mail
	Certification	Certification statement that tenant is authorized to participate in the Manure Manifest System on behalf of the property owner Effective dates of certification (start, end)
Manure Transfer Form	Manure Source Information	Date of pick-up Facility name CAFO operator name CAFO operator ID number Quantity of manure/wastewater transferred Product condition – wet, dry, composted, other
	Hauler Information	Company name Hauler name Hauler ID number Verification of quantity of manure/wastewater Verification of product condition Certification of handling as prescribed in conditions for approval
	Destination Information	Date of arrival Facility name Landowner name Landowner ID number Verification of quantity of manure/wastewater Verification of product condition Area(s) where product was applied Application method Certification of disposal/application as prescribed in conditions for approval
	Manifest System Office Use	Date of receipt Manifest database record number Check boxes for completion and notification of participating entities Area for comments and follow-up actions

Table 4. Forms and form fields for the San Jacinto Manure Manifest System.

Form	Category	Fields
Annual Renewal Form – CAFO Operators	CAFO Operator Information	CAFO Operator ID number (required) Facility name (required) Check box – Has contact information changed since the last renewal? If yes, update the following as needed (optional): • Facility address (physical location, not mailing address) • Operator name (primary contact) • Contact address (mailing address) • Contact phone, fax, email
	Manure Production	Check box – Has manure production information changed since the last renewal? If yes, update the following as needed (optional): • Number of milking cows • Number of dry cows • Number of heifers • Number of calves • Number/type of other animals
	Facility Information	Check box – Has facility information changed since the last renewal? If yes, update the following as needed (optional): • Total acreage • Cropland acreage • Corral acreage • Containment pond capacity • Wastewater disposal/pasture acreage
	Product Condition	Results of nutrient and dry matter analyses (required) Frequency of nutrient and dry matter analyses (required)
	Other	Estimated frequency or timeline for manure/wastewater removal (required)
Annual Renewal Form – Haulers	Hauler Information	Hauler ID number (required) Business name (required) Check box – Has contact information changed since the last renewal? If yes, update the following as needed (optional): • Business address (physical location, not mailing address) • Business license number • Contact name • Contact address (mailing address) • Contact phone, fax, e-mail
	Equipment Inventory	Number of trucks (required) Truck capacity (required)
	Proof of Insurance	Proof of insurance (required)
Annual Renewal Form – Landowners	Landowner Information	Landowner ID number (required) Facility name (required) Check box – Has contact information changed since the last renewal? If yes, update the following as needed (optional): • Property owner name • Property address (physical location, not mailing address) • Tenant name (if applicable) • Check box: Has tenant changed since last renewal? If yes, attach new landowner/tenant agreement form • Contact name • Contact address (mailing address) • Contact phone, fax, e-mail

Table 4. Forms and form fields for the San Jacinto Manure Manifest System.

Form	Category	Fields
	Facility Information (all fields required)	Acreage of land available for manure/wastewater application Current crops and associated acreage (per crop) • Type of crop grown • Number of cropland acres • Number of plantings per year Check box: NMP updated? Estimated frequency or timeline for manure/wastewater application

A Site Visit Checklist is also recommended for collecting detailed information about land application sites. Table 5 summarizes the type of information to be verified and collected during the site visit.

Table 5. Site visit checklist details.

Site Visit Checklist	Check box: initial site visit or post-application site visit
	Check box: Verify business and contact information as reported on NOI form Notes on business/contact information
	Check box: Verify current land use and crops on NOI form Notes on land use and crops
	Check box: Document planned land use (future crops and acreage, plantings per year, other uses) Notes on planned land use
	Check box: Determine neighboring property ownership and land use (may need to be verified with additional records) Notes on neighboring properties
	Check box: Verify soil sample information Notes on soil sample data
	Check box: Collect soil samples at locations where manure or wastewater will be applied (indicate location of soil samples on site map) Notes on soil sample collection sites
	Site drawing

Examples of the CAFO Operator NOI Form, Site Visit Form, and Manure Transfer Form are presented in Appendix A.

10. Manifest System Administration and Budget Recommendations

The SJBRCD has been identified as the organization best equipped to administer the Manure Manifest System. This organization has a well-established relationship with local dairies and farmers and has the technical expertise required to perform analyses and work with participants and regulators.

Tetra Tech identified three key staff positions to establish and run the Manure Manifest System. Note that each position is less than full time and the duties assigned to each, depending on staff qualifications, could be completed by one or more existing employees or through contractor support.

The Program Manager would perform the bulk of the day-to-day clerical activities, including sending out, processing, and reviewing forms and entering form data into the Manure Manifest Database. The Program Manager would also analyze data, create summary reports, and perform billing and collections tasks. The level of effort estimated for the Program Manager is 500 hours for System start-up and 481 hours annually in subsequent years for ongoing tasks (~25% FTE).

The Ag Specialist would be responsible for creating forms; reviewing NOI information; conducting initial and ongoing site visits; meeting with CAFO operators, haulers, and landowners as needed; processing Manure Transfer Forms; and collecting soil samples as needed. The level of effort estimated for the Ag Specialist is 798 hours for System start-up and 854 hours annually in subsequent years for ongoing tasks (~40% FTE).

The Information Technology/Geographic Information System (IT/GIS) Specialist would be involved mainly with Manure Manifest Database creation and management as well as researching GIS data to facilitate site analyses (e.g., ownership, neighboring properties, watershed location, groundwater management zone, etc.). The level of effort estimated for the IT/GIS Specialist is 168 hours for System start-up and 30 hours in subsequent years for database maintenance and upgrades (less than 10% FTE).

Tetra Tech developed a cost model to estimate initial setup costs and ongoing labor and expenditures to operate the Manure Manifest System. Several assumptions were made regarding staff salaries, the number of participants and forms filed each year, sampling and analysis costs, and equipment costs, as outlined in Table 6.

Table 6. Assumptions for the Manure Manifest System cost model.

Item	Value	Source/Notes
Program Manager	$27.50 per hour	Source: Holyoak, G. 2008
IT Specialist/ GIS	$41.69 per hour	Source: U.S. Department of Labor, Bureau of Labor Statistics, 2008.
Ag Specialist	$36.81 per hour	Source: U.S. Department of Labor, Bureau of Labor Statistics, 2008.
CAFO Operator NOI Applications	43	
Hauler NOI Applications	6	
Landowner NOI Applications	32	
Landowner/tenant agreement form	16	
Manure Transfer Forms filed annually	172	Assume four transfers per year per CAFO operator
Soil Sampling Cost	$15.00	A & L Western Agricultural Laboratories, no date, and Cornell Nutrient Analysis Laboratory, no date.
Samples per Site	25	Assume one sample per 4 acres and an average farm size of 100 acres
Digital Camera Cost	$300.00	Best Buy
Soil Sampling Auger Cost	$185.00	JMC Featherweight Auger Kit

Individual activities with associated costs were identified based on the process outlined above. Activities were assigned to one of three staff types: Program Manager, IT Specialist/ GIS, and Ag Specialist. The number of labor hours was estimated for each task and associated capital and operation and maintenance costs were included, as appropriate. Also, tasks were assigned a frequency: one time, ongoing, annual, every X years, etc. A list of activities and all associated hours and costs are presented in detail in Appendix B.

Table 7 summarizes the one-time start-up costs (labor and capital costs) and ongoing, annual costs (labor and operation and maintenance) based on the initial assumptions outlined above and presented in Appendix B. Start-up costs are estimated to be approximately $50,100 in labor and $12,500 in capital costs, yielding a total start-up cost of approximately $62,600. Annual costs, including renewal, manure transfer processing, soil testing, and other program activities, are estimated at approximately $49,900. Note that $4,000 of the annual operation and maintenance costs can be eliminated from the overall Manure Manifest System budget if the soil sample analysis costs are billed back to the landowner.

Table 7. Estimated costs for start-up and operation of the Manure Manifest System.

Program Costs	One-Time (Initial) Costs		Ongoing (Annual) Costs	
	Labor Cost	Capital Cost	Labor Cost	O&M Cost
Phase 1: Initiation & NOI	$10,406	$0	$0	$0
Phase 2: Review and Verification	$33,992	$12,485	$0	$0
Phase 3: Approval	$5,748	$0	$55	$0
Phase 4: Annual Renewal	$0	$0	$1,114	$0
Ongoing Manifest System Activities	$0	$0	$26,583	$4,000
Ongoing Manure Transfer Processing	$0	$0	$18,157	$0
TOTAL	**$50,146**	**$12,485**	**$45,909**	**$4,000**

The information presented in Appendix B and the assumptions listed above in Tables 4 and 5 are excerpts from a spreadsheet tool that will allow readers to readily modify assumptions, increase or decrease the level of effort, frequency, or timing of any task, and to add new tasks to better reflect actual conditions, economies of scale, existing equipment, savings from lessons learned, and other factors that can affect the Manure Manifest System's bottom line. The spreadsheet tool automatically calculates totals based on user-defined inputs for labor rates, capital costs, analysis costs, frequencies, staff type, etc. The tool is meant to be flexible and user-friendly to allow system planners to evaluate different scenarios; for example, the cost impact of hiring a new, clerical-level staff person at a lower hourly to perform certain administrative tasks can be evaluated by making a minor adjustment to the salary assumptions.

11. Manifest System Fee Assessment

11.1. Types of Fees

There are a number of options for allocating up-front and annual costs among the participants. Tetra Tech recommends a hybrid funding approach that combines annual membership fees with per-transfer fees and cost recovery for soil sample analysis to fund the program's operating expenses.

CAFO operators, haulers, and landowners would pay a membership fee billed annually upon initial approval and annual recertification. CAFO operators would additionally pay a hauling fee to the hauler based on the total amount of manure, which is the current practice, although this payment would not occur without approval from the Manure Manifest System. CAFO operators would also pay a tipping fee (based on the amount of manure) for loads that are applied in the San Jacinto Basin, helping to create an incentive for alternative disposal options and export of manure to other watersheds. Note that CAFO operators located outside of the San Jacinto Basin who wish to have manure hauled into the Basin would be required to pay membership and tipping fees to the Manure Manifest System to offset administrative and regulatory costs associated with the manure imports.

In addition to the membership fee, haulers would pay landowners to apply manure at their sites. This is the current practice, but any payment would be delayed pending review and approval from the Manure Manifest System.

Landowners would be responsible for their annual membership fee, and the Manure Manifest System would bill the actual cost of soil sample analyses to the landowner. Because larger tracts of land would require more Manure Manifest System staff time for more extensive site visits and ongoing spot-checks, the membership fee could be scaled based on the number of acres enrolled to ensure equitability in participation costs between large landowners and small landowners.

11.2. Effect of Manure Manifest System on Costs

Currently there are a number of costs associated with manure transfer and disposal. The following is a discussion of these costs and how they may change with implementation of the Manure Manifest System.

CAFO Operators

The CAFO operator pays the hauler for manure transfers and pays for analyses of manure nutrient content. These two costs would not change under the Manure Manifest System. The Manure Manifest System would eliminate any costs associated with potential liability for improper disposal, providing some “insurance” to CAFO operators. Additional costs would be seen in the annual membership fee and tipping fees.

Haulers

The haulers currently incur operating costs for marketing, fuel, equipment, labor, and payments to landowners accepting manure. These would not change under the Manure Manifest System. Haulers are currently paid by CAFO operators to haul manure and make payments to landowners to apply the manure at land application sites. The Manure Manifest System would not change these fees explicitly, though tipping fees and membership costs might affect the overall economics of manure transport and disposal. The Manure Manifest System will delay payments to the hauler and the landowner pending approval by Manifest System staff.

The Manure Manifest System would assist haulers in identifying land application sites by providing an inventory of participating landowners with capacity for land application. The hauler would also benefit from the reduced liability associated with improper disposal that the Manure Manifest System affords. Additional costs would be seen in the annual membership fee and tipping fees as well as additional equipment maintenance and modifications and staff training, if needed.

Landowners

The landowners currently incur costs associated with nutrient management such as soil sampling and application rate determination. They are paid by haulers who apply manure to their land. These costs and payments would not change under the Manure Manifest System. A possible cost savings may be available to landowners who wish to have soil sampling performed by Manifest System staff if competitive bulk sample analysis rates can be negotiated with the laboratory. Costs associated with TMDL compliance (fees assessed by the TMDL voluntary agricultural operator program) may be reduced if tipping fees are used to offset TMDL agricultural allocations or if the program reduces the amount of manure imported from outside the watershed. The Manure Manifest System could reduce liability for improper land application if the landowner follows guidelines and application limits specified by the System. Additional costs would be seen in annual membership fees and any costs associated with more stringent record-keeping requirements.

In summary, the net effect of the Manure Manifest System would be a slight increase in operating costs for all participants because of the need to pay membership and tipping fees. This additional cost should be weighed against the positive effects of reduced liability for improper disposal and enhanced compliance with local and state regulatory requirements.

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Appendix A. Manure Manifest Sample Forms

Manure Manifest System
CAFO Operator NOI Form

Operator ID number

FORM MM-1	**SJBRCD**	San Jacinto Basin Resource Conservation District CAFO Operator Notice of Intent Form Manure Manifest System

I. Operator Information	
Facility name	
Facility address (physical location, not mailing address)	Address: ..... City: ..... State: ..... Zip Code: ..... County: ..... or Latitude: ..... Longitude: .....
Operator name (primary contact)	Name: ..... Address: ..... City: ..... State:..... Zip Code:..... Telephone: (.....) ..... Facsimile: (.....)..... E-mail: .....

II. Type and Number of Animals		**III. Facility Information**	
Type		Total area (acres)	
Milking cows		Cropland area (acres)	
Dry cows		Corral area (acres)	
Heifers		Containment pond capacity (gallons)	
Calves		Wastewater disposal/pasture area (acres)	
Other (Please Specify)		Engineered waste management plan	Has a plan been prepared? ☐ Yes ☐ No Has the plan been certified? ☐ Yes ☐ No If yes, by whom?.....

IV. Product Condition	
Results of nutrient and dry matter analyses	
Frequency of nutrient and dry matter analyses	
Estimated frequency or timeline for manure/wastewater removal	

V. Certification	
Name and Official Title (*print or type*)	Phone No. ( )
Signature	Date Signed

Manure Manifest System
Site Visit Checklist

Landowner ID number

FORM MM-2	**SJBRCD**	San Jacinto Basin Resource Conservation District Site Visit Checklist Manure Manifest System

I. Basic Information			
Facility name			
Person(s) interviewed			
		Site visit type	☐ initial ☐ post-application

II. Site Visit Report	
Business and contact information as reported on NOI form	☐ Yes ☐ No Notes:
Current land use and crops on NOI form	☐ Yes ☐ No Notes:
Document planned land use (future crops and acreage, plantings per year, other uses)	☐ Yes ☐ No Notes:
Determine neighboring property ownership and land use	☐ Yes ☐ No Notes:
Have soil samples already been collected?	☐ Yes ☐ No Notes:
Collect soil samples at locations where manure or wastewater will be applied (indicate location of soil samples on site map)	☐ Yes ☐ No Notes:
Create site map and collect GPS points major site features, including corrals, manure and wastewater storage areas, site drainage points, BMPs, waterbodies, etc. Use back side of this form or additional pages if needed.	

III. Certification	
Name and official title (*print or type)*	Phone No. ( )
Signature	Date Signed

Manure Manifest System
Manure Transfer Form

Transfer ID Number

FORM MM-3	**SJBRCD**	San Jacinto Basin Resource Conservation District Manure Transfer Form Manure Manifest System

I. Date of pickup			
II. Manure Source Information			
Facility name			
CAFO operator name		Operator ID number	
Quantity of manure (specify units)			
Product condition			
III. Hauler Information			
Company name			
Hauler name		Hauler ID number	
Is manure quantity as reported above?	☐ Yes ☐ No Notes:		
Is product condition as reported above?	☐ Yes ☐ No Notes:		
Is handling consistent with Manure Manifest System Conditions of Approval?	☐ Yes ☐ No Notes:		
IV. Date of arrival			
V. Destination Information			
Watershed	☐ Within San Jacinto River Basin ☐ Exported to another watershed		
Facility name			
Landowner name		Landowner ID number	
Verification of quantity of manure/wastewater	☐ Yes ☐ No Notes:		
Verification of product condition	☐ Yes ☐ No Notes:		
Area(s) where product was applied			
Application method			
Is disposal/application consistent with Manure Manifest Conditions for Approval?	☐ Yes ☐ No Notes:		
VI. Manifest System (official use only)			
Date of receipt		Manifest database record number	
Manure transfer completed	☐ Yes ☐ No	Notification of participating entities	☐ Yes ☐ No
Comments and follow-up actions			

Appendix B. Manure Manifest System Cost Model

ID	Activity Description	Staff[1]	Labor Rate[2]	Hours per Response	Frequency of Activity	Number of Responses[3]	Total Hours	Total Labor Cost	Capital/ Start-Up Cost	O&M Cost	Total Annualized Capital and O&M Cost[4]
1.1	Create database	IT/GIS	$41.69	40.0	Once	1	40	$1,667	$0	$0	$0
1.2	Create forms	Ag	$36.81	20.0	Once	1	20	$736	$0	$0	$0
1.3	Distribute NOI forms to CAFO operators, haulers, and landowners	PM	$27.50	0.5	Once	81	41	$1,114	$0	$0	$0
1.4	Distribute landowner/tenant agreement form	PM	$27.50	0.5	Once	16	8	$220	$0	$0	$0
1.5	Receive/process forms	PM	$27.50	0.5	Once	97	49	$1,334	$0	$0	$0
1.6	Notify parties of receipt of NOI	PM	$27.50	0.5	Once	97	49	$1,334	$0	$0	$0
1.7	Enter form data into database	PM	$27.50	1.5	Once	97	146	$4,001	$0	$0	$0
2.1	Conduct review of NOI information	Ag	$36.81	4.0	Once	81	324	$11,928	$0	$0	$0
2.2	Research GIS data	IT/GIS	$41.69	4.0	Once	32	128	$5,336	$0	$0	$0
2.3.1	Site visit: Review NOI submission	Ag	$36.81	2.0	Once	32	64	$2,356	$0	$0	$0
2.3.2	Site visit: Verify site conditions	Ag	$36.81	2.0	Once	32	64	$2,356	$0	$0	$0
2.3.3	Site visit: Create site map and indicate setbacks	Ag	$36.81	2.5	Once	32	80	$2,945	$0	$0	$0
2.3.4	Site visit: Take digital photographs	Ag	$36.81	0.5	Once	32	16	$589	$300	$0	$43
2.3.5	Site visit: Collect soil samples (includes Analysis costs)	Ag	$36.81	3.2	Once	32	102	$3,770	$12,185	$0	$1,735
2.4	Conduct review of site visit information for application approval or rejection	Ag	$36.81	4.0	Once	32	128	$4,712	$0	$0	$0
3.1	Notify applicant in writing of approval status and describe conditions of approval or reasons for rejection if necessary, including schedules and fees	PM	$27.50	2.0	Once	32	64	$1,760	$0	$0	$0
3.2	Enter site visit data into database	PM	$27.50	1.0	Once	32	32	$880	$0	$0	$0

ID	Activity Description	Staff[1]	Labor Rate[2]	Hours per Response	Frequency of Activity	Number of Responses[3]	Total Hours	Total Labor Cost	Capital/ Start-Up Cost	O&M Cost	Total Annualized Capital and O&M Cost[4]
3.3	Enter approval status information and conditions (if any) into database	PM	$27.50	1.0	Once	32	32	$880	$0	$0	$0
3.4	Distribute Manure Transfer Forms to approved parties	PM	$27.50	0.5	Once	81	41	$1,114	$0	$0	$0
3.5	Enter Manure Transfer Form tracking numbers into database	PM	$27.50	0.5	Ongoing/ Annual	4	2	$55	$0	$0	$0
3.6	Create and distribute lists of approved CAFO operators, haulers and landowners with locations/conditions for manure application.	PM	$27.50	0.5	Once	81	41	$1,114	$0	$0	$0
4.1	Receive/process recertification forms	PM	$27.50	0.5	Ongoing/ Annual	81	41	$1,114	$0	$0	$0
5.1	Receive and process Manure Transfer Forms.	Ag	$36.81	1.0	Ongoing/ Annual	172	172	$6,332	$0	$0	$0
5.2	Enter Manure Transfer Form data into database.	PM	$27.50	0.5	Ongoing/ Annual	172	86	$2,365	$0	$0	$0
5.3	Notify all parties by mail that Manure Transfer Forms have been received and whether they are complete or if more information is needed. Follow up with relevant parties until discrepancies are resolved.	PM	$27.50	1.0	Ongoing/ Annual	172	172	$4,730	$0	$0	$0
6.1	Create annual summaries of participating parties, manure transfers, locations, etc.	PM	$27.50	8.0	Ongoing/ Annual	1	8	$220	$0	$0	$0
6.2	Conduct periodic site visits of CAFO operators to verify site conditions, animals, etc., collect additional data, verify conditions of participation.	Ag	$36.81	8.0	Ongoing/ Annual	43	344	$12,664	$0	$0	$0
6.3	Meet with hauler to verify paperwork, permits, licenses, and insurance and demonstrate any BMPs used or required.	Ag	$36.81	8.0	Ongoing/ Annual	6	48	$1,767	$0	$0	$0

ID	Activity Description	Staff[1]	Labor Rate[2]	Hours per Response	Frequency of Activity	Number of Responses[3]	Total Hours	Total Labor Cost	Capital/ Start-Up Cost	O&M Cost	Total Annualized Capital and O&M Cost[4]
6.4	Conduct periodic site visits to land application sites to verify information collected during the review and verification phase.	Ag	$36.81	8.0	Ongoing/ Annual	32	256	$9,425	$0	$0	$0
6.5	Perform billing and collections.	PM	$27.50	1.0	Ongoing/ Annual	172	172	$4,730	$0	$0	$0
6.6	Conduct database maintenance and upgrades as needed.	IT/GIS	$41.69	30.0	Ongoing/ Annual	1	30	$1,251	$0	$0	$0
7.1	Periodic soil samples (includes analysis costs)	Ag	$36.81	3.2	Every 3 years	~11	34	$1,257	$0	$4,000	$4,000

[1] Ag = Ag Specialist, IT/GIS = IT Specialist/GIS, PM = Program Manager
[2] Labor rates are based on input from Holyoak, 2008, and U.S. Department of Labor, Bureau of Labor Statistics, 2008.
[3] Number of responses are based on assumptions of the number of participants and the expected number of forms, visits, etc.
[4] Values are rounded to the nearest dollar.

Appendix J – Workshop Summary Dairy Waste Technologies & Management Practices October 14, 2009

Workshop Summary
Dairy Waste Technologies & Management Practices
October 14, 2009
Nuevo Water District

Funding for this project has been provided in full or in part through an agreement with the California State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. (Gov. code 7550, 40 CFR 31.20).

Workshop Objective: Identify and make choices about strategies and practices to support regulatory compliance and future sustainability of the dairy industry in the San Jacinto Watershed

Attendees:

Eric Boersma
Pat Boldt (WRCAC)
Essie Bootsma
John Bootsma
Jim Bootsma, Jr.
Marinus Dijkstra
Steve Domenigoni
Jennifer Ferrando (Tetra Tech)
Darin Ferreira
Jim Griffin (WUD)
Tom Hintz (SEAHOLD)
Ed Kashak (RWQCB)
Brent Lunt (Agri-Empire)
Don Meals (Tetra Tech)
Billy Offinga
Sid Offinga
John Oostdam
Michael Oosten
Steve Pastor (RCFB)
Brian Schouten
Bruce Scott
Brad Scott
Susan Smith (SEAHOLD)
Johnny Tevelde
Glen Van Dam
Rob VandenHeuvel (MPC)
Chastity Vermeer

The workshop opened at 11:00 a.m. Pat Boldt (WRCAC) and Bruce Scott presented some background information concerning regulatory and other issues facing San Jacinto dairies, with emphasis on the 2012 salt offset requirement and the nutrient TMDL. Scott emphasized the importance of local data and local choices in responding to these issues. An example of the need for local data is in the salt offset requirements that are currently based on textbook values for wastewater generation and dairy salt balance that should be refined. Jennifer Ferrando (Tetra Tech) presented the history and scope of the San Jacinto Integrated Regional Dairy Management Plan (IRDMP) and mentioned permission forms from dairy operators to allow for sampling on their dairies in support of ongoing salt offset assessments. There was considerable discussion about salt offset procedures and how dairies would receive “credit” for salt offset accomplished by other activities, including dairies going out of business. Although such events may reduce salt

generation in the San Jacinto watershed, the bottom line is that each dairy is to be regulated on its own salt generation and management.

Don Meals (Tetra Tech) summarized the context of the issues to be addressed in the workshop:

- Management changes will be required for dairies to address the upcoming regulations;
- Management changes will likely be needed both at the individual dairy and at the San Jacinto Watershed level;
- Requirements to manage salts from manure and wastewater are more restrictive than nutrient management requirements and will therefore present the dominant and most immediate challenges to San Jacinto dairies; and
- Few practices are effective in truly removing constituents of concern; in almost all cases, some additional management of residuals will be required. However some technologies will be of value in changing the bulk, composition, moisture content, or other characteristics of wastes to facilitate their subsequent management.

Meals emphasized that the purpose of the workshop was to identify the various approaches that were available and those that were likely to be accepted or preferred by the dairymen. It was most important to get an open, candid discussion of options discussed and to hear directly what the issues and concerns of the dairy operators were. The workshop agenda is included in Appendix A.

Meals presented a list of strategic questions that are important for San Jacinto dairymen to consider before selecting specific management measures to adopt; answers to these questions are also critical for the formulation of the IRDMP (questions are listed below). Discussion of these questions was postponed until after the presentation and discussion of the individual practice options. It was necessary to bring the group up to speed on the progress of WRCAC so that everyone had a full appreciation of what is being done, what the regulatory issues are, and what options are available to dairy operators.

Manure export. Meals stated that organized, systematic export of manure from the San Jacinto was very likely to be part of the response to upcoming regulations. He asked a series of questions designed to clarify some information needed to figure out such a system:

1. How often do you haul manure from your dairies?
   Daily – have ranch outside watershed

   2x/year is normal (perceived as required by permit). Usually before summer crop and before winter crop. Most dairies will be within that window. For dryland single crop you can land apply all summer long.

2. Contractor – what does the contractor do vs. the operator?
   Contractor does it all – some clean the corrals; soup to nuts; some of the SJ dairies scrape their own corrals.

3. To what destination is your manure hauled?
   One dairyman is composting – reduces volume by 50% Economy affects it – have market but haven't gotten it going yet.

   Another dairyman hauls manure out and backhauls silage in. Can't "dead head" back.

   Joyful Farms; Perris dumping

4. Do you have a direct business relationship with manure receiver or is it all arranged by hauler?
   Some dairymen have no say/relationship with recipient – some do. Hauler usually arranges (not always).

5. What is the most you are willing to pay to have your manure hauled?
   We are maxed out – not willing/able to pay more. Have a valuable product – need to make it valuable. Not much willingness to pay more except if you're saving on a tipping fee and you can haul farther. This is true even if composting.

6. Are you willing to scrape and haul more frequently than you do now? (e.g. 6x/year)
   Yes – if we're composting you have to. General agreement that it's feasible. General willingness to do. Need to be certain that you have the equipment to do this.

7. What is the location and vendor where you purchase your hay?
   Blythe, Brawley (155 miles), Some Utah (430 miles) and Nevada (500+) – demand for manure exists in Utah but will only take if composted. Those trucks already get freight going back to Utah?

   Arizona will take uncomposted manure – you have to pay.

General comments:
We need to consider whether this is a good long-term strategy? We need to figure out how to make the manure a value-added product so that there is long-term sustainability?

The problem is getting and keeping the land and water in the manure-receiving area; if you can get it cheap, it's easier to do. Impossible without backhauling. Suggests getting everyone together for long-term contract – 10 years (1/2 dairies gone in 10 years?); get some help from NRCS. Need to make it easy for dairies – out of corral and it's done. Lease/buy land and lease the water – it works great. No issues with physical problem of using same trucks (uses enclosed walking floors for both silage and manure hauling). Might be different for operator who is hauling hay – there are trucks you can use.

Lunch (12:15 – 1:00 p.m.). During lunch, Bruce Scott and Tom Hintz reported on a recent tour of Scott Brothers Dairy by a group of potential investors in a regional manure digester. Hintz reported on his ongoing work on evaluating a mass balance of manure feedstocks in the

San Jacinto and on the potential for making a regional digester more cost-effective through the use of various investment credits, including green energy and carbon capture programs.

BMP Discussion. Meals led a discussion of the pros and cons of specific Best Management Practices (BMPs) that have a potential for implementation in the San Jacinto watershed:

- **Source Reduction Practices**
  - Precision feeding
  - Nutrient Management
  - Waste amendment
  - Wash water minimization
  - Clean stormwater diversion
  - Manure export
- **Structural Practices**
  - Pond lining
  - Pond wastewater treatment/constructed wetlands
  - Chemical wastewater treatment
  - Digestion
  - Composting
  - Regional desalter
- **Innovative Practices**
  - VSEP
  - Manure to fuel
  - Physiochemical/microbiological treatments

Although not an exhaustive list, these practices were chosen because they are applicable to San Jacinto dairies and have the potential to either reduce nutrient or salt loads, improve the handling and management of manure and wastewater constituents, or generate an income stream to help offset costs of meeting the new regulatory requirements. The details of BMPs presented are in Appendix B.

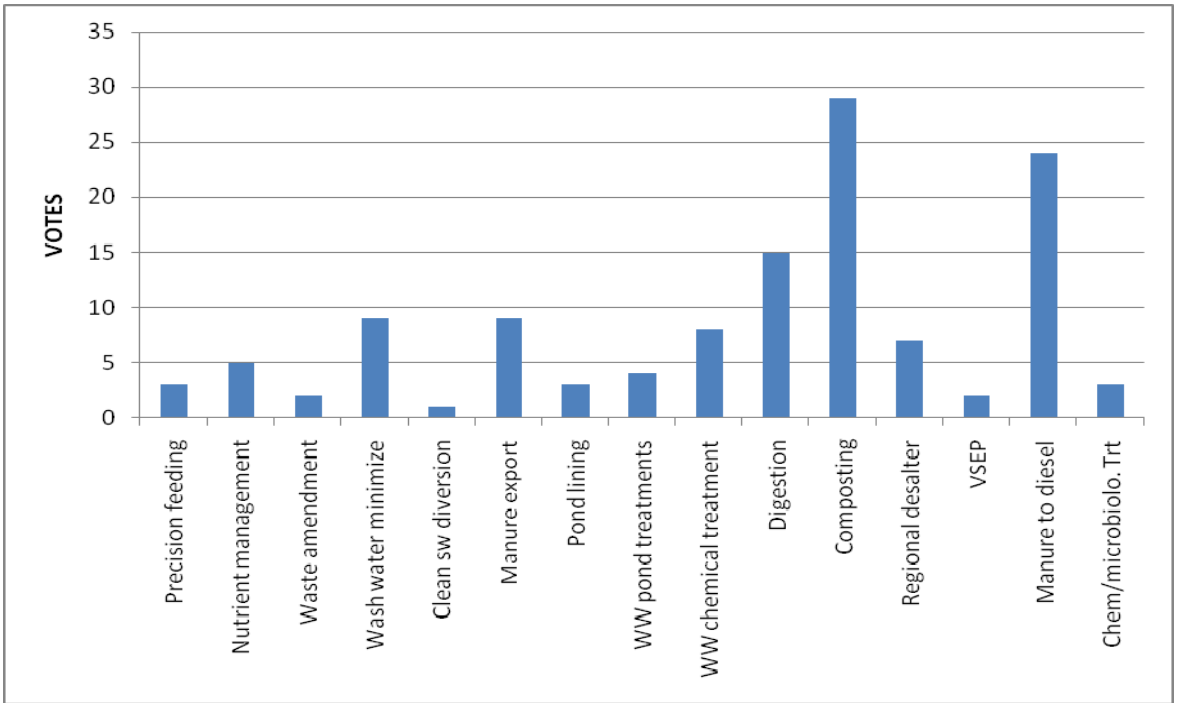
There was considerable discussion of many of the proposed BMPs. Naturally, manure digestion generated a lot of discussion. It was noted that digestion does not destroy or get rid of salts and nitrate, but that funds returned to dairies (from biogas generation, subsidies, credits, etc.) could be instrumental in financing salt disposal. It was also noted that the residuals from digestion can be readily compostable for application to food crops. Several questions were asked about potential markets or disposal options for salts concentrated by digestion; Hintz mentioned algae production and the Great Salt Lake as potential markets for salts. There was also some discussion of the closure of the Chino digester, the reasons for its failure, and the implications for development of a regional digester in the San Jacinto. The dairy economy, high tipping fees, outmoded technology, and management problems were cited as reasons contributing to the closure of the Chino digester. All of these issues can be solved, according to Hintz.

Composting was also a major topic of discussion. Johnny TeVelde reported on his composting operation and reported a 50% reduction in manure volume after composting. This volume reduction (similar to that for digestion) could help improve the cost-effectiveness of manure export. Biosecurity issues are important with respect to composting; compost must be effectively

heated to kill all pathogens and weed seeds before it is saleable to food crop producers. There are also regulatory issues associated with composting if the composting operation expands beyond a single dairy or imports material from outside the dairy. There was a general call for assistance from the Water Board in helping to work out these permitting problems in support of a practice that could significantly benefit the region.

Bruce Scott pointed out that extension of the brine line into the San Jacinto watershed is now a very real possibility, making a regional desalter a potentially viable option.

Following the discussion of the BMPs, participants were asked to vote on their preferences, based on whether they thought the practices would work on their dairy, would help solve salt or nutrient problems and meet regulatory requirements, and would be something they would consider implementing on their dairy. Participants expressed their preferences by anonymously voting with multiple stickers on individual flip charts. Results are shown below:



Clearly, composting, manure to diesel, and digestion were the most popular, although the appeal of manure to diesel was probably mostly conceptual or wishful thinking for a magic wand approach. Manure export, wash water minimization, chemical treatment of wastewater, and a regional desalter were in the second tier, and most other BMPs found much less support. Note that “chemical treatment” was very unspecific in the presentation.

Strategic Questions. Following the discussion of specific BMP options, the broad strategic questions were revisited:

1. Are SJ dairy operators willing to consider new manure/wastewater treatment operations on their own dairies and/or as a cooperative or regional enterprise? If this means a change to their current manure scraping/hauling and wastewater management to accommodate new treatment systems?
Affirmative – participants appeared to be willing both as individuals and in cooperation with their neighbors. They were also willing to change their current scraping/wastewater management to support new treatment systems.

2. Are SJ dairy operators willing to enter into long-term contracts for hauling, back-hauling, regional composters, or regional digesters or other facilities? What conditions would be required by the dairies in such contracts?
Yes, but….entering into contracts appeared to be acceptable, but there was much debate over the meaning of "long-term." Prevailing opinion seemed to be that up to 5 years was acceptable, but beyond that was dubious. There was a lot of discussion throughout the workshop about investors/operators of a regional digester needing some assurance of a continuous, ample supply of feedstock and therefore the need for a reasonably long-term commitment from dairies.

3. Are SJ dairy operators willing to consider cooperation or partnership with other dairies in the San Jacinto and/or from adjacent regions for a common approach, e.g., collaborating with Chino dairy operators and other businesses that produce potential digester/composter feedstock to collectively solve their waste management problems in the Santa Ana River watershed?
Participants appeared open to partnering/cooperating with other SJ dairies, but not so much for regional cooperation (with Chino, for example) The prevailing feeling was that SJ dairies have been taking on the problems from Chino for years without getting much in return. The exception to this feeling is that they would be willing to absorb manure from outside the SJ to provide adequate feedstock to a digester or composter <u>if the facility had available capacity</u>.

4. Are there any benefits to hauling a finished product such as composted or digested manure versus hauling untreated manure?
This was not explicitly answered, but the idea of bulk reduction from both composting and digestion was the subject of much discussion and seemed to be a key ingredient to manure hauling operations.

5. What incentives are needed by SJ dairies to address the water quality and air quality requirements they face? How much do SJ dairies know about and/or use available cost-share incentives, e.g., NRCS?
This was not discussed specifically, but there was considerable discussion of various tax credits/incentives that would support green energy from digesters

6. Are SJ dairy operators willing to consider a reduction in cow numbers or a reduction in dairying in response to the salt offset issues?
While many dairymen commented that this is happening by itself due to the economy, there was not a lot of enthusiasm for such a reduction as a voluntary measure.

APPENDIX A

Workshop

Dairy Waste Technologies & Management Practices

October 14, 2009

Nuevo Water District 11AM-3PM

Objective

Identify and make choices about strategies and practices to support regulatory compliance and future sustainability of the dairy industry in the San Jacinto Watershed

Agenda

11:00 a.m.	Background and introductions
11:15 a.m.	Discussion of strategic questions and issues for dairies in the San Jacinto Watershed
12:15	Lunch
1:00	Presentation and discussion of potential dairy management practices/systems
2:00	Identify and set priorities for management practices
2:30	Summary and wrap-up What are the next steps? Where do we go from here?
3:00	Close

APPENDIX B
CANDIDATE BMPs FOR SAN JACINTO DAIRIES

SOURCE REDUCTION

Precision feeding

Changes in feed formulation and management to decrease the P, N, and salt content of manure by more accurate application of current published dietary requirements, more precise ration formulation.

Applicability: Precision feeding is a management practice that could be adopted by all San Jacinto dairies.
Advantages: Reduces quantity of nutrients brought into the dairy and the watershed; reduces concentrations of nutrients in manure. To the extent that reduction dietary P and N content involves the reduction of purchased supplements, this practice could save money directly
Disadvantages: Purchasing lower-P feed may represent a low to moderate added cost; management effort may increase slightly
Cost: low

Nutrient management

Supply crop nutrients in quantities that take into consideration the amounts needed to produce a reasonable crop yield, the amounts already present in the soil, and the amounts contributed by all nutrient sources, including commercial fertilizers, animal manure, irrigation water, and other sources. Nutrients should be applied using rates, timing, and methods designed to minimize losses to surface and ground waters.

Applicability: Nutrient management can apply to all San Jacinto dairies that have cropland; required by permit
Advantages: Increases the efficiency of crop fertilization; generally reduces amount of nutrients applied to cropland. Reduces quantities of N and P available to be lost from cropland by runoff and leaching.
Disadvantages: Requires some increased management effort, soil, manure, and crop testing, and record-keeping, some of which may be done by an external crop consultant
Cost: low to moderate

Waste amendment
The use of chemicals like alum or water treatment residuals to immobilize P in animal waste to decrease the risk of soluble P losses from land application of manure. Materials rich in certain aluminum or iron oxides, such as alum and drinking water treatment residuals, can adsorb available P, converting P into less soluble and therefore less mobile aluminum- and iron-bound fractions. Such reactions could effectively reduce runoff losses of soluble P to surface waters by rendering a portion of manure P unavailable.

Applicability: Manure amendment can apply to all San Jacinto dairies; amendment of dairy wastewater applies only to dairies that store wastewater in a pond or other structure.
Advantages: Reduces P solubility of and therefore its availability for runoff or leaching from soils. Can reduce ammonia volatilization and may reduce odors.
Disadvantages: Net effects on N uncertain; may increase total N pool as ammonia loss is reduced. Small potential for metals addition and pH effects, depending on material used for amendment.
Cost: Low to moderate; use of water treatment residuals may involve no cost

Wash water minimization Minimizing the quantity of fresh water used for washing animals, cleaning milking parlors and other areas of the facility, or in flushing systems to reduce the volume of water generated by the dairy requiring additional management. Furthermore, minimizing the volume of wash water generated could potentially improve the cost-effectiveness of wastewater treatment conducted to meet salt offset requirements.

Applicability: Wash water management applies only to the few San Jacinto dairies that employ a flushing system. [But applies to all dairies in terms of minimizing water used for washing animals and milking parlors]
Advantages: Reduces volume of wastewater generated; may reduce total TDS load by minimizing use of high-TDS source water
Disadvantages: Net wastewater reduction may be lowered the more recycled water is used in flushing
Cost: very low

Clean stormwater diversion Diverting clean stormwater (i.e., stormwater from roofs and driveways) before it can contact manure or other waste and conveying the clean water out of the dairy's wastewater or stormwater management ponds**.**

Applicability: Dairies where roof runoff and other clean stormwater can be intercepted, diverted, and infiltrated without contacting manure or mixing with wastewater
Advantages: Reduces volume of stormwater to be contained and/or treated; provides low-TDS water for infiltration
Disadvantages: May be difficult to engineer on some facilities due to lack of space; some dairies may lack land area for acceptable infiltration
Cost: low to moderate

Manure export. Organized collection and shipment of dairy manure out of the San Jacinto watershed.

Applicability: Manure export could be practiced by all San Jacinto dairies
Advantages: Removes quantity of manure (and associated salts and nutrients) from the watershed; manure nutrients can be used for crop production where land application is feasible; can be cost-effective where back-hauling to forage-growing regions is possible and manure nutrients can replace inorganic fertilizers
Disadvantages: Likely to be very costly; manure-receiving areas may be difficult to identify; back-hauling may be logistically difficult
Cost: high

STRUCTURAL PRACTICES

Pond lining. Lining wastewater ponds with an impermeable membrane to prevent infiltration of wastewater and associated dissolved salts and protect the ground water.

Applicability: Applicable to all San Jacinto dairies that manage their wastewater in ponds; some dairies with limited land area and small pond surface area may not be able to evaporate all their wastewater.
Advantages: Eliminates TDS/NO3 loading from infiltration; Reduce or eliminate the volume of wastewater requiring subsequent disposal
Disadvantages: No net effect on salts or nutrients. Dairies with small pond surface area may need to expand the surface area of stored wastewater. Management while maintaining required stormwater capacity may be challenging.
Cost: moderate to high

Wastewater Treatment - Treat the wastewater to modify or reduce its salt and nutrient content before it reaches the land.

- **Multi-pond systems.** Wastewater ponds can be upgraded to provide better treatment, including nutrient reduction. Mechanical aeration (by agitation or pumping air into the pond) can add oxygen and promote nitrification (the transformation of ammonia-N to nitrate-N); sequence of ponds provide conditions for denitrification
- **Constructed wetlands.** Constructed wetlands including a variety of submerged, floating, and emergent plants can provide advanced wastewater treatment, including removal of nitrate and salts.

Applicability: Treatment practices can apply to individual San Jacinto dairies that store wastewater in a pond or other structure. Multiple pond and constructed wetland systems require additional space that may prevent consideration on some facilities.
Advantages: Some treatments can promote N removal by denitrification.
Disadvantages: Operation of multi-pond and constructed wetland systems requires water and energy inputs, a high degree of management, and some regular maintenance.
Cost: high

- **Chemical treatment**. Both particulate and dissolved constituents can be removed from wastewater by chemical precipitation.

Applicability: Treatment practices can apply to individual San Jacinto dairies that store wastewater in a pond or other structure.
Advantages: Chemical treatment can concentrate nutrients and reduce their solubility, improving handling characteristics
Disadvantages: Residuals from chemical treatment require management/disposal.
Cost: moderate

Digestion. Anaerobic digestion is the process by which organic materials in an enclosed vessel are broken down by microorganisms in the absence of oxygen. Anaerobic digestion produces biogas consisting primarily of methane and carbon dioxide, containing about 60% of the energy value of the same amount of natural gas. Depending on the system design, biogas can be burned as a fuel in a boiler or furnace, used to run a generator producing electricity and heat, or cleaned and used as a natural gas replacement. Digestion produces a liquid or semi-solid effluent that contains all the water, all the N, P, and other minerals and approximately half of the carbon from the incoming materials; this residue can be readily composted.

Applicability: Digestion can apply to all San Jacinto dairies; digestion is much more likely to be economically feasible at a multi-dairy or regional scale than for individual dairies
Advantages: Reduces mass/volume of waste for subsequent management. Could generate energy and income stream that may offset other management costs
Disadvantages: Has no net effect on nutrients and salts in dairy waste stream. Technically demanding; regional or multi-dairy facilities require transport of waste feedstocks. Dairies may recover less than 100% of benefits, but may be responsible for all of residuals.
Cost: High (potentially partially offset by returns on biogas and energy generated)

Composting. Composting is the aerobic microbiological degradation of manure and/or other organic materials. The resulting composted material is odorless and low-moisture. Composted manure is a value-added soil amendment that can be a source of income when sold in local or regional markets.

Applicability: Applicable to all San Jacinto dairies; may be most cost-effective as a multi-dairy or regional facility. Linkages to urban waste generators possible.
Advantages: Stabilizes manure and reduces bulk; results in a potentially value-added product; possible lower cost than hauling raw manure. Potential inclusion of urban green wastes.
Disadvantages: No net effect on nutrient or salt content of waste; volatilization losses may pose air quality issue. Requires market for product that may be limited by food safety concerns.
Cost: moderate to high

Regional desalter. A centralized facility for removing salts from liquid wastes.

Applicability: Applicable to all San Jacinto dairies as a regional facility. Potential for partnership with EMWD?
Advantages: Removal of salts from dairy wastewater and exporting from the watershed; opportunities for cooperation with other regional entities
Disadvantages: Extremely high cost; requires brine pipeline for disposal of residuals; very likely to require manure export as a condition (as in Chino basin)
Cost: extremely high

INNOVATIVE PRACTICES

VSEP system. The VSEP system uses an array of vibrating reverse osmosis (RO) membranes to separate and concentrate all suspended solids and most of the dissolved solids in the waste stream to produce clean safe water for reuse as cattle wash and possibly drinking water. The technique also has the potential to contribute to salt offset from dairy wastewater.

Applicability: Applicable to all San Jacinto dairies
Advantages: The VSEP process removes high percentages of salts and nitrate from the wastewater
Disadvantages: Requires substantial technical expertise. Costs and full-scale operational capability unknown; residuals must be managed or disposed of.
Cost: Unknown, but probably very high

Manure to fuel. A proposed process uses a variety of feedstocks – including manure and other agricultural waste – to produce mineral-quality liquid diesel fuel that can be used directly in diesel combustion engines.

Applicability: Applicable to groups of San Jacinto dairies in a multi-dairy or regional facility
Advantages: Provide income stream to dairies. Possible mechanism for removal or export of nutrient/salt residue, depending on contract arrangements
Disadvantages: No inherent reduction of nutrients or salts; dairies potentially responsible for residuals
Cost: unknown

Physiochemical and microbiological treatments. Proprietary treatment systems to remove nutrients and microorganisms from manure and wastewater

Applicability: Most technologies applicable to individual San Jacinto dairies that contain their wastewater in ponds
Advantages: Potential reductions in nutrients and salts in wastewater by some processes
Disadvantages: Poorly documented performance; inaccurate or misleading claims for effectiveness. Some processes have no direct effect on nutrients or salts
Cost: very high

Appendix K – Order No. R8-2007-0001 Monitoring and Reporting Program

California Regional Water Quality Control Board
Santa Ana Region

General Waste Discharge Requirements Concentrated Animal Feeding Operations

Order No. R8-2007-0001
NPDES No. CAG018001

Attachment B – Monitoring and Reporting Program

Title 40 of the Code of Federal Regulations (CFR) section 122.48 requires that all National Pollutant Discharge Elimination System (NPDES) permits specify monitoring and reporting requirements. California Water Code Sections 13267 and 13383 also authorize the Regional Water Quality Control Board (Regional Board) to require technical and monitoring reports. This Monitoring and Reporting Program (MRP) establishes monitoring and reporting requirements, which implement the federal and California regulations.

I. GENERAL MONITORING PROVISIONS

A. All monitoring data shall be maintained for at least five years and shall be made available to Regional Board, SWRCB, USEPA staff and/or their authorized representatives (including an authorized contractor acting as their representative), upon request.

B. All containment structures, including, but not limited to, ponds, berms, and wastewater distribution lines, shall be inspected at least once each week during the entire year and at least once each 24-hour period during a storm event in which rainfall exceeds 0.5 inches in 24 hours. The findings of these inspections shall be documented on the attached CAFO Weekly Storm Water Management Structure Inspections Log Sheet (Attachment 1). Information documented on this form shall include:

1. The depth of the process wastewater and storm water runoff in the containment ponds and impoundments. An estimate of the freeboard[1] for each pond or impoundment shall be recorded during each inspection. A marker shall be placed within each pond or impoundment to indicate the minimum capacity necessary to contain the runoff and direct precipitation of the 25-year, 24-hour rainfall event.

2. Any action taken to correct deficiencies noted as a result of facility inspections. Deficiencies not corrected within 30 days shall be accompanied by an explanation of the factors preventing immediate correction.

3. The approximate time of each storm-related discharge that results in an off-property discharge of storm water commingled with process wastewater or manure, along with its approximate duration. If sufficient space is not available on the form provided, the discharger shall provide supplemental attachment sheets, as needed.

REPORTING REQUIREMENTS

A. General Monitoring and Reporting Requirements

1. The discharger shall comply with all Standard Provisions (Attachment A) related to monitoring, reporting, and recordkeeping.

2. By January 15 of each year, the discharger shall submit an Annual Report of Animal Waste Discharge (Attachment 3), copies of Manure Tracking Manifest(s) (Attachment 4) for all manure hauling events that occurred, and an Annual Summary Report of CAFO Storm Water Management Structure Inspections (Attachment 2) for the previous calendar year. The Annual Report of Animal Waste Discharge, Manure Tracking Manifest, and Annual Summary Report of CAFO Storm Water Management Structure Inspections may be revised, as necessary, by the Executive Officer.

3. The discharger shall notify the Regional Board by telephone within 24 hours of any unauthorized discharge of wastes. This notification shall be followed by a written report which shall be submitted to the Regional Board within two weeks of the discharge. The written report shall contain:

   a. The approximate date and time of the discharge;
   b. The estimated flow rate and duration of the discharge;
   c. The specific type and source of the waste discharges (e.g., overflow from holding pond, rainfall runoff from manure storage areas, etc.); and
   d. A time schedule and a plan to implement necessary corrective actions to prevent the recurrence of the discharge.

4. All reports shall be signed by a responsible officer or duly authorized representative of the discharger(s) and shall be submitted under penalty of perjury.

B. Self Monitoring Reports (SMRs)

1. At any time during the term of this permit, the State or Regional Board may notify the discharger to electronically submit Self-Monitoring Reports (SMRs) using the State Board's California Integrated Water Quality System (CIWQS) Program Web site (http://www.waterboards.ca.gov/ciwqs/index.html). Until such notification is given, the discharger shall submit hard copy SMRs. The CIWQS Web site will provide additional directions for SMR submittal in the event there will be service interruption for electronic submittal.

2. The discharger shall submit annual monitoring results to the Regional Board by the 15th day of January for the preceding calendar year. The discharger shall report in the SMR the results for all monitoring specified in this MRP.

3. The discharger shall submit SMRs in accordance with the following requirements:

a. The discharger shall attach a cover letter to the SMR. The information contained in the cover letter shall clearly identify violations of the WDRs; discuss corrective actions taken or planned; and the proposed time schedule for corrective actions. Identified violations must include a description of the requirement that was violated and a description of the violation.

b. SMRs must be submitted to the Regional Board, signed and certified as required by the Standard Provisions.

Appendix L – Lake Elsinore and Canyon Lake TMDL Modeling

Lake Elsinore and Canyon Lake TMDL Modeling

Extensive modeling was performed to develop the nutrient TMDL for Lake Elsinore and Canyon Lake (Tetra Tech, 2003). Under this modeling effort, the San Jacinto Watershed was divided into 35 subwatersheds (Figure 1). These subwatersheds were aggregated into nine modeling zones (Figure 2) to examine N and P loading sources to Lake Elsinore and Canyon Lake under three scenarios:

- Scenario 1: Mystic Lake and Canyon Lake overflowed (wet year)
- Scenario 2: Canyon Lake overflowed, but Mystic Lake did not (moderately wet year)
- Scenario 3: Neither Mystic Lake nor Canyon Lake overflowed (dry year)

These three scenarios were selected to reflect the very different hydrologic conditions that can exist in the watershed. In very simplistic terms, flow in the watershed begins in upland forest areas (zone 9 in Figure 2) in the southeast portion of the watershed. The San Jacinto River flows in a generally northwestern direction through zones 8 and 7 toward Mystic Lake, passing by urban areas and many of the San Jacinto dairies along the way. Despite historic efforts to divert the San Jacinto River flow around Mystic Lake during low flow periods with a system of channels and levees, all of the river flow currently drains directly to Mystic Lake where it is impounded during average and low flow years (Tetra Tech, 2004). Impoundment in Mystic Lake can result in significant losses from evaporation, infiltration, and groundwater recharge, causing much of the volume stored in the lake to be lost from the San Jacinto River system. During major or prolonged rainfall events, however, the storage capacity of Mystic Lake can be exceeded, resulting in overflow back to the San Jacinto River through zone 6 and downstream to Canyon Lake. Canyon Lake also receives flow from the northwestern (zones 2 and 5) and south-central (Zones 3 and 4) portions of the watershed as depicted by the arrows in Figure 2. Lake Elsinore receives flow from local drainage in zone 1 and from zone 2 via overflow from Canyon Lake.

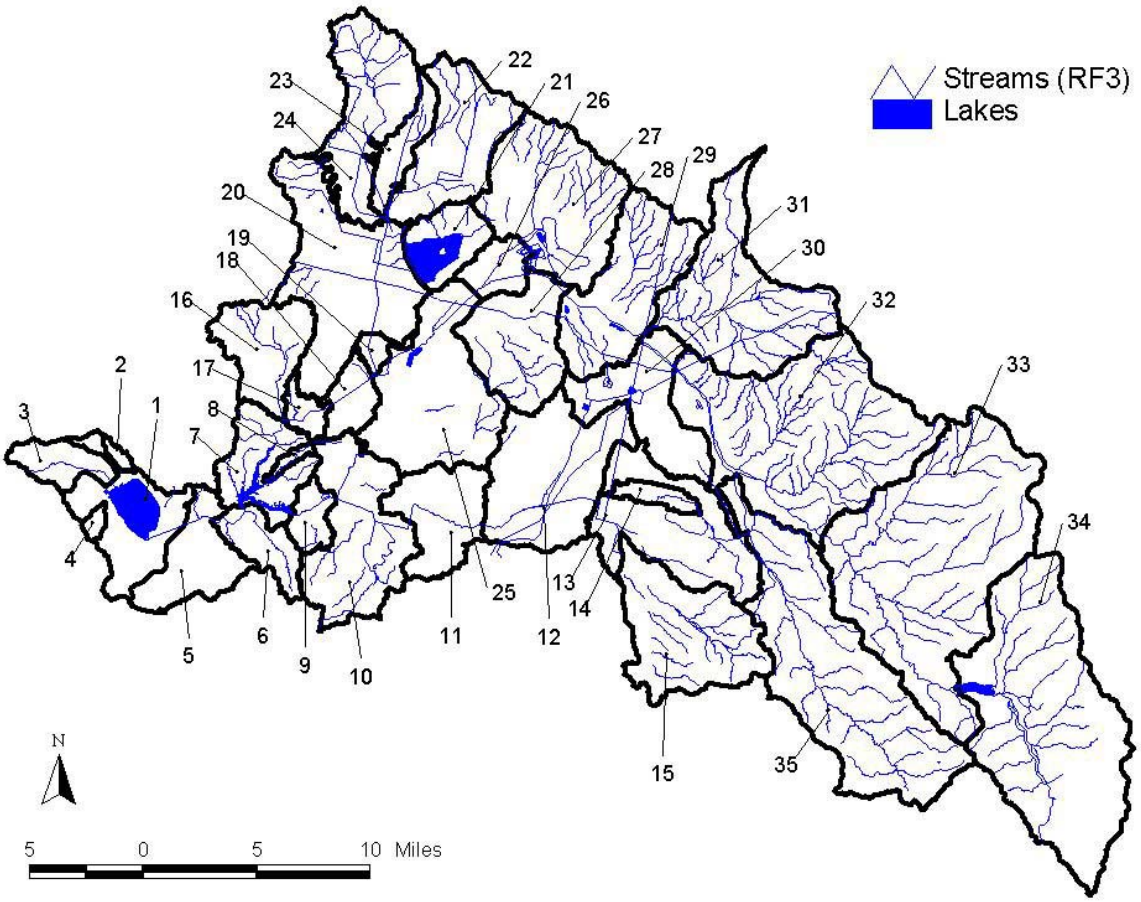


Figure 1. Nutrient Model Subwatersheds for San Jacinto Watershed (Tetra Tech, 2003)

The annual nutrient loads from the upper portions of the watershed do not typically reach Canyon Lake or Lake Elsinore when Mystic Lake is not overflowing (Scenarios 2 and 3). Likewise, unless Canyon Lake overflows (Scenarios 1 and 2), the nutrient loads from the entire San Jacinto River basin upstream of Canyon Lake will not reach Lake Elsinore (at least during the same year). Localized sources and contributions from areas downstream of Mystic Lake impact the lakes under all three scenarios, but they are most critical when Mystic Lake is not overflowing.

Modeling results for dairies and cropland, the sources most relevant to the IRDMP, are summarized in Table 2. Contributions of N and P from cropland and dairies in zone 9 are not included because they are insignificant. Interpretation of the loads for the various zones is governed by the following:

- Zones 1 and 2 are the load *to* Lake Elsinore and Canyon Lake, respectively.
    - Zone 2 includes the total load from zones 3 through 9 (subject to losses through delivery), combined with local loads from the area within the zone 2 boundary.
    - Zone 1 includes the load exported from Canyon Lake and the local load from the area within the zone 1 boundary.
- The load for zone 7 is the load *exported* from Mystic Lake.

- The reported loads for zones 3-9 are the net loads exported from the zones, including loads transported from upstream zones as indicated by the arrows in Figure 2.

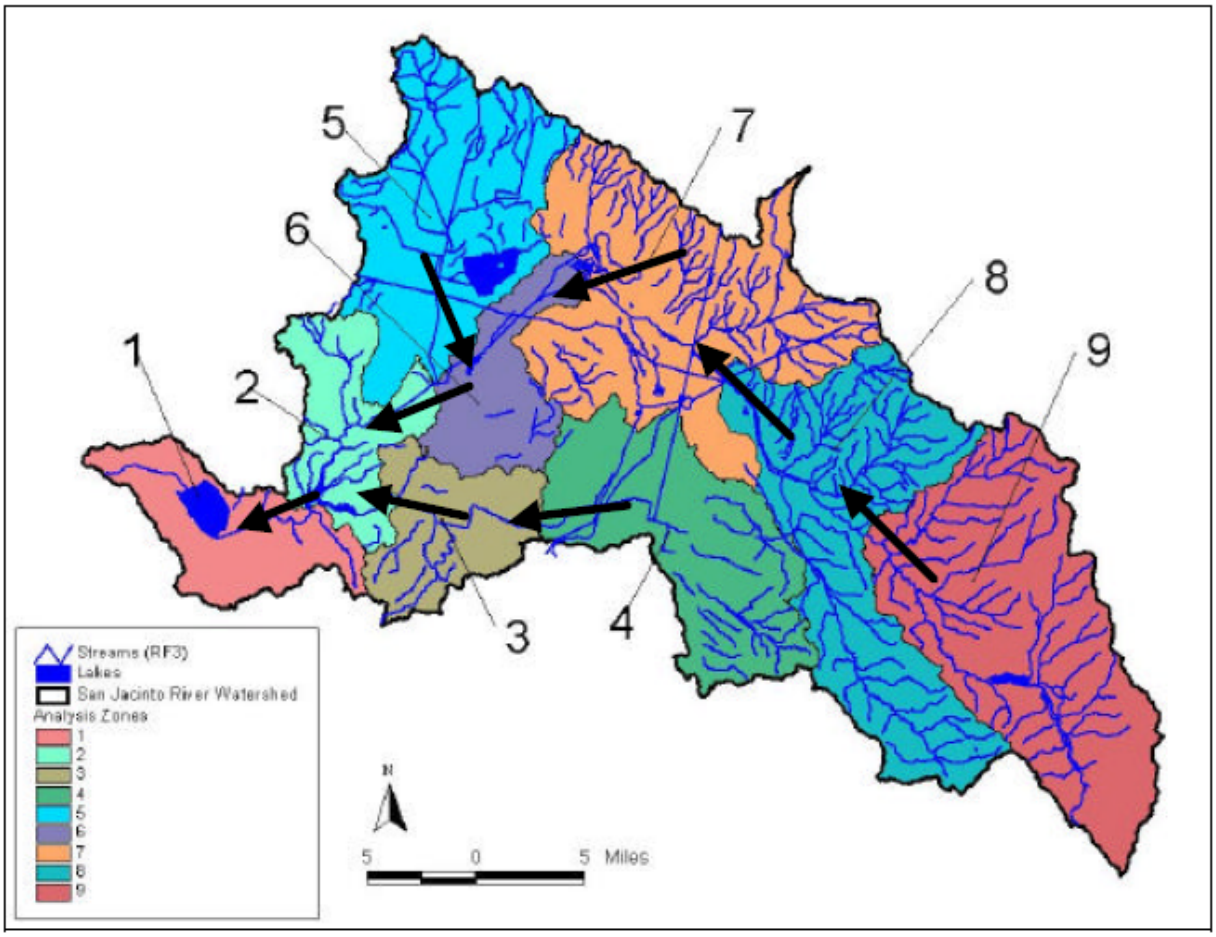


Figure 2. Zones for Nutrient Modeling (Tetra Tech, 2004)

San Jacinto dairies are primarily located in zones 7, 6 and 3. Modeling results clearly indicate that dairies contribute more to the export of N from Mystic Lake than does cropland under Scenario 1, whereas cropland contributes much more of the P export from Mystic Lake (Table 2). Zone 5 contributes much more N from cropland than from dairies under Scenario 1, shifting the zone 6 load more toward cropland sources. Cropland is a bigger contributor than dairies to both N and P in zones 4 and 3 under Scenario 1. Under scenarios 2 and 3, neither cropland nor dairies contribute much N or P through zone 6, while cropland contributes about twice as much N and 8-10 times as much P as dairies to the relatively small loads from zone 3.

The general pattern for cropland N under scenario 1 is an increase moving from zone 8 to zone 6, with zone 6 contributions coming from both Mystic Lake and zone 5. Cropland N also increases moving from zone 4 to zone 3, with additional N from within zone 2 contributing to the N load to Canyon Lake. Under scenarios 2 and 3, the zone 5 contributions are attenuated through zone 6, whereas crop N contributions continue to increase from zone 4 to zone 2.

Table 1. Modeled Nutrient Loads to Lake Elsinore and Canyon Lake (Tetra Tech, 2003)

Source	Scenario	Zone 1 Load to Lake Elsinore	Zone 2 Load to Canyon Lake	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7 Export from Mystic Lake	Zone 8
		N Load (1,000 pounds)							
Cropland	1	95	94	20	11	25	39	22	10
Dairies	1	32	32	8	1.4	1.5	26	33	10
Cropland	2	8	8	3.7	2.0	2.9	1	0	0.4
Dairies	2	1.4	1.4	1.5	0.3	0.2	0.06	0	1.3
Cropland	3	0.4	8.2	2.6	1.3	4.1	0.6	0	0.1
Dairies	3	0.05	1.2	1.4	0.2	0.2	0.03	0	0.7
		P Load (1,000 pounds)							
Cropland	1	46	46	7.4	4.3	8	27	22	4.5
Dairies	1	6.3	6.3	0.7	0.1	0.1	6.3	7.7	1
Cropland	2	0.64	2.9	1.4	0.8	0.9	0.4	0	0.1
Dairies	2	0.02	0.12	0.14	0.02	0.02	0	0	0.1
Cropland	3	0.5	2	0.8	0.4	0.9	0.1	0	0.04
Dairies	3	0.02	0.06	0.1	0.02	0.01	0	0	0.05

The general pattern for dairy N under scenario 1 indicates an accumulation from zone 8 to zone 7, followed by a slight decrease through zone 6, with little contribution from zone 5. The dairy N load from zone 6 represents about 80 percent of the total dairy N load to Canyon Lake, while the dairy N load from Mystic Lake equals 103 percent of the dairy N load to Canyon Lake. Dairy N contributions increase substantially from zone 4 to zone 3, increasing again within zone 2. Under scenarios 2 and 3, very little dairy N passes through zone 6, with zone 3 having the greatest, though relatively small, accumulation of dairy N. In fact, the dairy N load from zone 3 is roughly equivalent to the total dairy N loads to Canyon Lake under these scenarios.

For cropland P, the general pattern is similar to that for N under Scenario 1, with the exception that contributions from zone 5 are relatively small compared to those from Mystic Lake. As for N, cropland P increases from zone 4 to 3 under Scenario 1, with a substantial contribution from within zone 2 contributing to the load to Canyon Lake. The pattern is similar to cropland N under scenarios 2 and 3, where the zone 5 contributions are reduced through zone 6, but crop P contributions continue to increase from zone 4 to zone 2.

The general pattern for dairy P under scenario 1 is much like that for N, with an accumulation from zone 8 to zone 7, followed by a slight decrease through zone 6, with little contribution from zone 5. In fact, the dairy P load from zone 6 roughly equals the total dairy P load to Canyon Lake, and the dairy P load from Mystic Lake is equal to 122 percent of the dairy P load to Canyon Lake. Dairy P contributions increase from zone 4 to zone 3, with the load to Canyon Lake essentially equal to the load from zone 6. Under scenarios 2 and 3, no dairy P passes through zone 6, and zone 3 has the greatest, yet small, accumulation of dairy P. As for N, the dairy P load from zone 3 is roughly equivalent to the total dairy P loads to Canyon Lake under these scenarios.

Appendix M – Using Waste Revenue Projections for Technology Development Options

WRCAC

Western Riverside County Agriculture Coalition

Waste Revenue Path Technology And Options for Dairies in the San Jacinto Watershed

Version 2.0 ● December 29, 2009

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1 Executive Summary

The Integrated Regional Dairy Management Plan (IRDMP) for the San Jacinto Watershed has been developed in response to regional water quality regulatory mandates to reduce solids/salts load in the watershed; by the selection and demonstration of consistent practices of regional goals for water quality and environmental protection.

It is an impressive feat of the Western Riverside County Agriculture Coalition (WRCAC) to bring together the diverse participants for a common good. All the dairymen, agriculture producers, regulatory bodies and civic institutions are to be commended for their cooperative spirit in developing this plan.

A vital part of implementing the strategies presented by the IRDMP is to find a way to ultimately eliminate the primary waste produced by the dairy industry: the manure. The manure is a potential feedstock source for energy conversion technologies, such as anaerobic digesters. Manure volume can be dramatically reduced with the use of conversion systems such as an anaerobic digester. The residual produced through this process may be disposed of more economically through exportation from the basin entirely or via a controlled fertilizer application.

Manure is a unique byproduct, because of its potential to contribute to the environment when properly processed and handled. Manure can provide the base for income generation to dairies in the San Jacinto watershed in the form of “biogas” and the compost that result from the process of collecting the manure and using it as a feedstock for the digesters.

The digesters have the potential to create biogas for energy creation and compost for sale. A revenue opportunity does exist to offset investments expenses to reduce the manure volumes. The dairy operators will have the option to realize this potential incremental revenue stream by accepting responsibility for the entire process or by contributing the waste to a project by transferring the responsibility of the nutrients and salts to the anaerobic digester owners.

Permitting in the basin of a single farm AD system for biogas used in an engine to create electricity will be a challenge. Using biogas that is upgraded for use in a fuel cell for electrical generation avoids engine permit issues, but is economically difficult because of the cost of cleaning the gas. Unless the capital costs of individual farm scale compliant conversion systems are dramatically reduced a shared scale effort is more sensible.

A key goal of this group is delivering a “roadmap” for handling issues in the San Jacinto Watershed by addressing dairy management on a regional scale. Through this approach, each stakeholder acknowledges the other stakeholders concerns, which results in stronger, cooperative and more comprehensive solutions.

Developing an understanding of the revenue generating potentials of the waste products focuses upon these points:

- What is the individual and collective potential value of the dairy waste?
- What is the individual and collective capital expense for creating digesters?
- Will digesters contribute to reducing nutrients and salts responsibilities?

- The technologies reviewed for this document indicate that larger scale (i.e. “Shared/Community” or “Regional”) installations generate the most revenue and are the most cost effective.
- Financial incentives are available through state and federal loans and grants targeting renewable energy technologies.
- Consolidated Anaerobic Digesters may provide financial and environmental successes for the San Jacinto Watershed.

The next important steps for the follow on phase are:

- Organize the waste-to-energy early adopters in the basin and begin to formalize their goals and objectives.
- Build upon the information presented with interested stakeholders and attract additional local and regional support for a waste-to-energy effort using the dairy manure as a primary feedstock.
- Conduct research into additional feedstock opportunities to blend in with the dairy manure.
- Perform a formal potential feedstock radius survey.
- Do preliminary business case analysis for specific dairy farm(s) for locating and sizing a digester/conversion system technology.
- Develop additional feedstock opportunity relationships in order to create preliminary designs and economic models.
- Identify a step-by-step plan to start an initial digester and collection effort that is then capable of expanding to support the local feedstock of manure, additionally identify what is being currently imported and with a view to accommodate other feedstock.
- Seek to partner entities that are already permitted waste handling facilities to expedite either pilot or scale operations for waste-to-energy efforts.
- Develop relationships with energy, carbon credit and compost buyers for reasonable off take agreement(s).
- Size a viable project, identify funding and begin preliminary engineering effort.
- Apply lessons learned from other cooperative efforts and incorporate best practices in future projects in the San Jacinto area.

2 Introduction

2.1 Purpose of this document

All of the IRDMP plans and objectives for the dairies and other stakeholders in the San Jacinto Watershed will require an understanding of the economic impact of solutions. Any and all identified technologies and appropriate solutions that facilitate the overall “roadmap” will incur some kind of investment cost; either monetarily or though in-kind investment of the stakeholders. Through the exploration of conceptual possibilities that mirror, enhance, and support the goals of the IRDMP, revenue opportunities become apparent. The goal is to highlight the ability to create an economic benefit from a local waste stream that directly supports and enhances the goals of the IRDMP.

We explored the available technology options and conceptually present viable options that will create revenue from waste streams of the stakeholders. To begin this path the potential number of dairy farms were surveyed. The survey data included the working parameters of their operations such as herd breed, size, and composition of mature and young stock: heir style (open lot, flush or hybrid) and current method of manure management. Utilizing gross herd and manure volume estimates, a data set was developed for projecting biogas volumes.

Using typical assumptions for the biogas potential of the manure/head counts for each dairy have been formulated, then aggregated for a total potential. Manure samples were collected and submitted for testing and valuation of biogas potential. Obviously different conversion technologies can be considered for the manure stream for the production of energy values. There are different types of conversion technologies (thermal, chemical or biological.) For this conceptual plan effort, the focus was to generate energy revenues using proven and well known types of digester systems. Each conversion technology contains their own merit, but all have common advantages for the dairy operations and support the reduction of solids and nutrients for land application.

Additionally, an energy project will help to reduce dependence on waste exportation from the area as a possible primary solution, reduce emissions, capture methane, and create jobs in environmental and energy related industries. It is possible to produce renewable energy and green fuels, biodiesel, biomethane, compressed natural gas (CNG), and electricity. Turning the manure into an energy product will begin reducing manure/material disposal, transportation, environmental impacts, and lowering fossil fuel usage for out of area treatment and disposal. By providing a local solution, the local economy is bolstered by the addition of environmental sector jobs tied to food and energy production while providing sustainability for agricultural enterprises.

In the effort to meet one of IRDMP’s primary objectives, it is imperative to explore a waste-to-energy option. A fundamental goal for the IRDMP is to comply with several regulatory requirements, including: the Lake Elsinore and Canyon Lake Nutrient Total Maximum Daily Load (TMDL), requirements of the National Pollutant Discharge Elimination System (NPDES) waste discharge permit for dairies, and groundwater objectives in the “Water Quality Basin Plan Amendment” for the Santa Ana River Basin. Each method of energy conversion is possible for managing and reducing the total solids and nutrient loads. All of the energy conversion systems encourage timely collection and processing of manure from corrals and feed lanes. Timely collection and processing reduces nutrient contact time with soils and runoff from rains.

Combining the raw data of manure, volume, collection and production estimates into a table allows for the comparison of capital and operating costs for different conversion systems and technologies. (*See "Table 5 – Digester Technologies Capital & Operating Expense" in section 8.4 of this document.)*

The project's conceptual goal is to reduce manure volumes using waste-to-energy recovery efforts. The dairy conceptual efforts begin with understanding of the potential biogas volumes. The next steps will be to understand the potential and then the best conversion and use of the biogas; following with studying the opportunity for additional biomass feedstock. Other local feedstock will be useful to be added for possible tipping fees and biogas volume increases. The first additional feedstock's might be all on farm digestible waste and then approved off-farm contributions. This path increases both biogas output and tipping revenues. Additional revenues from methane capture and subsequent carbon offset credits are available for this effort. The dried digestate has a market, when it is pathogen and weed free, for a soil amendment. The conceptual project solution set goes from the extreme of having a suitable sized conversion technology at the individual farm, shared (communal) amongst several farms, to a full "regional" digester, accepting not only on-farm waste, but potentially off-farm waste streams. Creating a rough capital cost estimate of various conversion systems such as anaerobic digesters has been included in this study. Solution pathways become more visible with the preliminary capital cost understandings for various technologies and conceptual organizations of processing systems and equipment.

In order to effectively evaluate and eventually formulate a successful waste-to-energy plan, it was of vital importance to keep the overall goals of the IRDMP in the forefront. Any final plan for waste energy will be integrated with the IRDMP other efforts and recommendations to maximize the benefits to all stakeholders. Any recommendations for best practices or changes in practice from the IRDMP effort need to be in harmony with waste-to-energy suggestions solutions.

Attracting allied businesses, governmental, energy and technology support for a waste-to-energy effort is considered important. Illustrating the gross economic potential values and willingness of the local stakeholders to create a solution generates genuine interest from potential renewable buyers/investors. Another element of the initial phase of the conceptual goals is to attract others to an effort in order to achieve a truly viable solution that will effectively support the goals for the basin.

2.2 Benefits

The general benefit of this study effort is the increased knowledge base for evaluating various nutrient, manure and waste management solutions and technology paths to create energy and revenue. The specific benefit of understanding conversion options is to illustrate the likely investment levels required. The configuration and investment costs for individual and cooperative solutions are illustrated. Having this knowledge is very important. The capital cost to create a waste-to-energy solution is very large. Understanding the potential revenues and costs are important part of the technology selection process. Example potential energy end products sales revenue values are provided along with expected capital costs. Several different configurations of feedstock and biogas gathering and upgrade (gas cleaning, Hydrogen sulfide removal) layouts are illustrated. The different layouts require different capital investments. Another benefit of the study is to discuss the central vs. distributed efforts.

Implementing a waste-to-energy technology solution in the basin will provide measurable assistance to the efforts to reduce the amount of solids by reducing volumes by processing them. The installation of systems to manage manure and their salts load is important. Where the final process results of the

processing ends up is also important. The resulting compost is stale and with known nutrient levels for use land application in the basin. Exportation is also an option to meet basin goals. The value of the exported manure compost and nutrients in the form of weed and pathogen residual of the conversion process creates more value for everyone. As compost it is in a more acceptable condition for export to other regions. Compost is welcomed in areas that desire to add it to the soil as a fertilizer and conditioner. The basin presently accepts raw manure from other regions. Building processing systems to accommodate out of basin manure volumes are possible.

Understanding the conceptual feasibility of technology conversion options such as AD (Anaerobic Digestion) for an individual farm, groups and on a regional scale enables a dialogue on options to begin. Others have addressed the barriers to marketing the outputs, environmental permitting and dairy/stakeholder organizational formation concerns. This study focuses on conceptual design(s), cost(s) and potential revenues to pay for such a project. A reasonable roadmap to address and achieve the goals of the group will require projections of the energy production potential of the biogas, methane capture values (monetized as carbon credits) and solids resale from contributing stakeholders. Initial investment budgets can be sized with the expected revenue potential understood. The process technologies will support solids volume reduction. The potential revenues to offset the costs to attain the solids reductions are substantial, but will still likely require subsidies. There are different technological and process options to choose from. There are different entity formations and subsidies available. Preserving options for the dairy stakeholders begins with identifying then evaluating different paths to reach them.

2.3 Scope

For this section of the task, a review of current literature regarding the specific locations and operating style of the dairies in the San Jacinto was completed. Using this data, estimated biogas volumes were developed using expected and typical biogas projections. Additionally, manure samples were collected to validate basic assumptions. Using our own research and data collected on potential conversion technologies as compiled by SeaHold, the estimated capital expenditures were compared. Carbon credit values were estimated based upon industry and trade research to approximate revenues from methane capture. Additional feedstock sources were explored for potential inclusion in one concept of a regional digester.

3 Problem Statement

There is a challenge of paying for process and practice changes. They do require time, energy and financial resources. New and innovative technologies, which may at first seem out of the realm for what the existing practices are in the dairy industry, are needed to address the nutrient and groundwater issues affecting the dairymen in the San Jacinto watershed. These new technologies often come with seemingly huge costs to implement. The typical dairyman may find these costs to implement simply unacceptable. Selecting the best technology, for the watershed as a whole, is a paramount goal. It is well understood that in order to support the overall stakeholder goals, there will be both practical and technological innovations that need implementation to meet the regulatory mandates of the September 2010 deadline for salts offset and manure application reduction. It is essential, at this juncture, that the stakeholders become not only educated, but empowered. Financial investments will be likely. Finding the source of funding is a challenge, especially for the stakeholders that are “price takers.” Dairymen are forced to accept a set a price for their milk therefore cannot make adjustments to cover capital expenditures. The incremental investment costs are not able to be passed on in the price of their products. Creating an additional revenue stream from waste is one option. Identifying the value of the waste is an important issue to start the process. This is due to the fact that begin values are identified and potential new budgets are revealed. It is possible to begin attracting the funds and creating a revenue stream from waste-to-energy options to support investments.

In this section: Waste Revenue Path Technology and Options for Dairies in the San Jacinto Watershed, we have attempted to begin the dialogue on costs and revenues. Creating a budget to pay for new equipment and practice changes needs to be funded. We anticipate that waste-to-energy efforts will be a new way of thinking for the all of the stakeholders in the basin. Identifying the gross values of the revenue and investment was an important effort. As the values are presented budgeting for an effort can begin to be discussed by interested participants and stakeholders.

4 Conceptual Options for Supporting Waste-to-Energy Technology Options

In today's technology savvy market place, several waste-to-energy conversion technologies are available to analyze and select from. In this section we have focused on proven and well deployed conversion solutions. The merits of conversion technologies are well documented. The purpose of this sub-section is to illustrate biogas production possibilities. The final selection of any particular technology and/or energy output effort is subject to its ability to meet the goals of the participants and be inherent in the feasibility of stakeholders to implement a system.

A successful bio-energy project must have clearly established goals and objectives, agreed to in advance. This conceptual discussion document is intended to move these dialogues forward. It is not being suggested that these concepts are the only options, nor the preferred solution. The conceptual option scenarios outlined pre-suppose many assumptions. The assumption set includes the concept that energy and output revenues and profits would first be applied to project repayment to investors. One of the problems is the project investors and participants have not been completely identified. The investors may be the stakeholders in the basin, or a combination of financial and participating beneficial investors. The type of entity that would organize any activity in a shared use or ownership formation has not been identified.

In short, many potential barriers and hurdles between the conceptual options and revenues do exist. The important message is that there are options and should be illustrated for individual and shared solutions to achieve goals of the IRDMP using waste-to-energy systems. Reduction of manure solids and salt in the basin are possible with different technologies, but they need a revenue stream to pay for them - manure biogas is one path. A generalized process for addressing potential barriers to realizing revenue from biogas potential includes the following steps:

- Identify the participants and stakeholders.
- Clearly establish the goals and objectives.
- Identify the problems.
- Research the possibilities.
- Work the hurdles to the advantage of the project.

5 Waste-to-Energy Benefits

Meeting the environmental goals of the basin stakeholders through waste-to-energy efforts appear to be very compatible. The benefits of using anaerobic digesters (ADs) are well known and understood. AD systems will help reduce solids volumes and produce biogas. For the San Jacinto area dairies, processing the manure in this manner recycles the nutrients, addresses waste treatment and disposal concerns and improves odor control efforts. The biogas produced can be used to provide green energy and heat for on-farm/shared, communal or regional digester efforts. Selling the biogas through energy buyers off the farm generates new revenues. The energy may be used to create green electricity and fuels for these grids. Using manure and methane capture efforts makes the farms potentially eligible for carbon credits that can be sold on the voluntary carbon reduction markets and more unrealized revenues. Each one of these beneficial uses moves the dairy farm towards more sustainable operational practices. Processing manure and nutrients to a saleable product contributes to additional revenues and is environmentally important. For the dairies that have crop farming, they will have a source for fertilizer and soil amendment needs. When the compost is able to be used instead of purchased fertilizer inputs the farming operation saves money. The surplus compost is a useful and readily welcomed product for export from the basin, unlike raw manure.

ADs produce a material after the gas is created; it is a mixture of solids suspended in very thick liquid solution. It is this solution that is rich in nutrients such as ammonia, phosphorus, potassium along with important trace elements. This mixture, when treated as a part of the AD process, is accordingly weed, seed and pathogen free. It is this value added byproduct that is a desired soil conditioner as compost. This valuable compost, after the AD process, is stable, odor free and can be stored without the issues associated with raw manure. The compost will not attract flies, rodents or the attention of neighbors.

When using an AD processing system, the organic nitrogen in the manure becomes converted to ammonium. It is this ammonium that is available for uptake by plants. As a dried product it is easily stored and applied as a fertilizer. It can be applied onto crops or by end users when it is needed most. The remaining “digester fiber” (fibrous solids) have the potential to be used as an ingredient for fiberboard and other composite materials.

Good compost allows the farmers and other users to move away from being solely reliant upon petrochemical sources of fertilizers and nutrients. High quality compost can significantly reduce the fertilizer input costs for those using it. Excess waste heat from the AD, upgrade and processing of biogas is useful for heating and drying materials and digestate.

The digester process causes most of the odor causing volatile acids to be converted to biogas, as compared to having manure processed in typical solid or liquid storage practices. Noxious smells (and complaints) are reduced when an AD system is in place and being properly used.

AD systems reduce the potential of surface and ground water contamination for several reasons. The AD systems extract a large percentage of the nitrogen, phosphorous and potassium nutrient load that is normally present in manure. These nutrients move into the digester’s effluent, and then into the resulting compost product. This process contributes to an ability to reduce potential water pollution as compared to unprocessed piling of manure. Compost, when the final product of an AD process, has remaining beneficial nutrients that are more stable and balanced for application to soils for plants.

Using an AD system allows the potential methane to be effectively captured and channeled; this is used to replace fossil fuels and helps to reduce climate change. The carbon from this natural methane is recycled and is part of the natural carbon cycle of plants and consumption by animals and humans. There is a potential for methane capture credits for the dairies in the San Jacinto area. Again this is a potential revenue source to support the goals of the improving manure management practices. IRDMP goals for reduction of solids volumes in the basin are addressed using AD systems and the export of excess material as a product.

6 Brief Conversion Technology Overview

There are different types of conversion technologies: thermal, chemical, or biological. Each type of conversion technology provides ample options for vendors and versions. Each general technology and specific supplier's offering have different benefits and drawbacks. We are not recommending or disqualifying technologies or vendors (see Table 2 - Technology Providers & Technologies Reviewed. At this time we are illustrating or reporting their claimed performance within the use of the dairy manure feedstock as a source. For this example effort we have focused on various Anaerobic Digestion (AD) offerings.)

As AD systems are well deployed throughout the agricultural and industrial community, they are better understood. Pyrolysis, Pyrolysis/Gasification and Gasification technology options may need further exploration, once the exact goals are firmly defined. These technology options do often require more sophisticated management and operational skills than AD systems, and typically require larger feedstock inputs than the typical dairy in the area.

7 Brief Energy Output Production Overview

Biogas from any conversion technology will then be used for either for the direct burn of the biogas for heating value in a boiler for example (without upgrade/treatment); upgraded to remove the constituent elements such as Carbon Dioxide (CO2), Hydrogen Sulfide (H2S) then used to run a turbine, Internal Combustion Engine (ICE) or fuel cell to produce electricity; for production of Compressed Natural Gas (CNG)); or for natural gas pipeline injection into the grid. The creation of the biogas decision for potential and subsequent energy delivery/use requires another review to be in concert with the stakeholder and investor desires.

The biogas potential from AD systems is a good starting point for discussions. Beneficial end use of the BTU's value beyond the farm requires complex equipment and increased capital expense. More equipment is needed to increase the biogas quality to biomethane and value for other end uses.

Selecting the highest value end use and then delivering an economical product to a buyer is another discussion. The best solution for California dairies is more complicated, because of the air quality permits. The San Jacinto Basin will require air permits for any ICE used for electrical generation. These engines are not believed to be economical to deploy at this time because of the added capital cost to upgrade the biogas. The ICE units typically are not able to meet the air board requirements without treating the biogas extensively to remove the H2S, etc. When the ICE units are compliant, they are typically powering a generator to create electricity for use on the farm (net metering programs). This is not a viable option to deliver incrementally new revenues to the participants, as net metering only offers the farms current electrical consumption costs. Selling the excess of the farm's electrical consumption power to the grid is a better option. Distributed power generation and selling power beyond the farm to the grid requires more equipment beyond the AD systems and again more investment and skills to run additional equipment.

As the cost of the AD system can be proportionate to the size of the herd and style of dairy, we again have looked to biogas creation as the starting point of the waste-to-energy recovery steps. The conceptual solutions illustrated use manure feedstock for biogas; upgrading for either injection into the pipeline or producing CNG. The rationale for this concept is simple: biogas creation for most end energy sales and uses in California and the San Jacinto Basin will require a disproportionate investment in H2S and CO2 removal to meet air standards. Removal is done more economically in larger scale systems than what is typically available for unit sized dairies located in the San Jacinto Basin.

Gathering the waste to create energy value is a challenge. Collecting and moving the manure economically is a hurdle with processing the manure locally also important. Transporting manure solids is typically done with trucks. Another way to move the manure would be by a dedicated pipeline. Creating this dairy solids and liquid waste pipeline is doable, but likely to be a very substantial effort for engineering, water and land use. The ability to create a continuous flow of solids in a pipeline and the requisite water balancing tanks and pumps for the system is daunting. Gathering unprocessed waste to a centrally location via a sewer like system might be one option. It is believed to be more economical to produce biogas from individual/shared, communal or regional digesters, and move it to a central location for value added processing for energy sales. Moving solids by truck short distances to digesters is also a proven model. Creating economical biogas gathering lines by connecting individual AD systems is worthy of consideration. The farm stakeholders gain a method to collect and manage manure on site and export the biogas. Solids volumes are reduced by the AD systems and the subsequent materials are able to be

economically collected and processed for sale as a "product." Gathering biogas to upgrade/processing locations facilitates the potential use for creating biomethane for either burning in an engine, for electricity, liquid or gas fuels creation on-site, or injection into the pipeline grid. Interest in AB118 (Alternative and Renewable Fuel and Vehicle Technology Program) and AB32 (Global Warming Solutions Act of 2006; which has implementation deadlines starting in 2011); a single central process site may prove to be good at scale platform location. These are suggested conceptual solutions and the final focus and goals of stakeholders will be the deciding factor. The concepts put forth are to illustrate options. Knowing the options begins with knowing the potential biogas from an existing and consistent feedstock source. We have the known volumes of manure from dairies and amounts being imported from nearby communities in and around the San Jacinto basin. Using known amounts, we have projected biogas volumes from various assumptions and types of AD systems.

The following pages show some basic production estimates for the conceptual digester technologies reviewed. There are various technologies for converting waste-to-energy, and below is a summary of some of the various technologies typically used for dairy manure processing:

- Plug Flow - Long, rectangular concrete tank with an air-tight cover where manure flows in one end and out the other. Sometimes the tank is U-shaped, with the entrance and exit at the same end. Influent manure first enters a mixing pit, allowing solids to be adjusted by adding water. Then as manure is added the "plug" of manure slowly pushes the older manure down the tank. The tank is typically heated to maintain a mesophilic or thermophilic environment, often using recovered heat from the biogas burner. The tank volume commonly holds 15 to 30 days worth of manure and waste water, or in other words, a hydraulic retention time (HRT) of 15-30 days. Plug flow digesters require 11 to 13 percent total solids in the manure and work well with scraped dairy manure.

- Complete Mix - A complete mix digester has a sealed, cylindrical concrete or steel tank where manure is mechanically kept in suspension or "mixed" by a motor-driven impeller, pump, or various other devices. It is also referred to as a "continually stirred tank reactor." The manure is typically heated to maintain a mesophilic or thermophilic environment, often utilizing recovered heat from the biogas burner. The tank commonly holds 15 to 20 days worth of manure and waste water, or 15-20 day HRT. Slurry manure that is scraped or flushed with 3 to 10 percent total solids works best in this system.

- Covered Lagoon - An earthen lagoon fitted with a cover to contain and facilitate collection of biogas is the least expensive type of digester to install and operate. A covered lagoon is the least controlled system with the lowest gas production and the longest retention time due to its psychrophilic environment. In northern climates, there may be no gas production in cold weather. Odor may not be totally eliminated due to incomplete digestion. Best suited for flush manure collection systems with total solids of 0.5 to 3 percent.

- Fixed Film - A concrete or steel tank that is filled with plastic media called "biofilm." The biofilm supports a thin layer of anaerobic bacteria and maintains a concentrated population of mesophilic or thermophilic methanogens, supporting a larger volume of biogas production and shorter HRT (6 days or less) than the other digester types. Works best with flushed manure with less than 5 percent total solids. Slowly degradable solids must be separated out before entering this type of digester.

Sources: EPA 2005; NRCS

- Dry fermentation is a series of processes in which micro-organisms break down biodegradable material in the absence of oxygen. This dry fermentation process utilizes renewable resources as a

feedstock to produce a methane and carbon dioxide rich biogas suitable for energy production. The nutrient-rich solids left after digestion can be used as a fertilizer and compost. Emission of greenhouse gases are reduced by the dry fermentation process in a number of ways including, replacement of fossil fuels, reduction of landfill methane emissions, displacing chemical fertilizers and reducing vehicle movements. The dry fermentation is recognized as one of the most useful decentralized sources of energy supply, as they are less capital intensive than large power plants. Almost any organic material can be processed with dry fermentation. This includes biodegradable waste materials such as waste paper, grass clippings, leftover food, sewage and animal waste. The plants comprise a number of anaerobic digesters and CHP plants. Typically these are very large concrete enclosures that the waste is deposited in using front loaders, then the doors are closed and anaerobic organisms are delivered to the material in a liquid form. Once the process is complete only the inorganic material remains.

Suppliers were surveyed (selecting from the USDA lists and known providers) and the basic waste volumes and dairy farm distances between them were provided to gather their input on system design suggestions and likely costs. “Dry fermentation” system process providers were also contacted for providing a potential solution. The “Dry Fermentation” system gave a robust estimate for biogas production potential, however, this comes at a higher cost – the system was scaled to a 3,000 cow size, with the requirement of additional “green waste” materials in order for it to process properly – at a cost of $20,000,000. It was thought that a very flexible substrate system such as those used in the “dry” process might be useful for co-digestion with trash and garbage collection efforts.

There are examples of operating cooperative waste-to-energy efforts and these were explored as well. Applying the lessons and experience from other cooperative efforts is important next step to consider for any cooperative in the San Jacinto area.

(Note: The manure production in Tables 1-3 is based upon generally accepted figures of 125# of manure being produced per cow per day)

Table 1 - Complete Mix Tank Digester Production Estimates

WRCAC IRDMP Biogas Production Analysis
12/27/2009
Complete Mix Tank Digester Technology

				Biogas Production Estimates Low - 65 cuft				BioMethane Production Estimates	
Dairy ID	**2009 Approx Milk Cows**	**Daily Manure Production (tons)**	**Yearly Manure Production (tons)**	**SCFD**	**SCFM**	**mmBTU Biogas Daily**	**mmBTU Biogas Yearly**	**Potential BioMethane mmBTU Yield Per day**	**Potential BioMethane mmBTU Yield Per Yr**
WS-9009-82-11	342	21	7695	22,230	15.44	14.45	5,201.82	11.70	4,213.47
WS-9009-82-10	580	36	13050	37,700	26.18	24.51	8,821.80	19.85	7,145.66
WS-9009-82-01	700	44	15750	45,500	31.60	29.58	10,647.00	23.96	8,624.07
WS-9009-82-08	745	47	16763	48,425	33.63	31.48	11,331.45	25.50	9,178.47
WS-9009-82-05	810	51	18225	52,650	36.56	34.22	12,320.10	27.72	9,979.28
WS-9009-67-04	850	53	19125	55,250	38.37	35.91	12,928.50	29.09	10,472.09
WS-9009-82-09	925	58	20813	60,125	41.75	39.08	14,069.25	31.66	11,396.09
WS-9009-67-02	950	59	21375	61,750	42.88	40.14	14,449.50	32.51	11,704.10
WS-9009-82-03	1,000	63	22500	65,000	45.14	42.25	15,210.00	34.22	12,320.10
WS-9009-82-04	1,008	63	22680	65,520	45.50	42.59	15,331.68	34.50	12,418.66
WS-9009-82-12	1,027	64	23108	66,755	46.36	43.39	15,620.67	35.15	12,652.74
WS-9009-81-02	1,060	66	23850	68,900	47.85	44.79	16,122.60	36.28	13,059.31
WS-9009-82-13	1,150	72	25875	74,750	51.91	48.59	17,491.50	39.36	14,168.12
WS-9009-84-01	1,200	75	27000	78,000	54.17	50.70	18,252.00	41.07	14,784.12
WS-9009-82-02	1,300	81	29250	84,500	58.68	54.93	19,773.00	44.49	16,016.13
WS-9009-82-07	1,360	85	30600	88,400	61.39	57.46	20,685.60	46.54	16,755.34
WS-9009-82-06	1,415	88	31838	91,975	63.87	59.78	21,522.15	48.42	17,432.94
WS-9009-81-01	1,475	92	33188	95,875	66.58	62.32	22,434.75	50.48	18,172.15
WS-9009-67-01	1,500	94	33750	97,500	67.71	63.38	22,815.00	51.33	18,480.15
WS-9009-67-03	1,820	114	40950	118,300	82.15	76.90	27,682.20	62.28	22,422.58
WS-9009-83-01	2,100	131	47250	136,500	94.79	88.73	31,941.00	71.87	25,872.21
Total	**23,317**	**1,457**	**524,633**	**1,515,605**	**1,052.50**	**985.14**	**354,651.57**	**797.97**	**287,267.77**

Table 2 - Dry Fermentation Production Estimates

WRCAC IRDMP Biogas Production Analysis

12/27/2009

Dry Fermentation Technology

				Biogas Production Estimates				BioMethane Production Estimates Biogas = 55.1% Methane	
Dairy ID	**2009 Approx Milk Cows**	**Daily Manure Production (tons)**	**Yearly Manure Production (tons)**	**SCFD**	**SCFM**	**mmBTU Biogas Daily**	**mmBTU Biogas Yearly**	**Potential BioMethane mmBTU Yield Per day**	**Potential BioMethane mmBTU Yield Per Yr**
WS-9009-82-11	342	21	7695	22,230	15.44	14.45	5,201.82	28.67	10,321.03
WS-9009-82-10	580	36	13050	37,700	26.18	24.51	8,821.80	48.62	17,503.50
WS-9009-82-01	700	44	15750	45,500	31.60	29.58	10,647.00	58.68	21,124.91
WS-9009-82-08	745	47	16763	48,425	33.63	31.48	11,331.45	62.45	22,482.94
WS-9009-82-05	810	51	18225	52,650	36.56	34.22	12,320.10	67.90	24,444.54
WS-9009-67-04	850	53	19125	55,250	38.37	35.91	12,928.50	71.25	25,651.68
WS-9009-82-09	925	58	20813	60,125	41.75	39.08	14,069.25	77.54	27,915.06
WS-9009-67-02	950	59	21375	61,750	42.88	40.14	14,449.50	79.64	28,669.52
WS-9009-82-03	1,000	63	22500	65,000	45.14	42.25	15,210.00	83.83	30,178.45
WS-9009-82-04	1,008	63	22680	65,520	45.50	42.59	15,331.68	84.50	30,419.87
WS-9009-82-12	1,027	64	23108	66,755	46.36	43.39	15,620.67	86.09	30,993.26
WS-9009-81-02	1,060	66	23850	68,900	47.85	44.79	16,122.60	88.86	31,989.15
WS-9009-82-13	1,150	72	25875	74,750	51.91	48.59	17,491.50	96.40	34,705.21
WS-9009-84-01	1,200	75	27000	78,000	54.17	50.70	18,252.00	100.59	36,214.13
WS-9009-82-02	1,300	81	29250	84,500	58.68	54.93	19,773.00	108.98	39,231.98
WS-9009-82-07	1,360	85	30600	88,400	61.39	57.46	20,685.60	114.01	41,042.69
WS-9009-82-06	1,415	88	31838	91,975	63.87	59.78	21,522.15	118.62	42,702.50
WS-9009-81-01	1,475	92	33188	95,875	66.58	62.32	22,434.75	123.65	44,513.21
WS-9009-67-01	1,500	94	33750	97,500	67.71	63.38	22,815.00	125.74	45,267.67
WS-9009-67-03	1,820	114	40950	118,300	82.15	76.90	27,682.20	152.57	54,924.77
WS-9009-83-01	2,100	131	47250	136,500	94.79	88.73	31,941.00	176.04	63,374.73
Total	**23,317**	**1,457**	**524,633**	**1,515,605**	**1,052.50**	**985.14**	**354,651.57**	**1,954.64**	**703,670.81**

Table 3 - Plug Flow Mixed & Heated Digester Production Estimates

WRCAC IRDMP Biogas Production Analysis

12/27/2009

Mixed Plug Flow

				Biogas Production Estimates				BioMethane Production Estimates	
Dairy ID	**2009 Approx Milk Cows**	**Daily Manure Production (tons)**	**Yearly Manure Production (tons)**	**SCFD**	**SCFM**	**mmBTU Biogas Daily**	**mmBTU Biogas Yearly**	**Potential BioMethane mmBTU Yield Per day**	**Potential BioMethane mmBTU Yield Per Yr**
WS-9009-82-11	342	21	7695	24,451	16.98	15.89	5,721.63	11.29	4,064.12
WS-9009-82-10	580	36	13050	41,467	28.80	26.95	9,703.34	19.15	6,892.36
WS-9009-82-01	700	44	15750	50,047	34.75	32.53	11,710.93	23.11	8,318.36
WS-9009-82-08	745	47	16763	53,264	36.99	34.62	12,463.78	24.59	8,853.12
WS-9009-82-05	810	51	18225	57,911	40.22	37.64	13,551.22	26.74	9,625.54
WS-9009-67-04	850	53	19125	60,771	42.20	39.50	14,220.42	28.06	10,100.87
WS-9009-82-09	925	58	20813	66,133	45.93	42.99	15,475.16	30.53	10,992.12
WS-9009-67-02	950	59	21375	67,921	47.17	44.15	15,893.41	31.36	11,289.21
WS-9009-82-03	1,000	63	22500	71,495	49.65	46.47	16,729.90	33.01	11,883.38
WS-9009-82-04	1,008	63	22680	72,067	50.05	46.84	16,863.74	33.27	11,978.45
WS-9009-82-12	1,027	64	23108	73,426	50.99	47.73	17,181.61	33.90	12,204.23
WS-9009-81-02	1,060	66	23850	75,785	52.63	49.26	17,733.70	34.99	12,596.38
WS-9009-82-13	1,150	72	25875	82,220	57.10	53.44	19,239.39	37.96	13,665.88
WS-9009-84-01	1,200	75	27000	85,794	59.58	55.77	20,075.88	39.61	14,260.05
WS-9009-82-02	1,300	81	29250	92,944	64.54	60.41	21,748.87	42.91	15,448.39
WS-9009-82-07	1,360	85	30600	97,234	67.52	63.20	22,752.67	44.89	16,161.39
WS-9009-82-06	1,415	88	31838	101,166	70.25	65.76	23,672.81	46.71	16,814.98
WS-9009-81-01	1,475	92	33188	105,456	73.23	68.55	24,676.61	48.69	17,527.98
WS-9009-67-01	1,500	94	33750	107,243	74.47	69.71	25,094.85	49.51	17,825.07
WS-9009-67-03	1,820	114	40950	130,121	90.36	84.58	30,448.42	60.08	21,627.75
WS-9009-83-01	2,100	131	47250	150,140	104.26	97.59	35,132.79	69.32	24,955.09
Total	**23,317**	**1,457**	**524,633**	**1,667,056**	**1,157.68**	**1,083.59**	**390,091.13**	**769.68**	**277,084.73**

8 San Jacinto Basin Conceptual Option Scenarios

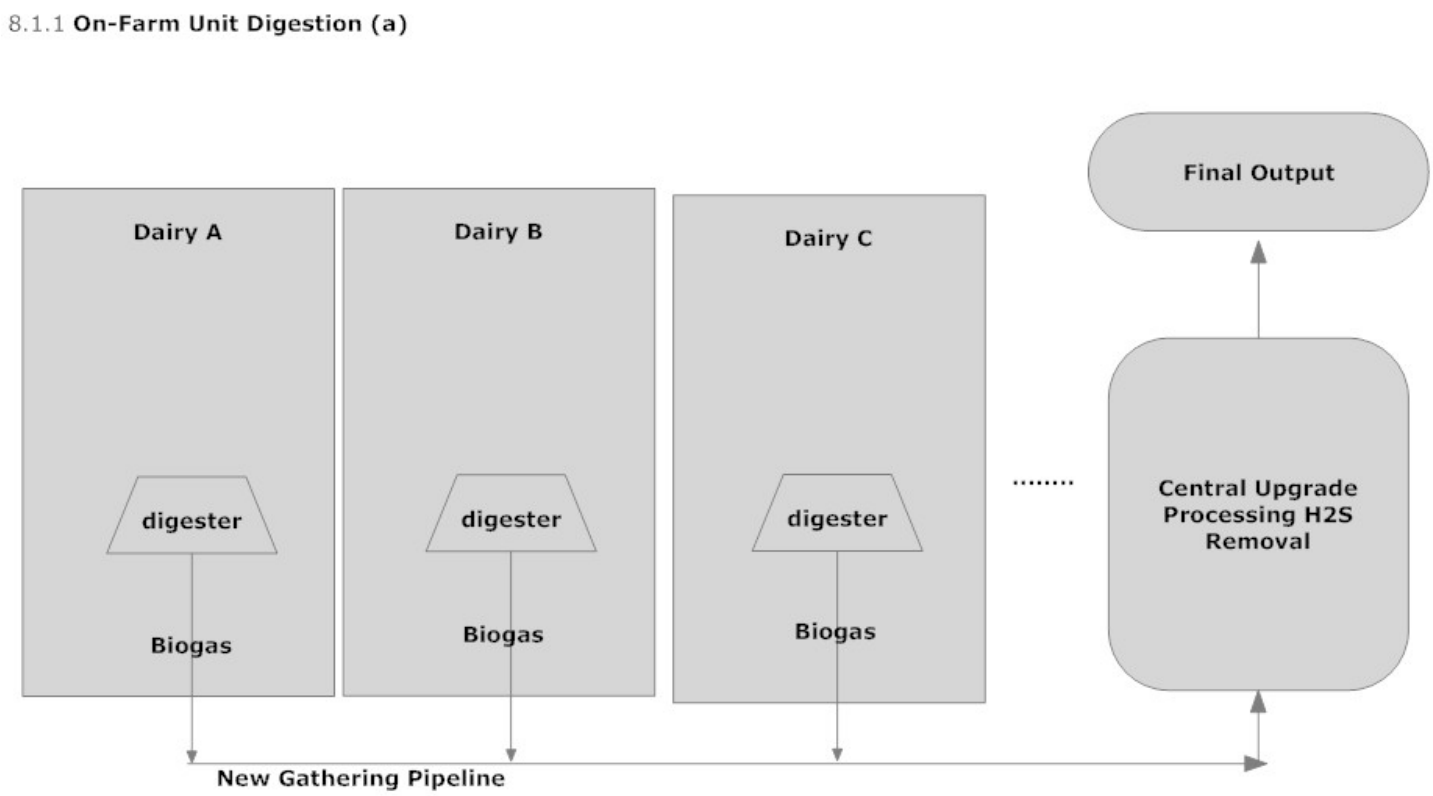
Three conceptual options featuring Anaerobic Digester (AD) systems are discussed below – an option to install a digester unit on every farm; an option to have larger units at designated “community” or “shared” digesters; and a third option – to have a large scaled – “Regional” digester that will utilize all local farm waste or a combination of both on-farm and off-farm waste streams.

8.1 On-Farm Unit Digestion for biogas energy production scenarios:

8.1.1 On-Farm Unit Digestion (a)

One digester at each dairy location, and routing the biogas production and output directly to a biogas gathering line. This would require the construction of new pipeline for the purpose of gathering on the dairy properties. The biogas gathering line would then deliver the biogas to a centralized upgrade/processing facility for value added processing for final output. This is a distributed AD biogas creation concept, with a centralized H2S (Hydrogen Sulfide) removal plant.

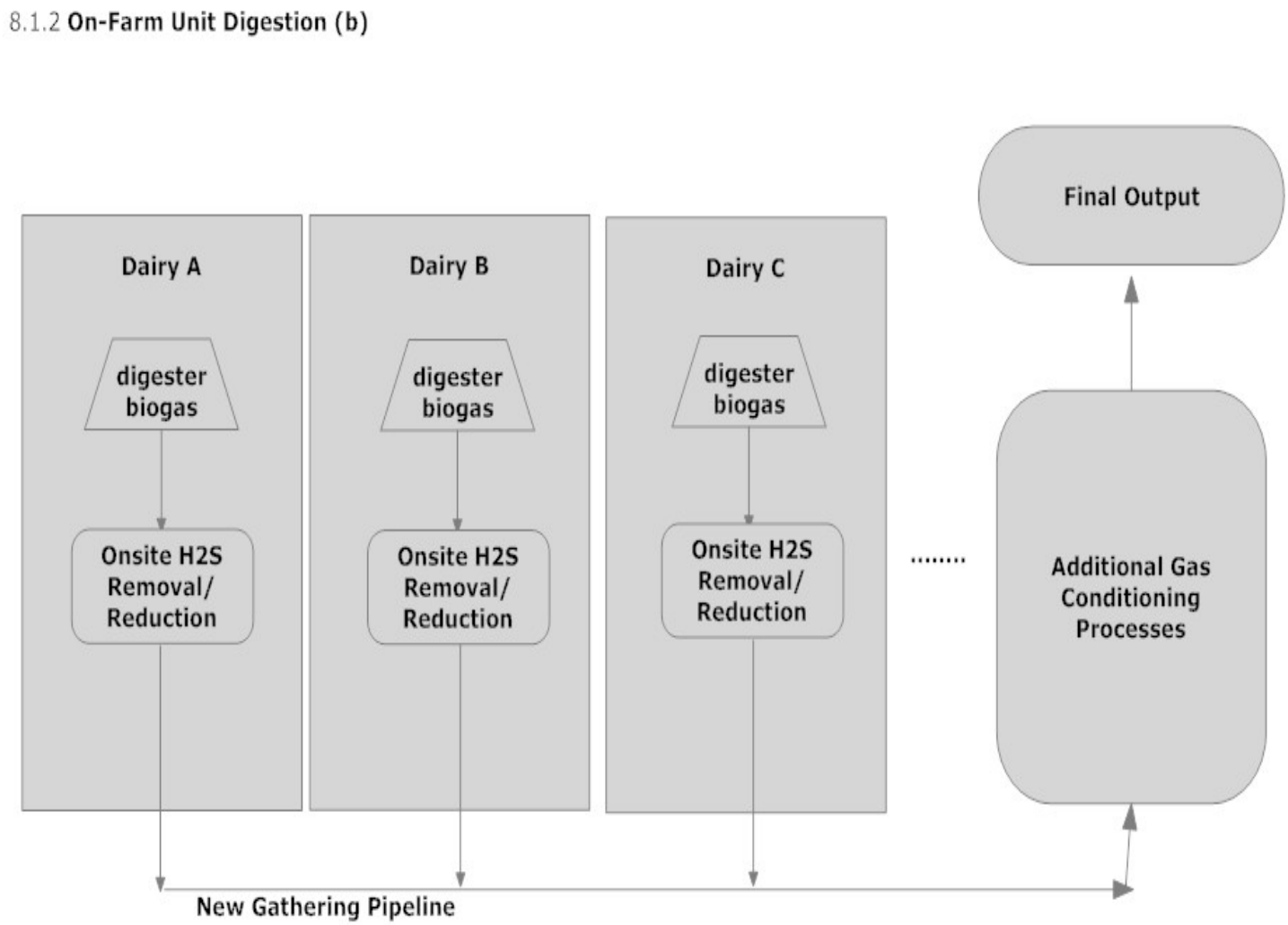
Figure 1 - On-Farm Unit Digestion (a)



8.1.2 On-Farm Unit Digestion (b)

One digester at each dairy location connected to a new gathering line, but with the H2S (Hydrogen Sulfide) being removed or reduced at each AD production location. Business, technical, permitting and operational complexities and barriers will likely be less in this scenario. However the economics for the size and style of dairies in the area tend to be more challenging if only the manure is used on the farm.

Figure 2 - On-Farm Unit Digestion (b)

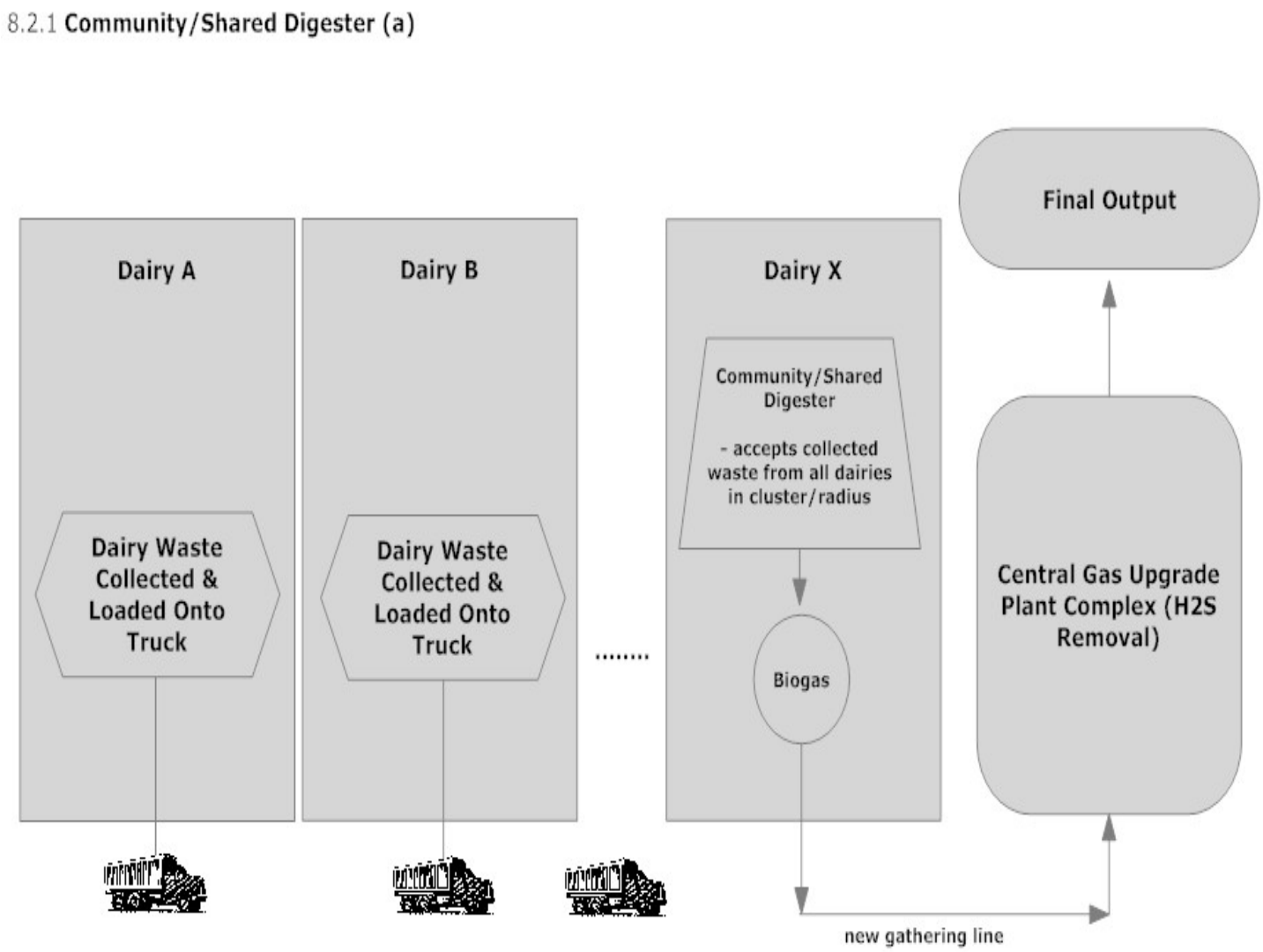


8.2 Community/Shared Digester scenarios:

8.2.1 Community/Shared Digester (a)

This is an option for pairing up dairies that are in close geographical proximity to each other, such as those linked by property line boundaries; or grouped dairies that are within an economical aggregation radius. Trucking and vacuuming the waste to one AD system complex, processing and the resulting biogas is sent via a gathering line to an upgrade plant complex. The H2S would be removed at this central complex. By including more than just a single contributor of dairy manure, the size and loading of digester systems tends to be more economical to manage.

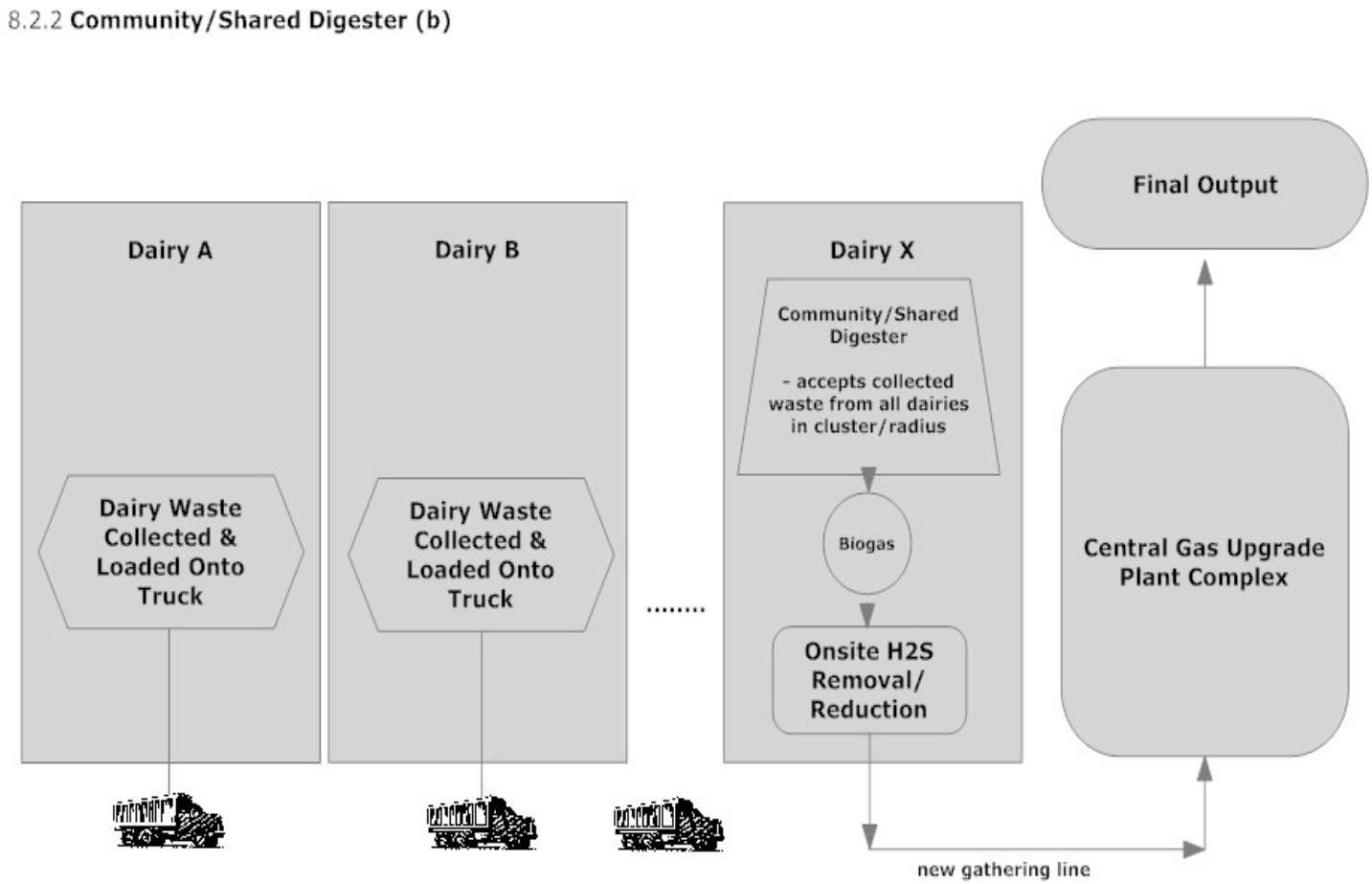
Figure 3 - Community/Shared Digester (a)



8.2.2 Community/Shared Digester (b)

Similar to the option above, this option makes use of pairing and/or grouping of dairies in close geographic proximity. These groups cooperatively share one AD system complex. The manure is delivered to this shared facility, loaded into the AD, and the output biogas has the H2S removed at this shared digester complex. Biogas, without H2S, is then sent via a gathering line to a central upgrade plant complex.

Figure 4 - Community/Shared Digester (b)



In these “Community/Shared Digester” scenarios, with more than one individual contributor, the obvious business complexities and permitting barriers increase. Having more than one contributor of dairy manure does improve the economies of scale. As the dairies in the area do not require the return of the solids for bedding the animals, more material will be available for sale to support the economics of the effort.

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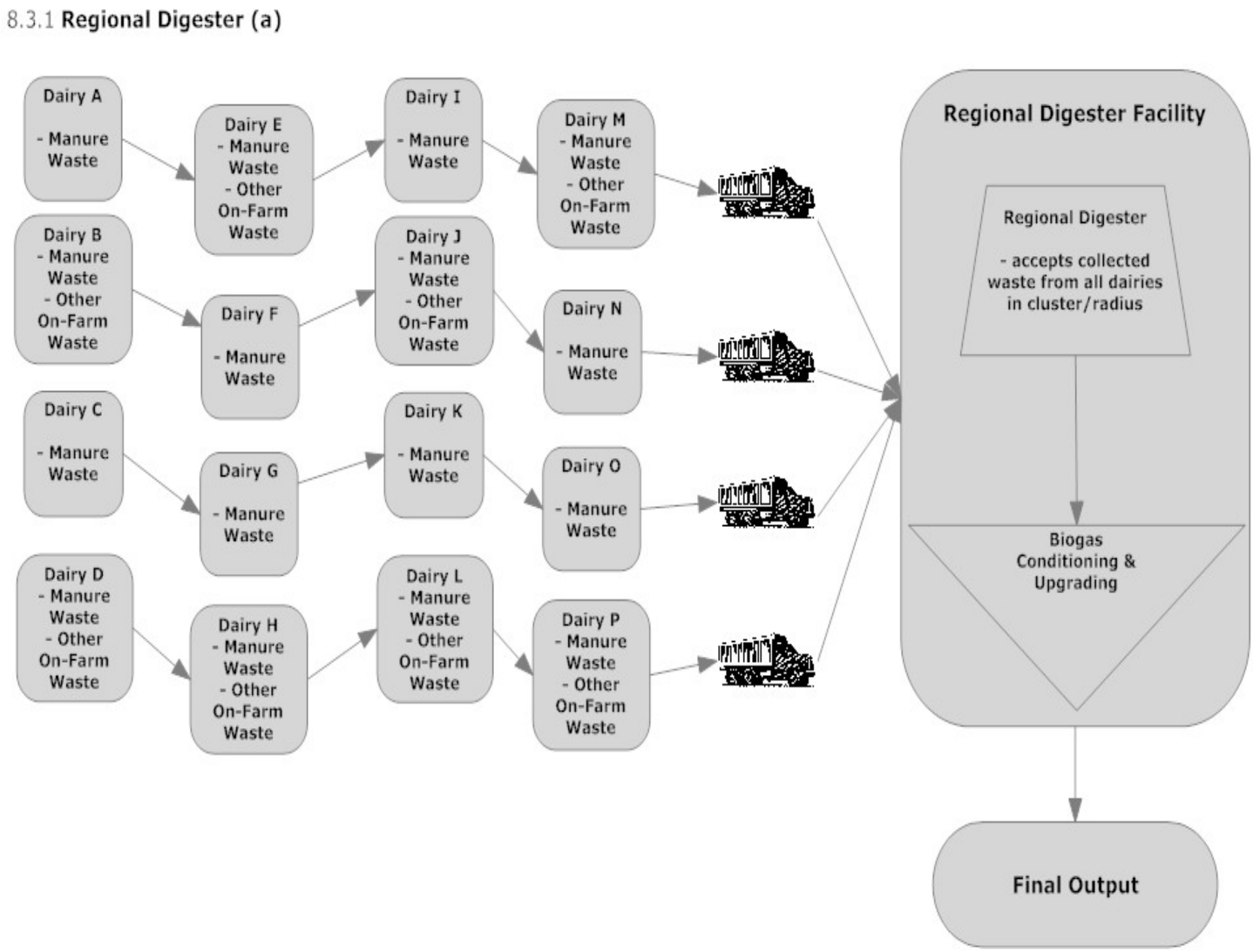
8.3 Regional Digester scenarios:

8.3.1 Regional Digester (a)

One digester complex set up to process farm manure as well as other on-farm wastes for digestion, and then optionally with (b):

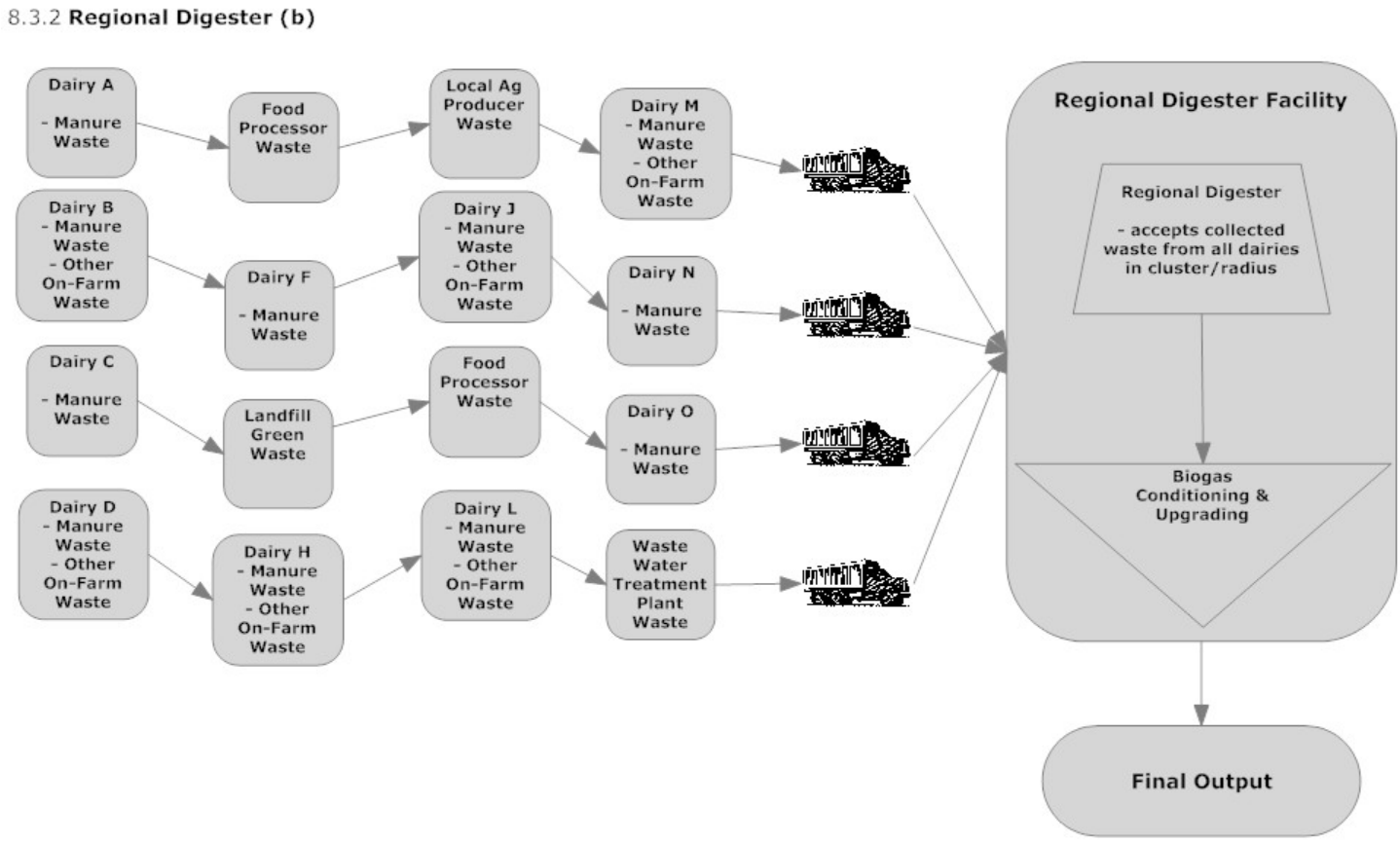
Figure 5 - Regional Digester (a)



8.3.2 Regional Digester (b)

One digester complex set up to process farm manure, on-farm wastes, and off-farm substrates considered for inclusion in the AD process stream.

Figure 6 - Regional Digester (b)



An interesting aggregation option is for the creation of one large capacity central digester complex using various current AD systems technologies. See Table 5 for the various technologies surveyed to support a regional system. The first scenario (8.3.1) relies only on dairy manure and on-farm eligible feedstock's being delivered by truck to one processing complex location. A complex of AD system digesters would process the manure into biogas, then upgrading to allow for further value added conversion to energy sales for revenue. One central location lends itself to leveraging economies of scale for gas upgrade and compression systems. Upgrading systems have not been historically cost effective for biogas volumes of those in the San Jacinto area, for individual or shared AD systems.

Another variation is to expand the feedstock base to include non-farm waste to increase biogas production and subsequent revenues. This biogas could be upgraded and processed for electrical, liquid or gas energy sales. A central upgrade complex option does requiring more sensitivity to finding a site. An ideal site is one that is convenient for feedstock(s) providers, has the land required for accommodating the circulation (truck traffic) delivery, storage and processing of materials; and has convenient utility access for the equipment and interconnection for potential energy sales.

A "Centralized Farm Renewable Energy Center" will eliminate the need and capital expenditures to create a biogas gathering line and the attendant issues and barriers. It is likely to lower the up-front capital commitment or investment per

individual dairy farm operation. Sharing the cost of a larger facility removes the challenges of organizing several shared digesters, but the business, organizational and operational structuring remains. Attracting investment and technology partners may be less challenging as the feedstock risks of one farm one digester or several small farms one digester are less of a concern. Having a larger number of dairies supplying an AD complex may be less disruptive operationally to existing dairies. Their on-farm practices may change in frequency, or interval, but not radically in nature. Initial participation by stakeholders does not need to be 100%, as in the other scenarios. As the goals of the IRDMP are being promoted with best management practices (BMP), each dairy chooses options that best fit its operational and financial disposition. Over time, the central complex is capable of being designed for adding dairies and other feedstock incrementally. Other options may require an “all-in” commitment to develop economic biogas production, collection and value added processing.

Delivery of energy output for sales as liquid fuel does not require pipelines or large compression capabilities, but does require additional processing capital equipment. CNG and pipeline delivery requires compression, but CNG does not require pipeline interconnection expense. Further study is needed to understand the best business, technical and financial options for the stakeholders in the area.

8.4 Technology Providers for Conceptual Round

The following technology providers were asked to participate in “conceptual round” presentations in order to help determine a best case for waste-to-energy options.

Table 4 - AD Technology Providers & Technologies Reviewed

Vendor Name	Technology Reviewed
Advanced Green Energy Solutions	Complete Mix Digester
American Anaerobic Digestion	Induced blanket anaerobic digester
Andgar Corporation	Complete Mix Digester
BioFERM Energy Systems	Dry fermentation digester
Biogas Energy	Complete Mix Digester
KTC Consultants	Civil Engineering
Energies Direct	Complete Mix Digesters
GHD, Inc.	Plug Flow Digester
New Bio E Systems	“Hybrid” Anaerobic Digesters
Onsite Power Systems	“Anaerobic Phased” Digesters
RCM International	Lagoon, Plug-Flow, Complete Mix Digesters

Schmack Bio-Energy	Complete Mix/Tank Digesters
Engineering Solutions	Civil Engineering
Provost & Pritchard	Civil Engineering
RBF Engineering	Civil Engineering
Acterra Group	Lagoon, Plug-Flow, Complete Mix Digesters
ADI Technologies	Submerged Anaerobic Digesters

These providers were asked to respond with not only details of the respective technology offerings, but were asked to provide conceptual solutions based on the various “conceptual option scenarios” described in sections 8.1 (On-Farm Unit Digestion For Biogas Energy Production Scenarios); section 8.2 (Community/Shared Digester Scenarios); section 8.3 (Regional Digester Scenarios). The technologies selected were based upon this authors experience with conversion technologies and suitability for the geographic area of possible installation. The numbers presented within represent very basic estimates for installations based upon the conceptual option models. Once the implementation and other hurdles are overcome, it is necessary to solicit more formal and complete information from the technology providers in order to fully align the waste-to-energy option to the stakeholder goal set.

The technologies selected for presentation in this document include:

- Complete Mix Tank Digester
- Dry Fermentation Digester
- Mixed Plug Flow Digester

Basic engineering diagrams for each of the technologies follow; these have been used with the permission of the creator and or believed to be allowed under the fair use laws and statues.

Figure 7 - Complete Mix Tank Digester – Basic Process Diagram

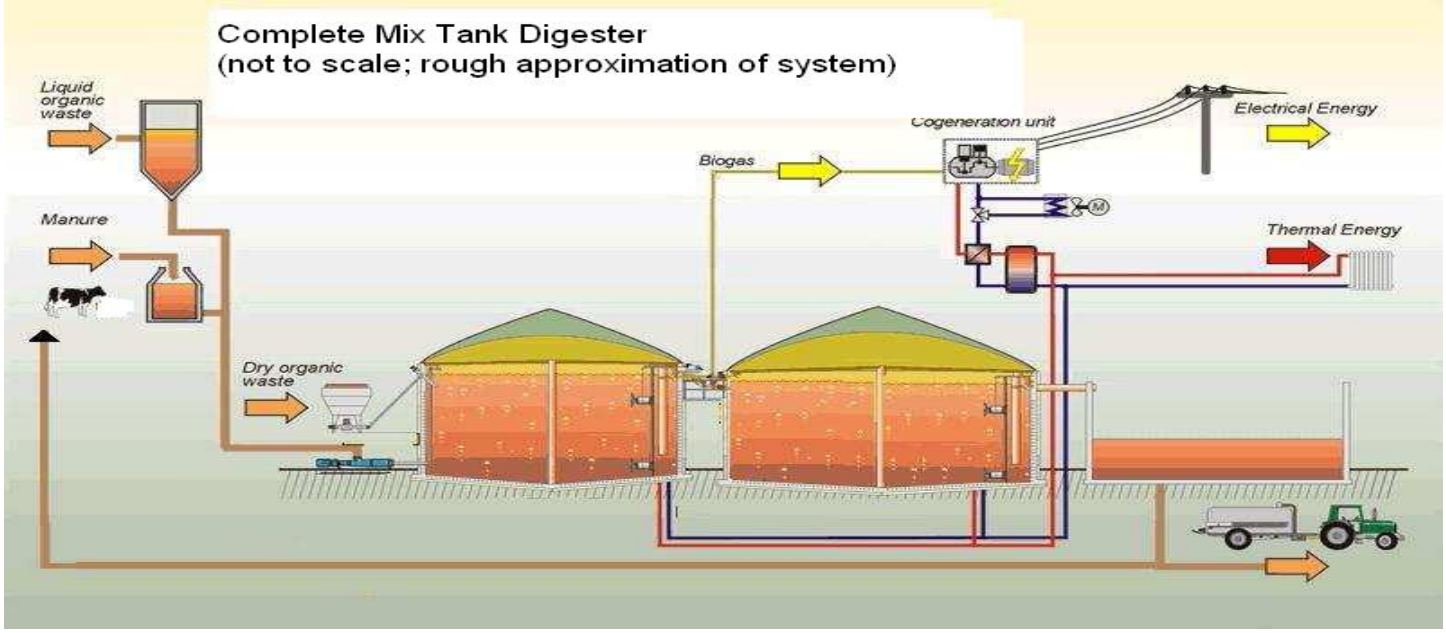


Figure 8 - Dry Fermentation Digester – Basic Process Diagram

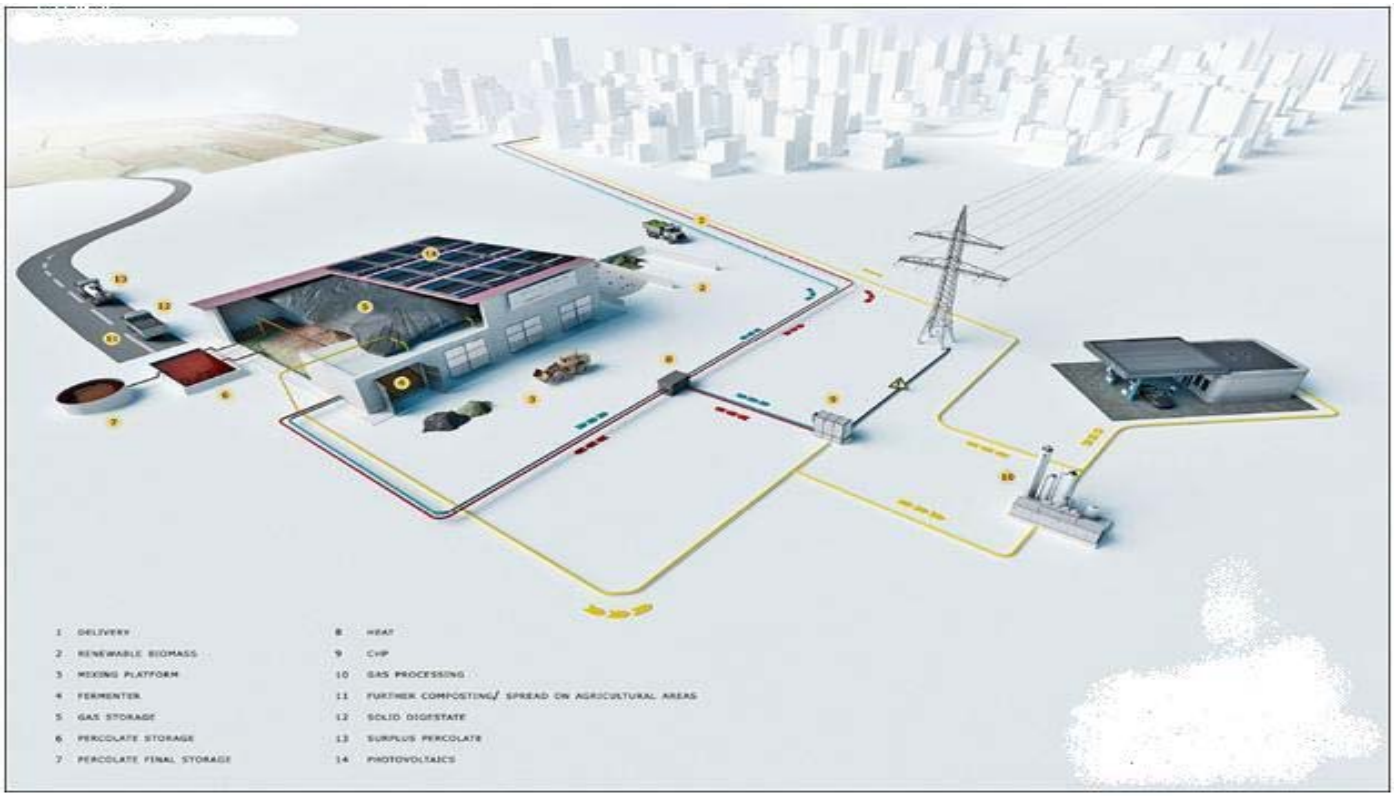


Figure 9 - Mixed Plug Flow Digester – Basic Process Diagram

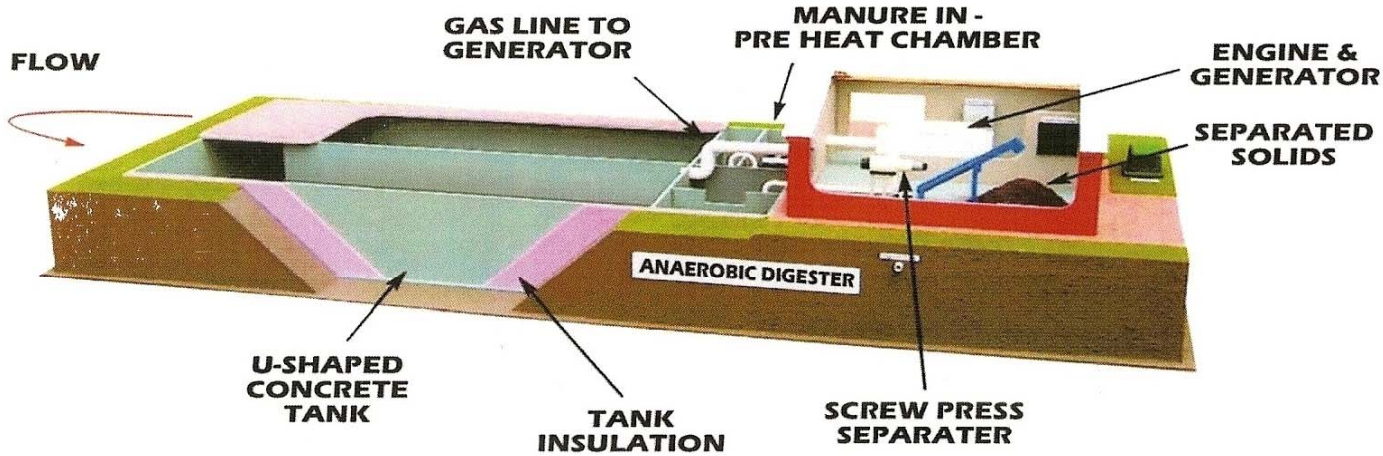


Table 5 - Digester Technologies Capital & Operating Expenses

Digester Technologies Capital Cost				
Capital Cost	**0-500 Milking**	**501-1000 Milking**	**1001-1500 Milking**	**1501-2500 Milking**
Complete Mix	$1,200,000.00	$ 1,500,000.00	$3,000,000.00	$ 5,600,000.00
Dry Fermentation	$2,651,933.70	$ 5,303,867.40	$7,955,801.10	$13,259,668.51
Mixed Plug Flow	$ 294,511.92	$ 589,023.85	$ 883,535.77	$ 1,472,559.61
Operating Cost	**0-500 Milking**	**501-1000 Milking**	**1001-1500 Milking**	**1501-2500 Milking**
Complete Mix	$ 24,000.00	$ 30,000.00	$ 60,000.00	$ 112,000.00
Dry Fermentation	$ 53,038.67	$ 106,077.35	$ 159,116.02	$ 265,193.37
Mixed Plug Flow	$ 5,890.24	$ 11,780.48	$ 17,670.72	$ 29,451.19
***note: The "Dry Fermentation" technology needs a minimum of 3000 cows for installation*				

9 Biogas Production Possibilities

Table 6 - SJ Basin/WRCAC Dairies Projected Maximum Biogas

San Jacinto Basin/WRCAC Dairies Projected Maximum Biogas mmBTU/day/Yr By Dairy Size			
# Milking Cows	**# Dairies**	**mmBTU Biogas/Day**	**mmBTU Biogas/yr**
0-500	1	16.67	6,002.10
501-1000	8	319.80	115,128.00
1001-1500	10	609.13	219,287.25
1500-2500	2	191.10	68,796.00
Total	**21**	**1,136.70**	**409,213.35**

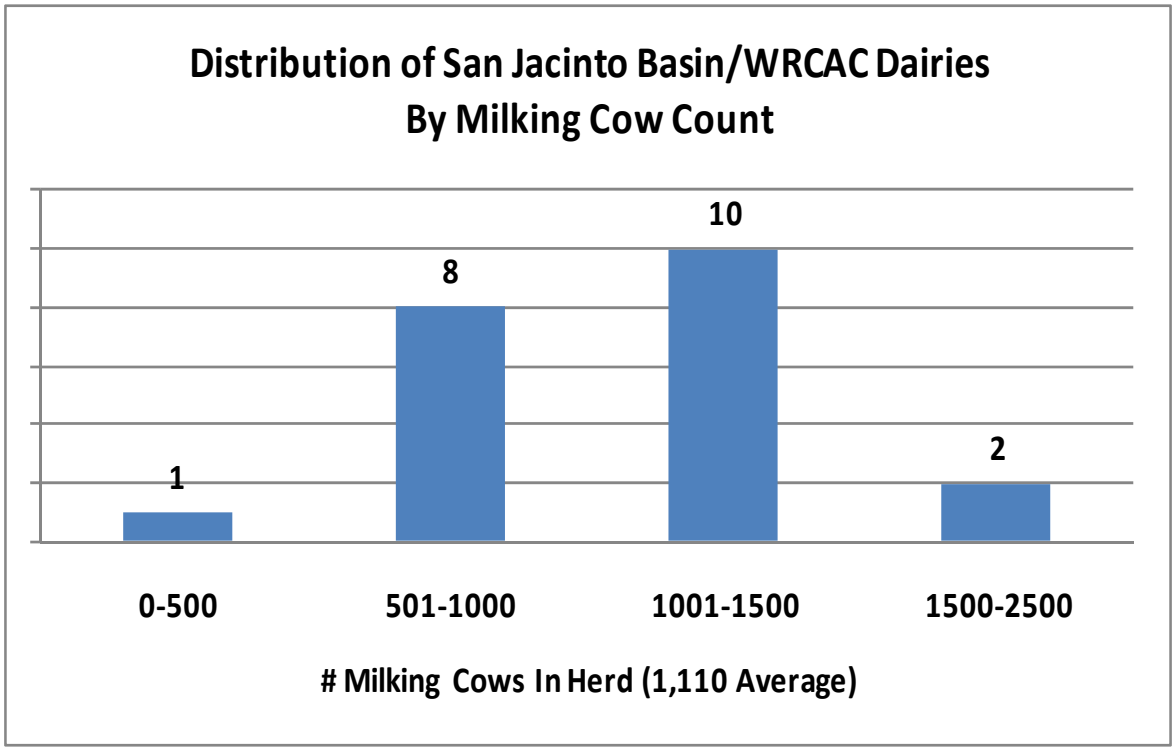
This is the “raw” biogas production projection.

Table 7 - SJ Basin/WRCAC Dairies Projected Maximum Biomethane

San Jacinto Basin/WRCAC Dairies Projected Maximum BioMethane mmBTU/day/Yr By Dairy Size			
# Milking Cows	**# Dairies**	**mmBTU BioMethane/Day**	**mmBTU BioMethane/Yr**
0-500	1	13.50	4,861.70
501-1000	8	259.04	93,253.68
1001-1500	10	493.40	177,622.67
1500-2500	2	154.79	55,724.76
Total	**21**	**920.73**	**331,462.81**

This is the projected production of a potential “finished” (i.e. has undergone the removal of impurities) Biomethane.

Graph 1 - San Jacinto Basin/WRCAC Dairies by Milking Cow Count



10 Creating a Budget for Building Waste-to-Energy Opportunities

The potential budgets available to create an energy to waste solution with any technology or system will likely consist of the funds currently being expended by stakeholders plus sales of the energy value, methane capture (carbon credits) and residual (compost) sales. The figures below were calculated from projections of a "Complete Mix" type of digester, operating at various production rates per day, based upon the type of feedstock being digested (65 SCF is low numbers of cows, manure only, 85 and 110 would be manure plus other feedstock such as other on-farm waste, green waste and/or biosolids from a waste water plant).

Table 8 - Projected Annual Revenues All Dairies in Region

Projected Annual Revenues For All Dairies In Region						
BioMethane - After Upgrade & 360 Day Production Cycle						
	Sales $4/mmBTU	**Sales $6/mmBTU**	**Sales $8/mmBTU**	**Sales $10/mmBTU**	**Sales $12/mmBTU**	**Sales $14/mmBTU**
65 SCF/Cow/Day	$1,149,071	$1,723,607	$2,298,142	$2,872,678	$3,447,213	$4,021,749
Carbon Credits	$111,172	$166,758	$222,344	$277,930	$333,516	$389,102
Compost/Solids	$992,689	$1,158,137	$13,231,585	$1,489,023	$1,654,481	$1,819,929
Projected Income	**$2,252,932**	**$3,048,502**	**$15,752,071**	**$4,639,631**	**$5,435,210**	**$6,230,780**
75 SCF/Cow/Day	$1,325,851	$1,988,777	$2,651,703	$3,314,628	$3,977,554	$4,640,479
Carbon Credits	$111,172	$166,758	$222,344	$277,930	$333,516	$389,102
Compost/Solids	$992,689	$1,158,137	$13,231,585	$1,489,023	$1,654,481	$1,819,929
Projected Income	**$2,429,712**	**$3,313,672**	**$16,105,632**	**$5,081,581**	**$5,965,551**	**$6,849,510**
85 SCF/Cow/Day	$1,502,631	$2,253,947	$3,005,263	$3,756,579	$4,507,894	$5,259,210
Carbon Credits	$111,172	$166,758	$222,344	$277,930	$333,516	$389,102
Compost/Solids	$992,689	$1,158,137	$13,231,585	$1,489,023	$1,654,481	$1,819,929
Projected Income	**$2,606,492**	**$3,578,842**	**$16,459,192**	**$5,523,532**	**$6,495,891**	**$7,468,241**
110 SCF/Cow/Day	$1,944,582	$2,916,873	$3,889,164	$4,861,455	$5,833,746	$6,806,036
Carbon Credits	$111,172	$166,758	$222,344	$277,930	$333,516	$389,102
Compost/Solids	$992,689	$1,158,137	$13,231,585	$1,489,023	$1,654,481	$1,819,929
Projected Income	**$3,048,443**	**$4,241,768**	**$17,343,093**	**$6,628,408**	**$7,821,743**	**$9,015,067**

The quantity of manure was considered as being processed in an AD system with several cases of gas productivity. While the unprocessed biogas is useful for direct heating in a boiler, there does not appear to be a ready and willing customer for the biogas for heating. The next step is to consider the biogas as being upgraded for sale as methane. This upgrade processing requires a capital expenditure to build a plant to separate out the methane, carbon dioxide and hydrogen sulfide. Once the gas is upgraded, the methane is thus concentrated and is able to be used for conversion to energy purposes. The methane could be used to create a CNG (Compressed Natural Gas) product for transportation fuels, injected into a natural gas pipeline, used in a fuel cell or used to create liquid fuels such as diesel. All of the value added steps requires additional capital expenditures in order to capture the additional values. Any waste-to-energy project will require the investment of the capital expenditures and operating expense to be deducted from the projected revenues. The expense of the digester(s) will also be deducted from the total budget for any project. In short, the potential project revenues are a function of the amount of material being processed and the efficiency of the digesters. The ownership and location and the cost of the digesters (conversion systems), upgrading plant and technologies are not being addressed in this review.

The example gross revenue projections budgets are based upon the assumption of using a complete mix heated digester(s). A range of price values of upgraded Biomethane sold per mmBTU of heating value are show in Table 8. This is presuming that the Biomethane, after the removal of impurities, will be of at least pipeline quality and grade, suitable for most other applications as well. The use of the gas in a CNG or fuel cell application may have higher value to the buyer-end user. This initial review will focus on a range of prices for pipeline quality Biomethane for illustration of the total project budgeting expectations. Typical assumptions have been made for the efficiency of the upgrade process up to the point prior to injection and pressurization to the pipeline pressures. The additional capital and operating cost of compression to the pipeline or for CNG use is not included in the review.

The possible budget to fund the effort for waste-to-energy options needs to be understood in terms of the cost to create the biogas and the cost to create a higher value energy product. The potential revenue opportunity for the sales of biogas and then Biomethane will require more research once there are agreed upon project goals amongst the stakeholders. Renewable biogas and Biomethane typically commands a premium over fossil fuels. Natural gas is now dramatically lower in price per mmBTU than one year ago as a result of new reserves being found. However, Biomethane is a storable green fuel and as such is more in demand than other renewable sources such as wind or solar. The demand for more renewable fuel is increasing, as the goals set for utilities require more renewable fuels and the percentage mix of Biomethane is likely to increase. The use of Biomethane from waste also is preferred because of the methane capture and carbon credit benefits to the environment. A range of values from $1,149,071 to $6,806,036 dollars is shown in the table of gross potential project revenues. From the gross revenues the entire capital infrastructure to produce the gas needs to be deducted to determine the net values to the stakeholders. The true potential of a project can be understood once potential gross revenues are postulated. The next step is to determine the exact goals of the stakeholders for a project and then to design a cost effect and efficient system to create the waste-to-energy plant(s). The likely costs of digesters are shown in Tables 9, including projected cost with potential subsidies/grants/loans, in terms of cost per cow and energy units (mmBTU).

Table 9 - Digester Costs Per mmBTU/Biomethane produced By Milking Cow

Complete Mix Digester Cost Per mmBTU/BioMethane By Milking Cow Simple 20 Yr Amortized Cost				
(before subsidies/grants/loans)				
# Milking Cows	**65 SCF Cow/Day**	**75 SCF Cow/Day**	**85 SCF Cow/Day**	**110 SCF Cow/Day**
0-500	$17.09	$14.81	$13.07	$10.10
501-1000	$8.86	$7.68	$6.78	$5.24
1001-1500	$10.74	$9.31	$8.21	$6.35
1500-2500	$12.15	$10.53	$9.29	$7.18

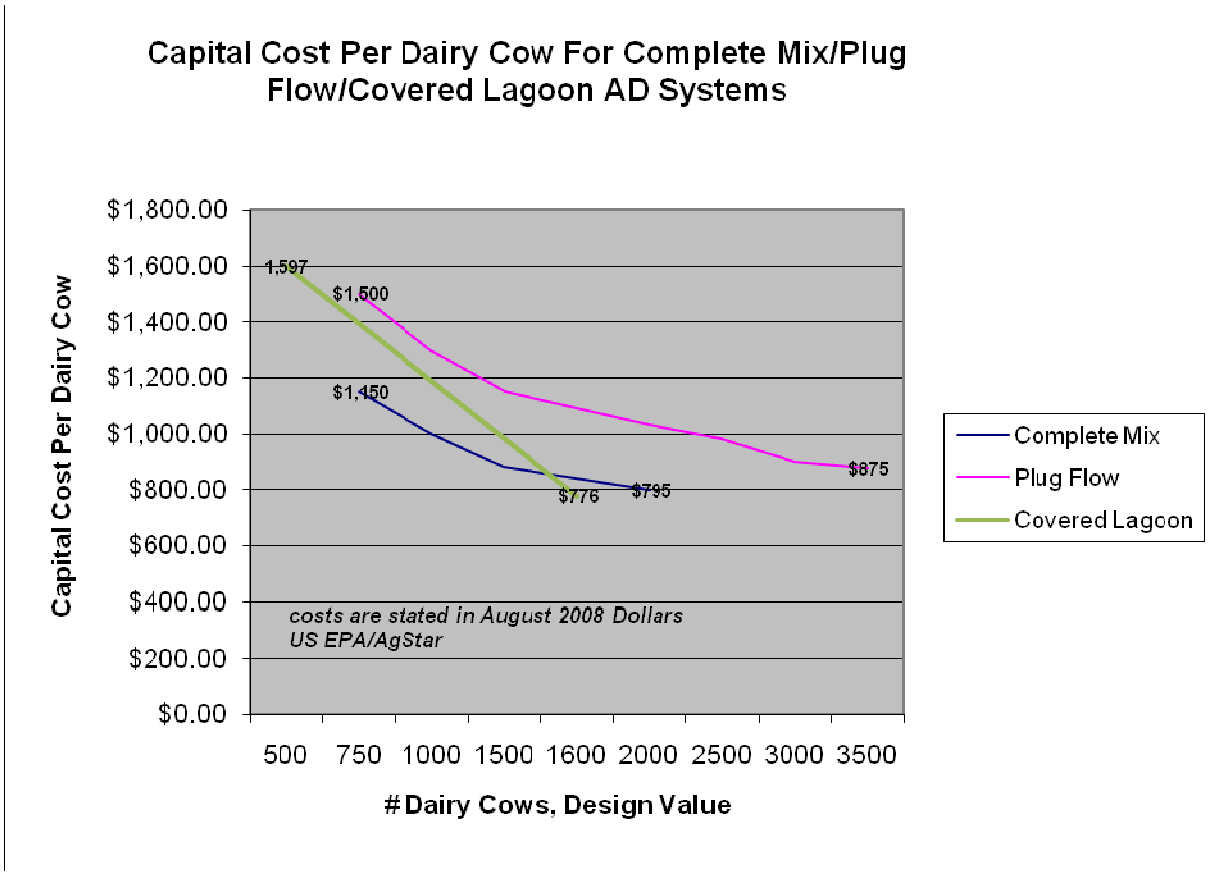
As the value of the sales revenues are aimed at supporting the goals of the IRDMP, it is hoped that each revenue source can be maximized.

Conceptually organizing the project brings a few hurdles and challenges to the forefront of the discussion. One of the first challenges is how to create inexpensive biogas; on individual farms or collectively. Second how to collect and or process the biogas. The third (upgrade process) is how to deliver biogas and or Biomethane to the market for the best energy values. What are the economic budgetary capital constraints for each element of any individual or collective system or

effort? These questions can be resolved once the stakeholders have agreed upon the exact goals and objectives of any effort. Initial concerns and risks about any waste-to-energy project will need to be addressed by the stakeholders.

In general the individual on farm AD system to convert daily manure volumes into biogas is operationally possible. Building and installing a digester on each dairy in the basin is likely to be cost prohibitive. It is expected to be very expensive, regardless of the type of AD system. The capital required to build one digester (see Graph 2)

Graph 2 - Cost Per Dairy Cow/Digester (from AgSTAR 2008)



does not scale down well for smaller herd sizes. In our reviews an engineering and economic challenge exists to create a low cost effective system for individual farms with less than 1,500 to 2,000 cows at this time. The economic cost per cow target expenditure needs to be identified. It is unlikely that discrete systems at individual farm systems in the basin are going to be economical at this time. It is suggested by the basic economics and business proposition that communal/group and or a regional digester would be the most likely organizational structure to effectively meet the goals of having the manure solids digested and thus the volumes reduced. Typically the manure is about 8% total solids and of that about 85% is volatile solids and thus a reduction in solids volume of about one-third is possible. Locating the system for waste processing at one or more digesters in the basin would likely be a more useful means of biogas creation. Developing a staged plan for creating a series of AD systems in one place or spread throughout the basin may allow for easier access for stakeholders to participate.

The capital costs are very large but with subsidy and community support the effort has a better chance to succeed. Grants, aids, subsidies and low interest loans are available from state organizations:

The California Energy Commission will fund up to 50% of the cost of an installation under its grant/solicitation "Alternative and Renewable Fuel and Vehicle Technology Program - Solicitation Number - PON-09-003 – Biomethane Production" - http://www.energy.ca.gov/contracts/PON-09-003/.

In addition, the United States Department of Treasury will fund up to 30% of the cost of an installation under its grand/incentives for "Renewable Energy" - http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US53F&re=1&ee=0

There are many sources for funding available; the Environmental Protection Agency (EPA) has a fairly complete resource page located at: http://www.epa.gov/region09/ag/dairy/funding.html.

Utilizing these as well as other available reductions in the capital expenditure with a long term contract for the biogas and or Biomethane production would likely be economically viable.

Table 10 Complete Mix Digester - 65 SCF - Costs W/Subsidies

Complete Mix Digester 65 SCF Production Level Cost Per mmBTU/BioMethane By Milking Cow Simple 20 Yr Amortized Cost				
(with subsidies/grants/loans)				
# Milking Cows	**No Subsidy**	**25% Subsidy**	**50% Subsidy**	**80% Subsidy**
0-500	$17.09	$13.53	$9.97	$5.70
501-1000	$8.86	$6.95	$5.04	$2.75
1001-1500	$10.74	$8.25	$5.77	$2.78
1500-2500	$12.15	$9.24	$6.33	$2.83

Table 11 - Complete Mix Digester - 75 SCF - Costs W/Subsidies

Complete Mix Digester 75 SCF Production Level Cost Per mmBTU/BioMethane By Milking Cow Simple 20 Yr Amortized Cost				
(with subsidies/grants/loans)				
# Milking Cows	**No Subsidy**	**25% Subsidy**	**50% Subsidy**	**80% Subsidy**
0-500	$14.81	$11.72	$8.64	$4.94
501-1000	$7.68	$6.03	$4.37	$2.38
1001-1500	$9.31	$7.15	$5.00	$2.41
1500-2500	$10.53	$8.01	$5.48	$2.45

Table 12 – Complete Mix Digester - 85 SCF - Costs W/Subsidies

Complete Mix Digester 85 SCF Production Level Cost Per mmBTU/BioMethane By Milking Cow				
(with subsidies/grants/loans)				
# Milking Cows	**No Subsidy**	**25% Subsidy**	**50% Subsidy**	**80% Subsidy**
0-500	$13.07	$10.34	$7.62	$4.36
501-1000	$6.78	$5.32	$3.86	$2.10
1001-1500	$8.21	$6.31	$4.41	$2.13
1500-2500	$9.29	$7.07	$4.84	$2.16

Table 13 - Complete Mix Digester - 110 SCF - Costs W/Subsidies

Complete Mix Digester 110 SCF Production Level Cost Per mmBTU/BioMethane By Milking Cow Simple 20 Yr Amortized Cost				
(with subsidies/grants/loans)				
# Milking Cows	**No Subsidy**	**25% Subsidy**	**50% Subsidy**	**80% Subsidy**
0-500	$5.96	$4.68	$3.39	$1.85
501-1000	$5.24	$4.11	$2.98	$1.63
1001-1500	$6.35	$4.88	$3.41	$1.65
1500-2500	$7.18	$5.46	$3.74	$2.16

11 Conclusion

In conclusion, the Waste Revenue Path Technology and Options for Dairies in the San Jacinto Watershed are now better understood with the potential sources of funding through energy sales, etc. The feasibility of a specific technology or vendor selection is the next step. In general, the types and kinds of systems are affordable only once the gross potential energy values are understood. Of course the cost(s) allocation of project elements and operational structures will need to be resolved before any group effort proceeds. Under the" Biogas Production Incentive Act of 2009," producers would receive a tax credit of $4.27 for every mmBTU – providing yet another monetary incentive to support implementing these technologies. Working together, the energy content and value of the waste stream can be monetized to pay for the technology selected.

The next important steps in the project are:

- Organize the waste-to-energy early adopters in the basin and begin to formalize the goals and objectives.
- Build upon the information presented with interested stakeholders and attract additional local and regional support for a waste-to-energy effort using the dairy manure as a key feedstock.
- Research additional feedstock opportunity to blend in with dairy manure.
- Perform a formal potential feedstock radius survey.
- Do preliminary business case analysis for specific dairy farm(s) for locating and sizing a digester.
- Develop additional feedstock opportunity relationships in order to create preliminary designs and economic models.
- Identify a step a by step plan to start an initial digester and collection effort that is then capable of expanding to support the local feedstock of manure and then what is being currently imported and with a view to accommodate other feedstock.
- Seek to partner entities that are already permitted waste handling facilities to expedite either pilot or scale operations for waste-to-energy efforts.
- Develop relationships with energy, carbon credit and compost buyers for likely off take agreement(s).
- Size a viable project, identify funding and begin preliminary engineering effort.
- Apply lessons and experience from other shared waste-to-energy efforts to any cooperative(s) in the San Jacinto area.

12 Appendix – Glossary

Ambient - outside air temperature. It is used in conjunction with an unheated, anaerobic digester.

Anaerobic –in the absence of oxygen microbe's breakdown organic material (i.e., animal manure).

Anaerobic Bacteria – microbes whose metabolisms require the absence of oxygen to survive.

Anaerobic Digestion – the breakdown of animal manure and other organic material in the absence of oxygen, (methane producing bacteria are most active in two temperature ranges, 95 to 105°F and 130 to 135°F. This is a living system and must be treated as such. The organic material is decomposed by acid formers into fatty acids and then into biogas by methane formers or methanogens.

Biofibers – the solid material separated from the effluent stream after treatment by an anaerobic digester. This is the solid material that could not be volatilized into biogas.

Biogas – the gas produced from decomposition of livestock manure in an anaerobic digester consisting of 60-80 percent methane, 30-40 percent carbon dioxide, and other trace gases such as hydrogen sulfide, ammonia and hydrogen.

Biomethane – biogas which has been processed/upgraded to be pipeline quality methane.

BOD (Biochemical Oxygen Demand) – a qualitative measurement indicating how fast biological organisms use up oxygen in a water body. It is an indication of the availability of nutrients and food in the water.

Complete Mix Digester - a tank designed above or below ground as part of a manure management system to handle manure containing 2-10 percent solids. The digester is heated and mixed mechanically or with gas-mixing systems to keep the solids suspended. This maximizes biological activity for destruction of volatile solids, methane production, and odor reduction.

Covered Lagoon Digester – a typical anaerobic lagoon is commonly used when manure has less than 2 percent solids. Decomposition of the manure occurs, methane is produced, and effluent odor is reduced. The lagoon is covered with a gas-tight cover to capture the biogas.

Digester – a sealed container or tank, where the biological digestion can occur of animal manure and biogas formed.

Effluent – organic liquid and solid material (slurry) leaving a digester.

Feedstock – liquid and solid material fed to the digester, usually manure and other organic material, also known as influent.

Fixed Film Digester – a tank designed as part of a manure management system to handle manure up to 3 percent solids. The digester is temperature controlled and a media is placed inside the digester. This design allows the microbial populations to attach to the media and grow as a biofilm (fixed film), thus preventing the microbes from being removed with the effluent.

Hydraulic Retention Time (HRT) – the average length of time the liquid influent remains in the digester for treatment.

Influent – liquid and solid material fed to the digester, usually manure.

Induction Generator – this type of generator operates in parallel with the utility for its phase, frequency and voltage and cannot operate in isolation (stand alone) -- in other words, it cannot operate without the power company.

Loading Rate – the total amount of solids and liquids fed to the digester daily.

Mesophilic – the temperature range of 95 to 105°F in which methanogenic microbes thrive.

Methane – a combustible gas produced by anaerobic digestion; also the principal component of natural gas.

Methanogens – methane producing microbes.

Micro turbine – a small-scale gas turbine generation system to combust gas and generate electricity.

Net Metering – an agreement with the utility company to purchase the electricity produced by the digester system at a rate equal to the farm electricity purchase rate.

Psychrophilic – less than 68°F.

Plug-Flow Digester – a tank designed for a manure management system which handles organic material containing 11-14 percent solids. The digester is given daily influent plugs that flow through the digester. The digester is heated. This helps with the destruction of volatile solids, methane production and odor reduction.

Settled Solids – the separated manure solids which settle to the bottom of the digester.

Slurry – the mixture of solids and water processed in the digester.

Synchronous Generator – this type of generator can operate in parallel with the utility or operate in isolation from the power company (stand alone). This generator does not need the utility voltage to create electricity; the machine is self excited. Generally, more expensive utility breaker controls are required.

Temperature-Phased Anaerobic Digester (TPAD) – two tanks designed as part of a residuals management system. The digesters are heated, the first digester in the thermophilic temperature range and the second digester in the mesophilic temperature range. This will maximize biological activity for the destruction of volatile solids, methane production and odor reduction.

Thermophilic – temperature range of 125 to 135°F where certain methanogenic bacteria are most active, the greatest pathogen destruction occurs in this temperature range.

Total Dissolved Solids (TDS) – the volume of solid material that cannot be filtered out.

Total Suspended Solids (TSS) - the volume of solid material that can be filtered out.

Toxicant – a component in manure or some other feedstock causing an adverse effect on bacterial metabolism.

Volatile Acids – these are present in the feedstock's and also produced in the digester by acid-forming bacteria and then used by the methane-forming bacteria to produce methane.

Volatile Solids – the organic matter which can be converted to gas.

13 Appendix – Calculation Notes

The following general formulas were used for computational purposes as to the data presented in this section:

Manure Production

Daily Manure Production (tons) = (# Cows * 125)/2000

Yearly Manure Production (tons) = Daily Manure Production * 360

Daily Biogas Production Potential

SCFD = # Cows * 65 (or 75 or 85 or 100)

SCFM = SCFD/1440

mmBTU biogas daily = (SCFD * 650)/1000000

mmBTU biogas Yearly = ((SCFD * 650)/100000) * 360

(This presumes that "biogas" is 65% methane)

Calculating Cost Per mmBTU

mmBTU biogas daily = mmBTU biogas Yearly / 360

90% BIOMETHANE Yield from BioGas = mmBTU biogas daily * .9

10% loss in final upgrade production = 90% BIOMETHANE Yield from BioGas * .1

BIOMETHANE per Day Yield = 90% BIOMETHANE Yield from BioGas - 10% loss in final upgrade production

Potential Biomethane mmBTU/yr = BIOMETHANE per Day Yield * 360

14 Appendix – COD Lab Analysis

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Account:
1234
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Midwest Laboratories, Inc.
13611 B Street • Omaha, Nebraska 68144-3693 • (402) 334-7770 • FAX (402) 334-9121 • www.midwestlabs.com

Date Reported:
12/17/09
Date Received:
12/09/09
Date Sampled:
12/07/09

SEAHOLD LLC

23551 ROSE QUARTZ DR
PERRIS CA 92570

PO/Project #: SEAHOLD-WRCAC-1207

Analysis Performed	As Received	Units	Detection Limit	Method	Analyst Date	Verifier Date
Lab number: 1658583 Sample ID: SEAHOLD-1						
Chemical oxygen demand	124,602	mg/kg	5000	EPA 410.4(MO	dmg/12-14	cmw/12-15
Lab number: 1658584 Sample ID: SEAHOLD-2						
Chemical oxygen demand	109,543	mg/kg	5000	EPA 410.4(MO	dmg/12-14	cmw/12-15
Lab number: 1658585 Sample ID: SEAHOLD-3						
Chemical oxygen demand	103,358	mg/kg	5000	EPA 410.4(MO	dmg/12-14	cmw/12-15

For questions contact
Heather Ramig
Client Service Representative
heather@midwestlabs.com (402)829-9891

The result(s) issued on this report only reflect the analysis of the sample(s) submitted. For applicable test parameters, Midwest Laboratories is in compliance with NELAC requirements.
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15 Appendix – BMP Lab Sample

(The following is a sample of the BMP lab analysis report that is utilized, and will be replaced with the final report once it is received from the lab)

Waste Biomass Anaerobic Digestion Biogas Potential in Support of Renewable Energy Development

ADREC

MICHIGAN STATE UNIVERSITY

BAE

Department of Biosystems and Agricultural Engineering

MSU Breakfast Waste
East Lansing, MI

Submitted to Biosystems and Agricultural Engineering

Date Sample Collected: January 26, 2009
Date Assay Conducted: February 23 – March 20, 2009

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