Title

GROUNDWATER RECHARGE POTENTIAL USING SECONDARY TREATED WASTEWATER: METHODS AND CASE STUDY IN THE SOUTHERN SAN JOAQUIN VALLEY, CALIFORNIA

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GROUNDWATER RECHARGE POTENTIAL USING SECONDARY TREATED WASTEWATER: METHODS AND CASE STUDY IN THE SOUTHERN SAN JOAQUIN VALLEY, CALIFORNIA

A dissertation submitted in partial satisfaction of the requirements
for the degree Doctor of Philosophy

in

Environmental Systems

by

Diganta D. Adhikari

Committee:
Professor Thomas C. Harmon, Chair
Professor Teamrat A. Ghezzehei
Professor Qinghua Guo
Professor David F. Zoldoske

2016

The Dissertation of Diganta D. Adhikari is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Teamrat A. Ghezzehei

Qinghua Guo

David F. Zoldoske

Thomas C. Harmon Chair

University of California, Merced

2016

DEDICATION

I dedicate this dissertation to all the countless people in my life without whom this dream of completing the PhD study could not have been possible. This dissertation is especially dedicated to my wife Anamika Barman-Adhikari who encouraged me to embark on this path, offered me the opportune encouragement, and ensured I had ample time to work on it, while she managed our three year old all by herself.

I would like to offer my sincere gratitude and thanks to my parents, Dhirendra Deb Adhikari and Reena Devi Adhikari, who instilled in us from a very young age the importance of education in life. They made innumerable personal sacrifices so we could have a better education and future.

Last, but not the least, this dissertation would not have been possible without our daughter Aahana Barman Adhikari. I wanted to prove it to her that it’s very important to finish what you start, and that there is no substitute to getting a higher education.

ABSTRACT

Water scarcity in a period of climate uncertainty necessitates exploring new avenues for recharging depleted groundwater. The Western United States, including the agriculturally rich San Joaquin Valley (SJV), is highly dependent on winter precipitation and accumulated snow pack to refill reservoirs for use during peak summer agricultural operations. However, severe weather patterns (such as the current drought) have drastically reduced both the amount and longevity of the snow pack resulting in the over-drafting of groundwater. This study investigated the potential for managed aquifer recharge (MAR) using secondary treated wastewater. The approach employs an infiltration basin water balance (WB), soil columns (SC) infiltration tests, subsurface simulations (Hydrus modeling), and geographic soil survey data (NRCS SSURGO) for regional upscaling. We address the following key questions: i) Is there a correlation between a field-scale water balance and a soil column study? ii) What portion of applied wastewater effluent leads to recharge?, and iii) What is the overall potential of MAR to supplement regional recharge, using the southern SJV as a case study? For the soils of the southern SJV, there were strong correlations between soil column study and water balance approach (Slope=0.75 and Intercept=22.35 with r^2=0.99). A WB method showed that basin infiltration rates dropped from 125.2 mm/day on day 7 to 40.6 mm/day on day 330. Given these infiltration rates, we estimated that 225-1220 hectares of land will be required to successfully dispose of 0.5-0.6 million m^3/day of wastewater (generated from the four regional waste water treatment facility in southern SJV). Hydrus 2D simulation package also successfully modeled field measurements of water content and the observed water balance percentage with recharge rates were 9.7-68.9 mm/day depending on area, soil type, and duration of use of the reclamation basin. Utilizing NRCS SSURGO data, recharge rate, and volume of wastewater, it is estimated that 5.8-42.2 % of the incoming wastewater could contribute to recharge if directed at all the candidate infiltration zones. California overdrafts approximately 2 million acre feet of groundwater annually, this associated regional MAR in SJV would reduce that volume by approximately 0.8-2.5%. It is important to add, however, that health concerns associated with reclaimed wastewater remain and need to be addressed before this approach can be fully embraced.

ACKNOWLEDGEMENTS

Funding and support for this work was provided by Center for Information Technology Research in the Interest of Society (CITRIS) and by City of Fresno Regional Wastewater Reclamation Facility (RWRF), which is gratefully acknowledged.

Firstly, I would like to express my sincere gratitude to my advising professors, Thomas C. Harmon (Chair and Supervisor), Teamrat A. Ghezzehei, Qinghua Guo, and David F. Zoldoske for their invaluable feedback, guidance for the continuous support of my Ph.D. study and related research, and for their patience, motivation, and immense knowledge.

I would also like to thank Alex Orozco, Christopher Butler, Jacob Moreno, and Patrick Barnes for their assistance at City of Fresno (RWRF), where this research was conducted.

Besides my advisor and my colleagues, I would like to thank Rosa Lau-Stagg, Steve Hoggs, Luis Garcia, Mark Banuelos, and David Furtado at the City of Fresno RWRF for their continued support.

Last but not the least, I would like to thank my family: my wife Anamika Barman-Adhikari, daughter Aahana Barman Adhikari, parents Dhirendra D. Adhikari, and Reena Devi Adhikari for supporting me whole heartedly throughout this process.

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EDUCATION

2008-expected 2016	PhD	Environmental Systems, ***with emphasis on instrumentation and control for modeling*** University of California, Merced School of Engineering Merced, California. **PhD Candidate.**
2006-2008	MS	Industrial Technology, ***with emphasis on process control and automated systems*** California State University, Fresno Department of Industrial Technology Fresno, California.
2002-2004	MS	Computer Science, ***with emphasis on encoding algorithm and embedded systems programming*** California State University, Fresno Department of Computer Science Fresno, California.
1994-2000	BS	Computer Science and Engineering North Eastern Regional Institute of Science & Technology, Itanagar, India.

DISSERTATION:

Dissertation Title: "GROUNDWATER RECHARGE POTENTIAL USING SECONDARY TREATED WASTEWATER: METHODS AND CASE STUDY IN THE SOUTHERN SAN JOAQUIN VALLEY, CALIFORNIA"

Using a wide array of advanced instrumentation & control system on telemetry, this study attempts to quantify groundwater recharge using secondary treated water which is otherwise considered grey water and not considered a source for groundwater recharge. Most municipalities with over half a million population generate about fifty million gallons of secondary treated water on a daily basis. This water is normally left to evaporate in an unlined ponding basin with least amount of attention to recharge. However, these unlined evaporation ponds lead to percolation of this water to the ground. The purpose of this study is to quantify the regional and statewide implications of groundwater recharge using such quality of water.

PROFESSIONAL APPOINTMENTS

2015-present: Director of Engineering, Irrometer Company Inc. Work responsibilities include new product development and engineering; research and development; support Irrometer research and validation with third party entities like Universities; and grant and contracts.

2014-2015: Product Engineer, Irrometer Company Inc. Work responsibilities include new product development and engineering support.

2011-2014: Research Scientist, Center for Irrigation Technology (CIT) /California Water Institute (CWI)/International Center for Water Technology (ICWT) , California State University, Fresno. Work responsibilities focus on research projects and regulations related to water conservation; air quality monitoring; land reclamation; and emerging green products testing and evaluation.

✓ **Crop Evapotranspiration (ET) and Satellite management project.** *Funding from NASA ROSES I & II and CSU Agricultural Research Initiative.*

- Collaborator, automation specialist, micrometeorological specialist, and system designer.
- Designed and deployed the control system for weighing lysimeters to measure plant ET.
- Develop in-house standards and procedures for calibrating various environmental sensors.
- Work with other agencies and growers to coordinate effort.

✓ **Nitrogen Dynamics and groundwater project: Measuring and Monitoring Nitrogen Dynamics in Central Valley Crops to prevent leaching of Nitrogen to groundwater.** *Funding from California Department of Water Resources (DWR) Prop 50 grant and CSU Agricultural Research Initiative.*

- Principal investigator, chief architect, and system designer.
- Investigate groundwater regulations; water quality standards; and plant nutrient requirements and schedule.
- Design, build, instrument, and troubleshoot a field scale system using spectrometer and lysimeters to quantity nitrogen fluxes in the soil to optimize nitrogen inputs to plants and prevent leaching of nitrogen to groundwater.
- Integrated micro-loggers, PLC's, wireless network, sensors, and spectrolyzers into the system for feedback loop and control.

✓ **Groundwater monitoring project: Groundwater monitoring, solute transport and remediation work for the winery stillage disposal sites at Fresno-Clovis Regional Wastewater Treatment Facility.** *Funding from University of California Center for Information Technology Research in the Interest of Society (CITRIS) and CSU Agricultural Research Initiative.*

- Design Vadose zone monitoring plan as required for compliance with the " Monitoring and Reporting Program", ordered by the California Regional Water Quality Control Board (CRWQCB).

✓ **Particulate Matter (PM) air quality project: Monitoring mitigation of particulate matter, fungal spores, pollen and organic compounds in fugitive dust during agricultural field operations.** *Funding San Joaquin Valley Pollution Control District, US Department of Agriculture (USDA) and CSU Agricultural Research Initiative.*

- Principal architect, co-principal investigator, automation specialist, database manager, and system designer.
- Investigate air quality standards and emission rates from various agricultural field operations.
- Develop specification and standards for automated system for procurement and programming of microloggers, PLC, and HMI.

- Integrated micro-loggers ,PLC's, Variable Frequency Drive (VFD) controllers with BGI Wright Dust Feeder, BGI PM Samplers(2.5 and 10) ,Optical Particle Seizer and Forward Looking Infrared (FLIR) camera for totally autonomous test setup and logging of all test run environment.

✓ **Particulate Matter (PM) air quality project: Emissions during Raisin Harvesting Operations and Landscape Maintenance Operation.** *Funding San Joaquin Valley Pollution Control District, Jordan College of Agricultural Science and Technologies, and CSU Agricultural Research Initiative.*

- Co-principal investigator, database manager , and system designer
- Developed testing protocol for various PM and TSP air samplers.
- Developed in house testing and QA&QC protocol for all field instruments and sensors.

✓ **Greenhouse gas project: Using elevated levels of carbon dioxide to enhance crop production.** *Funding CSU Agricultural Research Initiative.*

- Chief architect for automatic sampling systems.
- Developed testing protocol for sampling ambient and elevated levels of CO2.

✓ **Other projects: Other miscellaneous projects.** *Funding from State, Federal and private companies*

- Serve as a technical expert for ASABE and EPA to develop standards for the WaterSense labeling protocol for Evapotranspiration (ET) and Soil Moisture Sensor (SMS) based irrigation controllers.
- Designed, built, and troubleshoot SCADA system for: Freeze Prevention based Irrigation Controller, Real-time water quality measurement and flow control systems.
- Develop a control system for Variable Rate Irrigation (VRI) for a center pivot manufacturer.
- Integrate engine dynamometer and air quality instruments to quantify the effect on greenhouse gases from different blends of biofuels for small engines.
- Setup, design, and maintain field trials for efficacy of commercially available environmental product for validation.
- Supervise graduate students working on various research projects as part of their course work.
- Research Grant writing.

2008-2011: Faculty, Department of Industrial Technology, California State University, Fresno. Work responsibilities included:

- Teach courses related to basic electronics automation, control, robotics, and AUTOCAD.
- Research Grant writing.

2004-2008: Research Database Analyst, Center for Irrigation Technology (CIT), California State University, Fresno. Worked on various projects relating to air, water and soils, funded by State, Federal and private dollars. Work responsibilities included:

2001-2004: Graduate Student Assistant, Center for Irrigation Technology (CIT), CSU Fresno on various projects including field work at various projects sites in San Joaquin valley, Mendota and Oxnard, supervised other student help and lab work.

FUNDED PROJECTS

- CSU ARI-Project. Measuring and Monitoring Nitrogen Dynamics in Central Valley Crops. Funding **$225,000** (3 Year).
- California Department of Water Resources (DWR) Prop 50 grant. Distributed Sensor Network Based Optimization of Agricultural Practices to Assess Nutrient Dynamics and Limit Nitrogen Losses. Funding **$193,931** (3 Year).
- NASA ROSES I & II -NNH11ZDA001N-WATER: Mitigation of Drought Impacts on Agriculture through Satellite Irrigation Monitoring and Management Support. Funding **$1,346,500** (3 Year).
- USDA FAS. Agricultural Development for Afghanistan Pre-Deployment Training (ADAPT). Funding $**2,900,000** (2 Years)
- CSU ARI-Project. Surface Renewal Evapotranspiration (ET) Estimate under saline conditions: Phase II-Automated System. Funding **$60,000** (3 Year).
- CSU ARI-Project. Monitoring mitigation of particulate matter, fungal spores, pollen and organic compounds in fugitive dust during agricultural field operations. Funding: $**300,000** (3 Year)
- Valley-CAN. Simultaneous Measurements of Air Emissions and N Leaching of Dairy Effluent Application in San Joaquin Valley. Funding: **$29,000** (1 Year).
- Morrill Industries. Non Chemical Water treatment system research. Funding: **$39,000** (3 Year).
- Aqua-Phyd Inc. Effect of Aqua-Phyd Treated Water on Saline Sodic Soils. Funding: **$15,000** (2 Year).
- CSU ARI-Project: Comparison of Surface Renewal and Bowen Ratio Evapotranspiration Estimates for Crops Irrigated with Saline Drainage Water. Fundin**g $394,000.00** (3 Year).
- CSU ARI-Project: Automatic Data Collection, Monitoring, Analysis, and Reporting System for The Agriculture Industry. Funding **$ 25,000** (2 Year).
- CSU ARI-Project: Standardized Testing of Soil Water Monitoring Sensors. Funding **$ 199,000** (3 Year).

REVIEW WORK

- **AgGateway's PAIL and SPADE** Project. Vice-Chair Water Management Group.
- **American Society of Agricultural and Biological Engineer (ASABE) X633, and X627 and EPA WaterSense**: Member of the standards committee on Soil Moisture Sensors and Irrigation Controller. This group writes new standards for testing and evaluating soil moisture sensors and irrigation controllers.
- **IA-SWAT-TWG working group**. The group reviews current and future protocol work by Irrigation Association for water saving products.
- **AgTech PM Review Committee**: The purpose of this committee is to locate, receive, and review documents/studies/publications on air pollution that are of interest to the San Joaquin Valley (SJV) Air Pollution Control District and to the agricultural community.
- **International Commission on Irrigation and Drainage-CIID**: as peer reviewer.
- **Elsevier's Computer Standards & Interfaces Journal**: as peer reviewer.

FELLOWSHIPS AND HONORS

Aug, 2011	Team award: Federal Lab Consortium, Far West Region: Outstanding Partnership award.
May, 2011	Outstanding Research and Scholarly Activities Award (ORSA), Jordan College of Agricultural Science and Technology (JCAST) CSU Fresno.

May, 2009	Central California Research Symposium (CCRS) Best Poster.
May, 2008	Chancellors Doctoral Incentives Program (CDIP) Recipient.
Feb, 2005	Professional Development Travel Fund 2005.
Nov, 2004	Professional Development Travel Fund 2004.
Mar, 2003	Student Research Funds for Inter-CSU Research Presentation.

SCHOLARLY PUBLICATIONS

1. Alexandrou, A., **Diganta D. Adhikari**, and Charles F. Krauter 2013. A comparison of Particulate Matter (PM10) Emissions from Three Raisin Harvesting Practices in the San Joaquin Valley of California. *International Journal of Agricultural and Biological Engineering* (*accepted*).
2. Alexandrou, A., Klaus Tenberger, and **Diganta D. Adhikari** 2013. Energy Balance of a Typical U.S. Diet. *Foods* **2013**, *2*(2), 132-142; doi:10.3390/foods2020132. Published online 28 March 2013.
3. Melton, F., Lee Johnson, Chris Lund, Lars Pierce, Andrew Michaelis, Samuel Hiatt, Alberto Guzman, **Diganta Adhikari**, Adam Purdy, Carolyn Rosevelt, Petr Votava, Tom Trout, Bekele Temesgen, Kent Frame, Ed Sheffner, and Ramakrishna Nemani 2012. Satellite irrigation management support with the terrestrial observation and prediction system: a framework for integration of satellite and surface observations to support improvements in agricultural water resource management. *IEEE J*. Selected Topics In Applied Earth Observations and Remote Sensing, 5(6), 1709-1721.
4. Benes, S. E., **Diganta D. Adhikari**, Steve Grattan, and Rick Snyder. 2012. Evapotranspiration potential of forages irrigated with saline-sodic drainage water. *Agricultural Water Management*, 105, 1-7.
5. Goorahoo D., Florence F. Cassel, **Diganta D. Adhikari**, and Sharon E. Benes 2010.Soil Water Plant Relations. In *IA Sixth edition of "Irrigation"*, Book Chapter 3.
6. **Adhikari D.D.**, James Ayars, Dave Goorahoo, and Florence Cassel Sharma 2008. Micro Sprinkler Irrigation using SCADA and sensor network for freeze protection. *Arab Water World Magazine,* March issue, Beirut, Lebanon, pp 22-26.
7. Cassel S. F., Dave Goorahoo, David F. Zoldoske, and **Diganta D. Adhikari** 2008. Mapping Soil Salinity Using Ground-Based Electromagnetic Induction. In Remote Sensing of Soil Salinization: Impact and Land Management, G. Metternicht and A. Zinck (eds), *CRC Press,* <u>*book chapter 5*</u>.
8. Cassel S. F., Dave Goorahoo, **Diganta D. Adhikari**, and Shawn Ashkan 2007. Photosynthesis Response Curves for Strawberries Subjected to Elevated CO2 Levels. *Proceedings of the 2007 North American Strawberry Symposium (NASS) and the North American Strawberry Growers Association (NASGA)*, pp 141-145 (peer-reviewed).
9. Goorahoo D., **Diganta D. Adhikari**, D. Zoldoske, F. Cassel S., A. Mazzei, and R. Fanucchi. 2007. Potential for AirJection® Irrigation in Strawberry Production. *Proceedings of the 2007 North American Strawberry Symposium (NASS) and the North American Strawberry Growers Association (NASGA)*, pp 152-155 (<u>peer-reviewed</u>).

REFEREED CONFERENCE PRESENTATIONS

1. **Adhikari D.D**., Dave Goorahoo, Florence Cassel, David Zoldoske, and Paul Gupta 2008.Monitoring and Control of SMART Irrigation system. Oral presentation at the technical session of the Irrigation Association Show, Anaheim, CA Nov 2008.
2. **Adhikari D.D.,** Dave Goorahoo, Florence Cassel, and David Zoldoske 2008. “SMART” Sensors and Controllers- Optimizing Water Use Efficiency. Oral presentation at the technical session of the ASA-CSSA-SSSA Annual Meeting Houston TX, Oct 2008.
3. **Adhikari D.D**., Dave Goorahoo, Florence Cassel, and David Zoldoske 2008. Feasibility of a Micro Drip SCADA System to Mitigate Crop Freeze Damage. Oral presentation at the technical session of the ASABE Annual International Meetings, Providence, RI Jul 2008.

4. **Adhikari D.D.,** Dave Goorahoo, Florence Cassel, and David Zoldoske 2008. Optimizing Water Use Efficiency using "SMART" Sensors and Controllers. Oral presentation at the technical session of the Central California Research Symposium, Fresno CA Apr 2008.
5. **Adhikari D.D.**, Balaji Sethuramasamyraja, and Matthew Yen 2008. Feasibility of a Micro Drip SCADA System to Mitigate Crop Freeze Damage. Poster presentation at the ASABE CA-NV Chapter meeting, Tulare CA Feb 08.
6. **Adhikari D.D**, Dave Goorahoo, Florence Cassel, and Ed Norum 2007.Micro Sprinkler Irrigation Using SCADA and Sensor Network for Freeze Damage Prevention. Oral Presentation at the technical session of the Irrigation Association Show San Diego, Dec 2007.
7. **Adhikari D.D**, Dave Goorahoo, and Florence Cassel 2007. Automated Feedback Irrigation: A means for Freeze Damage Prevention. Oral presentation at the technical session of the ASA-CSSA-SSSA Annual Meeting New Orleans LA, Nov 2007.
8. Goorahoo D., **Diganta D. Adhikari**, Namratha Reddy, and David Zoldoske 2007. Application of AirJection® Irrigation in Organic Farming Systems. Poster presentation at ASA Annual Meetings New Orleans LA, Nov 2007.
9. Reddy N., Dave Goorahoo, and **Diganta D. Adhikari** 2007. Assessing Nitrogen Rates for Organic Bell Pepper Production Subjected to Airjection® Irrigation. Poster presentation at ASA Annual Meetings New Orleans LA, Nov 2007.
10. Chaganti V., Dave Goorahoo, Sharon Benes, and **Diganta Adhikari** 2007. Effect of Amendments on Hydraulic Properties of Soils Irrigated with Saline-Sodic Drainage Water: Methodology and Preliminary Results. Poster presentation at ASA Annual Meetings New Orleans LA, Nov 2007.
11. Ashkan S., Dave Goorahoo, Florence Cassel, and **Diganta D. Adhikari** 2007. Effects of Elevated CO2 on Berry Production in California. Poster presentation at ASA Annual Meetings New Orleans LA, Nov 2007. Poster presentation at ASA Annual Meetings New Orleans LA, Nov 2007.
12. Cassel F., Dave Goorahoo, **Diganta D. Adhikari,** and Shawn Ashkan 2007. Effects of Elevated Open-Field CO2 Levels on Photosynthesis Response Curves in Strawberries. Poster presentation at ASA Annual Meetings New Orleans LA, Nov 2007. Poster presentation at ASA Annual Meetings New Orleans LA, Nov 2007.
13. Goorahoo D., **Diganta D. Adhikari,** David Zoldoske, Florence Cassel, and Ed Norum, 2007. Assessment of Standardized Testing Protocol for Soil Moisture Sensors. Oral presentation at the International Soil Moisture Sensor Conference, Honolulu HI.
14. Goorahoo D., **Diganta D. Adhikari**, David Zoldoske, Florence Cassel, Angelo Mazzei, and Richard Fanucchi. Potential for AirJecion® Irrigation in Strawberry Production. Sixth North American Strawberry Symposium, Ventura, CA Feb 2007.
15. Goorahoo D., **Diganta D. Adhikari**, David Zoldoske, & Florence Cassel, 2006. Standardized testing of soil moisture sensor. Poster presentation at the 1st International Conference on Sustainable Irrigation Management, Technologies and Policies, Bologna Italy.
16. **Adhikari, D.D**., Dave Goorahoo, David Zoldoske and Edward Norum 2006. Standardized Testing of Soil Moisture Sensors used in "Smart Controller" Irrigation Systems. Oral presentation at the technical session of the 4th World Congress of Computers in Agriculture, Orlando Fl.
17. Goorahoo D., **Diganta D.Adhikari**, David Zoldoske, Angelo Mazzei, and Richard Fannuchi 2006. Impact of Air-jection™ on Yield and Quality of Vegetables Grown in California. Presentation at the technical session of the International Union of Soil Science Philadelphia-July 06.
18. Goorahoo D., **Diganta D.Adhikari**, David Zoldoske, Angelo Mazzei, and Richard Fannuchi 2006. AirJection™ Irrigation as a Best Management Practice for Crop Production. Presentation at the technical session of the Canadian Society of Soil Science, Alberta Canada.

19. **Adhikari, D.D.**, Dave Goorahoo, and Florence Cassel 2005. Vadose Zone Monitoring of Fields Irrigated with Recycled Processing and Municipal Wastewaters. Oral presentation at the technical session of the 26th Annual Irrigation Show, Phoenix, AZ.
20. Cassel F., **Diganta D .Adhikari**, and Dave Goorahoo 2005. Salinity mapping of fields irrigated with winery effluents. Presentation at the technical session of the 26th Annual Irrigation Show, Phoenix, AZ.
21. **Adhikari D.D.**, Dave Goorahoo, and David Zoldoske. 2005. Development of a Standardized Testing Protocol for Soil Moisture Sensors. 19th Annual CSU Student Research Symposium, CSU Sacramento- April 29th 2005.
22. **Adhikari D.D.**, Florence Cassel, Dave Goorahoo, Anil Shrestha, and Shawn Ashkan 2005. Impact of Open Field Carbon-Dioxide Enrichment on Growth and Yield of Strawberry. 26th Annual Central California Research Symposium, CSU-Fresno- April 21st 2005.
23. **Adhikari D.D.**, and. Dave Goorahoo 2005. Response of Digital Electromagnetic Probe to Soil Moisture and Electrical Conductivity. Presented at the CA Chapter of ASA, Feb 2005.
24. Cassel F., Dave Goorahoo, **Diganta D. Adhikari,** and Morton Rothberg 2005. Potential Use of a New Forage Grass for BMP Involving Irrigation with Dairy Wastewaters. Presented by at the CA Chapter of ASA, Feb 2005.
25. Goorahoo D., Sharon E. Benes, **Diganta D. Adhikari,** and Kim Senatore 2005. Characterization of Soils Irrigated with Saline-Sodic Drainage Water: Chemical Composition. International Salinity Forum, Riverside CA -April; 24-28th 2005.
26. **Adhikari D.D.**, Florence Cassel, and Dave Goorahoo 2004 Photosynthetic responses to enriched atmospheric carbon Dioxide in strawberry leaves .Presented at ASA-CSSA-SSSA International Annual Meetings/Conference 2004, Seattle, WA.
27. Ng J., A Chu.,Dave Goorahoo, Florence Cassel, **Diganta D. Adhikar**i 2004. Growing Broccoli with a Sustainable Manure-Based Fertilizing System (MBFS). Presented at ASA-CSSA-SSSA-CSSS Annual Meetings in Seattle, WA Sept 2004.
28. Goorahoo D., Sharon E. Benes, Kim Senatore, and **Diganta D. Adhikari** 2004. Impact of Irrigation with Saline-Sodic Drainage Waters on Soil Hydraulic and Chemical Properties. Presented at ASA-CSSA-SSSA-CSSS Annual Meetings in Seattle, WA Sept 2004.
29. Goorahoo D., **Diganta D. Adhikari**, Genett Carstensen, and David Zoldoske 2004. Impact of Aerated Subsurface Irrigation Water on the Growth and Yield of Crops. Presented at the Irrigation Association (IA) show in Tampa Florida on Nov. 2004.
30. Goorahoo D., Florence Cassel, Morton Rothberg, **Diganta D. Adhikari** , David Zoldoske, and Edward Norum 2004. Potential use of a New Forage Grass (Pennisetum Sp.) in Best Management Practices Involving Irrigation with Food Processing and Dairy Wastewaters. Presented the IA show in Tampa Florida on Nov. 2004.
31. **Adhikari D.D.**, and Dave Goorahoo 2004. Response of Digital Electromagnetic Sensor to Soil Moisture and Electrical Conductivity. Oral Presentation given at 18th Annual CSU Research Competition 2004, CSU Northridge, CA.
32. Cassel F.S., Dave Goorahoo, **Diganta D. Adhikari,** and Mary McClanahan 2004. Effect of Winery Wastewater Application on Soil Water Quality. 25th Journal of Annual Central California Research Symposium 2004, CSU Fresno, CA.
33. **Adhikari D.D.**, and Dave Goorahoo 2004. Effect of Air Injection Through Subsurface Drip Irrigation on Growth and Yield of Crops. Conference Proceedings of California Plant and Soil Conference 2004, Visalia. CA. pages 142-143.
34. Cassel F.S. Dave Goorahoo, and **Diganta D. Adhikari** 2004. Evaluating percolate water quality following land application of winery processing wastewater. Conference Proceedings of California Plant and Soil Conference 2004, Visalia. CA. pg. 174.

35. Goorahoo D., Florence Cassel, and **Diganta D. Adhikari**, 2004. Efficacy of Manure Based Fertilizer N201™ on Broccoli , Final Report Submitted to CK Life Sciences Hong Kong 2004..
36. **Adhikari D.D.**, and Dave Goorahoo 2003. Response of Acclima Digital TDTTM probe to Soil Moisture and Electrical Conductivity. Poster presented at Center for Irrigation Technology (CIT) booth at IA International Show. San Diego Nov 03.
37. Goorahoo D., Sharon E. Benes , and **Diganta D. Adhikari** 2003. Soil for Fields Irrigated with Recycled Saline Drainage Waters. Annual Meeting of the Irrigation Association held in San Diego California- Nov 2003.
38. Goorahoo D., Sharon E. Benes, **Diganta D. Adhikari,** and Jim Bartram 2003. Soil Characterization and Infiltration Measurements for Fields Irrigated with Recycled Saline Drainage Waters. Annual Meeting of the American Societies of Crop, Soils and Agronomy in Denver, CO., in November 2003.
39. Goorahoo D., Sharon E. Benes, and **Diganta D. Adhikari** 2003. Soil for Fields Irrigated with Recycled Saline Drainage Waters. Annual Meeting of the Irrigation Association held in San Diego California- Nov 2003.
40. Goorahoo D., Edward Norum, Florence Cassel, and **Diganta D. Adhikari** 2003. Development of a Standardized Testing Protocol for Soil Moisture Sensors: Current Status and Preliminary Test Results. Annual Meeting of the Irrigation Association held in San Diego California- Nov 2003.
41. Goorahoo D., Benes Sharon E. Benes, and **Diganta D. Adhikari** 2003. Infiltration in soils irrigated with saline-sodic drainage waters: experimental design and data analysis techniques. Poster presented at California Plant and Soil Conference Feb.5-6 in Modesto, CA

TEACHING EXPERIENCE

1. **Adjunct Faculty at the Department of Industrial Technology, CSUF-since Dec 2008. Teach courses related to automation, process control, system design and computer aided drafting and design.**
    i) IT052: Electricity and Electronics
    ii) IT151: Design and Documentation System-AUTOCAD
    iii) IT112: Industrial Process Control I
    iv) IT131: Automated System I
    v) IT133: Industrial Control Systems II

2. **Guest lectured classes at Fresno State, classes relating to Agriculture, Automation and Public Acceptance; including:**
    i) SW101: Crop Nutrition
    ii) SWS220: Community Organization
    iii) PL252: Plant Nutrition
    iv) PL253: Soil Water Relation
3. Worked as Faculty member at Jetking Computers, New Delhi, A sister concern of Heathkit Corporation USA, from June 2000-Nov 2000. Taught advanced electronics, networking and Novell Netware.

MEMBERSHIP IN PROFESSIONAL SOCIETY

1. American Society of Agricultural and Biological Engineer (ASABE).
2. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America (ASA-CSSA-SSSA).

3. Irrigation Association (IA).
4. US Society for Irrigation and Drainage Professional (USCID).
5. California Chapter of American Society of Agricultural (Ca-ASA).
6. Member of the Particulate Matter (PM) research review committee, San Joaquin Valley Unified Air Pollution Control District.
7. Member planning committee-International Symposium of Living with Potatoes 2008.

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INTRODUCTION

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INTRODUCTION

1.1 Background and Motivation

While agricultural and urban users compete and debate over water use in arid and semi-arid regions, agriculture accounts for 80% of developed water resources in California (Letey et al, 2002; Rijsberman, 2006;). In the drought prone Western United States, groundwater is often used to fill the gap between available surface water and water demand for urban, agriculture, environmental, and industrial needs (Gutzler and Robbins, 2011). More recently, a National Aeronautical and Space Administration (NASA) report suggested that 41,640 million m^3 (33.76 million acre feet) of water will be required to refill California's over-drafted aquifers (Argus, 2015; NASA, 2015). To replenish depleted groundwater, many cities and counties are forced to look for alternative sources of water (Nelson, 2012). Artificial recharge using flood water flows and grey water have been widely considered as a viable alternatives (Bischel et al., 2013; Lund et al., 2012; Rusteberg et al., 2012).

This work explores the potential of taking advantage of lands suitable for release of secondary treated water in support of recharging the aquifers. As a test case, we study the southern San Joaquin Valley (SJV). On average, the four major population centers in the southern SJV, namely Fresno, Tulare, Visalia, and Bakersfield, generate 0.5-0.6 million m^3 (405-486 acre feet) of secondary treated water daily. This is equivalent of 182-220 million m^3 annually or roughly 0.5% of the groundwater refill requirement proposed by NASA. While this is a relatively modest fraction, the amount is reliable and may grow over time with population growth in the SJV. Thus, it seems prudent to investigate the potential for supplementing current recharge in valley aquifers using treated wastewater effluent.

It is important to note that there will likely be health safety related reservations about water reuse, and there is enough scientific evidence to validate these concerns, especially as it relates to pollutants emerging from contaminants such as PPCP's (Mankand et al., 2015; NRC, 2012). However, it is imperative that we start exploring alternatives which could potentially address those concerns because water scarcity issues are very real, and unfortunately projected to get worse over time.

1.2 Objectives

As noted above, the scientific and broader community is gradually recognizing the critical need to explore alternatives to traditional groundwater recharge approaches (Fernald et al., 2012).The purpose of this work therefore is to address groundwater recharge potential for the southern SJV using secondary treated water, the caveat being that some of the aforementioned health and safety related concerns are not directly addressed in this work. Our estimation method relied upon onsite measurements of limited soil, water, and micrometeorological parameters, and model driven predictions. In the following chapters we use measurements and modeling techniques to support the following research objectives:

1) Develop a continuous, autonomous monitoring platform for assessing the water balance associated with an artificial recharge basin (and compare our monitoring

outcomes to those from the cognizant agency's more rudimentary monitoring approach);

2) Examine the efficacy of site-specific soil column tests for estimating the infiltration rate and duty cycle of an artificial recharge basin (compared to the full-scale basin estimates);
3) Estimate the portion of applied wastewater effluent that results in actual groundwater recharge (as opposed to evaporative losses or vadose zone storage);
4) Use the recharge data and available land estimates to upscale our pilot test results, providing a more realistic estimate of the potential impact of this approach on regional groundwater resources and;
5) Investigate sustainable options for using the infiltrated water to grow salt tolerant crops (like forages, such as alfalfa and sudangrass, or fiber crops).

1.3 Approach

This project focuses on the potential use of secondary municipal wastewater effluent to enhance aquifer recharge in over-drafted, semi-arid regions. We studied this problem at three scales, using: (1) experimental soil columns, (2) an instrumented full-scale recharge basin, and (3) regional scale computations for the southern San Joaquin Valley (SJV) as a case study. We obtained soil samples and operated the full-scale recharge test at the Fresno-Clovis Regional Wastewater Reclamation Facility for 465 days (Oct 2010-Jan 2012).

Since this study involved secondary effluent (containing suspended solid materials), we used soil columns to estimate the effect of clogging on representative soils' ability to transmit fluid. Previous studies have also documented the effect of clogging, the depth at which clogging occurs, and its onset using soil columns (Talsma and van der Lelji, 1976; Dillion et al. 1999; Pavelic et al. 2005). Most studies with treated water have reported clogging as a surface phenomenon and showed no significant onset of clogging until year 2-5 (Gharaibeh & Ghezzehei under review). To compare the soil column findings to basin study results, we used the water balance approach.

Water balance and soil columns provided infiltration data as a surface phenomenon and so we needed an additional approach for translating observed infiltration rates to groundwater recharge rates. Because the depth to groundwater may be substantial in arid and semi-arid environments, such as the SJV (Delfs, 2013; Hillel, 2012), we elected to use an unsaturated flow model to simulate the connection between infiltration and recharge. Specifically, we chose the Hydrus 1D and 2D models. Estimated recharge potential obtained from the method above was used to extrapolate our findings to the overall southern SJV (mainly within areas proximate to the RWRFs at Tulare, Visalia and Bakersfield).

1.4 Dissertation Overview

The subsequent chapters detail our research approach and findings. Chapter 2 contains a detailed account of the methods for assessing recharge in our columns and the test reclamation basins. Chapter 3 provides the results from the column, basin water balance, and analysis of these results using computational modeling and explores the scale-up potential in the context of the southern SJV, and Chapter 4 summarizes the key findings and implications of this work, and proposes next steps from our research agenda.

References

Argus, D. (2015, April). Change in Water Resources in California During the 2011–2014 Drought Estimated Using GPS, GRACE, and InSAR. In *California Drought Conference*. Agu.

Bischel, H. N., Lawrence, J. E., Halaburka, B. J., Plumlee, M. H., Bawazir, A. S., King, J. P., ... & Luthy, R. G. (2013). Renewing urban streams with recycled water for streamflow augmentation: hydrologic, water quality, and ecosystem services management. *Environmental Engineering Science*, *30*(8), 455-479.

Delfs, J. O., Wang, W., Kalbacher, T., Singh, A. K., & Kolditz, O. (2013). A coupled surface/subsurface flow model accounting for air entrapment and air pressure counterflow. *Environmental earth sciences*, *69*(2), 395-414.

Gutzler, D. S., & Robbins, T. O. (2011). Climate variability and projected change in the western United States: regional downscaling and drought statistics. *Climate Dynamics*, *37*(5-6), 835-849.

Hillel, D. (2012). *Applications of soil physics*. Elsevier.

Lund, J., Cutter, W. B., Gray, B., Houston, D., Howitt, R., Jessoe, K., & Wilkinson, R. (2012). *Water and the California Economy*. Public Policy Institute of California.

Mankad, A., Walton, A., & Alexander, K. (2015). Key dimensions of public acceptance for managed aquifer recharge of urban stormwater. *Journal of Cleaner Production, 89,* 214-223.

Letey, J., Williams, C. F., & Alemi, M. (2002). Salinity, drainage and selenium problems in the Western San Joaquin Valley of California. *Irrigation and Drainage Systems*, *16*(4), 253-259.

NRC, 2012. Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater. Washington D.C.

Nelson, R. L. (2012). Assessing local planning to control groundwater depletion: California as a microcosm of global issues. *Water Resources Research*, *48*(1).

Riggs, E. M. (2005). Field-based education and indigenous knowledge: Essential components of geoscience education for Native American communities. *Science Education*, *89*(2), 296-313.

Rijsberman, F. R. (2006). Water scarcity: Fact or fiction?. *Agricultural water management*, *80*(1), 5-22.

Rusteberg, B., Rahman, M. A., Bear, J., Bensabat, J., Gogu, R. C., Brouyère, S., ... & Sauter, M. (2012). Decision support for MAR planning in the context of Integrated Water Resources Management: The Gabardine DSS. *Water Reclamation Technologies for Safe Managed Aquifer Recharge*, 383.

Slichter, C. S. (1905). Field measurements of the rate of movement of underground waters. *United States Geological Survey Water-Supply and Irrigation Paper*, *140*.

CHAPTER 2

USE OF SOIL COLUMNS AND ONE-DIMENSIONAL MODELING TO ESTIMATE ENGINEERED BASIN INFILTRATION AND AQUIFER RECHARGE RATES

ABSTRACT

In water-scarce regions, groundwater is often used to close the gap between variable surface water supplies and relatively steady urban, agricultural, industrial, and environmental water demands. To address this groundwater overdraft problem, artificial recharge using flood water flows and grey water have been widely considered as a viable alternative. In this paper, we present infiltration results from experimental soil column study using soils from a reclamation basin and water balance data from the same reclamation basin (area 69,808 m^2 or 17.25-acre) at the Fresno-Clovis Regional Wastewater Reclamation Facility (RWRF). The Hydrus computer modeling simulating one-dimensional unsaturated soil water movement, was also used to estimate deep percolation leading to recharge. The primary concern before the start of this study was the potential for basin soil clogging, so laboratory soil columns experiments were setup to understand and predict the onset of clogging. Most utilities in-charge of managing grey water desire site-specific tools for quantify the amounts percolated through the recharge/reclamation basins and assessing the need for engineering interventions (e.g. raking). This work describes the methods and results obtained from a series of twenty four experimental columns, and water balance results from basin study operated over a period of 465 days. The column method consistently reported water balance at 33% higher rate in the 40-125 mm/day range, and were closely correlated (Slope=0.75 and Intercept=22.35 with r^2=0.99). The initial infiltration rates at 7-10 days were similar (130 mm/day, S.E=1.2) for all columns and the water balance method. The infiltration rate dropped to 43.1%, 60.6%, and 53.1% for soil column control, soil column treated, and water balance respectively at the end of day 210, which was 7% lower for the treated soil columns compared to the water balance. Utilities could consider the use of small, inexpensive column experiments to estimate the infiltration potential of their given soil type using secondary treated water.

2.1. Introduction

In water-stressed regions, groundwater is used to narrow the gap between water demand and supplies from surface water and inter-basin transfers (Arnell et al. 2001). This often results in groundwater overdrafting, which can create short-term (e.g., inadequate well depths) as well as longer term water resource sustainability challenges. Other problems associated with groundwater overdraft include reductions in streams flow and reduced aquatic habitat, degradation of groundwater and surface water quality, and increased potential for sea water intrusion and land subsidence (Gallardo, 2009; Harvey et al. 2007;Werner, 2009;; Zektser et al. 2005).

Groundwater overdraft is a problem that is challenging to overcome in a short time period. First, recharge is one of the more poorly understood components of the hydrologic cycle. Second, the rate of groundwater replenishment (recharge) is slow comparative to the rates of groundwater withdrawal. A recent multi-agency map (Figure 1) chronicles the increasing deficit that we are facing nationwide.

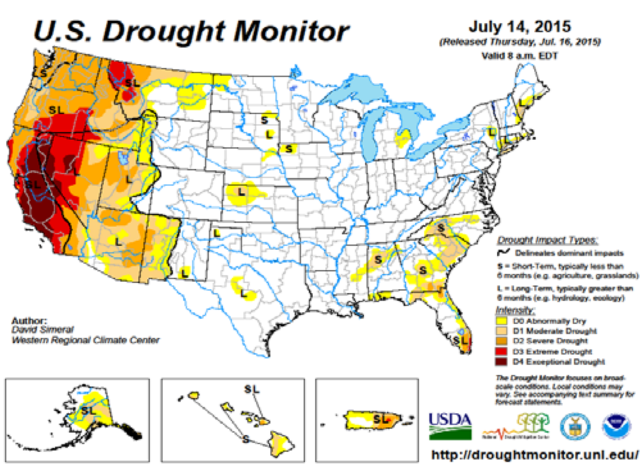

Figure 1: Multi-agency, drought monitor map, shows the impact of drought in the United States, predominantly in the west.

In snow-dominated watersheds, such as in the semi-arid western U.S., the changing climate threatens to aggravate this problem by reducing the amount and longevity of our annual snow pack (Lettenmaier et al., 1999; Sophocleous, 2004). To deal with threats to the environment and water supply from overdraft of groundwater sources, artificial recharge of groundwater is considered a potential option in California and other semi-arid regions (Racz et al., 2012).

Excess stream flow, agricultural runoff or treated wastewater are some of the potential sources of water for artificial recharge (Bouwer, 2002; Greskowiak et al., 2005; Massmann at al., 2008; Prommer and Stuyfzand, 2005). One common managed aquifer recharge (MAR) method is the use of a surface infiltration basin (Racz, 2012). Maintaining an efficient surface infiltration basin requires maintaining relatively high hydraulic conductivity in the vadose zone. Generally, the hydraulic conductivity is relatively high in the beginning but decreases over time because of physical, chemical, and biological processes (Bouwer, 2001).

In a host of studies, accumulation of suspended solids from the wastewater in the soil pores caused progressive clogging (Knowles et al. 2011; Ripley and Saleem, 1973; Sou et al. 2013; Vigneswaran and Suazo, 1987; Viviani and Iovino 2004; Wood and Signor, 1975). Studies in the past have documented the effect of clogging, the depth at which clogging occurs, and its onset at various stages of laboratory studies (Talsma and van der Lelji, 1976; Winterer, 1922, 1923).

Early studies using soil columns have documented the variation in water flow through soils, where temporal decreases in saturated hydraulic conductivity were observed (Green and Ampt, 1911). Similar studies were done using industrial and domestic waste waters as there were practical difficulties with disposal of these waters due to the drastic reduction in hydraulic conductivity over time (Goss et al., 1973; Laak, 1970; Marchand, 1971). These early studies attest to the importance of temporal changes in saturated hydraulic conductivity (Baveye et al., 2010). Restricted flow as a function of decreases in soil permeability can be attributed to filtration processes leading to the gradual reduction in pore space and changes in friction coefficients in soils (Bear, 2012; Dullien 2012; Matthews et al., 2010). These changes in the soil pore structure are not purely physical in nature; they are a combination of biological/microbial, chemical, and physical factors (Baveye et al., 1998; Chadwick et al., 1974; Jawson, 1976; Kreissl, 1978; Metzger et al., 1983; Vandevivere and Baveye 1992; Warner et al., 1994).

Surface infiltration basin projects are most often operated in arid and semiarid climates, where not all of the applied water replenishes the underlying aquifer. Some of the water evaporates, some infiltrates but is retained within the vadose zone, and the balance continues to the water table through saturated or unsaturated flow processes. The latter portion depends strongly on soil conditions and separation between the inverted water table (beneath the spreading basin) and the natural water table below (Heilweil, 2007; Izbicki, 2008; Racz, 2011). The infiltration process may occur as both conventional unsaturated flow (Richards's equation) and preferential flow following macro-pores or fissures in the soil horizon (Hendrick and Flury 2001). Beyond hydraulic considerations, surface chemistry and colloidal transport processes also play critical roles as filtration tends to clog the soil, reducing the efficiency of the surface infiltration basin operation (Bradford and Torkzaban, 2008; Hiemenz and Rajagopalan, 1997). This is particularly true when storm water or reclaimed wastewater is the source water. Understanding these processes is important both in terms of determining the suitability of a surface infiltration basin site and managing the site operationally (e.g., basin raking events).

Treated municipal or industrial wastewater has long been recognized in terms of advantageous second use potential (Asano, 1998; Asano and Levine, 1996; Tchobanoglous and Burton 1991). In recent years, mounting water costs combined with the massive shortage of water have provided new incentive for using treated wastewaters for reclamation and recharge, but implementation requires knowledge of potential recharge rates which may be uncertain (Taylor et al., 2013; Gleeson et al.,2012). It is important to add that the amount of treatment required, depends on the specific reuse objectives and on the accompanying water quality requirements (Ramalho, 2012).

In spite of its potential, there remain concerns about the use of secondary treated water for recharge. These concerns are generally related to potentially negative health impacts. In recent years, as the use of reclaimed water has become more prevalent, research has focused on the retention and transport of colloids, including pathogens, in the vadose zone. Under unsaturated flow conditions, reduced colloidal movement and reduced water movement has been demonstrated, compared to saturated flows (Auset and Keller 2004; Han et al. 2006; Sirivithayapakorn and Keller 2003). Additionally, there are growing concerns about presence of emerging contaminants, such as pharmaceutical and personal care products (PPCPs), linked to the use of domestic wastewater discharge (Drewes et al. 2003). However, as freshwater becomes scarce and we strive to introduce reused water into our daily lives, efforts will have to be made to understand and overcome risks, both real and perceived. In other words, broader adoption of reused water will require changing the public's outlook towards reused water, and focus our attention towards where and how recycled water is derived from, managed, recycled, used and priced (Grant et al., 2012).

Studies have demonstrated that when adequate hydraulic conditions are achieved, surface infiltration under saturated conditions considerably improves infiltrated water quality. The extent of improvement depends on the wastewater pretreatment levels, soil type, and the depth of the groundwater (although the water will not likely be close to drinking water standards without advanced pretreatment). However, the estimated cost and energy requirement associated with this process (soil as the bio-filter) is considerably less than that of in-plant treatment (Crites et al., 2014). While we recognize these health and safety concerns, associated with wastewater reuse, this study was not designed to understand how recharge with secondary treated water influences people's health. As noted before, this study was focused more narrowly on estimating the infiltration capacity of secondary treated water in a typical Western U.S. semi-arid region.

This study strives to identify and assess the parameters that influence infiltration at a reclamation site using secondary treated effluent. The study is situated in San Joaquin Valley, CA region, one of the worst hit regions in terms of water shortage and drought in recent years. Four key aims addressed in this research were: 1) To investigate the use of soil columns to estimate duty cycle of a basin long term, 2) To assess the correlation between basin water balance and soil column based infiltration rate and duty cycle estimates, 3) To compare the cognizant agency's "simple" infiltration rate observations with our continuously monitored infiltration rates, and 4) To identify sustainable options for use of the infiltrated water from reclamation wells.

2.2. Methods

In this study, the focus was on understanding the longitudinal (time dependent) behavior characteristics of infiltration rates, we used a three-pronged approach to measure infiltration rate and recharge potential using secondary treated water. Our approach involved: i) conducting experiments with soil columns using soil and water from the utility site, ii) taking continuous onsite measurement of inputs to the reclamation basin for 465 days, and iii) conducting 1D modeling exercises using observations from the two methods above to estimate basin recharge potential from infiltration rates. The soil column data were used to estimate the infiltration rate over an extended period of time in order to establish the duty cycle (time between management actions) for the infiltration basin. Continuous real-time data from the reclamation basin were used to test a modern instrumentation approach (relative to conventional utility assessment approaches) for estimating the infiltration rate and to test the relevance of the soil column results to the field observations. This study is innovative as it is among the first to compare continuously assessed infiltration rate with the utilities infiltration rate.

2.2.1 Location

Data were collected continuously from 17 October 2010 to 25 January 2012 at Fresno-Clovis Regional Wastewater Reclamation Facility (RWRF) reclamation basin number 3, located southwest of Fresno CA (36 ° 41’ 59.84 “N, 119° 53’ 48.73” W). Fresno is the fifth largest city in California, and is in the center of the San Joaquin Valley.

At its current capacity, the RWRF (Figure 2) facility is a biological, secondary level treatment plant meeting the Title 22 California Code of regulation and can be used to grow fiber crops, not crops for human consumption. The secondary effluent discharges into 101 reclamation basins varying in size from 49 - to 60 hectares each. The soil acts as a filter with the infiltrating water and the consistent infiltration forms a groundwater mound underneath the basin. A series of shallow reclamation wells then extract the infiltrated water from the mound and discharge the water into Fresno Irrigation District canals for supply to farm lands. On average, the Fresno RWRF extracts 29.6 million m^3 of water from the shallow reclamation wells and supplies to Fresno Irrigation District on a need per basis. Additionally, about 12%-15% of the secondary treated water goes directly to farmers leasing land within the RWRF or to nearby farmers where they mainly grow forage like alfalfa, corn, or sudan grass and the balance is sent to the reclamation basin for disposal.

Figure 2: Satellite image of Fresno RWRF obtained from Google Earth, basin #3 marked by the black circle is on the South West corner of the treatment facility, located at 5607 W Jensen Ave, Fresno, Ca 93706.

The study basin (number 3) is 6.9 ha or 17.25 acres in area and sits on top of sandy loam, loamy sand, and sandy clay loam soil textures with average saturated hydraulic conductivity values ranging from 12 to 122 mm/day (National Resources Conservation Service (NRCS) SSURGO Soils database and laboratory analysis of site-specific soil samples). The climate in Fresno is Mediterranean with an average annual high temperature of 37 °C and average low of 13 °C. The average annual precipitation is 280mm with majority of the rainfall occurring November to April. Reclamation basin number 3 was maintained with an average water depth of 90-122 cm during the 465 days of the study period.

Fresno-Clovis RWRF tracks the infiltration rate of their 101 reclamation basins throughout the year. This helps them maintain the inventory of their basins and plan the movement of the treated water through their network of open canals. To estimate basin infiltration rates, they use a simplified water balance approach, which takes into account water inflow duration, basin area, assume 70% of evapotranspiration rate from California Irrigation Management Information System (CIMIS) as evaporation, and periodically (weekly or bi-monthly) estimate the height of water column at staff gauge. Their infiltration measurements are not done on a daily basis but normally coincides with the dates they take the staff gauge measurements. We reviewed the saturated infiltration rate records for Fresno-Clovis from 2010-2013 for all basins in order to estimate their maximum and minimum infiltration rates. The highest infiltration rate reported from all basins was 152.4 mm/day and lowest was 12.7 mm/day. Basin 3 was put into operation from Oct 17 2010, and the RWRF staff began tracking it on 1 Nov 2010. According to their data basin 3 had the highest estimated saturated infiltration rate of 76.2 mm/day for the first 14-150 days (Nov to Mar 2011). The estimated rate dropped to 69.9 mm/day for the next 151-210 days (Apr-May 2011), followed by 35.5 mm/day for the next 211-331 days. The final infiltration rate estimate at the end of Dec 2011(day 440) was with 12.7 mm/day.

2.2.2 Soil Column experiments

A total of 24 soil columns (height: 61 cm, diameter: 11.4 cm; packed inside clear plexi-glass tubes) were used (Figure 3) to test soil samples collected from three locations within the reclamation basin (to a depth of 60 cm): east, middle, and west (Table 1). Soils were collected in 15 cm increments up to a depth of 150 cm and separated into different buckets. The soils were air dried in the laboratory and disaggregated using a laboratory soil grinder to aid in packing the soil columns to the same bulk density as the field. A part of the homogenized air dried sample was analyzed for soil texture using ASTM D422-63(2007) e2 method. Also, method ASTM F1815-11 was used to determine porosity and bulk density for undisturbed soil cores collected at the same depths as above.

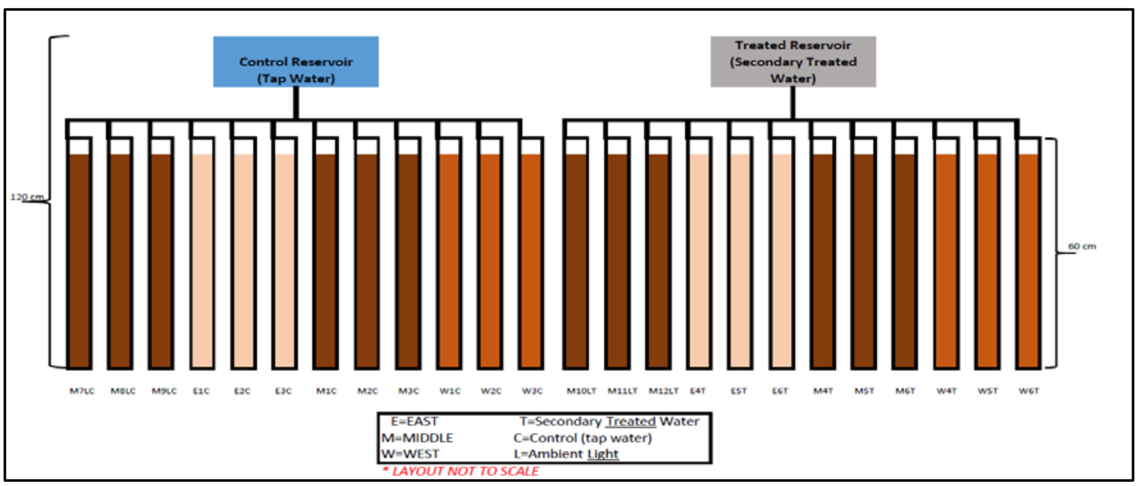

Figure 3: Layout and design of the 24 soil columns. The two tanks on top provided constant head of water for the soil columns during the test.

Of the 24 soil columns, 18 soil columns (6 each from locations east, middle and west) were wrapped in black paper to prevent exposure of light along the length of the column, similar to natural environment. The six remaining columns (soil from the middle location) were exposed to light in order to ascertain the effect of light on infiltration rate if any due to clogging caused by ambient light. These six columns exposed to ambient light along the length of the column were split into three replicates each for treatment and control respectively. The replicated pairs mentioned above (Figure 3) were split into two pairs at the beginning (treated and control) of the experiment, where the first pair designated as treated, received treated wastewater from the treatment plant. The other pair designated as control, received potable drinking water (Table 2). Two separate tanks were used to provide the columns with water. Both tanks were located at an identical fixed elevation of 60 cm above the columns to supply a constant pressure head to the columns below. To assess the column discharge rates, the volume of water exiting each column was collected individually and measured as a cumulative volume for that column every 24 hours. Flow rates were converted to hydraulic conductivity estimates using Darcy's Law (equation 1).

$$Q/A = K\ (\Delta h/\Delta L) \qquad (1)$$

where Q [L^3/T] is flow, K [L/T] the hydraulic conductivity of the porous media, $\Delta h/\Delta L$ [-] the hydraulic gradient, and A [L^2] the cross section area. All the recorded flux data (collected daily on a 24 hour basis) were averaged to get the everyday values.

Table 1: Soils classification data for basin 3 at various depths.

Depth	**Porosity**	**Bulk Density**	**% Sand**	**%Silt**	**%Clay**	**ESP**	**USDA Soil Type**
cm	%	g/cm3	%	%	%	%	Classification
0-60	41.8	1.43	46.8%	22.5%	30.7%	5.95%	Sandy Clay Loam
60-120	47.6	1.34	56.7%	28.3%	14.9%	3.76%	Sandy Loam
120-180	32.6	1.46	86.0%	5.0%	9.0%	2.44%	Loamy Sand
180-240	39.6	1.42	89.5%	1.5%	9.0%	2.27%	Sand
240-300	42.6	1.47	70.0%	9.0%	21.0%	3.66%	Sandy Clay Loam
300-360	53.2	1.52	42.6%	28.5%	29.0%	4.22%	Clay Loam
360-420	43.6	1.46	56.6%	14.5%	29.0%	3.15%	Sandy Clay Loam
420-480	44.3	1.45	54.6%	24.5%	21.0%	2.36%	Sandy Clay Loam
480-540	45.6	1.54	58.3%	20.7%	21.0%	2.04%	Sandy Clay Loam

The maximum and minimum air temperatures at the reclamation basin site for the period of the study were 38.7 °C and -2.0 °C, respectively, with an average of 15.83 °C. The soil columns had maximum and minimum air temperature of 41.3 °C and -2.35 °C respectively, with an average of 16.7 °C. At any given point of time the difference in the air temperature of these two locations were between 0.35 and -2.64 ° C (Figure 4).

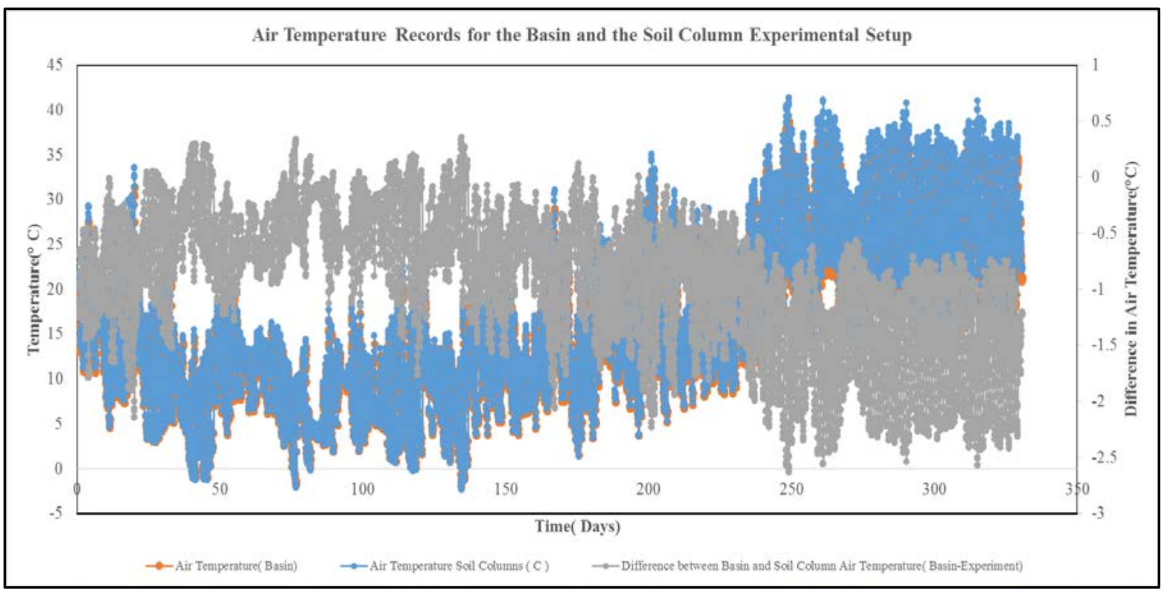

Figure 4: Air temperature records for the basin and soil column experimental setup during the course of the study. The secondary axis shows the difference between the air temperature near basin and the soil column experimental setup.

It is well documented that temperature has an effect on the viscosity of water, which changes by approximately 2%/°C in the of 15-35°C temperature range, and this change is responsible for an estimated 40% change of infiltration rate between the summer and winter months (Barga et al., 2007; Lin et al., 2003).The basin experiment was conducted in the open while the soil column experiment was in a confined environment, leading to some difference in temperature between the two location. Our record of the measured hourly air temperature at both locations indicate some variation. This variation in the air temperature difference between laboratory and field conditions (basin) altered the viscosity of water modestly. However, these temperature variations are not actual difference in water temperature which directly dictates the change in viscosity but rather difference in measured air temperature. Water temperature at these locations were more likely to be stable (since we had at least 120 cm of water on top of our soil at both locations) than air and the water in the storage tanks possibly buffered some of these difference, therefore the resulting effect on viscosity were possibly less drastic. Moreover, even if the entire difference in temperature was in air, we it considered to have affected the temperature of water on a 1:1 ratio. The maximum difference in water viscosity levels due to temperature variations (maximum and minimum at 0.35 and -2.64 ° C) were found to be very minimal at 5.47×10^{-8} m^2/s to 7.3×10^{-9} m^2/s, than at the standard temperature of 25°C, but we took that into account in our overall infiltration calculation.

Table 2: Water quality data for secondary treated water and control water used for this study.

Parameters	Units	EPA Method	Source: Secondary Treated Water	Tap Water
pH	-	150.1	7.51	7.69
Conductivity	µmho/cm	120.1	853	222
TDS	mg/L	160.1	448	104
TSS	mg/L	160.2	<5	<5
Ammonia N	mg/L	350	15	0.15
Nitrate N	mg/L	353	3.6	0.12
TKN	mg/L	351	17	<2
Chloride	mg/L	325	89	104
O-Phosphate	mg/L	365	0.47	<0.02
Sulfates	mg/L	375	35	1.5
Total Organic Carbon	mg/L	415.1	.	.
Alkalinity Total CaCO3	mg/L	310.1	230	102
Calcium	mg/L	200.7	29.2	16.2
Iron	mg/L	200.7	0.07	<0.05
Magnesium	mg/L	200.7	14.6	5.35
Manganese	mg/L	200.7	0.03	<0.005
Potassium	mg/L	200.7	19	4

2.2.3 Water Balance

To estimate the whole basin infiltration rate on a daily basis, we used a water balance approach (equation 2):

$$I = V + P - E - \Delta V \qquad (2)$$

Water balance estimates varies with time but do not fluctuate substantially on an hour by hour basis for the infiltration basin (beyond the initial flooding period), for this large scale study the estimate was limited to daily basis to keep the modeling inputs within reasonable means. In a water balance approach, the infiltration (I) is a summation of total water input (V), precipitation (P), evaporation (E) and change in the basin volume (ΔV).

To monitor the infiltration rate (I) using water balance method, we installed an automated data acquisition system with five CR1000 data loggers (Campbell Scientific Inc., CR1000, Logan UT) along with 900 MHz radios (Campbell Scientific Inc., RF401, Logan UT), which communicated to a phone network. Three systems were placed in the basin at locations: east, middle, and west, to coincide with the soil cores location used for the soil column study. For each of location, we installed a Hydra Probe II (Stevens Water Monitoring Systems, Hydra II, Portland OR) that logged volumetric moisture content, temperature, and salinity (soil electrical conductance) at 0.6, 1.5, 3.0 and 5.5 m below the basin (Figure 5 & 6) every 15 minutes. The fourth station was installed next to the water inlet (SW Corner of the basin) and logged the cumulative volumetric input over time (V) to the basin using a magnetic water meter (EuroMag International, MUT220EL, Mestrino Italy), basin change in depth for estimating the active volume (ΔV) using pressure transducers (Global Water, WL400, College Station TX), rainfall (P) using a

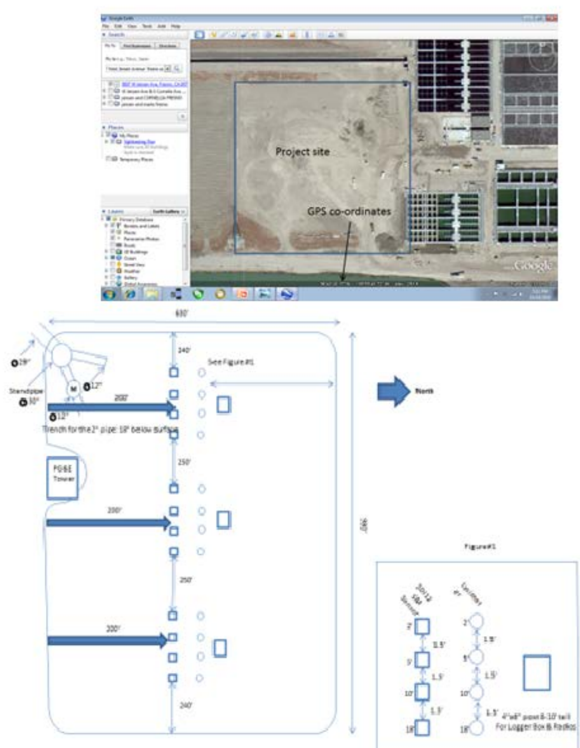

Figure 5: Reclamation Basin 3 at City of Fresno RWRF was instrumented with various sensors for the water balance and modeling work. The figure on top shows the aerial view of the basis, while the two schematics on the bottom shows the sensor layout.

digital tipping rain bucket (Texas electronics, TE525, Dallas TX). Evaporation (E) was estimated using Penman 1948 mass transfer equation(2) with the aid of a wind speed (RM Young, 5305, Traverse City MI), relative humidity sensor (Campbell Scientific Inc., HMP45C, Logan UT), air temperate (Campbell Scientific Inc., FW3, Logan UT) and barometric pressure (Campbell Scientific Inc., CS100, Logan UT) (Figures 6). This station on site collected data every 15 seconds and averaged it every 15 minutes before relaying it to the fifth (the base station) located about 1 km away near the treatment facility main office. The base station relayed the data to the server at California State University, Fresno daily at midnight using a phone system and modem (Campbell Scientific Inc., COM220, Logan UT). The central server computed the water budget data for the day at midnight after receipt of the data transmission and compared that to the acceptable high and low values for the soil type from the site.

Water flow into the reclamation basin is a key component of the water balance calculation. Inadequate installation and design of flow measuring instruments has resulted in underestimation of vertical hydraulic conductivity (Bomana et al. 1997). In our study site, accurate measurement of inflow of water into the reclamation basin provided some additional challenge as treated secondary water is normally moved around the RWRF facility using a series of open channel. Some of these channels are lined V-concrete channels while the rest are unlined earthen drains. Accurate measurement of flow in open channels presents some challenges (Bos et al., 1984; Shiono and Knight, 1991; Chanson, 2004). Our study reclamation basin 3 was connected to the open channel through an underground pipe that interfaced with a screw gate, creating issues with construction of a simple flume for flow measurements (Samani and Magallanez, 2000). We estimated that we needed a pipe size of over 50 cm to keep up with inflow to the basin. Flow meters for this pipe size were found to be prohibitively expensive. To address this issue, we built a standpipe assembly at the end of the underground pipe and connected that to two 30 cm diameter pipe for outflow; this also helped stabilize the water before it reached the measurement outlet. The two 30 cm diameter pipes were of same length and were levelled horizontally at the same elevation (Figure 6). An electronic magnetic meter providing minimal head loss was installed in one of the 30 cm diameter outlet pipes for flow measurement (Shinn et al., 2002; Belanger and

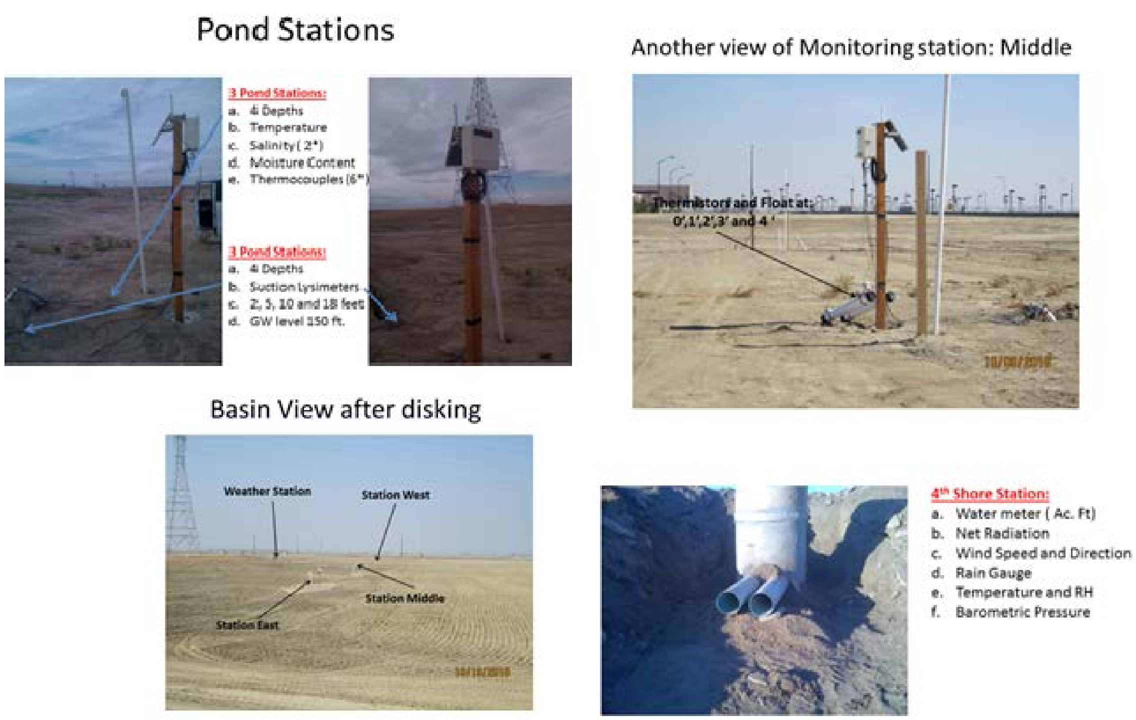

Figure 6: Instrumentations setup for basin 3, the three pond instrumentation location at were West, Middle, and East as shown in the bottom left image. The image on the bottom right show the modified standpipe assembly for measurement of water inputs.

Montgomery, 1992; Fellows and Brezonik, 1980). We tested and calibrated the magnetic flow meter at the International Center for Water Technology (ICWT) laboratory before installation and at the end of the study. We then calculated total flow by doubling the flow meter value.

The water supply to basin 3 was managed by the RWRF in consultation with the research team. Average flow rate in the basin were maintained at about 4.5 m^3/min with the aid of the screw gate adjustment. Once the basin was initially filled, water levels were maintained at depths ranging from 90-122 cm. We tracked the pond level changes with the aid of the aforementioned pressure transducers and a barometric sensor.

To account for direct precipitation on the basin, we used two tipping buckets, one located 2 m above the water surface in the middle of the basin and the other along the shore 2 m above the ground surface. The tipping buckets were inspected and calibrated on a biweekly basis. Data from the tipping buckets were averaged and compared against the National Weather Service (NWS) and CIMIS network for Fresno area. The data from the two tipping buckets agreed consistently but the overall data varied by about 7-12% as compared to the CIMIS and NWS, which can be attributed to local conditions.

Evaporation, a major component of water balance studies in arid/semi-arid settings like Fresno, involves interaction between components of soil, plants (if any) and the micrometeorological conditions (Xu and Singh, 1998). Evaporation primarily depends on supply of heat energy and the vapor pressure gradient, which indirectly depends on micrometeorological factors like temperature, wind speed, solar radiation, water quality, and atmospheric pressure (Stewart, 1976; Morton, 1968; Ferguson, 1952).

Evaporation rates from saturated soil surface and free-water evaporation from open basins are estimated the same way using potential evaporation (Bartholomeus et al., 2015; Winter et al., 1995; Panu and Nguyen, 1994). According to Xu and Singh (1998), the Penman (1948) method represents the best estimation of evaporation, agreeing most closely with pan evaporation. For this study, we used the Penman approach (3) to estimate evaporation from the basin.

$$E = 0.35(1 + 0.24u_2)(e_0 - e_a) \qquad (3)$$

where, E is free water evaporation, u_2 wind speed at 2 m height in m/s, and e_0 and e_a represents saturated and actual vapor pressure in mb respectively. To capture temporal changes in evaporation, we instrumented the station in the middle of the basin with, wind speed and direction sensors at 2 m height along with relative humidity sensor and barometric pressure sensor to calculate the rest of the parameters needed to estimate evaporation. Estimated evaporation rates were compared with evaporation rates reported by the National Weather Service and the CIMIS network (station #80). On-site estimates of evaporation were typically 2.7-6.9 % lower that CIMIS station#80, it is believed that the basin’s proximity to other water bodies (basins) led to some cooling effect in the micro-climate compared to the CIMIS weather stations. CIMIS weather stations are normally located on open fields with no water body in close proximity.

When water is added to the reclamation basin, the height of the water in the basin either increased or decreased depending on the rate of inflow relative to the infiltration and evaporation rates. The change in volume was positive when the height of water in the basin increased and negative when the water height decreased. This was captured by the level sensor (pressure transducer with an accuracy of ± 0.2% over the 0-150 cm range).

On a bi-weekly basis, all sensors with the exception of the ones buried in the soil, were inspected and tested against known calibration samples/standardized method. Any anomalies in the test results were flagged, with these accounting for less than 0.52 % of the total data set. Any flagged or missing meteorological data were replaced with data from the nearby CIMIS station #80. Flagged or missing underground sensor data were replaced with the average from the two other station locations in the basin.

The total precipitation measured at the site was 69.6 mm which was 11.1% higher than the amount of precipitation reported by two nearby CIMIS stations. Similarly, Evaporation data estimated using Penman (1948) during our study was 69.32 mm, which is 77.31% of the ET reported by nearly CIMIS network. The differences are mainly a function of the local conditions, like close proximity to water bodies (reclamation basins) and open land area, compared to the urban settings of the CIMIS stations.

The 15 minute data for flow rate (V), change in volume (ΔV**),** precipitation (P), and evaporation (E) were aggregated into hourly data to estimate the hourly infiltration rates; final data reported for this paper were converted into daily averages. Even though the instrumentation was setup to collect data at 15 minutes interval, our estimation showed minimal difference with every progressing hour (after the initial wetting period). Therefore to keep the number of model inputs reasonable the data was summarized for daily basis. Also, given the scale of this study, the emphasis was on estimating on a relatively broader timescale rather than estimate it on a minute by minute basis.

2.2.4 1D Modeling using Hydrus

Soil column and water balance method provides estimates on the amounts of water that infiltrates the soil surface, however it in not an indicator of the amounts that reaches the groundwater. To estimate the amounts of infiltrated water that contributes to recharge, computer modeling was needed. The Hydrus 1D version 4.16.0110 (Simunek, 2005) simulation package was used to simulate water movement at deeper depths using van Genuchten-Mualem single porosity soil hydraulic properties model:

$$S_e = \frac{\Theta - \Theta_r}{\Theta_s - \Theta_r} = [1 + (\alpha h)^n]^{-m}\text{, h} < 0, m = 1 - \frac{1}{n}$$

$$K(S_e) = K_s(S_e)^{0.5}[1 + (1 - {S_e}^{1/m})^m]^2$$

where S_e is dimensionless effective fluid saturation, Θ_r and Θ_s residual and saturated soil water content [L^3L^{-3}], K is hydraulic conductivity [LT^{-1}], K_s is the saturated hydraulic conductivity [LT^{-1}], n and m dimensionless shape parameters, and α is a scale parameter inversely proportional to mean pore diameter [L^{-1}] (van Genuchten 1980).

To estimate the recharge potential, the bottom of the model domain was set at 18 m below ground surface (at the average GW level) with observation nodes placed at 0.5, 1.5, 3 and 5.5 m depths to replicate sensor position in the reclamation basin number 3(Figure 7). Time units were set in days, and time- variable boundary conditions for each of the 465 days were pressure head (from the level logger), time dependent soil temperature at the soil surface boundary, and time dependent temperature of the incoming water (all of which were imported from the weather station and pond station middle) (Table 4).

Time series for meteorological and soil data were obtained from the middle station only, and the results from the three stations were quite similar.

Soil volumetric water content collected by the Stevens Hydra Probe II at 0.5, 1.5, 3 and 5.5 m depths was used as part of the inverse solution to optimize the soil hydraulic parameters. The soil water content values were corrected for soil type and water quality by running calibration equation in the laboratory prior to installation and corrected for in the logging program. Even though the soil moisture sensors were logging data every 15 minutes the input data to the inverse solution was limited to 15 minutes for the first 15 days then expanded to 3 hours for the next 15 days followed by every 3 hours for the next 30 days and then to once a day (this was done to keep the inverse data points to under 9860 records). For the water flow boundary condition, the upper layer was set to variable pressure and the lower boundary condition set to deep drainage.

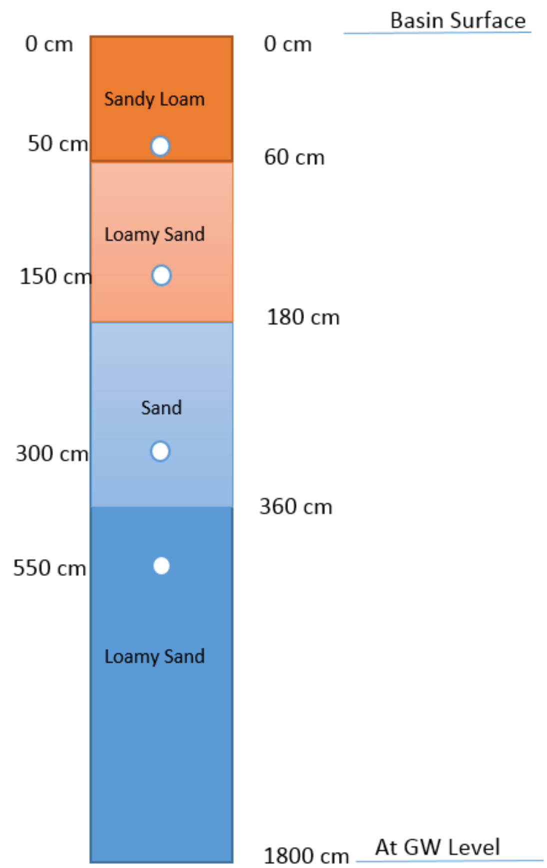

Figure 7: The soil profile geometry, soil type, and the location of the observation nodes within the profile. The observation nodes denoted by the white circles represents the Stevens Hydra Probe II at 0.5, 1.5, 3.0 and 5.5 m below the basin surface. The profile shown is not to scale

The total number of soils layers were limited to four (top layer Sandy loam, next layer Loamy sand, followed by Sand and again Loamy Sand as the bottom layer). Table 3 shows the ranges of hydraulic parameters of the four soils that were fitted. Ks values for the top layer was chosen from the soil column experiment (since the height of the soil column accurately represented the height of the top soil layer in the basin and in the model). For the bottom soil material (loamy sand), we used the Ks ranges using the sand, silt, clay content of the actual soil along with the bulk density (Table 1) used as input to the US Salinity labs Rosetta soil parameter estimation model. The hydraulic parameters were optimized first for the top layer followed by next layer below the bottom layer, sequentially for Θ_r , Θ_s, α, n , and K_s. The optimization process had to be repeated several times until no further improvement was noticed for water balance % and model residuals.

Table 3: Hydrus 1D modeling parameters.

Variables	Conditions	Selection
Main Process	Water flow	Yes
	Heat Transport	Yes
Inverse function	Soil Hydraulic Parameters & Resident Concentration	Yes & data points 9860
Geometry Information	Number of Soil Material	4
	Number of Layers for Mass Balance	4
	Depth	1800cm
Time Information	Time Units	Days
	Initial time step	0.001
	Final time step	465
	Time Variable Boundary Condition	465
	Meteorological data	465
Soil Hydraulic Model	van Genuchten-Maulem, with Air Entry and No Hysteresis	
Water Flow Boundary Condition	Upper Boundary Condition	Atmospheric BC with Surface layer
	Lower Boundary Condition	Deep Drainage
Heat Transport Boundary Condition	Upper Boundary Condition	Temperature BC
	Lower Boundary Condition	Zero Gradient

2.3. Results

2.3.1 Soil Columns

Soil column experimental data collected over the 330 day period were analyzed for infiltration rates, and compared with the mass balance method; compared within the three location and compared for differences in quality of the water used in the infiltration experiment (Figures 8-12 and Table 4).

For the columns blocked from sunlight, there was a considerable difference between the treated and control soil after several months of operation. At day 7, the behavior of the treated and control columns was roughly the same (Figures 8, 9, 10 & 11; Table 4), with the treated column infiltration averaging 129.3, 133.9, and 128.5 mm/day (*S.E =1.61*) for east, middle and west soils respectively. The corresponding control column infiltration rates for the same time period were approximately the same: 128.3, 132.3, and 128.8 mm/day (*S.E = 1.27*) for east, middle and west soils respectively (Figures 8, 9, & 10 and Table 4). The ANOVA analysis, shows that the means of treated and control are equal (F< Fcrit) with a P-value of 0.51. However, at day 150 the treatment columns were 75.1 (*S.E = 1.04*) and control rates with no light were at 91.3 mm/day (*S.E = 1.11*), indicating an average declining difference of 12.3% for the treated columns. We begin to see the effect of clogging and there is statistical differences between treated and control soil columns.

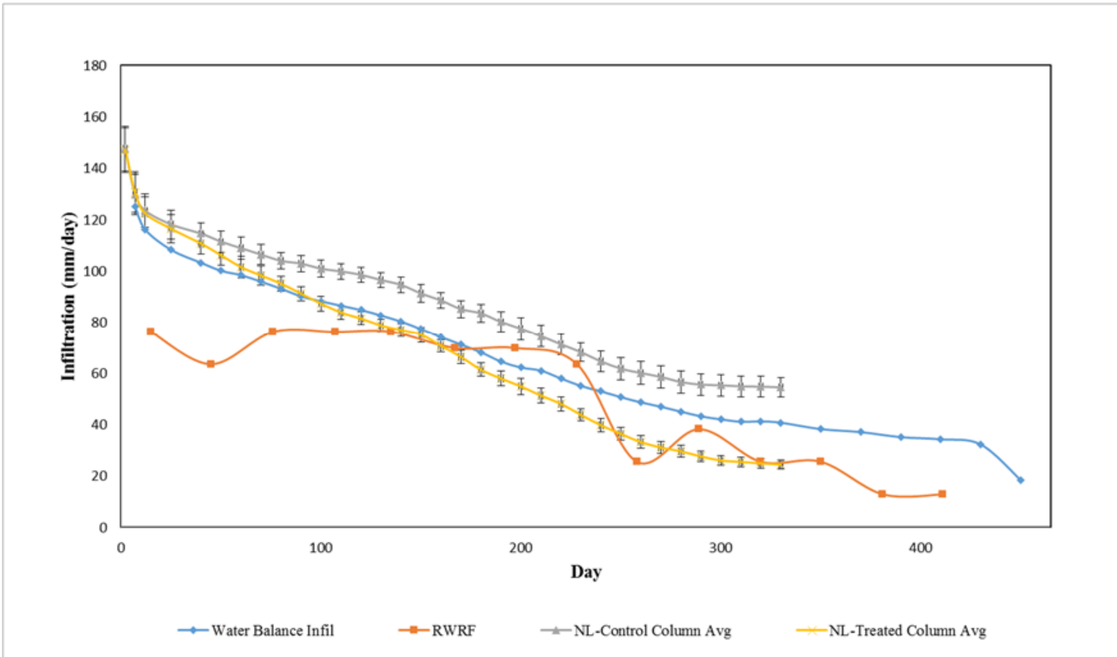

Figure 8: Longitudinal comparison of infiltration measurements using soil columns, our water balance calculation, and RWRF water balance method. The soils for the column experiment were identical for both control and treated, but treated columns received secondary treated water while the control columns received tap water. The error bars indicate the SE due to the difference in air temperature for the two location, and are very negligible.

Similarly, at day 210 the treated soil columns with no light were at 51.2 mm/day (*S.E = 2.87*) and control rates with no light were at 74.5 mm/day (*S.E = 2.41*), with an average difference of 17.5% and decline in the rate for the treated side with time. Finally, on day 330 the values were at 24.3 mm/day (*S.E=3.67*) and control rates were at 54.4 mm/day (*S.E=3.89*), again a difference of 23.2 % and decline in the rate for the treated side with statistical difference (F> Fcrit) with a p-value of 5×10^{-10}.

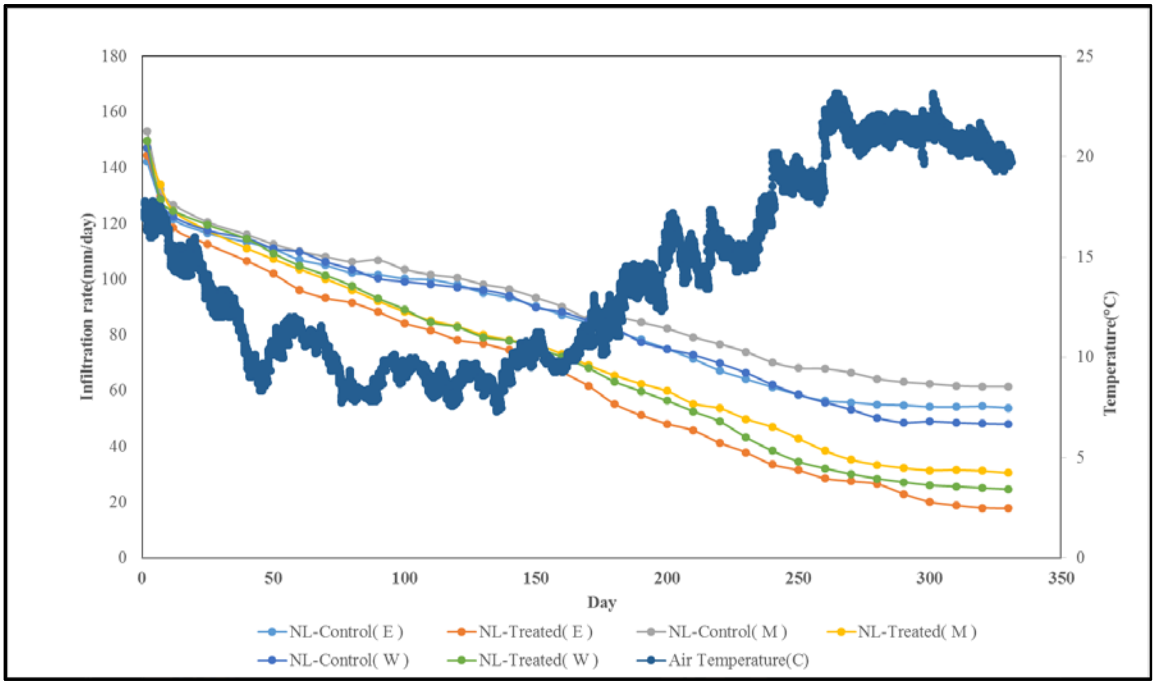

Figure 9: Longitudinal comparison of infiltration measurements between columns treated with secondary water and tap water. The primary-axis is for the infiltration rate while the secondary-axis is for the air temperature of the column experimental study area. Air temperature data is used to see to verify if there were any seasonal fluctuation in the infiltration rate due to change in temperature.

The gap between control and treated soil column rates increased as time progressed, with differences being negligible in the beginning and increased with time. The differences were 0.93, 16.2, 23.3, and 30.1 mm/day for days 7, 150, 210, and 330 respectively for columns not exposed to light. Aside from the use of treated water versus potable tap water, all other factors were same for treated versus control columns. The only logical explanation to these differences can be attributed to the presence of total suspended solids in the treated water that led to clogging and/or the soils became more bio-active due to the nutrient load of the effluent water. The soils packed into the soil columns were air dried and not sterilized such that the columns supported biological growth when wetted. Additionally, we believe the control columns also exhibited a steady slow down due to bio-active nature of the soils, even though they were exposed to potable water (which obviously had minimal nutrient and TSS loads, Table 2).

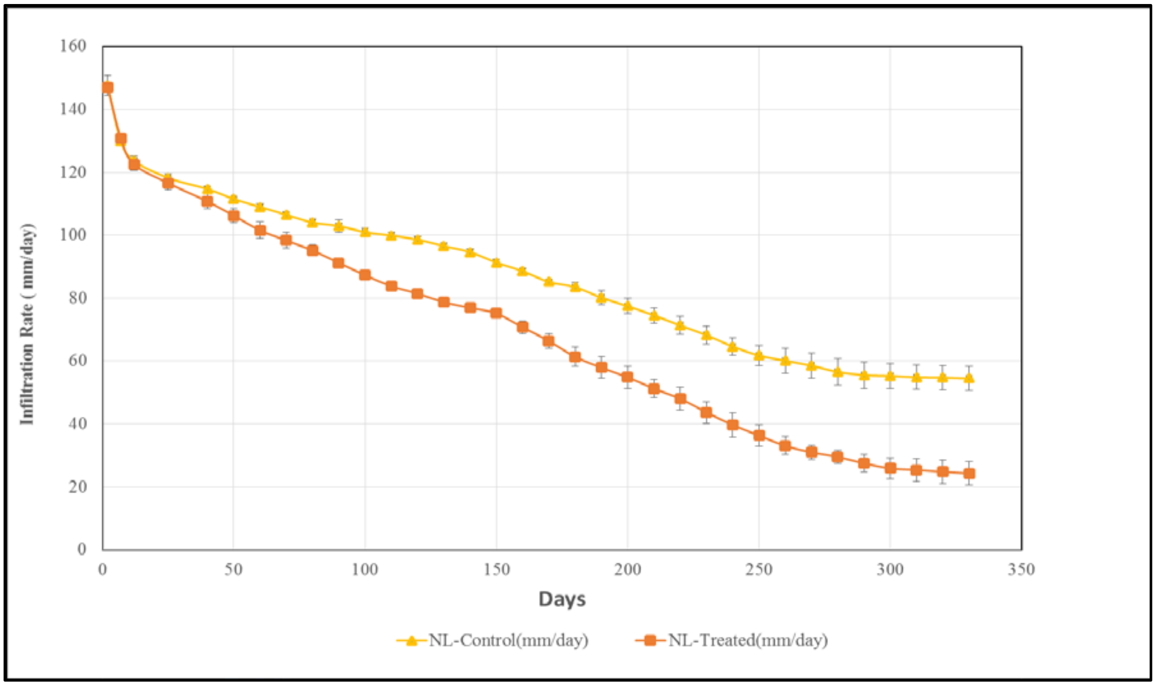

Figure 10: Longitudinal comparison of infiltration measurements between columns treated with secondary water and tap water exposed to ambient light. The graph shows the standard error between the two water qualities.

Possible reasons for the clogging in the control columns included (1) biological growth of soil microorganisms utilizing soil organic matter as a substrate, (2) redistribution of fine materials (silts, clays) so as to restrict soil permeability, and (3) gradual accumulation of the low-levels of TSS from the potable water.

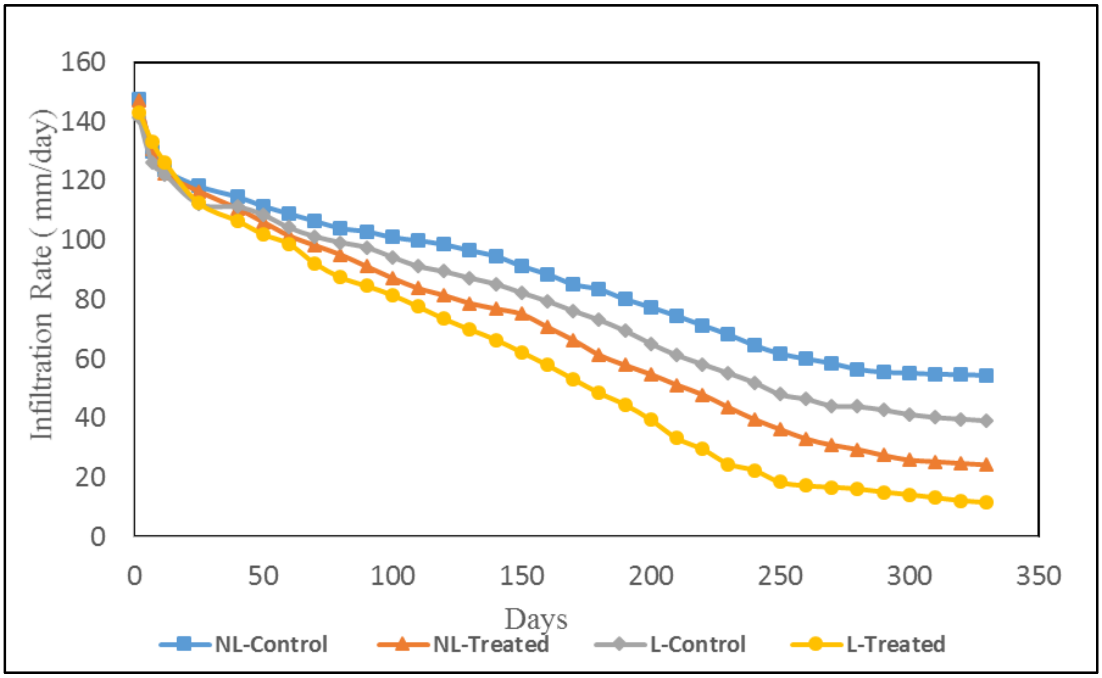

Figure 11: Longitudinal comparison of averages from soil columns with ambient light and no light conditions.

For the same time period, the columns exposed to light exhibited lower infiltration rates (Figure 11 and Table 4). For the treated columns they were 133.3 (*S.E=1.13*), 62.3(*S.E=0.86*), 33.2 (*S.E=0.20*) and 11.6 (*S.E=.17*) mm/day for days 7, 150, 210 and 330 respectively. While the corresponding control infiltration values were at 126.23, 82.29, 61.25 and 39.14 mm/day for days 7, 150, 210 and 330 respectively. These values correspond with ratios for treated to control columns of 1.05, 0.75, 0.54 and 0.29 for day 7, 150, 210 and 330 respectively. The columns exposed to light exhibited greater reductions in infiltration over time, compared to the columns not exposed to light. We believe this increased difference could be attributed to photosynthesizing organisms (e.g. algae) from the effluent in the soil. However, we cannot specify the organisms that may have caused the reduced infiltration rate, since no biological work was done with this column contents.

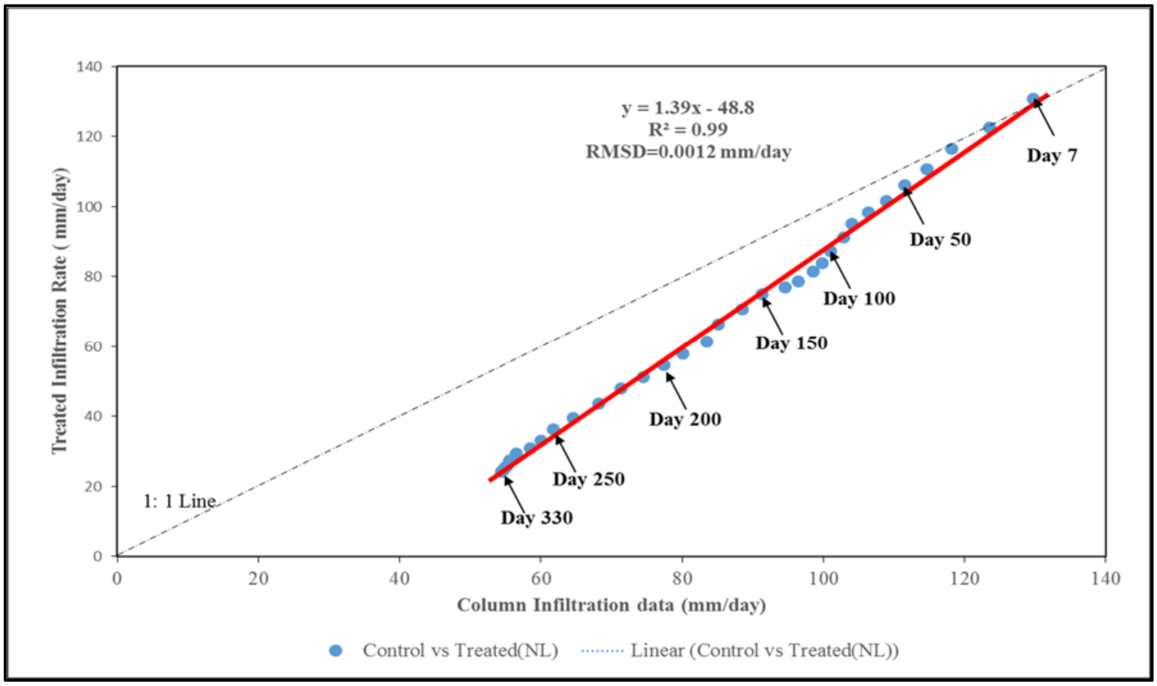

Figure 12: Relationship between control columns and treated columns under no light condition. The linear equation provides the correction factor along with the regression.

In spite of the difference in infiltration rate for treated vs control soil columns over the period of 330 days, there seems to be a linear relationship to the steady decline in the infiltration rate between the two water qualities (Figure 12).

Table 4: Comparison of Saturated Hydraulic Conductivity in Soil Columns during various phases of the study.

	Location(under no light)									
Days	**East(mm/day)**		**Middle(mm/day)**		**West(mm/day)**		**All(Std Err)**		**Columns fully exposed to light**	
	Ctrl	**Trt**	**Ctrl**	**Trt**	**Ctrl**	**Trt**	**Ctrl**	**Trt**	**Ctrl**	**Trt**
7	128.3	129.8	132.3	133.8	128.8	128.5	1.3	1.6	126.2	133.3
150	90.4	73.2	93.4	76.7	89.9	75.4	1.1	1.0	82.3	62.3
210	71.3	45.7	79.2	55.4	72.9	52.6	2.4	2.9	61.3	33.2
330	53.8	17.7	61.4	30.5	48.0	24.6	3.9	3.7	39.1	11.6

2.3.2 Water Balance

The highest infiltration rate by the water balance approach was 125.2 mm/day and min was 17.0 mm/day (Figure 8). Basin 3 was put into operation from Oct 17 2010, however data could not be reliably computed for the first 6 days as the basin was slowly filling up, creating a lot of turbulence on the surface for the level gauge to detect the change in level. Infiltration rate from basin number 3 using water balance method was 125.2 mm/day for day 7, compared to 130.7 mm/day for the treated none light exposed soil columns. At day 150 the numbers reduced to 77.26 mm/day or 38.3 % reduction compared to 35.9 % reduction for the soil columns. Similarly, at day 210 the water balance method resulted in infiltration rate of 60.96 mm/day which is a 51.3 % reduction compared to 60.8 % reduction for the soil columns. Finally, on day 330 the soil columns exhibited a reduction of 81.4 % compared to 67.5 % at 40.6 mm/day for the water balance method. In Figure 13, the relationship between soil column infiltration rate and water balance-based infiltration rate is summarized. As we can see from Figure 13, the infiltration rates were quite high for both methods in the beginning and slowly declined over time. The higher values to the right of the graph as denoted by the annotation are from the beginning of the study and shifted to lower values and moved to the left. However, irrespective of the decline in the rate, there was a close linear correlation between the two methods and is confirmed by the regression equation and r^2 values (Figure 13).

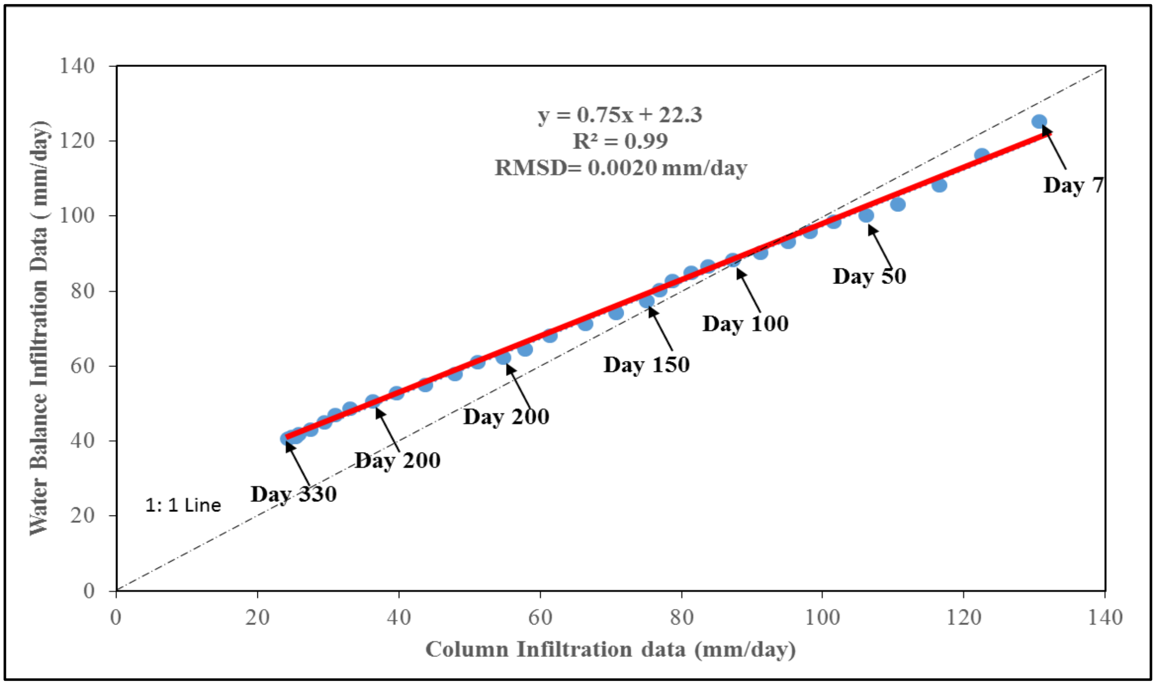

Figure 13: Relationship between soil column infiltration rates versus water balance. The linear equation provides the relationship and fit between the two methods as it progressed with time. The values being higher in the beginning of the study compared to low values towards the end.

2.3.3 HYDRUS modeling

Because our infiltration monitoring and the water balance approach test mainly assess to surface and shallow subsurface phenomena, we used Hydrus 1D to simulate the water flow at deeper depths to groundwater at 18 meters. Since a limited portion of the data and analysis was used in 1D simulation of Hydrus, we will limit the findings in this chapter to model calibration results to the hydraulic parameters. Hydrus 1D converged reasonably well with field measurements of water content (r^2 = 0.72). Figure 14 shows the model fit and corresponding sensor data for calibration. The time axis of the calibration fit (Figure 14) is in log scale. The fitted parameters (α, n and Ks) were forced to remain within the range expected for the three soil types used (sandy loam, loamy sand

and sand). Table 5 shows the actual soil parameters based on the soil texture classification, and Table 6 is the final parameter based on Hydrus model fit. For the best-fitting simulations, bottom drainage flux values output by Hydrus 1D pointed to a steady recharge rate of 12 mm/day at 18 m (at GW level) on day 53 of operating the basin, dropping to 9.7 mm/day at day 223.

Table 5: Hydraulic parameters for the four soils types used in the Hydrus modeling based on the soil sample average for basin 3.

USDA Soil Texture Class	Θ_r	Θ_s	α	n	K_s
Sandy Loam(0-60 cm)	0.053	0.418	0.0172	1.46	42.87
Loamy Sand (60-180 cm)	0.056	0.419	0.0318	2.04	220.74
Sand (180-360 cm)	0.060	0.422	0.0294	2.33	320.93
Loamy Sand (360-1800 cm)	0.057	0.427	0.0311	2.14	267.93

The Hydrus 1D model water balance numerical error for the best-fitting simulations was 0.3% with a root mean square weighted error RMSE=0.045. Unlike r^2, which is a relative measure of a models fit, RMSE is an absolute measure of fit. RMSE is also an indicator of samples standard deviation of the observed versus fitted, and is a good measure of accuracy.

Table 6: Hydraulic parameters obtained from best fit of the model.

USDA Soil Texture Class	Θ_r	Θ_s	α	n	K_s	**R^2**
Sandy Loam(0-60 cm)	0.08	0.37	0.039	2.5	36.49	0.78
Loamy Sand (60-180 cm)	0.08	0.39	0.035	2.42	170.24	
Sand (180-360 cm)	0.03	0.35	0.09	2.75	223.46	
Loamy Sand (360-1800 cm)	0.09	0.32	0.042	2.39	161.54	

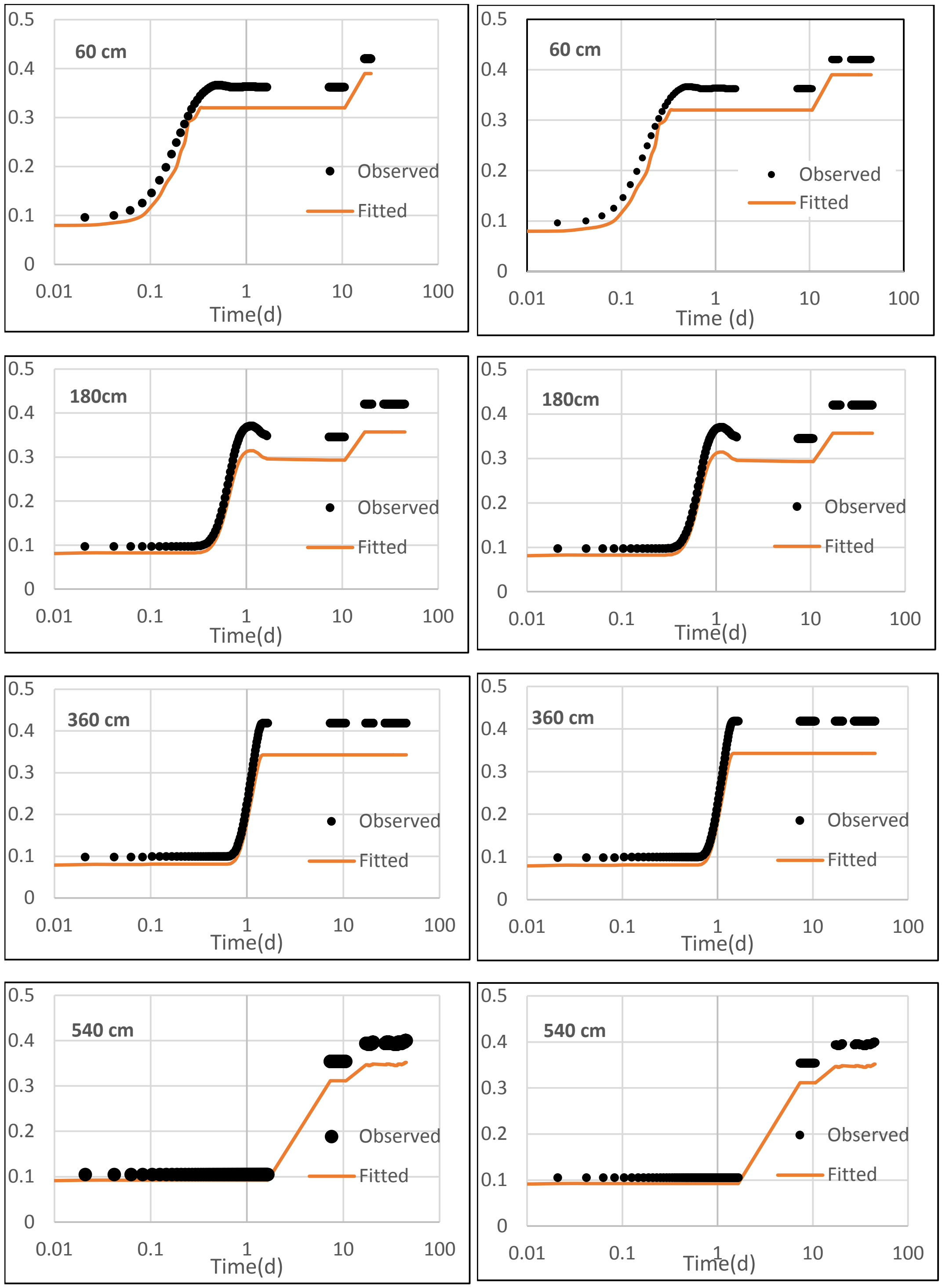

Figure 14: Basin 3, Hydrus 1 D observed and simulated results for water content, day 3 (left) and day 45 (right). The time on x-axis is logarithmic scale, log scale is used to demonstrate the magnitude change appropriately.

2.4 Discussion

The soil column results were roughly the same for all replicates at each location and between the three locations (east, middle and west). The soil column infiltration rates were comparable but 33% higher than those observed in the basin using the water balance approach. Such variations between column and *in situ* flow behavior is commonly attributed to differences in soil structure and are not surprising (Hillel, 1980; Wolf, 1987; Mueller, 2013). The soils packed into the columns were disaggregated and homogenized to aid in packing, and represent a more idealized, homogenous system in which the flow is forced (by the column walls) to infiltrate vertically. In the basin subsurface, flow will tend to move horizontally if barriers or reductions in permeability are encountered in the vertical dimension.

Even though we had differences between water balance and soil columns infiltration values, the difference were consistent throughout the test period (Figure 8). The results indicate that the basin infiltration rate was consistently between 68-82 % of the soil column rate. This finding is consistent with that of Ollivier et al. (2013), who found that basin infiltration rates were approximately 68.3 % of soil column rates. While this result demonstrates the potential for using less expensive approaches such as soil columns as physical models of basin behavior, they also point to the limitations of simplistic approaches. Thus, although the correlation is strong in this case, it applies only to the single basin test case and should not be taken as a general finding.

For the water balance method in our test basin, the overall infiltration rate was similar to the potential infiltration rates reported by NRCS/USDA for these loamy soils.

The initial infiltration rates started high, followed by a sharp decline for the first 30 days. It was followed by a slower decline for the next nine months and reached steady infiltration state for the reminder of the test period. This behavior is consistent with previous findings (Sisson et al. 1981; Bear, 2010). The higher infiltration rates is observed initially when the moisture content is low, mainly due to the influence of macrostructure, preferential pathways and anisotropy (Cislerova et al 1988). As infiltration progresses, the moisture content increases, increasing the air entrapment in the large pores sealed off by water films severely reducing saturated hydraulic conductivity (Parlange and Hill; 1976). Infiltration rates reaches a minimum steady rate, when the soil reaches saturated moisture content. Water balance unlike the soil column method (where samples were collected from various location in the basin and analyzed separately for spatial variability) gives us the overall infiltration rate for the whole basin. We know soils vary spatially with different infiltration rate areas within the basin, which in this process gets masked and we get an average rate for the whole basin.

With respect to comparing our continuous monitoring approach with the City of Fresno's current approach, their rate were initially low but after about 150 days their observation were within the upper (soil column) and lower (basin water balance) bounds (Figure 8). Our water balance estimates were higher than RWRF reported infiltration rate for the initial 90-150 day period. The difference amounts to roughly 434,700 m^3 of water (352.4 acre-ft) of infiltration not accounted for by the city. We believe this is due to the irregularity of the manual 30 cm graduated staff gauge used by the city, and estimation error in the evaporation component as they average the evaporation as 70% of ET, which is not always true (Popov, 2001). During our study period we noticed the evaporation values to be anywhere within 59-87 % of the local ET, depending on weather conditions and time of the year. CIMIS now maintains an evaporation pan for most of its stations, and use of this data would likely improve the City's estimate. While this data is not available on the regular CIMIS download page, it can be obtained by contacting the local CIMIS office. In addition, data is collected by city authorities for their estimation once every 7-10 days and averaged for the month. The irregularity of the observations coupled with the inaccurate staff gauge could have contributed to inaccuracy of their estimation method.

The City's water balance method did not provide an accurate estimation of the infiltration rate of the basin's and thereby reflecting on the duty cycle of the pond. Inaccurate and untimely servicing of the reclamation basin due to the poor water balance method used by the City adds not only financial cost and manpower but also impacts the environment (since servicing the basin require the use of heavy machinery like a D7 or a D9 caterpillar, which consume fuel and has a relatively large carbon footprint).

2.5. Conclusions

Our laboratory and field data showed close agreement between the fields measured data and laboratory data, even after the effects of the temperature was over accounted for in our calculation. As secondary treated water becomes a viable alternative to enhance aquifer recharge, assuming environmental concerns can be addressed, utilities can examine the use of small, inexpensive column experiments to estimate the infiltration potential of their given soil type using secondary treated water. This not only provides them the infiltration potential, but this extended method provides added information on the duty cycle or time series analysis of these basin for management purposes. The column approach also reduces the need for elaborate and expensive water balance procedure. Based on our study data on loamy soil conditions, the actual water balance infiltration estimates could be derived from the soil columns by using the experimental multiplier and offset (for the present case, the multiplier = 0.75 and offset = 22.35). However, to obtain good reliable data, the columns needs to be packed carefully to maintain the same soil profile and bulk density as in the field conditions. Our estimated infiltration data agree with the literature data for these soil types and water quality (NRCS and USDA 2014, Pavelic et al. 2005, Dillion et al. 1999).

The accuracy of the RWRF data is possibly compromised due to the use of a staff gauge with 30 cm graduation, rounding off of water run times and lack of on-site precipitation data and of daily data collection. Some of the error may be also be attributed to the constant 70% of evapotranspiration(ET) value, used for evaporation estimate throughout the year regardless of local conditions. This is definitely of concern for the utilities as it leads to use inefficient use of man power and machinery, both of which can have financial and environmental impact.

Both water balance and soil column approaches mainly address infiltration of water into the shallow subsurface and deeper vadose zone. However, that fails to demonstrate groundwater recharge directly, and hence we address this aspect of the problem using a detailed computational approach in Chapter 3.

Reference

Arnell, N. W., Liu, C., Compagnucci, R., da Cunha, L., Hanaki, K., Howe, C., ... & Stakhiv, E. (2001). Climate Change 2001: impacts, adaptation and vulnerability. *Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, 191-234.

Asano, T. (Ed.). (1998). *Wastewater Reclamation and Reuse: Water Quality Management Library* (Vol. 10). CRC Press.

Asano, T., & Levine, A. D. (1996). Wastewater reclamation, recycling and reuse: past, present, and future. *Water Science and Technology*, *33*(10), 1-14.

Auset, M., & Keller, A. A. (2004). Pore-scale processes that control dispersion of colloids in saturated porous media. *Water Resources Research*, *40*(3).

Braga, A., Horst, M., & Traver, R. G. (2007). Temperature effects on the infiltration rate through an infiltration basin BMP. *Journal of irrigation and drainage engineering*, *133*(6), 593-601.

Bartholomeus, R. P., Stagge, J. H., Tallaksen, L. M., & Witte, J. P. M. (2015). Sensitivity of potential evaporation estimates to 100 years of climate variability. *Hydrology and Earth System Sciences*, *19*(2), 997-1014.

Baveye, P., Vandevivere, P., Hoyle, B. L., DeLeo, P. C., & de Lozada, D. S. (1998). Environmental impact and mechanisms of the biological clogging of saturated soils and aquifer materials. *Critical Reviews in Environmental Science and Technology*, *28*(2), 123-191.

Bear, J. (2012). *Hydraulics of groundwater*. Courier Corporation.

Belanger, T. V., & Montgomery, M. T. (1992). Seepage meter errors. *Limnology and Oceanography*, *37*(8), 1787-1795.

Bomana, G. K., Molz, F. J., & Boonec, K. D. (1997). Borehole flowmeter application in fluvial sediments: Methodology, results, and assessment. *Groundwater*, *35*(3), 443-450.

Bos, M. G., Replogle, J. A., & Clemmens, A. J. (1984). Flow measuring flumes for open channel systems.

Bouwer, H. (1991). Role of groundwater recharge in treatment and storage of wastewater for reuse. *Water Science & Technology*, *24*(9), 295-302.

Bouwer, H., Ludke, J., & Rice, R. C. (2001). Sealing pond bottoms with muddy water. *Ecological Engineering*, *18*(2), 233-238.

Bouwer, H. (2002). Artificial recharge of groundwater: hydrogeology and engineering. *Hydrogeology Journal*, *10*(1), 121-142.

Bradford, S. A., & Torkzaban, S. (2008). Colloid transport and retention in unsaturated porous media: A review of interface-, collector-, and pore-scale processes and models. *Vadose Zone Journal*, *7*(2), 667-681.

Chadwick, M. J., Edworthy, K. J., Rush, D., & Williams, P. J. (1974). Ecosystem irrigation as a means of groundwater recharge and water quality improvement. *Journal of Applied Ecology*, 231-247.

Chandrasekar, V., Chen, H., & Maki, M. (2012, November). Urban flash flood applications of high-resolution rainfall estimation by X-band dual-polarization radar network. In *SPIE Asia-Pacific Remote Sensing* (pp. 85230K-85230K). International Society for Optics and Photonics.

Chanson, H. (2004). *Hydraulics of open channel flow*. Butterworth-Heinemann

Císlerová, M., Šimůnek, J., & Vogel, T. (1988). Changes of steady-state infiltration rates in recurrent ponding infiltration experiments. *Journal of hydrology*, *104*(1), 1-16.

Dean, R. B., & Lund, E. (1981). Water reuse: problems and solutions. *Academic Press, London England. 1981. 264*.

Dillon, P., Toze, S., Pavelic, P., Ragusa, S., Wright, M., Peter, P., ... & Rinck-Pfeiffer, S. (1999). Storing recycled water in an aquifer: benefits and risks. *WATER-MELBOURNE THEN ARTARMON-*, *26*, 21-30.

Drewes, J. E., Heberer, T., Rauch, T., & Reddersen, K. (2003). Fate of pharmaceuticals during ground water recharge. *Groundwater Monitoring & Remediation*, *23*(3), 64-72.

Dullien, F. A. (2012). *Porous media: fluid transport and pore structure*. Academic press.

Fellows, C. R., & Brezonik, P. L. (1980). SEEPAGE FLOW INTO FLORIDA LAKES1.

Ferguson, J. (1952). The rate of natural evaporation from shallow ponds. *Australian Journal of Chemistry*, *5*(2), 315-330.

Fleckenstein, J., Anderson, M., Fogg, G., & Mount, J. (2004). Managing surface water-groundwater to restore fall flows in the Cosumnes River. *Journal of Water Resources Planning and Management*, *130*(4), 301-310.Green, W.H. and Ampt, G.A., Studies on soil physics. I. The flow of air and water through soils, *J. Agric. Sci.*, 4, 1–24, 1911.

Gallardo, A. H., Marui, A., Takeda, S., & Okuda, F. (2009). Groundwater supply under land subsidence constrains in the Nobi Plain. *Geosciences Journal*, *13*(2), 151-159.

Gleeson, T., Wada, Y., Bierkens, M. F., & van Beek, L. P. (2012). Water balance of global aquifers revealed by groundwater footprint. *Nature*, *488*(7410), 197-200.

Grant, S. B., Saphores, J. D., Feldman, D. L., Hamilton, A. J., Fletcher, T. D., Cook, P. L., ... & Marusic, I. (2012). Taking the “waste” out of “wastewater” for human water security and ecosystem sustainability. *Science*, *337*(6095), 681-686.

Gravity Recovery and Climate Experiment (GRACE) (2011). Gravity Recovery and Climate Experiment. Retrieved November 05, 2011 from http://www.csr.utexas.edu/grace/

Greskowiak, J., Prommer, H., Massmann, G., Johnston, C. D., Nützmann, G., & Pekdeger, A. (2005). The impact of variably saturated conditions on hydrogeochemical changes during artificial recharge of groundwater. *Applied Geochemistry*, *20*(7), 1409-1426.

Goss, D. W., Smith, S. J., Stewart, B. A., & Jones, O. R. (1973). Fate of suspended sediment during basin recharge. *Water Resources Research*, *9*(3), 668-675.

Habib, E., Krajewski, W. F., & Kruger, A. (2001). Sampling errors of tipping-bucket rain gauge measurements. *Journal of Hydrologic Engineering*, *6*(2), 159-166.

Han, J., Jin, Y., & Willson, C. S. (2006). Virus retention and transport in chemically heterogeneous porous media under saturated and unsaturated flow conditions. *Environmental science & technology*, *40*(5), 1547-1555.

Harou, J. J., & Lund, J. R. (2008). Ending groundwater overdraft in hydrologic-economic systems. *Hydrogeology Journal*, *16*(6), 1039-1055.

Harvey, F. E., Ayers, J. F., & Gosselin, D. C. (2007). Ground water dependence of endangered ecosystems: Nebraska's eastern saline wetlands. *Groundwater*, *45*(6), 736-752.

Heilweil, V. M., Solomon, D. K., & Gardner, P. M. (2006). Borehole environmental tracers for evaluating net infiltration and recharge through desert bedrock. *Vadose Zone Journal*, *5*(1), 98-120.

Hendrickx, J. M., & Flury, M. (2001). Uniform and preferential flow mechanisms in the vadose zone. *Conceptual models of flow and transport in the fractured vadose zone*, 149-187.

Heilweil, V. M., Solomon, D. K., & Gardner, P. M. (2007). *Infiltration and recharge at Sand Hollow, an upland bedrock basin in Southwestern Utah*. US Geological Survey.

Hiemenz, P. C., & Rajagopalan, R. (Eds.). (1997). *Principles of Colloid and Surface Chemistry, revised and expanded* (Vol. 14). CRC press.

Hillel, D. (1980). *Fundamentals of soil physics*. Academic Press, Inc.(London) Ltd.

Humphrey, M. D., Istok, J. D., Lee, J. Y., Hevesi, J. A., & Flint, A. L. (1997). A new method for automated dynamic calibration of tipping-bucket rain gauges. *Journal of Atmospheric and Oceanic Technology*, *14*(6), 1513-1519.

Izbicki, J. A., Flint, A. L., & Stamos, C. L. (2008). Artificial recharge through a thick, heterogeneous unsaturated zone. *Groundwater*, *46*(3), 475-488.

Javier, J. R. N., Smith, J. A., Meierdiercks, K. L., Baeck, M. L., & Miller, A. J. (2007). Flash flood forecasting for small urban watersheds in the Baltimore metropolitan region. *Weather and Forecasting*, *22*(6), 1331-1344.

Jawson, M. D. (1976). *Soil clogging by septic tank effluent: causes, methods of correction*. University of Wisconsin--Madison.

Knowles, P., Dotro, G., Nivala, J., & García, J. (2011). Clogging in subsurface-flow treatment wetlands: occurrence and contributing factors. *Ecological Engineering*, *37*(2), 99-112.

Kreissl, J.F. (1978). *Management of small waste flows, in Project on small scale waste management.* University of Wisconsin at Madison.

Larson, L. W., & Peck, E. L. (1974). Accuracy of precipitation measurements for hydrologic modeling. *Water Resources Research*, *10*(4), 857-863.

Lin, C., Greenwald, D., & Banin, A. (2003). Temperature dependence of infiltration rate during large scale water recharge into soils. *Soil Science Society of America Journal*, *67*(2), 487-493.

Lettenmaier, D. P., Wood, A. W., Palmer, R. N., Wood, E. F., & Stakhiv, E. Z. (1999). Water resources implications of global warming: A US regional perspective. *Climatic Change*, *43*(3), 537-579.

Matthews, G. P., Laudone, G. M., Gregory, A. S., Bird, N. R. A., Matthews, A. G., & Whalley, W. R. (2010). Measurement and simulation of the effect of compaction on the pore structure and saturated hydraulic conductivity of grassland and arable soil. *Water Resources Research*, *46*(5).

Massmann, G., Sültenfuß, J., Dünnbier, U., Knappe, A., Taute, T., & Pekdeger, A. (2008). Investigation of groundwater residence times during bank filtration in Berlin: a multi-tracer approach. *Hydrological Processes*, *22*(6), 788-801.

McMillan, H., Jackson, B., Clark, M., Kavetski, D., & Woods, R. (2011). Rainfall uncertainty in hydrological modeling: An evaluation of multiplicative error models. *Journal of Hydrology*, *400*(1), 83-94.

Maxey, G. B., & Eakin, T. E. (1949). *Ground water in White River Valley, White Pine, Nye, and Lincoln Counties, Nevada*. Nevada State Engineer.

METZGER, L., YARON, B., & MINGELGRIN, U. (1983). Soil hydraulic conductivity as affected by physical and chemical properties of effluents. *Agronomie*, *3*(8), 771-778..

Morton, F. I. (1968). EVAPORATION AND CLIMATE- A STUDY IN CAUSE AND EFFECT.

Mueller, L., Shepherd, G., Schindler, U., Ball, B. C., Munkholm, L. J., Hennings, V., ... & Hu, C. (2013). Evaluation of soil structure in the framework of an overall soil quality rating. *Soil and Tillage Research*, *127*, 74-84.

Nimmo, J. R., Stonestrom, D. A., & Akstin, K. C. (1994). The feasibility of recharge rate determinations using the steady-state centrifuge method. *Soil Science Society of America Journal*, *58*(1), 49-56.

Nellor, M. H., Rodger B. B,, & John R. S. (1985). "Health effects of indirect potable water reuse." *Journal-American Water Works Association* 77.7, 88-96.

Ollivier, P., Surdyk, N., Azaroual, M., Besnard, K., Casanova, J., & Rampnoux, N. (2013). Linking water quality changes to geochemical processes occurring in a reactive soil column during treated wastewater infiltration using a large-scale pilot experiment: Insights into Mn behavior. *Chemical Geology*, *356*, 109-125.

Panu, U. S., & Nguyen, T. (1994). Estimation of mean areal evaporation in northwestern Ontario. *Canadian Water Resources Journal*, *19*(1), 69-82.

Pavelic, P., Nicholson, B. C., Dillon, P. J., & Barry, K. E. (2005). Fate of disinfection by-products in groundwater during aquifer storage and recovery with reclaimed water. *Journal of contaminant hydrology*, *77*(4), 351-373.

Popov, V. S. (2001). Principles of Symmetry and Relative Errors of Instrumentation and Transducers. *Automation and Remote Control*, *62*(5), 842-846.

Prommer, H., & Stuyfzand, P. J. (2005). Identification of temperature-dependent water quality changes during a deep well injection experiment in a pyritic aquifer. *Environmental science & technology*, *39*(7), 2200-2209.

Racz, A. J., Fisher, A. T., Schmidt, C. M., Lockwood, B. S., & Huertos, M. L. (2012). Spatial and temporal infiltration dynamics during managed aquifer recharge. *Groundwater*, *50*(4), 562-570.

Ramalho, R. (2012). *Introduction to wastewater treatment processes*. Elsevier.

Ripley, D. P., & Saleem, Z. A. (1973). Clogging in simulated glacial aquifers due to artificial recharge. *Water Resources Research*, *9*(4), 1047-1057.

Reinelt, P. (2005). Seawater intrusion policy analysis with a numerical spatially heterogeneous dynamic optimization model. *Water resources research*, *41*(5).

Samani, Z., & Magallanez, H. (2000). Simple flume for flow measurement in open channel. *Journal of Irrigation and Drainage Engineering*, *126*(2), 127-129.

Schilling, W. (1991). Rainfall data for urban hydrology: what do we need?. *Atmospheric Research*, *27*(1), 5-21.

Shiono, K., & Knight, D. W. (1991). Turbulent open-channel flows with variable depth across the channel. *Journal of Fluid Mechanics*, *222*, 617-646.

Shinn, E. A., Reich, C. D., & Hickey, T. D. (2002). Seepage meters and Bernoulli's revenge. *Estuaries*, *25*(1), 126-132.

Simunek, J., Van Genuchten, M. T., & Sejna, M. (2005). The HYDRUS-1D software package for simulating the movement of water, heat, and multiple solutes in variably saturated media, version 3.0, HYDRUS software series 1.*Department of Environmental Sciences, University of California Riverside, Riverside, California*, 270.

Sirivithayapakorn, S., & Keller, A. (2003). Transport of colloids in saturated porous media: A pore-scale observation of the size exclusion effect and colloid acceleration. *Water Resources Research*, *39*(4).

Sisson, J. B., & Wierenga, P. J. (1981). Spatial variability of steady-state infiltration rates as a stochastic process. *Soil Science Society of America Journal*, *45*(4), 699-704.

Sophocleous, M. (2004). Climate change: why should water professionals care?. *Groundwater*, *42*(5), 637-637.

Sou, M. Y., Mermoud, A., Yacouba, H., & Boivin, P. (2013). Impacts of irrigation with industrial treated wastewater on soil properties. *Geoderma*, *200*, 31-39.

Slichter, C. S. (1905). Field measurements of the rate of movement of underground waters. *United States Geological Survey Water-Supply and Irrigation Paper*, *140*.

Stewart, R. B., & Rouse, W. R. (1976). A simple method for determining the evaporation from shallow lakes and ponds. *Water Resources Research*, *12*(4), 623-628.

Talsma, T., & Lelij, A. V. D. (1976). Infiltration and water movement in an in situ swelling soil during prolonged ponding. *Soil Research*, *14*(3), 337-349.

Taylor, R. G., Scanlon, B., Döll, P., Rodell, M., Van Beek, R., Wada, Y., ... & Treidel, H. (2013). Ground water and climate change. *Nature Climate Change*, *3*(4), 322-329.

Tchobanoglous, G., & Burton, F. L. (1991). Wastewater engineering. *Management*, *7*, 1-4.

Vandevivere, P., & Baveye, P. (1992). Effect of bacterial extracellular polymers on the saturated hydraulic conductivity of sand columns. *Applied and Environmental Microbiology*, *58*(5), 1690-1698.

Vigneswaran, S., & Suazo, R. B. (1987). A detailed investigation of physical and biological clogging during artificial recharge. *Water, Air, and Soil Pollution*, *35*(1-2), 119-140.

Viviani, G., & Iovino, M. (2004). Wastewater reuse effects on soil hydraulic conductivity. *Journal of irrigation and drainage engineering*, *130*(6), 476-484.

Warner, J. W., Gates, T. K., Namvargolian, R., Miller, P., & Comes, G. (1994). Sediment and microbial fouling of experimental groundwater recharge trenches. *Journal of contaminant hydrology*, *15*(4), 321-344.

Werner, A. D., & Simmons, C. T. (2009). Impact of sea-level rise on sea water intrusion in coastal aquifers. *Groundwater*, *47*(2), 197-204.

Winter, T. C., Rosenberry, D. O., & Sturrock, A. M. (1995). Evaluation of 11 equations for determining evaporation for a small lake in the north central United States. *Water Resources Research*, *31*(4), 983-993.

Wood, W. W., & Signor, D. C. (1975). Geochemical factors affecting artificial groundwater recharge in the unsaturated zone. *Transactions of the ASAE (USA).*

Wolf, J. P. (1987). Soil-structure-interaction analysis in time domain. In *Structural mechanics in reactor technology*.

Xu, C. Y., & Singh, V. P. (1998). Dependence of evaporation on meteorological variables at different time-scales and intercomparison of estimation methods. *Hydrological processes*, *12*(3), 429-442.

Zadaka-Amir, D., Nasser, A., Nir, S., & Mishael, Y. G. (2012). Removal of methyl tertiary-butyl ether (MTBE) from water by polymer–zeolite composites. *Microporous and Mesoporous Materials*, *151*, 216-222

Zektser, S., Loáiciga, H. A., & Wolf, J. T. (2005). Environmental impacts of groundwater overdraft: selected case studies in the southwestern United States. *Environmental Geology*, *47*(3), 396-404.

Zhu, H. J., & Schilling, W. (1996). Simulation errors due to insufficient temporal rainfall resolution—Annual combined sewer overflow. *Atmospheric research*, *42*(1), 19-32.

CHAPTER 3

GROUNDWATER RECHARGE POTENTIAL USING SECONDARY TREATED WASTEWATER: A CASE STUDY IN THE SOUTHERN SAN JOAQUIN VALLEY, CALIFORNIA

Abstract

Drought conditions place increasing pressures on groundwater to meet the agricultural, industrial and municipal demands. Groundwater overdraft is common in such instances, particularly in heavily irrigated arid and semi-arid regions. Hence, it is critical to develop engineered or managed aquifer recharge (MAR) schemes, using floodwater during wet years and reusing wastewater whenever safely possible. This work explores MAR potential using secondary treated municipal wastewater in unusable or fallow lands. We develop a case study for the South San Joaquin Valley (SJV), where the four major population centers (Fresno, Tulare, Visalia, and Bakersfield) generate 0.5-0.6 million m^3 (405-486 acre feet) of effluent daily. The work begins by examining MAR at a typical recharge basin at the Fresno-Clovis Regional Wastewater Reclamation Facility, using a two-dimensional unsaturated soil hydraulics model (Hydrus 2D) to estimate recharged based on the observed recharge basin water balance. There are approximately 28,000 ha of fallow or unusable land in southern SJV that could be potentially used for recharge of groundwater. Given this quantity of potentially available land, we scale up these results to the southern SJV using Natural Resource Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) geospatial data. Utilizing NRCS SSURGO an area within 10 Km of the wastewater facility were selected to determine areas totally suitable for wastewater disposal, and downgrade in elevation from the treatment facility were finally separated as potential usable land for recharge purpose. We estimate that most soils will have an average infiltration capacity of 50-70 mm/day; especially if the land is prepared with some form of deep ripping, resulting in infiltration of 500-700 m^3/day of water for every hectare of land used. To successfully dispose of 0.5-0.6

million m^3 of wastewater on a daily basis, we would need approximately 1250 hectares of land. While there will likely be reservations about water reuse related to emerging contaminants, it is imperative that we start exploring alternatives for addressing water scarcity issues in the near future.

3.1. Introduction

The latest National Aeronautics and Space Administration (NASA) Gravity Recovery Climate Experiment (GRACE) map (Figure 1) illustrates the increasing groundwater deficit that we are facing both in California and nationwide. Climate projections for the future will likely exacerbate this issue in some regions. For example, California is projected to receive an increasing fraction of its precipitation as rain rather than snow (Screen and Simmonds 2012). This will force adaptation with regard to water resource management in the region by existing storage capacity in the form of snow pack

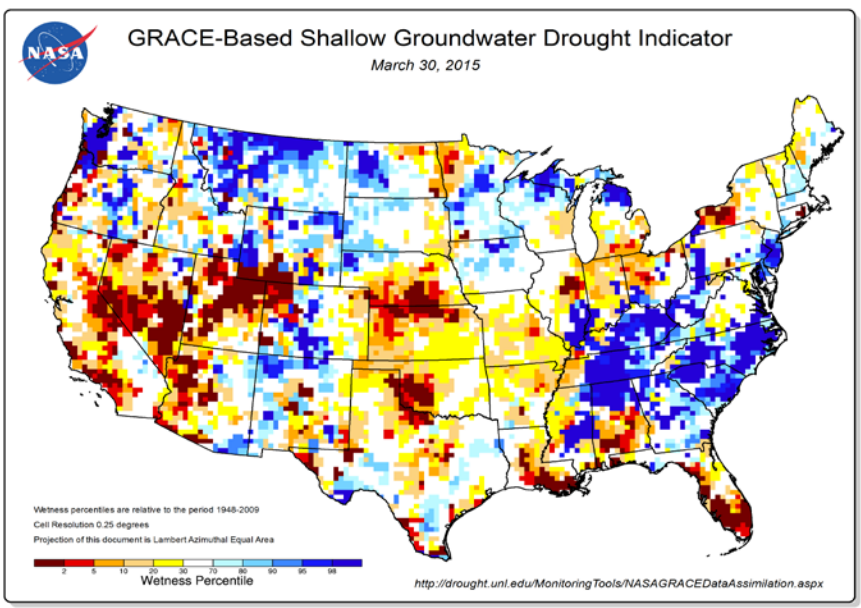

Figure 1: Multi-agency Drought and groundwater indicator, showing the extent of drought in United States.

and placing additional pressure on groundwater. It is clear that we need alternative ways to replenish/recharge the groundwater (Biemans et al. 2011). Recharge processes are relatively slow (Lee and Lee, 2000), relying mainly on natural processes (e.g., snow melt) and incidental recharge (e.g., via irrigation). These pathways have proven to be inadequate to keep pace with demand (Konikow and Kendy, 2005), forcing water purveyors to seek alternate sources of water to sustain groundwater levels (Gleick 2014).

One such alternative is to look at recharge using secondary and tertiary treated water from utilities. Reuse of treated municipal or industrial wastewater for recharge (and other applications) is known as beneficial second use (Crites et al. 2014). The necessary degree of treatment depends on the specific reuse application and on the associated water quality requirements (Crittenden 2012, Gupta 2012, Ramalho 2012). For artificial recharge, effluent is typically routed through a series of pipes/canals to reclamation basins where the water evaporates, infiltrates, part of it trapped in the vadose zone as soil moisture, and the remaining portion eventually reaches the water table and contributes to recharge. There are numerous factors that influence the infiltration rate of artificial reclamation basins, such as type of soil, hydraulic conductivity of the underlying soil, depth of soil preparation, water holding capacity of the soil, quality of water, and micro-meteorological conditions (Bhuiyan 2015).

There are legitimate health concerns regarding the use of secondary treated water for recharge. In recent years, as use of reclaimed water has become more prevalent, research has focused on the retention and transport of colloids (e.g., bacteria, viruses) in the vadose zone (Steinel 2012). Under unsaturated flow conditions, reduced colloidal movement has been demonstrated relative to saturated flows (Auset and Keller 2004; Sirivithayapakorn, and Keller 2003; Han et al. 2006). Concerns have also been raised about pharmaceutical and personal care products (PPCPs) and other emerging contaminants in aquatic environments, which tend to persist at low levels (parts per trillion) in conventional secondary effluent (Drewes et al. 2003).

Given these concerns, direct wastewater reuse for drinking water and food crop irrigations is avoided, but reuse may be allowed for other purposes. For instance, wastewater effluent is commonly used to grow crops for forage in spite of the fact that certain contaminants tend to bio-concentrate and may still pose a risk to human health (Pedersen et al., 2005; Williams and Adamsen, 2006; Chefetz et al., 2008; Siemens et al., 2008; and Oulton et al., 2010;). In one specific example, the crop uptake of PPCP has been documented in vegetable crops like tomato, cucumber and sweet potatoes (Boxall et al., 2006; Herklotz et al., Wu et al., 2013; Goldstein et al., 2014; Malchi et al., 2014).

Although there are significant health concerns, escalating water costs coupled with the massive water shortages during droughts have provided for an incentive to consider treated wastewaters for reclamation and recharge (Wahl, 2013). For example, LOTT Clean Water alliance in Washington started a multi-year study in 2012 to understand potential risk from infiltration of reclaimed water. Similarly, in Los Angeles, CA, reclaimed water has been in use for recharge since 1962. In one response to these health concerns, researchers have investigated improving the water quality through soil aquifer treatment (SAT), which is a potential added benefit of artificial recharge. Excess stream flows, agricultural runoffs or treated wastewater are some of the sources of water for SAT recharge (Bouwer, 2002; Greskowiak et al., 2005; Prommer and Stuyfzand, 2005; Massmann at al., 2008). Despite the success of SAT, there are concerns about removal of certain compounds like carbamazepine, sulfamethoxazole and metoprolol (Arye et al., 2011; Lev et al., 2012). Another common artificial recharge method is the use of a surface infiltration basin called a “managed aquifer recharge” (MAR) system (Racz et al., 2012). Maintaining an efficient SAT or MAR system requires maintaining relatively high hydraulic conductivity in the vadose zone, so that infiltration conveys water efficiently to the subsurface. Generally, the hydraulic conductivity is high in the beginning but decreases over time because of physical, chemical, and biological processes (e.g., biofilm growth, particle filtration) that lead to soil permeability reduction (Bouwer, 2001).

This study explores the feasibility of using wastewater for recharge in a semi-arid region. We focused first on improving our understanding of recharge rates and recharge basin maintenance cycle assessment using observations from a continuously monitored MAR test basin and a two-dimensional flow unsaturated flow model. We then use the outcomes from this test basin to estimate potential regional impact of secondary effluent-based MAR on a regional basis, using the Southern San Joaquin Valley in Central California as a case study. Two key questions addressed by the work are: i) What fraction of the applied effluent actually serves as recharge? and, ii) What is the potential annual contribution to recharge afforded by wastewater effluent, and what land area is needed to realize this potential?

3.2 Methods

In this study, we used a three-pronged approach to estimate water recharge at the reclamation site. We collected continuous onsite measurement of inputs to the reclamation basin to estimate infiltration rate and hydraulic conductivity using: i) heat as a tracer to examine flow from the reclamation basin using Hydrus 2D in heat transport mode; ii) mass balance method for infiltration rate of the reclamation basin number 3; and iii) use of soil columns (see Chapter 2) to calibrate the Hydrus 2D model. The outcomes from the three approaches for our study site in Fresno were then scaled up to provide a regional estimate of the effluent recharge capacity of the South San Joaquin Valley based on soil type and micrometeorological data.

3.2.1 Location

Data were collected from 17 October 2010 to 25 January 2012 at the Fresno-Clovis RWRF, which is located southwest of Fresno, CA (36° 41’ 59.19” N 119° 53’ 48.26” W) at reclamation basin number 3. Fresno is the fifth largest city in California, and is in the center of SJV, one of the worst hit regions in the United States by drought and groundwater overdraft (*Figure 1*). Wastewater generated from residential and commercial areas of Fresno and Clovis travels through a network of 1,500 miles of sewer lines to this facility. On an average this facility receives 2, 57,408 m^3 (68 Million US gallons or 208 acre feet) of wastewater daily. At its current capacity, the facility is a biological, secondary level treatment plant and meets the Title 22 California Code of regulation and its effluent can be used to grow fiber crops not fit for human consumption. The secondary treated water is finally disposed of into one hundred and one (101) reclamation basins varying in size from 49,371- 3, 60,170 m^2. The soil beneath the reclamation basin acts as a filter before the water meets the water table, which forms a mound beneath the basin. About 12-15% of the secondary treated water goes for direct reuse to farmers leasing land within the RWRF or to nearby farmers where they mainly grow forage like alfalfa, corn or sudan grass. The remaining effluent is routed to the reclamation basins. The treatment facility is under constant pressure to effectively manage these huge amounts of treated water, and with the growth of the Fresno-Clovis metro area, the volume of wastewater is expected to increase in the future. The facility is also monitored and mandated by the California Water Board (CWB) to assess the impact of these waters on drinking water supplies and the groundwater in general (City of Fresno, 2015).

Our study takes place in reclamation basin number 3 (*Figure 2*), which is 69,808 m^2 or 17.25 acres in area and sits on top of a sandy loam (0-35.5 cm) and loamy sand (35.5-550 cm or more) soil structure with an average saturated hydraulic conductivity of 12 to 122 mm/day (soils data per soils sample collected and NRCS/SSURGO soils database). Fresno has a Mediterranean like climate with average high of 37 °C and average low of 13 °C, with average precipitation of 280mm/year with majority of the rainfall occurring between November to April. The RWRF facility on an average processes 68 million gallons of water daily and these numbers fluctuate seasonally. The reclamation basin for this study was maintained with an average depth of 900-1220 mm of water during the 465 days of the study period.

Fresno-Clovis RWRF tracks the infiltration rate of all their reclamation basins (n=101) throughout the year. This helps them maintain the inventory of their basins and plan the movement of the treated water through their network of open canals. They have a system in place where they use data such as run times of the water inflow, area of the reclamation basin, evapotranspiration data from CIMIS as evaporation (they assume 70% of ET), and change in water height of water column at staff gauge to estimate infiltration rate. We investigated the saturated infiltration rate records for Fresno-Clovis from 2010-2013 for all basins to estimates of expected infiltration rates, both highs and lows. The highest infiltration rate reported from all basins was 152 mm/day and min was 13 mm/day. Basin#3 was put into operation from Oct 17 2010, and the RWRF staff began tracking it on1st Nov 2010. According to their data, the highest saturated infiltration rate of 76.2 mm/day was observed for the first 14-150 days (Nov to Mar 2011). The rate dropped to 69.9 mm/day for the next 151-210 days (Apr-May 2011), followed by 35.5 mm/day for the next 211-331 days. The final infiltration rate at the end of Dec 2011(day 440) was with 12.7 mm/day.

3.2.2 Instrumentation and Data Collection

A detailed description of the water balance instrumentation system was provided in Chapter 2. The system is summarized here and includes three systems installed in the middle of the basin (east, middle, and west) to log air temperature (Campbell Scientific Inc., FW3 Thermocouple, Logan UT), wind speed & wind direction (RM Young, 5305, Traverse City MI), water temperature (Grainger, 10K Thermistors), along with SDI 12 soil moisture and salinity sensor (Stevens Water Monitoring Systems, Hydra Probe II, Portland, OR) at 0.6, 1.5, 3.0, and 5.49 m below the basin surface (*Figures 3 & 4*). One station was placed right next to the water inlet to calculate the total input (V) to the basin using magnetic water meters (EuroMag International, MUT220EL, Mestrino Italy), tracked basin change in volume (ΔV) using pressure transducers(Global Water, WL400,College Station TX), tracked rainfall using tipping rain bucket (P) (Texas Electronics, TE525 Rain Gage, Dallas TX), and estimated evaporation (E) using a wind speed (RM Young, 5305, Traverse City MI), relative humidity sensor (Campbell Scientific Inc., HMP45C, Logan UT), air temperate (Campbell Scientific, FW3, Logan UT) and barometric pressure (Campbell Scientific, CS100, Logan UT)(*Figures 3*). The four stations on site collected data every 15 seconds and averaged it every 15 minutes before relaying it to the fifth or the base station ½ mile away located near the treatment facility office. The base station relayed the data to the central server at Fresno State every day at midnight using the phone system and modem. The central server computed

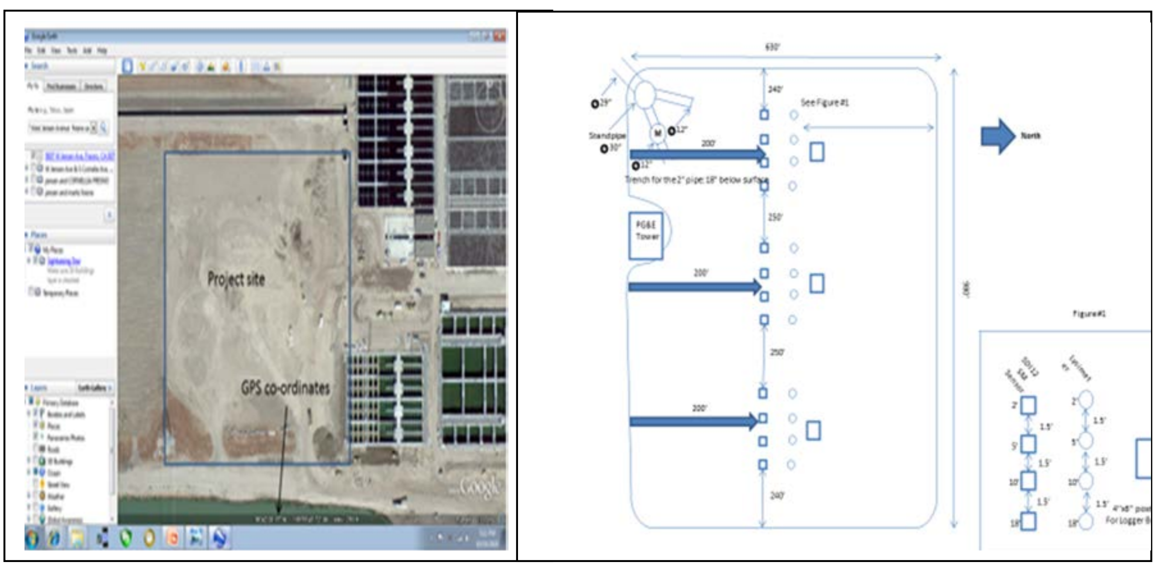

Figure 2: RWRF aerial view of basin 3 along with instrumentation setup schematics.

the water budget data using both mass balance for the day at midnight after receipt of the data transmission and compared that to the acceptable high and low values for the soil type from the site. The input data for the heat as a tracer was manually entered into the Hydrus 2D software at the end of the trial. On a bi-weekly basis, all sensors with the exception of the ones buried in the soil, were inspected and tested against known calibration samples. Any anomaly in the data were flagged for deletion in the final analysis.

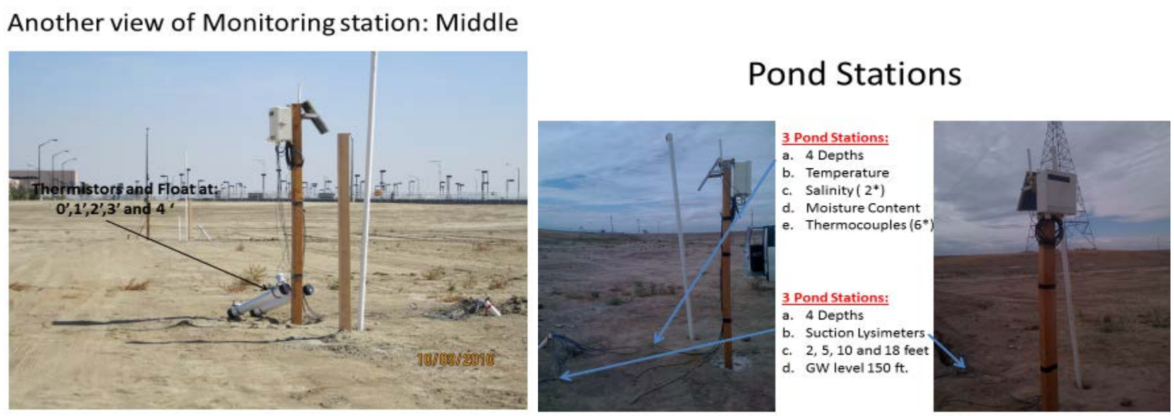

Figure 3: Instrumentation layout for basin 3, along with datalogger and sensor layout (temperatures, soil moisture, and salinity: Stevens Hydrus II SDI).

3.2.3 Estimating Recharge from Observed Infiltration

Our scale up approach involves estimating recharge rates over spatially distributed soil and meteorological conditions, and determining land area needed for effective recharge. To estimate recharge we used computer model (Hydrus 2D) and the infiltration, water balance data and Hydrus 1D simulations described in the previous chapter. SPSS

(Norušis, & SPSS Inc., 1994) and Microsoft excel macros (Levine et al., 1999) were used for data processing, and formatting the data for the computer model.

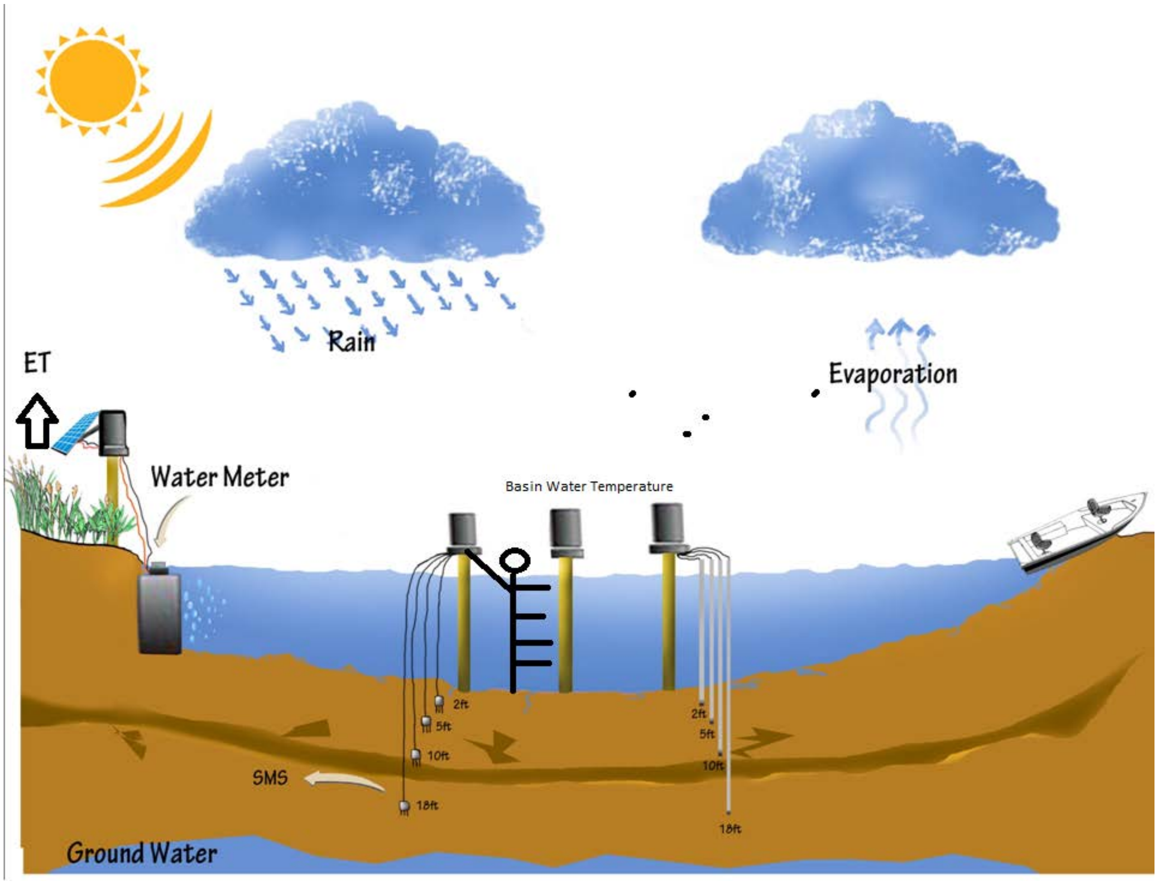

Figure 4: Overall schematics of the recharge basin number 3.

3.2.3.1. Computer Modeling-Hydrus 2D:

We used a 2D simulation model (Hydrus 2D) to estimate recharge or deep percolation resulting from the surface infiltration. In most cases, the flow of water is 3 dimensional (3D), but for most hydraulic modeling studies a 1D or 2D model provides all the information required for design and analysis. For our recharge basin number 3 there were some differences between east, west and middle section (*Figure 6*). To cover the spatial and temporal variability, a 2D model was employed.

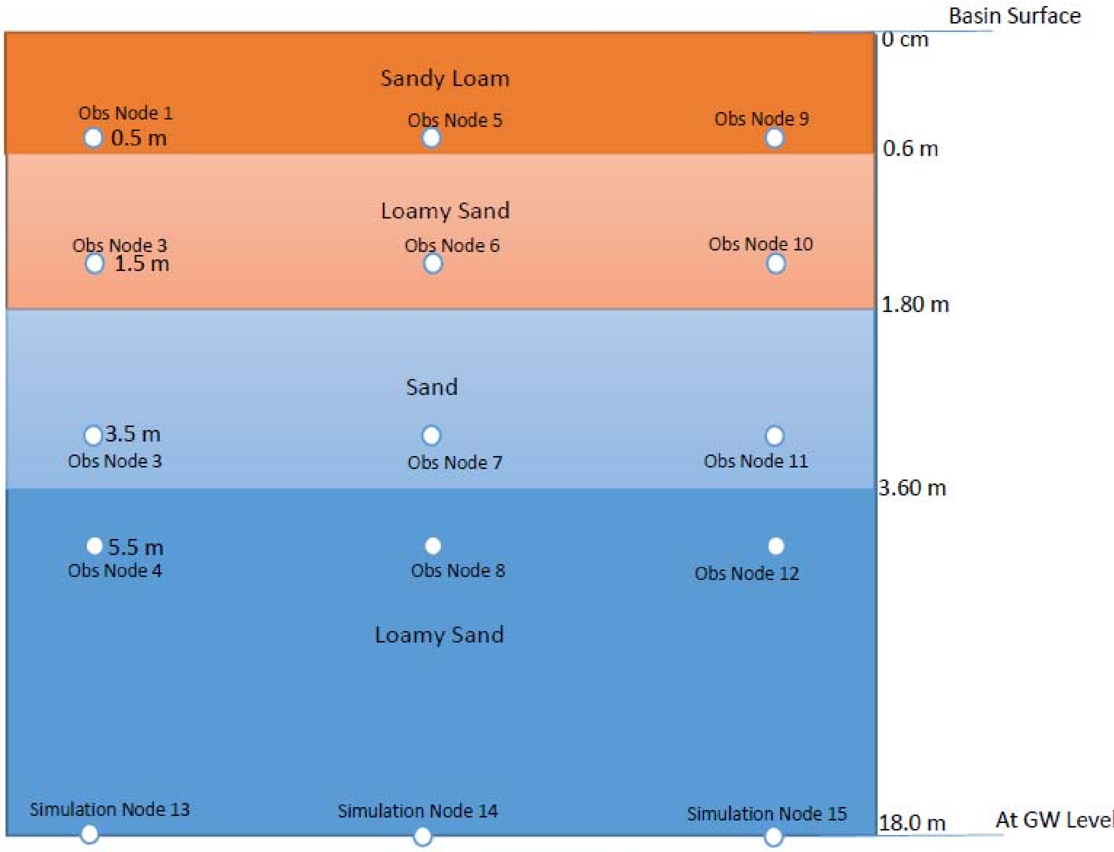

Figure 5: Placement of the observation nodes (where the actual sensors were located at various depths under basin #3) in the Hydrus 2D model. The top of the model space or basin surface was assigned pressure head, while the two sides were assigned seepage space and the bottom assigned deep drainage.

The Hydrus 2D modeling environment is a software package for simulating, water flow, heat flow and solute movement for various saturated media. HYDRUS uses the Richards equation for water flow and advection-dispersion equation for heat and solute (Simunek et. al, 1996; Skaggs et. al, 2004). To estimate the recharge potential, the model geometry was set to an 18m depth (at the GW level) by 420 m wide to mimic recharge basin 3, with observation nodes placed at 0.5, 1.5, 3 and 5.5 m depths for each of the east, middle and west section to replicate sensor positions (*Figure 5*). Time-variable boundary conditions were input for the 465 day period, including precipitation, potential evaporation, wind speed, humidity, time dependent soil temperature at the soil surface boundary, and the temperature of the incoming water. However, on running the few initial runs it was determined that time dependent pressure head, was a better choice for the model fit compared to the environmental inputs of water, like evaporation and precipitation. All of these data were imported from the weather station and three basin stations.

Soil volumetric water content collected by the Stevens Hydra Probe II at 0.5, 1.5, 3 and 5.5 m depths was used as part of the inverse solution to optimize the soil hydraulic parameters for the three locations independently (east, middle, and west). The soil water content values were corrected for soil type and water quality after laboratory calibration prior to installation and algorithmic corrections were applied in the logging program. Even though the soil moisture sensors were logging data every 15 minutes the input data to the inverse solution was limited to 15 minutes for the first 15 days then expanded to 3 hours for the next 15 days followed by every 3 hours for the next 30 days and then to once a day. This was allowed because the most dynamic portion of the infiltration front behavior occurred within the first 15 days.

For the water flow boundary condition, the upper layer was set to variable pressure and the lower boundary condition set to deep drainage. The total number of soils layers was limited to four, based on the soil borings at the site. Table 1 shows the ranges of hydraulic parameters for the four soil layers of the model domain, these values are based on the soil texture and bulk density of the actual soils obtained during the boring process outlines above.

Table 1: Initial hydraulic parameter estimates for the four soils types used in the Hydrus modeling domain based on the soil sample average for basin 3.

USDA Soil Texture Class	θ_r	θ_s	α	n	K_s
Sandy Loam(0-60 cm)	0.053	0.418	0.0172	1.46	42.87
Loamy Sand (60-180 cm)	0.056	0.419	0.0318	2.04	220.74
Sand (180-360 cm)	0.060	0.422	0.0294	2.33	320.93
Loamy Sand (360-1800 cm)	0.057	0.427	0.0311	2.14	267.93

K_s values for the top layer for Hydrus 2D model was chosen from the soil column experiment (since the height of the soil column accurately represented the height of the top soil layer in the basin and in the model). For the remaining soil material , we used the K_s ranges using the sand, silt, clay content of the actual soil along with the bulk density used as input to the US Salinity labs Rosetta soil parameter estimation model.

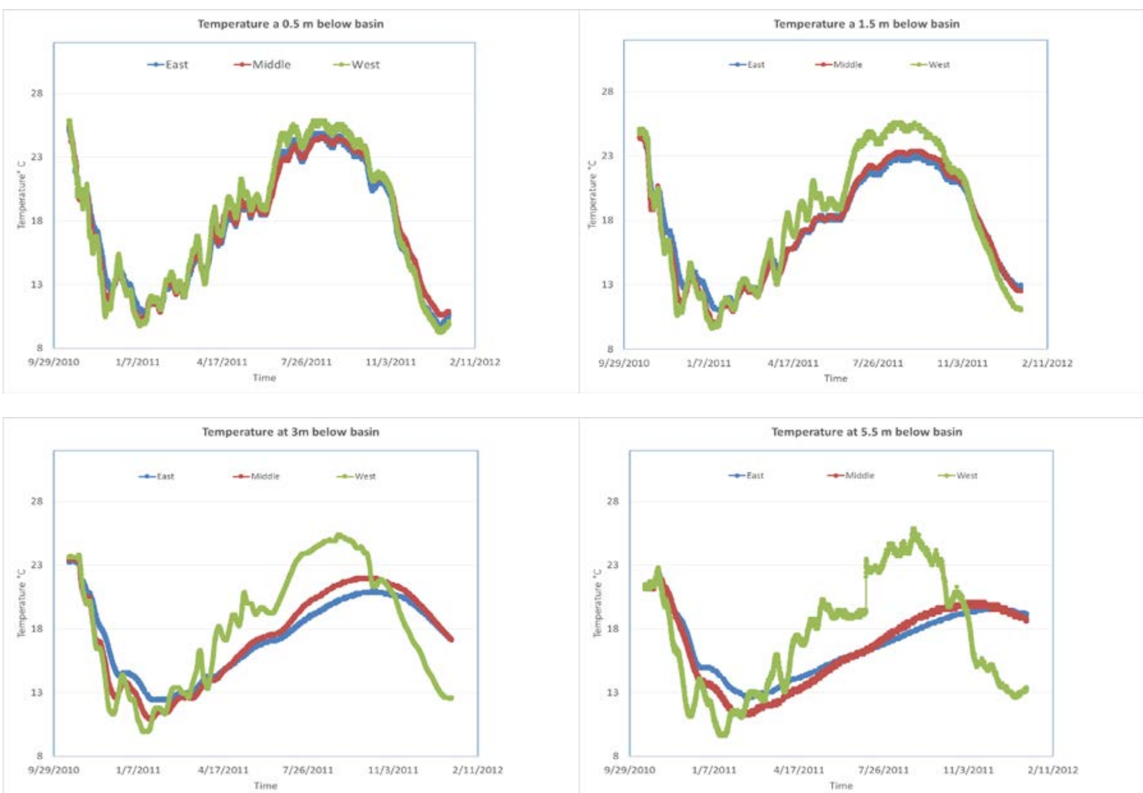

Figure 6: Soil temperature variation at different depths (0.5, 1.5, 3 and 5.5 m below basin) for east, middle, and west location.

Tables 1 and 2 show the various settings employed for Hydrus modeling. Hydrus modeling included soil hydraulics, profile/geometry, initial and boundary conditions, micrometeorological data and inverse data.

Using heat as a tracer, we also modeled soil temperature changes using Hydrus 2D. The temperature (Figure 6), moisture, salinity (conductivity converted to salinity using UNESCO 1983) and pressure head data (Figure 9 & 10) for the initial 45 days were inputted into the model at 30 minutes interval, for the next 30 days at 4 hours interval and for the remainder of the period at an interval of every 8 hours. The data input were staggered and spaced to keep the maximum data points to under 10,000 lines, and keep the run time and convergence of the model reasonable. The moisture, temperature, and salinity log for the 4 depths (0.5, 1.5, 3.5 and 5.5 m) (Figure 8) were staggered and inputted more frequently in the beginning and spaced out with time, as inverse function to the model for better model fit. Soil core were collected from the basin floor at increments of 60 cm and were analyzed for bulk density; porosity; ESP; and sand, silt and sand content. These soils data were inputted into the Hydrus model (Table 1).

Soil cores collected from various depth of basin 3 at Fresno RWRF were analyzed for soil texture using ASTM D422-63(2007) e2 method. The texture data were fed into the ROSETTA software model, developed by US Salinity lab (Schaap, et al., 2001) to predict the soil moisture retention model parameters (van Genuchten 1980): residual soil water content (Θ_r), saturated water content (θ_s), alpha (α), an empirical parameter η, and saturated hydraulic conductivity (K_s). These parameters were input (Table 1) as initial values and then allowed to vary by a reasonable degree (± 5 %) to obtain better model fit.

Table 2: Hydrus 2D modeling settings and parameters for this work.

Variables	Conditions	Selection
Main Process	Water flow	Yes
	Solute Transport	Standard Solute Transport
	Heat Transport	Yes
Inverse function	Soil Hydraulic Parameters & Resident Concentration	Yes & data points 9860
Geometry Information	Number of Soil Material	4
	Number of Layers for Mass Balance	4
	Depth	1800cm
Time Information	Time Units	Days
	Initial time step	0.001
	Final time step	465
	Time Variable Boundary Condition	465
	Meteorological data	465
Soil Hydraulic Model	van Genuchten-Maulem, with Air Entry and No Hysteresis	
Water Flow Boundary Condition	Upper Boundary Condition	Time variable pressure head
	Lower Boundary Condition	Deep Drainage
Solute Transport	Time Weighted Scheme	Crank-Nicolson Scheme
	Units	PSS
	None equilibrium Solute Transport Models	Equilibrium Model
	Tortuosity	Millington & Quirk
Heat Transport Boundary Condition	Upper Boundary Condition	Temperature BC
	Lower Boundary Condition	Zero Gradient

The hydraulic parameters were optimized first for the top layer followed by the subsequent layers, sequentially. The optimization process used the inverse solution function which included soil moisture and salinity data collected by the sensor at 0.5, 1.5, 3.5 and 5.5 m totaling 9219 records. The optimization process had to be repeated several times until no further improvement was noticed for water balance % and model residuals. To assess the quality of the model optimization, the observed versus fit values were compared along with the model fit correlation (r2) values.

Additionally, the model was run on with forward modeling upto day 550 to ascertain model behavior (Figure 10 & 11)). Once the model parameters were optimized, it was rerun with twice and half the Ks values for the various soil layers to check if change in Ks is directly proportional to recharge rate.

For the three non-instrumented RWRFs, we ran the Hydrus 2D model using local soil data (obtained from NRCS SSURGO), weather data from local CIMIS stations, and groundwater levels from USGS wells. Using the same boundary and initial conditions used for basin number 3, we developed three simulations model using the NRCS saturated hydraulic conductivity value.

3.2.3.2 Regional Managed Aquifer Recharge Estimates

To estimate the potential impact of MAR on the Southern San Joaquin Valley water resources we identified suitable recharge sites in the region, then applied recharge rates scaled from our observations at the Fresno pilot study. The criterion for site selection included: (i) access to canal infrastructure, (ii) proximate to (< 10 km) and (iii) down-grade from treatment facility (to support water movement using gravity), and (iv) suitability of soil type and crops grown in the area. To scale from the Fresno soils to local soils we used USDA-NRCS SSURGO soil survey data. This database contains soil information collected by National Cooperative Soil Survey over a course of a century (NRCS 2015). The information is available in the form of tables and maps (shape file and vector polygon) for analysis, and served by USDA-NRCS. The map units provide soil and other components that have distinctive properties, analyses, and productivity. This mapping database in specifically provided free of cost for natural resource management and planning by landowners, townships, and counties. Example of information available from the database includes soil water holding capacity, soil reaction, soil electrical conductivity, frequency of flooding, yields from crops, rangeland, pastureland, woodland, building site development and other engineering uses (Ford et al. 2015; NRCS 2015). Land use data for recharge potential of south SJV was estimated using this database like many other past studies (example Hempel et al., 2016; Bratsch et al., 2015; Goldman and Needelman, 2015; Miles and Brad, 2015).

3.2.3.3 Estimation of available land for recharge

Soil type data from NRCS SSURGO, satellite data for accessibility and elevation, and USBR land use data were used in ArcGIS/NRCS Web online software were used to estimate the availability of land suitable for recharge (Figures 15, 16, 17 & 18). Initial estimation of land area needed for recharge was performed on the metadata downloaded from SSURGO database using Arc MAPS 10.1.However, we found the relatively new NRCS soils online website to be GIS enabled and could perform the same task as performed on ArcGIS mentioned above (appendix A-C).We believe the NRCS web online was a better option and user friendly, especially considering that Utilities and City managers are familiar with this site and does not need programming experience. The “waste management” feature of the NRCS web-online was used on the downloaded

SSURGO database, this tool is designed to guide users in evaluating soil for use of wastewater and organic waste as productive resource. Discharge of secondary treated water for recharge was evaluated for four different scenarios, namely rapid infiltration, slow rate infiltration, disposal of wastewater as municipal sludge and disposal for irrigation.

According the Wastewater management tool, each area/polygon is distinguished for the disposal method in various ratings. The rating class indicates the extent to which the soils are limited by soil properties. "Not limited" is an indicator that the soil favors the specific use, where as "somewhat limited" indicates the soil properties favor the specific use moderately. Similarly, "very limited" indicates that one or more feature of the soil are unfavorable for that specific use. Some of the unfavorable limitations could be overcome by soil reclamation, special design, or elaborate and expensive installation methods. A complete analysis report for the various ratings at each of the four RWRF's at Fresno, Visalia, Tulare and Bakersfield is provided in appendices A-C.

It should also be noted that the four different recharge option (irrigation, slow & rapid infiltration and land application) will lead to different recharge rate.

3.2.4 Model reanalysis

We estimated infiltration rate from the water balance data using equation 1, where the mean value of each parameter was averaged over 15 minutes. Daily values were generated from the cumulative of the 15 minutes data over a day.

$$I=V+P-E-\Delta V \qquad (1)$$

The daily values were compared against previous readings to look for unusual increasing or decreasing trends. The results were also compared against published infiltration rates for the soil type.

We estimated the land use requirements using equation 2, where A is area of the recharge basin/pond (L^2), Q is volumetric flow rate of wastewater (L^3/T), E is evaporation rate (L/T) and I is the infiltration rate (L/T). We ran equation 2 using the maximum and minimum infiltration rate of the soils selected for that area (within each specific RWRF), this gave us an estimate of the range of land area required to dispose-off all the secondary treated water. Additionally, equation 3 was used to calculate the recharge fraction based on land areas used.

$$A = Q / (E+I) \qquad (2)$$

$$\text{Recharge fraction} = 1-(EA / Q) \qquad (3)$$

In the total land use required estimation (eqn 2 & 3), precipitation was ignored as it is negligible compared to the volume of the wastewater for the SJV climate.

Potential minimum and maximum recharge were calculated as the product of recharge rate (Hydrus model) times the land required (minimum and maximum) resulting in potential minimum and maximum recharge per day. Similarly, the % wastewater that leads to recharge factor was calculated as fraction of recharge to incoming wastewater. Equation 4 is an indicator of recharge fraction, if we use the stipulated amount of land as described in Table 3, we would achieve 100% infiltration capacity (volume of water infiltrated will equal volume of wastewater), if lesser amounts of land is used the recharge fraction will reduce and exact figures could be computer using this equation.

3.3. Results

3.3.1 Water Balance

For the RWRF the total precipitation measured at the site using the average of two tipping buckets rain gauge were 69.6 mm which was 11.1% higher than the amount of precipitation reported by two nearby CIMIS stations. Similarly, Evaporation data estimated using Penman (1948) during our study was 69.32 mm, which averaged 77.31% of the ET reported by nearly CIMIS network.

The 15 minute data for flow rate (V), change in volume (ΔV**),** precipitation (P), and evaporation (E) were aggregated into hourly data to estimate the hourly infiltration rate using water balance approach; final data reported for this paper were converted into daily averages. The highest infiltration rate by the water balance approach was 125.2 mm/day and the minimum was 17.0 mm/day. Basin 3 was put into operation from Oct 17 2010, however data could not be reliably computed for the first 6 days as the basin was slowly filling, creating a lot of turbulence on the surface for the level gauge to accurately detect the change in level. Infiltration data for basin 3 for the time period of first 7-150 days (Oct 24, 2010 to 1st Mar 2011) was as high as 125.2 mm/day and steadily dropped to

79.2 mm/day. The rate dropped to 60.9 mm/day for the next 210 days (1st June 2011), and was about 40.6 mm/day for the by 331 days. The final infiltration rate at the end of Dec 2011(day 440) was at 17.02 mm/day (Figure 7).

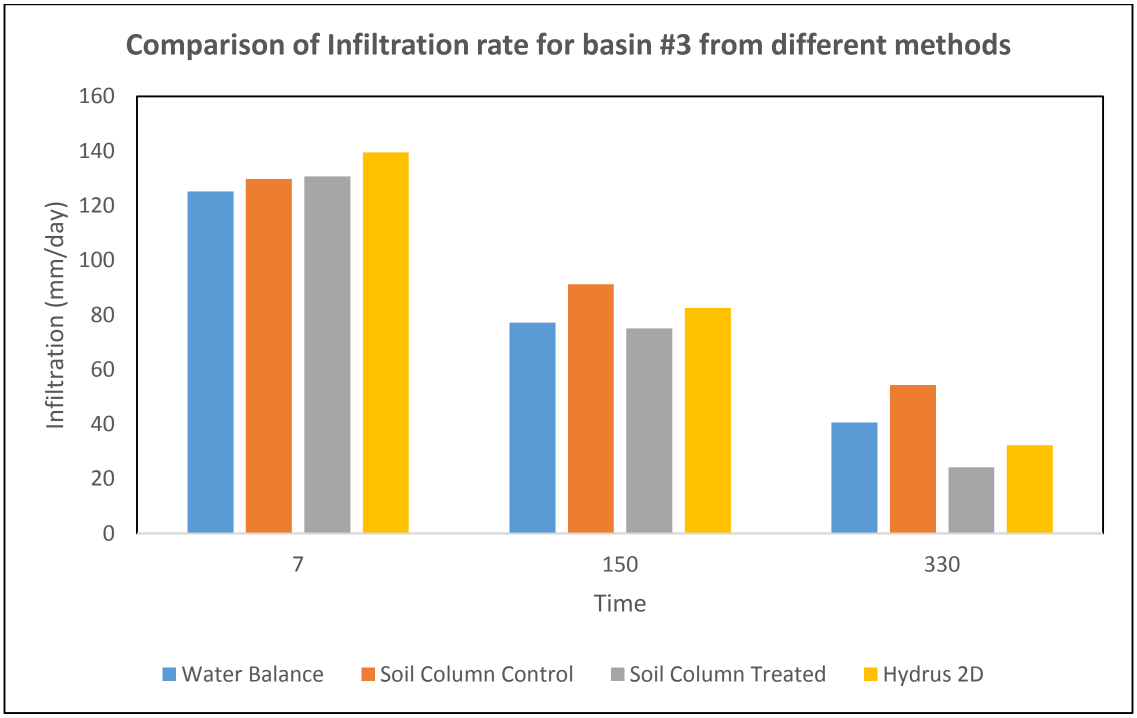

Figure 7: Comparison of infiltration rate from three different methods for reclamation basin number 3 at City of Fresno RWRF.

3.3.2 Hydrus Modeling

Hydrus 2D modeling was performed on the data collected from 10/25/2010 to 1/10/2012 at basin number 3 using the pressure head, groundwater level, moisture, temperature, conductivity (converted to salinity), and other parameters (Tables 2 and 3). We used the Hydrus-2D simulation to estimate groundwater recharge (as opposed to infiltration). The mean of maximum infiltration rate at basin 3 was 130 mm/day and minimum of 20 mm/day over the 465 day period at the soil-water interface as reported by

Hydrus model. However the average infiltration estimated by Hydrus were 82 mm/day compared to 66 mm/day reported by the water balance method for basin 3. To estimate recharge the cumulative bottom flux was taken from the Hydrus output at the bottom of the simulation domain (18 m depth), at the water table (Figure 5 & 12).

Table 3: Hydraulic parameters obtained from best fit of the model.

USDA Soil Texture Class	Θ_r	Θ_s	α	n	K_s	R^2
Sandy Loam(0-.6m)	0.072 [0.053]	0.39[0.42]	0.018[0.017]	1.42[1.46]	36.5[42.8]	0.75
Loamy Sand (.6-1.8m)	0.064 [0.056]	0.39[0.42]	0.04[0.034]	2.24[2.04]	170.2[220.7]	
Sand (1.8-3.6m)	0.044 [0.060]	0.36[0.42]	0.018[0.03]	2.23[2.33]	223.5[320.9]	
Loamy Sand (3.6-18m)	0.074 [0.057]	0.38[0.43]	0.033[0.03]	2.20[2.14]	161.5[267.9]	

On increasing the pressure head at the surface by 500mm (day 35-62, 71-110 and 112-150) (Figure 10 & 11), did not show a significant change in the recharge rate. However on day 350-362 when pressure head was increased again there was a temporary increase over a short duration of time. After the initial 62 days, drastic change in pressure head did not yield any significant change to the infiltration rate since the soils under the basin were all close to saturation and had reached steady state. Prior to the first 62 days the infiltration rate increased by 6.8% for every 30 cm increase in pressure head at the surface. Thereafter, the boundary pressure head was relatively constant (averaging 80 cm) and did not affect infiltration rate substantially. The water balance error derived from the inverse solution was 0.112% and the r^2 for the regression of predicted vs observed was 0.75 with an average residual of -0.0725.The model runs exhibited similar fit (r2, lower residual and WB%), when ran for a shorter period of 50 days and then for the whole 465 days (Figure 13 & 14). This reinforced the robustness of the model. Additionally, the values within parenthesis in Table 3 represents the actual hydraulic parameters predicted by US Salinity labs ROSSETTA model, while the values outside the parameters are as obtained from best fit of the model. The actual and fitted values were within reasonable values for these soils types. The model observation and fit were very closely correlated for the wetting front, however there was a consistent and difference between fitted and observed at the saturated end.

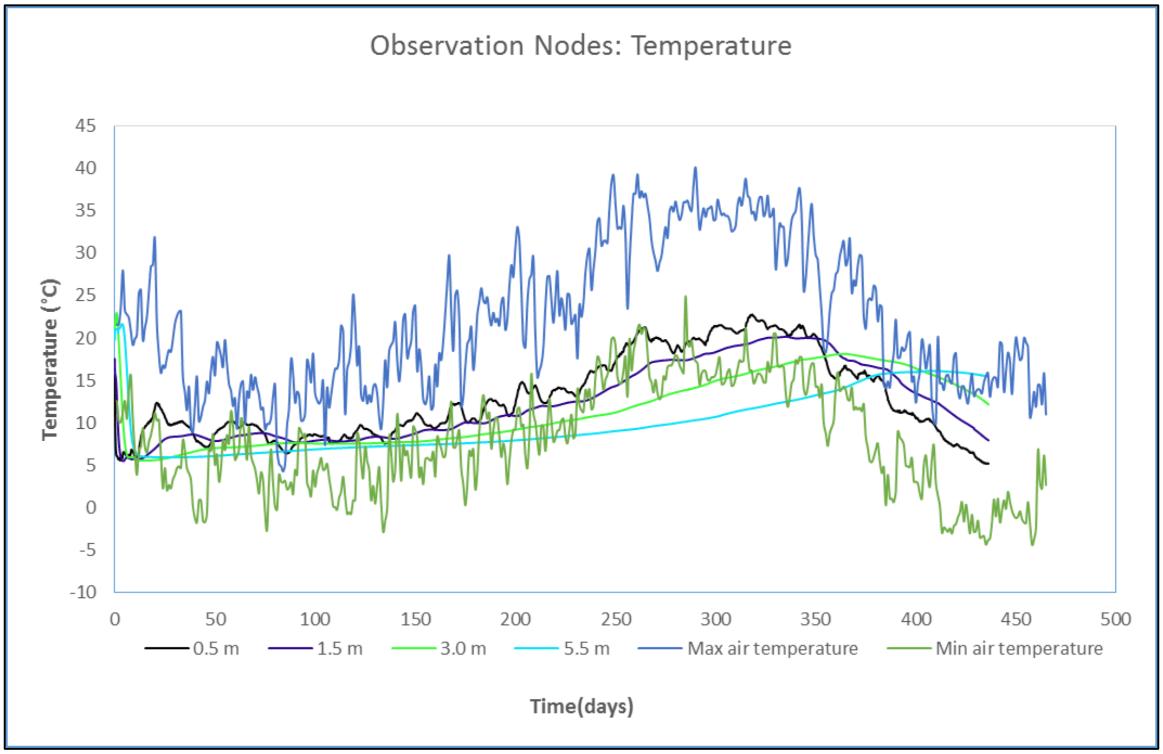

Figure 8: Temperature profile for the different observation nodes at Fresno RWRF basin 3.

Daily recharge values estimated from 10/25/2010 to 1/10/2012 demonstrated a fast decline in the infiltration during the first 15-20 days, followed by a steady decline over the next 210 days and attained steady state, there was a slight increase at day 221 and maintained that steady state after that. This observation concurs with other studies on infiltration rate, demonstrating a fast decline initially and demonstrating towards a steady state eventually. The infiltration rate were below 100 mm/day past the 210 days period and were at 50mm/day beyond 300 days with a slight decline over time .This helps us make the assumption that beyond 330 days, infiltration starts slowing down but without effecting recharge rate. At the end of the 450 days when water supply was cut off, we saw a steady increase in recharge rate (Figure 9& 10) as flow transitioned from a saturated to unsaturated flow.

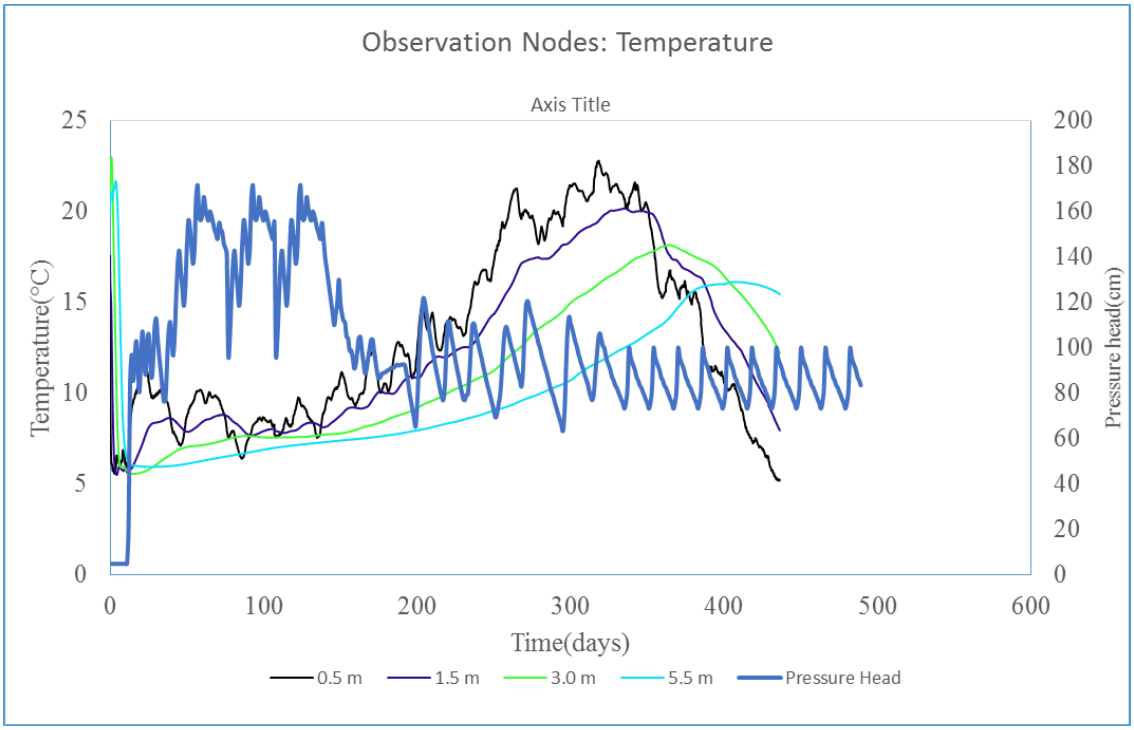

Figure 9: Average soil temperature and pressure head for basin from the 3 locations (west, middle, and north) at basin 3 Fresno RWRF.

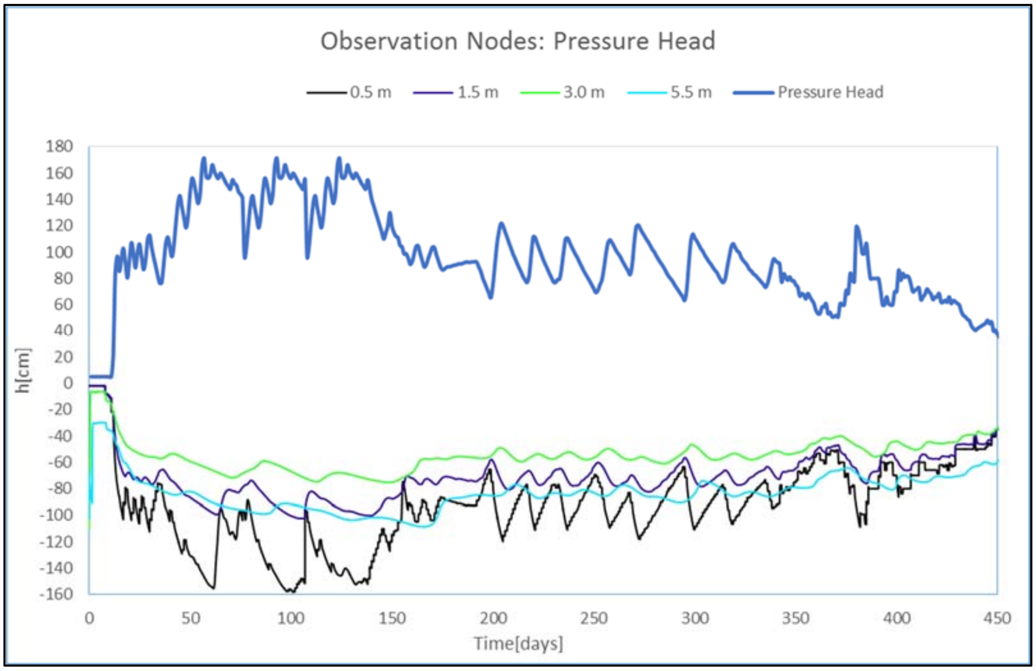

Figure 10: Actual surface pressure head for basin 3 and the resulting pressure head at the observation nodes at various depths.

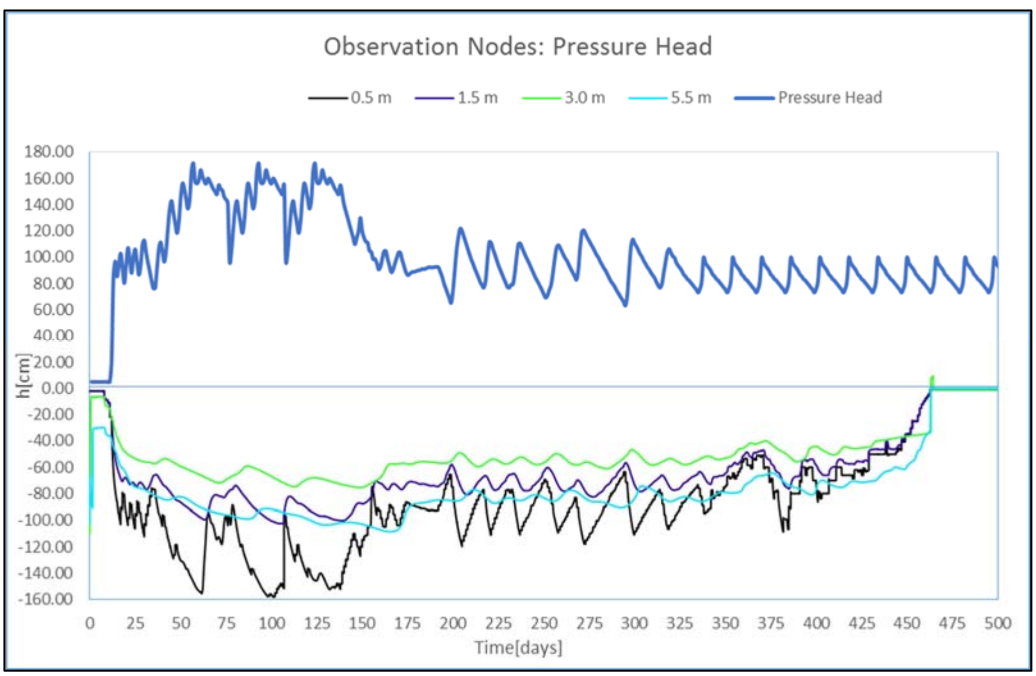

Figure 11: For the purposes of forward modeling, beyond day 465, the data was expanded with historic data to run a forward model simulation for 500 days.

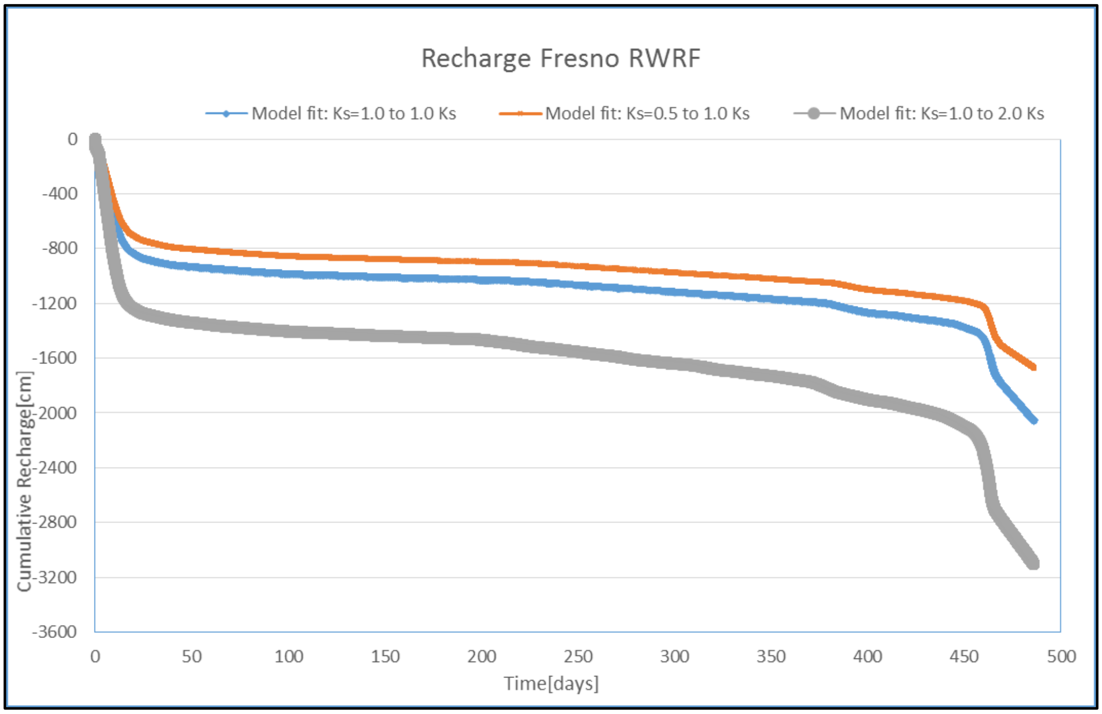

Figure 12: The Ks value limits were rerun after the optimal model fit (1:1 Ks) were obtained that illustrated the optimal Ks values with the aid of inverse solution data. Ks values were reinitialized to have values between 0.5 to 1.0 times of the actual value; and again 1.0 to 2.0 times actual value to show the recharge values changed accordingly.

To test the robustness of the model, the fits were compared for an initial period of 50 days and then compared to the full 465 days, for location west and middle respectively (Figure 13 & 14), both runs produced similar fit with r^2 of 0.75. Also, as illustrate in figure 12, the model recharge values increased or decreased proportional to the change in Ks values of the various soil layers. This also confirms that, not only is the model fit consistent over the initial or full spectrum of the data, but any change in the model parameters is directly proportional to the output.

For the other 3 RWRF's we modeled Hydrus 2D with constant pressure head (900 mm), online soils survey data for soil textures, GW levels from USGS, and weather parameters from local weather stations. Based on the Hydrus modeling cumulative bottom flux for Tulare, Visalia and Bakersfield RWRFs, we found the average recharge rate to be 30.12-41.56 mm/day, 43.12-64.58 mm/day, and 41.56-68.97 for Tulare, Visalia and Bakersfield respectively (Table 4). The higher recharge range for each site is during the initial unsaturated flow conditions. The lower numbers of recharge are steady state rate. Since on-site data was not available for these 3 RWRF's, to perform inverse solution, no water balance regression or r^2 fit could be performed.

3.3.3 Available land for recharge

To quantify the regional potential for MAR using reclaimed water, we extrapolated our findings to the overall south SJV (mainly within the confines of the other three RWRF's at Visalia, Tulare and Bakersfield).

Wastewater treatment facilities are normally located outside of the populated areas of the communities to meet National Pollutant Discharge Elimination System (NPDES) and Water Pollution Control Facilities (WPCF) requirements among other factors (Qasim 1998). In addition they are located down gradient of the city to use gravity for flow. We found this to be true for the four RWRF we used for our study (Table 7).

Using the parameters described in equation 3, we found the minimum and maximum land requirement for Fresno RWRF to be 193 and 119 ha respectively (Table 4).Similarly for Tulare, Visalia and Bakersfield the minimum and maximum figures were 14.9-44.1, 7.5-22.6 and 10.1-34.8 ha respectively.

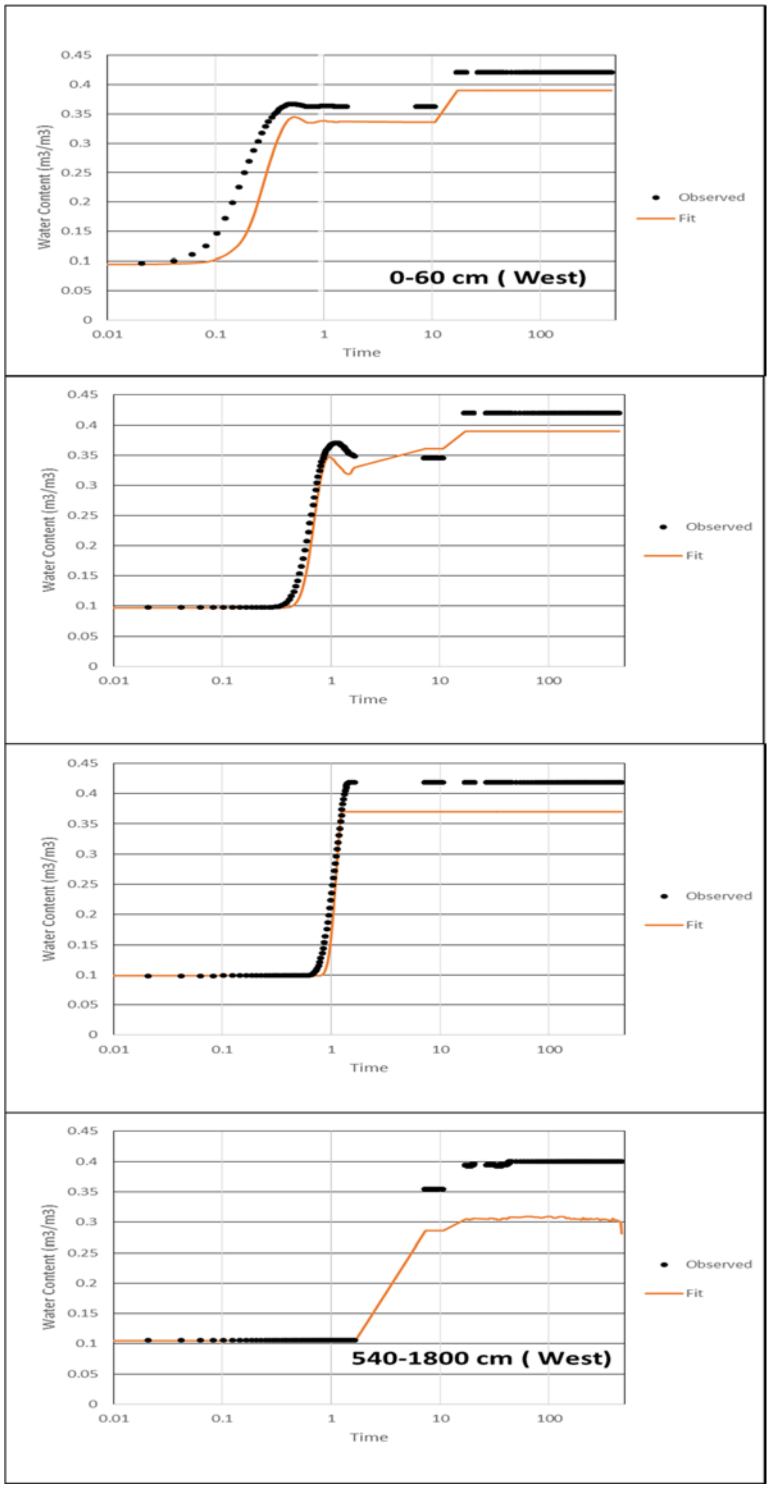

Figure 13: Basin 3, Hydrus 2D observed and simulated results for water content, for west station at day 50 (top to bottom: 0-60, 60-180, 180-540 & 540-1800 cm). The x-axis is time scale in log units.

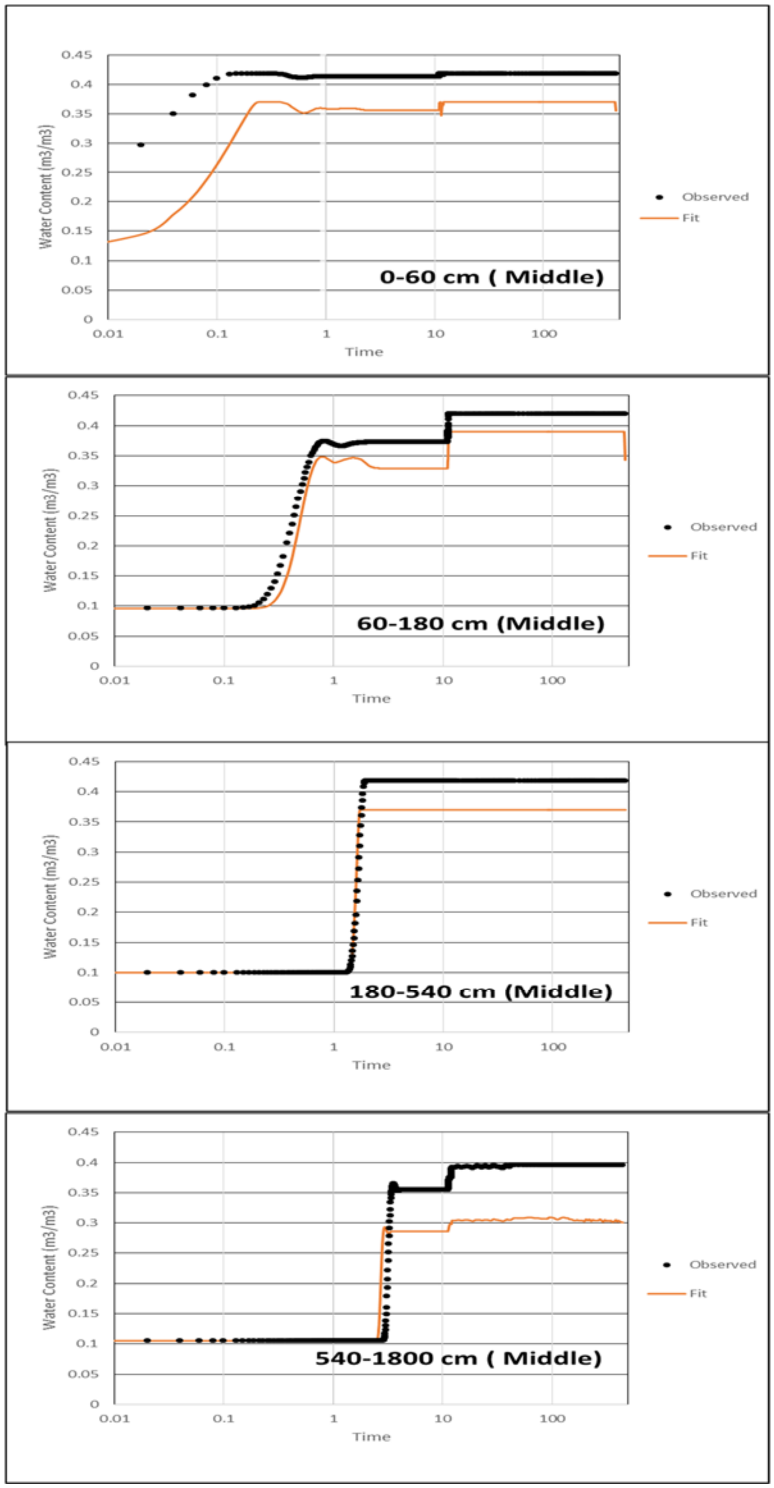

Figure 14: Basin 3, Hydrus 2 D observed and simulated results for water content, for middle station at day 465 (top to bottom: 0-60, 60-180, 180-540 & 540-1800 cm). The x-axis is time scale in log units.

It should be noted that there is a significant amount of differences in the amounts of land needed for each of the RWRFs and the corresponding percentage recharge. These numbers are indicative of the infiltration rate and the amounts of water available for recharge (quantity of wastewater available at each RWRF is also a function of the population size being serviced by each of these RWRF).

Table 4: Recharge land required per RWRF and recharge potential

Location	Wastewater (MM m3/day)	Avg Infiltration rate of soil (mm/day)	Steady State Recharge Rate of soil (mm/day)	Land Required to recharge efficiently(ha)	Potential minimum recharge (m3/day)	Potential maximum recharge (m3/day)	As % of Wastewater received
Fresno (model)	0.2574	20-130	9.70-19.10	193-1119	36863	108543	14.3-42.2
Tulare (NRCS)	0.055	121.9-365.8	30.12-41.56	14.9-44.1	6192	13282	11.3-24.2
Visalia (NRCS)	0.0833	365-1100	43.21-64.58	7.5-22.6	4843	9765	5.8-11.7
Bakersfield (NRCS)	0.1211	345.6-1200	41.56-68.97	10.1-34.8	6965	27840	5.8-11.9

Based on the location of Fresno RWRF, it was ascertained from GIS and Satellite data, that areas immediately south and south west of the treatment facility were down gradient of the Fresno metropolis area. The treatment facility is at 76.8 m meters above sea level (city elevation 93.87 m) and areas up to 10 km south and south-west of facility steadily dropped to between 59.5-70.2 m above sea level from 76.8 m (Table 7 & Figure 15). To investigate potential areas for recharge with the four different disposal method (irrigation, rapid infiltration, slow infiltration and land application of wastewater) we focused on these portions of land. We narrowed our recharge area in this vicinity with access to existing canal infrastructure and selected an area of 21,027 ha and found 2185 ha (10.4 %), 1092(5.2%), 2139(10.2%) and 8457(40.2%) suitable for disposal by irrigation, rapid infiltration, land application and slow infiltration respectively (Table 5 and Figure 15). These numbers are in access of the maximum area (1119 ha) needed to successfully dispose-off 0.2574 x 106 m3/day of waste water, except for land application method. Using either of the four disposal method we can expect recharge to be around 14.2-42.2 % of the total incoming wastewater (Figure 19).

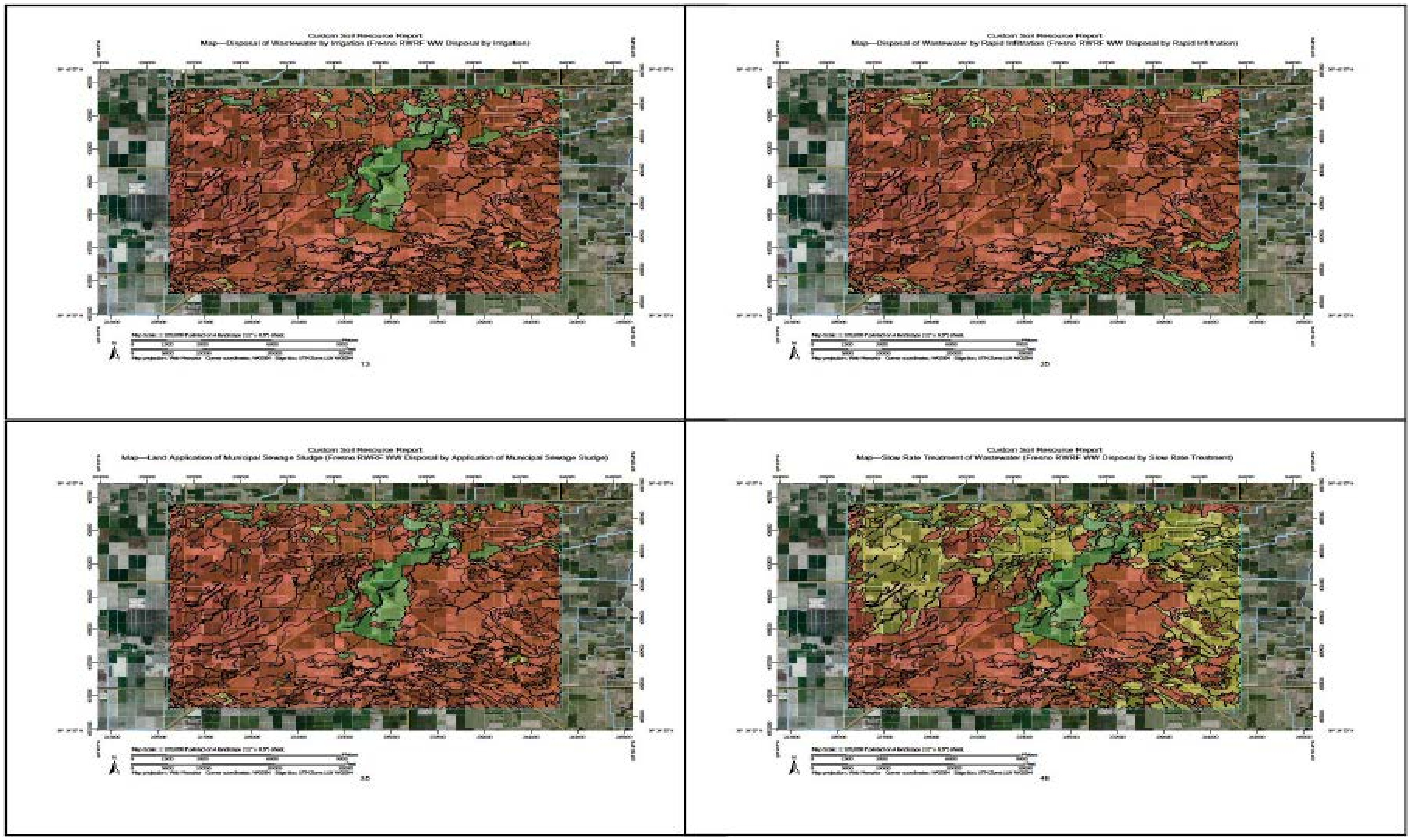

Figure 15: Fresno RWRF proposed recharge area potential for wastewater discharge using Irrigation, Rapid Infiltration, Sewage Sludge and Slow Rate Treatment of WW (RWRF: top right corner of the selected area).The areas designated by , , ,and represents very limited, somewhat limited, not limited, and not rated areas for discharge within the selected polygon.

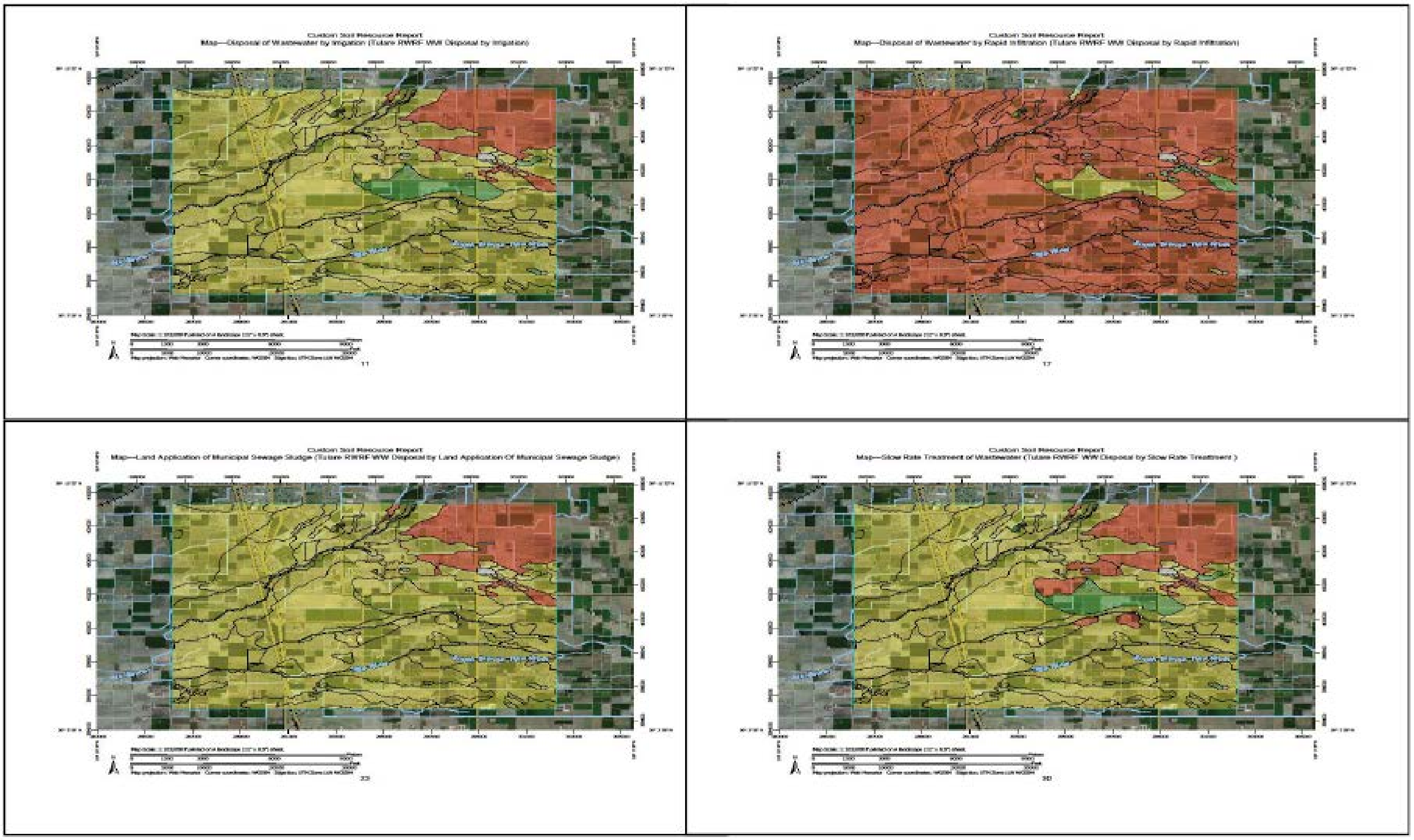

Figure 16: Tulare RWRF proposed recharge area potential for wastewater discharge using Irrigation, Rapid Infiltration, Sewage Sludge and Slow Rate Treatment of WW (RWRF: top right corner of the selected area). The areas designated by , , ,and represents very limited, somewhat limited, not limited, and not rated areas for discharge within the selected polygon.

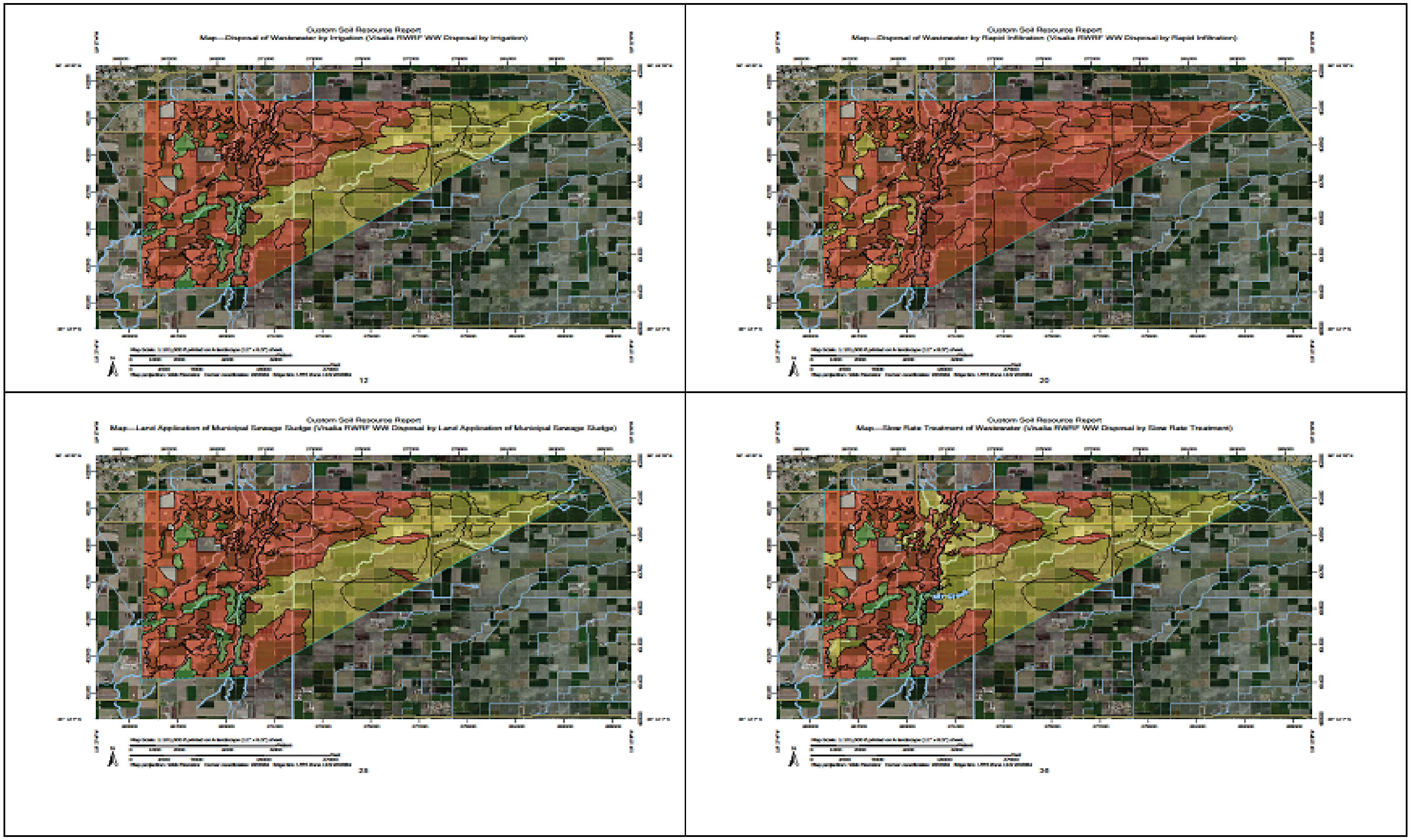

Figure 17: Visalia RWRF proposed recharge area potential for wastewater discharge using Irrigation, Rapid Infiltration, Sewage Sludge and Slow Rate Treatment of WW (RWRF: top right corner of the selected area). The areas designated by , , ,and represents very limited, somewhat limited, not limited, and not rated areas for discharge within the selected polygon.

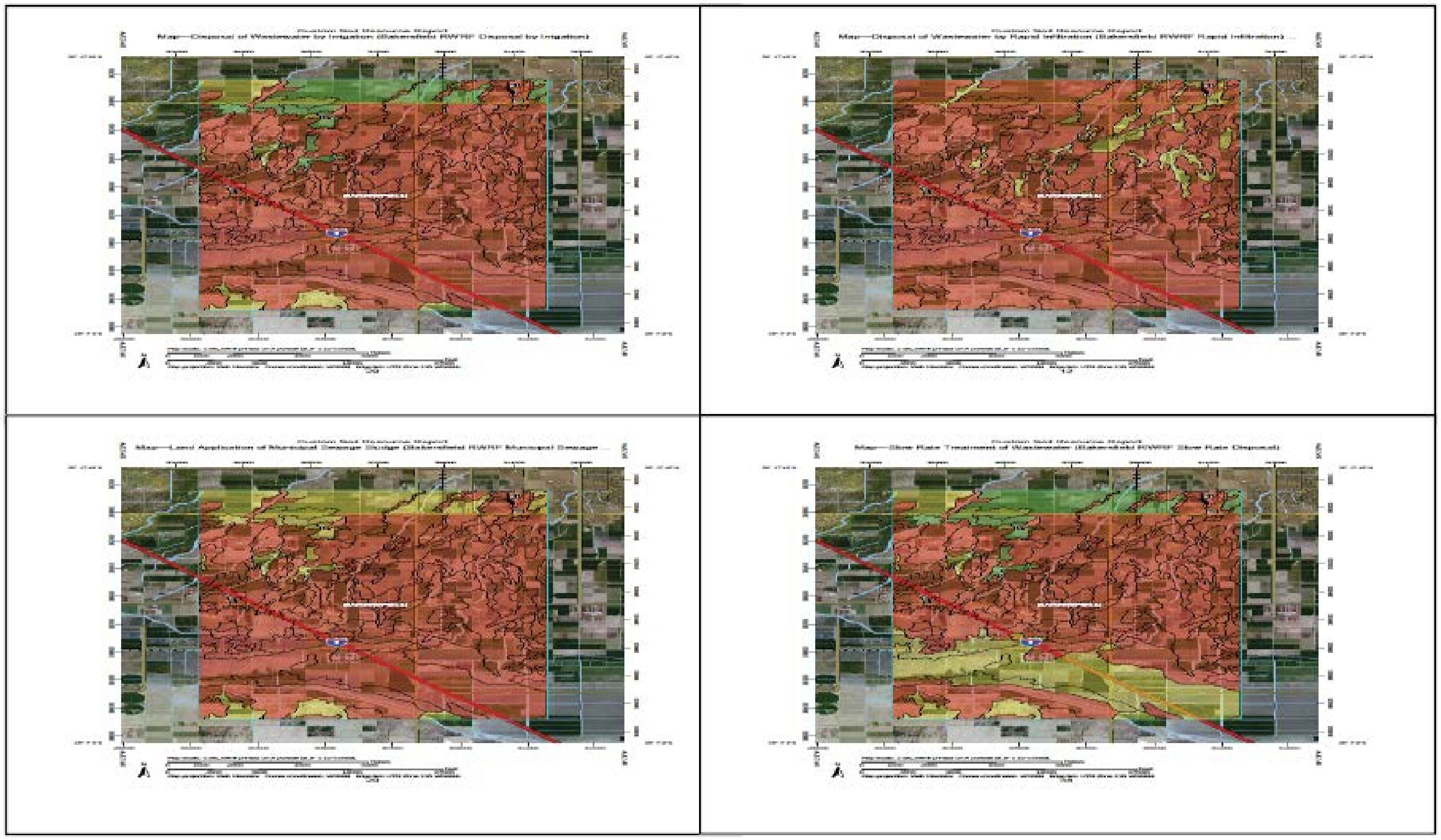

Figure 18: Bakersfield RWRF proposed recharge area potential for wastewater discharge using Irrigation, Rapid Infiltration, Sewage Sludge and Slow Rate Treatment of WW (RWRF: top right corner of the selected area). The areas designated by , , ,and represents very limited, somewhat limited, not limited, and not rated areas for discharge within the selected polygon.

Table 5: Total land area potentially available to attain efficient recharge at Fresno and Tulare RWRF's. Figures within the parenthesis indicates the percentage available within the total area of interest (AOI).

	Location and Area Selected (hectares and [percentage])							
	Fresno				Tulare			
Rating	**Disposal by Irrigation**	**Rapid Infiltration**	**Land Application**	**Slow Infiltration**	**Disposal by Irrigation**	**Rapid Infiltration**	**Land Application**	**Slow Infiltration**
Very limited	18392 [87.5%]	18972 [90.2%]	18392 [87.5%]	10365 [49.3%]	2100 [10.7%]	18543 [94%]	2100 [10.7%]	2529 [12.8%]
Not limited	2185 [10.4%]	1092 [5.2%]	2139 [10.2%]	8457 [40.2%]	687 [3.5%]	153 [0.8%]	0 [0%]	687 [3.5%]
Somewhat limited	430 [2%]	942 [4.5%]	475 [2.3%]	2184 [10.4%]	16621 [84.3%]	713 [3.6%]	17309 [87.8%]	16192 [82.1%]
Null or Not Rated	19 [0.1%]	19 [0.1%]	19 [0.1%]	19 [0.1%]	310 [1.6%]	310 [1.6%]	310 [1.6%]	310 [1.6%]
Total for AOI	**21027**	**21027**	**21027**	**21027**	**19720**	**19720**	**19720**	**19720**

Table 6: Total land area potentially available to attain efficient recharge at Visalia and Bakersfield RWRF's. Figures within the parenthesis indicates the percentage available within the total area of interest (AOI).

	Location and Area Selected (hectares and [percentage])							
	Visalia				**Bakersfield**			
Rating	**Disposal by Irrigation**	**Rapid Infiltration**	**Land Application**	**Slow Infiltration**	**Disposal by Irrigation**	**Rapid Infiltration**	**Land Application**	**Slow Infiltration**
Very limited	6452[55.2%]	10624[90.9%]	6451[55.2%]	5165[44.2%]	13236[87.2%]	14066[92.7%]	13236[87.2%]	10555[69.6%]
Not limited	1934[6.7%]	0[0%]	782[6.7%]	782[6.7%]	1321[8.7%]	0[0%]	0[0%]	1321[8.7%]
Somewhat limited	4195[35.9%]	804[6.9%]	4195[35.9%]	5480[46.9%]	583[3.8%]	1073[7.15]	1904[12.6%]	32[21.5%]
Null or Not Rated	260[2.2%]	260[2.2%]	260[2.2%]	260[2.2%]	32[0.2%]	32[0.2%]	32[0.2%]	32[0.2%]
Total for AOI	**11689**	**11689**	**11689**	**11689**	**15171**	**15171**	**15171**	**15171**

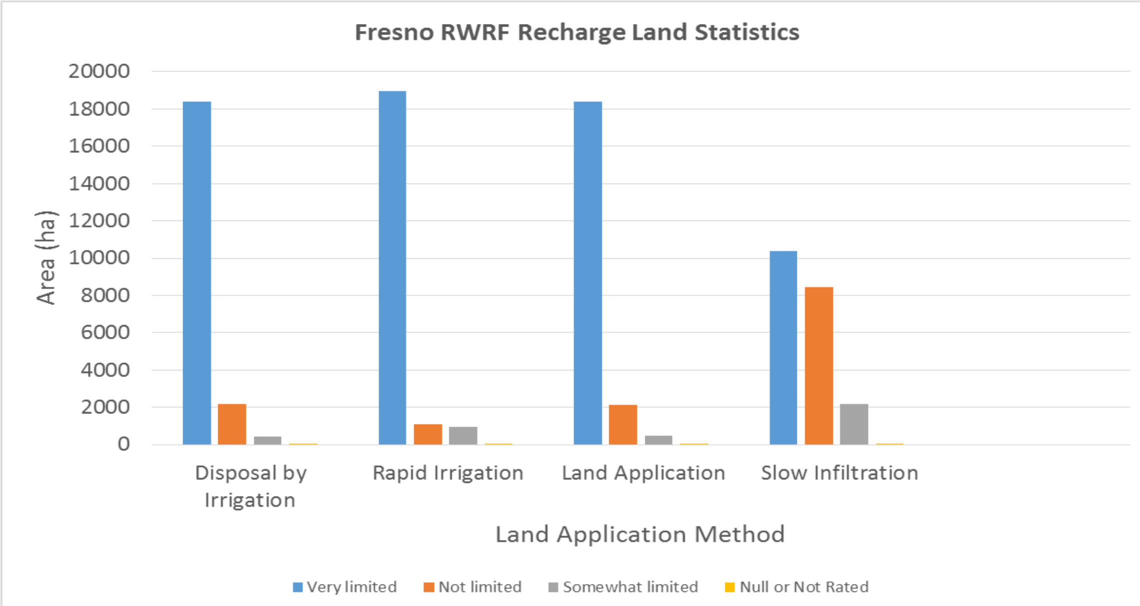

Figure 19: Fresno RWRF proposed recharge area potential for wastewater discharge using Irrigation, Rapid Infiltration, Sewage Sludge and Slow Rate Treatment of WW.

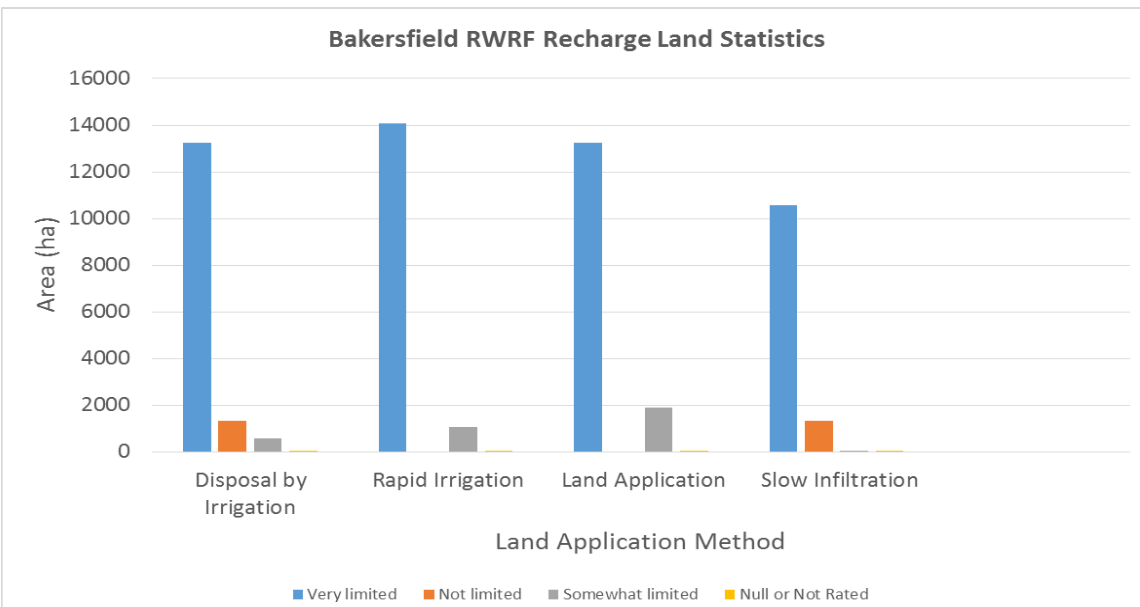

Figure 20: Bakersfield RWRF proposed recharge area potential for wastewater discharge using Irrigation, Rapid Infiltration, Sewage Sludge and Slow Rate Treatment of WW.

For, Tulare RWRF areas west and south-west of the facility were down gradient and went from 78.33 m above sea level at the facility to 65-67 m above sea level in areas mentioned above with a steady decline in elevation (city elevation 88.09 m)(Table 7 and Figure 16). To investigate potential areas for recharge, we focused on these portions of land. We selected an area of 19720 ha and found 687 ha (3.5 %), 153(0.8%), 0(0%) and 687 (3.5%) suitable for disposal by irrigation, rapid infiltration, land application and slow infiltration respectively (Table 5 and Figure 16). These numbers are in access of the maximum area (44.1 ha) needed to successfully dispose-off 0.55 x 10^6 m^3/day of waste water, except for land application method. This will potentially contribute to 11.3-24.2 % of the incoming wastewater leading to recharge. These numbers are slightly lower than Fresno, as the soils in Tulare area had higher conductivities leading to less land required but did not have relatively comparable recharge rate (Table 4).

Table 7: Elevation of Study area cities and treatment facility (RWRF)

RWRF	Elevation of City above Sea level (m)	Elevation of RWRF above Sea level (m)
Fresno RWRF	93.87	76.8
Tulare RWRF	88.09	78.33
Visalia RWRF	100.89	85.64
Bakersfield-B RWRF	132.14	108

At, Visalia RWRF the treatment facility is at 85.64 m above sea level and areas west and south-west of the facility were down gradient and were at 69-71 m above sea level at 20 km from the facility with gradual decline in elevation (city elevation 100.89 m) (Table 7 and Figure 17). We narrowed our recharge area in this vicinity and selected an area of 11689 ha and found 1934 ha (3.5 %), 0(0%), 782(6.7%) and 782 (6.7%) suitable for disposal by irrigation, rapid infiltration, land application and slow infiltration respectively (Table 7 and Figure 17). For this RWRF we selected a triangular area due to the canal infrastructure, compared to a rectangular polygon for the other RWRFs. This will potentially contribute to 5.8-11.7 % of the incoming wastewater leading to recharge. These numbers are again slightly lower than Fresno and Tulare, as the soils in Visalia area had higher conductivities compared to Fresno and Tulare needing less land for infiltration but had comparatively less recharge potential (*Table 4*). This may be attributed to the saturated mound that formed underneath the basin, for soils with higher infiltration rate the mounds would develop sooner, restricting flow from top.

Lastly, at Bakersfield RWRF-B the treatment facility is at 108 m above sea level and areas west and south of the facility were down gradient and were from 91-101 m above sea level at 10 km from the facility with gradual decline in elevation (city elevation 132 m) (Table 7 and Figure 18). Lastly, for Bakersfield area we selected an area of 15171 ha and found 1321 ha (8.7 %), 0(0%), 0(0%) and 1321 (8.7%) suitable for disposal by irrigation, rapid infiltration, land application and slow infiltration respectively (Table 7 and Figure 18). This will potentially contribute to 5.8-11.9 % of the incoming wastewater leading to recharge. These numbers are again slightly lower than Fresno and Tulare, but comparable to Visalia. This area exhibited favorable criterion for disposal by Irrigation and slow infiltration but were totally unfavorable for rapid infiltration and land application. This could be attributed to the high infiltration rate, where rapid infiltration and land application could lead to contaminants present in the wastewater to pass through the soil without getting filtered through the soil, leading to health hazard. Again, this is a prime example of how the model is able to filter out one disposal method from another based on soil features.

Based on the Hydrus modeling for Fresno, Tulare, Visalia and Bakersfield RWRF's recharge rate and the infiltration capacity of the soil, the estimated land needed to achieve maximum recharge was estimated at 193-1119 ha, 14.9-44.1 ha, 7.5-22.6 ha, and 10.1-34.8 ha for Fresno, Tulare, Visalia and Bakersfield respectively (Table 6 & 7). Priority should be on the maximum land area needed as it represents a steady state of recharge which is achieved after 10-30 days (Figure 19 & 20). Again, the numbers are based on the actual land area needed, but to implement this we will likely need additional land to be able to cycle through different parcels and keep the recharge process ongoing (or move to other areas if agronomic/management practices does not permit immediate reuse for the site for the next cycle). We estimated the recharge percentage (%) as a function of the volume of the incoming wastewater, these figures vary from location to location based on the soil hydrology. The percentage recharge for the four RWRF locations were 14.3-42.2%, 11.3-24.2%, 5.8-11.7%, and 5.8-11.9 % for Fresno, Tulare, Visalia and Bakersfield respectively(Table 4). The variation is in direct correlation to the hydraulic conductivity of the local soils; the soils were much coarser as we moved south of Fresno, leading to a mound being formed faster in the coarser soil.

In this study the effort was mainly focused on demonstrating the recharge potential, and to show that land areas could be available if needed. Additionally, we factored in four different disposal method for recharge so utilities could mix and match based on need. These four study sites are in the heart of America's agricultural operation;

cropping pattern, and crop rotation for row crops vary every year based on market demand, water availability, and agronomic practices. So it is very hard to accurately predict, which parcel of land could be potentially available. But our land area analysis shows (*Table 5 and Figures 15-18*), shows that we have sufficient amount of land potentially available for recharge compared to the actual acreage needed, this is very promising and should not create any bottlenecks in the process.

3.4 Discussion

In this section we limit our discussion mainly to cover Hydrus modeling and land use data.

3.4.1 Hydrus modeling

Our Hydrus modeling primarily focused on the Fresno RWRF basin. We expected our data set to demonstrate infiltration rates lower than the ones reported by USDA/NRCS: SSURGO soils survey. USDA/NRCS soils survey indicated an infiltration capacity of 78-106 mm/day, however our soil columns and water balance showed the infiltration capacity to be around 20-130mm/day. Past research has demonstrated these differences as well, which is attributed mainly to variability in soil type, map scale, spatial location, and specific soil property (Muttiah and Wurbs 2002, Lin et al. 2005, Beaudette and O'Geen 2009).The initial infiltration rate is slightly higher than the USDA/NRCS data, which again may be attributed to soil variability, however the lower infiltration rate over time is mainly accredited to the quality of the secondary treated water (Arye, Tarchitzky and Chen 2011; Bekele 2011;Knowles, Dotro, Nivala and Garcia 2011; Pesco and Arar 2013).

Once the Hydrus flow/transport model was calibrated with our field data (*Figure 8-9*), various scenarios were run to be able to port the model for the other three RWRF's (Abbasi,Feyen and van Genuchten 2004; Moriasi et al. 2012) . The model showed no long term increase in recharge rate if the pressure head were increased by 500 mm after the onset of inverted table at 330 days. But recharge rates demonstrated a slight increase when the pressure head was increased again (Sophocleous 2002; Racz,Fisher,Schmidt, and Lockwood 2012); we maintained the head at 800-1400 mm in the actual field condition. The model also indicated that recharge capacity would remain the same as long as a minimum head of 800 mm was maintained. However, the infiltration rate increased to 6.8% for every 300 mm increase in head (Bear 2012; Schmidt, Fisher, Racz and Wheat 2012). From a recharge point of view, this could be really beneficial as the water could be spread out to bigger areas rather than have a pond with maximum allowable head; however this could also be detrimental for utilities as it reduces the infiltration capacity. Utilities are mostly concerned with infiltration rate rather than recharge, as disposing off the water in a quicker fashion helps them maintain a steady flow of water out of the treatment plant. Nonetheless, having this new information could be helpful in deciding if recharge or infiltration takes precedence based on availability of access land.

With the current drought scenario, we don't have too many exposed water bodies. Even lakes and reservoirs are at its all-time low, this leads to reduced evaporation which eventually affects the hydrological cycle. Maintaining low water heads allows for the water to be spread over a larger area which not only aids in recharge but also the evaporation of water, which is greatly needed to alleviate drought conditions (Sun and Chen 2012; Monteith and Unsworth 2013) .

3.4.2 Estimation of available land for recharge

USBR data and our data computation of unusable or fallow land from these sources show that we have over 28,700 ha of fallow or unusable not suitable for agriculture in Central SJV. Recent CA SJV land use data shows that these numbers are growing due to CA State Water project's inability to supply water to farmers (Howitt, Medelln-Azuara, Lund and MacEwan 2014). Our estimates were similar to the previous study above, but we also included range lands belonging to USBR and land designated for the Central Valley Basin reclamation project similar to the concept proposed by Esnault and colleagues (2014).

We expected the infiltration and recharge process to be slow, however our model parameters indicate that if the recharge scheme were to be implemented in reality, we can estimate the recharge to be anywhere from 5.8-42.2% of the daily wastewater generated. In these times of drought and groundwater depletion, these numbers could over time help minimize the depleting groundwater. Again our work is similar effort as illustrated by (Racz 2012), but accounts for extrapolation of this method over a bigger geographical-area using secondary treated water. Again, the whole concept of this premise is to look for alternatives to recharging groundwater, provided we can comprehensively address the real health concerns that are associated with the reuse of wastewater.

Moreover, we focused on recharge using four methods of disposal. For example in under these drought conditions, where farmers are struggling to grow more with depleting water supplies, some of the irrigation water could be sourced as " disposal by irrigation". Disposal by irrigation will allow for crops like cotton, alfalfa, sudan grass and other salt (TDS) tolerant crops to be grown with wastewater, freeing up much needed fresh water for other crops fit for human consumption(Deinlein et al., 2014; Roy, Negrão, and Tester,2014;Yamaguchi and Blumwald, 2005). Not all areas have similar soils and access to land for disposal using a single method of disposal for recharge, having more than one option allows for beneficial second use and still aid with recharge.

Additionally, to frequently flush some of these recharge areas of the bio contaminates, we could periodically introduce fresh water or blend freshwater with the treated water. For example for every 1 m^3 of wastewater treated at the treatment plant the City of Fresno has 0.75 m^3 of fresh water left over from the SJ and KR water rights. Fresno-Clovis RWWTF treats about 90 MM m^3 of wastewater annually, while the city has left over of or unappropriated 60 MM m^3 of fresh water form SJ and KR. This could be used for either blending the wastewater or to periodically flush the recharge areas (Fresno Bee, 2015).

3.4.4 Health Concerns

Fortunately, researchers have recently developed relatively cheaper and more innovative alternatives to further scrub wastewater based on the contaminants to be removed so it could be safely reused for purposes like recharge. Recently developed polymer-soil composite compound can absorb specific target compounds more efficiently than conventional sorbents such as active carbon (Bleiman and Mishael,2010; Ganigar et al., 2010; Radian et al., 2011, Zadaka-Amir et al.,2012;Radian and Mishael, 2012).

Polymer-soil compounds have been used in the past as sorbents without much success because it primarily focused on contaminant as a function of clay flocculation (Theng 1979). Conversely, these new polymer-soils are specifically tailored based on contaminants to be removed, but research regarding this process is still in its infancy stage (Radian and Mishael, 2008; and Zhu et al 2011). These specific sorbents hold great promise but have not yet been tried and tested on treatment of the wastewater as it passes through the vadose zone to the aquifer (Lim et al., 2008 ; Dickenson et al., 2011;.Jasper and Sedlak, 2013; Grebel et al., 2013)

3.4.5 Salinity Built Up

For this study we have discounted the health concern arising out of the use of secondary treated water for recharge, but salinity is another issue that needs to address. We know the salinity of the secondary treated water is not significantly high and is under 1dS/m, however overtime it could add up if we don't pay attention to the salt balance. Salt balance is governed by three principle: 1) salt added should be equal to salts removed, 2) and the buildup could be less abrupt in shallow groundwater areas due to intermixing of incoming water and old water and, 3) due to slow movement of salts it takes a relatively extended period of time for these salts to reach groundwater (Latey, 2000; Schopas et al., 2005). In our current proposed system, since the recharge sites will be moved around based on availability of water, and land use type available, its still conceivable that salinity build up in the soil or salt reaching groundwater might be an issue. But the hope is that some scientific breakthrough in the current polymer membrane technology might be able to harness the salts in the vadose zone so it could be extracted out of the system before it reached groundwater(Dickenson et al., 2011; Grebel et al., 2013).

3.5. Conclusions

The water balance method describe here provides for direct and accurate measurement of infiltration rate at water reclamation ponds. While this method is accurate it needs significant instrumentation and data processing capability to analyze the data. City utilities could use a simplified version of this method by deploying a simplified flume to estimate water delivered to the basins and using a graduated staff gauge or inexpensive level loggers to keep track of level changes. The rest of the parameters needed for water balance can be obtained from local weather stations. The Fresno facility currently uses 80% of the reported evapotranspiration value in estimating infiltration. This assumption is generally not true and can be off by ±15%. A simple pan evaporation setup like the University of Georgia EASY PAN could be constructed and maintained at the utility site for accurate estimates. These will help utilities immensely in deciding the duty cycle of these ponds and minimize the error in the computation of their infiltration rate which is as high as 200% at times.

Modeling software like Hydrus and MODFLOW are great tools to estimate recharge from these utilities, this not only helps manage these basins better but could aid in the recharge process and keep a track of the groundwater health.

User friendly USDA/NRCS SSURGO driven online websites makes it relatively easy for utilities and city manager to plan recharge options and land use pattern.

Finally the modeling effort indicate that if the recharge scheme were to be implemented in reality, we can estimate the recharge to be anywhere from 5.8-42.2% of the daily wastewater generated, which is roughly 0.5% of the groundwater refill requirement proposed by NASA for the central valley.

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References:

Abbasi, F., Feyen, J., & Van Genuchten, M. T. (2004). Two-dimensional simulation of water flow and solute transport below furrows: model calibration and validation. *Journal of Hydrology*, *290*(1), 63-79.

Arye, G., Dror, I., Berkowitz, B., 2011. Fate and transport of carbamazepine in soil aquifertreatment (SAT) infiltration basin soils. Chemosphere 82, 244–52.

Arye, G., Tarchitzky, J., & Chen, Y. (2011). Treated wastewater effects on water repellency and soil hydraulic properties of soil aquifer treatment infiltration basins. *Journal of hydrology*, *397*(1), 136-145.

Azooz, R. H., & Arshad, M. A. (1996). Soil infiltration and hydraulic conductivity under long-term no-tillage and conventional tillage systems. *Canadian Journal of Soil Science*, *76*(2), 143-152.

Bear, J. (2012). *Hydraulics of groundwater*. Courier Corporation.

Bekele, E., Toze, S., Patterson, B., & Higginson, S. (2011). Managed aquifer recharge of treated wastewater: Water quality changes resulting from infiltration through the vadose zone. *Water research*, *45*(17), 5764-5772.

Bhuiyan, C. (2015). An approach towards site selection for water banking in unconfined aquifers through artificial recharge. *Journal of Hydrology*, *523*, 465-474.

Biemans, H., Haddeland, I., Kabat, P., Ludwig, F., Hutjes, R. W. A., Heinke, J., ... & Gerten, D. (2011). Impact of reservoirs on river discharge and irrigation water supply during the 20th century. *Water Resources Research*, *47*(3).

Boxall, A.B. a, Johnson, P., Smith, E.J., Sinclair, C.J., Stutt, E., Levy, L.S., 2006. Uptake of veterinary medicines from soils into plants. J. Agric. Food Chem. 54, 2288–97.

Bartsch, W. M., Axler, R. P., & Host, G. E. (2015). Evaluating a Great Lakes scale landscape stressor index to assess water quality in the St. Louis River Area of Concern. *Journal of Great Lakes Research*, *41*(1), 99-110.

Chen, Z. (2014). A novel standardized assessment for the new end uses of recycled water schemes.

Chefetz, B., Mualem, T., Ben-Ari, J., 2008. Sorption and mobility of pharmaceutical compounds in soil irrigated with reclaimed wastewater. Chemosphere 73, 1335–43.

Cheremisinoff, N. P. (2001). *Handbook of water and wastewater treatment technologies*. Butterworth-Heinemann.

Coelhan, M. (2006). Occurrence and biodegradability studies of selected pharmaceuticals and personal care products in sewage effluent. *Agricultural water management*, *86*(1), 72-80.

Crites, R. W., Middlebrooks, E. J., & Bastian, R. K. (2014). *Natural wastewater treatment systems*. CRC Press.

Crittenden, J. C., Trussell, R. R., Hand, D. W., Howe, K. J., & Tchobanoglous, G. (2012). *MWH's Water Treatment: Principles and Design: Principles and Design*. John Wiley & Sons.

Debo, T. N., & Reese, A. (2002). *Municipal stormwater management*. CRC Press.

Deinlein, U., Stephan, A. B., Horie, T., Luo, W., Xu, G., & Schroeder, J. I. (2014). Plant salt-tolerance mechanisms. *Trends in plant science*, *19*(6), 371-379.

Eckstein, G., & Sherk, G. W. (2011). Alternative Strategies for Addressing the Presence and Effects of Pharmaceutical and Personal Care Products in Fresh Water Resources. *U. Denv. Water L. Rev.*, *15*, 369.

Esnault, L., Gleeson, T., Wada, Y., Heinke, J., Gerten, D., Flanary, E., ... & van Beek, L. P. (2014). Linking groundwater use and stress to specific crops using the groundwater footprint in the Central Valley and High Plains aquifer systems, US. *Water Resources Research*, *50*(6), 4953-4973.

Grant, S. B., Saphores, J. D., Feldman, D. L., Hamilton, A. J., Fletcher, T. D., Cook, P. L., ... & Marusic, I. (2012). Taking the “waste” out of “wastewater” for human water security and ecosystem sustainability. *Science*, *337*(6095), 681-686Jim, T. Y., Bouwer, E. J., &

Gleick, P. H. (Ed.). (2014). *The World's Water Volume 8: The Biennial Report on Freshwater Resources*. Island Press.

Goldman, M. A., & Needelman, B. A. (2015). Wetland Restoration and Creation for Nitrogen Removal: Challenges to Developing a Watershed-Scale Approach in the Chesapeake Bay Coastal Plain. *Advances in Agronomy*.

Goldstein, M., Shenker, M., Chefetz, B., 2014. Insights into the uptake processes of wastewater-borne pharmaceuticals by vegetables. Environ. Sci. Technol. 48, 5593–600.

Gupta, V. K., Ali, I., Saleh, T. A., Nayak, A., & Agarwal, S. (2012). Chemical treatment technologies for waste-water recycling—an overview. *RSC Advances*, *2*(16), 6380-6388.

Horton, R. E. (1933). The role of infiltration in the hydrologic cycle. *Eos, Transactions American Geophysical Union*, *14*(1), 446-460.

Hempel, J. W., Libohova, Z., Odgers, N. P., Thompson, J. M., Smith, S. S., & Lelyk, G. W. (2016). Versioning of GlobalSoilMap. net raster property maps for the North American Node. *Computing Ethics: A Multicultural Approach*, *1*(250,000), 429.

Herklotz, P. a, Gurung, P., Vanden Heuvel, B., Kinney, C. a, 2010. Uptake of human pharmaceuticals by plants grown under hydroponic conditions. Chemosphere 78, 1416–21.

Jung, C., Son, A., Her, N., Zoh, K. D., Cho, J., & Yoon, Y. (2015). Removal of endocrine disrupting compounds, pharmaceuticals, and personal care products in water using carbon nanotubes: A review. *Journal of Industrial and Engineering Chemistry*.

Konikow, L. F., & Kendy, E. (2005). Groundwater depletion: a global problem. *Hydrogeology Journal*, *13*(1), 317-320

Lee, J. Y., & Lee, K. K. (2000). Use of hydrologic time series data for identification of recharge mechanism in a fractured bedrock aquifer system. *Journal of Hydrology*, *229*(3), 190-201.

Lev, O., Geser, G., Seldekevich, S., Shalkov, R., 2012. Report for the Israeli Water Authority: Micro-pollutants in effluents of different purification stages.

Levine, D. M., Berenson, M. L., & Stephan, D. (1999). *Statistics for managers using Microsoft Excel* (Vol. 660). Upper Saddle River, NJ: Prentice Hall.

Lin, H., Wheeler, D., Bell, J., & Wilding, L. (2005). Assessment of soil spatial variability at multiple scales. *Ecological Modeling*, *182*(3), 271-290.

Malchi, T., Maor, Y., Tadmor, G., Shenker, M., Chefetz, B., 2014. Irrigation of root vegetables with treated wastewater: evaluating uptake of pharmaceuticals and the associated human health risks. Environ. Sci. Technol. 48, 9325–33.

Mamedov, A. I., Shainberg, I., & Levy, G. J. (2000). Irrigation with Effluent Water Effects of Rainfall Energy on Soil Infiltration. *Soil science society of America Journal*, *64*(2), 732-737.

Marija J. Norušis, & SPSS Inc. (1994). *SPSS professional statistics 6.1*. Prentice Hall.

Miles, B., & Band, L. E. (2015). Ecohydrology Models without Borders?. In *Environmental Software Systems. Infrastructures, Services and Applications* (pp. 311-320). Springer International Publishing.

Mitch, W., Sharp, J., 2003. N-nitrosodimethylamine (NDMA) as a drinking water contaminant: a review. Environ. Eng. Sci. 20, 389–404.

Monteith, J., & Unsworth, M. (2013). *Principles of Environmental Physics: Plants, Animals, and the Atmosphere*. Academic Press.

Moriasi, D. N., Wilson, B. N., Douglas-Mankin, K. R., Arnold, J. G., & Gowda, P. H. (2012). Hydrologic and water quality models: Use, calibration, and validation. *Transactions of the ASABE*, *55*(4), 1241-1247.

Muttiah, R. S., & Wurbs, R. A. (2002). Scale-dependent soil and climate variability effects on watershed water balance of the SWAT model. *Journal of Hydrology*, *256*(3), 264-285.

NRC, 2012. Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater. Washington D.C.

Oulton, R.L., Kohn, T., Cwiertny, D.M., 2010. Pharmaceuticals and personal care products in effluent matrices: A survey of transformation and removal during wastewater treatment and implications for wastewater management. J. Environ. Monit. 12, 1956–78.

Pedersen, J. a, Soliman, M., Suffet, I.H.M., 2005. Human pharmaceuticals, hormones, and personal care product ingredients in runoff from agricultural fields irrigated with treated wastewater. J. Agric. Food Chem. 53, 1625–32.

Pescod, M. B., & Arar, A. (Eds.). (2013). *Treatment and Use of Sewage Effluent for Irrigation: Proceedings of the FAO Regional Seminar on the Treatment and Use of Sewage Effluent for Irrigation Held in Nicosia, Cyprus, 7–9 October, 1985*. Elsevier.

Plappally, A. K. (2012). Energy requirements for water production, treatment, end use, reclamation, and disposal. *Renewable and Sustainable Energy Reviews*, *16*(7), 4818-4848.

Racz, A. J., Fisher, A. T., Schmidt, C. M., Lockwood, B. S., & Huertos, M. L. (2012). Spatial and temporal infiltration dynamics during managed aquifer recharge. *Groundwater*, *50*(4), 562-570.

Roy, S. J., Negrão, S., & Tester, M. (2014). Salt resistant crop plants. *Current Opinion in Biotechnology*, *26*, 115-124.

Qasim, S. R. (1998). *Wastewater treatment plants: planning, design, and operation*. CRC Press.

Ramalho, R. (2012). *Introduction to wastewater treatment processes*. Elsevier.

Randall, C. W., Barnard, J. L., & Stensel, H. D. (Eds.). (1998). *Design and Retrofit of Wastewater Treatment Plants for Biological Nutritient Removal* (Vol. 5). CRC Press.

Schaap, M. G., Leij, F. J., & van Genuchten, M. T. (2001). ROSETTA: a computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions. *Journal of hydrology*, *251*(3), 163-176.

Schmidt, C. M., Fisher, A. T., Racz, A., Wheat, C. G., Los Huertos, M., & Lockwood, B. (2012). Rapid nutrient load reduction during infiltration of managed aquifer recharge in an agricultural groundwater basin: Pajaro Valley, California. *Hydrological Processes*, *26*(15), 2235-2247.

Schoups, G., Hopmans, J. W., Young, C. A., Vrugt, J. A., Wallender, W. W., Tanji, K. K., & Panday, S. (2005). Sustainability of irrigated agriculture in the San Joaquin Valley, California. *Proceedings of the National Academy of Sciences*, *102*(43), 15352-15356.

Screen, J. A., & Simmonds, I. (2012). Declining summer snowfall in the Arctic: Causes, impacts and feedbacks. *Climate dynamics*, *38*(11-12), 2243-2256.

Shannon, M. A., Bohn, P. W., Elimelech, M., Georgiadis, J. G., Mariñas, B. J., & Mayes, A. M. (2008). Science and technology for water purification in the coming decades. *Nature*, *452*(7185), 301-310.

Simunek, J., Sejna, M., & Van Genuchten, M. T. (1996). HYDRUS-2D: Simulating water flow and solute transport in two-dimensional variably saturated media. *International Groundwater Modeling Center*, *Colorado School of Mines*, *Golden*, *Colorado*.

Skaggs, T. H., Trout, T. J., Šimůnek, J., & Shouse, P. J. (2004). Comparison of HYDRUS-2D simulations of drip irrigation with experimental observations. *Journal of irrigation and drainage engineering*.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [07/10/2015].

Sophocleous, M. (2002). Interactions between groundwater and surface water: the state of the science. *Hydrogeology journal*, *10*(1), 52-67.

Steinel, A. (2012). Stormwater Reuse via Aquifer Storage and Recovery: Risk Assessment for Sandy Aquifers. In *Climate Change and the Sustainable Use of Water Resources* (pp. 17-42). Springer Berlin Heidelberg.

Siemens, J., Huschek, G., Siebe, C., Kaupenjohann, M., 2008. Concentrations and mobility of human pharmaceuticals in the world's largest wastewater irrigation system, Mexico City-Mezquital Valley. Water Res. 42, 2124–34.

Tsihrintzis, V. A., & Hamid, R. (1997). Modeling and management of urban stormwater runoff quality: a review. *Water Resources Management*, *11*(2), 136-164.

Wahl, R. W. (2013). *Markets for federal water: Subsidies, property rights, and the Bureau of Reclamation*. Routledge.

Wexler, E. J. (1992). *Analytical solutions for one-, two-, and three-dimensional solute transport in ground-water systems with uniform flow*. US Government Printing Office.

Williams, C.F., Adamsen, F.J., 2006. Sorption-desorption of carbamazepine from irrigated soils. J. Environ. Qual. 35, 1779–83.

Wu, X., Ernst, F., Conkle, J.L., Gan, J., 2013. Comparative uptake and translocation of pharmaceutical and personal care products (PPCPs) by common vegetables. Environ. Int. 60, 15–22.

Yamaguchi, T., & Blumwald, E. (2005). Developing salt-tolerant crop plants: challenges and opportunities. *Trends in plant science*, *10*(12), 615-620

Yu, Y., Wu, L., & Chang, A. C. (2013). Seasonal variation of endocrine disrupting compounds, pharmaceuticals and personal care products in wastewater treatment plants. *Science of the Total Environment*, *442*, 310-316.

CHAPTER 4

CONCLUSIONS

CHAPTER 4

CONCLUSIONS

This work was driven by the on-going drought in California and other parts of the world. Groundwater is often overused to close the gap between inconsistent surface water supplies and somewhat steady urban, agricultural, industrial, and environmental water demands. This practice leads to the problem of over-drafted groundwater basins. Due to unpredictable climatic conditions our current water supply versus demand will only become worse. We investigated the prospect of using secondary treated wastewater as an alternative to help recharge regional groundwater levels, and estimated the potential for such recharge to impact the Southern SJV as a test case.

4.1 "Easy Tool" for Utilities to accurately estimate infiltration

The first objective for this research was to develop a continuous, autonomous monitoring platform for assessing an infiltration basin water balance artificial recharge and to compare the resulting infiltration estimates to those estimated using the agency's current approach. For the soils of southern SJV, there were strong correlations between soil column study and water balance (WB) approach, with the soil columns results being about 33% higher than the WB rate. However, our results differed drastically from the Fresno-RWRF agency estimates. The Fresno-RWRF rates were lower by as much as 200% in the beginning and end of the experiment. We believe the anomaly in the Fresno-RWRF data is due to some of their measurement methods. First, their incoming water volume calculation is a simplistic estimate based on the timing of open gates and a rough channel flow rate estimate. We recommend using some form of a calibrated flume or weir system (equipped with a stage sensor) to more accurately measure flow volumes.

Second, the Fresno-RWRF basin water column/height estimate is based on a visual gauging staff estimate. We believe Fresno-RWRF can improve their accuracy and compute temporal fluctuations (which are typically missed) using relatively inexpensive pressure transducers (e.g., level loggers). This will not only accurately log data at frequent interval but will also take away the need for manual readings. Lastly, evaporation component is used as a fixed % of local evapotranspiration throughout the year, which is not always correct. A simple pan evaporation setup like the University of Georgia EASY PAN could be constructed and maintained at the utility site for accurate estimates. These will help utilities immensely in deciding the duty cycle of these ponds and minimize the error in the computation of their infiltration rate which is as high as 200% at times.

We think these recommendation will incur minimal cost but will provide greater accuracy and returns on investment. RWRF's current water balance spreadsheet does not need any modification, the error lies not in the spreadsheet but in the estimation of the parameters needed for water balance.

4.2 Soil texture and recharge

The second and third objectives of this research were to examine the efficacy of site-specific soil columns for estimating infiltration rate and duty cycle of an artificial recharge basin and estimate the portion of the applied effluent that results in recharge. As mentioned earlier in the previous section, the water balance and soil column exhibited a close correlation, making soil columns an ideal candidate to estimate basin infiltration rate and duty cycle. Soil texture, hydraulic conductivity, and depth of soil profile, are a good indicator of recharge potential, however soils are spatially variable. When these estimates are done over a larger domain and soils with multiple soil texture profile, they reveal the variability in recharge potential. For example in our study area the soil got coarser and exhibited higher hydraulic conductivity as we moved south from Fresno. Fresno RWRF recharge potential was 3.2-6.4% while for Bakersfield it was 13.9-23 % of the total incoming wastewater. But for each of the four RWRF's, the recharge potential and approach were different, this was primarily due to the soils texture and distribution. For example Fresno RWRF area had 40.2 % available land (within the Area of Interest (AOI), < 10 KM for the treatment plant) suitable for recharge using slow infiltration compared to 3.5, 6.7 and 8.7 % for Tulare, Visalia and Bakersfield respectively. Fortunately, for each of these four RWRFs the total land required to implement the recharge scheme is much lower then what is available. As an example Fresno will only need 13.2 % of the land within the area of interest to implement the recharge scheme. Similarly, Tulare will only need 6.4 %, followed by 2.8% for Visalia and 2.6% for Bakersfield. This indicates we have sufficient amounts of land potentially available to implement this recharge approach.

These numbers agree with our finding of 41-69 mm/day for coarser soils in Bakersfield/Visalia area and 9-42 mm/day for medium textured soil in Fresno and Tulare (Knapton et al. 2004).

California currently overdrafts approximately 2 million acre feet of groundwater annually (CA DWR 2015), this associated regional MAR in SJV would reduce that volume by approximately 0.8-2.5%. Additionally, this recharge estimate is roughly 0.5% of the groundwater refill requirement proposed by NASA for the central valley (NASA

2015). While not a substantial amount, these MAR volumes could be significant with steady use over a decade or more, using readily available effluent.

4.3 Hybrid approach

One of the last objective of the research was to investigate sustainable options for using the infiltrated water to grow salt tolerant crops (like forages, such as alfalfa and sudangrass, or fiber crops). As the effluent water infiltrates through the vadose zone some of contaminants, micro-nutrients and macro nutrients are filtered out or bio degraded (Adriaens et. al. 2002, and Chege, 2014). During the course of this study, limited amounts of soil-water samples were collected from the suction lysimeters located at 0.5, 1.5, 3.5 and 5.5 m below the basin. Laboratory analysis of the lysimeter water samples indicated the electrical conductivity of the water to be under 0.9 dS/m, and NPK levels (nitrogen, phosphorus and potassium) within sufficiency limits for most crops. Due to health concerns, crops suitable for human consumption cannot be grown with these water quality, however crop like cotton which accounts for over 173,000 ha of farming in California depletes 283 x 10^6 m^3 (2300 x 10^6 ac/feet) of good quality irrigation water (CCGGA, 2015, and Hansen, 2012). Similarly, alfalfa another major crop in California, requires 653 x 10^6 m^3 (5300 x 10^6 ac/feet) of irrigated water. Other forages accounts for 407 x 10^6 m^3 (3300 x 10^6 ac/feet) of irrigated water (Hansen, 2012). These three candidate crops are salt tolerant (except for some variety of corn) and could be grown with the water derived from the reclamation wells, this approach will contribute to 3.3 % of the groundwater refill requirement proposed by NASA (Chu et. al. 2015).

4.4 Future work

There are numerous water treatment options like membrane bioreactors (MBR), and biologically aerated filters (BAF) being currently researched that could safely treat water for reuse, however they are constrained by their tendency to foul and economically not viable (Gander, Jefferson, and Judd, 2000; Jerrerson et al. 2000). Polymer-soil composite that can absorb specific target compounds could be an alternative to economically treat wastewater before it infiltrates through the vadose zone for recharge (Grebel et al., 2013; Jasper and Sedlak, 2013).

Another viable option would be to explore crops that’s tolerant to these wastewater, and could potentially scrub or bio degrade some of the contaminants in the wastewater. Future studies could include contaminants study past the root zone to explore the fate of these contaminants in the vadose zone in conjunction with the recharge work.

Insights gained about the recharge potential may also accelerate research in other fields of engineering and soil sciences. Research investigation into alternative to groundwater recharge and estimation of recharge assessment may perhaps benefit from the findings of this research.

References

Adriaens, P., Alvarez, P. J. J., Bastiaans, L., Diels, L., Major, D., Filip, Z., & Springael, D. (2002). Biodegradation and bioremediation. In *Innovative Approaches to the On-Site Assessment and Remediation of Contaminated Sites* (pp. 67-113). Springer Netherlands.

California Cotton Growers and Ginners Association (CCGGA) (2015). CA Cotton Facts Retrieved November 18, 2016. http://www.ccgga.org/cotton-information/ca-cotton-facts/

California Department of Water Resources (CA DWR) (2015). Chapter 1: Groundwater- California's Hidden Resource. Retrieved November 18, 2016 http://www.water.ca.gov/pubs/groundwater/bulletin_118/california's_groundwater__bulletin_118_-_update_2003_/bulletin118-chapter1.pdf

Chege, N. J. (2014). *Analysis of Runoff, Infiltration Rate, Sediment Release and Nutrient Drain From Four Vegetation Types in South Kinangop Forest, Nyandarua County* (Doctoral dissertation, Kenyatta University).

Chu, X., Wang, C., Chen, X., Lu, W., Li, H., Wang, X., ... & Guo, X. (2015). The Cotton WRKY Gene GhWRKY41 Positively Regulates Salt and Drought Stress Tolerance in Transgenic Nicotiana benthamiana. *PloS one*, *10*(11), e0143022.

Ehmke, T. (2013). US North-Central: Reusing wastewater for crop irrigation in Kansas. *Crops and Soils*, *46*(5), 26-29.

Knapton, A., Jolly, P., Pavelic, P., Dillon, P., Barry, K., Mucha, M., & Gates, W. (2004). Feasibility of a Pilot 600ML/yr Soil Aquifer Treatment Plant at the Arid Zone Research Institute. *Water Resources Branch, Conservation and Natural Systems, DIPE Technical Report*, (29).

Gander, M., Jefferson, B., & Judd, S. (2000). Aerobic MBRs for domestic wastewater treatment: a review with cost considerations. *Separation and purification Technology*, *18*(2), 119-130.

Grebel, J. E., Mohanty, S. K., Torkelson, A. A., Boehm, A. B., Higgins, C. P., Maxwell, R. M., ... & Sedlak, D. L. (2013). Engineered infiltration systems for urban stormwater reclamation. *Environmental Engineering Science*, *30*(8), 437-454.

Jasper, J. T., & Sedlak, D. L. (2013). Photo transformation of wastewater-derived trace organic contaminants in open-water unit process treatment wetlands. *Environmental science & technology*, *47*(19), 10781-10790.

Jefferson, B., Laine, A., Parsons, S., Stephenson, T., & Judd, S. (2000). Technologies for domestic wastewater recycling. *Urban water*, *1*(4), 285-292.

APPENDIX A

FRESNO RWRF SOIL SURVEY AND LAND USE ESTIMATE: OBTAINED FROM NRCS SOILS ONLINE

United States Department of Agriculture

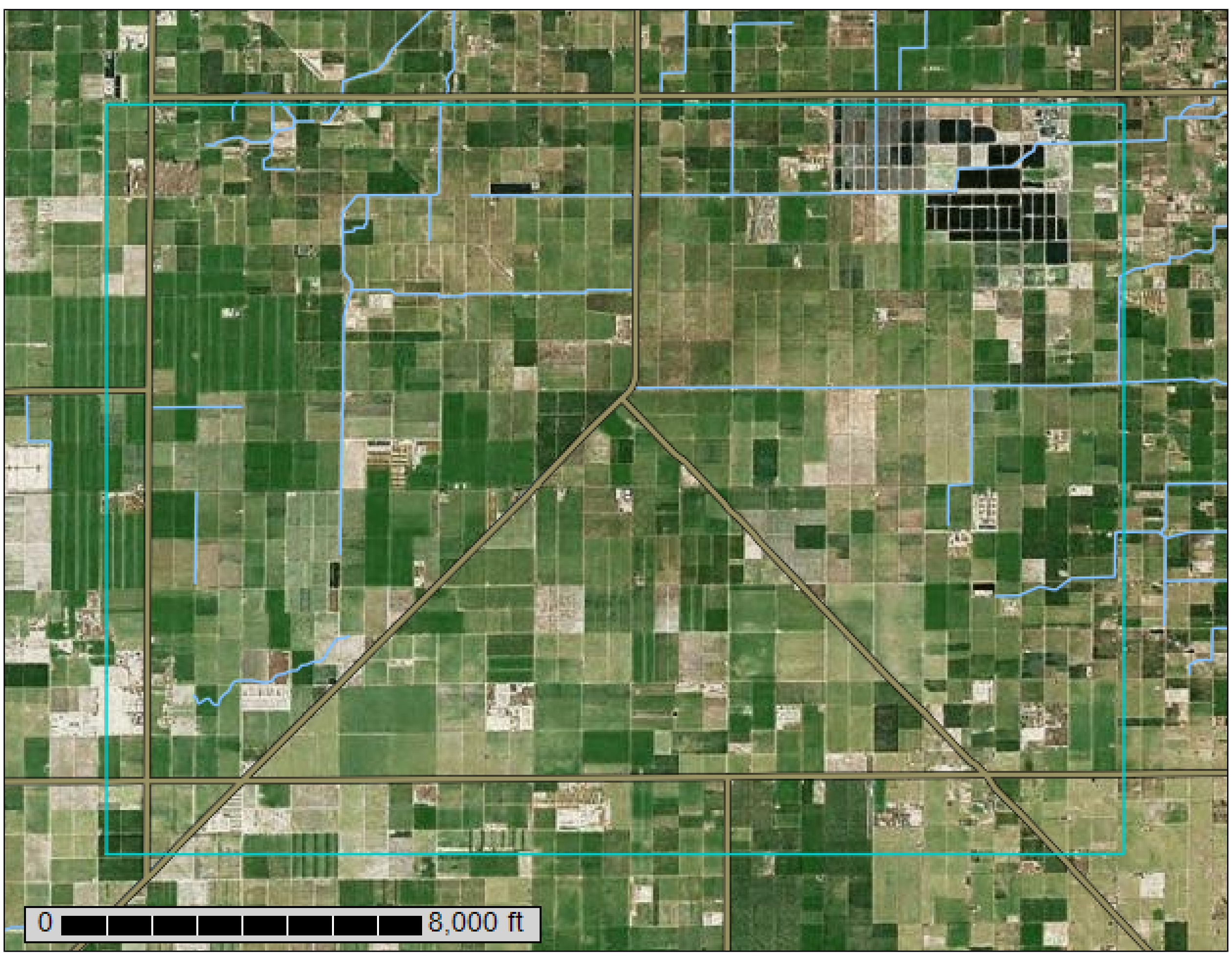
NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Eastern Fresno Area, California



July 11, 2015

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

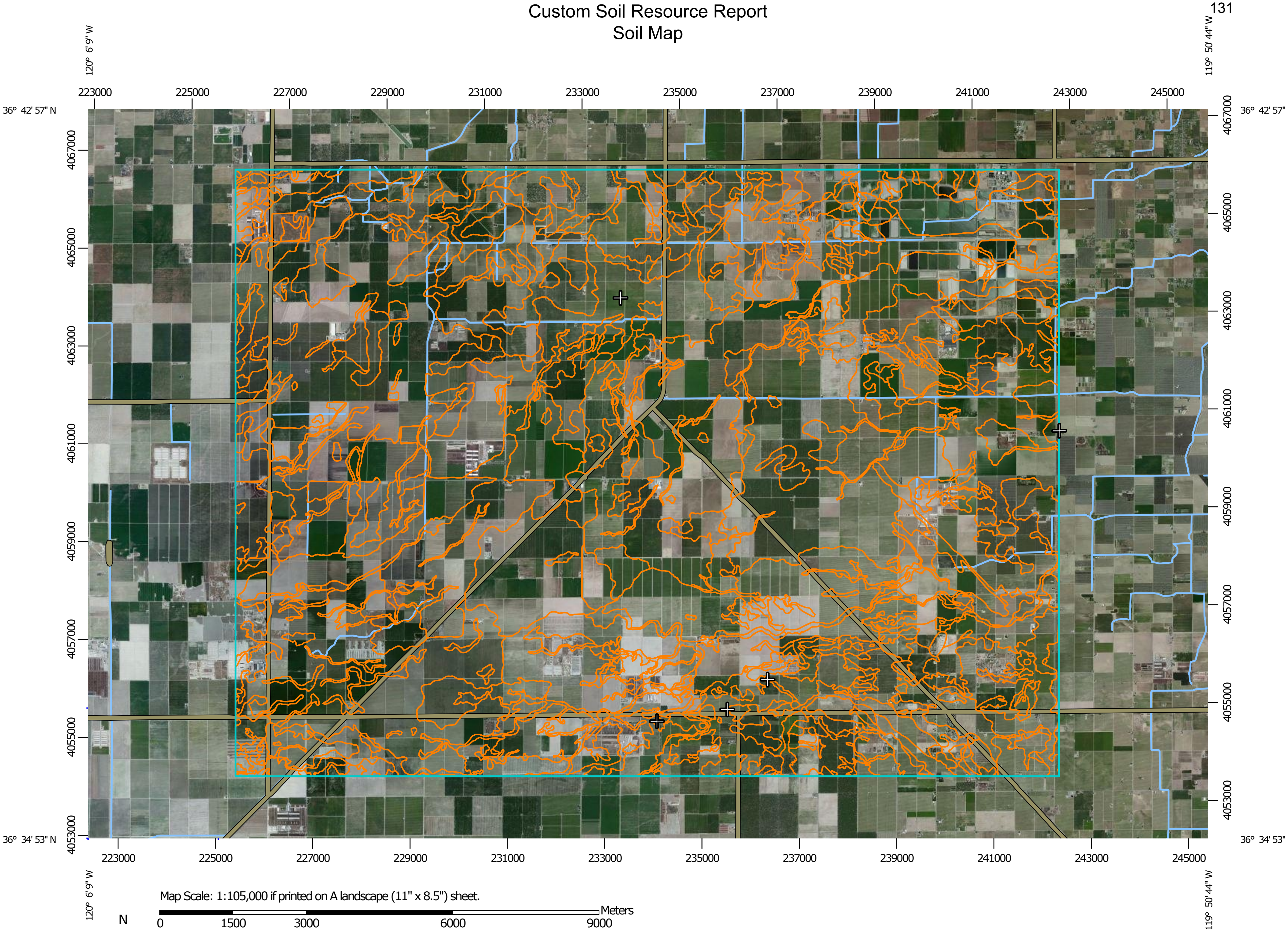
Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

Contents

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map



Map Scale: 1:105,000 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 1500 3000 6000 9000

Feet: 0 5000 10000 20000 30000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Eastern Fresno Area, California
Survey Area Data: Version 7, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 12, 2010—Aug 20, 2013

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Eastern Fresno Area, California (CA654)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AoA	Atwater loamy sand, 0 to 3 percent slopes	118.8	0.2%
ArA	Atwater sandy loam, 0 to 3 percent slopes	24.0	0.0%
Bn	Borden loam	50.5	0.1%
Bs	Borden loam, saline-alkali	11.1	0.0%
Bt	Borden loam, moderately deep	397.6	0.8%
Bu	Borden loam, moderately deep, saline alkali	480.7	0.9%
Ca	Cajon loamy coarse sand	166.7	0.3%
Cc	Cajon coarse sandy loam	16.8	0.0%
Cd	Cajon coarse sandy loam, saline alkali	25.4	0.0%
Ce	Cajon coarse sandy loam, moderately deep, saline alkali	44.4	0.1%
CfA	Calhi loamy sand, 0 to 3 percent slopes	1,612.0	3.1%
CfB	Calhi loamy sand, 3 to 9 percent slopes	53.3	0.1%
CgA	Calhi loamy sand, moderately deep, 0 to 3 percent slopes	861.1	1.7%
DeA	Delhi sand, 0 to 3 percent slopes, MLRA 17	30.6	0.1%
DeB	Delhi sand, 3 to 9 percent slopes	10.8	0.0%
DhA	Delhi loamy sand, 0 to 3 percent slopes, MLRA 17	892.3	1.7%
DhB	Delhi loamy sand, 3 to 9 percent slopes	32.7	0.1%
DlA	Delhi loamy sand, moderately deep, 0 to 3 percent slopes	227.1	0.4%
Ec	El Peco sandy loam	28.4	0.1%
Ed	El Peco fine sandy loam	3,983.6	7.7%
Ep	El Peco loam	731.7	1.4%
Es	Exeter sandy loam	192.6	0.4%
Fs	Fresno sandy loam	492.5	0.9%
Ft	Fresno sandy loam, shallow	516.8	1.0%
Fu	Fresno fine sandy loam	6,538.6	12.6%
Fv	Fresno fine sandy loam, shallow	3,744.4	7.2%
Fw	Fresno clay loam	302.0	0.6%
Fx	Fresno-Traver complex	223.1	0.4%

Eastern Fresno Area, California (CA654)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
GuA	Greenfield sandy loam, moderately deep, 0 to 3 percent slopes	43.6	0.1%
Ha	Hanford coarse sandy loam	481.3	0.9%
Hc	Hanford sandy loam	447.7	0.9%
Hg	Hanford sandy loam, silty substratum	221.1	0.4%
Hk	Hanford sandy loam, hard substratum	220.1	0.4%
Hm	Hanford fine sandy loam	42.0	0.1%
Ho	Hanford fine sandy loam, silty substratum	85.3	0.2%
Hsa	Hesperia coarse sandy loam	111.1	0.2%
Hsd	Hesperia sandy loam	2,080.8	4.0%
Hse	Hesperia sandy loam, saline-alkali	476.3	0.9%
Hsm	Hesperia sandy loam, moderately deep	6,322.0	12.2%
Hsn	Hesperia sandy loam, moderately deep, saline-alkali	1,127.7	2.2%
Hso	Hesperia sandy loam, shallow	272.2	0.5%
Hsp	Hesperia sandy loam, shallow, saline-alkali	928.5	1.8%
Hsr	Hesperia fine sandy loam	837.5	1.6%
Hss	Hesperia fine sandy loam, saline alkali	97.6	0.2%
Hst	Hesperia fine sandy loam moderately deep	4,160.3	8.0%
Hsy	Hesperia fine sandy loam, moderately deep, saline-alkali	3,314.7	6.4%
Ma	Madera sandy loam	36.0	0.1%
Mc	Madera loam	62.8	0.1%
Md	Madera loam, saline-alkali	78.7	0.2%
Pa	Pachappa loam	92.1	0.2%
Pc	Pachappa loam, saline alkali	61.3	0.1%
Pd	Pachappa loam, moderately deep	1,246.6	2.4%
Pe	Pachappa loam, moderately deep, saline-alkali	2,957.6	5.7%
Pl	Playas	46.9	0.1%
Ps	Pond sandy loam, moderately deep	89.0	0.2%
Pt	Pond fine sandy loam	163.1	0.3%
Pu	Pond fine sandy loam, moderately deep	81.0	0.2%

Eastern Fresno Area, California (CA654)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Pw	Pond loam, moderately deep	1,183.6	2.3%
Rb	Ramona sandy loam, hard substratum	4.1	0.0%
Rc	Ramona loam	41.4	0.1%
Re	Ramona loam, hard substratum	25.9	0.0%
Tr	Traver sandy loam	86.1	0.2%
Ts	Traver sandy loam, moderately deep	972.2	1.9%
Tt	Traver fine sandy loam	30.6	0.1%
Tu	Traver fine sandy loam, moderately deep	1,136.5	2.2%
TzbA	Tujunga loamy sand, 0 to 3 percent slopes	491.1	0.9%
Ws	Wunjey fine sandy loam	22.4	0.0%
Totals for Area of Interest		**51,988.5**	**100.0%**

Soil Information for All Uses

Suitabilities and Limitations for Use

The Suitabilities and Limitations for Use section includes various soil interpretations displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each interpretation.

Waste Management

Waste Management interpretations are tools designed to guide the user in evaluating soils for use of organic wastes and wastewater as productive resources. Example interpretations include land application of manure, food processing waste, and municipal sewage sludge, and disposal of wastewater by irrigation or overland flow process.

Disposal of Wastewater by Irrigation (Fresno RWRF WW Disposal by Irrigation)

Wastewater includes municipal and food-processing wastewater and effluent from lagoons or storage ponds. Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

Disposal of wastewater by irrigation not only disposes of municipal wastewater and wastewater from food-processing plants, lagoons, and storage ponds but also can improve crop production by increasing the amount of water available to crops. The ratings are based on the soil properties that affect the design, construction, management, and performance of the irrigation system. The properties that affect design and management include the sodium adsorption ratio, depth to a water table, ponding, available water capacity, saturated hydraulic conductivity (Ksat), slope, and flooding. The properties that affect construction include stones, cobbles, depth to bedrock or a cemented pan, depth to a water table, and ponding. The properties that affect performance include depth to bedrock or a cemented pan, bulk density, the sodium adsorption ratio, salinity, reaction, and the cation-exchange capacity, which is used to estimate the capacity of a soil to adsorb heavy metals. Permanently frozen soils are not suitable for disposal of wastewater by irrigation.

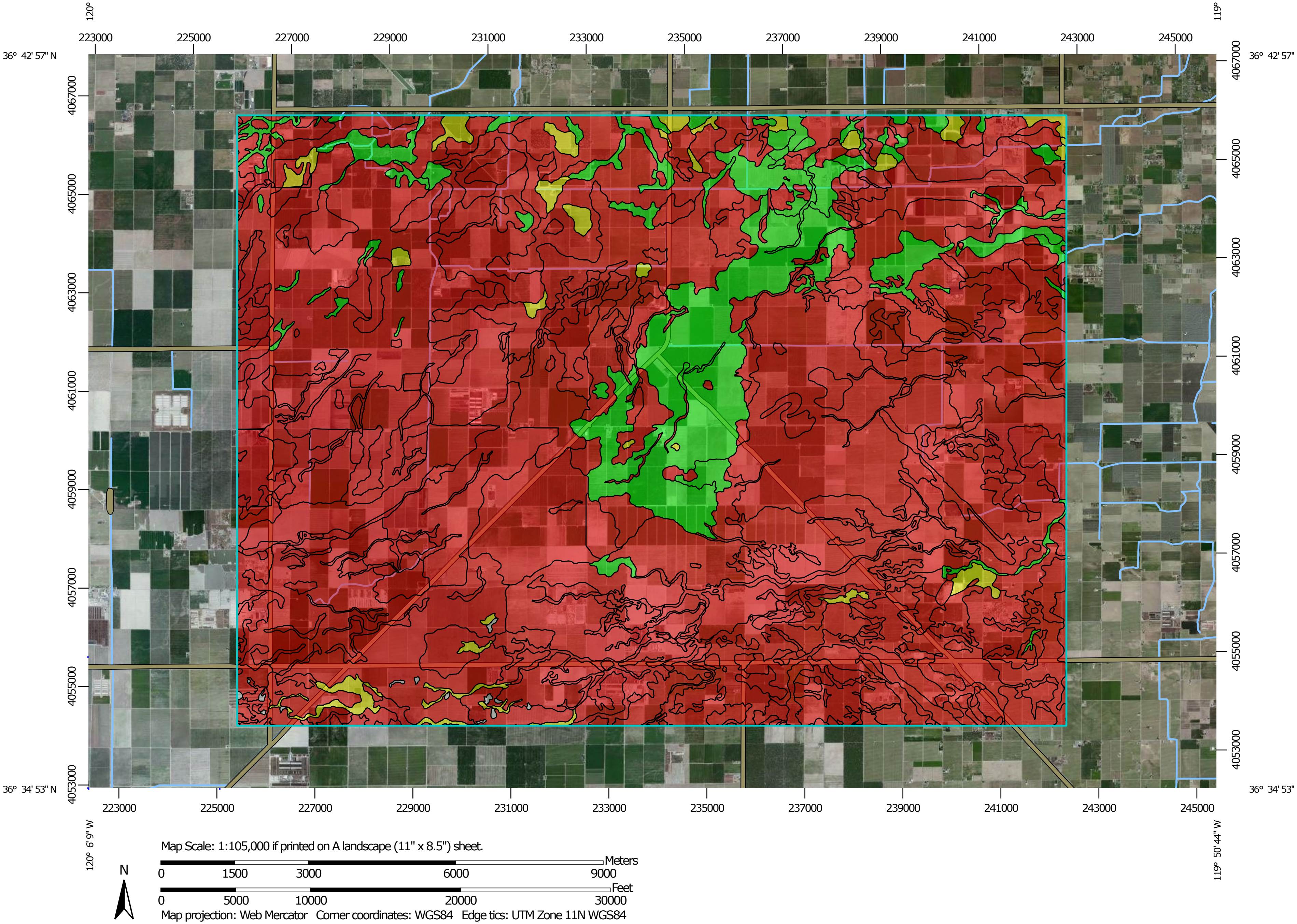
The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Map—Disposal of Wastewater by Irrigation (Fresno RWRF WW Disposal by Irrigation)



MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Eastern Fresno Area, California
Survey Area Data: Version 7, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 12, 2010—Aug 20, 2013

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Disposal of Wastewater by Irrigation (Fresno RWRF WW Disposal by Irrigation)

Disposal of Wastewater by Irrigation— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
AoA	Atwater loamy sand, 0 to 3 percent slopes	Very limited	Atwater (85%)	Filtering capacity (1.00)	118.8	0.2%
ArA	Atwater sandy loam, 0 to 3 percent slopes	Not limited	Atwater (85%)		24.0	0.0%
Bn	Borden loam	Somewhat limited	Borden (85%)	Slow water movement (0.37)	50.5	0.1%
Bs	Borden loam, saline-alkali	Somewhat limited	Borden (85%)	Slow water movement (0.37)	11.1	0.0%
Bt	Borden loam, moderately deep	Very limited	Borden (85%)	Slow water movement (1.00)	397.6	0.8%
Bu	Borden loam, moderately deep, saline alkali	Very limited	Borden (85%)	Slow water movement (1.00)	480.7	0.9%
Ca	Cajon loamy coarse sand	Very limited	Cajon (85%)	Filtering capacity (1.00)	166.7	0.3%
				Droughty (0.30)		
Cc	Cajon coarse sandy loam	Very limited	Cajon (85%)	Filtering capacity (1.00)	16.8	0.0%
				Droughty (0.13)		
Cd	Cajon coarse sandy loam, saline alkali	Very limited	Cajon (85%)	Filtering capacity (1.00)	25.4	0.0%
				Droughty (0.13)		
Ce	Cajon coarse sandy loam, moderately deep, saline alkali	Very limited	Cajon (85%)	Filtering capacity (1.00)	44.4	0.1%
				Slow water movement (1.00)		
CfA	Calhi loamy sand, 0 to 3 percent slopes	Very limited	Calhi (85%)	Filtering capacity (1.00)	1,612.0	3.1%
				Droughty (0.68)		
CfB	Calhi loamy sand, 3 to 9 percent slopes	Very limited	Calhi (80%)	Filtering capacity (1.00)	53.3	0.1%
				Droughty (0.68)		
				Too steep for surface application (0.68)		

Disposal of Wastewater by Irrigation— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
CgA	Calhi loamy sand, moderately deep, 0 to 3 percent slopes	Very limited	Calhi (85%)	Filtering capacity (1.00)	861.1	1.7%
				Slow water movement (1.00)		
DeA	Delhi sand, 0 to 3 percent slopes, MLRA 17	Very limited	Delhi (85%)	Filtering capacity (1.00)	30.6	0.1%
				Droughty (0.65)		
DeB	Delhi sand, 3 to 9 percent slopes	Very limited	Delhi (85%)	Filtering capacity (1.00)	10.8	0.0%
				Too steep for surface application (0.68)		
				Droughty (0.32)		
DhA	Delhi loamy sand, 0 to 3 percent slopes, MLRA 17	Very limited	Delhi (85%)	Filtering capacity (1.00)	892.3	1.7%
				Droughty (0.65)		
DhB	Delhi loamy sand, 3 to 9 percent slopes	Very limited	Delhi (85%)	Filtering capacity (1.00)	32.7	0.1%
				Too steep for surface application (0.68)		
				Droughty (0.29)		
DlA	Delhi loamy sand, moderately deep, 0 to 3 percent slopes	Very limited	Delhi (85%)	Filtering capacity (1.00)	227.1	0.4%
				Slow water movement (1.00)		
Ec	El Peco sandy loam	Very limited	El Peco (85%)	Salinity (1.00)	28.4	0.1%
				Droughty (1.00)		
				Slow water movement (1.00)		
				Depth to cemented pan (0.95)		
Ed	El Peco fine sandy loam	Very limited	El Peco (85%)	Salinity (1.00)	3,983.6	7.7%
				Droughty (1.00)		
				Slow water movement (1.00)		
				Depth to cemented pan (0.95)		
Ep	El Peco loam	Very limited	El Peco (85%)	Salinity (1.00)	731.7	1.4%
				Droughty (1.00)		

Disposal of Wastewater by Irrigation— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
				Slow water movement (1.00)		
				Depth to cemented pan (0.95)		
Es	Exeter sandy loam	Somewhat limited	Exeter (85%)	Droughty (0.65)	192.6	0.4%
				Depth to cemented pan (0.46)		
Fs	Fresno sandy loam	Very limited	Fresno (85%)	Slow water movement (1.00)	492.5	0.9%
				Droughty (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
				Depth to cemented pan (0.99)		
Ft	Fresno sandy loam, shallow	Very limited	Fresno (85%)	Slow water movement (1.00)	516.8	1.0%
				Depth to cemented pan (1.00)		
				Droughty (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
Fu	Fresno fine sandy loam	Very limited	Fresno (80%)	Slow water movement (1.00)	6,538.6	12.6%
				Droughty (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
				Depth to cemented pan (0.99)		
Fv	Fresno fine sandy loam, shallow	Very limited	Fresno (85%)	Slow water movement (1.00)	3,744.4	7.2%
				Depth to cemented pan (1.00)		
				Salinity (1.00)		
				Droughty (1.00)		

Disposal of Wastewater by Irrigation— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
				Sodium content (1.00)		
Fw	Fresno clay loam	Very limited	Fresno (85%)	Slow water movement (1.00)	302.0	0.6%
				Depth to cemented pan (1.00)		
				Droughty (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
Fx	Fresno-Traver complex	Very limited	Fresno (50%)	Slow water movement (1.00)	223.1	0.4%
				Droughty (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
				Depth to cemented pan (0.99)		
			Traver (35%)	Sodium content (1.00)		
				Slow water movement (1.00)		
				Salinity (1.00)		
GuA	Greenfield sandy loam, moderately deep, 0 to 3 percent slopes	Somewhat limited	Greenfield (85%)	Droughty (0.12)	43.6	0.1%
				Depth to cemented pan (0.01)		
Ha	Hanford coarse sandy loam	Not limited	Hanford (85%)		481.3	0.9%
Hc	Hanford sandy loam	Not limited	Hanford (85%)		447.7	0.9%
Hg	Hanford sandy loam, silty substratum	Very limited	Hanford (85%)	Slow water movement (1.00)	221.1	0.4%
Hk	Hanford sandy loam, hard substratum	Somewhat limited	Hanford (85%)	Droughty (0.36)	220.1	0.4%
				Depth to cemented pan (0.06)		
Hm	Hanford fine sandy loam	Not limited	Hanford (85%)		42.0	0.1%
Ho	Hanford fine sandy loam, silty substratum	Very limited	Hanford (85%)	Slow water movement (1.00)	85.3	0.2%

Disposal of Wastewater by Irrigation— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
Hsa	Hesperia coarse sandy loam	Not limited	Hesperia (85%)		111.1	0.2%
Hsd	Hesperia sandy loam	Very limited	Hesperia (85%)	Slow water movement (1.00)	2,080.8	4.0%
Hse	Hesperia sandy loam, saline-alkali	Somewhat limited	Hesperia (85%)	Salinity (0.50)	476.3	0.9%
Hsm	Hesperia sandy loam, moderately deep	Very limited	Hesperia (85%)	Slow water movement (1.00)	6,322.0	12.2%
Hsn	Hesperia sandy loam, moderately deep, saline-alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	1,127.7	2.2%
				Salinity (0.50)		
Hso	Hesperia sandy loam, shallow	Very limited	Hesperia (85%)	Slow water movement (1.00)	272.2	0.5%
Hsp	Hesperia sandy loam, shallow, saline-alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	928.5	1.8%
				Salinity (0.50)		
Hsr	Hesperia fine sandy loam	Very limited	Hesperia (85%)	Slow water movement (1.00)	837.5	1.6%
Hss	Hesperia fine sandy loam, saline alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	97.6	0.2%
				Salinity (0.50)		
Hst	Hesperia fine sandy loam moderately deep	Very limited	Hesperia (85%)	Slow water movement (1.00)	4,160.3	8.0%
Hsy	Hesperia fine sandy loam, moderately deep, saline-alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	3,314.7	6.4%
				Salinity (0.50)		
Ma	Madera sandy loam	Very limited	Madera (85%)	Slow water movement (1.00)	36.0	0.1%
				Droughty (1.00)		
				Depth to cemented pan (0.20)		
Mc	Madera loam	Very limited	Madera (85%)	Slow water movement (1.00)	62.8	0.1%
				Droughty (0.84)		

Disposal of Wastewater by Irrigation— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
				Depth to cemented pan (0.20)		
Md	Madera loam, saline-alkali	Very limited	Madera (85%)	Slow water movement (1.00)	78.7	0.2%
				Droughty (0.84)		
				Sodium content (0.68)		
				Depth to cemented pan (0.20)		
				Salinity (0.13)		
Pa	Pachappa loam	Not limited	Pachappa (85%)		92.1	0.2%
Pc	Pachappa loam, saline alkali	Very limited	Pachappa (85%)	Salinity (1.00)	61.3	0.1%
Pd	Pachappa loam, moderately deep	Not limited	Pachappa (85%)		1,246.6	2.4%
Pe	Pachappa loam, moderately deep, saline-alkali	Not limited	Pachappa (85%)		2,957.6	5.7%
Pl	Playas	Not rated	Playas (95%)		46.9	0.1%
			Unnamed (5%)			
Ps	Pond sandy loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	89.0	0.2%
				Sodium content (1.00)		
				Salinity (1.00)		
				Droughty (0.01)		
Pt	Pond fine sandy loam	Very limited	Pond (85%)	Filtering capacity (1.00)	163.1	0.3%
				Slow water movement (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
				Droughty (0.28)		
Pu	Pond fine sandy loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	81.0	0.2%
				Sodium content (1.00)		
				Salinity (1.00)		

Disposal of Wastewater by Irrigation— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
				Droughty (0.28)		
Pw	Pond loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	1,183.6	2.3%
				Sodium content (1.00)		
				Salinity (1.00)		
				Droughty (0.21)		
Rb	Ramona sandy loam, hard substratum	Somewhat limited	Ramona (80%)	Slow water movement (0.37)	4.1	0.0%
				Droughty (0.02)		
			Ramona, moderately deep (15%)	Slow water movement (0.37)		
				Droughty (0.23)		
				Depth to cemented pan (0.06)		
Rc	Ramona loam	Somewhat limited	Ramona (80%)	Slow water movement (0.37)	41.4	0.1%
				Droughty (0.04)		
Re	Ramona loam, hard substratum	Somewhat limited	Ramona (85%)	Slow water movement (0.37)	25.9	0.0%
				Droughty (0.14)		
				Depth to cemented pan (0.06)		
			Ramona (10%)	Slow water movement (0.37)		
				Droughty (0.00)		
Tr	Traver sandy loam	Very limited	Traver (85%)	Sodium content (1.00)	86.1	0.2%
				Slow water movement (1.00)		
				Salinity (1.00)		
				Droughty (0.09)		
Ts	Traver sandy loam, moderately deep	Very limited	Traver (85%)	Sodium content (1.00)	972.2	1.9%
				Slow water movement (1.00)		
				Salinity (1.00)		

Disposal of Wastewater by Irrigation— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
Tt	Traver fine sandy loam	Very limited	Traver (85%)	Sodium content (1.00)	30.6	0.1%
				Slow water movement (1.00)		
				Salinity (1.00)		
				Droughty (0.09)		
Tu	Traver fine sandy loam, moderately deep	Very limited	Traver (85%)	Sodium content (1.00)	1,136.5	2.2%
				Slow water movement (1.00)		
				Salinity (1.00)		
TzbA	Tujunga loamy sand, 0 to 3 percent slopes	Very limited	Tujunga (85%)	Filtering capacity (1.00)	491.1	0.9%
				Droughty (0.65)		
				Flooding (0.60)		
Ws	Wunjey fine sandy loam	Very limited	Wunjey (85%)	Salinity (1.00)	22.4	0.0%
Totals for Area of Interest					**51,988.5**	**100.0%**

Disposal of Wastewater by Irrigation— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	45,473.8	87.5%
Not limited	5,402.3	10.4%
Somewhat limited	1,065.5	2.0%
Null or Not Rated	46.9	0.1%
Totals for Area of Interest	**51,988.5**	**100.0%**

Rating Options—Disposal of Wastewater by Irrigation (Fresno RWRF WW Disposal by Irrigation)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Disposal of Wastewater by Rapid Infiltration (Fresno RWRF WW Disposal by Rapid Infiltration)

Rapid infiltration of wastewater is a process in which wastewater applied in a level basin at a rate of 4 to 120 inches per week percolates through the soil. The wastewater may eventually reach the ground water. The application rate commonly exceeds the rate needed for irrigation of cropland. Vegetation is not a necessary part of the treatment; thus, the basins may or may not be vegetated. The thickness of the soil material needed for proper treatment of the wastewater is more than 72 inches. As a result, geologic and hydrologic investigation is needed to ensure proper design and performance and to determine the risk of ground-water pollution.

Soil properties are important considerations in areas where soils are used as sites for the treatment and disposal of organic waste and wastewater. Selection of soils with properties that favor waste management can help to prevent environmental damage.

Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

The ratings are based on the soil properties that affect the risk of pollution and the design, construction, and performance of the system. Depth to a water table, ponding, flooding, and depth to bedrock or a cemented pan affect the risk of pollution and the design and construction of the system. Slope, stones, and cobbles also affect design and construction. Saturated hydraulic conductivity (Ksat) and reaction affect performance. Permanently frozen soils are unsuitable for waste treatment.

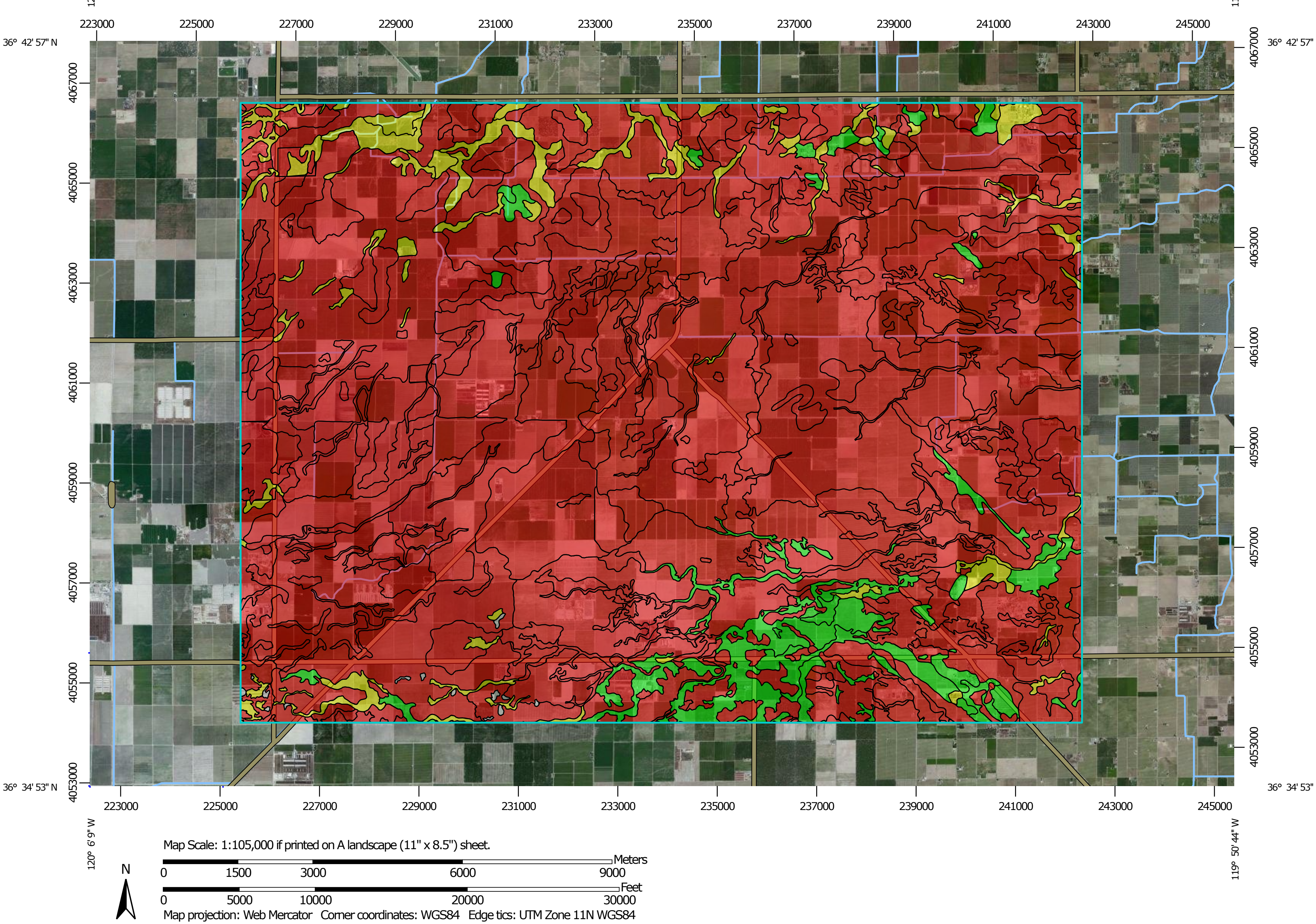
The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Custom Soil Resource Report
Map—Disposal of Wastewater by Rapid Infiltration (Fresno RWRF WW Disposal by Rapid Infiltration)



MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Eastern Fresno Area, California
Survey Area Data: Version 7, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 12, 2010—Aug 20, 2013

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Disposal of Wastewater by Rapid Infiltration (Fresno RWRF WW Disposal by Rapid Infiltration)

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
AoA	Atwater loamy sand, 0 to 3 percent slopes	Somewhat limited	Atwater (85%)	Slow water movement (0.32)	118.8	0.2%
ArA	Atwater sandy loam, 0 to 3 percent slopes	Somewhat limited	Atwater (85%)	Slow water movement (0.32)	24.0	0.0%
Bn	Borden loam	Very limited	Borden (85%)	Slow water movement (1.00)	50.5	0.1%
Bs	Borden loam, saline-alkali	Very limited	Borden (85%)	Slow water movement (1.00)	11.1	0.0%
Bt	Borden loam, moderately deep	Very limited	Borden (85%)	Slow water movement (1.00)	397.6	0.8%
Bu	Borden loam, moderately deep, saline alkali	Very limited	Borden (85%)	Slow water movement (1.00)	480.7	0.9%
Ca	Cajon loamy coarse sand	Not limited	Cajon (85%)		166.7	0.3%
Cc	Cajon coarse sandy loam	Somewhat limited	Cajon (85%)	Slow water movement (0.32)	16.8	0.0%
Cd	Cajon coarse sandy loam, saline alkali	Somewhat limited	Cajon (85%)	Slow water movement (0.32)	25.4	0.0%
Ce	Cajon coarse sandy loam, moderately deep, saline alkali	Very limited	Cajon (85%)	Slow water movement (1.00)	44.4	0.1%
CfA	Calhi loamy sand, 0 to 3 percent slopes	Not limited	Calhi (85%)		1,612.0	3.1%
CfB	Calhi loamy sand, 3 to 9 percent slopes	Somewhat limited	Calhi (80%)	Slope (0.50)	53.3	0.1%
CgA	Calhi loamy sand, moderately deep, 0 to 3 percent slopes	Very limited	Calhi (85%)	Slow water movement (1.00)	861.1	1.7%
DeA	Delhi sand, 0 to 3 percent slopes, MLRA 17	Not limited	Delhi (85%)		30.6	0.1%
DeB	Delhi sand, 3 to 9 percent slopes	Somewhat limited	Delhi (85%)	Slope (0.50)	10.8	0.0%

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
DhA	Delhi loamy sand, 0 to 3 percent slopes, MLRA 17	Not limited	Delhi (85%)		892.3	1.7%
DhB	Delhi loamy sand, 3 to 9 percent slopes	Somewhat limited	Delhi (85%)	Slope (0.50)	32.7	0.1%
DlA	Delhi loamy sand, moderately deep, 0 to 3 percent slopes	Very limited	Delhi (85%)	Slow water movement (1.00)	227.1	0.4%
Ec	El Peco sandy loam	Very limited	El Peco (85%)	Slow water movement (1.00)	28.4	0.1%
				Depth to cemented pan (1.00)		
Ed	El Peco fine sandy loam	Very limited	El Peco (85%)	Slow water movement (1.00)	3,983.6	7.7%
				Depth to cemented pan (1.00)		
Ep	El Peco loam	Very limited	El Peco (85%)	Slow water movement (1.00)	731.7	1.4%
				Depth to cemented pan (1.00)		
Es	Exeter sandy loam	Very limited	Exeter (85%)	Depth to cemented pan (1.00)	192.6	0.4%
				Slow water movement (1.00)		
Fs	Fresno sandy loam	Very limited	Fresno (85%)	Slow water movement (1.00)	492.5	0.9%
				Depth to cemented pan (1.00)		
Ft	Fresno sandy loam, shallow	Very limited	Fresno (85%)	Slow water movement (1.00)	516.8	1.0%
				Depth to cemented pan (1.00)		
Fu	Fresno fine sandy loam	Very limited	Fresno (80%)	Slow water movement (1.00)	6,538.6	12.6%

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
				Depth to cemented pan (1.00)		
Fv	Fresno fine sandy loam, shallow	Very limited	Fresno (85%)	Slow water movement (1.00)	3,744.4	7.2%
				Depth to cemented pan (1.00)		
Fw	Fresno clay loam	Very limited	Fresno (85%)	Slow water movement (1.00)	302.0	0.6%
				Depth to cemented pan (1.00)		
Fx	Fresno-Traver complex	Very limited	Fresno (50%)	Slow water movement (1.00)	223.1	0.4%
				Depth to cemented pan (1.00)		
			Traver (35%)	Slow water movement (1.00)		
GuA	Greenfield sandy loam, moderately deep, 0 to 3 percent slopes	Very limited	Greenfield (85%)	Depth to cemented pan (1.00)	43.6	0.1%
				Slow water movement (0.32)		
Ha	Hanford coarse sandy loam	Somewhat limited	Hanford (85%)	Slow water movement (0.32)	481.3	0.9%
Hc	Hanford sandy loam	Somewhat limited	Hanford (85%)	Slow water movement (0.32)	447.7	0.9%
Hg	Hanford sandy loam, silty substratum	Very limited	Hanford (85%)	Slow water movement (1.00)	221.1	0.4%
Hk	Hanford sandy loam, hard substratum	Very limited	Hanford (85%)	Depth to cemented pan (1.00)	220.1	0.4%
				Slow water movement (0.32)		
Hm	Hanford fine sandy loam	Somewhat limited	Hanford (85%)	Slow water movement (0.32)	42.0	0.1%
Ho	Hanford fine sandy loam, silty substratum	Very limited	Hanford (85%)	Slow water movement (1.00)	85.3	0.2%

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
Hsa	Hesperia coarse sandy loam	Somewhat limited	Hesperia (85%)	Slow water movement (0.32)	111.1	0.2%
Hsd	Hesperia sandy loam	Very limited	Hesperia (85%)	Slow water movement (1.00)	2,080.8	4.0%
Hse	Hesperia sandy loam, saline-alkali	Somewhat limited	Hesperia (85%)	Slow water movement (0.32)	476.3	0.9%
Hsm	Hesperia sandy loam, moderately deep	Very limited	Hesperia (85%)	Slow water movement (1.00)	6,322.0	12.2%
Hsn	Hesperia sandy loam, moderately deep, saline-alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	1,127.7	2.2%
Hso	Hesperia sandy loam, shallow	Very limited	Hesperia (85%)	Slow water movement (1.00)	272.2	0.5%
Hsp	Hesperia sandy loam, shallow, saline-alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	928.5	1.8%
Hsr	Hesperia fine sandy loam	Very limited	Hesperia (85%)	Slow water movement (1.00)	837.5	1.6%
Hss	Hesperia fine sandy loam, saline alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	97.6	0.2%
Hst	Hesperia fine sandy loam moderately deep	Very limited	Hesperia (85%)	Slow water movement (1.00)	4,160.3	8.0%
Hsy	Hesperia fine sandy loam, moderately deep, saline-alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	3,314.7	6.4%
Ma	Madera sandy loam	Very limited	Madera (85%)	Slow water movement (1.00)	36.0	0.1%
				Depth to cemented pan (1.00)		
Mc	Madera loam	Very limited	Madera (85%)	Slow water movement (1.00)	62.8	0.1%
				Depth to cemented pan (1.00)		

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
Md	Madera loam, saline-alkali	Very limited	Madera (85%)	Slow water movement (1.00)	78.7	0.2%
				Depth to cemented pan (1.00)		
Pa	Pachappa loam	Very limited	Pachappa (85%)	Slow water movement (1.00)	92.1	0.2%
Pc	Pachappa loam, saline alkali	Very limited	Pachappa (85%)	Slow water movement (1.00)	61.3	0.1%
Pd	Pachappa loam, moderately deep	Very limited	Pachappa (85%)	Slow water movement (1.00)	1,246.6	2.4%
Pe	Pachappa loam, moderately deep, saline-alkali	Very limited	Pachappa (85%)	Slow water movement (1.00)	2,957.6	5.7%
Pl	Playas	Not rated	Playas (95%)		46.9	0.1%
			Unnamed (5%)			
Ps	Pond sandy loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	89.0	0.2%
Pt	Pond fine sandy loam	Very limited	Pond (85%)	Slow water movement (1.00)	163.1	0.3%
Pu	Pond fine sandy loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	81.0	0.2%
Pw	Pond loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	1,183.6	2.3%
Rb	Ramona sandy loam, hard substratum	Very limited	Ramona (80%)	Slow water movement (1.00)	4.1	0.0%
				Depth to cemented pan (1.00)		
			Ramona, moderately deep (15%)	Slow water movement (1.00)		
				Depth to cemented pan (1.00)		
Rc	Ramona loam	Very limited	Ramona (80%)	Slow water movement (1.00)	41.4	0.1%
Re	Ramona loam, hard substratum	Very limited	Ramona (85%)	Slow water movement (1.00)	25.9	0.0%

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
				Depth to cemented pan (1.00)		
			Ramona (10%)	Slow water movement (1.00)		
				Depth to cemented pan (1.00)		
Tr	Traver sandy loam	Very limited	Traver (85%)	Slow water movement (1.00)	86.1	0.2%
Ts	Traver sandy loam, moderately deep	Very limited	Traver (85%)	Slow water movement (1.00)	972.2	1.9%
Tt	Traver fine sandy loam	Very limited	Traver (85%)	Slow water movement (1.00)	30.6	0.1%
Tu	Traver fine sandy loam, moderately deep	Very limited	Traver (85%)	Slow water movement (1.00)	1,136.5	2.2%
TzbA	Tujunga loamy sand, 0 to 3 percent slopes	Somewhat limited	Tujunga (85%)	Flooding (0.60)	491.1	0.9%
Ws	Wunjey fine sandy loam	Very limited	Wunjey (85%)	Slow water movement (1.00)	22.4	0.0%
Totals for Area of Interest					**51,988.5**	**100.0%**

Disposal of Wastewater by Rapid Infiltration— Summary by Rating Value		
Rating	Acres in AOI	Percent of AOI
Very limited	46,908.7	90.2%
Not limited	2,701.6	5.2%
Somewhat limited	2,331.3	4.5%
Null or Not Rated	46.9	0.1%
Totals for Area of Interest	**51,988.5**	**100.0%**

Rating Options—Disposal of Wastewater by Rapid Infiltration (Fresno RWRF WW Disposal by Rapid Infiltration)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Land Application of Municipal Sewage Sludge (Fresno RWRF WW Disposal by Application of Municipal Sewage Sludge)

Application of sewage sludge not only disposes of waste material but also can improve crop production by increasing the supply of nutrients in the soils where the material is applied. Sewage sludge is the residual product of the treatment of municipal sewage. The solid component consists mainly of cell mass, primarily bacteria cells that developed during secondary treatment and have incorporated soluble organics into their own bodies. The sludge has small amounts of sand, silt, and other solid debris. The content of nitrogen varies. Some sludge has constituents that are toxic to plants or hazardous to the food chain, such as heavy metals and exotic organic compounds, and should be analyzed chemically prior to use.

The content of water in the sludge ranges from about 98 percent to less than 40 percent. The sludge is considered liquid if it is more than about 90 percent water, slurry if it is about 50 to 90 percent water, and solid if it is less than about 50 percent water.

The ratings are based on the soil properties that affect absorption, plant growth, microbial activity, erodibility, the rate at which the sludge is applied, and the method by which the sludge is applied. The properties that affect absorption, plant growth, and microbial activity include saturated hydraulic conductivity (Ksat), depth to a water table, ponding, the sodium adsorption ratio, depth to bedrock or a cemented pan, available water capacity, reaction, salinity, and bulk density. The wind erodibility group, soil erosion factor K, and slope are considered in estimating the likelihood that wind erosion or water erosion will transport the waste material from the application site. Stones, cobbles, a water table, ponding, and flooding can hinder the application of sludge. Permanently frozen soils are unsuitable for waste treatment.

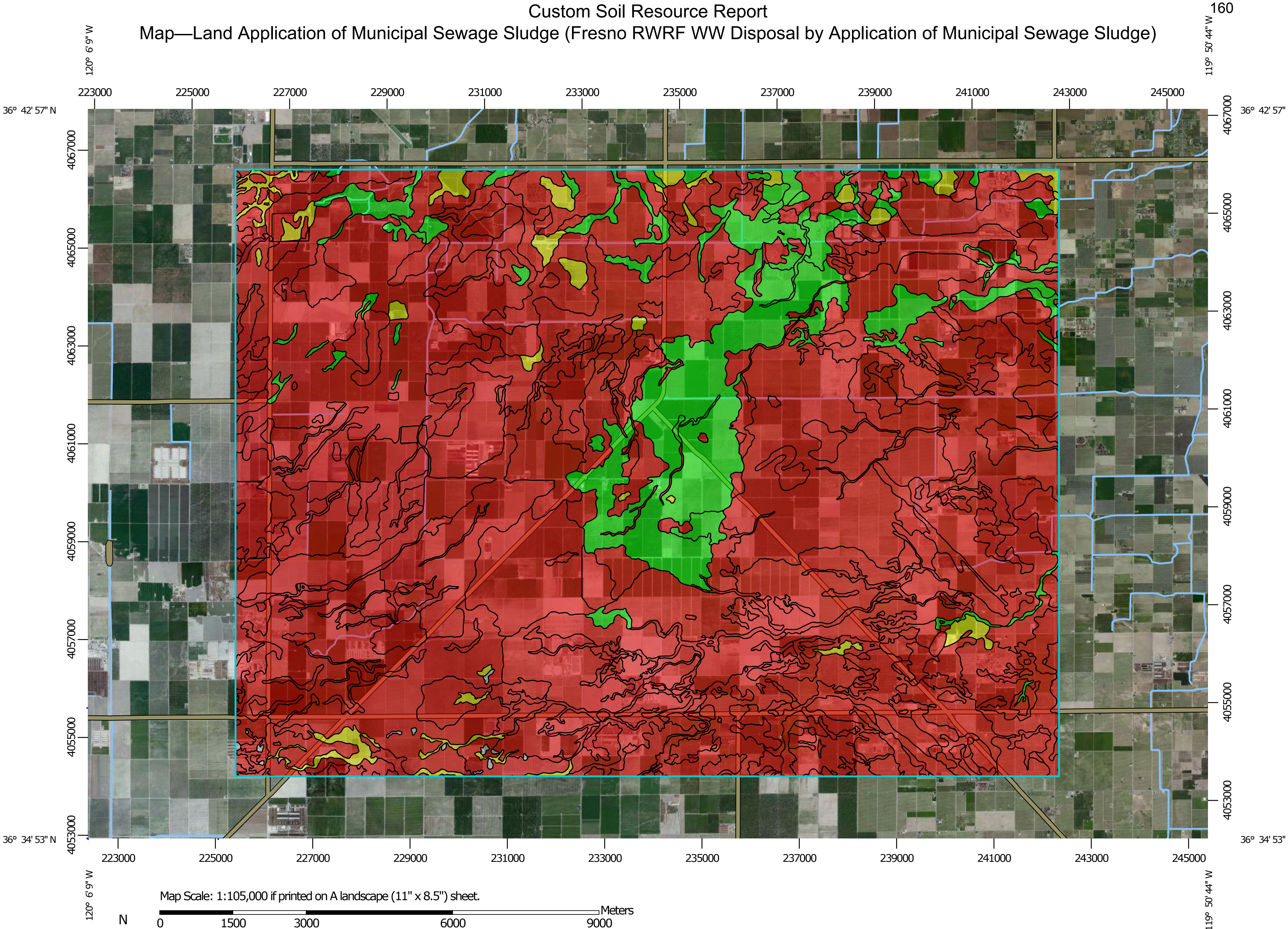
The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

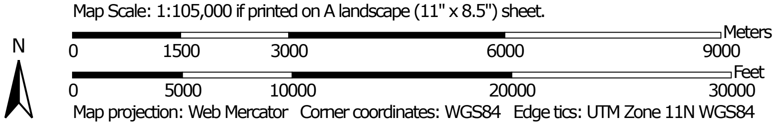
The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Map—Land Application of Municipal Sewage Sludge (Fresno RWRF WW Disposal by Application of Municipal Sewage Sludge)



Map Scale: 1:105,000 if printed on A landscape (11" x 8.5") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

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Soil Survey Area: Eastern Fresno Area, California
Survey Area Data: Version 7, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 12, 2010—Aug 20, 2013

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Land Application of Municipal Sewage Sludge (Fresno RWRF WW Disposal by Application of Municipal Sewage Sludge)

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
AoA	Atwater loamy sand, 0 to 3 percent slopes	Very limited	Atwater (85%)	Filtering capacity (1.00)	118.8	0.2%
ArA	Atwater sandy loam, 0 to 3 percent slopes	Not limited	Atwater (85%)		24.0	0.0%
Bn	Borden loam	Somewhat limited	Borden (85%)	Slow water movement (0.37)	50.5	0.1%
Bs	Borden loam, saline-alkali	Somewhat limited	Borden (85%)	Slow water movement (0.37)	11.1	0.0%
Bt	Borden loam, moderately deep	Very limited	Borden (85%)	Slow water movement (1.00)	397.6	0.8%
Bu	Borden loam, moderately deep, saline alkali	Very limited	Borden (85%)	Slow water movement (1.00)	480.7	0.9%
Ca	Cajon loamy coarse sand	Very limited	Cajon (85%)	Filtering capacity (1.00)	166.7	0.3%
				Droughty (0.30)		
Cc	Cajon coarse sandy loam	Very limited	Cajon (85%)	Filtering capacity (1.00)	16.8	0.0%
				Droughty (0.13)		
Cd	Cajon coarse sandy loam, saline alkali	Very limited	Cajon (85%)	Filtering capacity (1.00)	25.4	0.0%
				Droughty (0.13)		
Ce	Cajon coarse sandy loam, moderately deep, saline alkali	Very limited	Cajon (85%)	Filtering capacity (1.00)	44.4	0.1%
				Slow water movement (1.00)		
CfA	Calhi loamy sand, 0 to 3 percent slopes	Very limited	Calhi (85%)	Filtering capacity (1.00)	1,612.0	3.1%
				Droughty (0.68)		
CfB	Calhi loamy sand, 3 to 9 percent slopes	Very limited	Calhi (80%)	Filtering capacity (1.00)	53.3	0.1%
				Droughty (0.68)		
CgA	Calhi loamy sand, moderately deep, 0 to 3 percent slopes	Very limited	Calhi (85%)	Filtering capacity (1.00)	861.1	1.7%
				Slow water movement (1.00)		

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
DeA	Delhi sand, 0 to 3 percent slopes, MLRA 17	Very limited	Delhi (85%)	Filtering capacity (1.00)	30.6	0.1%
				Droughty (0.65)		
DeB	Delhi sand, 3 to 9 percent slopes	Very limited	Delhi (85%)	Filtering capacity (1.00)	10.8	0.0%
				Droughty (0.32)		
DhA	Delhi loamy sand, 0 to 3 percent slopes, MLRA 17	Very limited	Delhi (85%)	Filtering capacity (1.00)	892.3	1.7%
				Droughty (0.65)		
DhB	Delhi loamy sand, 3 to 9 percent slopes	Very limited	Delhi (85%)	Filtering capacity (1.00)	32.7	0.1%
				Droughty (0.29)		
DlA	Delhi loamy sand, moderately deep, 0 to 3 percent slopes	Very limited	Delhi (85%)	Filtering capacity (1.00)	227.1	0.4%
				Slow water movement (1.00)		
Ec	El Peco sandy loam	Very limited	El Peco (85%)	Salinity (1.00)	28.4	0.1%
				Droughty (1.00)		
				Slow water movement (1.00)		
				Depth to cemented pan (0.95)		
				Flooding (0.40)		
Ed	El Peco fine sandy loam	Very limited	El Peco (85%)	Salinity (1.00)	3,983.6	7.7%
				Droughty (1.00)		
				Slow water movement (1.00)		
				Depth to cemented pan (0.95)		
				Flooding (0.40)		
Ep	El Peco loam	Very limited	El Peco (85%)	Salinity (1.00)	731.7	1.4%
				Droughty (1.00)		
				Slow water movement (1.00)		
				Depth to cemented pan (0.95)		
				Flooding (0.40)		
Es	Exeter sandy loam	Somewhat limited	Exeter (85%)	Droughty (0.65)	192.6	0.4%

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
				Depth to cemented pan (0.46)		
Fs	Fresno sandy loam	Very limited	Fresno (85%)	Slow water movement (1.00)	492.5	0.9%
				Droughty (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
				Depth to cemented pan (0.99)		
Ft	Fresno sandy loam, shallow	Very limited	Fresno (85%)	Slow water movement (1.00)	516.8	1.0%
				Depth to cemented pan (1.00)		
				Droughty (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
Fu	Fresno fine sandy loam	Very limited	Fresno (80%)	Slow water movement (1.00)	6,538.6	12.6%
				Droughty (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
				Depth to cemented pan (0.99)		
Fv	Fresno fine sandy loam, shallow	Very limited	Fresno (85%)	Slow water movement (1.00)	3,744.4	7.2%
				Depth to cemented pan (1.00)		
				Salinity (1.00)		
				Droughty (1.00)		
				Sodium content (1.00)		
Fw	Fresno clay loam	Very limited	Fresno (85%)	Slow water movement (1.00)	302.0	0.6%
				Depth to cemented pan (1.00)		

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
				Droughty (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
Fx	Fresno-Traver complex	Very limited	Fresno (50%)	Slow water movement (1.00)	223.1	0.4%
				Droughty (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
				Depth to cemented pan (0.99)		
			Traver (35%)	Sodium content (1.00)		
				Slow water movement (1.00)		
				Salinity (1.00)		
GuA	Greenfield sandy loam, moderately deep, 0 to 3 percent slopes	Somewhat limited	Greenfield (85%)	Droughty (0.12)	43.6	0.1%
				Depth to cemented pan (0.01)		
Ha	Hanford coarse sandy loam	Not limited	Hanford (85%)		481.3	0.9%
Hc	Hanford sandy loam	Not limited	Hanford (85%)		447.7	0.9%
Hg	Hanford sandy loam, silty substratum	Very limited	Hanford (85%)	Slow water movement (1.00)	221.1	0.4%
Hk	Hanford sandy loam, hard substratum	Somewhat limited	Hanford (85%)	Droughty (0.36)	220.1	0.4%
				Depth to cemented pan (0.06)		
Hm	Hanford fine sandy loam	Not limited	Hanford (85%)		42.0	0.1%
Ho	Hanford fine sandy loam, silty substratum	Very limited	Hanford (85%)	Slow water movement (1.00)	85.3	0.2%
Hsa	Hesperia coarse sandy loam	Somewhat limited	Hesperia (85%)	Flooding (0.40)	111.1	0.2%
Hsd	Hesperia sandy loam	Very limited	Hesperia (85%)	Slow water movement (1.00)	2,080.8	4.0%
				Flooding (0.40)		

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
Hse	Hesperia sandy loam, saline-alkali	Somewhat limited	Hesperia (85%)	Salinity (0.50)	476.3	0.9%
				Flooding (0.40)		
Hsm	Hesperia sandy loam, moderately deep	Very limited	Hesperia (85%)	Slow water movement (1.00)	6,322.0	12.2%
				Flooding (0.40)		
Hsn	Hesperia sandy loam, moderately deep, saline-alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	1,127.7	2.2%
				Salinity (0.50)		
				Flooding (0.40)		
Hso	Hesperia sandy loam, shallow	Very limited	Hesperia (85%)	Slow water movement (1.00)	272.2	0.5%
				Flooding (0.40)		
Hsp	Hesperia sandy loam, shallow, saline-alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	928.5	1.8%
				Salinity (0.50)		
				Flooding (0.40)		
Hsr	Hesperia fine sandy loam	Very limited	Hesperia (85%)	Slow water movement (1.00)	837.5	1.6%
				Flooding (0.40)		
Hss	Hesperia fine sandy loam, saline alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	97.6	0.2%
				Salinity (0.50)		
				Flooding (0.40)		
Hst	Hesperia fine sandy loam moderately deep	Very limited	Hesperia (85%)	Slow water movement (1.00)	4,160.3	8.0%
				Flooding (0.40)		
Hsy	Hesperia fine sandy loam, moderately deep, saline-alkali	Very limited	Hesperia (85%)	Slow water movement (1.00)	3,314.7	6.4%
				Salinity (0.50)		
				Flooding (0.40)		
Ma	Madera sandy loam	Very limited	Madera (85%)	Slow water movement (1.00)	36.0	0.1%
				Droughty (1.00)		
				Depth to cemented pan (0.20)		

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
Mc	Madera loam	Very limited	Madera (85%)	Slow water movement (1.00)	62.8	0.1%
				Droughty (0.84)		
				Depth to cemented pan (0.20)		
Md	Madera loam, saline-alkali	Very limited	Madera (85%)	Slow water movement (1.00)	78.7	0.2%
				Droughty (0.84)		
				Sodium content (0.68)		
				Depth to cemented pan (0.20)		
				Salinity (0.13)		
Pa	Pachappa loam	Not limited	Pachappa (85%)		92.1	0.2%
Pc	Pachappa loam, saline alkali	Very limited	Pachappa (85%)	Salinity (1.00)	61.3	0.1%
Pd	Pachappa loam, moderately deep	Not limited	Pachappa (85%)		1,246.6	2.4%
Pe	Pachappa loam, moderately deep, saline-alkali	Not limited	Pachappa (85%)		2,957.6	5.7%
Pl	Playas	Not rated	Playas (95%)		46.9	0.1%
			Unnamed (5%)			
Ps	Pond sandy loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	89.0	0.2%
				Sodium content (1.00)		
				Salinity (1.00)		
				Flooding (0.40)		
				Strongly contrasting textural stratification (0.10)		
Pt	Pond fine sandy loam	Very limited	Pond (85%)	Filtering capacity (1.00)	163.1	0.3%
				Slow water movement (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
				Flooding (0.40)		
Pu	Pond fine sandy loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	81.0	0.2%
				Sodium content (1.00)		
				Salinity (1.00)		
				Flooding (0.40)		
				Droughty (0.28)		
Pw	Pond loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	1,183.6	2.3%
				Sodium content (1.00)		
				Salinity (1.00)		
				Flooding (0.40)		
				Droughty (0.21)		
Rb	Ramona sandy loam, hard substratum	Somewhat limited	Ramona (80%)	Slow water movement (0.37)	4.1	0.0%
				Droughty (0.02)		
			Ramona, moderately deep (15%)	Slow water movement (0.37)		
				Droughty (0.23)		
				Depth to cemented pan (0.06)		
Rc	Ramona loam	Somewhat limited	Ramona (80%)	Slow water movement (0.37)	41.4	0.1%
				Droughty (0.04)		
Re	Ramona loam, hard substratum	Somewhat limited	Ramona (85%)	Slow water movement (0.37)	25.9	0.0%
				Droughty (0.14)		
				Depth to cemented pan (0.06)		
			Ramona (10%)	Slow water movement (0.37)		
				Droughty (0.00)		
Tr	Traver sandy loam	Very limited	Traver (85%)	Sodium content (1.00)	86.1	0.2%

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
				Slow water movement (1.00)		
				Salinity (1.00)		
				Flooding (0.40)		
				Droughty (0.09)		
Ts	Traver sandy loam, moderately deep	Very limited	Traver (85%)	Sodium content (1.00)	972.2	1.9%
				Slow water movement (1.00)		
				Salinity (1.00)		
				Flooding (0.40)		
Tt	Traver fine sandy loam	Very limited	Traver (85%)	Sodium content (1.00)	30.6	0.1%
				Slow water movement (1.00)		
				Salinity (1.00)		
				Flooding (0.40)		
				Droughty (0.09)		
Tu	Traver fine sandy loam, moderately deep	Very limited	Traver (85%)	Sodium content (1.00)	1,136.5	2.2%
				Slow water movement (1.00)		
				Salinity (1.00)		
				Flooding (0.40)		
TzbA	Tujunga loamy sand, 0 to 3 percent slopes	Very limited	Tujunga (85%)	Filtering capacity (1.00)	491.1	0.9%
				Flooding (1.00)		
				Droughty (0.65)		
Ws	Wunjey fine sandy loam	Very limited	Wunjey (85%)	Salinity (1.00)	22.4	0.0%
				Flooding (0.40)		
Totals for Area of Interest					**51,988.5**	**100.0%**

Land Application of Municipal Sewage Sludge— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	45,473.8	87.5%
Not limited	5,291.3	10.2%
Somewhat limited	1,176.5	2.3%
Null or Not Rated	46.9	0.1%
Totals for Area of Interest	**51,988.5**	**100.0%**

Rating Options—Land Application of Municipal Sewage Sludge (Fresno RWRF WW Disposal by Application of Municipal Sewage Sludge)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Slow Rate Treatment of Wastewater (Fresno RWRF WW Disposal by Slow Rate Treatment)

Slow rate treatment of wastewater is a process in which wastewater is applied to land at a rate normally between 0.5 inch and 4.0 inches per week. The application rate commonly exceeds the rate needed for irrigation of cropland. The applied wastewater is treated as it moves through the soil. Much of the treated water may percolate to the ground water, and some enters the atmosphere through evapotranspiration. The applied water generally is not allowed to run off the surface. Waterlogging is prevented either through control of the application rate or through the use of tile drains, or both.

Soil properties are important considerations in areas where soils are used as sites for the treatment and disposal of organic waste and wastewater. Selection of soils with properties that favor waste management can help to prevent environmental damage.

Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

The ratings are based on the soil properties that affect absorption, plant growth, microbial activity, erodibility, and the application of waste. The properties that affect absorption include the sodium adsorption ratio, depth to a water table, ponding, available water capacity, saturated hydraulic conductivity (Ksat), depth to bedrock or a cemented pan, reaction, the cation-exchange capacity, and slope. Reaction, the sodium adsorption ratio, salinity, and bulk density affect plant growth and microbial activity. The wind erodibility group, soil erosion factor K, and slope are considered in estimating the likelihood of wind erosion or water erosion. Stones, cobbles, a water table, ponding, and flooding can hinder the application of waste. Permanently frozen soils are unsuitable for waste treatment.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

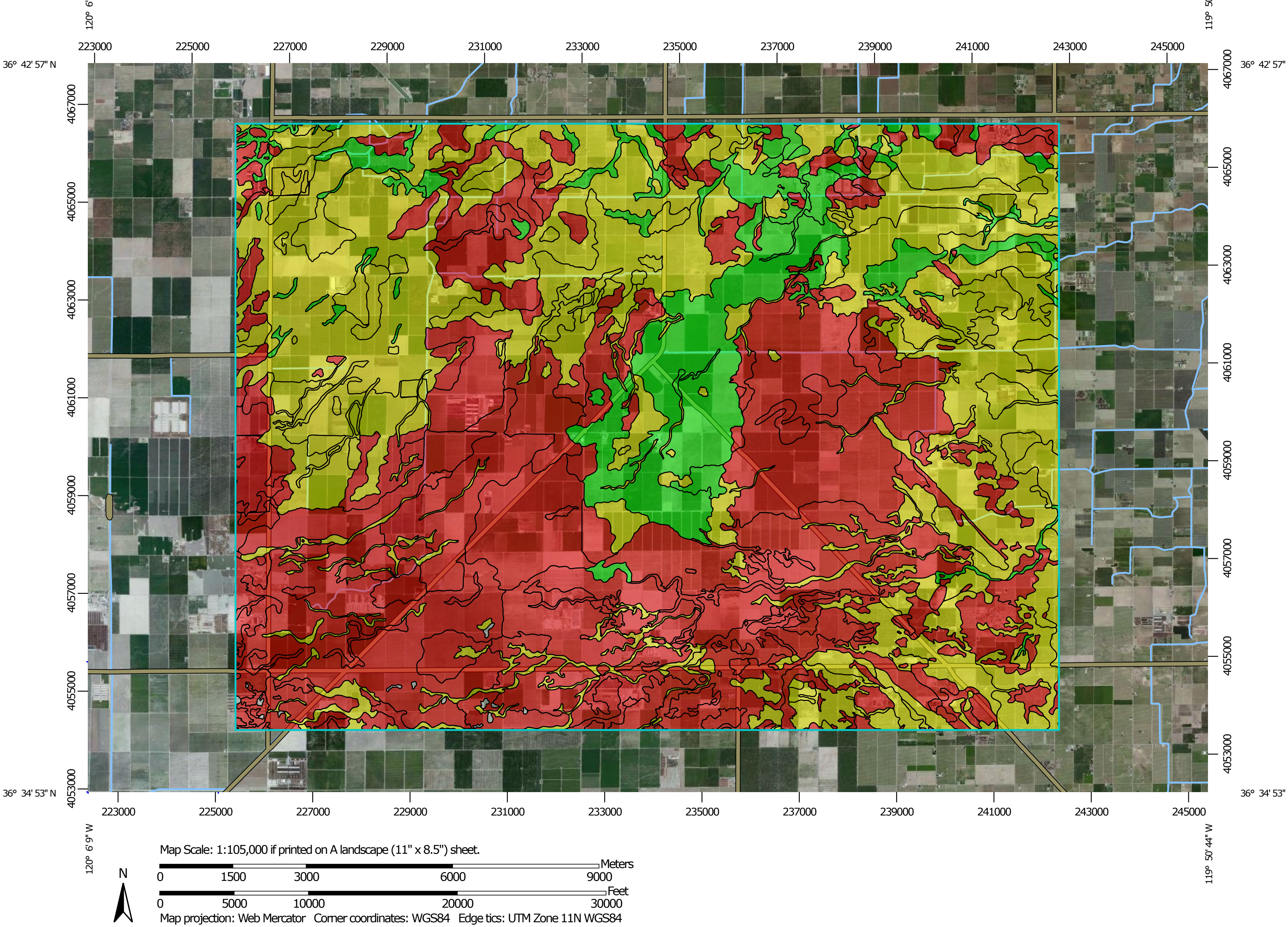
Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Custom Soil Resource Report

Map—Slow Rate Treatment of Wastewater (Fresno RWRF WW Disposal by Slow Rate Treatment)



MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Eastern Fresno Area, California
Survey Area Data: Version 7, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 12, 2010—Aug 20, 2013

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Slow Rate Treatment of Wastewater (Fresno RWRF WW Disposal by Slow Rate Treatment)

Slow Rate Treatment of Wastewater— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
AoA	Atwater loamy sand, 0 to 3 percent slopes	Very limited	Atwater (85%)	Filtering capacity (1.00)	118.8	0.2%
ArA	Atwater sandy loam, 0 to 3 percent slopes	Not limited	Atwater (85%)		24.0	0.0%
Bn	Borden loam	Somewhat limited	Borden (85%)	Slow water movement (0.26)	50.5	0.1%
Bs	Borden loam, saline-alkali	Somewhat limited	Borden (85%)	Slow water movement (0.26)	11.1	0.0%
Bt	Borden loam, moderately deep	Somewhat limited	Borden (85%)	Slow water movement (0.96)	397.6	0.8%
Bu	Borden loam, moderately deep, saline alkali	Somewhat limited	Borden (85%)	Slow water movement (0.96)	480.7	0.9%
Ca	Cajon loamy coarse sand	Very limited	Cajon (85%)	Filtering capacity (1.00)	166.7	0.3%
Cc	Cajon coarse sandy loam	Very limited	Cajon (85%)	Filtering capacity (1.00)	16.8	0.0%
Cd	Cajon coarse sandy loam, saline alkali	Very limited	Cajon (85%)	Filtering capacity (1.00)	25.4	0.0%
Ce	Cajon coarse sandy loam, moderately deep, saline alkali	Very limited	Cajon (85%)	Filtering capacity (1.00)	44.4	0.1%
				Slow water movement (0.96)		
CfA	Calhi loamy sand, 0 to 3 percent slopes	Very limited	Calhi (85%)	Filtering capacity (1.00)	1,612.0	3.1%
CfB	Calhi loamy sand, 3 to 9 percent slopes	Very limited	Calhi (80%)	Filtering capacity (1.00)	53.3	0.1%
				Too steep for surface application (0.68)		
CgA	Calhi loamy sand, moderately deep, 0 to 3 percent slopes	Very limited	Calhi (85%)	Filtering capacity (1.00)	861.1	1.7%
				Slow water movement (0.96)		

Slow Rate Treatment of Wastewater— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
DeA	Delhi sand, 0 to 3 percent slopes, MLRA 17	Very limited	Delhi (85%)	Filtering capacity (1.00)	30.6	0.1%
DeB	Delhi sand, 3 to 9 percent slopes	Very limited	Delhi (85%)	Filtering capacity (1.00)	10.8	0.0%
				Too steep for surface application (0.68)		
DhA	Delhi loamy sand, 0 to 3 percent slopes, MLRA 17	Very limited	Delhi (85%)	Filtering capacity (1.00)	892.3	1.7%
DhB	Delhi loamy sand, 3 to 9 percent slopes	Very limited	Delhi (85%)	Filtering capacity (1.00)	32.7	0.1%
				Too steep for surface application (0.68)		
DlA	Delhi loamy sand, moderately deep, 0 to 3 percent slopes	Very limited	Delhi (85%)	Filtering capacity (1.00)	227.1	0.4%
				Slow water movement (0.96)		
Ec	El Peco sandy loam	Very limited	El Peco (85%)	Depth to cemented pan (1.00)	28.4	0.1%
				Salinity (1.00)		
				Slow water movement (0.96)		
Ed	El Peco fine sandy loam	Very limited	El Peco (85%)	Depth to cemented pan (1.00)	3,983.6	7.7%
				Salinity (1.00)		
				Slow water movement (0.96)		
Ep	El Peco loam	Very limited	El Peco (85%)	Depth to cemented pan (1.00)	731.7	1.4%
				Salinity (1.00)		
				Slow water movement (0.96)		
Es	Exeter sandy loam	Very limited	Exeter (85%)	Depth to cemented pan (1.00)	192.6	0.4%
Fs	Fresno sandy loam	Very limited	Fresno (85%)	Slow water movement (1.00)	492.5	0.9%

Slow Rate Treatment of Wastewater— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
				Depth to cemented pan (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
Ft	Fresno sandy loam, shallow	Very limited	Fresno (85%)	Slow water movement (1.00)	516.8	1.0%
				Depth to cemented pan (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
Fu	Fresno fine sandy loam	Very limited	Fresno (80%)	Slow water movement (1.00)	6,538.6	12.6%
				Depth to cemented pan (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
Fv	Fresno fine sandy loam, shallow	Very limited	Fresno (85%)	Slow water movement (1.00)	3,744.4	7.2%
				Depth to cemented pan (1.00)		
				Salinity (1.00)		
				Sodium content (1.00)		
Fw	Fresno clay loam	Very limited	Fresno (85%)	Slow water movement (1.00)	302.0	0.6%
				Depth to cemented pan (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
Fx	Fresno-Traver complex	Very limited	Fresno (50%)	Slow water movement (1.00)	223.1	0.4%
				Depth to cemented pan (1.00)		

Slow Rate Treatment of Wastewater— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
				Sodium content (1.00)		
				Salinity (1.00)		
			Traver (35%)	Sodium content (1.00)		
				Salinity (1.00)		
				Slow water movement (0.96)		
GuA	Greenfield sandy loam, moderately deep, 0 to 3 percent slopes	Very limited	Greenfield (85%)	Depth to cemented pan (1.00)	43.6	0.1%
Ha	Hanford coarse sandy loam	Not limited	Hanford (85%)		481.3	0.9%
Hc	Hanford sandy loam	Not limited	Hanford (85%)		447.7	0.9%
Hg	Hanford sandy loam, silty substratum	Somewhat limited	Hanford (85%)	Slow water movement (0.96)	221.1	0.4%
Hk	Hanford sandy loam, hard substratum	Very limited	Hanford (85%)	Depth to cemented pan (1.00)	220.1	0.4%
Hm	Hanford fine sandy loam	Not limited	Hanford (85%)		42.0	0.1%
Ho	Hanford fine sandy loam, silty substratum	Somewhat limited	Hanford (85%)	Slow water movement (0.96)	85.3	0.2%
Hsa	Hesperia coarse sandy loam	Not limited	Hesperia (85%)		111.1	0.2%
Hsd	Hesperia sandy loam	Somewhat limited	Hesperia (85%)	Slow water movement (0.96)	2,080.8	4.0%
Hse	Hesperia sandy loam, saline-alkali	Somewhat limited	Hesperia (85%)	Salinity (0.50)	476.3	0.9%
Hsm	Hesperia sandy loam, moderately deep	Somewhat limited	Hesperia (85%)	Slow water movement (0.96)	6,322.0	12.2%
Hsn	Hesperia sandy loam, moderately deep, saline-alkali	Somewhat limited	Hesperia (85%)	Slow water movement (0.96)	1,127.7	2.2%
				Salinity (0.50)		
Hso	Hesperia sandy loam, shallow	Somewhat limited	Hesperia (85%)	Slow water movement (0.96)	272.2	0.5%

Slow Rate Treatment of Wastewater— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
Hsp	Hesperia sandy loam, shallow, saline-alkali	Somewhat limited	Hesperia (85%)	Slow water movement (0.96)	928.5	1.8%
				Salinity (0.50)		
Hsr	Hesperia fine sandy loam	Somewhat limited	Hesperia (85%)	Slow water movement (0.96)	837.5	1.6%
Hss	Hesperia fine sandy loam, saline alkali	Somewhat limited	Hesperia (85%)	Slow water movement (0.96)	97.6	0.2%
				Salinity (0.50)		
Hst	Hesperia fine sandy loam moderately deep	Somewhat limited	Hesperia (85%)	Slow water movement (0.96)	4,160.3	8.0%
Hsy	Hesperia fine sandy loam, moderately deep, saline-alkali	Somewhat limited	Hesperia (85%)	Slow water movement (0.96)	3,314.7	6.4%
				Salinity (0.50)		
Ma	Madera sandy loam	Very limited	Madera (85%)	Slow water movement (1.00)	36.0	0.1%
				Depth to cemented pan (1.00)		
Mc	Madera loam	Very limited	Madera (85%)	Slow water movement (1.00)	62.8	0.1%
				Depth to cemented pan (1.00)		
Md	Madera loam, saline-alkali	Very limited	Madera (85%)	Slow water movement (1.00)	78.7	0.2%
				Depth to cemented pan (1.00)		
				Sodium content (0.68)		
				Salinity (0.13)		
Pa	Pachappa loam	Not limited	Pachappa (85%)		92.1	0.2%
Pc	Pachappa loam, saline alkali	Very limited	Pachappa (85%)	Salinity (1.00)	61.3	0.1%
Pd	Pachappa loam, moderately deep	Not limited	Pachappa (85%)		1,246.6	2.4%
Pe	Pachappa loam, moderately deep, saline-alkali	Not limited	Pachappa (85%)		2,957.6	5.7%

Slow Rate Treatment of Wastewater— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
Pl	Playas	Not rated	Playas (95%)		46.9	0.1%
			Unnamed (5%)			
Ps	Pond sandy loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	89.0	0.2%
				Sodium content (1.00)		
				Salinity (1.00)		
Pt	Pond fine sandy loam	Very limited	Pond (85%)	Filtering capacity (1.00)	163.1	0.3%
				Sodium content (1.00)		
				Salinity (1.00)		
				Slow water movement (0.96)		
Pu	Pond fine sandy loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	81.0	0.2%
				Sodium content (1.00)		
				Salinity (1.00)		
Pw	Pond loam, moderately deep	Very limited	Pond (85%)	Slow water movement (1.00)	1,183.6	2.3%
				Sodium content (1.00)		
				Salinity (1.00)		
Rb	Ramona sandy loam, hard substratum	Somewhat limited	Ramona (80%)	Depth to cemented pan (1.00)	4.1	0.0%
				Slow water movement (0.26)		
Rc	Ramona loam	Somewhat limited	Ramona (80%)	Slow water movement (0.26)	41.4	0.1%
Re	Ramona loam, hard substratum	Very limited	Ramona (85%)	Depth to cemented pan (1.00)	25.9	0.0%
				Slow water movement (0.26)		
Tr	Traver sandy loam	Very limited	Traver (85%)	Sodium content (1.00)	86.1	0.2%
				Salinity (1.00)		
				Slow water movement (0.96)		

Slow Rate Treatment of Wastewater— Summary by Map Unit — Eastern Fresno Area, California (CA654)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
Ts	Traver sandy loam, moderately deep	Very limited	Traver (85%)	Sodium content (1.00)	972.2	1.9%
				Salinity (1.00)		
				Slow water movement (0.96)		
Tt	Traver fine sandy loam	Very limited	Traver (85%)	Sodium content (1.00)	30.6	0.1%
				Salinity (1.00)		
				Slow water movement (0.96)		
Tu	Traver fine sandy loam, moderately deep	Very limited	Traver (85%)	Sodium content (1.00)	1,136.5	2.2%
				Salinity (1.00)		
				Slow water movement (0.96)		
TzbA	Tujunga loamy sand, 0 to 3 percent slopes	Very limited	Tujunga (85%)	Filtering capacity (1.00)	491.1	0.9%
				Flooding (0.60)		
Ws	Wunjey fine sandy loam	Very limited	Wunjey (85%)	Salinity (1.00)	22.4	0.0%
Totals for Area of Interest					**51,988.5**	**100.0%**

Slow Rate Treatment of Wastewater— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	25,629.8	49.3%
Somewhat limited	20,909.4	40.2%
Not limited	5,402.3	10.4%
Null or Not Rated	46.9	0.1%
Totals for Area of Interest	**51,988.5**	**100.0%**

Rating Options—Slow Rate Treatment of Wastewater (Fresno RWRF WW Disposal by Slow Rate Treatment)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

References

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.

Federal Register. July 13, 1994. Changes in hydric soils of the United States.

Federal Register. September 18, 2002. Hydric soils of the United States.

Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.

National Research Council. 1995. Wetlands: Characteristics and boundaries.

Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_054262

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053577

Soil Survey Staff. 2010. Keys to soil taxonomy. 11th edition. U.S. Department of Agriculture, Natural Resources Conservation Service. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053580

Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service and Delaware Department of Natural Resources and Environmental Control, Wetlands Section.

United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.

United States Department of Agriculture, Natural Resources Conservation Service. National forestry manual. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053374

United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1043084

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053624

United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052290.pdf

APPENDIX B

TULARE RWRF SOIL SURVEY AND LAND USE ESTIMATE: OBTAINED FROM NRCS SOILS ONLINE

United States Department of Agriculture

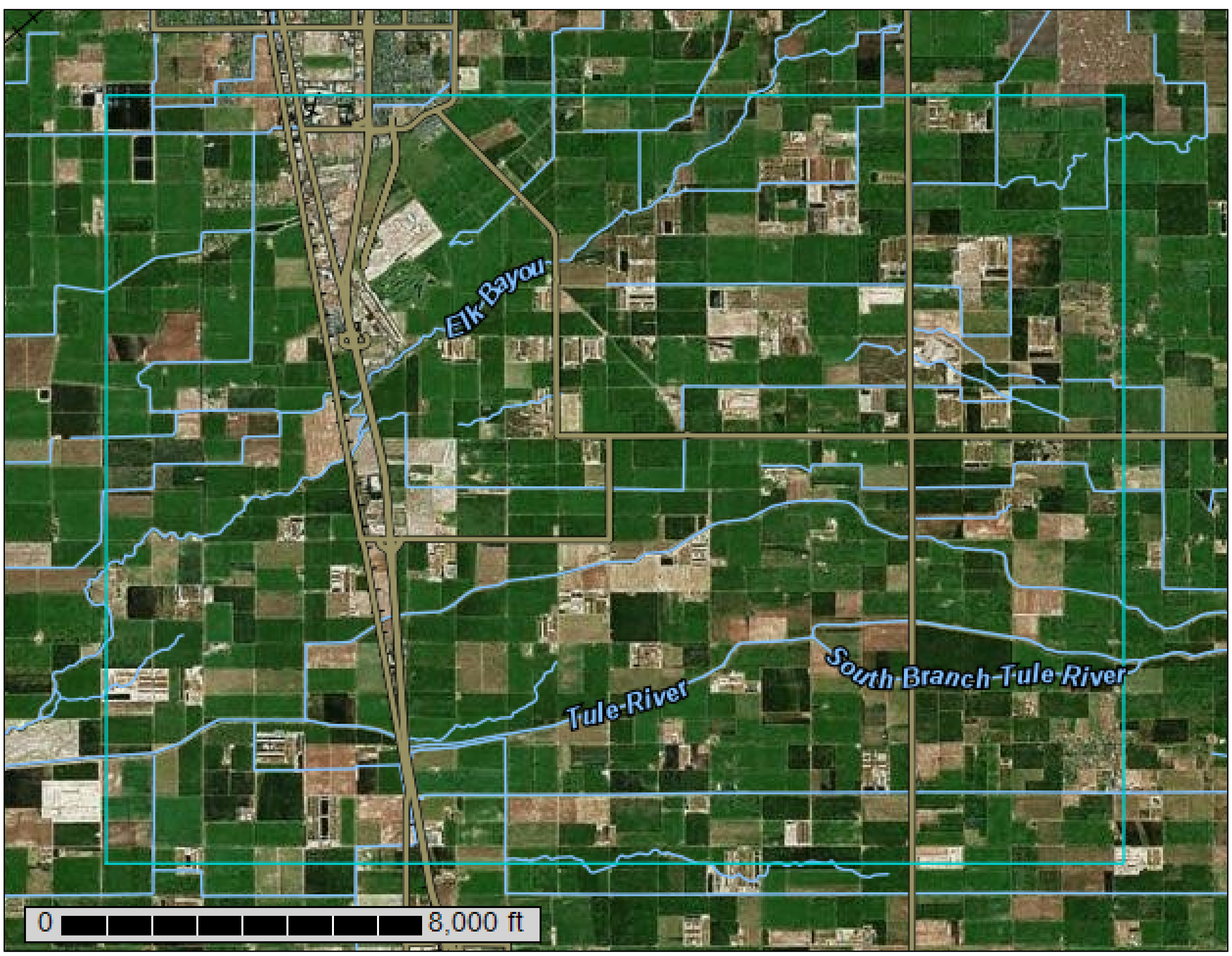
NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Tulare County, Western Part, California



July 11, 2015

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

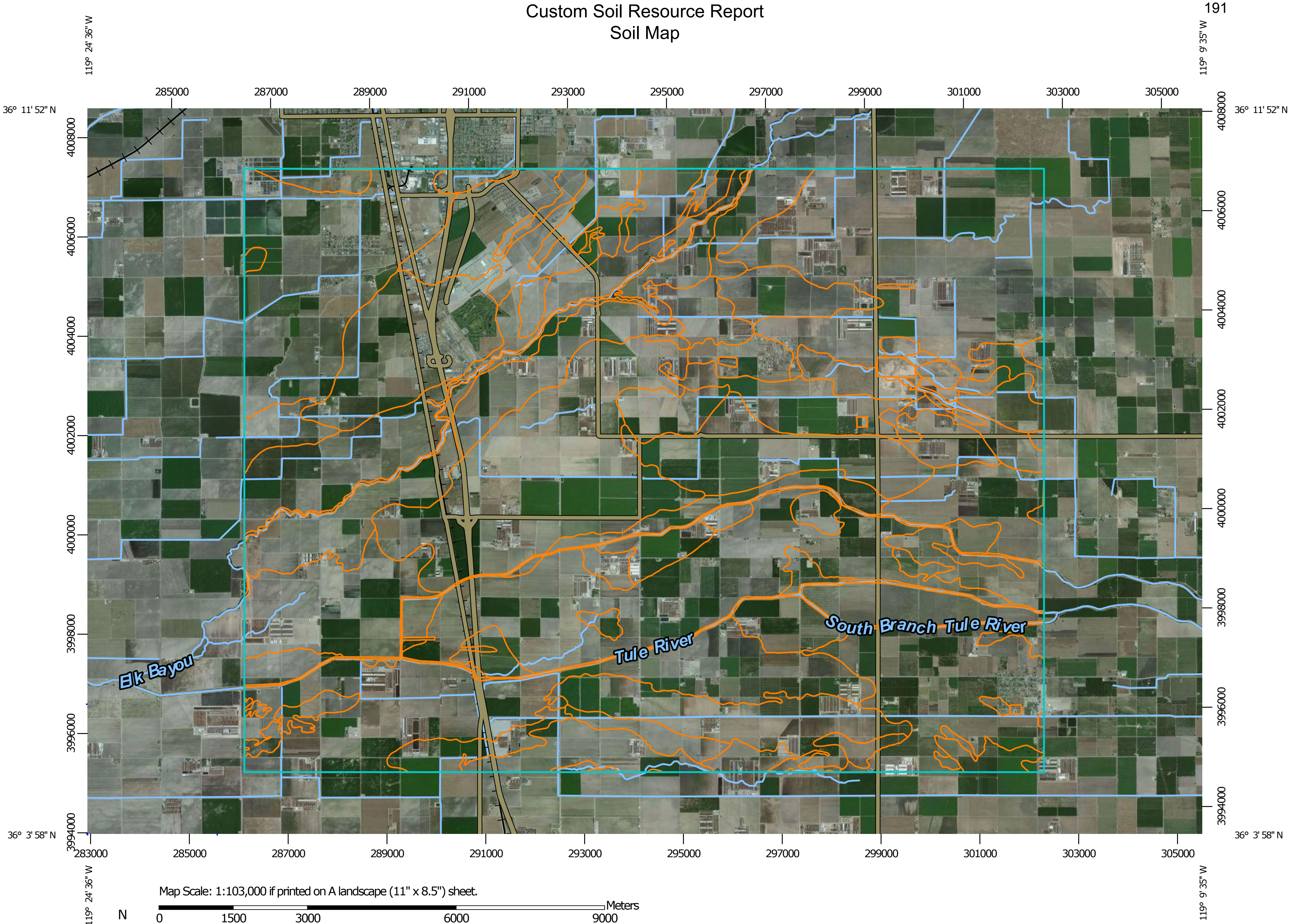
Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

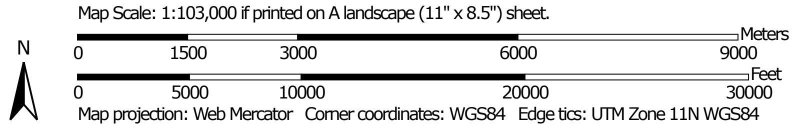
Contents

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map





MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Unit Polygons

Soil Map Unit Lines

Soil Map Unit Points

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Tulare County, Western Part, California
Survey Area Data: Version 8, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 27, 2010—Jul 3, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Tulare County, Western Part, California (CA659)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
101	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	2,834.8	5.8%
104	Biggriz-Biggriz, saline-Sodic, complex, 0 to 2 percent slopes	3,322.4	6.8%
105	Calgro-Calgro, saline-Sodic, complex, 0 to 2 percent slopes	1,059.7	2.2%
108	Colpien loam, 0 to 2 percent slopes	17,349.6	35.6%
109	Crosscreek-Kai association, 0 to 2 percent slopes	8,187.8	16.8%
112	Dumps	78.5	0.2%
116	Flamen loam, 0 to 2 percent slopes	3,260.4	6.7%
124	Hanford sandy loam, 0 to 2 percent slopes	64.0	0.1%
130	Nord fine sandy loam, 0 to 2 percent slopes	4,210.1	8.6%
131	Pits	67.7	0.1%
132	Quonal-Lewis association, 0 to 2 percent slopes	4,750.8	9.7%
134	Riverwash	620.8	1.3%
137	Tagus loam, 0 to 2 percent slopes	870.9	1.8%
138	Tujunga loamy sand, 0 to 2 percent slopes	378.6	0.8%
143	Yettem sandy loam, 0 to 2 percent slopes	1,699.0	3.5%
Totals for Area of Interest		**48,755.2**	**100.0%**

Soil Information for All Uses

Suitabilities and Limitations for Use

The Suitabilities and Limitations for Use section includes various soil interpretations displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each interpretation.

Waste Management

Waste Management interpretations are tools designed to guide the user in evaluating soils for use of organic wastes and wastewater as productive resources. Example interpretations include land application of manure, food processing waste, and municipal sewage sludge, and disposal of wastewater by irrigation or overland flow process.

Disposal of Wastewater by Irrigation (Tulare RWRF WW Disposal by Irrigation)

Wastewater includes municipal and food-processing wastewater and effluent from lagoons or storage ponds. Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

Disposal of wastewater by irrigation not only disposes of municipal wastewater and wastewater from food-processing plants, lagoons, and storage ponds but also can improve crop production by increasing the amount of water available to crops. The ratings are based on the soil properties that affect the design, construction, management, and performance of the irrigation system. The properties that affect design and management include the sodium adsorption ratio, depth to a water table, ponding, available water capacity, saturated hydraulic conductivity (Ksat), slope, and flooding. The properties that affect construction include stones, cobbles, depth to bedrock or a cemented pan, depth to a water table, and ponding. The properties that affect performance include depth to bedrock or a cemented pan, bulk density, the sodium adsorption ratio, salinity, reaction, and the cation-exchange capacity, which is used to estimate the capacity of a soil to adsorb heavy metals. Permanently frozen soils are not suitable for disposal of wastewater by irrigation.

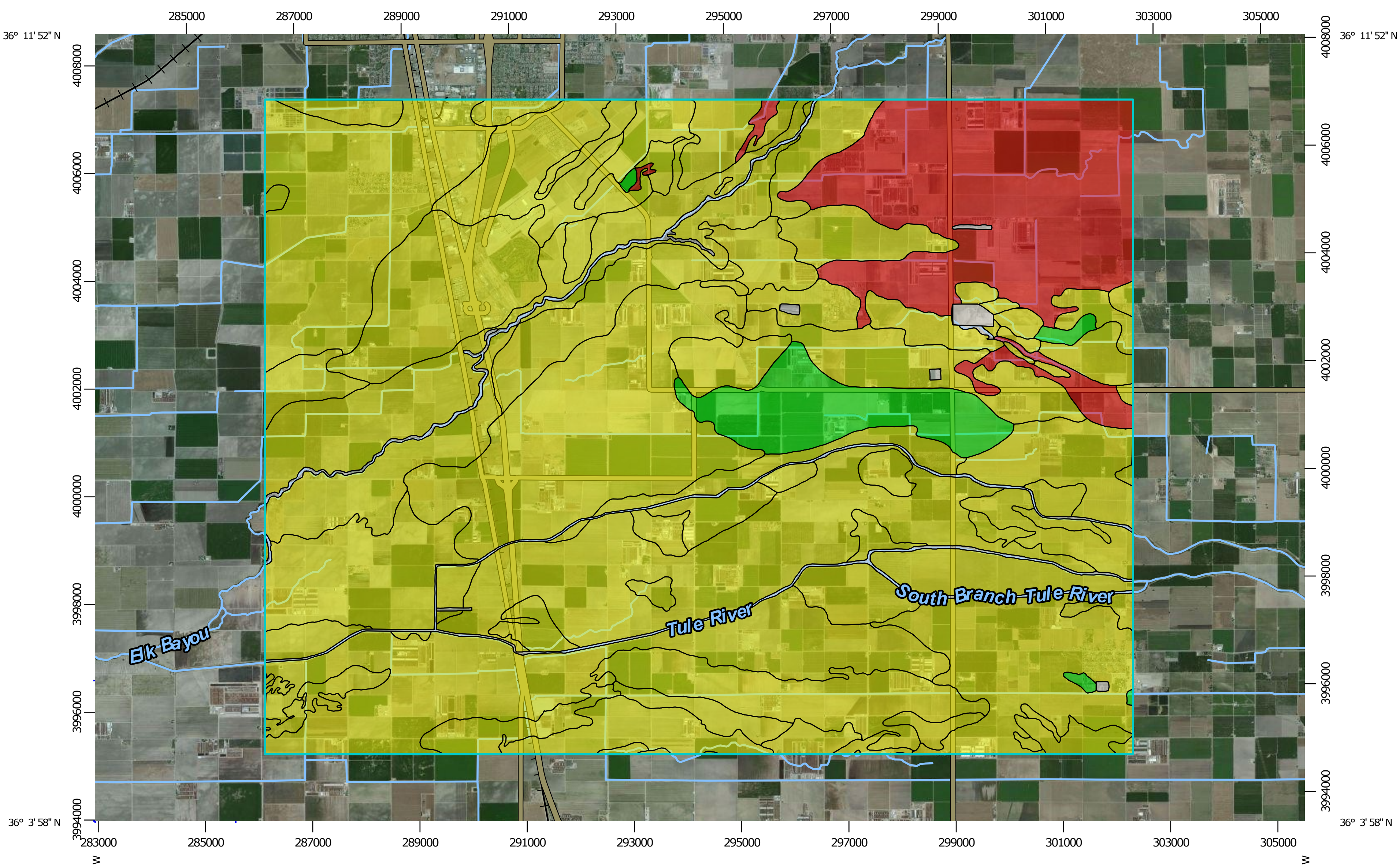
The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Map—Disposal of Wastewater by Irrigation (Tulare RWRF WW Disposal by Irrigation)



Map Scale: 1:103,000 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0, 1500, 3000, 6000, 9000

Feet: 0, 5000, 10000, 20000, 30000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Tulare County, Western Part, California
Survey Area Data: Version 8, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 27, 2010—Jul 3, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Disposal of Wastewater by Irrigation (Tulare RWRF WW Disposal by Irrigation)

Disposal of Wastewater by Irrigation— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
101	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Akers (60%)	Sodium content (0.32)	2,834.8	5.8%
104	Biggriz-Biggriz, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Biggriz (55%)	Sodium content (0.32)	3,322.4	6.8%
				Slow water movement (0.31)		
105	Calgro-Calgro, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Calgro (60%)	Droughty (0.91)	1,059.7	2.2%
				Depth to cemented pan (0.84)		
				Sodium content (0.32)		
108	Colpien loam, 0 to 2 percent slopes	Somewhat limited	Colpien (85%)	Sodium content (0.32)	17,349.6	35.6%
				Slow water movement (0.31)		
109	Crosscreek-Kai association, 0 to 2 percent slopes	Somewhat limited	Crosscreek (70%)	Salinity (0.72)	8,187.8	16.8%
				Sodium content (0.32)		
				Slow water movement (0.31)		
112	Dumps	Not rated	Dumps (100%)		78.5	0.2%
116	Flamen loam, 0 to 2 percent slopes	Somewhat limited	Flamen (85%)	Sodium content (0.32)	3,260.4	6.7%
124	Hanford sandy loam, 0 to 2 percent slopes	Very limited	Hanford (85%)	Filtering capacity (1.00)	64.0	0.1%
				Sodium content (0.02)		
130	Nord fine sandy loam, 0 to 2 percent slopes	Somewhat limited	Nord (85%)	Sodium content (0.18)	4,210.1	8.6%
131	Pits	Not rated	Pits (100%)		67.7	0.1%
132	Quonal-Lewis association, 0 to 2 percent slopes	Very limited	Quonal (70%)	Slow water movement (1.00)	4,750.8	9.7%
				Sodium content (1.00)		
				Droughty (0.06)		

Disposal of Wastewater by Irrigation— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
			Lewis (15%)	Sodium content (1.00)		
				Slow water movement (1.00)		
				Droughty (1.00)		
				Salinity (1.00)		
				Depth to cemented pan (0.84)		
134	Riverwash	Not rated	Riverwash (100%)		620.8	1.3%
137	Tagus loam, 0 to 2 percent slopes	Somewhat limited	Tagus (85%)	Sodium content (0.18)	870.9	1.8%
138	Tujunga loamy sand, 0 to 2 percent slopes	Very limited	Tujunga (85%)	Filtering capacity (1.00)	378.6	0.8%
				Droughty (0.89)		
143	Yettem sandy loam, 0 to 2 percent slopes	Not limited	Yettem (85%)		1,699.0	3.5%
Totals for Area of Interest					**48,755.2**	**100.0%**

Disposal of Wastewater by Irrigation— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Somewhat limited	41,095.7	84.3%
Very limited	5,193.3	10.7%
Not limited	1,699.0	3.5%
Null or Not Rated	767.1	1.6%
Totals for Area of Interest	**48,755.2**	**100.0%**

Rating Options—Disposal of Wastewater by Irrigation (Tulare RWRF WW Disposal by Irrigation)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Disposal of Wastewater by Rapid Infiltration (Tulare RWRF WW Disposal by Rapid Infiltration)

Rapid infiltration of wastewater is a process in which wastewater applied in a level basin at a rate of 4 to 120 inches per week percolates through the soil. The wastewater may eventually reach the ground water. The application rate commonly exceeds the rate needed for irrigation of cropland. Vegetation is not a necessary part of the treatment; thus, the basins may or may not be vegetated. The thickness of the soil material needed for proper treatment of the wastewater is more than 72 inches. As a result, geologic and hydrologic investigation is needed to ensure proper design and performance and to determine the risk of ground-water pollution.

Soil properties are important considerations in areas where soils are used as sites for the treatment and disposal of organic waste and wastewater. Selection of soils with properties that favor waste management can help to prevent environmental damage.

Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

The ratings are based on the soil properties that affect the risk of pollution and the design, construction, and performance of the system. Depth to a water table, ponding, flooding, and depth to bedrock or a cemented pan affect the risk of pollution and the design and construction of the system. Slope, stones, and cobbles also affect design and construction. Saturated hydraulic conductivity (Ksat) and reaction affect performance. Permanently frozen soils are unsuitable for waste treatment.

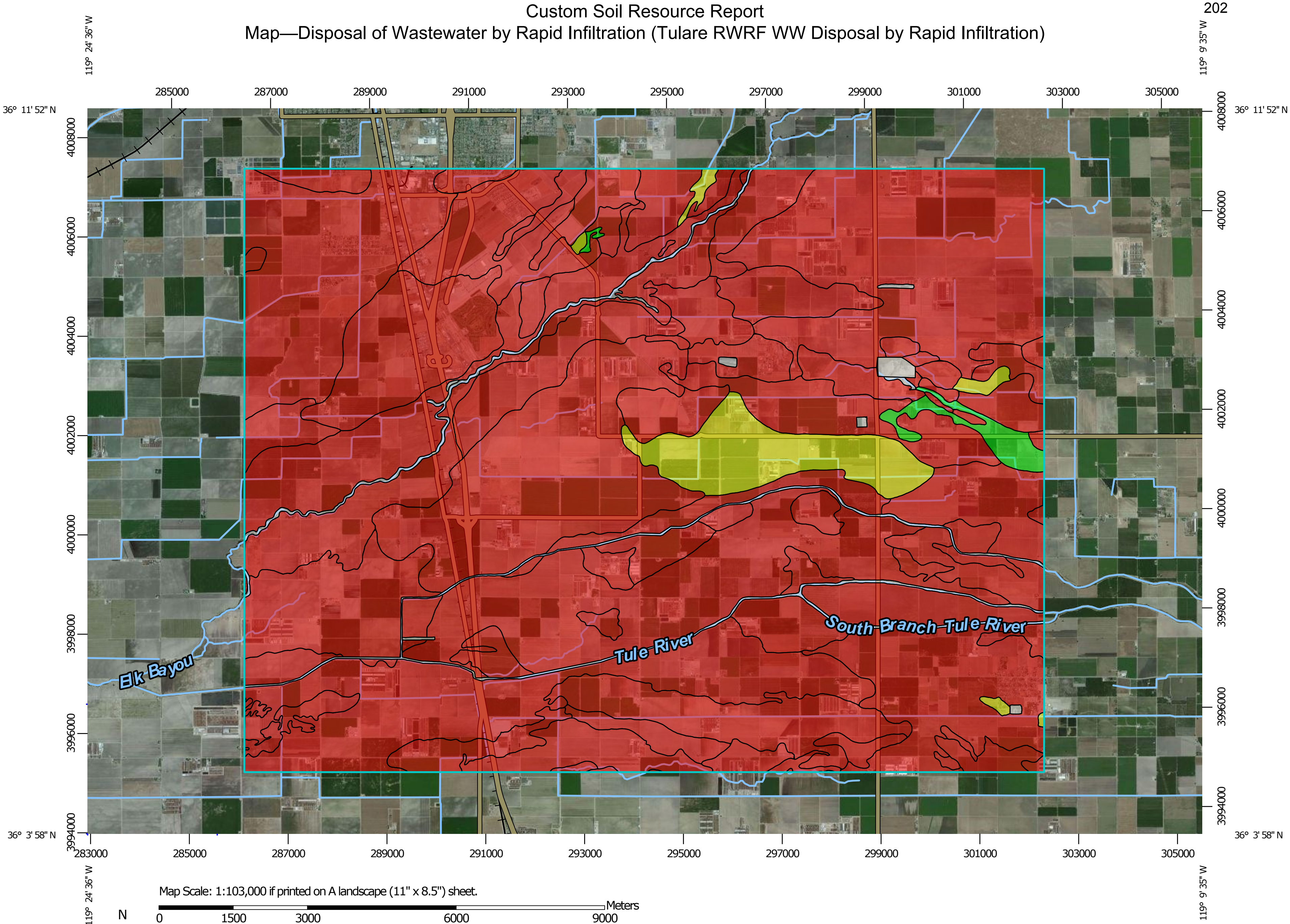
The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Custom Soil Resource Report
Map—Disposal of Wastewater by Rapid Infiltration (Tulare RWRF WW Disposal by Rapid Infiltration)



Map Scale: 1:103,000 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 | 1500 | 3000 | 6000 | 9000

Feet: 0 | 5000 | 10000 | 20000 | 30000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- Very limited
- Somewhat limited
- Not limited
- Not rated or not available

Soil Rating Lines
- Very limited
- Somewhat limited
- Not limited
- Not rated or not available

Soil Rating Points
- Very limited
- Somewhat limited
- Not limited
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Tulare County, Western Part, California
Survey Area Data: Version 8, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 27, 2010—Jul 3, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Disposal of Wastewater by Rapid Infiltration (Tulare RWRF WW Disposal by Rapid Infiltration)

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
101	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Very limited	Akers (60%)	Slow water movement (1.00)	2,834.8	5.8%
			Akers, saline-sodic (25%)	Slow water movement (1.00)		
104	Biggriz-Biggriz, saline-Sodic, complex, 0 to 2 percent slopes	Very limited	Biggriz (55%)	Slow water movement (1.00)	3,322.4	6.8%
			Biggriz, saline-sodic (30%)	Slow water movement (1.00)		
105	Calgro-Calgro, saline-Sodic, complex, 0 to 2 percent slopes	Very limited	Calgro (60%)	Depth to cemented pan (1.00)	1,059.7	2.2%
				Slow water movement (1.00)		
			Calgro, saline-sodic (25%)	Depth to cemented pan (1.00)		
				Slow water movement (1.00)		
108	Colpien loam, 0 to 2 percent slopes	Very limited	Colpien (85%)	Slow water movement (1.00)	17,349.6	35.6%
109	Crosscreek-Kai association, 0 to 2 percent slopes	Very limited	Crosscreek (70%)	Slow water movement (1.00)	8,187.8	16.8%
				Depth to cemented pan (1.00)		
			Kai (15%)	Slow water movement (1.00)		
				Depth to cemented pan (1.00)		
112	Dumps	Not rated	Dumps (100%)		78.5	0.2%
116	Flamen loam, 0 to 2 percent slopes	Very limited	Flamen (85%)	Depth to cemented pan (1.00)	3,260.4	6.7%
				Slow water movement (1.00)		

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
124	Hanford sandy loam, 0 to 2 percent slopes	Somewhat limited	Hanford (85%)	Slow water movement (0.31)	64.0	0.1%
130	Nord fine sandy loam, 0 to 2 percent slopes	Very limited	Nord (85%)	Slow water movement (1.00)	4,210.1	8.6%
131	Pits	Not rated	Pits (100%)		67.7	0.1%
132	Quonal-Lewis association, 0 to 2 percent slopes	Very limited	Quonal (70%)	Slow water movement (1.00)	4,750.8	9.7%
				Depth to cemented pan (1.00)		
			Lewis (15%)	Slow water movement (1.00)		
				Depth to cemented pan (1.00)		
134	Riverwash	Not rated	Riverwash (100%)		620.8	1.3%
137	Tagus loam, 0 to 2 percent slopes	Very limited	Tagus (85%)	Slow water movement (1.00)	870.9	1.8%
138	Tujunga loamy sand, 0 to 2 percent slopes	Not limited	Tujunga (85%)		378.6	0.8%
143	Yettem sandy loam, 0 to 2 percent slopes	Somewhat limited	Yettem (85%)	Slow water movement (0.31)	1,699.0	3.5%
Totals for Area of Interest					**48,755.2**	**100.0%**

Disposal of Wastewater by Rapid Infiltration— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	45,846.5	94.0%
Somewhat limited	1,763.0	3.6%
Not limited	378.6	0.8%
Null or Not Rated	767.1	1.6%
Totals for Area of Interest	**48,755.2**	**100.0%**

Rating Options—Disposal of Wastewater by Rapid Infiltration (Tulare RWRF WW Disposal by Rapid Infiltration)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Land Application of Municipal Sewage Sludge (Tulare RWRF WW Disposal by Land Application Of Municipal Sewage Sludge)

Application of sewage sludge not only disposes of waste material but also can improve crop production by increasing the supply of nutrients in the soils where the material is applied. Sewage sludge is the residual product of the treatment of municipal sewage. The solid component consists mainly of cell mass, primarily bacteria cells that developed during secondary treatment and have incorporated soluble organics into their own bodies. The sludge has small amounts of sand, silt, and other solid debris. The content of nitrogen varies. Some sludge has constituents that are toxic to plants or hazardous to the food chain, such as heavy metals and exotic organic compounds, and should be analyzed chemically prior to use.

The content of water in the sludge ranges from about 98 percent to less than 40 percent. The sludge is considered liquid if it is more than about 90 percent water, slurry if it is about 50 to 90 percent water, and solid if it is less than about 50 percent water.

The ratings are based on the soil properties that affect absorption, plant growth, microbial activity, erodibility, the rate at which the sludge is applied, and the method by which the sludge is applied. The properties that affect absorption, plant growth, and microbial activity include saturated hydraulic conductivity (Ksat), depth to a water table, ponding, the sodium adsorption ratio, depth to bedrock or a cemented pan, available water capacity, reaction, salinity, and bulk density. The wind erodibility group, soil erosion factor K, and slope are considered in estimating the likelihood that wind erosion or water erosion will transport the waste material from the application site. Stones, cobbles, a water table, ponding, and flooding can hinder the application of sludge. Permanently frozen soils are unsuitable for waste treatment.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

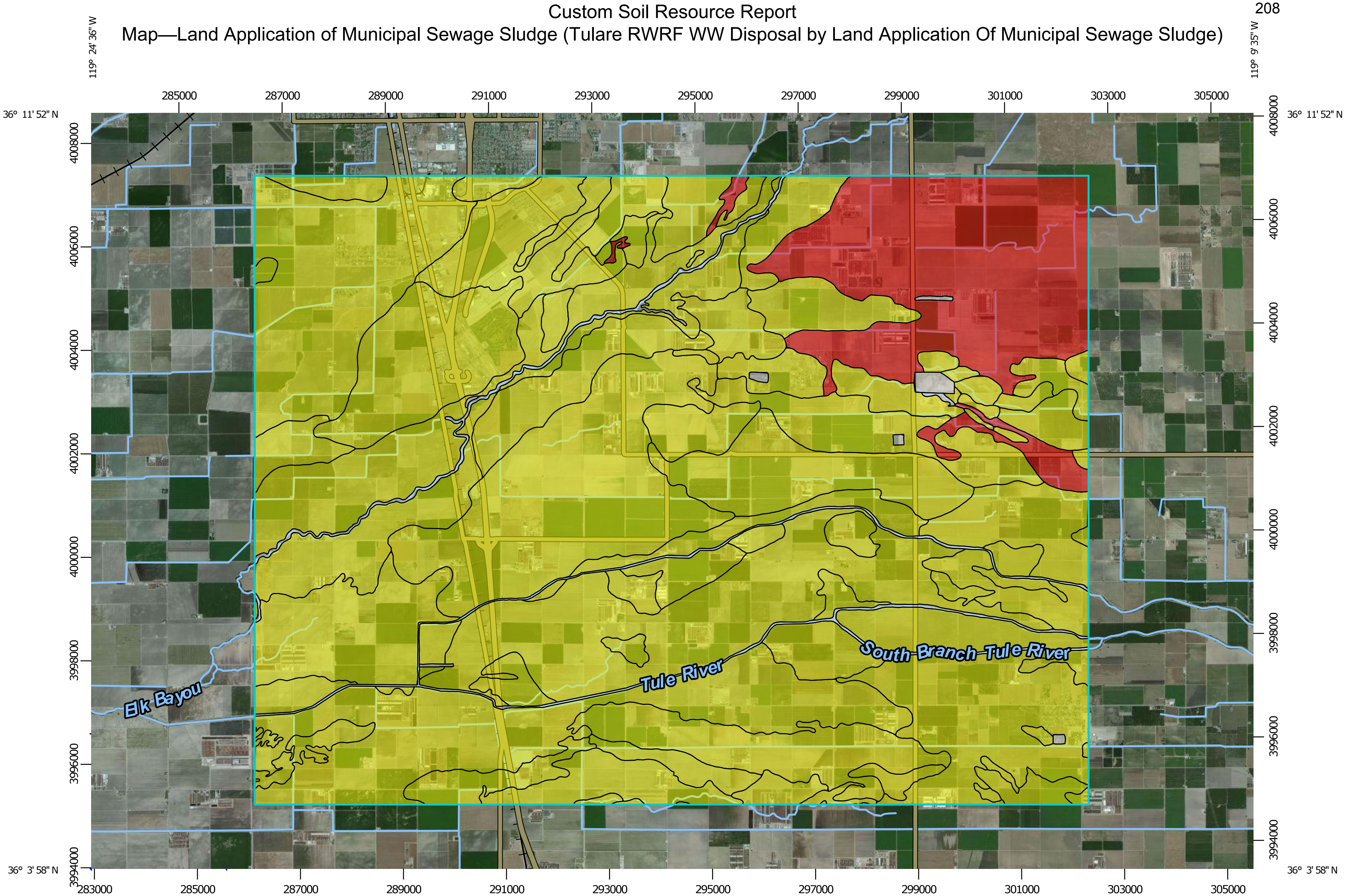
Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Custom Soil Resource Report

Map—Land Application of Municipal Sewage Sludge (Tulare RWRF WW Disposal by Land Application Of Municipal Sewage Sludge)



Map Scale: 1:103,000 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 1500, 3000, 6000, 9000

Feet: 0, 5000, 10000, 20000, 30000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Tulare County, Western Part, California
Survey Area Data: Version 8, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 27, 2010—Jul 3, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Land Application of Municipal Sewage Sludge (Tulare RWRF WW Disposal by Land Application Of Municipal Sewage Sludge)

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
101	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Akers (60%)	Sodium content (0.32)	2,834.8	5.8%
				Flooding (0.20)		
104	Biggriz-Biggriz, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Biggriz (55%)	Flooding (0.40)	3,322.4	6.8%
				Sodium content (0.32)		
				Slow water movement (0.31)		
105	Calgro-Calgro, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Calgro (60%)	Droughty (0.91)	1,059.7	2.2%
				Depth to cemented pan (0.84)		
				Sodium content (0.32)		
				Flooding (0.20)		
108	Colpien loam, 0 to 2 percent slopes	Somewhat limited	Colpien (85%)	Flooding (0.40)	17,349.6	35.6%
				Sodium content (0.32)		
				Slow water movement (0.31)		
109	Crosscreek-Kai association, 0 to 2 percent slopes	Somewhat limited	Crosscreek (70%)	Salinity (0.72)	8,187.8	16.8%
				Sodium content (0.32)		
				Slow water movement (0.31)		
				Flooding (0.20)		
112	Dumps	Not rated	Dumps (100%)		78.5	0.2%
116	Flamen loam, 0 to 2 percent slopes	Somewhat limited	Flamen (85%)	Sodium content (0.32)	3,260.4	6.7%
				Flooding (0.20)		
124	Hanford sandy loam, 0 to 2 percent slopes	Very limited	Hanford (85%)	Filtering capacity (1.00)	64.0	0.1%
				Flooding (0.20)		
				Sodium content (0.02)		
130	Nord fine sandy loam, 0 to 2 percent slopes	Somewhat limited	Nord (85%)	Flooding (0.20)	4,210.1	8.6%

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
				Sodium content (0.18)		
131	Pits	Not rated	Pits (100%)		67.7	0.1%
132	Quonal-Lewis association, 0 to 2 percent slopes	Very limited	Quonal (70%)	Slow water movement (1.00)	4,750.8	9.7%
				Sodium content (1.00)		
				Flooding (0.20)		
				Droughty (0.06)		
			Lewis (15%)	Sodium content (1.00)		
				Slow water movement (1.00)		
				Droughty (1.00)		
				Salinity (1.00)		
				Depth to cemented pan (0.84)		
134	Riverwash	Not rated	Riverwash (100%)		620.8	1.3%
137	Tagus loam, 0 to 2 percent slopes	Somewhat limited	Tagus (85%)	Flooding (0.20)	870.9	1.8%
				Sodium content (0.18)		
138	Tujunga loamy sand, 0 to 2 percent slopes	Very limited	Tujunga (85%)	Filtering capacity (1.00)	378.6	0.8%
				Droughty (0.89)		
				Flooding (0.40)		
143	Yettem sandy loam, 0 to 2 percent slopes	Somewhat limited	Yettem (85%)	Flooding (0.20)	1,699.0	3.5%
Totals for Area of Interest					**48,755.2**	**100.0%**

Land Application of Municipal Sewage Sludge— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Somewhat limited	42,794.7	87.8%
Very limited	5,193.3	10.7%
Null or Not Rated	767.1	1.6%
Totals for Area of Interest	**48,755.2**	**100.0%**

Rating Options—Land Application of Municipal Sewage Sludge (Tulare RWRF WW Disposal by Land Application Of Municipal Sewage Sludge)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Slow Rate Treatment of Wastewater (Tulare RWRF WW Disposal by Slow Rate Treattment)

Slow rate treatment of wastewater is a process in which wastewater is applied to land at a rate normally between 0.5 inch and 4.0 inches per week. The application rate commonly exceeds the rate needed for irrigation of cropland. The applied wastewater is treated as it moves through the soil. Much of the treated water may percolate to the ground water, and some enters the atmosphere through evapotranspiration. The applied water generally is not allowed to run off the surface. Waterlogging is prevented either through control of the application rate or through the use of tile drains, or both.

Soil properties are important considerations in areas where soils are used as sites for the treatment and disposal of organic waste and wastewater. Selection of soils with properties that favor waste management can help to prevent environmental damage.

Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

The ratings are based on the soil properties that affect absorption, plant growth, microbial activity, erodibility, and the application of waste. The properties that affect absorption include the sodium adsorption ratio, depth to a water table, ponding, available water capacity, saturated hydraulic conductivity (Ksat), depth to bedrock or a cemented pan, reaction, the cation-exchange capacity, and slope. Reaction, the sodium adsorption ratio, salinity, and bulk density affect plant growth and microbial activity. The wind erodibility group, soil erosion factor K, and slope are considered in estimating the likelihood of wind erosion or water erosion. Stones, cobbles, a water table, ponding, and flooding can hinder the application of waste. Permanently frozen soils are unsuitable for waste treatment.

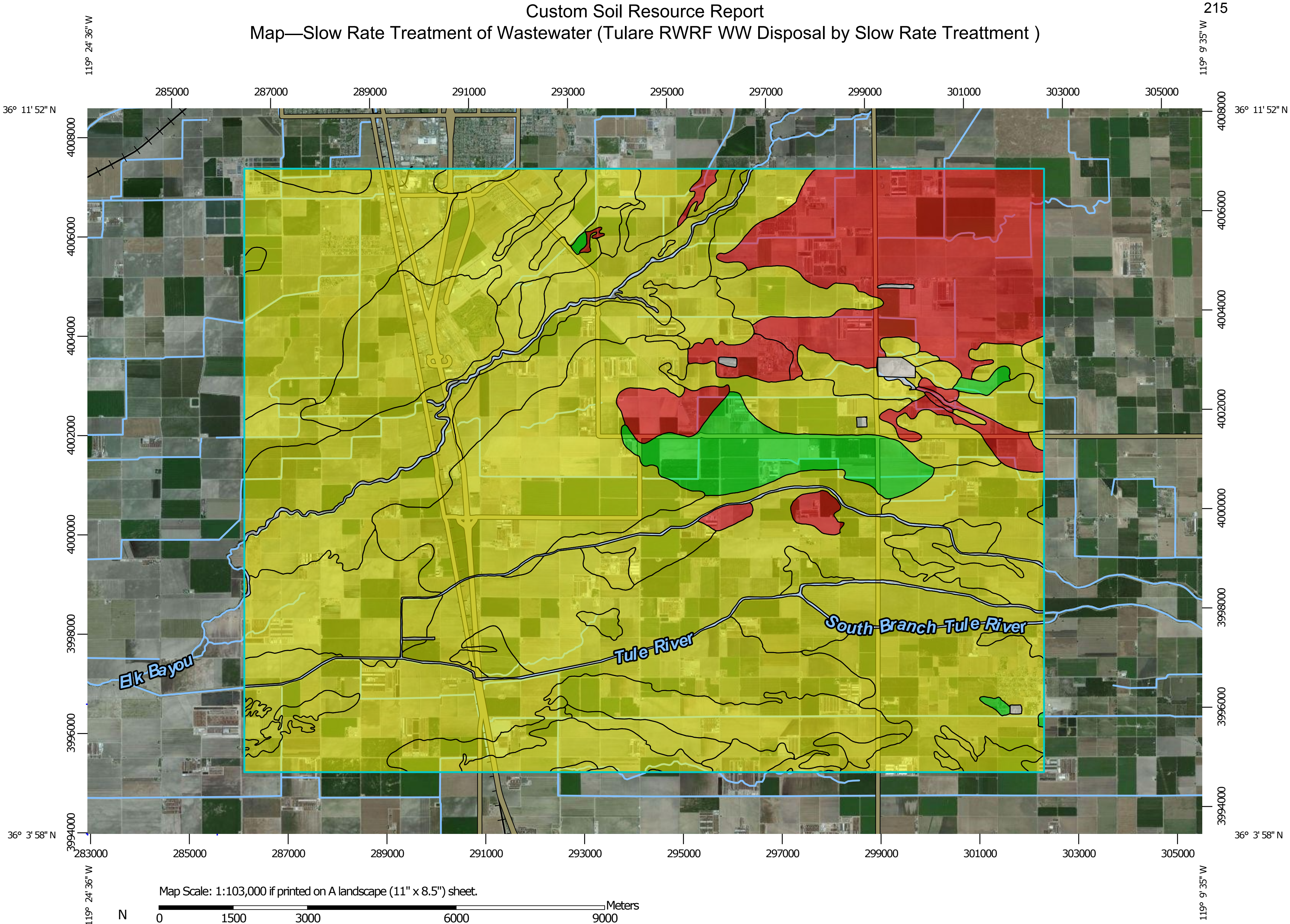
The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Map—Slow Rate Treatment of Wastewater (Tulare RWRF WW Disposal by Slow Rate Treattment)



Map Scale: 1:103,000 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0, 1500, 3000, 6000, 9000

Feet: 0, 5000, 10000, 20000, 30000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Tulare County, Western Part, California
Survey Area Data: Version 8, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 27, 2010—Jul 3, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Slow Rate Treatment of Wastewater (Tulare RWRF WW Disposal by Slow Rate Treattment)

Slow Rate Treatment of Wastewater— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
101	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Akers (60%)	Sodium content (0.32)	2,834.8	5.8%
104	Biggriz-Biggriz, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Biggriz (55%)	Sodium content (0.32)	3,322.4	6.8%
				Slow water movement (0.21)		
105	Calgro-Calgro, saline-Sodic, complex, 0 to 2 percent slopes	Very limited	Calgro (60%)	Depth to cemented pan (1.00)	1,059.7	2.2%
				Sodium content (0.32)		
			Calgro, saline-sodic (25%)	Depth to cemented pan (1.00)		
				Sodium content (1.00)		
				Salinity (0.13)		
108	Colpien loam, 0 to 2 percent slopes	Somewhat limited	Colpien (85%)	Sodium content (0.32)	17,349.6	35.6%
				Slow water movement (0.21)		
109	Crosscreek-Kai association, 0 to 2 percent slopes	Somewhat limited	Crosscreek (70%)	Salinity (0.72)	8,187.8	16.8%
				Sodium content (0.32)		
				Slow water movement (0.21)		
				Depth to cemented pan (0.08)		
112	Dumps	Not rated	Dumps (100%)		78.5	0.2%
116	Flamen loam, 0 to 2 percent slopes	Somewhat limited	Flamen (85%)	Depth to cemented pan (0.94)	3,260.4	6.7%
				Sodium content (0.32)		
124	Hanford sandy loam, 0 to 2 percent slopes	Very limited	Hanford (85%)	Filtering capacity (1.00)	64.0	0.1%
				Sodium content (0.02)		

Slow Rate Treatment of Wastewater— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
130	Nord fine sandy loam, 0 to 2 percent slopes	Somewhat limited	Nord (85%)	Sodium content (0.18)	4,210.1	8.6%
131	Pits	Not rated	Pits (100%)		67.7	0.1%
132	Quonal-Lewis association, 0 to 2 percent slopes	Very limited	Quonal (70%)	Slow water movement (1.00)	4,750.8	9.7%
				Sodium content (1.00)		
				Depth to cemented pan (0.99)		
			Lewis (15%)	Depth to cemented pan (1.00)		
				Sodium content (1.00)		
				Salinity (1.00)		
				Slow water movement (1.00)		
134	Riverwash	Not rated	Riverwash (100%)		620.8	1.3%
137	Tagus loam, 0 to 2 percent slopes	Somewhat limited	Tagus (85%)	Sodium content (0.18)	870.9	1.8%
138	Tujunga loamy sand, 0 to 2 percent slopes	Very limited	Tujunga (85%)	Filtering capacity (1.00)	378.6	0.8%
143	Yettem sandy loam, 0 to 2 percent slopes	Not limited	Yettem (85%)		1,699.0	3.5%
Totals for Area of Interest					**48,755.2**	**100.0%**

Slow Rate Treatment of Wastewater— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Somewhat limited	40,036.0	82.1%
Very limited	6,253.1	12.8%
Not limited	1,699.0	3.5%
Null or Not Rated	767.1	1.6%
Totals for Area of Interest	**48,755.2**	**100.0%**

Rating Options—Slow Rate Treatment of Wastewater (Tulare RWRF WW Disposal by Slow Rate Treattment)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

References

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.

Federal Register. July 13, 1994. Changes in hydric soils of the United States.

Federal Register. September 18, 2002. Hydric soils of the United States.

Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.

National Research Council. 1995. Wetlands: Characteristics and boundaries.

Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_054262

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053577

Soil Survey Staff. 2010. Keys to soil taxonomy. 11th edition. U.S. Department of Agriculture, Natural Resources Conservation Service. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053580

Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service and Delaware Department of Natural Resources and Environmental Control, Wetlands Section.

United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.

United States Department of Agriculture, Natural Resources Conservation Service. National forestry manual. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053374

United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1043084

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053624

United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052290.pdf

APPENDIX C

VISALIA RWRF SOIL SURVEY AND LAND USE ESTIMATE: OBTAINED FROM NRCS SOILS ONLINE

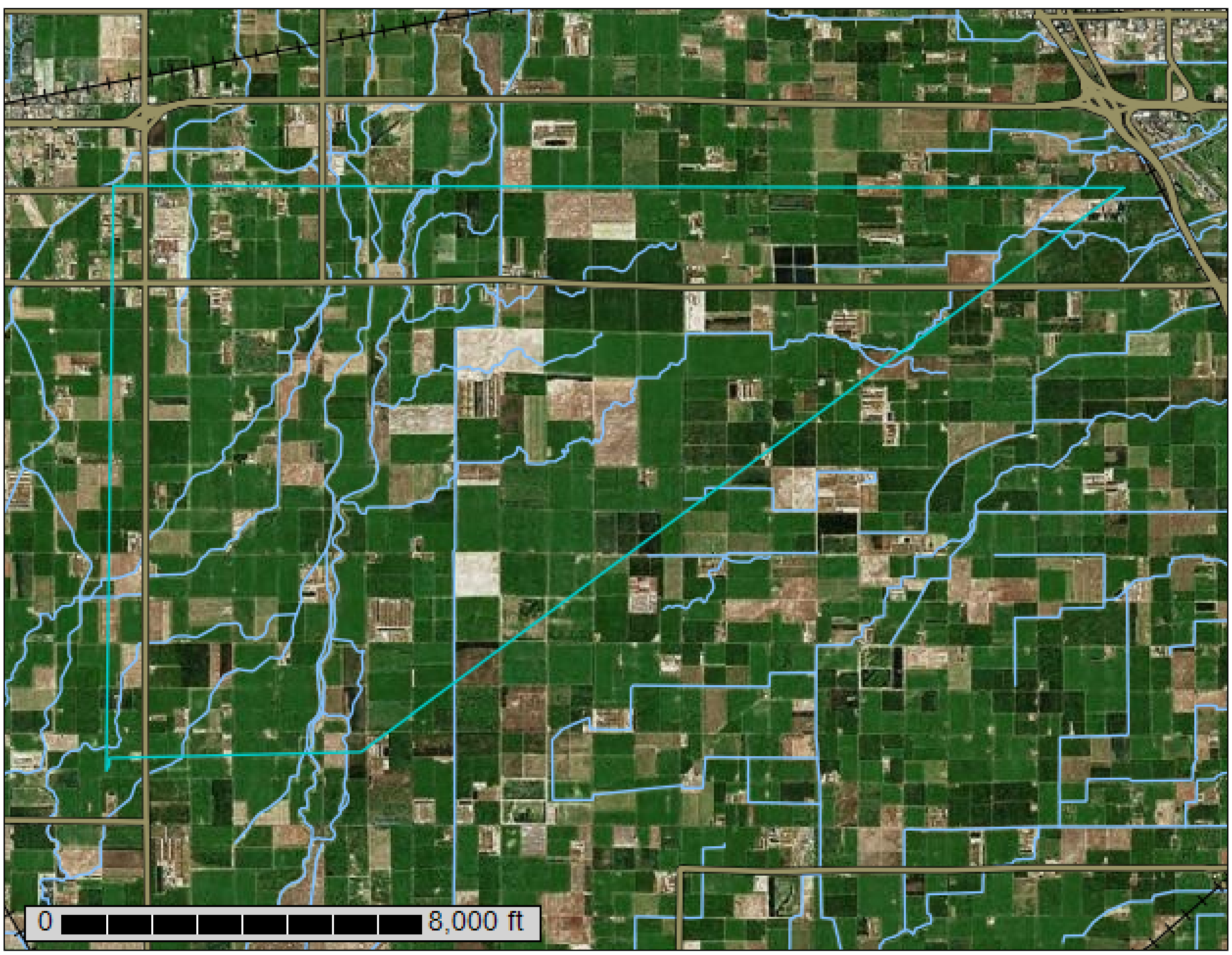
United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Kings County, California; and Tulare County, Western Part, California



July 11, 2015

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

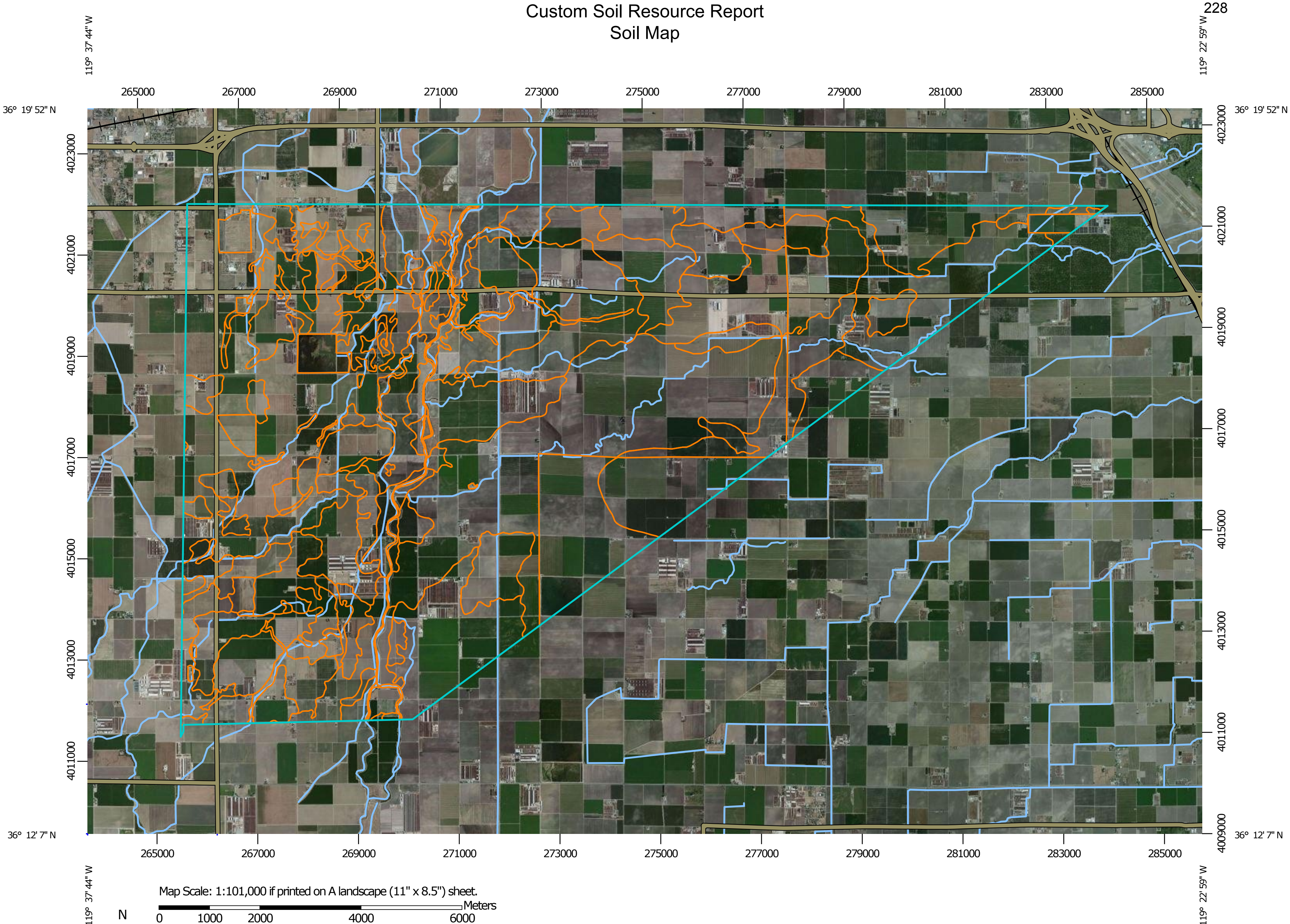
The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means

Contents

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map



Map Scale: 1:101,000 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 1000, 2000, 4000, 6000

Feet: 0, 4500, 9000, 18000, 27000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Kings County, California
Survey Area Data: Version 10, Sep 15, 2014

Soil Survey Area: Tulare County, Western Part, California
Survey Area Data: Version 8, Sep 30, 2014

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 27, 2010—Jul 3, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Kings County, California (CA031)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
101tw	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	737.4	2.6%
104	Cajon sandy loam	579.5	2.0%
108	Corona silt loam	275.8	1.0%
108tw	Colpien loam, 0 to 2 percent slopes	459.4	1.6%
112	Excelsior sandy loam	1,576.6	5.5%
113	Garces loam	1,419.6	4.9%
117tw	Gambogy loam, drained, 0 to 1 percent slopes	3,686.9	12.8%
120	Grangeville fine sandy loam, partially drained	675.5	2.3%
121	Grangeville fine sandy loam, saline-alkali, partially d rained	529.6	1.8%
130	Kimberlina fine sandy loam, saline-alkali	5,883.6	20.4%
132	Kimberlina saline alkali-Garces complex	2,551.7	8.8%
135	Lakeside clay loam, drained	819.9	2.8%
140	Melga silt loam	264.0	0.9%
149	Nord complex	528.6	1.8%
154	Pits and Dumps	136.9	0.5%
158	Remnoy very fine sandy loam	44.7	0.2%
167	Urban land	110.2	0.4%
174	Wasco sandy loam, 0 to 5 percent slopes	1,405.5	4.9%
178	Westhaven clay loam, saline-alkali, 0 to 2 percent slop es	1,328.0	4.6%
179	Whitewolf coarse sandy loam	3.3	0.0%
181	Water	296.0	1.0%
Subtotals for Soil Survey Area		**23,312.8**	**80.7%**
Totals for Area of Interest		**28,899.3**	**100.0%**

Tulare County, Western Part, California (CA659)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
101	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	725.9	2.5%
108	Colpien loam, 0 to 2 percent slopes	1,352.8	4.7%

Tulare County, Western Part, California (CA659)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
117	Gambogy loam, drained, 0 to 1 percent slopes	1,085.5	3.8%
130	Nord fine sandy loam, 0 to 2 percent slopes	1,378.2	4.8%
137	Tagus loam, 0 to 2 percent slopes	944.8	3.3%
145	Water-perennial	99.4	0.3%
Subtotals for Soil Survey Area		**5,586.5**	**19.3%**
Totals for Area of Interest		**28,899.3**	**100.0%**

Soil Information for All Uses

Suitabilities and Limitations for Use

The Suitabilities and Limitations for Use section includes various soil interpretations displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each interpretation.

Waste Management

Waste Management interpretations are tools designed to guide the user in evaluating soils for use of organic wastes and wastewater as productive resources. Example interpretations include land application of manure, food processing waste, and municipal sewage sludge, and disposal of wastewater by irrigation or overland flow process.

Disposal of Wastewater by Irrigation (Visalia RWRF WW Disposal by Irrigation)

Wastewater includes municipal and food-processing wastewater and effluent from lagoons or storage ponds. Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

Disposal of wastewater by irrigation not only disposes of municipal wastewater and wastewater from food-processing plants, lagoons, and storage ponds but also can improve crop production by increasing the amount of water available to crops. The ratings are based on the soil properties that affect the design, construction, management, and performance of the irrigation system. The properties that affect design and management include the sodium adsorption ratio, depth to a water table, ponding, available water capacity, saturated hydraulic conductivity (Ksat), slope, and flooding. The properties that affect construction include stones, cobbles, depth to bedrock or a cemented pan, depth to a water table, and ponding. The properties that affect performance include depth to bedrock or a cemented pan, bulk density, the sodium adsorption ratio, salinity, reaction, and the cation-exchange capacity, which is used to estimate the capacity of a soil to adsorb heavy metals. Permanently frozen soils are not suitable for disposal of wastewater by irrigation.

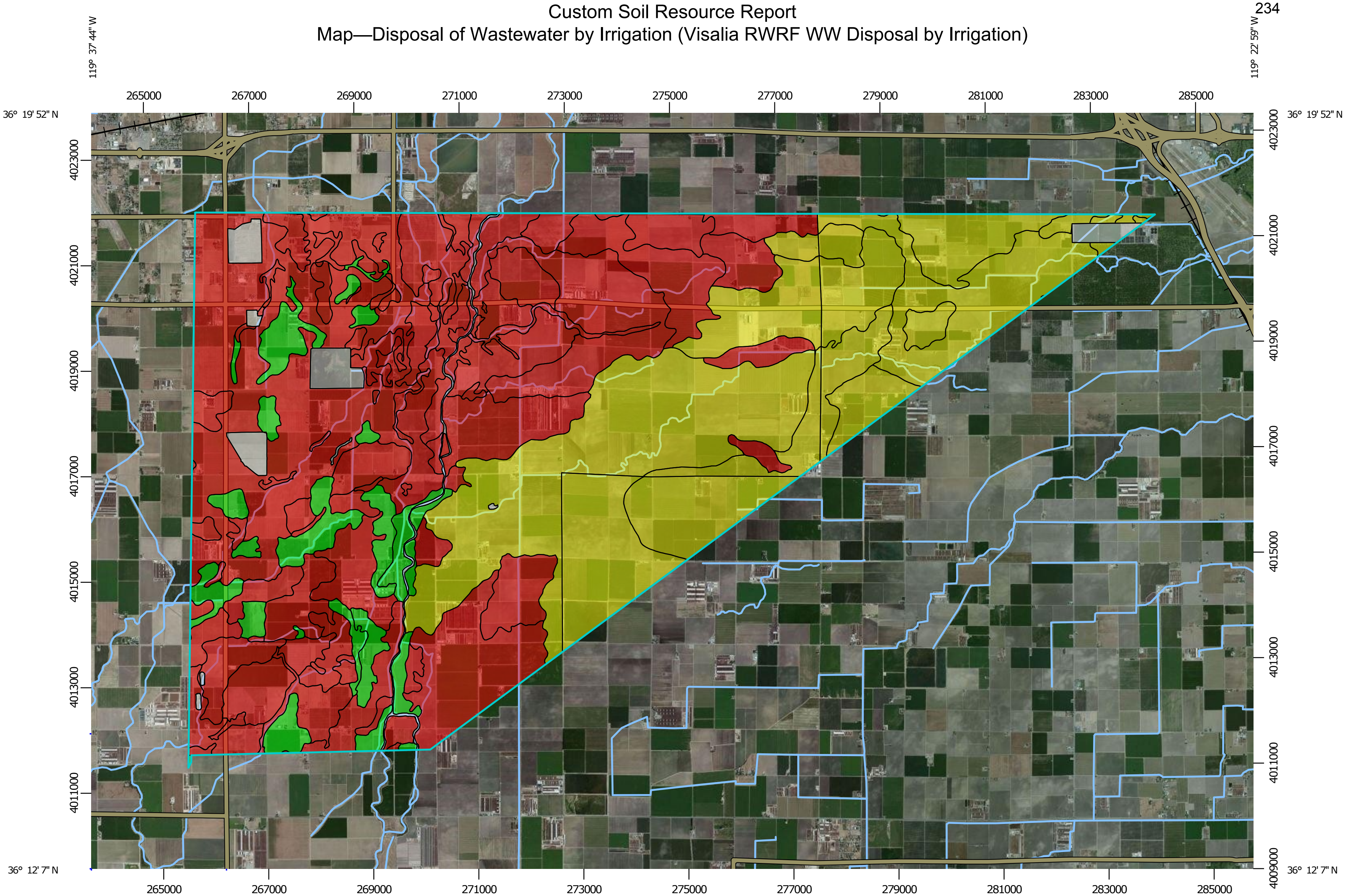
The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Custom Soil Resource Report
Map—Disposal of Wastewater by Irrigation (Visalia RWRF WW Disposal by Irrigation)



Map Scale: 1:101,000 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 1000 2000 4000 6000

Feet: 0 4500 9000 18000 27000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

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Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
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Tables—Disposal of Wastewater by Irrigation (Visalia RWRF WW Disposal by Irrigation)

Disposal of Wastewater by Irrigation— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
101tw	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Akers (60%)	Sodium content (0.32)	737.4	2.6%
104	Cajon sandy loam	Very limited	Cajon (85%)	Filtering capacity (1.00)	579.5	2.0%
108	Corona silt loam	Very limited	Corona (85%)	Slow water movement (1.00)	275.8	1.0%
108tw	Colpien loam, 0 to 2 percent slopes	Somewhat limited	Colpien (85%)	Sodium content (0.32)	459.4	1.6%
				Slow water movement (0.31)		
112	Excelsior sandy loam	Very limited	Excelsior (85%)	Slow water movement (1.00)	1,576.6	5.5%
113	Garces loam	Very limited	Garces (85%)	Slow water movement (1.00)	1,419.6	4.9%
				Sodium content (1.00)		
				Salinity (0.13)		
117tw	Gambogy loam, drained, 0 to 1 percent slopes	Somewhat limited	Gambogy (85%)	Sodium content (0.32)	3,686.9	12.8%
				Slow water movement (0.31)		
120	Grangeville fine sandy loam, partially drained	Very limited	Grangeville (85%)	Depth to saturated zone (1.00)	675.5	2.3%
121	Grangeville fine sandy loam, saline-alkali, partially d rained	Very limited	Grangeville (85%)	Depth to saturated zone (1.00)	529.6	1.8%
				Sodium content (1.00)		
				Salinity (0.50)		
130	Kimberlina fine sandy loam, saline-alkali	Very limited	Kimberlina (85%)	Sodium content (1.00)	5,883.6	20.4%
				Droughty (1.00)		
				Salinity (0.50)		
				Slow water movement (0.37)		

Disposal of Wastewater by Irrigation— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
132	Kimberlina saline alkali-Garces complex	Very limited	Kimberlina (50%)	Sodium content (1.00)	2,551.7	8.8%
				Droughty (1.00)		
				Salinity (0.50)		
				Slow water movement (0.37)		
			Garces (35%)	Slow water movement (1.00)		
				Sodium content (1.00)		
				Salinity (0.13)		
135	Lakeside clay loam, drained	Very limited	Lakeside (85%)	Sodium content (1.00)	819.9	2.8%
				Salinity (1.00)		
				Slow water movement (0.37)		
140	Melga silt loam	Very limited	Melga (85%)	Slow water movement (1.00)	264.0	0.9%
				Depth to cemented pan (1.00)		
				Sodium content (1.00)		
				Droughty (1.00)		
				Flooding (0.60)		
149	Nord complex	Not limited	Nord (50%)		528.6	1.8%
154	Pits and Dumps	Not rated	Pits (45%)		136.9	0.5%
			Dumps (45%)			
			Kimberlina (1%)			
			Panoche (1%)			
			Nord (1%)			
			Wasco (1%)			
			Unnamed, rare flooding (1%)			
			Cajon (1%)			
			Delgado (1%)			
			Henneke (1%)			
158	Remnoy very fine sandy loam	Very limited	Remnoy (85%)	Depth to cemented pan (1.00)	44.7	0.2%
				Droughty (1.00)		

Disposal of Wastewater by Irrigation— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
				Sodium content (1.00)		
				Slow water movement (1.00)		
				Salinity (1.00)		
167	Urban land	Not rated	Urban land (85%)		110.2	0.4%
			Nord (2%)			
			Kimberlina (2%)			
			Grangeville (2%)			
			Lemoore (2%)			
			Lethent (1%)			
			Lakeside (1%)			
			Wasco (1%)			
			Unnamed, rare flooding (1%)			
			Panoche (1%)			
174	Wasco sandy loam, 0 to 5 percent slopes	Not limited	Wasco (85%)		1,405.5	4.9%
178	Westhaven clay loam, saline-alkali, 0 to 2 percent slop es	Very limited	Westhaven (85%)	Slow water movement (1.00)	1,328.0	4.6%
				Salinity (0.50)		
179	Whitewolf coarse sandy loam	Very limited	Whitewolf (85%)	Filtering capacity (1.00)	3.3	0.0%
				Droughty (0.76)		
181	Water	Not rated	Water (100%)		296.0	1.0%
Subtotals for Soil Survey Area					**23,312.8**	**80.7%**
Totals for Area of Interest					**28,899.3**	**100.0%**

Disposal of Wastewater by Irrigation— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
101	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Akers (60%)	Sodium content (0.32)	725.9	2.5%
108	Colpien loam, 0 to 2 percent slopes	Somewhat limited	Colpien (85%)	Sodium content (0.32)	1,352.8	4.7%
				Slow water movement (0.31)		
117	Gambogy loam, drained, 0 to 1 percent slopes	Somewhat limited	Gambogy (85%)	Sodium content (0.32)	1,085.5	3.8%

Disposal of Wastewater by Irrigation— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
				Slow water movement (0.31)		
130	Nord fine sandy loam, 0 to 2 percent slopes	Somewhat limited	Nord (85%)	Sodium content (0.18)	1,378.2	4.8%
137	Tagus loam, 0 to 2 percent slopes	Somewhat limited	Tagus (85%)	Sodium content (0.18)	944.8	3.3%
145	Water-perennial	Not rated	Water (100%)		99.4	0.3%
Subtotals for Soil Survey Area					**5,586.5**	**19.3%**
Totals for Area of Interest					**28,899.3**	**100.0%**

Disposal of Wastewater by Irrigation— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	15,951.8	55.2%
Somewhat limited	10,370.8	35.9%
Not limited	1,934.1	6.7%
Null or Not Rated	642.6	2.2%
Totals for Area of Interest	**28,899.3**	**100.0%**

Rating Options—Disposal of Wastewater by Irrigation (Visalia RWRF WW Disposal by Irrigation)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Disposal of Wastewater by Rapid Infiltration (Visalia RWRF WW Disposal by Rapid Infiltration)

Rapid infiltration of wastewater is a process in which wastewater applied in a level basin at a rate of 4 to 120 inches per week percolates through the soil. The wastewater may eventually reach the ground water. The application rate commonly exceeds the rate needed for irrigation of cropland. Vegetation is not a necessary part of the treatment; thus, the basins may or may not be vegetated. The thickness of the soil material needed for proper treatment of the wastewater is more than 72 inches. As a result, geologic and hydrologic investigation is needed to ensure proper design and performance and to determine the risk of ground-water pollution.

Soil properties are important considerations in areas where soils are used as sites for the treatment and disposal of organic waste and wastewater. Selection of soils with properties that favor waste management can help to prevent environmental damage.

Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

The ratings are based on the soil properties that affect the risk of pollution and the design, construction, and performance of the system. Depth to a water table, ponding, flooding, and depth to bedrock or a cemented pan affect the risk of pollution and the design and construction of the system. Slope, stones, and cobbles also affect design and construction. Saturated hydraulic conductivity (Ksat) and reaction affect performance. Permanently frozen soils are unsuitable for waste treatment.

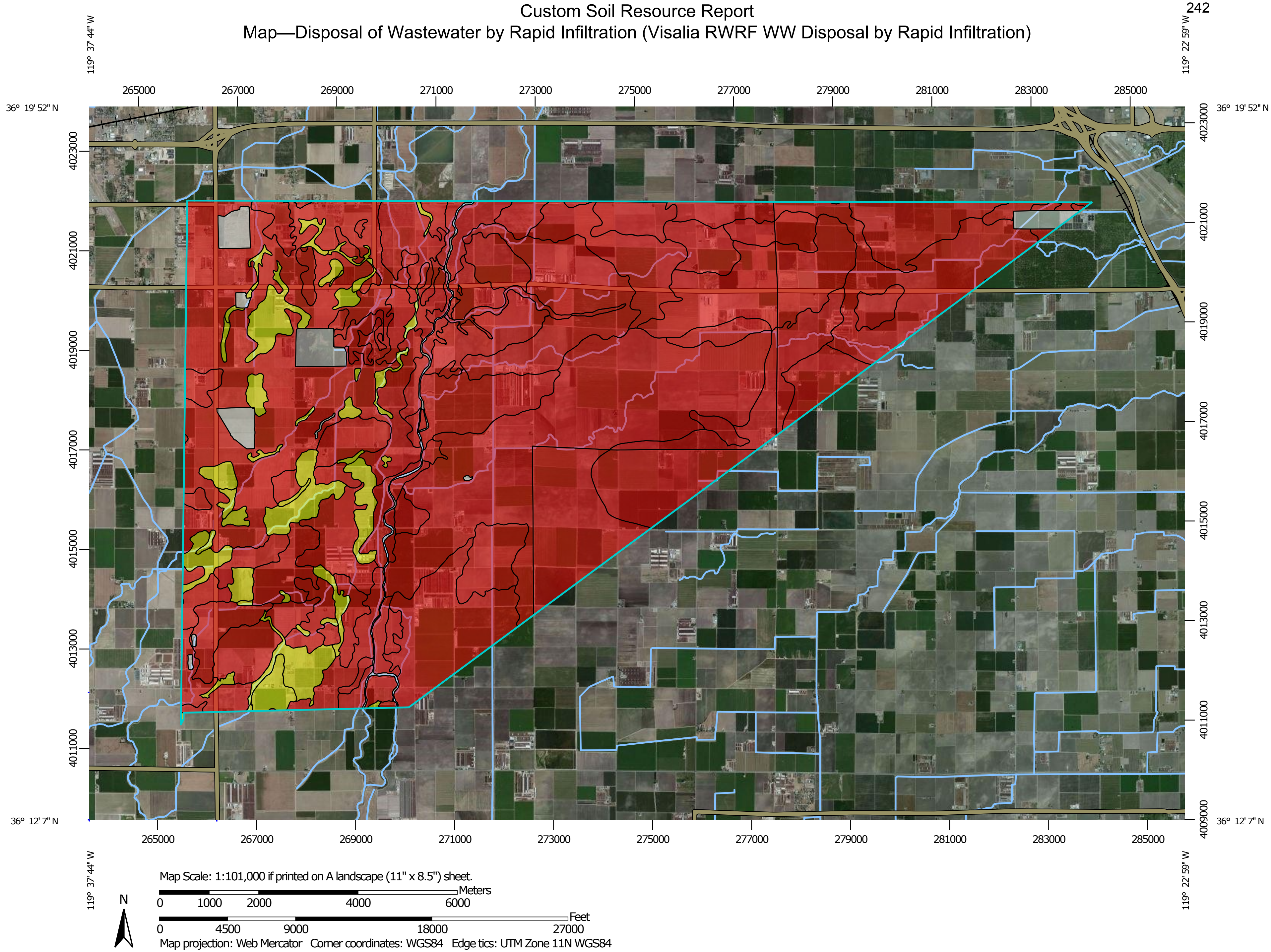
The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Custom Soil Resource Report
Map—Disposal of Wastewater by Rapid Infiltration (Visalia RWRF WW Disposal by Rapid Infiltration)



MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Kings County, California
Survey Area Data: Version 10, Sep 15, 2014

Soil Survey Area: Tulare County, Western Part, California
Survey Area Data: Version 8, Sep 30, 2014

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 27, 2010—Jul 3, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Disposal of Wastewater by Rapid Infiltration (Visalia RWRF WW Disposal by Rapid Infiltration)

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
101tw	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Very limited	Akers (60%)	Slow water movement (1.00)	737.4	2.6%
			Akers, saline-sodic (25%)	Slow water movement (1.00)		
104	Cajon sandy loam	Somewhat limited	Cajon (85%)	Slow water movement (0.32)	579.5	2.0%
108	Corona silt loam	Very limited	Corona (85%)	Slow water movement (1.00)	275.8	1.0%
108tw	Colpien loam, 0 to 2 percent slopes	Very limited	Colpien (85%)	Slow water movement (1.00)	459.4	1.6%
112	Excelsior sandy loam	Very limited	Excelsior (85%)	Slow water movement (1.00)	1,576.6	5.5%
113	Garces loam	Very limited	Garces (85%)	Slow water movement (1.00)	1,419.6	4.9%
117tw	Gambogy loam, drained, 0 to 1 percent slopes	Very limited	Gambogy (85%)	Slow water movement (1.00)	3,686.9	12.8%
120	Grangeville fine sandy loam, partially drained	Very limited	Grangeville (85%)	Depth to saturated zone (1.00)	675.5	2.3%
				Slow water movement (0.32)		
121	Grangeville fine sandy loam, saline-alkali, partially d rained	Very limited	Grangeville (85%)	Depth to saturated zone (1.00)	529.6	1.8%
				Slow water movement (1.00)		
130	Kimberlina fine sandy loam, saline-alkali	Very limited	Kimberlina (85%)	Slow water movement (1.00)	5,883.6	20.4%
132	Kimberlina saline alkali-Garces complex	Very limited	Kimberlina (50%)	Slow water movement (1.00)	2,551.7	8.8%
			Garces (35%)	Slow water movement (1.00)		

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
135	Lakeside clay loam, drained	Very limited	Lakeside (85%)	Slow water movement (1.00)	819.9	2.8%
140	Melga silt loam	Very limited	Melga (85%)	Slow water movement (1.00)	264.0	0.9%
				Depth to cemented pan (1.00)		
				Flooding (0.60)		
149	Nord complex	Very limited	Nord (50%)	Slow water movement (1.00)	528.6	1.8%
			Nord (40%)	Slow water movement (1.00)		
154	Pits and Dumps	Not rated	Pits (45%)		136.9	0.5%
			Dumps (45%)			
			Kimberlina (1%)			
			Panoche (1%)			
			Nord (1%)			
			Wasco (1%)			
			Unnamed, rare flooding (1%)			
			Cajon (1%)			
			Delgado (1%)			
			Henneke (1%)			
158	Remnoy very fine sandy loam	Very limited	Remnoy (85%)	Slow water movement (1.00)	44.7	0.2%
				Depth to cemented pan (1.00)		
167	Urban land	Not rated	Urban land (85%)		110.2	0.4%
			Nord (2%)			
			Kimberlina (2%)			
			Grangeville (2%)			
			Lemoore (2%)			
			Lethent (1%)			
			Lakeside (1%)			
			Wasco (1%)			
			Unnamed, rare flooding (1%)			
			Panoche (1%)			

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
174	Wasco sandy loam, 0 to 5 percent slopes	Somewhat limited	Wasco (85%)	Slow water movement (0.32)	1,405.5	4.9%
178	Westhaven clay loam, saline-alkali, 0 to 2 percent slop es	Very limited	Westhaven (85%)	Slow water movement (1.00)	1,328.0	4.6%
179	Whitewolf coarse sandy loam	Somewhat limited	Whitewolf (85%)	Slow water movement (0.32)	3.3	0.0%
181	Water	Not rated	Water (100%)		296.0	1.0%
Subtotals for Soil Survey Area					**23,312.8**	**80.7%**
Totals for Area of Interest					**28,899.3**	**100.0%**

Disposal of Wastewater by Rapid Infiltration— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
101	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Very limited	Akers (60%)	Slow water movement (1.00)	725.9	2.5%
			Akers, saline-sodic (25%)	Slow water movement (1.00)		
108	Colpien loam, 0 to 2 percent slopes	Very limited	Colpien (85%)	Slow water movement (1.00)	1,352.8	4.7%
117	Gambogy loam, drained, 0 to 1 percent slopes	Very limited	Gambogy (85%)	Slow water movement (1.00)	1,085.5	3.8%
130	Nord fine sandy loam, 0 to 2 percent slopes	Very limited	Nord (85%)	Slow water movement (1.00)	1,378.2	4.8%
137	Tagus loam, 0 to 2 percent slopes	Very limited	Tagus (85%)	Slow water movement (1.00)	944.8	3.3%
145	Water-perennial	Not rated	Water (100%)		99.4	0.3%
Subtotals for Soil Survey Area					**5,586.5**	**19.3%**
Totals for Area of Interest					**28,899.3**	**100.0%**

Disposal of Wastewater by Rapid Infiltration— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	26,268.4	90.9%
Somewhat limited	1,988.3	6.9%
Null or Not Rated	642.6	2.2%
Totals for Area of Interest	**28,899.3**	**100.0%**

Rating Options—Disposal of Wastewater by Rapid Infiltration (Visalia RWRF WW Disposal by Rapid Infiltration)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Land Application of Municipal Sewage Sludge (Visalia RWRF WW Disposal by Land Application of Municipal Sewage Sludge)

Application of sewage sludge not only disposes of waste material but also can improve crop production by increasing the supply of nutrients in the soils where the material is applied. Sewage sludge is the residual product of the treatment of municipal sewage. The solid component consists mainly of cell mass, primarily bacteria cells that developed during secondary treatment and have incorporated soluble organics into their own bodies. The sludge has small amounts of sand, silt, and other solid debris. The content of nitrogen varies. Some sludge has constituents that are toxic to plants or hazardous to the food chain, such as heavy metals and exotic organic compounds, and should be analyzed chemically prior to use.

The content of water in the sludge ranges from about 98 percent to less than 40 percent. The sludge is considered liquid if it is more than about 90 percent water, slurry if it is about 50 to 90 percent water, and solid if it is less than about 50 percent water.

The ratings are based on the soil properties that affect absorption, plant growth, microbial activity, erodibility, the rate at which the sludge is applied, and the method by which the sludge is applied. The properties that affect absorption, plant growth, and microbial activity include saturated hydraulic conductivity (Ksat), depth to a water table, ponding, the sodium adsorption ratio, depth to bedrock or a cemented pan, available water capacity, reaction, salinity, and bulk density. The wind erodibility group, soil erosion factor K, and slope are considered in estimating the likelihood that wind erosion or water erosion will transport the waste material from the application site. Stones, cobbles, a water table, ponding, and flooding can hinder the application of sludge. Permanently frozen soils are unsuitable for waste treatment.

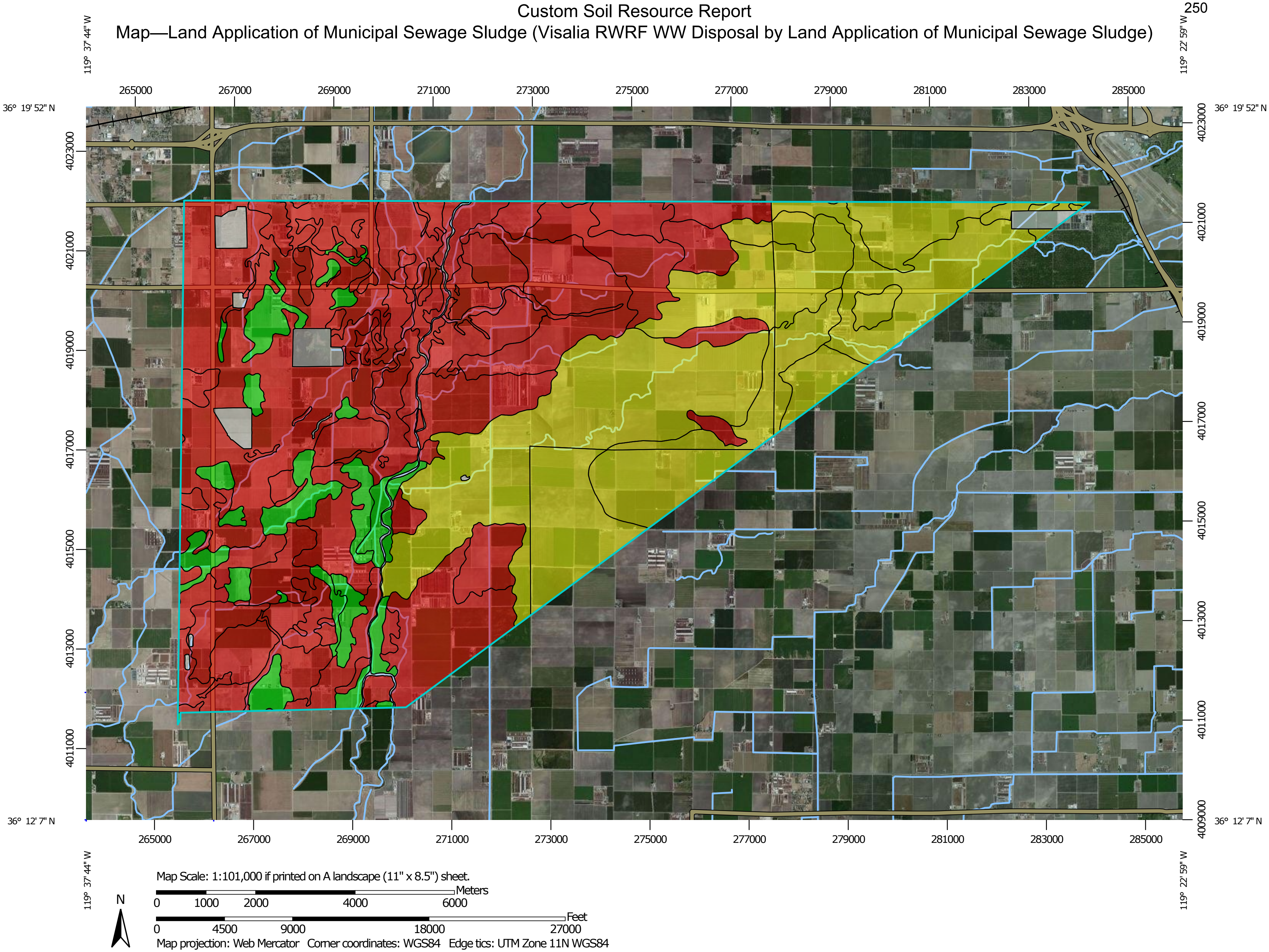
The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Custom Soil Resource Report
Map—Land Application of Municipal Sewage Sludge (Visalia RWRF WW Disposal by Land Application of Municipal Sewage Sludge)



Map Scale: 1:101,000 if printed on A landscape (11" x 8.5") sheet.

Meters: 0 1000 2000 4000 6000

Feet: 0 4500 9000 18000 27000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Kings County, California
Survey Area Data: Version 10, Sep 15, 2014

Soil Survey Area: Tulare County, Western Part, California
Survey Area Data: Version 8, Sep 30, 2014

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 27, 2010—Jul 3, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Land Application of Municipal Sewage Sludge (Visalia RWRF WW Disposal by Land Application of Municipal Sewage Sludge)

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
101tw	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Akers (60%)	Sodium content (0.32)	737.4	2.6%
				Flooding (0.20)		
104	Cajon sandy loam	Very limited	Cajon (85%)	Filtering capacity (1.00)	579.5	2.0%
108	Corona silt loam	Very limited	Corona (85%)	Slow water movement (1.00)	275.8	1.0%
108tw	Colpien loam, 0 to 2 percent slopes	Somewhat limited	Colpien (85%)	Flooding (0.40)	459.4	1.6%
				Sodium content (0.32)		
				Slow water movement (0.31)		
112	Excelsior sandy loam	Very limited	Excelsior (85%)	Slow water movement (1.00)	1,576.6	5.5%
113	Garces loam	Very limited	Garces (85%)	Slow water movement (1.00)	1,419.6	4.9%
				Sodium content (1.00)		
				Salinity (0.13)		
117tw	Gambogy loam, drained, 0 to 1 percent slopes	Somewhat limited	Gambogy (85%)	Flooding (0.40)	3,686.9	12.8%
				Sodium content (0.32)		
				Slow water movement (0.31)		
120	Grangeville fine sandy loam, partially drained	Very limited	Grangeville (85%)	Depth to saturated zone (1.00)	675.5	2.3%
121	Grangeville fine sandy loam, saline-alkali, partially d rained	Very limited	Grangeville (85%)	Depth to saturated zone (1.00)	529.6	1.8%
				Sodium content (1.00)		
				Salinity (0.50)		
130	Kimberlina fine sandy loam, saline-alkali	Very limited	Kimberlina (85%)	Sodium content (1.00)	5,883.6	20.4%
				Droughty (1.00)		

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
				Salinity (0.50)		
				Slow water movement (0.37)		
132	Kimberlina saline alkali-Garces complex	Very limited	Kimberlina (50%)	Sodium content (1.00)	2,551.7	8.8%
				Droughty (1.00)		
				Salinity (0.50)		
				Slow water movement (0.37)		
			Garces (35%)	Slow water movement (1.00)		
				Sodium content (1.00)		
				Salinity (0.13)		
135	Lakeside clay loam, drained	Very limited	Lakeside (85%)	Sodium content (1.00)	819.9	2.8%
				Salinity (1.00)		
				Slow water movement (0.37)		
140	Melga silt loam	Very limited	Melga (85%)	Slow water movement (1.00)	264.0	0.9%
				Depth to cemented pan (1.00)		
				Sodium content (1.00)		
				Flooding (1.00)		
				Droughty (1.00)		
149	Nord complex	Not limited	Nord (50%)		528.6	1.8%
154	Pits and Dumps	Not rated	Pits (45%)		136.9	0.5%
			Dumps (45%)			
			Kimberlina (1%)			
			Panoche (1%)			
			Nord (1%)			
			Wasco (1%)			
			Unnamed, rare flooding (1%)			
			Cajon (1%)			
			Delgado (1%)			
			Henneke (1%)			

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
158	Remnoy very fine sandy loam	Very limited	Remnoy (85%)	Depth to cemented pan (1.00)	44.7	0.2%
				Sodium content (1.00)		
				Droughty (1.00)		
				Slow water movement (1.00)		
				Salinity (1.00)		
167	Urban land	Not rated	Urban land (85%)		110.2	0.4%
			Nord (2%)			
			Kimberlina (2%)			
			Grangeville (2%)			
			Lemoore (2%)			
			Lethent (1%)			
			Lakeside (1%)			
			Wasco (1%)			
			Unnamed, rare flooding (1%)			
			Panoche (1%)			
174	Wasco sandy loam, 0 to 5 percent slopes	Not limited	Wasco (85%)		1,405.5	4.9%
178	Westhaven clay loam, saline-alkali, 0 to 2 percent slop es	Very limited	Westhaven (85%)	Slow water movement (1.00)	1,328.0	4.6%
				Salinity (0.50)		
179	Whitewolf coarse sandy loam	Very limited	Whitewolf (85%)	Filtering capacity (1.00)	3.3	0.0%
				Droughty (0.76)		
181	Water	Not rated	Water (100%)		296.0	1.0%
Subtotals for Soil Survey Area					**23,312.8**	**80.7%**
Totals for Area of Interest					**28,899.3**	**100.0%**

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
101	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Akers (60%)	Sodium content (0.32)	725.9	2.5%
				Flooding (0.20)		
108	Colpien loam, 0 to 2 percent slopes	Somewhat limited	Colpien (85%)	Flooding (0.40)	1,352.8	4.7%
				Sodium content (0.32)		

Land Application of Municipal Sewage Sludge— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
				Slow water movement (0.31)		
117	Gambogy loam, drained, 0 to 1 percent slopes	Somewhat limited	Gambogy (85%)	Flooding (0.40)	1,085.5	3.8%
				Sodium content (0.32)		
				Slow water movement (0.31)		
130	Nord fine sandy loam, 0 to 2 percent slopes	Somewhat limited	Nord (85%)	Flooding (0.20)	1,378.2	4.8%
				Sodium content (0.18)		
137	Tagus loam, 0 to 2 percent slopes	Somewhat limited	Tagus (85%)	Flooding (0.20)	944.8	3.3%
				Sodium content (0.18)		
145	Water-perennial	Not rated	Water (100%)		99.4	0.3%
Subtotals for Soil Survey Area					**5,586.5**	**19.3%**
Totals for Area of Interest					**28,899.3**	**100.0%**

Land Application of Municipal Sewage Sludge— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	15,951.8	55.2%
Somewhat limited	10,370.8	35.9%
Not limited	1,934.1	6.7%
Null or Not Rated	642.6	2.2%
Totals for Area of Interest	**28,899.3**	**100.0%**

Rating Options—Land Application of Municipal Sewage Sludge (Visalia RWRF WW Disposal by Land Application of Municipal Sewage Sludge)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Slow Rate Treatment of Wastewater (Visalia RWRF WW Disposal by Slow Rate Treatment)

Slow rate treatment of wastewater is a process in which wastewater is applied to land at a rate normally between 0.5 inch and 4.0 inches per week. The application rate commonly exceeds the rate needed for irrigation of cropland. The applied wastewater is treated as it moves through the soil. Much of the treated water may percolate to the ground water, and some enters the atmosphere through evapotranspiration. The applied water generally is not allowed to run off the surface. Waterlogging is prevented either through control of the application rate or through the use of tile drains, or both.

Soil properties are important considerations in areas where soils are used as sites for the treatment and disposal of organic waste and wastewater. Selection of soils with properties that favor waste management can help to prevent environmental damage.

Municipal wastewater is the waste stream from a municipality. It contains domestic waste and may contain industrial waste. It may have received primary or secondary treatment. It is rarely untreated sewage. Food-processing wastewater results from the preparation of fruits, vegetables, milk, cheese, and meats for public consumption. In places it is high in content of sodium and chloride. The effluent in lagoons and storage ponds is from facilities used to treat or store food-processing wastewater or domestic or animal waste. Domestic and food-processing wastewater is very dilute, and the effluent from the facilities that treat or store it commonly is very low in content of carbonaceous and nitrogenous material; the content of nitrogen commonly ranges from 10 to 30 milligrams per liter. The wastewater from animal waste treatment lagoons or storage ponds, however, has much higher concentrations of these materials, mainly because the manure has not been diluted as much as the domestic waste. The content of nitrogen in this wastewater generally ranges from 50 to 2,000 milligrams per liter. When wastewater is applied, checks should be made to ensure that nitrogen, heavy metals, and salts are not added in excessive amounts.

The ratings are based on the soil properties that affect absorption, plant growth, microbial activity, erodibility, and the application of waste. The properties that affect absorption include the sodium adsorption ratio, depth to a water table, ponding, available water capacity, saturated hydraulic conductivity (Ksat), depth to bedrock or a cemented pan, reaction, the cation-exchange capacity, and slope. Reaction, the sodium adsorption ratio, salinity, and bulk density affect plant growth and microbial activity. The wind erodibility group, soil erosion factor K, and slope are considered in estimating the likelihood of wind erosion or water erosion. Stones, cobbles, a water table, ponding, and flooding can hinder the application of waste. Permanently frozen soils are unsuitable for waste treatment.

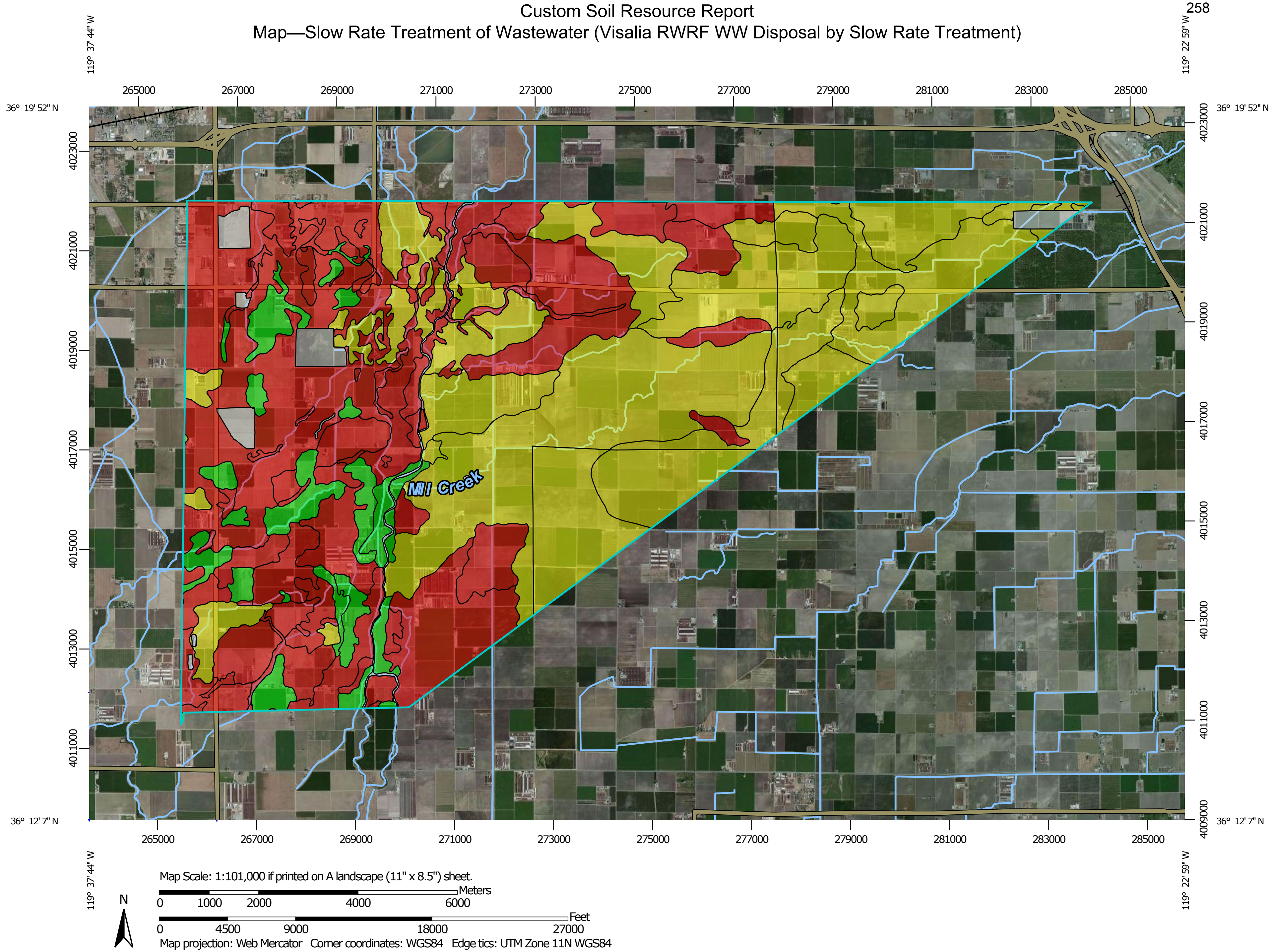
The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect agricultural waste management. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Custom Soil Resource Report
Map—Slow Rate Treatment of Wastewater (Visalia RWRF WW Disposal by Slow Rate Treatment)



MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Kings County, California
Survey Area Data: Version 10, Sep 15, 2014

Soil Survey Area: Tulare County, Western Part, California
Survey Area Data: Version 8, Sep 30, 2014

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 27, 2010—Jul 3, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Slow Rate Treatment of Wastewater (Visalia RWRF WW Disposal by Slow Rate Treatment)

Slow Rate Treatment of Wastewater— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
101tw	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Akers (60%)	Sodium content (0.32)	737.4	2.6%
104	Cajon sandy loam	Very limited	Cajon (85%)	Filtering capacity (1.00)	579.5	2.0%
108	Corona silt loam	Somewhat limited	Corona (85%)	Slow water movement (0.96)	275.8	1.0%
108tw	Colpien loam, 0 to 2 percent slopes	Somewhat limited	Colpien (85%)	Sodium content (0.32)	459.4	1.6%
				Slow water movement (0.21)		
112	Excelsior sandy loam	Somewhat limited	Excelsior (85%)	Slow water movement (0.96)	1,576.6	5.5%
113	Garces loam	Very limited	Garces (85%)	Slow water movement (1.00)	1,419.6	4.9%
				Sodium content (1.00)		
				Salinity (0.13)		
117tw	Gambogy loam, drained, 0 to 1 percent slopes	Somewhat limited	Gambogy (85%)	Sodium content (0.32)	3,686.9	12.8%
				Slow water movement (0.21)		
120	Grangeville fine sandy loam, partially drained	Very limited	Grangeville (85%)	Depth to saturated zone (1.00)	675.5	2.3%
121	Grangeville fine sandy loam, saline-alkali, partially d rained	Very limited	Grangeville (85%)	Depth to saturated zone (1.00)	529.6	1.8%
				Sodium content (1.00)		
				Salinity (0.50)		
130	Kimberlina fine sandy loam, saline-alkali	Very limited	Kimberlina (85%)	Sodium content (1.00)	5,883.6	20.4%
				Salinity (0.50)		
				Slow water movement (0.26)		

Slow Rate Treatment of Wastewater— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
132	Kimberlina saline alkali-Garces complex	Very limited	Kimberlina (50%)	Sodium content (1.00)	2,551.7	8.8%
				Salinity (0.50)		
				Slow water movement (0.26)		
			Garces (35%)	Slow water movement (1.00)		
				Sodium content (1.00)		
				Salinity (0.13)		
135	Lakeside clay loam, drained	Very limited	Lakeside (85%)	Sodium content (1.00)	819.9	2.8%
				Salinity (1.00)		
				Slow water movement (0.26)		
140	Melga silt loam	Very limited	Melga (85%)	Slow water movement (1.00)	264.0	0.9%
				Depth to cemented pan (1.00)		
				Sodium content (1.00)		
				Flooding (0.60)		
149	Nord complex	Not limited	Nord (50%)		528.6	1.8%
154	Pits and Dumps	Not rated	Pits (45%)		136.9	0.5%
			Dumps (45%)			
			Kimberlina (1%)			
			Panoche (1%)			
			Nord (1%)			
			Wasco (1%)			
			Unnamed, rare flooding (1%)			
			Cajon (1%)			
			Delgado (1%)			
			Henneke (1%)			
158	Remnoy very fine sandy loam	Very limited	Remnoy (85%)	Depth to cemented pan (1.00)	44.7	0.2%
				Sodium content (1.00)		
				Salinity (1.00)		

Slow Rate Treatment of Wastewater— Summary by Map Unit — Kings County, California (CA031)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
				Slow water movement (0.96)		
167	Urban land	Not rated	Urban land (85%)		110.2	0.4%
			Nord (2%)			
			Kimberlina (2%)			
			Grangeville (2%)			
			Lemoore (2%)			
			Lethent (1%)			
			Lakeside (1%)			
			Wasco (1%)			
			Unnamed, rare flooding (1%)			
			Panoche (1%)			
174	Wasco sandy loam, 0 to 5 percent slopes	Not limited	Wasco (85%)		1,405.5	4.9%
178	Westhaven clay loam, saline-alkali, 0 to 2 percent slop es	Somewhat limited	Westhaven (85%)	Slow water movement (0.96)	1,328.0	4.6%
				Salinity (0.50)		
179	Whitewolf coarse sandy loam	Very limited	Whitewolf (85%)	Filtering capacity (1.00)	3.3	0.0%
181	Water	Not rated	Water (100%)		296.0	1.0%
Subtotals for Soil Survey Area					**23,312.8**	**80.7%**
Totals for Area of Interest					**28,899.3**	**100.0%**

Slow Rate Treatment of Wastewater— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
101	Akers-Akers, saline-Sodic, complex, 0 to 2 percent slopes	Somewhat limited	Akers (60%)	Sodium content (0.32)	725.9	2.5%
108	Colpien loam, 0 to 2 percent slopes	Somewhat limited	Colpien (85%)	Sodium content (0.32)	1,352.8	4.7%
				Slow water movement (0.21)		
117	Gambogy loam, drained, 0 to 1 percent slopes	Somewhat limited	Gambogy (85%)	Sodium content (0.32)	1,085.5	3.8%
				Slow water movement (0.21)		
130	Nord fine sandy loam, 0 to 2 percent slopes	Somewhat limited	Nord (85%)	Sodium content (0.18)	1,378.2	4.8%

Slow Rate Treatment of Wastewater— Summary by Map Unit — Tulare County, Western Part, California (CA659)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
137	Tagus loam, 0 to 2 percent slopes	Somewhat limited	Tagus (85%)	Sodium content (0.18)	944.8	3.3%
145	Water-perennial	Not rated	Water (100%)		99.4	0.3%
Subtotals for Soil Survey Area					**5,586.5**	**19.3%**
Totals for Area of Interest					**28,899.3**	**100.0%**

Slow Rate Treatment of Wastewater— Summary by Rating Value		
Rating	Acres in AOI	Percent of AOI
Somewhat limited	13,551.2	46.9%
Very limited	12,771.4	44.2%
Not limited	1,934.1	6.7%
Null or Not Rated	642.6	2.2%
Totals for Area of Interest	**28,899.3**	**100.0%**

Rating Options—Slow Rate Treatment of Wastewater (Visalia RWRF WW Disposal by Slow Rate Treatment)

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie. The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

References

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.

Federal Register. July 13, 1994. Changes in hydric soils of the United States.

Federal Register. September 18, 2002. Hydric soils of the United States.

Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.

National Research Council. 1995. Wetlands: Characteristics and boundaries.

Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_054262

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053577

Soil Survey Staff. 2010. Keys to soil taxonomy. 11th edition. U.S. Department of Agriculture, Natural Resources Conservation Service. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053580

Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service and Delaware Department of Natural Resources and Environmental Control, Wetlands Section.

United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.

United States Department of Agriculture, Natural Resources Conservation Service. National forestry manual. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053374

United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1043084

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053624

United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052290.pdf