RECLAMATION

Managing Water in the West

Enhanced Recharge Demonstration Project, Increasing Treated Effluent Recharge Rates in the Santa Cruz River, Tucson, Arizona

Photo Source: Google Earth, April 26, 2011

U.S. Department of the Interior
Bureau of Reclamation
Phoenix Area Office

April 2012

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Enhanced Recharge Demonstration Project Increasing Treated Effluent Recharge Rates in the Santa Cruz River, Tucson, Arizona

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List of Acronyms

ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AFY	acre-feet per year
APP	Aquifer Protection Permit
ASLD	Arizona State Land Department
ASU	Arizona State University
AVID	Avra Valley Irrigation District
AVRP	Avra Valley Recharge Project
AWSA	Arizona Water Settlements Act
CAP	Central Arizona Project
CEC	Categorical Exclusion Checklist
cfs	cubic foot per second
CMID	Cortaro-Marana Irrigation District
COT	City of Tucson
County	Pima County
CY	cubic yards
EA	Environmental Assessment
EIS	Environmental Impact Statement
ERDP	Enhanced Recharge Demonstration Project
°F	Fahrenheit
FONSI	Finding of No Significant Impact

FPUP	Floodplain Use Permit
FWID	Flowing Wells Irrigation District
HCP	Habitat Conservation Plan
IGA	Intergovernmental Agreement
JHA	Job Hazard Analysis
LSCRMRP	Lower Santa Cruz River Managed Recharge Project
LSCRP	Lower Santa Cruz Recharge Project
LTSC	Long Term Storage Credits
Marana	Town of Marana
MDWID	Metropolitan Domestic Water Improvement District
MHP	Marana High Plains
Nation	Tohono O'odham Nation
NEPA	National Environmental Policy Act
NWP	Nationwide Permit
PCDEQ	Pima County Department of Environmental Quality
PCRWRD	Pima County Regional Wastewater Reclamation Department
PCRFCD	Pima County Regional Flood Control District
RSHS	Reclamation Safety and Health Standards
SAWRSA	Southern Arizona Water Rights Settlement Act
SCR	Santa Cruz River
Trico	Trico Electric Cooperative, Incorporated
UA	University of Arizona

USACE	United States Army Corp of Engineers
USF	Underground Storage Facility
USGS	United States Geological Survey

Enhanced Recharge Demonstration Project Increasing Treated Effluent Recharge Rates in the Santa Cruz River, Tucson, Arizona

I. Executive Summary

Water resources in Tucson, Arizona are limited. Water conservation and management are essential to ensure that future public and environmental water demands be met. Treated effluent is currently discharged to the Santa Cruz River (SCR), which is designated as an effluent dependent river that supports habitat. The treated effluent is also the source of water recharged by Reclamation and local Partners in the Lower Santa Cruz River Managed Recharge Project (Managed Recharge Phase II or MR II). An agreement with the City of Tucson provides 28,200 AFY of treated effluent to the Secretary of the Interior (Secretary), managed by Reclamation, to assist in meeting Arizona Water Settlements Act and Southern Arizona Water Rights Settlement Act obligations to the Tohono O'odham Nation. Reclamation recharges a portion of this effluent at the MR II project to meet these obligations.

The MR II project does not currently recharge at its permitted volume and as a result water flows out of the project and out of the Tucson region. Underutilization of the treated effluent has encouraged regional water management entities to consider removal of the treated effluent from the river for other uses. Such action would reduce groundwater recharge along the channel and lessen the water supporting riparian habitat. If effluent is better utilized at in-channel recharge projects and retained in the Tucson region, this water resource could yield improved benefit to the watershed, the public, and the environment.

The Bureau of Reclamation (Reclamation) facilitated a collaborative effort with partners to construct and operate the Enhanced Recharge Demonstration Project (ERDP) to increase recharge of treated effluent at the MR II project. The ERDP was developed to: divert water from the SCR channel into adjacent, dry, secondary flow channels; increase infiltration rates and accrual of Long Term Storage Credits; assess recharge methods; operate under existing permits; comply with environmental requirements; and promote regional cooperation through collaborative work with Partners. The ERDP was constructed in the SCR channel in the Town of Marana, Arizona, at the Powerline Gravel Bar site. The site was selected for construction of the ERDP based on: 1) small elevation differences between the SCR flow channel and adjacent dry flow channels, 2) lower construction costs, 3) favorable land ownership, 4) suitability of the channel sediments for recharge, and 5) favorable access to the site. Depth to groundwater in the vicinity of the ERDP is approximately 200 feet, below land surface.

ERDP construction began on January 3, 2011 and was the first time that Tucson Water, Flowing Wells Irrigation District, Pima County Regional Wastewater Reclamation Department, Metropolitan Domestic Water Improvement District and Reclamation, collectively referred to as "Partners," constructed a project together. All construction equipment and operators for construction of the ERDP were donated by Partners as part of the collaborative effort. Construction was originally estimated to take 10 to 15 days and instead was completed in 8 days.

Construction primarily consisted of excavation of the ERDP channels and the diversion inlet and was completed at the end of the winter rainy season (November through January) to collect data before the summer monsoon season began (June through August). The ERDP was expected to be operable for six months to two years depending on the occurrence of storm flows in the SCR. Diversions into the project began on January 28, 2011. The project was washed out on July 5, 2011 by summer monsoon storm flows when the flumes and inlet were buried by sediment. Three maintenance events were completed during the ERDP to discourage formation of a biologic clogging layer and to promote maximum infiltration rates. Maintenance included diversion inlet improvements and drying, scraping, and ripping of the channel bottoms. A storm flow event on September 10, 2011 scoured the ERDP allowing flow to continue into and out of the ERDP, although unmonitored, and maintaining the increased infiltration area as of October 27, 2011.

Recharge at the ERDP provided a unique opportunity to monitor the SCR channel during pre-recharge, start up and sustained recharge conditions. Typically research has been done in the already wetted channel. This project provided an opportunity to research conditions before and after the channel had been wetted. Flow into and out of the ERDP was monitored by Reclamation. Two monitoring studies funded by Reclamation were conducted by University of Arizona and Arizona State University research teams and are titled, "*Gravity monitoring of the Lower Santa Cruz River Enhanced Recharge Demonstration Project*" and "*Prospectus to Study Biological Clogging on the Powerline Gravel Bar Managed Recharge Project*," respectively.

Reclamation installed two, 10 cubic feet per second, maximum capacity Non-Adjustable EF10 Galvanized Steel Nuway "EZ Flow" Flumes at upstream and downstream locations of the ERDP to measure water flow into, and out of, the project. These points provide the data necessary for infiltration calculations. PVC stilling wells with locking caps were attached to the flumes for transducer/datalogger installation. HOBO U20 Water Level Logger's were installed in the stilling wells to record and store water pressure data. The infiltration area was approximately 17,890 square feet.

Notable results and conclusions of the ERDP include:

- Spreading flows across the SCR channel bottom in this small stream segment increased infiltration rates and recharge volumes by 88.8 acre feet (AF) over a period of 124 days;
- Partners experienced increased communication and information sharing by collaborating on construction;
- Recharge rates for this demonstration project were 0.28 AF per day for the first 60 days of operations and, after channel maintenance to remove sediment, 1.13 AF per day during the last 64 days of operation;
- Fine sediment from construction initially caused a low infiltration rate;
- Constructing multiple flow channels in an area with small elevation differences from the SCR main flow channel requires a minimal construction effort but results in a project that is susceptible to flood damage;
- After washout, additional storm flow scour can continue to augment flow in the ERDP channels.

The ERDP showed that diverting flows from the incised SCR channel into adjacent abandoned flow channels is a viable option to increase infiltration and associated recharge. Based on ERDP recharge rates (3.3 AF/mile/day), to fully utilize the SAWRSA effluent volume of 28,200 AFY, a constructed in-channel recharge project would require six 10-foot wide channels long enough to comprise approximately 4 miles of total flow length. The SCR channel bottom width in the vicinity of the ERDP is approximately 600 feet. An in-channel constructed recharge project of these dimensions would use 10% of the channel width in the Powerline Gravel Bar area. Channels would require some degree of lateral separation so as not to create interfering mounds in the vadose zone below them. It is likely that maintenance methods improved over those used in this demonstration project could increase infiltration rates and reduce the channel area required for this type of enhanced recharge.

II. Introduction

A. Purpose

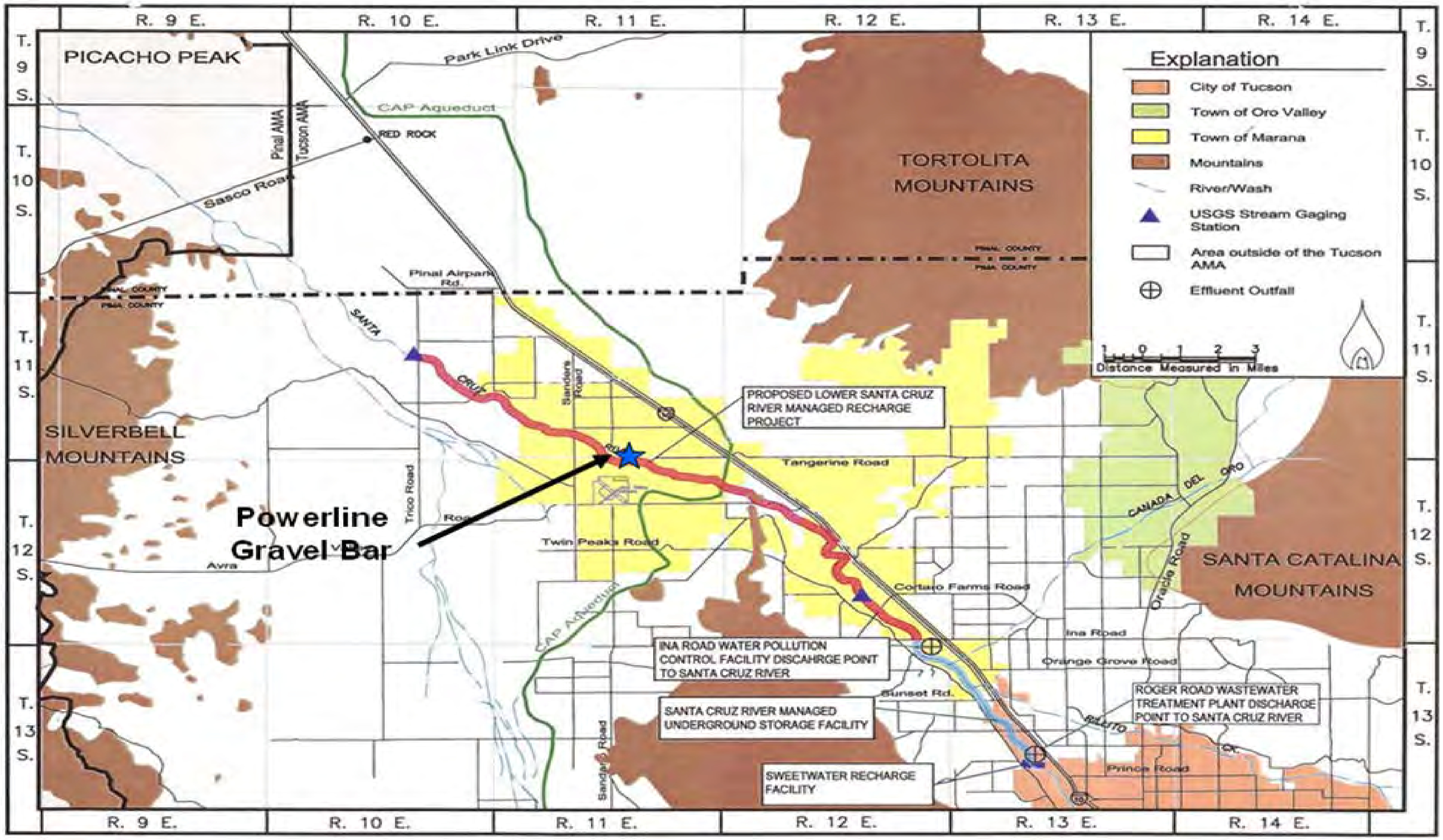
Reclamation facilitated a collaborative effort to construct and operate the Enhanced Recharge Demonstration Project (ERDP) to increase recharge of treated effluent at the Lower Santa Cruz River Managed Recharge Project (Managed Recharge Phase II or MR II) under existing Arizona Department of Water Resources (ADWR) Underground Storage Facility (USF) permit number 71- 591928 and Arizona Department of Environmental Quality (ADEQ) Aquifer Protection Permit (APP) number 100630. The MR II USF is permitted to recharge 43,000 acre-feet per year (AFY) but historically has recharged less than 50% of the permitted recharge volume.

Increasing infiltration would increase the number of Long Term Storage Credits (LTSC) that are accrued annually at the project and would be accomplished by diverting water from the incised flow channel into secondary low flow channels to spread flows across the Santa Cruz River (SCR) channel bottom.

The ERDP would: increase infiltration rates, allow evaluation of recharge techniques, be constructed under the existing USF and APP permits, comply with environmental requirements, and promote regional cooperation through collaborative work with Partners.

B. Location

The ERDP site is located on land owned by the Pima County Regional Flood Control District (PCRFCD) within the Town of Marana (Marana), Arizona within the Santa Cruz River (SCR) channel along the southwestern boundary of Section 34, Township 11 South, Range 11 East, at Latitude 32°25'27.78"N and Longitude 111°12'50.40"W (Figure 1).



Source: Base map was taken from the Application for Underground Storage Facility Permit (Managed) and Water Storage Permit, Lower Santa Cruz River Managed Recharge Project

Figure 1. – Location for the Enhanced Recharge Demonstration Project within the MR II Recharge Project

C. General Description

A portion of the SCR flow was diverted into an abandoned thalweg for recharge at the ERDP. A hydraulic connection between the SCR and the ERDP was excavated, lowering the bottom elevation of the abandoned thalweg to allow SCR water to enter the thalweg via gravity flow. Flows into and out of the ERDP were recorded and infiltration rates were calculated to monitor the impact of ERDP recharge operations. Diversions into the ERDP ranged from less than 1 cubic foot per second (cfs) to approximately 5 cfs. The ERDP was operated from January 28, 2011 to July 5, 2011.

III. Background

The Southern Arizona Water Rights Settlement Act (SAWRSA) was enacted by Congress in 1982 to resolve water use issues between the Tohono O'odham Nation (Nation), the City of Tucson and others. The Arizona Water Settlements Act (AWSA), enacted in 2004, allows for, among other things, full implementation of SAWRSA. An agreement with the City of Tucson provides 28,200 AFY of treated effluent to the Secretary of the Interior (Secretary), managed by Reclamation, to assist in meeting AWSA and SAWRSA obligations to the Tohono O'odham Nation (Nation). These obligations include maintaining a funding source for delivery of the Nation's 66,000 acre foot per year Central Arizona Project (CAP) allocation and firming 28,200 acre feet of Non-Indian Agricultural priority water so that it is delivered in the same manner as municipal and industrial priority CAP water during water shortages. Reclamation currently recharges this effluent to meet these obligations.

Reclamation recharges a portion of this effluent in the MR II USF under an Intergovernmental Agreement (IGA) between partners: City of Tucson (Tucson), Pima County (County), Town of Marana (Marana), Metropolitan Domestic Water Improvement District (MDWID), Flowing Wells Irrigation District (FWID), Town of Oro Valley, Cortaro-Marana Irrigation District (CMID) and Avra Valley Irrigation District (AVID). State Statute provides LTSC's for 50% of the total volume of treated effluent that infiltrates in managed recharge facilities. A managed recharge facility allows credit accrual for water discharged to a natural streambed which percolates into the aquifer without the assistance of constructed methodologies such as infiltration basins or injection wells.

Reclamation and its Partners constructed the ERDP to increase infiltration rates under the MR II USF and increase the number of LTSC's accrued at the facility. Increasing recharge via the ERDP could also assist with addressing a pending issue associated with Tucson regional effluent potentially flowing downstream, during storm events, through the Ak-Chin Indian Community which may violate water quality standards.

IV. Chronological Index of Events

Reclamation and participating Partner's began preliminary investigations of potential ERDP sites in 2006. Planning was tabled in 2007 to meet the MR II IGA requirement to develop a Recovery Plan and prevent termination of the Facility Permit and began again in March 2009 when Reclamation staff and participating Partners conducted a site visit to the SCR oxbow to evaluate potential enhanced recharge locations. Reclamation staff conducted preliminary surveys of potential ERDP sites at the Oxbow Diversion Berm and the Powerline Gravel Bar.

Based on the surveys, the Powerline Gravel Bar site was selected. Design drawings were prepared and permits and permissions were acquired. Construction began on January 3, 2011 and was completed on January 12, 2011. Water was diverted on January 28, 2011 and the ERDP was operated through July 5, 2011 when the project was washed out by storm flows in the SCR.

V. Site Selection

The area of the SCR, referred to as the Oxbow, was selected for potential ERDP locations. An oxbow is created when a river changes course, follows a straight path and cuts off a meander or river bend (Press and Siever, 1974). The SCR formerly flowed in the oxbow until a flood in 1983 modified the channel. Subsequently, a soil berm was constructed to divert a portion of the water into the oxbow. The oxbow diversion berm is maintained under USACE 404 permit number 974-0474-RJD to support diversions for agricultural irrigation by private entities and for the Marana High Plains (MHP) constructed recharge project that is operated by the Pima County Regional Flood Control District (PCRFCD).

Two locations, the Oxbow Diversion Berm and the Powerline Gravel Bar, were considered for ERDP construction. Primary considerations for the sites were: 1) the existing USACE 404 permit for the Oxbow Diversion Berm could be used for construction of the ERDP, and 2) smaller excavation volumes would be required for the Powerline Gravel Bar site. Each site provided an opportunity to spread surface flows across the channel bottom to increase the infiltration area.

During an April 2009 site visit, potential ERDP sites in the oxbow area were assessed by participating Partners and elevation data were collected by Reclamation.

1. Oxbow Diversion Berm

The oxbow diversion berm site is located at Latitude 32°25'22.13"N, Longitude 111°12'33.93"W. The proposed design involved rebuilding the oxbow diversion berm to its historic dimensions. This would raise the SCR water surface enough to divert water into nearby abandoned thalwegs. The work would be completed under the existing Oxbow Diversion Berm USACE 404 permit.

Based on elevation data, the Oxbow Diversion Berm location would require that the water surface be raised 4 feet to divert water via gravity from the current SCR flow channel into the adjacent abandoned thalweg. If the ERDP were constructed at this location the inflow, outflow, and recharge channels would require excavation of more than 660 cubic yards of material which is the limit of the existing 404 permit.

2. Powerline Gravel Bar

The Powerline Gravel Bar, named for the Trico Electric Cooperative, Inc., powerline that crosses the SCR at the location, is within the Oxbow and downstream from the diversion berm at Latitude 32°25'27.78"N and Longitude 111°12'50.40"W.

The proposed design included diverting a portion of the SCR flow, via gravity, into an abandoned thalweg that was cut off during flooding sometime between 2006 and 2009. To divert water into the secondary channel, the receiving channel would be lowered approximately two feet. Although the small elevation difference would make ERDP construction easier, it also would make it more susceptible to destruction during storm flows.

The Powerline Gravel Bar site was selected for construction of the ERDP based on: 1) smaller elevation differences between the SCR flow channel and the abandoned thalweg, 2) lower construction costs, 3) favorable land ownership, 4) suitability of the secondary low flow channel sediments for recharge, and 5) favorable access to site.

VI. Environmental Conditions

A. Climate

Tucson’s climate is semi-arid with year round warm temperatures, sunny days, and minimal rainfall. A weather station was not established for the ERDP however preliminary climate data was obtained from the National Weather Service (NWS) for Tucson, Arizona from January 28 to July 5, 2011. Average air temperatures measured in Tucson during operation of the ERDP ranged from 51.9 to 90.4 degrees Fahrenheit (°F), the maximum ranged from 73 to 112 °F, and the minimum ranged from 18 to 68 °F. Total measured precipitation was 3.06 inches. Average wind speed ranged from 6.8 to 8.5 miles per hour and it was sunny 142 out of 159 days during ERDP operations.

Table 1. – Preliminary Climate Data for Tucson, Arizona (Latitude 32° 7' N and Longitude 110° 56'W)

2011 Month	Max Temp in degrees F	Min Temp in degrees F	Ave Temp in degrees F	Precipitation Total in Inches	Ave Wind Speed M.P.H.	Sunshine Clear Days
January 28 -31	73	36	54.2	0	7.2	4
February	82	18	51.9	0.25	7.3	24
March	90	40	64	0.02	6.8	30
April	95	37	69.7	0.28	7.8	22
May	100	47	73.5	0.0	8.0	31
June	112	56	86.1	1	7.4	26
July 1 - 5	111	68	90.4	1.51	8.5	5

Source: National Weather Service – Climate Data (http://www.weather.gov/climate/index.php?wfo=twc, accessed on September 1, 2011)

B. Regional Geology

The ERDP is located in the Tucson basin in the upper SCR drainage basin. The Tucson basin is located within a broad alluvial valley with elevations of approximately 2,900 feet above mean sea level (ft, amsl) in the south and 2,000 ft, amsl at the northwest outlet and is surrounded by mountain ranges with peaks reaching elevations of 9,400 ft, amsl. The basin is approximately 50 miles long and is from 15 to 20 miles wide to the south and 4 miles wide at the northwest outlet (Davidson, 1973).

C. Site Geology

The ERDP is at an elevation of approximately 1,990 ft, amsl. It is located on surficial Holocene stream and flood-plain alluvial deposits of the SCR which are comprised primarily of gravel and gravelly sand to sandy silt (Davidson, 1973). These deposits typically overlie older sedimentary units and range from a thin veneer to tens of feet thick (Davidson, 1973).

D. Surface Water and Groundwater

1. Surface Water

Historically, portions of the SCR flowed perennially or year round. Agricultural surface water diversions, associated erosion, and groundwater pumping ultimately dried up the SCR in the Tucson region making it an ephemeral stream, flowing in response to storm events. In the Tucson region, ADEQ designates the SCR as an effluent dependent river. SCR surface water flows and habitat are dependent on treated effluent discharges from the Roger Road Wastewater Reclamation Facility and the Ina Road Water Pollution Control Facility, two regional wastewater treatment facilities. Wastewater treatment is regulated by ADEQ and treated effluent must meet established standards prior to discharge to the river.

The U.S. Geological Survey (USGS) maintains two stream gages that measure flow on the SCR in the vicinity of the ERDP. The USGS 09486500 SCR at Cortaro, Arizona stream gage is located upstream from the ERDP and the USGS 09486520 SCR at Trico Road, near Marana, Arizona stream gage is located downstream. Over the past 10 years, annual average SCR stream flows at the Cortaro gage ranged from 74 cfs to 139 cfs. SCR flow is dependent on treated effluent releases from the wastewater reclamation facilities and flow rates fluctuate diurnally based on regional water use. For example, on June 1, 2011 flows ranged from 22 cfs at 8:00 a.m. to 58 cfs at 11:45 p.m. at the Cortaro gage.

Flood flows have been measured at 250 cfs for a 1 year return period, 8,780 cfs for a 2 year return period and 46,000 cfs for a 100 year return period. Slope of the SCR channel bottom is approximately 0.002 ft/ft, based on survey results measured upstream from the Powerline Gravel Bar site. In the vicinity of the ERDP, the river bed material consists of poorly graded gravel with sand and cobbles. Maximum cobble size is approximately five inches.

During operation of the ERDP from January 28 to July 5, 2011 SCR monthly flow rates at the Cortaro gage ranged from 37 cfs to 75 cfs and averaged 55 cfs. Maximum flow rates declined from 75 cfs in February and March to less than 66 cfs in April, May, and June. Minimum flows also declined from more than 50 cfs in February to less than 50 cfs in the following months. Average flow rates declined from 63 cfs in February to 46 cfs in June. The July 22 through July 31data is provisional until validated by the USGS.

Table 2. – USGS 09486500 Santa Cruz River at Cortaro, AZ Monthly Stream Flow, cfs

Date	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11
Days	31	28	31	30	31	30	31
MAX	67	75	75	66	54	64	330
MIN	54	52	46	48	41	43	37
AVE	61	63	59	56	50	46	73

2. Groundwater

The primary water source in the Tucson basin, prior to importation and use of Colorado River water delivered via the Central Arizona Project (CAP), is derived from alluvial groundwater aquifers comprised of several sedimentary formations that extend to depths greater than 2,000 feet (Davidson, 1973).

Depth to groundwater is measured monthly in monitor wells for the Marana High Plains (MHP) constructed recharge facility which is located approximately three quarters of a mile downgradient from the ERDP. Monitor well HP-1, (D-11-11)33cad, is completed in the regional aquifer. Groundwater levels measured in HP-1 ranged from 182.0 feet, below land surface (ft,bls) on January 20, 2011 to 189.8 ft, bls on June 23, 2011 and did not show a response to recharge at ERDP. Monitor well HP-2, (D-11-11)33cad, is completed at a depth of 80 ft, bls and is used to monitor perched water conditions. HP-2 was dry throughout ERDP operations.

Depth to water is also measured in MR II USF groundwater monitor wells. Depth to water is measured quarterly in monitor well SC-10, (D-11-11)33bcb, which is located approximately one and one quarter miles northwest and downgradient from the ERDP. SC-10 water levels ranged from 181.4 ft, bls to 185.6 ft, bls in 2010. Depth to water is measured monthly in monitor well TANG-2, (D-12-11) 2acd, located approximately one and one quarter miles east and upgradient from the ERDP. Depth to water in TANG-2 during 2010 ranged from 211.4 ft, bls to 215.9 ft, bls.

This data indicates that groundwater levels beneath the ERDP are approximately 200 ft, bls and that there is sufficient storage capacity for additional recharge.

E. Recharge Facilities

1. Marana High Plains

MHP is a constructed effluent recharge project developed by the PCRFCD in cooperation with Reclamation, Arizona Water Protection Fund, and PCRWRD. MHP is located in T11S, R11E Section 33 approximately three quarters of a mile northwest and downgradient from the ERDP. MHP is designed to recharge treated effluent and create habitat and public recreation opportunities. MHP began operating in 2003, is permitted to recharge 600 AFY of effluent or surface water in one settling basin and four spreading basins (recharge cells) totaling 4.5 acres of recharge area. MHP recharged 427 AF in 2010. Recharge at the downgradient MHP facility would not impact recharge at the ERDP.

2. Lower Santa Cruz Recharge Project

The Lower Santa Cruz Recharge Project (LSCRP) recharge facility is located in T12S, R11E, Section 3 and is less than one half mile southeast and upgradient from the ERDP. The LSCRP is owned by the Central Arizona Water Conservation District and permitted to recharge 50,000 AFY of CAP water in three basins that cover 30 acres. The LSCRP began operations in 2000. Infiltration rates at the project exceed 7 feet per day (CAP, 2011). Recharge at the LSCRP would probably not impact recharge at the ERDP unless subsurface conditions provide a conduit for lateral movement towards the ERDP. Additional investigations would be necessary to determine if recharge at the LSCRP would impact recharge at the ERDP.

3. Avra Valley Recharge Project

The Avra Valley Recharge Project (AVRP) is located in T12S, R11E, Section 3 and is approximately one half mile south and upgradient from the ERDP. MDWID purchased the AVRP from CAWCD on January 1, 2011. The AVRP is permitted to recharge 11,000 AFY of CAP water in four basins that cover 10.8 acres. The AVRP was operated as a pilot from 1996 to 1998, with full scale operations beginning in 1998. Infiltration rates vary from 1 foot per day up to 3.5 feet per day. A clay layer impeded infiltration rates at basin 4 (CAP, 2011b) until MDWID completed infiltration enhancements in August 2011. Additional investigations would be necessary to determine if recharge at the AVRP would impact recharge at the ERDP.

VII. Permitting and Approvals

Reclamation identified requirements and obtained necessary permits and approvals prior to ERDP construction. This included Partner approvals at various stages of the project, environmental permits, permits required to work in the SCR channel, right of way permits for site access and construction, and permission from agencies that regulate the MR II project.

A. Intergovernmental Agreement Partner Approval’s

Reclamation coordinated with the IGA Partners throughout the ERDP planning process for project development and status updates. Partner’s approved Reclamation to coordinate as necessary with regulatory agencies including ADWR, ADEQ, and the USACE. On April 27, 2010, Partners approved construction of the ERDP and on December 22, 2010, Partners approved use of IGA accrued annual dues to pay for a water truck for dust control during construction (Appendix A).

B. National Environmental Policy Act

In 1970, the National Environmental Policy Act (NEPA) became effective. NEPA requires evaluation of the environmental effects of federal projects. Different levels of environmental assessments can apply to a project. At the first level, a categorical exclusion may be applied if a project is determined to have no significant environmental impact. Reclamation uses a Categorical Exclusion Checklist (CEC) to determine whether this level of environmental evaluation is appropriate for a project. If a CEC review shows that there are no negative potential effects to environmentally sensitive areas or resources and there is no potential for public controversy over environmental effects, than the CEC is sufficient and the federal project can proceed. If a proposed action is determined to have impacts on the environment, then the next level of review consists of an Environmental Assessment (EA)/Finding of No Significant Impact (FONSI). If required, the third and highest level of environmental evaluation is an Environmental Impact Statement (EIS).

The ERDP is a demonstration project constructed under an existing project that had already undergone an environmental evaluation. Reclamation's NEPA specialist determined that a CEC was the appropriate tool to evaluate the potential environmental impact of the ERDP.

1. Categorical Exclusion Checklist

Reclamation used a CEC to assess potential environmental impacts of the ERDP. A CEC was completed for the ERDP in November 2010 (Appendix B). The exclusion category was 516 DM 14.5 C(3) and included "Minor construction activities associated with authorized projects which correct unsatisfactory environmental conditions or which merely augment or supplement, or are enclosed within existing facilities." Based on the CEC, the recommended NEPA action was a Categorical Exclusion.

2. United States Army Corp of Engineers Section 404 permit - Nationwide Permit 18 "Minor Discharges"

The Powerline Gravel Bar is within an area regulated by the USACE who has jurisdiction under the Clean Water Act permitting program. Reclamation submitted a Preconstruction Notification for a Nationwide Permit (NWP) to the USACE in April 2010. A site visit to the Powerline Gravel Bar was conducted with Reclamation and USACE staff on May 14, 2010 to review the proposed design elements. As a result, project design revisions were made and it was determined that the ERDP work would be done under NWP Number 18 "Minor Discharges". The NWP 18 allows for an unrestricted volume of material to be excavated, as long as it is completely removed from jurisdictional waters, and allows up to 25 cubic yards of material to be excavated and used within the channel as a part of the ERDP diversion.

Based on the USACE recommendations, Reclamation submitted a revised NWP application for a Section 404 NWP Number 18 "Minor Discharges" on July 26, 2010. USACE issued a letter of verification on November 10, 2010, File Number: SPL-2010-00458-JWL, valid through March 18, 2012. All permit terms and conditions for the NWP 18 and "Special Conditions" were complied with during construction.

3. Biological Resource Survey

A survey of biological resources was conducted in November 2009 and it was determined that the project would have no effect on plants and animals in the vicinity of the ERDP. Vegetation at the site was considered too dense to qualify as a "desertscrub or strand community" and not tall or structured enough to be considered a "forest and woodland community". No aquatic vegetation was observed at the ERDP location during the survey. Riparian vegetation was limited to two small Goodding willow trees (*Salix gooddingii*), tamarisk (*Tamarix ramosissima*) and desert broom (*Baccharis sarathroides*). It was found that disturbance to the site during construction would be similar to what occurs during normal flood events in the SCR. The project area occurs within the range of the lesser long-nosed bat, the only federally listed species in the project area, however the habitat in the immediate area of the ERDP was not suitable for the bat and it was determined that there would be no effect to this species. The Town of Marana's Habitat Conservation Plan (HCP) has not been finalized, however based on the survey, it was determined that there would be no effect on the HCP listed sensitive species because the ERDP area does not provide suitable habitat for the species (CEC, 2010).

4. Archaeology Survey

Archaeology surveys were conducted along: the sandbar channel where the ERDP would be constructed, the vehicle/equipment access roads, and potential soil disposal locations in preparation for construction. For the ERDP site and access roads, Class I literature surveys and a Class III intensive survey was completed. The Class I survey identified seven prior surveys within a half-mile radius of the site. Three artifact scatter sites were identified from the literature review, no subsurface features or deposits were identified. A Class III survey was completed in November 2009. The ERDP is located within the active SCR channel and has been regularly disturbed by flooding. Results of a less intensive survey of the ERDP show a generally disturbed environment with evidence of deposits of relatively recent historic era. The direct project impacts would be in these disturbed deposits and it was determined that the impacts would not have any effect on cultural resources. It was also determined that indirect impacts of the project, such as vehicle access, would not impact cultural resources. The disturbed setting, coupled with a lack of cultural resources in the survey area, resulted in a finding of no effect to historic properties. Ground disturbance during project construction would be kept within the boundaries of the planned project area, and access would be by established rights-of-way (DI-BR-PXAO-ICRS-2009-038, 2010). 2010).

A Class I and a Class III survey was also completed for five potential soil disposal locations. The Class I survey showed that eight prior surveys had been completed within a half-mile radius of the ERDP. A Class III survey was completed on 4.37 acres in June 2010. The results of the surveys show that no historic or prehistoric sites were identified and that the ERDP work would have no effect on cultural resources (DI-BR-PXAO-ICRS-2010-006, 2010).

C. Right of Way

The ERDP was constructed in the SCR channel on land owned by the PCRFCD. There were several access routes that crossed land owned by Marana and the Arizona State Land Department (ASLD). Right of Way (ROW) agreements were developed between Reclamation and each affected land owner.

1. Arizona State Land Department and Lessee's

Reclamation received a Temporary Right-of-Entry from the ASLD valid from February 16, 2010 to February 15, 2011 (Appendix C). The ASLD requested that Reclamation also request permission to cross ASLD leased land from lessee's. Trico provided written permission to use the Trico powerline access road on March 22, 2010 (Appendix C). Lessee John Kai gave verbal permission on March 19, 2010 to cross his leased land (Appendix C). Sub-Lessee Brad Despain gave verbal permission to cross his subleased land during the April 2009 field trip.

2. Pima County Regional Flood Control District

A license agreement (License) was issued by the PCRFCD granting permission to Reclamation to access and construct ERDP on PCRFCD owned tax parcels 215-03-011C, 217-53-0460, and 217-53-042B. The License was approved and signed by the Pima County Board of Supervisors on June 15, 2010 and recorded at Docket 13837 Page 2881 on June 24, 2010 in the office of the Pima County Recorder (Appendix D). The License is effective through June 24, 2035.

3. Town of Marana

A License was issued by Marana allowing Reclamation temporary access through Marana's Heritage Park (T11S, R11E, Section 34) during ERDP construction and operation. The License was recorded by the Pima County Recorder's Office in Docket 13763, Page 1195 on March 11, 2010 (Appendix E) and remains in effect until it is modified or terminated.

D. Town of Marana Floodplain Use Permit/Grading Permit

Marana administrates the SCR floodplain at the ERDP. Work in the SCR channel is regulated under the Marana Land Development Code. A Floodplain Use

Permit (FPUP) and Type II Grading Permit must be obtained from Marana prior to construction in the river channel. A proposed project must show compliance with the terms and conditions of the Marana land development code as it relates to floodplain impacts, including no rise in base flood elevations.

Reclamation staff met with Marana on January 29, 2010 in a pre-application meeting. The meeting was held to identify permit and regulatory requirements, discuss ERDP design elements and streamline the application process. Preliminary design elements were reviewed and Marana made design recommendations which facilitated the permit application process.

1. Hydraulic Analysis

A preliminary flood plain analysis was completed by Reclamation to determine the change in water surface elevation due to the proposed ERDP diversion channels. HEC-2 was used to model the 100 year peak flow analysis along the project boundaries. The Pima County Flood Control District provided Reclamation with an existing model, “HEC-2 Santa Cruz Levee and Channel Improvement Model Revised 3-05-2004”, for comparison of post construction water surface elevations. The Marana Land Development Code defines the regulatory 100 year design flood for the Santa Cruz River as 70,000 cubic feet per second (ft^3/s). This flow rate was used for hydraulic modeling of the ERDP to meet FPUP and Grading Permit requirements. The hydraulic analysis indicated that ERDP construction will have minimal impacts to the regulatory flood elevations. It was found that the increase in water surface elevation due to the ERDP diversion structure was offset by increased conveyance provided by a new recharge channel.

2. Floodplain Use Permit

Reclamation submitted a Floodplain Use Permit (FPUP) application to Marana for excavation in the main channel of the SCR along the southern boundary of T11S, R11E, Section 34. The ERDP is located within the Federal Emergency Management Agency (FEMA) map designated floodplain zone AE per Flood Insurance Rate Map (FIRM) Panel 04019C0990. Marana issued FPUP number FP1004-001 on May 3, 2010 and it was valid through May 3, 2011 (Appendix F). Reclamation submitted a closeout package after construction, monitoring, and maintenance at the ERDP were completed. Marana terminated the FPUP on November 14, 2011 (Appendix F).

3. Grading Permit

Reclamation submitted a Type II Grading Permit application to Marana for excavation in the main channel of the SCR (Latitude 32°25’27.78”N, Longitude 111°12’50.40”W; T11S, R11E, Section 34) for the ERDP. Marana issued

Grading Permit number T21005-001 on May 3, 2010, valid through October 30, 2010 (Appendix F). On October 6, 2010, Marana granted an extension of the permit through April 29, 2011. Reclamation submitted a closeout package after construction, monitoring, and maintenance at the ERDP were completed. Marana terminated the Grading Permit on November 14, 2011 (Appendix F).

E. Pima County Department of Environmental Quality Air Quality Permit

Reclamation applied to Pima County Department of Environmental Quality (PDEQ) for an Air Quality Activity Permit: Fugitive Dust. PDEQ issued permit number 6353 (Appendix G), effective from 4/8/2010 to 4/7/2011. A water truck was used for dust control throughout construction of the ERDP from 1/3/2011 to 1/12/2011.

F. Arizona Department of Water Resources approval under Existing Underground Storage Facility permit

Reclamation and participating Partners met with ADWR staff on April 21, 2011 to provide an overview of the ERDP and to request ADWR's approval to construct and operate the ERDP under LSCRMRP USF Permit No. 71-591928. ADWR approved construction of the ERDP in correspondence dated April 21, 2011 (Appendix H).

G. Arizona Department of Environmental Quality approval under existing Aquifer Protection Permit

Reclamation and participating Partners met with ADEQ staff on May 26, 2010 to provide an overview of the proposed ERDP and to request ADEQ's approval to construct and operate ERDP under the Pima County's Ina Road WRF Aquifer Protection Permit (APP) No. P-100630. ADEQ approved construction of the ERDP in email correspondence dated June 14, 2010 (Appendix I).

VIII. ERDP Planning and Construction

A. Design

The initial design for the ERDP was developed in 2006 and consisted of diverting water from the incised SCR stream channel into adjacent, abandoned thalwegs. Final ERDP designs were developed for the Powerline Gravel Bar site, a 5.6 acre gravel bar. The ERDP design (Figure 2) consisted of a diversion berm and an inlet channel to divert one to six cfs of SCR flow, via gravity, into two flow channels.

B. Planning

ERDP was planned and constructed as a collaborative effort between participating Partners. Site orientation visits to the ERDP were conducted individually with each participating Partner to walk the project area, assess access routes, and discuss equipment needs. After the individual site visits were completed, group site visits with all participating partners were conducted to plan the coordinated construction effort, finalize equipment needs and the construction schedule.

C. Surveys

Reclamation initially conducted an informal land survey at the ERDP as part of the site selection. Additional surveys were completed for design and construction purposes. On August 20, 2009, elevations were surveyed to prepare cross sections of the gravel bar. The data were used to design the diversion structure and to identify channel excavation requirements. On January 27 and 28, 2010, a horizontal and vertical survey control was established near the site using Arizona Central Zone State Plane, Horizontal Datum: NAD 1983 (2007) and Vertical Datum: NAVD 1988, GEIOD 09. Work completed included: a topographic survey of the gravel bar; a profile of the thalweg line of the river along the gravel bar; three cross sections of the river were surveyed; and a surface model of the proposed ERDP design was prepared. On October 7, 2010, work was completed to: resurvey the gravel bar following SCR storm flows; establish a control point for the University of Arizona gravity survey research; and a new surface model for the ERDP design was prepared. On December 28, 2010, the channel alignments were surveyed and staked with 15 foot offsets at 50 foot intervals in preparation for construction.

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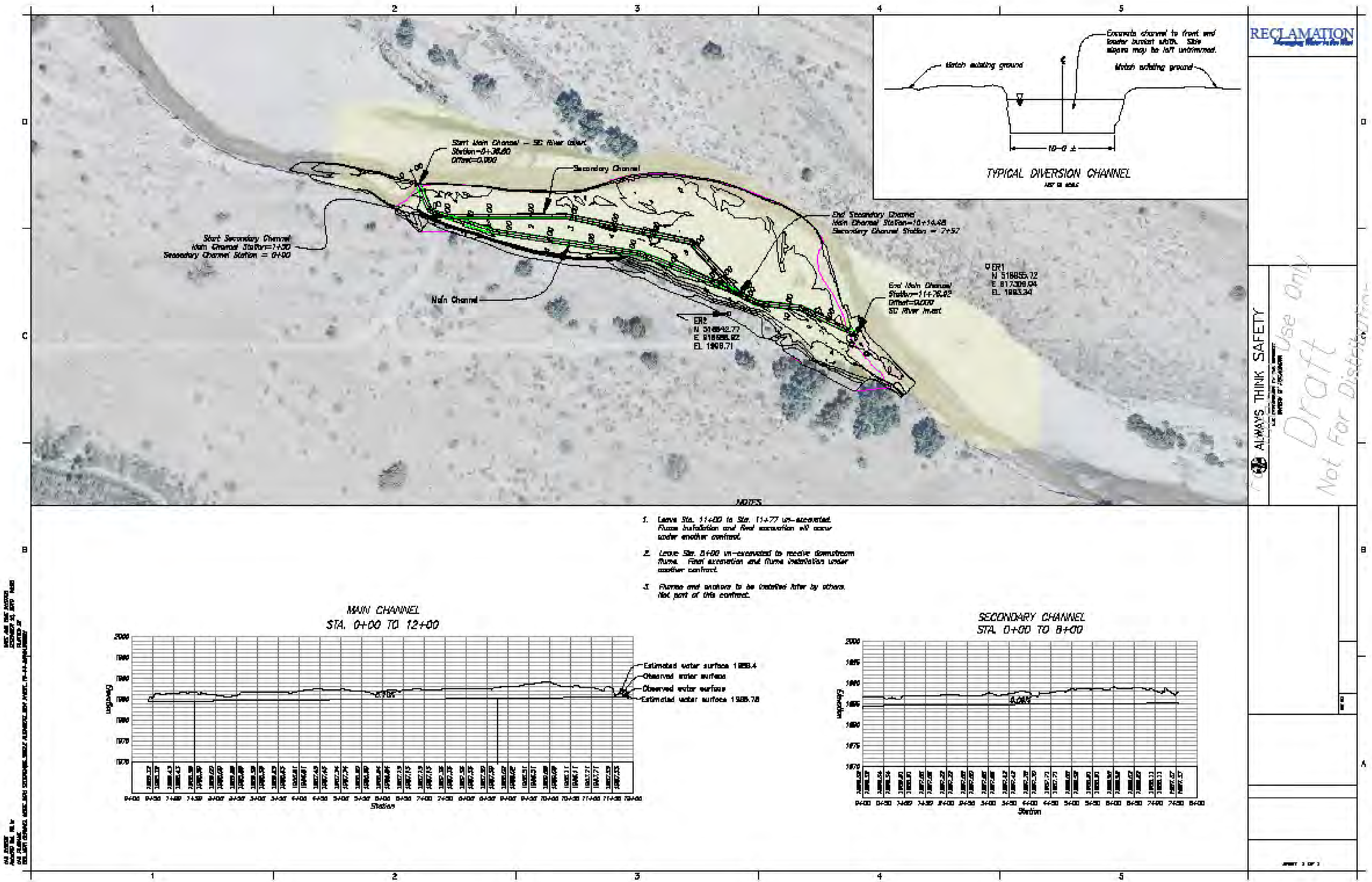

Figure 2. – Design for Enhanced Recharge Demonstration Project

D. Blue Stake

On January 24, 2011 a blue stake survey was conducted for the ERDP site and no underground utilities were located (Appendix J). It should be noted during construction of the ERDP an exposed underground utility was located downstream of the project site, the exposed underground utility was not identified by bluestake during the ERDP survey.

The ERDP site was located in a remote area on the west side of the SCR channel. Land use within a mile of the west side of the channel consists of: undeveloped land; the MHP, AVRP, and LSCRP recharge projects; the Avra Valley Airport; and agricultural fields and open range. The above ground Trico power line runs along the southern border of the ERDP. Excavation of the channels was above the scour zone in reworked sediments in an area where utilities would not be located. The blue stake survey for underground utilities was not conducted prior to most of the excavation work. When this oversight was identified, ELM Locating and Utility Services was scheduled to conduct a blue stake survey.

E. Access Routes

Several access routes to the ERDP provided flexibility during construction and monitoring (Figure 3). Access Route 1 was from Tangerine Farms Road through the Marana Heritage River Park on the east side of the SCR and then across the SCR channel bottom. Access Route 1 provided indefinite access and could be used during site visits, surveys and project monitoring. Access Route 2b was from North Sanders Road across ASLD leased land, along the Trico powerline road and finally crossing PCRFCD owned land, entering the ERDP from the west side of the SCR. Route 2b was accessible for one year, from February 16, 2010 to February 15, 2011 and provided access for heavy equipment during construction, site visits, site surveys, and project monitoring. Permission to access these lands for project purposes was authorized by each entity through issuance of either a right-of-entry or license agreements.

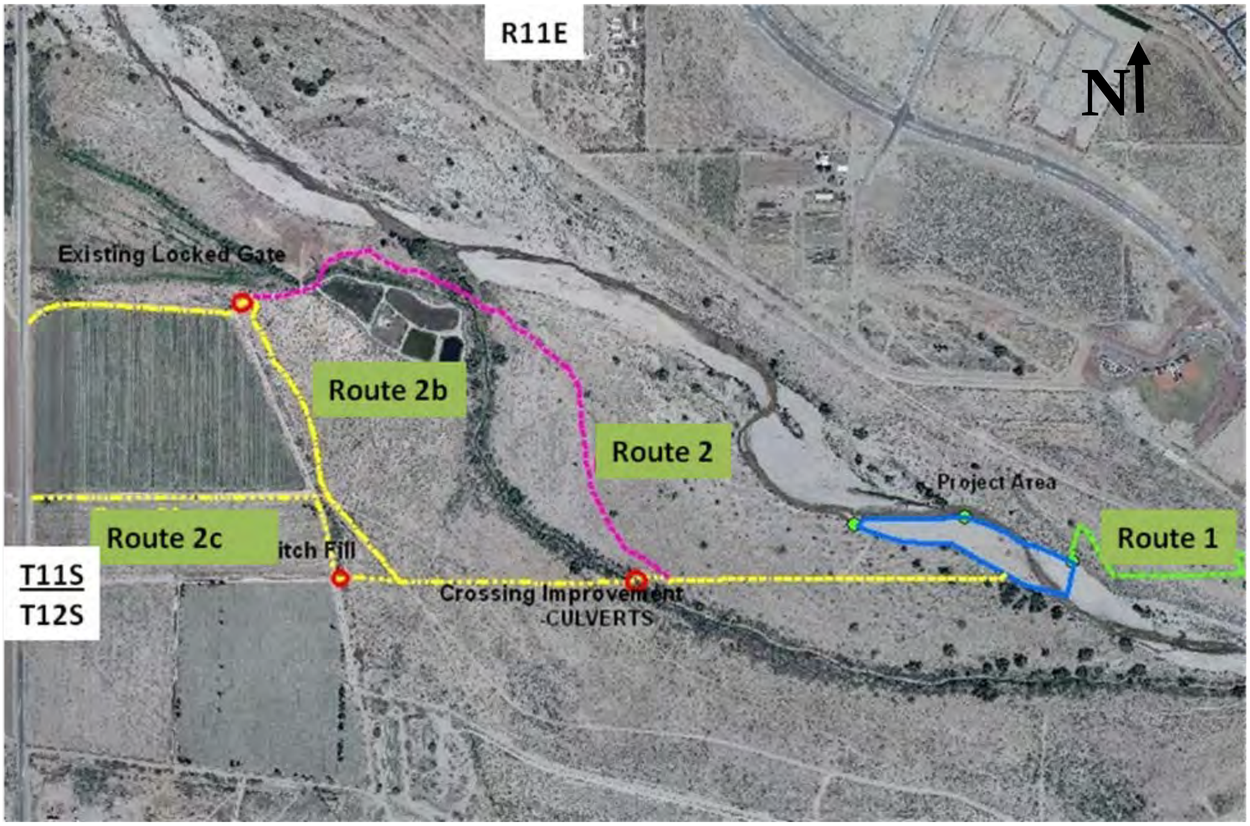

Figure 3. – Access Routes for the Enhanced Recharge Demonstration Project

F. Job Hazard Analysis and Safety Briefings

Reclamation's written safety document, Reclamation Safety and Health Standards (RSHS) dated October 2009, governs construction work and contracts. This document comprises a part of Reclamation's comprehensive safety program. ERDP construction work, done by the participating Partners, was covered by the RSHS. The RSHS provides requirements for work planning that apply to all Reclamation and contractor activities and provides guidance for preparing a Job Hazard Analysis (JHA) document.

A written JHA and amendments were prepared for field work associated with ERDP construction (Appendix K). The JHA identifies the work to be completed, required safety apparel and equipment, hazards and solutions, safety standards requirement references, and emergency services. Prior to starting construction work at the ERDP, the construction supervisor held safety meetings and reviewed the JHA with the equipment operators. A copy of the JHA was available at the work site throughout construction activities.

The RSHS addresses issues, including safety concerns, with non Reclamation staff using their own equipment on the Reclamation construction project. Provided that the contributed construction equipment complied with the RSHS, there was no problem using the donated equipment. There also was no problem with non-Reclamation staff operating government furnished equipment as long as the non-Reclamation operator had been properly trained and the training records were available. Reclamation's designated safety officer was present for the on-site safety meeting.

G. Site Inspector

Reclamation staff provided on-site construction management. The construction manager surveyed excavation and grade elevations and provided inspections throughout construction. The construction manager prepared Daily Inspection Reports (Appendix L) that identify staff and site visitors; equipment used, major work activities, and photographs of the construction work.

H. Equipment and Labor

All construction equipment and operators used to construct the ERDP were donated as part of the collaborative construction effort with the IGA Partners. Due to this generous contribution, Reclamation did not have to procure construction equipment. This resulted in a large time and financial savings. The total monetary value for personnel and equipment contributions from Partners was $27,339.

1. Tucson Water

Tucson Water provided $5,768 of in-kind contributions that consisted of: backhoe, fuel truck, equipment operators, management staff, support truck, and fuel for all heavy equipment used during construction of ERDP.

2. PCRWRD

PCRWRD provided $4,114 of in-kind contributions that consisted of: water pump, equipment operator for water wagon, support and management staff, and a support truck.

3. FWID

FWID provided $6,705 of in-kind contributions that consisted of: backhoe, equipment operator, support truck, and management staff. FWID also took responsibility for all paperwork associated with rental of a water wagon.

4. MDWID

MDWID provided $3,630 of in-kind contributions that consisted of: dump truck, equipment operator, management staff, and support truck.

5. IGA Partners

The IGA Partners provided $5,772 of accrued IGA annual dues to be used for rental of a water wagon for dust control during ERDP construction. CMID provided $1,350 of in-kind contributions that consisted of attorney staff time to prepare a budget agreement for use of the IGA funds.

6. Reclamation

Reclamation provided project management for the ERDP. In addition, Reclamation's interdisciplinary team completed requirements under the National Environmental Policy Act (NEPA), obtained necessary permits and permissions, surveyed the site, prepared design drawings, prepared the construction schedule and provided on-site construction management, and performance monitoring inspections.

7. Others

Brad Despain, owner of Bridlebit Ranch and former Marana Utilities Director and current ASLD land sub-lessee, provided support for site access, informal site security, ERDP maintenance, and an in-depth knowledge of the SCR in the vicinity of the ERDP.

I. Equipment storage

Most of the equipment used during construction was stored near the ERDP. Public access to the ERDP site is via a locked gate west of the site or via the SCR channel. Brad Despain gave permission to store the construction equipment in his livestock corrals located approximately one mile from the ERDP and adjacent to the MHP. Mr. Despain monitored the area twice a day during maintenance of his pastures and livestock corrals. MDWID drove their dump truck to and from the site every day.

J. Dust Control

To meet PDEQ Air Permit number 6353 requirements, it was necessary to implement dust control measures. A water wagon was used to water the construction site and access roads. PCRWRD provided equipment to pump treated effluent from the oxbow into the water wagon.

K. Construction

ERDP construction focused on excavation to: lower the elevation of abandoned thalwegs, provide a hydraulic connection to divert a portion of the SCR flows into the ERDP, spread flows across the SCR channel bottom to increase the surface area for infiltration, and increase recharge and accrual of LTSC.

ERDP construction began on January 3, 2011 and was the first time that Tucson Water, FWID, Pima County Regional Wastewater Reclamation Department (PCRWRD), MDWID and Reclamation constructed a project together. Heavy equipment was mobilized to the site, Reclamation held a safety meeting, site preparations were made, and excavation began. Tasks completed on the first construction day included: the culvert at the oxbow crossing was shored, a water pump was set up, vegetation was cleared from the excavation area, and Channel 1 excavation began. Rainfall on December 23rd, 29th and 30th, 2010 provided sufficient moisture for dust control during the first construction day. A Port-O-Let was delivered on January 4, 2011.

Daily construction activities included excavation, build-up of the access roads using excavated material, dust control, and checking grade and excavation elevations. Access roads were graded to drain storm water and to strengthen the road surface. Channel 1 was excavated to a depth of 0.5 to 2 feet along its 1,100 foot length to create a 0.1 percent slope between the upstream and downstream ends of the channel. Channel 2 was excavated to a depth of 2.5 to 3 feet along its 720 foot length to create a 0.09 percent slope from the upstream to the downstream end of the channel. The average width of Channels 1 and 2 was approximately 10 feet. The infiltration areas were estimated to be 10,197 square feet for Channel 1 and 7,693 square feet for Channel 2.

Photo 1. – Vegetation Cleared and Start of Excavation in Channel 1.
Photo taken by Deborah Tosline.

An estimated total of 2,300 cubic yards (CY) of material was excavated during construction of the ERDP. 1,115 CY was excavated from Channel 1and 945 CY was excavated from Channel 2. The remaining 240 CY were due to swell. During excavation, soil becomes less compacted and results in increased soil volumes, this is referred to as swell.

All excavated material was placed in a dump truck and transported out of jurisdictional waters and deposited on the access roads up to the oxbow culvert crossing. Additional excavated material was stock piled at the culvert crossing until it was spread by front end loaders.

Photo 2. – Removal of Excavated Material during Excavation.
Photo by Carol Hansen.

Other construction activities included placement of sandbags in the mouth of Channel 2 at the divergence between Channel 2 and Channel 1 to prevent water from entering Channel 2 and excavation of an approach basin immediately above the upstream flume.

Excavation at Channel 1 was completed on January 7, 2011. Excavation began at Channel 2 on January 6, 2011 and was completed on January 12, 2011. Construction was originally estimated to take 10 to 15 days and instead was completed in 8 days.

Photo 3. – Completion of Channel 1 Excavation.
Photo taken by Deborah Tosline.

All but one piece of heavy equipment were demobilized on January 13, 2011. The last piece of equipment, a front-end loader, was removed on January 14, 2011.

On January 28th, a backhoe was used to excavate holes for the flume anchors which consisted of buried concrete weights. During excavation of the downstream anchor hole, soil moisture was encountered at approximately 7 feet below land surface (ft, bls). The upstream anchor hole was excavated to approximately 10 ft, bls and seeping water was observed at approximately 7 ft, bls. The upstream anchor hole consisted of sand and silt from 0 to 7 ft, bls, pebbles from 7 to 7.5 ft, bls, and clay at 7.5 ft, bls. Another hole was excavated to approximately 10 ft, bls between the SCR flow channel and the east side of Channel 2. The material consisted of brownish-tan sand and silt with lenses of black sand. Water seeped into the hole at approximately 6 ft, bls.

Photo 4. – Placement of Concrete Anchor for Upstream Flume.
Photo taken by Deborah Tosline.

Final construction elements included: installation of dataloggers in the stilling wells of the upstream and downstream flumes, excavation of the soil plug at the downstream end of the ERDP, and excavation of the inlet channel to allow water to be diverted from the SCR flow channel into the ERDP.

The Port-O-Let was demobilized on January 31, 2011.

L. Flumes

Two flumes with PVC stilling wells were installed at the ERDP on January 20, 2011. The upstream flume was placed approximately 100 feet downstream from the SCR diversion point and the downstream flume was placed approximately 150 feet upstream from the ERDP channel outlet.

A flume is an open artificial channel used to measure water flow rates. The flume is designed to force water flow to accelerate as it passes through the shaped, open-channel, flow sections. Acceleration is accomplished by raising the bottom of the flume, or converging the side walls, or both (USBR, 2001). This design creates conditions that are suitable to quantifying water flows. Reclamation purchased and assembled two, 10 cfs maximum capacity Non-Adjustable EF10 Galvanized Steel Nuway “EZ Flow” flumes. The flumes accelerate water flow via a raised bottom, which is referred to as a broad-crested weir. The flumes weigh about 100 pounds and measure 48 inches by 36 inches by15 inches.

For flow measurement accuracy, flumes are installed downstream from tranquil flow to prevent flow measurement errors. An approach basin was excavated to provide a straight unobstructed approach and smooth flow conditions above the upstream flume.

Flumes were installed at upstream and downstream locations of the ERDP to measure water flow into and out of the project and to provide the data necessary for infiltration calculations. Final grading of the installation base for the flumes was done with hand tools. The area around the flumes was backfilled, and secured and stabilized with sandbags. During operations, it was discovered that the upstream and downstream flumes were not level. Flumes should be installed so that they are level from side to side and from the inflow to the outflow for accurate flow measurements. This did not impede data collection and processing, however future installations should ensure that flumes are level to reduce compounded error in data collection.

The flumes were equipped with direct reading, 1 to 10 cfs, sidewall gauges for on-site flow volume readings. PVC stilling wells with locking caps were attached to the flumes for transducer/datalogger installation. The stilling wells were vented to the atmosphere. The flumes were anchored with a cable to a concrete weight buried in the channel alluvium below scour depth to secure the flumes during flood events. The scour depth was determined by the project engineers to be 10 ft below the river bed.

Photo 5. – 10 cfs Maximum Capacity Non-Adjustable EF10 Galvanized Steel Nuway "EZ Flow" and Stilling Well with Locking Cap.
Looking Upstream at Diversion Inlet and Approach Basin.
Photo taken by John Bodenchuk.

Pre-mix concrete was used to prepare the flume anchors. The concrete was mixed onsite using water from the river, placed into the anchor forms along with a line of steel cable, and allowed to set-up overnight. On January 28, 2011, a front end loader was used to excavate the holes for placement of the anchors. The steel cables were attached to the flumes upon installation.

The information contained in this report regarding commercial products or firms may not be used for advertising or promotional purposes and is not to be construed as an endorsement of any product or firm by the Bureau of Reclamation.

M. Transducers/Dataloggers

Reclamation purchased three HOBO U20 Water Level Logger's, a Waterproof shuttle, and HOBOware Pro data processing software for Windows. The U20 HOBO Water Level Loggers measure absolute pressure that is later converted to water level measurements and ultimately into flow volumes. The loggers measure within a water depth range of zero to thirteen feet and have a pressure range of zero to twenty-one pounds per square inch. Absolute pressure includes atmospheric pressure and water head which is compensated with barometric pressure measurements. Three loggers were installed in the stilling wells. Two loggers were installed in the upstream flume, one to measure barometric pressure and one to measure water levels. One logger was installed in the downstream flume to measure water levels. The loggers were programmed to store data every half hour and were downloaded during site visits.

Photo 6. – HOBO U20 Water Level Logger's.
Photo taken by Deborah Tosline.

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IX. Operations and Maintenance

The ERDP project was operated in a manner to discourage formation of a biologic clogging layer. Construction was completed at the end of the winter rainy season (November through January) to collect data before the summer monsoon season began (June through August). The ERDP was expected to be operable for six months to two years depending on the occurrence of storm flows in the SCR. Diversions into the project began on January 28, 2011. Monitoring at the ERDP ceased on July 5, 2011 when summer monsoon storm flows washed the project out, buried the flumes and deposited sediment in the diversion inlet preventing further inflows into the project.

Photo 7. – Looking Downstream at the Diversion from the SCR Flow Channel (on Right) into the ERDP (on Left).

Photo taken by Deborah Tosline.

Photo 8. – Water First Diverted to ERDP on January 28, 2011. Note fines on bottom of Channel 1.

Photo taken by Andrew Ashby.

SCR diurnal flow variations impacted flows into the ERDP. Low flow at ERDP occurred late morning/early afternoon and high flows occurred later in the evening. For example, on April 13, 2011 a low flow of 0.08 cfs occurred at 3:00 p.m. and a high flow of 1.85 cfs occurred at 9:00 p.m. Flow rates into the project varied, but diurnal flow times remained consistent.

The ERDP was initially operated undisturbed for eight weeks or 60 days while inflows and outflows from the project were monitored. Visual observations were made and photographs were taken during site visits. During the first operation phase, sedimentation occurred in the approach basin to the upstream flume. Despite the sedimentation, water flow above the upstream flume appeared smooth. Algal growth was first observed on the sides of both channels during the February 15, 2011 site visit.

The initial plan was to wet Channel 1 and keep Channel 2 dry until flow into Channel 1 would be diverted into Channel 2 and Channel 1 would be dried for maintenance. To accomplish this, a low dirt berm and a row of sand bags were placed at the divergence between Channel 1 and Channel 2. A low dirt berm was also placed at the downstream convergence between Channel 1 and Channel 2. These flow barrier measures were not effective. When water was diverted into the project, the berm and sand bags were breached at the divergence and the berm was breached at the confluence and Channel 2 was wetted. Throughout the duration of the project both channels were wetted during operations and both channels were dried during maintenance. In the future, more rigorous designs are required to ensure that water barriers are not breached.

Photo 9. – Sandbag and Dirt Berm Barrier Breached at Divergence of Channels 1 and 2.

Photo taken by Deborah Tosline.

Photo 10. – Looking Upstream at the Dirt Berm Barrier that was Breached at the Convergence of Channels 1 and 2.

Photo taken by Deborah Tosline.

Photo 11. – Aerial Image of Constructed ERDP.

Photo source: Google Maps, accessed April 26, 2011.

Three maintenance events were completed during operation of the ERDP. The maintenance events began on March 29, 2011; May 12, 2011; and on June 21, 2011. Channel maintenance was completed to promote maximum infiltration rates and included: improvements to the diversion inlet and drying, scraping, and ripping of the channel bottoms. Equipment used for maintenance: TYM T433 tractor with front loader and backhoe, 50 horsepower (HP); Montana 3040 tractor with gannon box and front loader, 45 HP; John Deere 4240 Tractor with Big 0x 3-parabolic 36-inch shanks foot, 145 HP; John Deere 4240 tractor with 36-inch ripper, 145 HP.

The first maintenance effort began on March 29, 2011 when the diversion channel was dammed and flows into the ERDP ceased. The ERDP was allowed to dry for two weeks before doing channel maintenance work, although the area 40 feet above the downstream flume remained too wet for passage of heavy equipment and maintenance was not completed in this area. In most locations along Channels 1 and 2, a fine sediment layer up to 2 inches thick had been deposited on the channel bottom and formed desiccation or mud cracks after drying. Activities completed during this maintenance effort included: excavation of sediment deposits from the mouth of the diversion inlet channel, excavation of sediment deposits in the approach basin above the upstream flume, removal of sandbags from the mouth of Channel 2 at its divergence with Channel 1, scraping and removal of fines from Channels 1 and 2 to locations outside of jurisdictional waters, and ripping of Channels 1 and 2 once with a 36-inch ripper.

Photo 12. – Mudcracks in Channel 1 after 7 Days of Drying during First Maintenance Event. Brad Despain is crossing channel.

Photo taken by Deborah Tosline.

Photo 13 – Channel 2 after Drying, Scraping, and Ripping during Maintenance Event 1.

Photo taken by Deborah Tosline.

The project was rewetted on April 12, 2011, at 9:30 AM. Flows reached the downstream flume on April 13th at 10:00 PM. The project was operated for 30 days. Sedimentation in the diversion inlet reduced or blocked flows into the project during daily diurnal low flows. Sedimentation in the approach basin above the upstream flume ceased. A dry section in Channel 2 persisted during low and high flows. Smaller inflows, decreasing outflows, and increasing air temperatures resulted in stagnant conditions in Channels 1 and 2 and algal growth. As temperatures increased, weeds began to grow along the edges of the ERDP.

On May 12, 2011, the second maintenance effort began when the diversion inlet channel was plugged and flows into the ERDP ceased. The ERDP was dried for 9 days. Unlike conditions during the first maintenance event, minimal fines were deposited on the channel bottoms except immediately downstream from the upstream flume and immediately upstream from the downstream flume. In some locations, there was a thin layer of dried algae. The lack of fines and mudcracks present during the second maintenance effort indicates that the fine sediment deposits observed during the first maintenance and drying effort were remnants of ERDP construction and that the fines were not deposited into the project via SCR flows. Minor cattle tracks were observed in the channel bottoms. Maintenance included: excavation of sediments from the diversion inlet, leveling of high spots in Channel 2, and ripping of Channels 1 and 2 twice.

Photo 14. – Looking Downstream at the Divergence between Channels 1 and 2 after Drying during Second Maintenance Event.

Photo taken by Deborah Tosline.

The project was rewetted on May 23, 2011, at 8:00 AM. Water reached the downstream flume on May 25th at 6:00 PM. The project was operated for 29 days. Flow rates into the ERDP increased as a result of additional excavation from the diversion inlet channel. Channel 2 was entirely wetted and flow downstream was unimpeded. Algae developed in Channels 1 and 2 at a slower rate than during the first and second operating periods. Sedimentation in the diversion inlet decreased and flows into the project were not impeded. There was no sedimentation in the approach basin above the upstream flume. Weeds grew prolifically along the edges of the project.

The final maintenance event began June 21, 2011 when the diversion inlet was plugged and flows into the ERDP ceased. The project was dried for 8 days. No other maintenance was conducted. After 8 days, the dried channel bottom consisted primarily of a whitish dried and cracked algal mat. Desiccation cracks were present immediately downstream from the upstream flume and immediately upstream from the downstream flume. Cattle tracks in the bottom of the channel were observed. An increase in vegetation was present in the diversion inlet above the plug.

Photo 15. – Looking Downstream at the Divergence between Channels 1 and 2 after Drying during Third Maintenance Event.

Photo taken by Deborah Tosline.

The project was rewetted on June 29, 2011 at 8:30 AM. Flows reached the downstream flume on June 30, 2011 at 5:00 AM. The project was operated for 5 days before it was washed out on July 5, 2011 by storm flows in the SCR. On July 5th, the Cortaro gage recorded a maximum flow rate of 917 cfs and on July 6th a maximum flow rate of 2,070 cfs was recorded.

Photo 16. – Looking Downstream at Channel 1 and Buried Upstream Flume after July 5th and 6th Stormflows Washed Out Project.

Photo taken by Deborah Tosline.

Photo 17. – Buried Upstream Flume after July 5th and 6th Stormflows.
Photo taken by Deborah Tosline.

On July 8, 2011, the buried flumes, still cabled to their anchors, were dug out. The upstream flume was completely buried. After unearthing the flume, it was found to be intact and the upstream datalogger was retrieved. The downstream flume was only partially buried and although it was intact it was bent out of shape. The stilling well cap lock was gone however the downstream datalogger was retrieved.

The July stormflows deposited sediments in the diversion inlet preventing normal SCR flows from entering the ERDP. Sedimentation raised the elevations of the ERDP channel bottoms. Future recharge in ERDP would be possible only if the diversion inlet and Channels 1 and 2 were re-excavated. It was determined that further recharge at ERDP would not be pursued.

After the project was washed out by storm events on July 5 and 6, 2011, another significant storm flow event occurred on September 10, 2011 with a maximum discharge measurement of 11,900 cfs at the Cortaro gage. This event scoured and deposited significant material in and around the ERDP. The end result is that the

ERDP, although no longer monitored for flow volumes, is again flowing and additional acreage is infiltrating. While the dynamic nature of the SCR is a constant challenge when locating projects of this type, the excavation of ERDP may have influenced the river's return to this abandoned channel.

Photo 18. – Looking Upstream at Confluence of Channels 1 and 2, Flow in ERDP Continues Following September 2011 Storm Flows.

Photo taken by Deborah Tosline on October 27, 2011.

X. Monitoring

ERDP was developed to enhance recharge and accrue additional effluent LTSC and to test in-channel constructed recharge techniques for potential future constructed recharge projects. Monitoring was essential to evaluate the effectiveness of using abandoned dry channels for spreading SCR flows across the channel bottom and enhancing groundwater recharge. Reclamation monitored inflow and outflow from the ERDP. In addition, Reclamation provided funding for collaborative monitoring partnerships with University of Arizona (UA) and Arizona State University (ASU) researchers.

Recharge at the ERDP provided a unique opportunity to monitor the SCR channel during pre-recharge, start up and sustained recharge conditions. Typically research has been done in the already wetted channel. This project provided an opportunity to research conditions before and after the channel has been wetted. Specialized monitoring provided information regarding the movement of recharged water in the subsurface and development of a biologic clogging layer. This information will be useful for the design and maintenance of potential constructed in-channel recharge projects.

Efforts to develop a collaborative monitoring program during operation of the ERDP resulted in the following proposals:

USGS – proposed repeat measurement of gravity to directly quantify subsurface wetting during infiltration for $80,000.00 to $120,000.00 annually. This two year USGS project would consist of equipment installation and monitoring, groundwater flow modeling and publication of a USGS Science Investigation Report.

UA - Dr. Ty Ferre – proposed taking gravity measurements (GM) during pre- and post-recharge. The proposed gravity investigation would be approximately $23,500.00 and would provide information regarding changes in hydraulic conductivity that would be used to track changes in subsurface water storage.

UA - Dr. Tom Meixner – proposed taking temperature measurements for approximately $30,000.00 to assess channel bottom clogging.

ASU - Dr. Julie Stromberg and Natalie Case – proposed monitoring development of a biological clogging layer for approximately $3,000.00.

Due to limited availability of funds, two monitoring proposals were funded for the ERDP, UA's proposal titled, "*Gravity monitoring of the Lower Santa Cruz River Enhanced Recharge Demonstration Project*" and ASU's proposal titled, "*Prospectus to Study Biological Clogging on the Powerline Gravel Bar Managed Recharge Project*"

These proposals provided low cost options to provide monitoring information.

The UA research was funded under a Bureau of Reclamation Assistance Agreement R11AC32022, under Pub. L. 111-11, Omnibus Public Land Management Act of 2009, Section 9504(b) and the Southern Arizona Water Rights Settlement Act (1982) and the Arizona Water Settlements Act (2004) (LC-7000); A10-1468.

The ASU research was funded as a grant under the Reclamation Act of 1902 (43 U.S.C. Chapter 12), as amended and supplemented by the Colorado River

Basin Project Act, Public Law 90-537, and as amended by Public Law 97-373 and Public Law 95-578, and the Southern Arizona Water Rights Settlement Act (P.L. 97-293) enacted in 1982 and the Arizona Water Settlements Act (AWSA, S-437, Title III), enacted in 2004 and under Public Law 111-11, Omnibus Public Land Management Act of 2009, Section 9504(b) and in accordance with the Desert Southwest Cooperative Ecosystems Studies Unit Agreement No. R10AC40042.

A. Reclamation

Reclamation monitored flow into and out of the ERDP and used the data to calculate and monitor ERDP infiltration rates and recharge volumes for the project.

Raw transducer pressures (in psi) and temperatures (^{0}F) were measured and logged automatically every one-half hour starting on January 28, 2011 by each of the three Hobo U20 pressure transducers. The transducers were installed in the two stilling well tubes attached hydraulically to the upstream and downstream flumes. These internally logged readings were periodically downloaded in the field to a Hobo reader (Shuttle) and then brought back to the office. Fourteen separate data sets were downloaded over the course of the project between January 28 and July 7, 2011. Each day, 48 readings were taken at each transducer.

The data sets varied in duration (dependent on the frequency of site visits) from 8 to 25 days of daily readings. Each data set from the Shuttle included three Onset Hobo format data files. Each of these files were opened using the Hoboware Pro V. 3.0 software program and exported out as *.csv format files for post-processing in Microsoft Excel. Each *.csv data file had the date and time (every 30 minutes) and the corresponding pressure and temperature measurements listed. One data file included barometric pressure and air temperature readings, and the other two files were the upstream flume flow data file and the downstream flume flow data file with the date/time and corresponding water pressure and water temperatures.

The individual data sets were ultimately combined into a master worksheet (“MRII ERP_Flumes_FlowCalcs_1-28to7-8 MASTER.xlsx”). The worksheet was used to store the raw readings, calculate the net transducer pressure, convert net pressures to feet of hydraulic head, store the EZ flume constants and coefficients, and calculate the discharge through the flume using the Nuway flume equation. From these discharges, accumulated flow volumes and infiltration rates were estimated.

Transducer data were processed by subtracting the barometric pressure readings (in psi) from the absolute pressure (sum of water and air pressure acting on the transducer diaphragm) to derive the corrected hydraulic head pressure (in psi). The hydraulic head pressure was then converted to feet of water. For the upstream flume, a 0.33-foot offset was subtracted, and for the downstream flume, an offset of 0.36 feet was subtracted to account for the portion of the transducer diaphragm that was installed in a sump (submerged) below the zero cfs datum of the flume (see Figure 4). Otherwise, the transducer pressure readings would be 0.33 feet and 0.36 feet too large. The corrected zero cfs hydraulic head (in feet) is the h1 variable in the Nuway flume formula shown below. The Nuway Flume and Equipment Co., Inc. provided specifications and the flume formula for the EF10 Nuway EZ Flow flume via faxogram on February 15, 2011. The formula is based on the Winflume software (Wahl, Tony L., et al, 2000). For the 10 cfs EF10 EZ Flow Flumes used in this project, the K1 coefficient is 11.85 feet.

The Nuway formula is: $\mathbf{Q_{cfs} = K1*(h1)^{1.619}}$

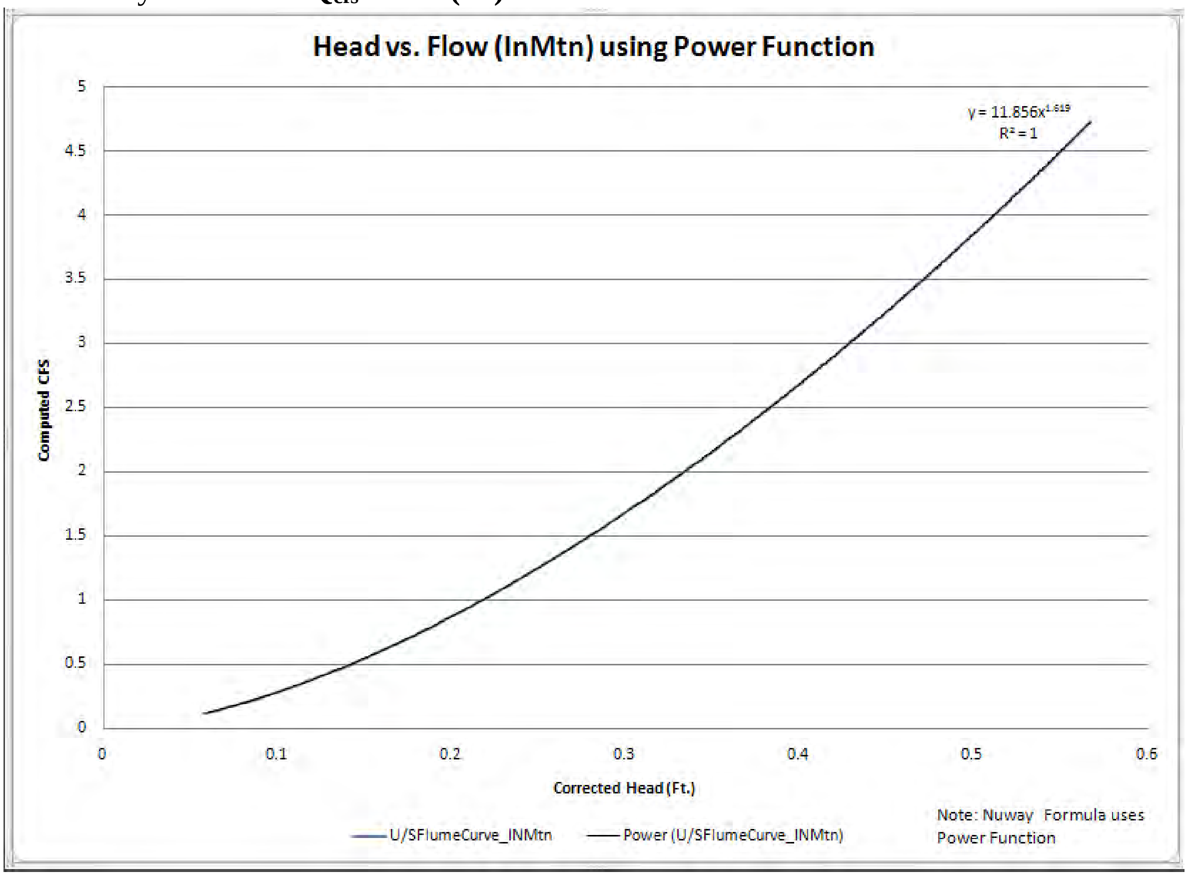

Figure 4 – Stage - Discharge Relationship for the 10 CFS Nuway EZ Flume

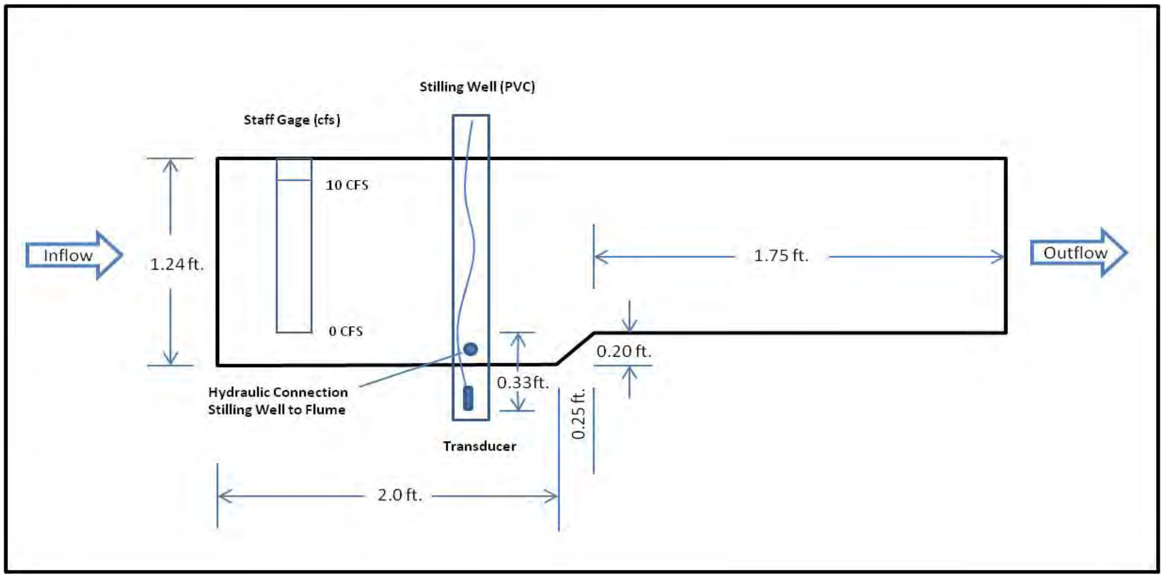

Figure 5. – Profile of Nuway EF10 EZ Flow Flume Showing Pressure Transducer Location (Upstream flume shown with 0.33-foot offset)

To estimate infiltration in the project, the downstream flume discharge was subtracted from the upstream flume discharge to derive the difference in volumetric flow rate (actually an instantaneous per second value at the time the reading was logged) which was used to estimate the effluent flow infiltrated in the ERDP channels between the flumes. This “lost” volume in cubic-feet/second each 30 minutes was converted to an equivalent acre-feet/day and cubic-feet/day reading, considered as constant over each 30-minute interval (diurnal flows varied throughout a given day but for purposes of estimating the infiltration and volume of effluent recharged in the project, flows were assumed to be constant each 30-minutes). Dividing the cubic feet/day reading by the channel area of 17, 890 square feet yielded the average infiltration rate for each 30-minute reading in terms of feet/day.

Average daily infiltration in feet/day was calculated (days were incremented at midnight) by taking the flow values (cfs) calculated for each 30-minute measurement and subtracting the downstream flume flow values from the upstream flume values.

To estimate the volume of effluent recharged in the ERDP, the difference in flow (cfs) between the upstream and downstream flumes was converted to gallons for each 30 minute interval and summed to derive the total volume in gallons and acre-feet per day of effluent recharged in the ERDP channels.

Calculated flow in the downstream flume was periodically greater than in the upstream flume at a given 30 minute interval. When downstream flume flows were higher than upstream flume flows this resulted in negative flow values for the project, which made it appear as if the project produced water and complicated the infiltration analysis. When deriving estimated cumulative volume of effluent recharged in the project, negative flows (cfs) were not used and were zeroed out. It is theorized that diurnal fluctuations in the effluent flow, the resulting stage height changes in the flumes, and normally close stage heights in the upstream and downstream flumes, are mostly the reason for this. Increases in the downstream stage height could also be due to lateral seepage adding water to the project downstream of the upstream flume. Lateral seepage would most likely come from the mainstem SCR, but possibly from nearby recharge facilities such as the Lower Santa Cruz Replenishment Project which is only one-half mile upgradient and has high infiltration rates or less likely, the Avra Valley Recharge Project (AVRP) which is also one-half mile upgradient and 24 feet above the ERDP. Surface seepage from AVRP has not been observed in the northern excavated face or ground level of BKW Farm's shooting range which lies immediately north of AVRP and upgradient of ERDP (MDWID, 2012, personal communication with Mark Stratton). Future work could include water quality sampling of lateral flows for laboratory analysis of nitrate, sulfate, and chloride to determine whether the lateral flow source is from recharged CAP water or from the SCR mainstream. Another possible reason that flow levels in the downstream flume were sometimes higher than those in the upstream flume, may have been due to debris that was caught in the flume, damming outflows and resulting in raising the water level in the downstream flume and associated stilling well.

Periodically, visual readings (in cfs of flow) were taken from flume staff gages during field visits. Manual staff gage readings taken from the eastern sides of the upstream and downstream flumes were compared to the calculated flows from the transducers at the same time and day, or in several cases, to the nearest 15 to 30 minutes. For the upstream flume, out of 17 readings, the calculated flow (cfs) was almost always lower than the manual reading being 33 to 98 percent of the manual readings. Two calculated readings were higher. Of 15 manual readings for the east side staff gage on the downstream flume, eleven calculated flows were 10 to 99 percent of the manual readings (smaller), with two higher than the manual readings. Three zero flow readings matched. These comparisons were based on flows usually less than 1 cfs. The order of magnitudes were comparable. Higher flows or smaller flumes (such as the EF5, or 5 cfs flume) likely would have provided better resolution.

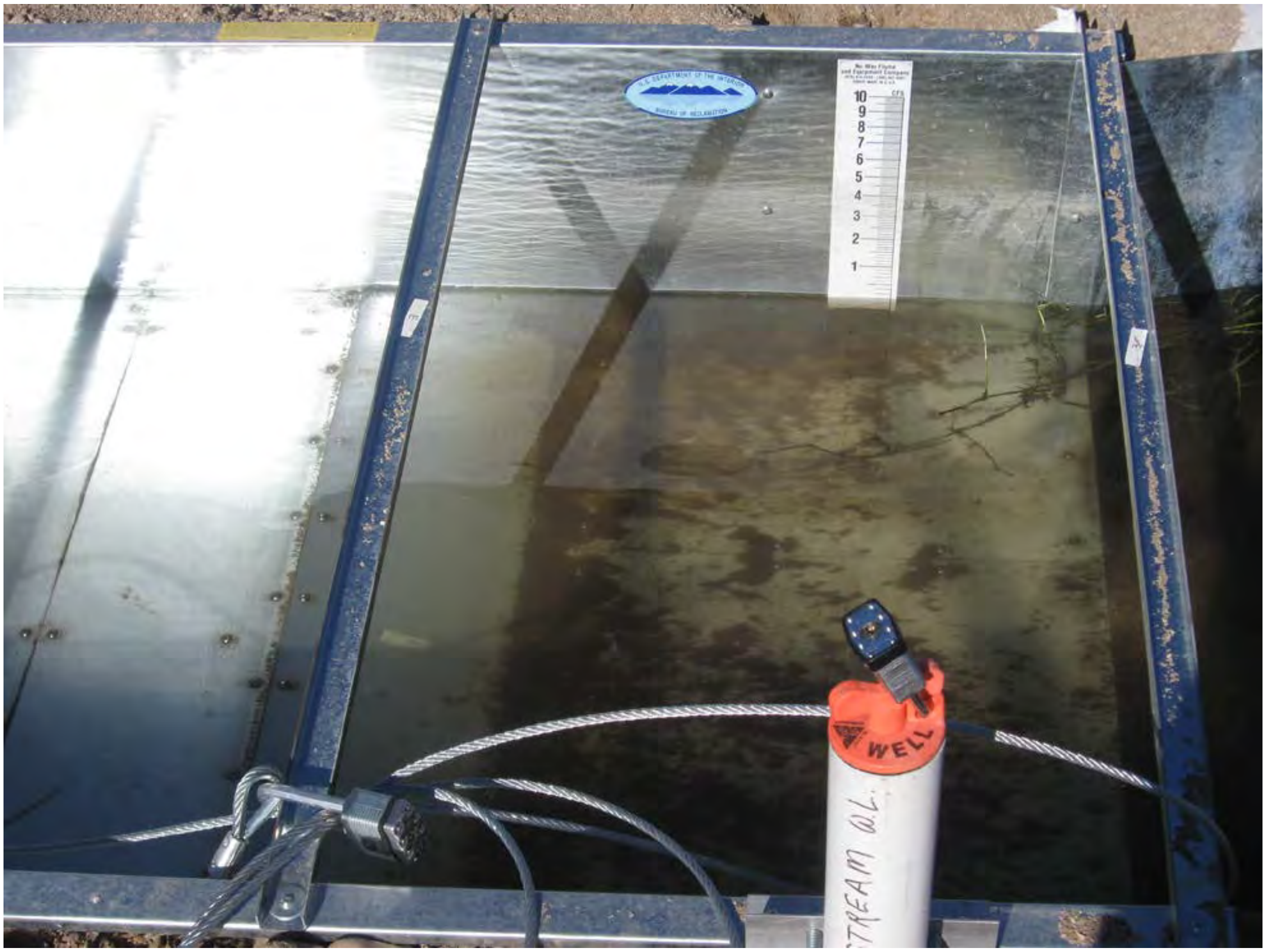

Photo 19. – Staff Gage on Sidewall of Upstream Flume.
Photo taken by Deborah Tosline.

B. Arizona State University

ASU staff Natalie Case and Dr. Julie Stromberg conducted research to capture trends and highlight factors that contribute to biologic clogging of channel sediments in the ERDP. The resulting report entitled, "Biological Clogging on the Enhanced Recharge Project" is provided in Appendix M.

Treated effluent contains nutrients that promote development of a biologic clogging layer on the channel bottom. When the channel bottom becomes clogged, a long narrow flow channel develops which results in decreased infiltration area and recharge. Storm flows can scour the channel bottom, break up the biologic clogging layer, spread flows across the channel bottom, and increase recharge until the biologic clogging layer develops again. The researchers hypothesized that the constant supply of warm, high-nutrient effluent that feeds the river and ERP channel would promote biological clogging. The objectives of the research were to monitor the ERDP channel from its initial construction, development, and disturbance regime to capture trends in infiltration and sediment biology and pinpoint factors that may contribute to reduced infiltration. Four sampling transects were established at the ERDP, three transects along Channel 1 and one transect in the SCR (Figure 6).

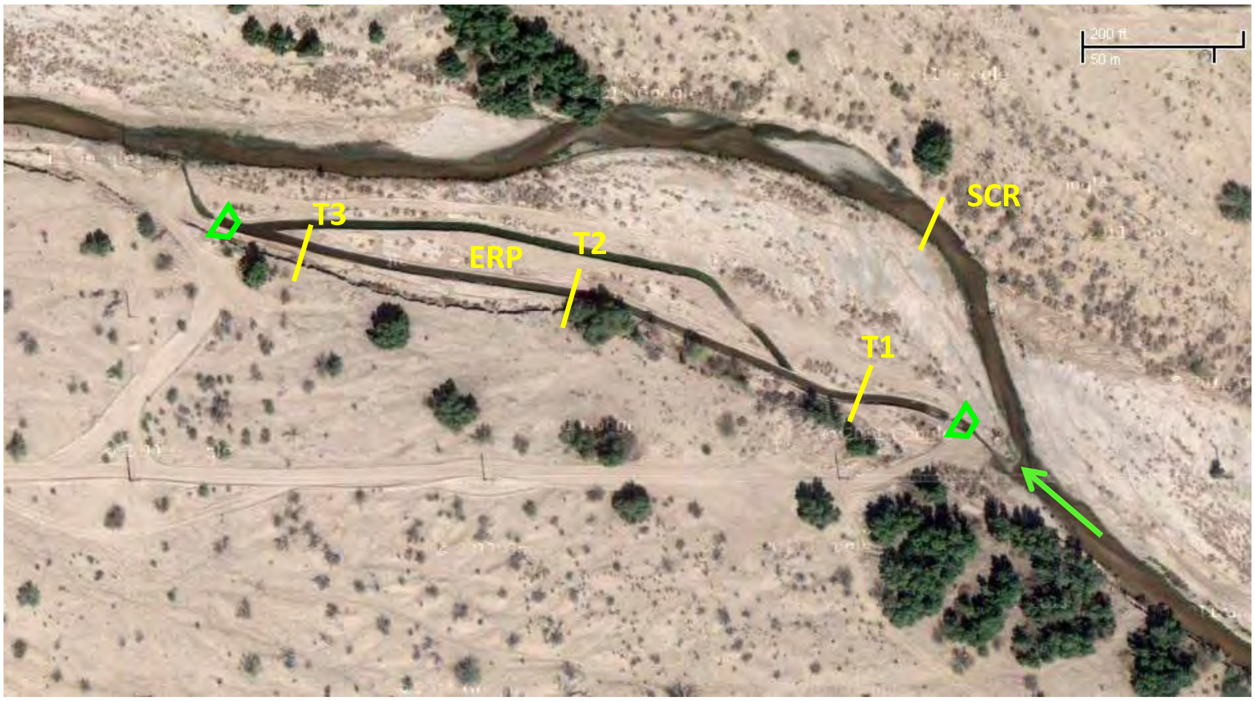

Figure 6. – SCR and Two Previously Abandoned Low Flow ERDP Channels.
Yellow lines indicate locations of transects, and green boxes are the flumes used to measure flow diverted from the main channel into and out of the secondary channels.
Photo source: Google Maps, accessed 8/2011

Monitoring at each transect included: hydraulic conductivity (the rate at which water moves through the ground and an indicator of clogging), sediment cores for bacterial biomass measurements, and measurements of flow, dissolved oxygen, and temperature. Measurements were made to determine if reduced infiltration and bacterial biomass are correlated. Monitoring began on January 29, 2011.

Conclusions, taken from the ASU report:

> "While the duration of the ERP pilot study was short, we found a number of patterns that may be useful in guiding future studies in improving infiltration:
>
> - Low flow conditions in the ERP promoted high biological activity and retention of fine particles, leading to declines in hydraulic conductivity.

- Texture may be a limiting factor on conductivity - flooding or flushing the ERP may help reduce fines and improve overall conductivity.
- Low conductivity can be overcome by drying and ripping, but the time between channel disruptions could potentially be extended if flow in the channel were increased.
- There was evidence for biological clogging before treatment/maintenance events, but not after treatment. Further research is needed to clarify this relationship.
- The small sample size and short sampling period of this study increase uncertainty, leaving these as preliminary conclusions.

Conclusions from this study could be applied to future scenarios for the Santa Cruz River. Water use projections indicate that treated wastewater will be increasingly utilized in the urban setting, leaving less volume available for discharge to the river. If projections that the amount of water discharged to the Santa Cruz is significantly reduced in the near future, then low flow conditions in the channel could become the norm. In this case, we would expect to see more clogging conditions and poor infiltration in the river. If future infiltration studies are conducted with the ERP, it would be interesting to use the two ERP channels as separate treatments over the same period to determine if one combination of drying, scraping, and ripping is more effective than another. Examining treatments over the same time period would reduce interfering variables like temperature increases or changes in the water quality being discharged."

C. University of Arizona

Dr. Ferré and his students at the University of Arizona conducted gravity monitoring at the Enhanced Recharge Demonstration Project (ERDP). The resulting report entitled, "Monitoring Enhanced Stream-Bed Recharge Using Time Lapse Gravity" is provided in Appendix N.

Five gravity monitoring stations were installed perpendicular to the ERDP (Figure 7) and were designed to capture both vertical infiltration and lateral subsurface water movement away from the excavated channel. During the survey, background gravity values were collected prior to release of water to the ERDP and subsequent measurements were taken after water was diverted into the ERDP. Gravity surveys began January 18, 2011.

Figure 7. – UA Gravity Monitoring Station Locations at the ERDP.
Photo source: Google Maps accessed on April 26, 2011.

Gravity measurements were taken using a Burris gravimeter, a ground based relative gravity meter, to directly measure changes in subsurface water storage. This method, which measures changes in the Earth's local gravity field to infer mass changes, is directly sensitive to mass storage change. The unique aspect of this work was the geometry of the infiltration area, which was comprised of a relatively short linear feature adjacent to an active streambed. The objectives were: 1) to compare gravity-based estimates of mass change with time integrated gauging measurements to test the ability of gravity measurements to monitor enhanced recharge, and 2) to develop recommendations for future, similar uses of gravity for recharge monitoring and hydraulic property estimation.

Conclusions, taken from the UA report:

> "Time-lapse gravity measurements provided insight into changes in storage due to infiltration into the excavated channel. The gravity change time series is consistent with a conceptual model of infiltration and mounding in two adjacent streams, suggesting that this could form the basis for more quantitative hydrologic modeling, where necessary. Gravity results showed significant water movement laterally from the excavated channel, in the direction away from the active channel. Similar monitoring efforts could be

very useful in determining the potential for water and solute movement laterally from active channels. "

XI. Results

The ERDP was initially operated undisturbed for eight weeks or 60 days while inflows and outflows from the project were monitored. Measured flow rates into the project during this time ranged from 4.81 cfs to zero cfs and averaged 1.96 cfs. Total volume of water recharged during this time was 16.8 AF with a daily average recharge rate of 0.27 AF. Infiltration rates, shown in Figure 8 and Table 3, averaged 1 foot per day (ft/d), and ranged from a maximum of 15 ft/d to a minimum of 0 ft/d. Infiltration rates declined steadily to February 6, 2011 when they remained below 1 ft/d until the first maintenance event.

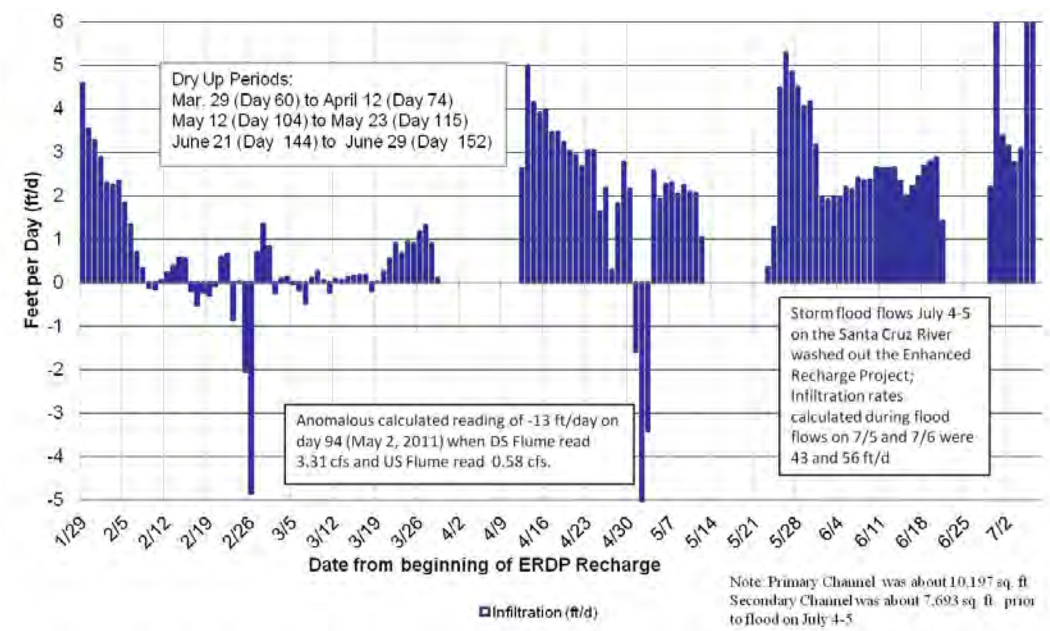

Figure 8. – Daily Average Infiltration Rate using Computed (Nuway) Formula January 28 through July 8, 2011.

After the first maintenance event, the project was rewetted on April 12, 2011. The project was operated for 30 days. SCR flow rates measured at the SCR Cortaro gage declined from a maximum of 75 cfs in February and March to a maximum of 66 cfs in April. Measured flow rates into the project averaged 0.78 cfs and ranged from 2.28 cfs to zero cfs. Total volume recharged during this time was 30.3 AF and the average daily recharge rate was 1.01 AF. Infiltration rates averaged 3 feet per day (ft/d), and ranged from a maximum of 10 feet per day (ft/d) to a minimum of zero ft/d.

Table 3. – ERDP Operations, Maintenance Schedule and Flow Rates Measured at the Upstream Flume

Dates	Days	Status	Max Flow (cfs[3])	Min Flow (cfs)	Ave Flow (cfs)	Total Volume Recharged (AF[4])	Average Daily Volume Recharged (AF)	Average Daily Infiltration Rate (ft/d[5])	Maintenance Activities
1/28/11 to 3/29/11	60	O[1]	4.81	0	1.96	16.8	0.28	Max 15 Min 0 Ave 1	
3/29/11 to 4/12/11	15	M[2]	---	---	---				Dry, scrape, rip once
4/12/11 to 5/12/11	30	O	2.28	0	0.78	30.3	1.01	Max 10 Min 0 Ave 3	
5/12/11 to 5/23/11	12	M	---	---	---				Dry, rip twice
5/23/11 to 6/21/11	29	O	2.52	0	1.07	33.2	1.14	Max 9 Min 0 Ave 3	
6/21/11 to 6/2911	8	M	---	---	---				Dry only
6/29/11 to 7/5/11, 0230	5	O	6.42	0.007	1.40	8.5	1.69	Max 17 Min 0 Ave 4	
Total	124	O				88.8			

Footnote:
[1] O = Operating
[2] M = Maintenance
[3] cfs = Cubic Feet per Second
[4] AF = Acre Feet
[5] ft/d = feet per day

After the second maintenance event on May 12, 2011, the project was rewetted on May 23, 2011. The project was operated for 29 days. Flow rates into the ERDP increased as a result of additional excavation at the diversion inlet channel. The project was operated for 30 days. Measured flow rates into the project averaged 1.07 cfs and ranged from 2.52 cfs to zero cfs. Total volume recharged during this time was 33.2 AF and the average daily volume recharged was 1.11 AF. Infiltration rates averaged 3 feet per day (ft/d), and ranged from a maximum of 9 feet per day (ft/d) to a minimum of zero ft/d.

After the final maintenance event on June 21, 2011 the project was rewetted on June 29, 2011. Measured flow rates into the project averaged 1.40 cfs and ranged from 6.42 cfs to 0.007 cfs. Total volume recharged during this time was 8.5 AF and the average daily volume recharged was 1.69 AF. Infiltration rates averaged 4 feet per day (ft/d) and ranged from a maximum of 17 feet per day (ft/d) to a minimum of 0 ft/d.

XII. Conclusions

As a demonstration project, the ERDP provided an opportunity for Reclamation to work collaboratively with Partners during planning and construction activities, increase recharge and LTSC accrual at the MR II USF, test in-channel recharge methods, and use the results for planning potential large scale in-channel recharge projects.

There were no major errors that impeded the project, however small errors occurred that may be considered when planning future potential in-channel recharge projects. These included:

- Pre-construction blue stake survey was not completed prior to excavation.
- Barriers to prevent water flow at the divergence and convergence between Channel 1 and Channel 2 were breached.
- Flumes were not level and could have been sized smaller.
- During early operations, there was no flow into the ERDP during SCR diurnal low flows.

The results of the project show:

- Spreading flows across the SCR channel bottom increased infiltration rates and recharge volumes.
- Consistent communication and information sharing with Partners promotes efficiency during collaborative construction efforts.
- Fine sediments present on the channel bottom during the first maintenance event were residual from construction, once they were removed; deposition of fine sediments on the channel bottom was minimal.
- During each operation phase, in-channel recharge rates declined over time.

- Channel maintenance increased recharge rates initially 4 to 5 times that of pre-maintenance rates.
- 88.8 AF were recharged at the ERDP over a period of 124 days.
- Recharge rates were 0.28 AF per day during the first 60 days of operations and 1.13 AF per day during the last 64 days of operations; this increase was due to maintenance and represents possible rates for SCR in-channel effluent recharge in an area 10 feet wide and 1,820 feet long.
- Using the 1.13 AF per day infiltration rate, an equivalent recharge rate for the project would be 3.3 AF/mile/day.
- Higher flow rates for in-channel recharge of effluent may reduce biological activity, flush fine particles, reduce maintenance requirements, and improve hydraulic conductivity and infiltration rates.
- Time-lapse gravity measurements provide insight into changes in storage due to infiltration and may form the basis for quantitative hydrologic modeling.
- Constructing multiple flow channels in an area with small elevation differences from the SCR flow channel requires a smaller construction effort but is more susceptible to destruction from flood flows.
- Although the flow measuring devices were washed out during the July storm flows, September storm flow scour resulted in water continuing to flow in the ERDP channels, spreading flows across the SCR channel and presumably increasing infiltration.

The success of this project was due to the expertise provided by the IGA Partners and Reclamations interdisciplinary team. Extensive planning, coordination, communication, and information sharing supported the collaborative effort resulting in productive and efficient teamwork. The comprehensive planning process facilitated easy adaptation of any required changes. Working relationships were established and detailed project information was provided, which facilitated open discussions about the project throughout each phase.

In the future, Reclamation may build constructed recharge projects to more effectively utilize SAWRSA effluent. The ERDP provided an opportunity to: identify the steps required to build in-channel constructed recharge projects, establish relationships with regulatory representatives, and construct and test in-channel recharge methods. The experience gained from the ERDP may be used towards development of potential future constructed in-channel effluent recharge projects.

XIII. Recommendations

The ERDP showed that diverting flows from the incised SCR channel into adjacent abandoned flow channels increases infiltration and associated recharge. Based on ERDP recharge rates (3.3 AF/mile/day), to fully utilize the SAWRSA effluent volume of 28,200 AFY, a constructed in-channel recharge project would require six, 10-foot wide, 4 mile long channels to recharge 28,908 AFY. The SCR channel bottom width in the vicinity of the ERDP is approximately 600 feet. An in-channel constructed recharge project of these dimensions would use 10% of the channel width in this area. The dimensions of the constructed recharge channels could be modified depending on location and site specific conditions. Also, changes in maintenance and operation methods could increase recharge rates and reduce project size requirements. In-channel recharge has multiple benefits including conservation and management of water resources, maintenance and enhancement of environmental habitat and increased public recreation opportunities.

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Appendix A.

Resolution Amending the 2010 budget and Authorizing Expenditure under the Intergovernmental Agreement regarding Permitting and operating Managed In-Channel recharge of Effluent in the Santa Cruz River Channel

RESOLUTION
AMENDING THE 2010 BUDGET AND AUTHORIZING EXPENDITURE UNDER THE INTERGOVERNMENTAL AGREEMENT REGARDING PERMITTING AND OPERATING MANAGED IN-CHANNEL RECHARGE OF EFFLUENT IN THE SANTA CRUZ RIVER CHANNEL

THE UNDERSIGNED, being duly authorized and representing not less than a majority of the voting participants to the Intergovernmental Agreement Regarding Permitting and Operating Managed In-Channel Recharge of Effluent in the Santa Cruz River Channel, initially filed with Pima County Recorder at Docket No. 12066, pages 3364- 3412, and as subsequently recorded reflecting the addition of the Bureau of Reclamation as a participant (the "IGA"),

DO HEREBY RESOLVE that:

1. The Annual budget for the Lower Santa Cruz Managed Storage Facility for Calendar year 2010 be and hereby is amended to include the expenditure of up to $6,500 for the rental of a 5,000 gallon water wagon to be paid for from retained funds held by the Facility Operator pursuant to the IGA and not from additional assessments;

2. The rented equipment is to be utilized solely in conjunction with the Bureau of Reclamation's Enhanced Recharge Project;

3. Sidney Smith, acting on behalf of the Facility Operator of the Lower Santa Cruz Managed Storage Facility, be and hereby is authorized and directed to expend up to $6,500 of retained funds held by the Facility Operator pursuant to the IGA toward the cost of renting, including the offered insurance, a 5,000 gallon water wagon as set forth below;

4. Payment shall be made to the entity renting the 5,000 gallon water wagon within five (5) business days of the Facility Operator being presented with a copy of the rental company's invoice therefore and a statement that it was for use in conjunction with Enhanced Recharge Project. The entity receiving the funds shall pay the rental company within five (5) business days after receiving payment and shall provide proof of such payment to the Facility Operator.

5. By this Resolution, the Participants and the Facility Operator are merely a funding source and this Resolution shall not create or infer any responsibility for the rental, operation, care, maintenance, condition, or return of the equipment rented, or any other aspect of the Enhanced Recharge Project, other than the provision of up to $6,500 toward the cost of the rental of a 5,000 gallon water wagon payable in the manner set forth herein.

Dated this 22 day of December 2010.

CORTARO-MARANA IRRIGATION DISTRICT

By: Sidney Smith

METROPOLITAN DOMESTIC WATER IMPROVEMENT DISTRICT

By: [signature]

FLOWING WELLS IRRIGATION DISTRICT

By: [signature]

PIMA COUNTY

By: [signature]

TOWN OF MARANA

By: Dorothy O'Brien

CITY OF TUCSON

By: [signature]

TOWN OF ORO VALLEY

By: Philip Saletta

AVRA VALLEY IRRIGATION AND DRAINAGE DISTRICT

By: [signature]

BUREAU OF RECLAMATION

By: [signature]

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Appendix B

Categorical Exclusion Checklist (CEC) – Enhanced Recharge Demonstration Project on the Santa Cruz River

7-1596B (9-89)
Bureau of Reclamation

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NOV - 9 2010

MEMORANDUM

To: Area Manager, Phoenix, Arizona
Attention: PXAO-1000

From: Bruce D. Ellis
Chief, Environmental Resource Management Division

Bruce D. Ellis

Subject: Categorical Exclusion Checklist (CEC) – Enhanced Recharge Demonstration Project on the Santa Cruz River

The subject CEC is attached for your approval and signature. If you have any questions, please contact Mr. John McGlothlen at extension 6256.

Attachment

cc: Attention: LC-2624 (Vernier)
PXAO-7005 (Tosline)
(w/att to ea)

WBR:McGLOTHLEN:JHaragara:11/8/10
1500 Chrono
1500 File: SAWRSA – Managed Recharge

Categorical Exclusion Checklist

Date: November 2010

Project: Southern Arizona Water Rights Settlement Act (SAWRSA).

Nature of Action: Enhanced ground-water recharge demonstration project on the Santa Cruz River (SCR).

Exclusion Category: 516 DM 14.5 C(3) – Minor construction activities associated with authorized projects which correct unsatisfactory environmental conditions or which merely augment or supplement, or are enclosed within existing facilities.

Evaluation of criteria for Categorical Exclusion:

1.	This action or group of actions would have a significant effect on the quality of the human environment. (40 CFR 1502.3)	No_X_ Uncertain_ Yes_
2.	This action or group of actions would have highly controversial environmental effects or involve unresolved conflicts concerning alternative uses of available resources. (43 CFR 46.215 (c))	No_X_ Uncertain_ Yes_
3.	This action would have significant impacts on public health or safety. (43 CFR 46 215 (a))	No_X_ Uncertain_ Yes_
4.	This action would have significant impacts on such natural resources and unique geographical characteristics as historic or cultural resources; parks, recreation and refuge lands; wilderness areas; wild or scenic rivers; natural national landmarks; sole source aquifers; wetlands; floodplains; prime farmlands; migratory birds; and other ecologically significant or critical areas. (43 CFR 46.215 (b))	No_X_ Uncertain_ Yes_
5.	This action would have highly uncertain and potentially significant environmental effects or involve unique or unknown environmental risks. (43 CFR 46 215 (d))	No_X_ Uncertain_ Yes_
6.	This action would establish a precedent for future actions or represent a decision in principle about future actions with potentially significant effects. (43 CFR 46.215 (e))	No_X_ Uncertain_ Yes_
7.	This action would have a direct relationship to other actions with individually insignificant, but cumulatively significant, environmental effects. (43 CFR 46.215(f))	No_X_ Uncertain_ Yes_

8. This action would have significant impacts on properties listed, or eligible for listing, on the National Register of Historic Places as determined by Reclamation. (43 CFR 46.215 (g)) — No X Uncertain_ Yes_

9. This action would have significant impacts on species listed, or proposed to be listed, on the List of Endangered or Threatened Species, or have significant impacts on designated Critical Habitat for these species. (43 CFR 46 215 (h)) — No X Uncertain_ Yes_

10. This action would violate Federal, State, local, or tribal law or requirements imposed for protection of the environment. (43 CFR 46 215 (i)) — No X Uncertain_ Yes_

11. This action would adversely affect Indian Trust Assets. (S.O. 3175) — No X Uncertain_ Yes_

12. This action would have a disproportionately high and adverse effect on low income or minority populations. (43 CFR 46 215 (j)) — No X Uncertain_ Yes_

13 This action would limit access to and ceremonial use of Indian sacred sites on Federal lands by Indian religious practitioners or significantly adversely affect the physical integrity of such sacred sites. (43 CFR 46 215 (k)) — No X Uncertain_ Yes_

14. This action would contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area or result in actions that may promote the introduction, growth, or expansion of the range of such species. (43 CFR 46 215 (l)) — No X Uncertain_ Yes_

NEPA Action Recommended -	
Categorical Exclusion	X
EA	_
EIS	_

Explanation / remarks

Background

The Department of the Interior, through Reclamation, receives 28,200 acre-feet per year (AFY) of secondary treated effluent from Tucson area wastewater treatment plants to assist in implementation of the Southern Arizona Water Rights Settlement Act (SAWRSA) of 1982. Reclamation recharges this effluent at a Managed Underground Storage Facility (USF) in the Santa Cruz River (SCR) at the Lower Santa Cruz River Managed Recharge Project (Phase II, permit number 71-591928), which is permitted to recharge up to 43,000 AFY. The Phase II facility begins at Ina Road and extends 17.91 miles along the SCR channel to Trico Road in Pima County. A managed recharge permit allows for treated effluent to be discharged to a streambed to percolate into the aquifer, without the assistance of a constructed device, to accrue Long-Term Storage Credits (LTSC) for one-half of the volume of water recharged.

Reclamation is working with partners Cortaro-Marana Irrigation District, Town of Marana, Avra Valley Irrigation and Drainage District, Flowing Wells Irrigation District, Metropolitan Domestic Water Improvement District, Pima County, Town of Oro Valley, and the City of Tucson to conduct the proposed demonstration project to enhance recharge at the Phase II facility, which historically has recharged less than 50 percent of the permitted volume. Reclamation and its partners would like to enhance infiltration rates at the Phase II Project to recharge the allowable permitted volume and increase the number of LTSC that are accrued annually. The proposed demonstration project would involve diverting water from the current thalweg and spreading the water across dry portions of the SCR utilizing secondary low-flow channels.

Project Purpose

Current recharge in the Phase II facility does not fully utilize the recharge potential of the 28,200 AFY of treated effluent available to Reclamation. The proposed demonstration project will examine possible increased recharge from spreading diverted effluent onto dry channels. Feedback from the demonstration project would be incorporated into planning and design of a permanent Constructed Recharge Facility to increase recharge of effluent and accrue a higher percentage of LTSC to meet the objectives of the SAWRSA. The demonstration project would run up to a maximum of 2 years, beginning in the summer of 2010.

Project Location

Recharge Demonstration Site. A preliminary investigation of potential enhanced recharge sites within the Phase II facility began in 2006. Preliminary surveys of potential sites were conducted and a design concept has been developed for a site known as the Powerline Gravel Bar (Figures 1-3). The Powerline Gravel Bar is located on the main channel of the SCR along the southern boundary of Section 34, Range 11 East, Township 11 South (Latitude 32°25'27.78"N Longitude 111°12'50.40"W), on land owned by the Pima County Regional Flood Control District within the Town of Marana.

Properties that include and/or adjoin the project site are owned by the Arizona State Land Department (ASLD), Pima County, and Town of Marana. Primary access to the site is from Tangerine Farms Road through the Marana Heritage River Park (via Heritage Park Drive) on the east side of the SCR. Secondary access is possible from North Sanders Road along an existing powerline maintenance road on the west side of the SCR. The primary access route crosses land owned by the Town of Marana; the secondary access route crosses land owned by the ASLD and Pima County. Permission to access these lands for project purposes were authorized by each entity through issuance of either a right-of-entry (ASLD) or license agreement (Pima County and Marana).

The Town of Marana is the administrator of the floodplain of the SCR where the demonstration project would be located. As such, they require a floodplain use permit be obtained prior to construction of enhanced recharge features. Additionally, since the project site is within the Marana Town Limits a Type II grading permit is required. For compliance with the provisions of the flood plain use permit the project must show compliance with the terms and conditions of the Town of Marana's land development code as related to floodplain impacts, including no rise in base flood elevations. As a condition for coverage under the Type II grading permit, a Pima County Air

Quality Activity Permit for Fugitive Dust was required and was obtained on April 8, 2010. Flood plain use and Type II grading permit coverage was granted by the Town on May 3, 2010.

Sediment Disposal Sites. Two sites are available for disposal of excavated material that is removed from the recharge demonstration area (Figure 4). Site 1 is adjacent to an existing road leading to the Marana High Plains recharge site. The fill will be placed in previously disturbed areas adjacent to the road. Site 2 consists of an existing dike road adjacent to the SCR. Fill would be placed on top of the road to stabilize it. Both sites are located on ASLD land leased to John Kai and subleased to Charles "Brad" DeSpain. Mr. DeSpain has granted permission to Reclamation to dispose of the excavated material on this leased area.

Project Description

The proposed demonstration project would divert a portion of the flow from the current thalweg into a historic thalweg (secondary low-flow channel) cut off during flooding that occurred between 2006 and 2009 (Figures 2 and 3). A hydraulic connection to the former thalweg will be provided by a combination of excavation and redirection of flows. The approximate alignment of the historic thalweg would be lowered through excavation to match the invert elevation of the SCR. Figure 3 shows the diversion point and channel alignment as well as a section through the SCR channel near the diversion point. Expected flow diverted from the SCR is approximately one to seven cubic feet per second. The demonstration project would operate for approximately two years.

Diversion structure. Excavated material would be placed in the SCR to direct flow into the newly excavated channel (Figure 3). This material would form a berm (22-feet long by 6-feet wide by 2 feet high) both perpendicular and parallel to the stream flow direction. The projection into the stream is anticipated to be about 7 feet with the remaining 18 feet of the berm parallel to stream flow producing an L-shaped structure. Two concrete anchors will be installed in the channel alluvium to act as anchorage points for the flow measurement devices. The flumes would be cabled to buried, pre-cast concrete anchors to prevent them from being dislodged and carried away by flood flows (Figure 2). Placement of excavated material to produce the L-shaped berm requires approximately 10 cubic yards of material with a footprint of 0.004 acres in the jurisdictional waters. Excavation and subsequent backfill for setting the anchors would require the placement of approximately 3 cubic yards of fill material. Placement of this fill material would affect 0.0003 acre of jurisdictional waters.

Channel excavation. Approximately 730 cubic yards of material would be excavated along the alignment of the historic thalweg to provide a hydraulic connection with the SCR. The receiving channel's final dimensions consist of a five foot bottom width, 2:1 side slopes, and an invert slope of approximately 0.0025 ft/ft. Average excavation depths range from approximately 1 - 2.75 feet. The alignment and limits of excavation along the historic thalweg are shown on Figure 2. This excavation would affect approximately 0.37 acre. With the exception of alluvial material used for construction of the diversion and flow calming features, excavated material would be removed with an excavator, deposited directly into a dump truck, and transported to an upland disposal site. The following two receiving sites have been identified for this material: (1) road surface on the secondary access route immediately east and north of the High Plains recharge basins and (2) farm land north and east of the recharge basins. Translocation of this material to an upland disposal site is intended to avoid the discharge of additional material into waters of the United States.

Calming features. In order to enhance recharge, several flow calming features (check dams and meander installations) will be installed in the secondary low-flow channel to produce backwater effects or increased flow paths, see Figures 2 and 3. Flow obstruction will span either the full channel width to provide a backwater, or approximately half the channel width to induce a meander in the flow. Flow depth in the channel with no installations is expected to be about one foot. With the features in place there will be localized increases in the water surface. The total number of flow calming features installed is undetermined at this time but the estimated maximum would be 10 check dams and 5 meander installations. After the initial diversion is made to the former channel and calming feature effectiveness is quantified, the group may decide to enlarge or reconfigure the main receiving channel or develop additional flow channels across the gravel bar to further increase the potential for recharge. Additional channels would be fed by diverting water from the main receiving channel. Any excavation required to further develop the recharge potential would be treated similarly as during the main diversion by hauling the material to an upland disposal site. Flow calming features may be installed in future channels in a similar fashion to the preliminary channel. See Figure 2 for illustrations of potential future enhancements. These installations will be constructed using approximately 11 cubic yards of excavated alluvial material.

Flow measurement. Flow measurement devices constructed of sheet metal would be installed in the inlet of the receiving channel and near the downstream connection point with the SCR to monitor inflow and outflow. These devices will be removed upon completion of the demonstration project.

Biological Resources

A site visit was conducted by a Reclamation biologist on November 19, 2009. The east bank of the SCR floodplain has been stabilized with soil cement and urban development (residential housing and the Heritage River Park) has encroached to the edge of the floodplain. The west bank of the SCR remains natural and the adjacent terrace is undeveloped with the exception of a powerline, access road, and unauthorized trails.

The Sonoran Riparian Scrubland community (Brown 1994) occurs in and along drainages where the vegetation is considered too dense to qualify as a "desertscrub or strand community" and not tall or structured enough to be considered a "forest and woodland community". The vegetation has adapted to the successional situations that occur in the flood-prone areas it inhabits (Brown 1994). Vegetation in the project area varies in density from low to moderate. Vegetation along the lower floodplain terrace is dominated by quail bush (*Atriplex lentiformis*) and to a lesser extent four-wing saltbush (*Atriplex canescens*). The side channel (into which the effluent will be diverted) is also dominated by quailbush and four-wing saltbush and lined along the south bank with Athol tamarisk (*Tamarix aphylla*) and two small Goodding willow (*Salix gooddingii*) trees. The remaining floodplain vegetation consists of: saltcedar (*Tamarix* sp.), mesquite (*Prosopis velutina*), desert broom (*Baccharis sarathroides*), a small patch of common reed (*Phragmites australus*), and cocklebur (*Xanthium* sp.). The adjacent upland habitat consists of typical Sonoran Desertscrub species: littleleaf paloverde (*Parkensonia microphylla*) and velvet mesquite (*Prosopis velutina*).

Wildlife species in the project area are typical of the lower Sonoran Desert. The lack of gallery riparian vegetation will result in reduced numbers of avian species. But the project area still provides suitable habitat for resident birds such as Abert's towhee (*Pipilo aberti*) and Gambel's quail (*Callipepla gambelii*) as well as wintering sparrows due to the extensive stand of *Atriplex*. The upper floodplain terrace provides suitable habitat for various reptiles and small mammals. The SCR also provides a movement corridor for larger mammals such as mule deer (*Odocoileus hemionus*), bobcat (*Felis rufus*), coyote (*Canis latrans*) and javelina (*Tayassu tajacu*).

Although Marana has not finalized their Habitat Conservation Plan (HCP), the project area occurs within the potential range for several sensitive species: cactus ferruginous pygmy-owl (*Glaucidium* *brasilianum cactorum*), western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), southwestern willow flycatcher (*Empidonax traillii extimus*), burrowing owl (*Athene cunicularia*), pale Townsends's big-eared bat (*Corynorhinus townsendii pallescens*), Merrriam's mesquite mouse (*Peromyscus merriami*), Tucson shovel-nosed snake (*Chionactis occipitalis klauberi*), and the ground snake (*Sonora semiannulata*).

Habitat Effects. In the recharge demonstration area, approximately 0.37 acre of mostly barren sand and gravel habitat would be disturbed via excavation at the mouth and along the extent of the historic thalweg. Channel excavation would result in the loss of a few saltcedar trees and *Atriplex* shrubs. Installation of the Jersey barriers will result in disturbance to 0.02 acre of river habitat along the west bank of the SCR. Installation of the check dams and meander structures would have no effect on existing vegetation. No aquatic vegetation or wetlands occur within the area affected by construction.

The sediment disposal sites have been previously disturbed, and ground cover is sparse to absent. No vegetation will be impacted with the exception of minor trimming of velvet mesquite (*Prosopis velutina*) branches along road the road to the Marana High Plains recharge site.

No invasive or noxious weed survey was conducted although several non-native, invasive plants were identified during the site visit: common reed, salt cedar, Athol tamarisk, Mexican paloverde (*Parkensonia aculeata*), and cocklebur. These species (with the potential exception of common reed) are well established throughout the SCR system. The proposed project will occur within the active river channel and consequently disturbance to the river channel will be similar to what would occur through natural flooding. The proposed project will not increase the potential spread of noxious weeds.

Wildlife Effects. There will be minor noise related disturbance to wildlife and potential loss of some small mammals and reptiles during construction and disposal of excavated material.

Special Status Species. The project area occurs within the range of the lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*), which is the only federally listed species in the project area. There are no caves, roosts or suitable foraging habitat in the immediate project area. There will be no impact to lesser long-nosed bat or any other special status or sensitive species (Federal, State, or local) from construction and operation of the demonstration recharge project or the disposal of excavated material.

There is no suitable habitat in the project area for the cactus ferruginous pygmy-owl, western yellow-billed cuckoo or the southwestern willow flycatcher. No roost site or foraging habitat for the pale Townsend's big-eared bat would be affected. No burrowing owl burrows were observed in the immediate project area. The project area does not appear have sufficient habitat density to support Merriam's mesquite mouse.

Marana's HCP identified the project area as potential habitat for both the ground snake and Tucson shovel-nosed snake. Dr. Phil Rosen (University of Arizona) concluded that for both of these species, soil type can be the best predictor of habitat suitability (RECON 2009). Ground snakes prefer heavy soils of the valley bottoms while the shovel-nosed snake prefers loose sandy soil to accommodate its underground movement. Soil in the project area was not classified. However, the project location in and adjacent to the active stream channel, the limited project size and the short duration of construction should minimize any potential impact to these species.

Cultural Resources

Archaeological surveys were performed at the proposed recharge demonstration area and sediment disposal area. A Class III (intensive) archaeological survey was performed in the area around the mouth of the receiving channel where river water would be diverted into the recharge demonstration area. Less intensive survey covered the rest of the gravel bar and along the western bank of the channel. No cultural resources, historic or prehistoric, were noted in the demonstration area. The project area is regularly flooded and cyclically disturbed, and there is little chance that cultural resources would survive these events. Vehicular access to the project area would be along existing roads; no cultural resources will be disturbed by this access. A Class III survey of the two sediment disposal areas identified no prehistoric or historic artifacts, features, or sites. Reclamation submitted findings of "No Effect to Historic Properties" for the recharge demonstration and sediment disposal areas to the State Historic Preservation Office (SHPO), pursuant to a Programmatic Memorandum of Agreement (PMOA) for Negative Findings, dated November 13, 1990, between Reclamation, the SHPO, and the Advisory Council on Historic Preservation. In accordance with the PMOU, the project may proceed without further coordination between Reclamation and the SHPO.

Clean Water Act Compliance

As described above, approximately 24 cubic yards of fill material would be placed in jurisdictional waters to construct the diversion structure, flow measurement devices, and calming features. Placement of this fill material qualifies for 404 permit coverage under Nationwide Permit 18 (Minor Discharges) and the associated conditional 401 water quality certification. The U.S. Army Corps of Engineers approved use of NWP 18 for the proposed project on November 4, 2010 (Attachment 1).

Indian Trust Assets (ITAs)

ITAs are legal interests in property held in trust by the United States for Indian Tribes or individuals. Reclamation has reviewed the proposed action for possible effects to ITAs. The project area encompasses lands owned by Pima County, the Town of Marana, and the ASLD. No ITAs would be affected by the recharge demonstration project.

References

Brown, D. 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. Dave E. Brown, editor. University of Utah Press. 432 pp.

RECON. 2009. Marana Public Draft. Habitat Conservation Plan. Prepared for the U.S. Fish and Wildlife Service and Town of Marana. March 2009.

Preparer's Name and Title: John McGlothlen - Environmental Protection Specialist

Project Archaeologist concurrence with Item 8 & 13: Jon S Czaplicki 9NOV2010

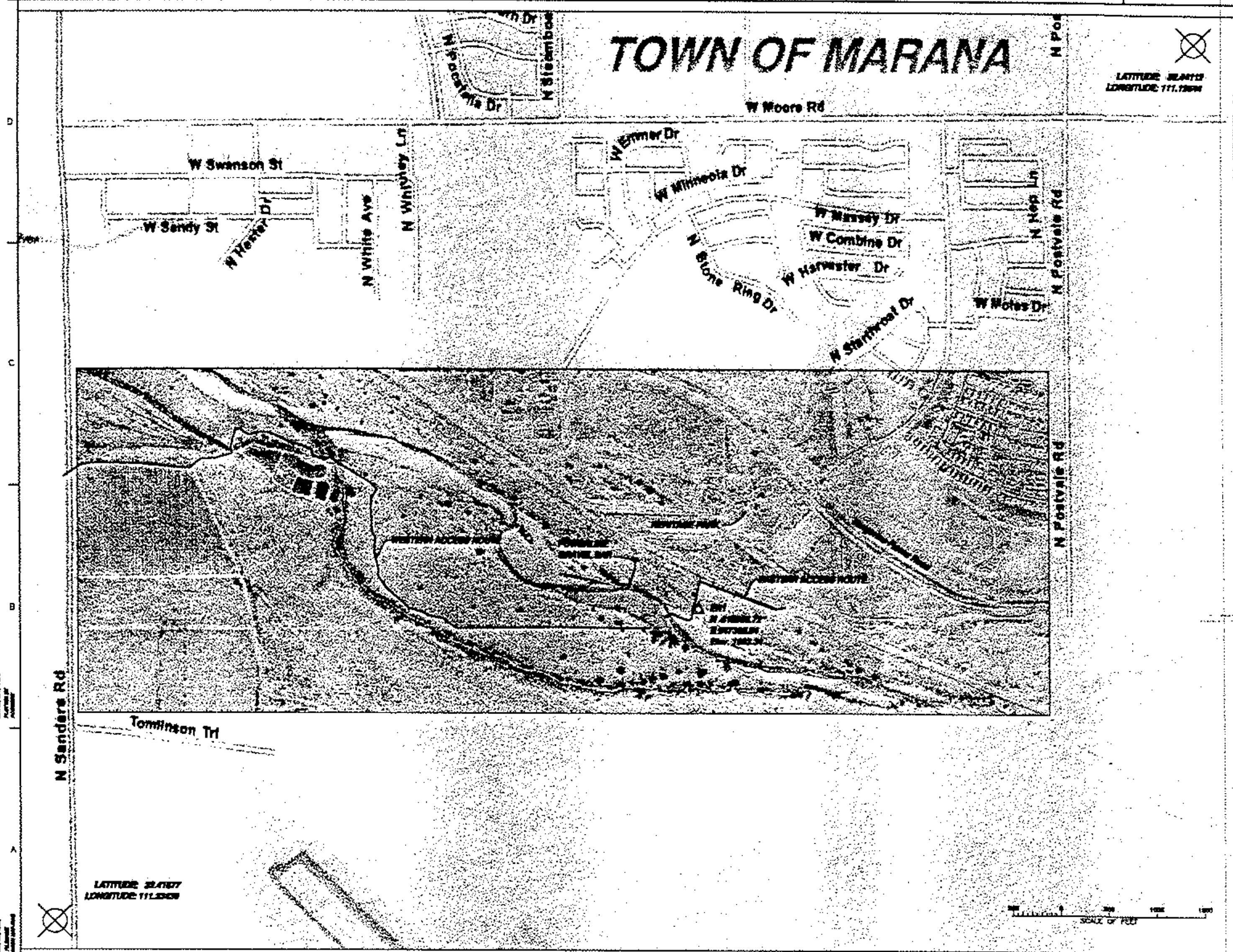
Project Biologist concurrence with Item 9 & 14: Diane M. Laush 9NOV2010

ITA designee concurrence with Item 11: Jon S Czaplicki 9NOV2010

Concur: Bruce D. Ellis Date: 11/9/2010
Chief, Environmental Resource Management Division

Approve: [signature] Date: 11/15/2010
Area Manager

Categorical Exclusion No. PXAO-10-21 Date: NOV 15 2010



GENERAL NOTES

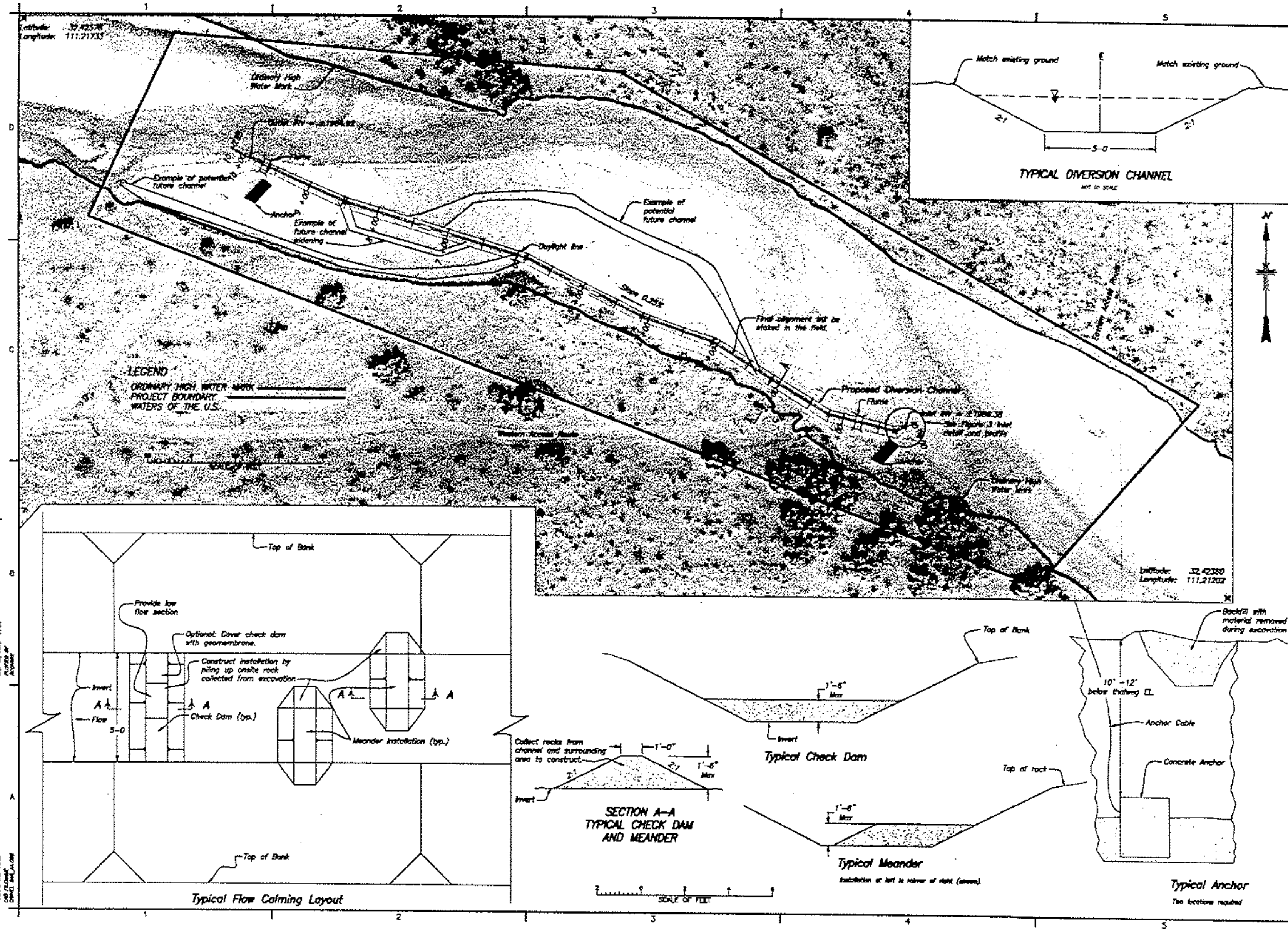
1. Arizona State Plane, Central Zone, International feet, NAD 83, NAVD 88.
2. The project is located on the main channel of the Santa Cruz River along the southern boundary of Section 34, Township 11s, Range 11 East, Gila and Salt River Base and Meridian.

RECLAMATION
Managing Water in the West

ALWAYS THINK SAFETY

SANTA CRUZ RIVER
MANAGED RECHARGED PHASE II
ENHANCED RECHARGED DEMONSTRATION

FIGURE 1
LOCATION
MAP

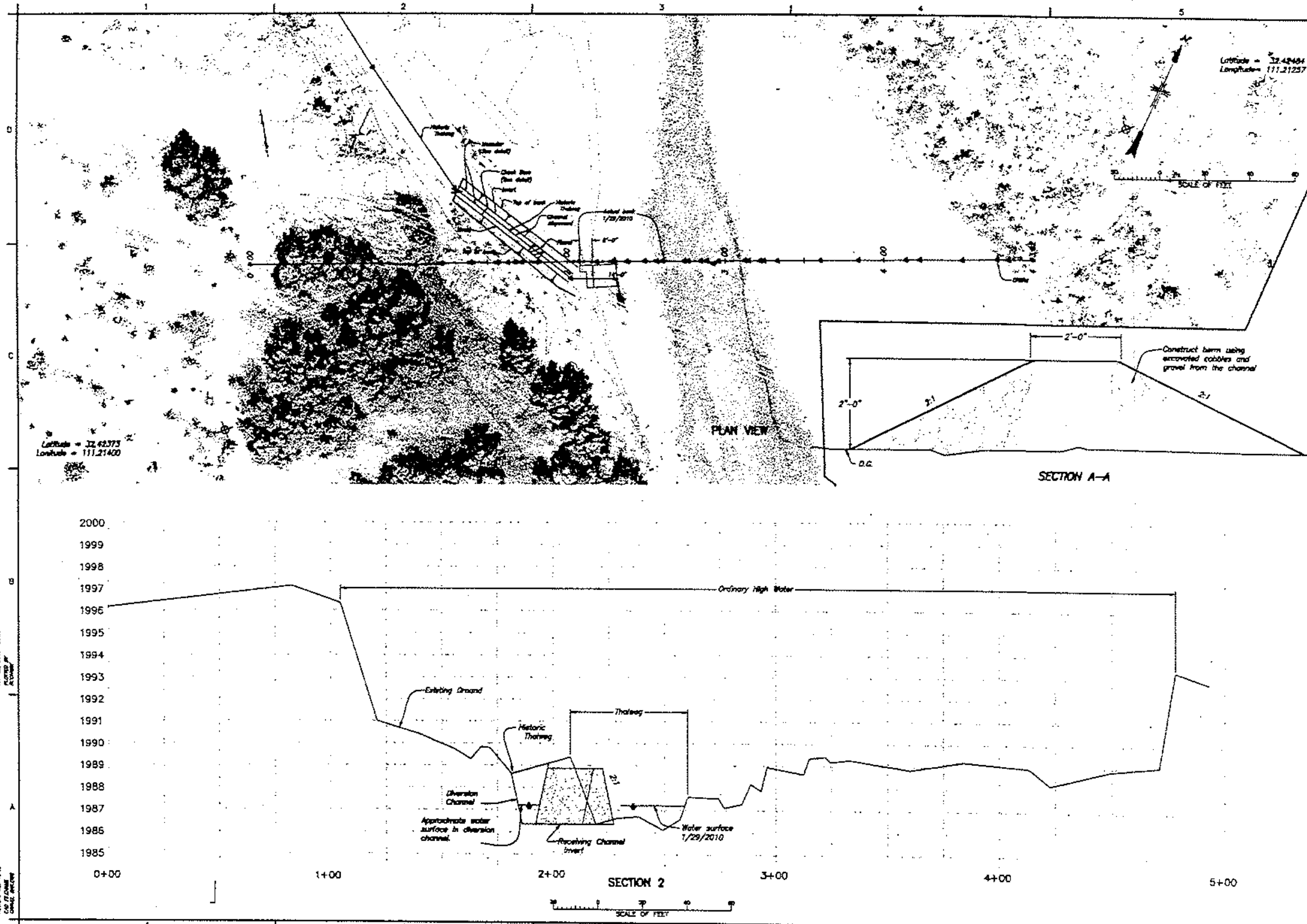


RECLAMATION

ALWAYS THINK SAFETY

SANTA CRUZ RIVER
MANAGED RECHARGE PHASE II
ENHANCED RECHARGE DEMONSTRATION

FIGURE 2
GRADING AND TYPICAL DETAILS



RECLAMATION
Managing Water in the West

ALWAYS THINK SAFETY

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SANTA CRUZ RIVER
MANAGED RECHARGE PHASE II
ENHANCED RECHARGE DEMONSTRATION

FIGURE 3
PLAN AND
CROSS SECTION VIEW

SHEET 1 OF 1

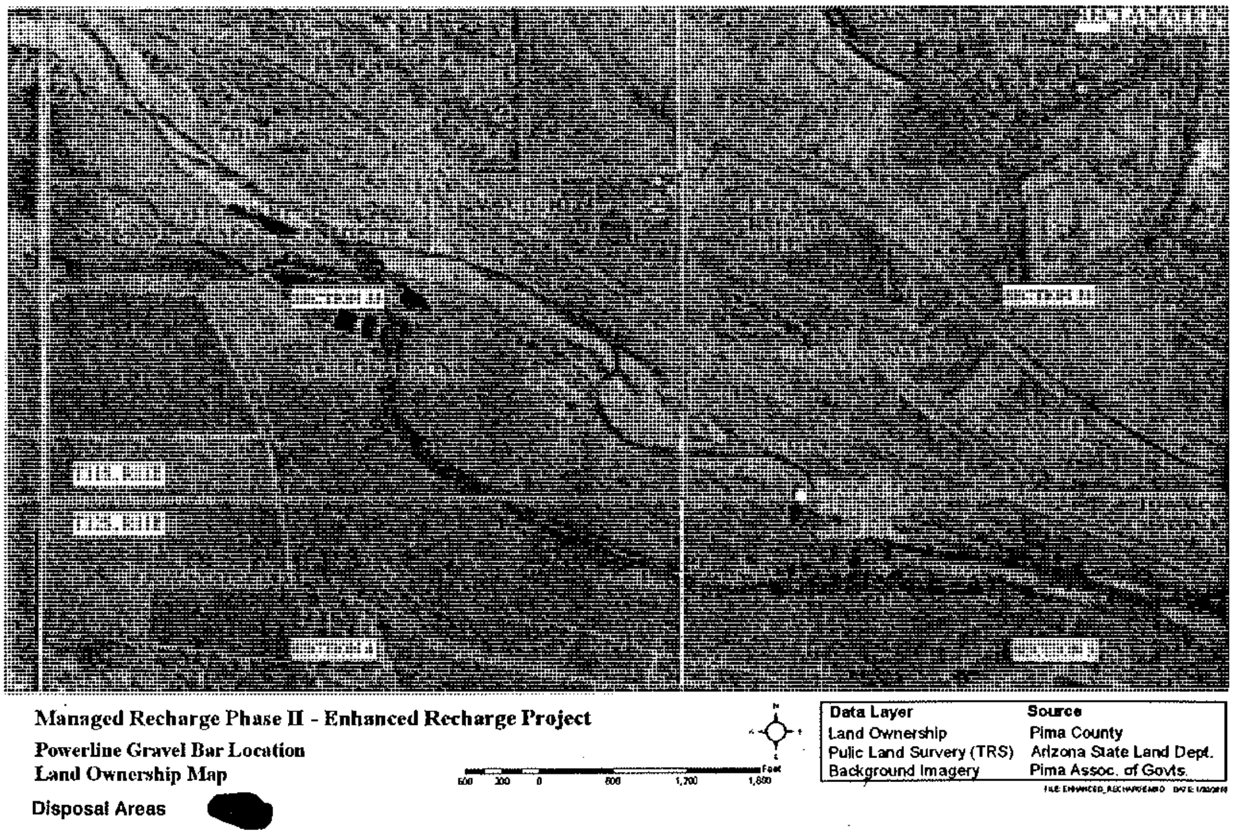


Figure 4. Location of disposal sites.

ATTACHMENT 1

DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT, CORPS OF ENGINEERS
TUCSON RESIDENT OFFICE
5205 EAST COMANCHE STREET
TUCSON, ARIZONA 85707
November 04, 2010

REPLY TO
ATTENTION OF:

Office of the Chief
Regulatory Division

DEPARTMENT OF THE ARMY NATIONWIDE PERMIT AUTHORIZATION

Mr. Bruce D. Ellis
Chief, Environmental Resource Management Division
Bureau of Reclamation
Phoenix Area Office
6150 West Thunderbird Road
Glendale, Arizona 85306-4001

File Number: SPL-2010-00458-JWL

Dear Mr. Ellis:

This is in reply to the application received July 26, 2010 concerning your proposal to construct a Recharge Demonstration Project in the Santa Cruz River Floodway. The proposed construction will include temporary and permanent discharges of fill material into the Santa Cruz River east of Sanders Road, (Section 34, T11S, R11E), Marana, Pima County, Arizona. It is our understanding that you intend to excavate 730 cubic yards (cy) of native sediment below the ordinary high water mark under the Excavation Exclusion. This activity, if done properly, is not regulated under Section 404 of the Clean Water Act.

Based on the information you have provided, the Corps of Engineers has determined, under Section 404 of the Clean Water Act (33 U.S.C. 1344), that your proposed activity complies with the terms of Nationwide Permit No. 18 "Minor Discharges." You must comply with all terms and applicable conditions (regional and general conditions) described in Enclosure 1 and complete the compliance statement (Enclosure 2).

Specifically, as shown on the attached 4 figures, you are authorized to:

1. Construct an L shaped diversion berm using select native material or concrete jersey barriers, 10 cy.
2. Construct 10 native sand and gravel check dams, 5cy.
3. Construct 5 native sand and gravel meander structures, 5 cy.
4. Place 2 flumes to measure flow into and out of the excavated channel.
5. Excavate and backfill 3 cy of native material to set anchors.

Furthermore, you must comply with the following **Special Condition(s)**:

a) The permittee shall comply with all requirements and conditions of Section 401 state water quality certification as shown on Enclosure 1.

b) Pursuant to 36 C.F.R. section 800.13, in the event of any discoveries during construction of either human remains, archeological deposits, or any other type of historic property, the permittee shall, within 24 hours, notify the State Historic Preservation Office at (602)542-7137 and the Corps at (520) 584-1677. The Permittee shall immediately suspend all work in any area(s) where potential cultural resources are discovered. The Permittee shall not resume construction in the area surrounding the potential cultural resources until the Corps re-authorizes project construction, per 36 C.F.R. section 800.13.

c) The permittee shall not stockpile material below the ordinary high water mark of any water of the U.S.

d) The permittee shall immediately remove all excavated material to an upland disposal site.

e) The permittee shall not divert flows outside of the ordinary high water mark of any water of the U.S. except as specifically authorized by this permit.

f) The permittee shall not excavate, fill, or grade in the watercourses outside of the boundaries permitted for construction.

g) The permittee shall not use areas below the ordinary high water mark as a fill source except as authorized by this verification

h) During construction, the permittee shall restrict vehicular traffic from entering the watercourses outside the boundaries permitted for construction.

i) The permittee shall not use areas below the ordinary high water mark for the staging of equipment or materials.

j) The permittee shall remove all excess fill and/or construction debris/equipment from the site immediately upon completion of construction.

k) The permittee shall make all reasonable effort to remove flumes and jersey barriers from the channel prior to predicted large flow events.

l) The permittee shall remove all surface structures and equipment, not constructed of native sand and gravel, upon completion of the demonstration project or by March 18, 2012, whichever comes first.

m) Prior to onset of construction/excavation, the permittee shall provide the contractor(s) with a copy of this permit. The contractor shall read and agree to comply with all conditions herein. A copy of this permit shall be posted on site at all times during construction.

This letter of verification is valid through March 18, 2012 unless the nationwide permit(s) referenced herein is modified, reissued, or revoked before this date. It is incumbent upon you to remain informed of changes to the nationwide permit program.

If you sell/transfer the property associated with this letter of verification you should work with the new owner to complete the enclosed Transfer Statement (Enclosure 3). This transfer is necessary to ensure that the new owner of the property is aware of all terms and conditions of this letter of this verification including any special conditions that will continue to be binding on the new owner.

A nationwide permit does not grant any property rights or exclusive privileges. Also, it does not authorize any injury to the property or rights of others or authorize interference with any existing or proposed Federal project. Furthermore, it does not obviate the need to obtain other Federal, state, or local authorizations required by law.

Thank you for participating in our regulatory program. If you have questions, please contact Jesse Laurie at jesse.laurie@usace.army.mil or (520)584-1677.

Sincerely,

Marjorie E. Blaine

Marjorie E. Blaine
Senior Project Manager
Arizona Branch, Regulatory Division

Enclosures

Appendix C

Fully Executed Federal Right-of-Entry Agreement for Access to Bureau of Reclamation Pilot Recharge Project

United States Department of the Interior
BUREAU OF RECLAMATION
Phoenix Area Office
6150 West Thunderbird Road
Glendale, Arizona 85306-4001

TAKE PRIDE IN AMERICA

IN REPLY REFER TO:

PXA0-4000
LND-3.00

FEB 25 2010

Mr. James Rees
Right-of-Way Administrator
Arizona State Lands Department
1616 West Adams Street
Phoenix, AZ 85007

Subject: Fully Executed Federal Right-of-Entry Agreement (Agreement) for Access to Bureau of Reclamation Pilot Recharge Project (Project)

Dear Mr. Rees:

Enclosed is a fully executed copy of the subject Agreement for your files. On behalf of the Bureau of Reclamation, I wish to personally thank you for your help and cooperation with our mutually beneficial Project.

Should you desire additional information, please feel free to contact Mr. David Deyle, of this office, at 623-773-6244 or by email at ddeyle@usbr.gov.

Sincerely,

CAROL LYNN ERWIN

Carol Lynn Erwin
Area Manager

Enclosure

bc: PXAO-7005 (Holler) (w/encl)

Chrono 4000
WBR:DDeyle:mrc:final:02/19/2010:623-773-6244
(u:\mcolon\4000new\David D\Executed Copy Letter ROE to AZ State Lands
(A10-1468-1050-002-92-0-0 - SA003)

Janice K. Brewer
Governor

Maria Baier
State Land
Commissioner

ARIZONA STATE LAND DEPARTMENT

February 16, 2010

U.S. Bureau of Reclamation
David A. Deyle, Realty Specialist
6150 W. Thunderbird Road
Glendale, AZ 85306-4001
623-773-6244
ddeyle@usbr.gov

Re: Federal Temporary Right-of-Entry Across State Trust Lands
For Access To A Bureau of Reclamation Pilot Recharge Project
Issued By The Arizona State Land Department ("Department")

Dear Mr. Deyle:

This letter serves as the U.S. Bureau of Reclamation's (and its agents) Right-of-Entry across State Trust lands effective upon receipt by the Department of this original letter signed by the U.S. Bureau of Reclamation in the space provided.

PURPOSE:

Access across State Trust lands ONLY

LOCATION:

The subject property is a linear road alignment which encompasses approximately .10 acre, more or less, of State Trust land west of the Santa Cruz River in Marana. It is preliminarily described as Metes&Bounds thru the S2N2SW; the W2SE; and the SWSESE of S33, T11S, R11E, Pima County, Arizona.

TERMS:

From: February 16, 2010 **To: February 15, 2011**

CONDITIONS:

In order for this Right-of-Entry to remain in effect, the following conditions must apply:

1. It is understood and agreed that this Right-of-Entry is in the nature of a license, and does not create a lease, easement, other estate or right in real property. In the event this document or any supplemental attachments contain any wording that a court of law interprets as creating a leasehold interest that wording shall be void, but shall not affect the remaining terms and conditions of this Right-of-Entry permit. The holder of this Right-of-Entry shall be called the

Permittee and the Grantor of this Right-of-Entry shall be called the Permittor for the purposes of this Right-of-Entry.

2. As a license this Right-of-Entry grants authority only for the specific purpose listed on Page 1 under the heading "Purpose", and no activity or functions of any other type whatsoever are permitted.

3. Any and all structures placed upon the subject property shall be removed at the Permittee's expense if a Right-of-Way for this Right-of-Entry's purpose is not approved by the Permittor. Any such structures placed upon the State Trust premises which are not expressly authorized herein, shall be forfeited and become property of the State of Arizona.

4. As a license this Right-of-Entry expires on the date indicated, carries no holdover rights, and is not assignable or saleable. This Right-of-Entry represents personal property of the Permittee, and does not survive the death or termination by the Permittee.

5. In the event any land affected by this Right-of-Entry is reclassified by order of the State Land Commissioner this right will automatically cancel as of the effective date of the reclassification.

6. Permittee shall not interfere with any other Permittees' or Lessees' use of State Trust land. Further, Permittee is required to inform the affected Department Lessees in advance when the Permittee or its agents will be crossing the affected State Trust leases.

7. Permittee shall not harass livestock or wildlife, nor damage or destroy any livestock or wildlife improvement or facility (i.e. windmills, tanks, corrals, fencing, watering structures, etc.).

8. Permittee shall leave gates either opened or closed as they are found (General rule: If a gate is opened and wired or tied back to the fence, it should be left open). No fences will be cut or laid down.

9. Permittee shall not leave trash or refuse on State Trust land.

10. Permittee shall not remove any natural products from State Trust land, including rocks, soil or firewood for home use.

11. Permittee shall comply with the provisions of the Arizona Native Plant Law and with all laws relating to prehistoric or historic archaeological sites or artifacts. No archaeological site or artifacts, either prehistoric or historic, will be disturbed or removed.

12. Vehicles will only travel on established roads, and minimum pull-out to park vehicles is allowed. Do not block gates or park within a quarter mile of livestock or wildlife water.

13. Permittee is responsible for obtaining any other permits (local, state and federal) necessary to the activity defined in this Right-of-Entry.

14. Permittee shall adhere to all rules, regulations, ordinances, and building codes as promulgated

by local jurisdictions and any applicable agencies.

15. Other:

    a. Ground disturbance is strictly prohibited, except as necessary to accomplish the purpose of this Temporary Right-of-Entry and in conformance with the Restoration provisions that are a part of the Temporary Right-of-Entry.
    b. Permittee shall provide the Department with all reports and results of its investigations, if applicable.

INSURANCE AND INDEMNITY FOR UNITED STATES GOVERNMENT PERMITTEES:

Any claims for damages resulting from the activities of the United States Government Agency under this agreement shall be promptly processed by the United States Government Agency under the Federal Tort Claims Act, 28 U.S.C. 2671 et seq., and the Contract Disputes Act of 1978, 41 U.S.C. 601-613, or other applicable Federal authorities, provided that this paragraph shall not be construed as a waiver of the discretionary powers of the Arizona State Land Commissioner.

Permittee agrees to conduct said operations so as to not pollute any groundwater supply.

ENVIRONMENTAL INDEMNITY FOR UNITED STATES GOVERNMENT PERMITTEES:

To the extent consistent with Federal law, Permittee shall protect, defend, indemnify and hold harmless the Permittor from and against all liabilities, costs, charges and expenses, including attorneys' fees and court costs, arising out of or related to the presence of or existence of any substance regulated under any applicable federal, state or local environmental laws, regulations, ordinances or amendments thereto because of: (a) any substance that came to be located on the Premises resulting from any use or occupancy of the lands by the Permittee before or after the issuance of the Right-of-Entry; or (b) any release, threatened release or escape of any substance in, on, under or from said Premises that is caused, in whole or in part, by any conduct, actions or negligence of the Permittee, regardless of when such substance came to be located on the Premises.

Prior to the termination of this Temporary Right-of-Entry and in addition to those obligations set forth in this Temporary Right-of-Entry, Permittee shall restore the Subject Property by removing any and all Regulated Substances caused to come into existence on the Subject Property as a result of Permittee's actions or inactions or the actions or inactions of Permittee's agents. For the purposes of this Right-of-Entry the "regulated substances" shall include substances defined as "regulated substances", "hazardous waste", "hazardous substances", "hazardous materials", "toxic substances" or "pesticides" in the Resource Conservation and Recovery Act, as amended by the Hazardous and Solid Waste Amendments of 1984, the Comprehensive Environmental Response, Compensation and Liability Act, the Hazardous Materials Transportation Act, the Toxic Substance Control Act, the Federal Insecticide, Fungicide and Rodenticide Act, the relevant local and state environmental laws, and the regulations, rules and ordinances adopted and publications promulgated pursuant to the local, state and federal laws. To the extent consistent with Federal law, this indemnification shall include, without limitation, claims or damages arising out of any violations of applicable environmental laws, regulations, ordinances or subdivisions thereof, regardless of any real or alleged strict liability on the part of the Permittor. To the extent consistent with Federal law, this environmental indemnity shall survive the expiration or termination of this Right-of-Entry and/or any transfer of all or any portion of the Premises and shall be governed by the laws of the State of Arizona.

In addition, the restoration shall include, but not be limited to, removal of all waste and debris deposited by the Permittee, as well as restoration to grade level of all trenches, holes, etc. that were created as a result of the Permittee's Due Diligence investigation. If the Subject Property or any portions thereof are damaged or destroyed as a result of the existence or presence of any Regulated Substance or if the Subject Property or any portions thereof are damaged or destroyed in any way relating to or arising out of the removal, treatment, storage, disposition, mitigation, cleanup or remedying of any Regulated Substance by the Permittee or its agents, Permittee shall arrange, at its expense, for the repair, removal, remediation, restoration, and reconstruction to the Subject Property to the original condition existing on the date that the Permittee first entered *upon* the Subject Property, to the satisfaction of the Department. In any event, any damage, destruction, or restoration by the Permittee shall not relieve the Permittee from its obligations and liabilities under this Temporary Right-of-Entry.

The Department hereby acknowledges and agrees that, with respect to this Right-of-Entry, no liability shall attain in favor of the Department as against any officer, director, member, agent or employee of the Permittee, but that the department shall look solely to the assets of the Permittee for satisfaction of this Right-of-Entry.

Maria Baier,
State Land Commissioner

By: James L. Adams, Director
Real Estate Division

Cc: Public Records
Ruben Ojeda, Manager, Rights-of-Ways Section

Attachment: Public Land Ownership map

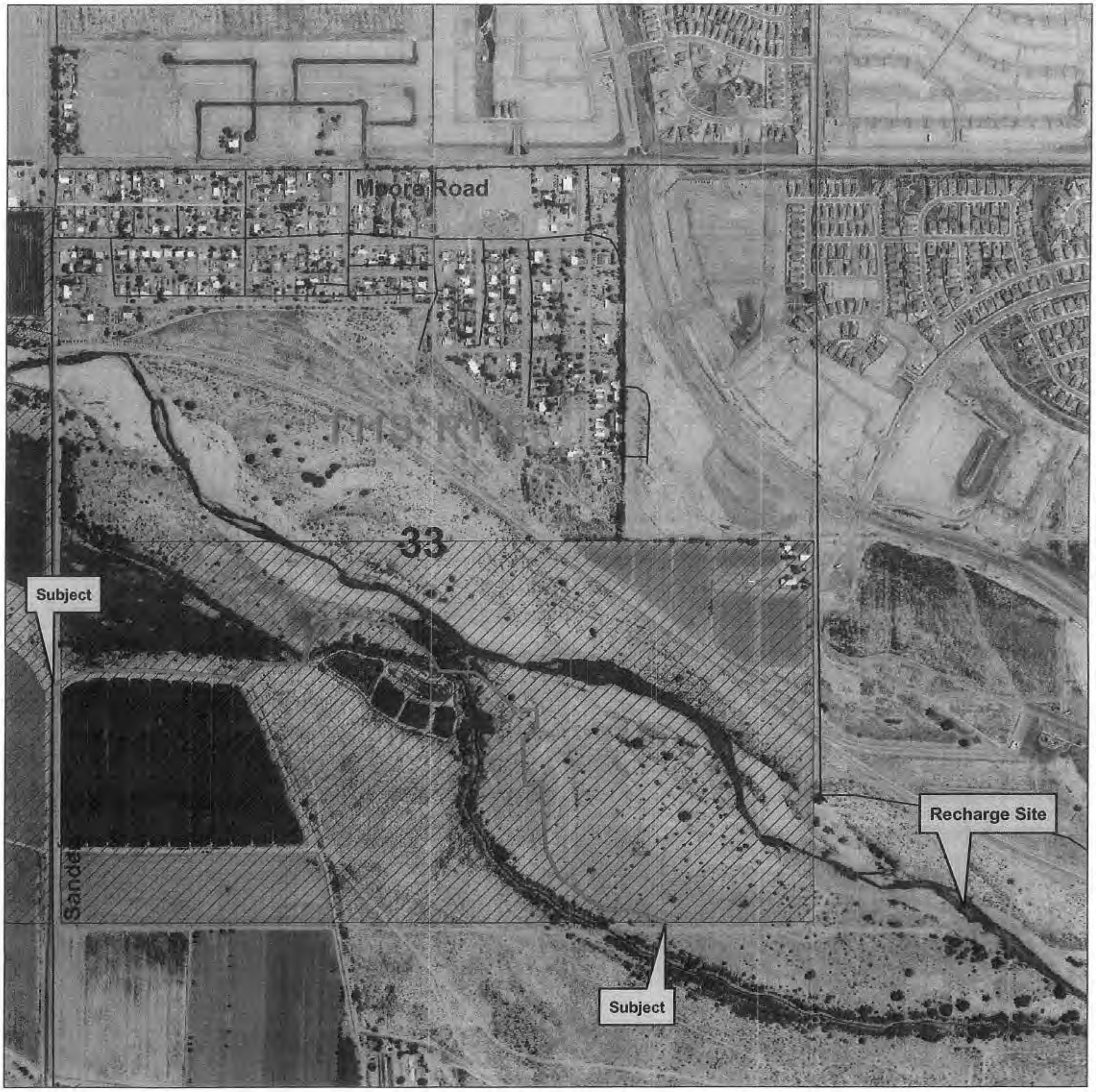
U.S. Bureau of Reclamation

AGREED TO AND ACCEPTED THIS 25 DAY OF FEBRUARY, 2010

By: ______________________

Its: AREA MANAGER

Access to U.S. Bureau of Reclamation Recharge Site



Public Land Ownership

CATEGORY

Private

State Trust

N
W E
S

Miles
0 0.04 0.08 0.16

Arizona State Land Department

The Arizona State Land Department makes no warranties, implied or expressed, with respect to the information shown on this map.

Map produced by the Arizona State Land Department December 23, 2009

D:\jrees\11S 11E (BoR).mxd
James Rees

Appendix C2

ASLD Trico Powerline Access Road Permission

From: Chuck Wilcox [cwilcox@trico.coop]
Sent: Monday, March 22, 2010 3:01 PM
To: Tosline, Deborah J; 'Charles B DeSpain'
Cc: Holler, Frank (Eric) E
Subject: RE: Trico Powerline Access Road

Debra,

Trico has no objections to the Bureau of Reclamation using Trico’s power line road right-of-way across
the north boundary of Sections 3 and 4, Township 12 South, Range 11 East, Pima County, Arizona, as an
access route during construction and maintenance of the pilot research project located in the Santa
Cruz River. The Bureau of Reclamation also needs to obtains the land owner’s approval to use said
right-of-way.

If you have any question, let me know.

Chuck Wilcox, SR/WA
Right of Way Coordinator
Trico Electric Cooperative, Inc.
P.O. Box 930
Marana, AZ 85658
Phone (520)744-2944 ex 1324
Fax (520)682-4887
Email - cwilcox@trico.coop

From: Tosline, Deborah J [mailto:DTosline@usbr.gov]
Sent: Monday, March 22, 2010 1:02 PM
To: Charles B DeSpain; cwilcox@trico.coop
Cc: Holler, Frank (Eric) E
Subject: RE: Trico Powerline Access Road

Hi Brad,

Hope all is well with you!

I have not received any correspondence from TRICO. Permission to use TRICO’s powerline road during
construction/maintenance of the Enhanced Recharge Project may be provided in an email.

Thanks,

Deborah Tosline, R.G.
Hydrologist/Assistant Program Manager
U.S. Department of Interior
Bureau of Reclamation
300 W. Congress Rm 1L (FB-37)
Tucson, AZ 85701
Office: 520-670-4806
Fax: 520-670-4745
Cell: 520-404-1083
dtosline@usbr.gov
www.usbr.gov

From: Charles B DeSpain [mailto:bridlebitranch@triconet.org]
Sent: Monday, March 22, 2010 10:36 AM
To: Tosline, Deborah J; cwilcox@trico.coop

Cc: Holler, Frank (Eric) E
Subject: RE: Trico Powerline Access Road

Debra
Any progress with Trico?
The culvert is in
Brad

From: Tosline, Deborah J [mailto:DTosline@usbr.gov]
Sent: Thursday, January 14, 2010 3:09 PM
To: cwilcox@trico.coop
Cc: Holler, Frank (Eric) E; bridlebitranch@triconet.org
Subject: RE: Trico Powerline Access Road

Chuck,

I am writing to follow up with the request for permission for Reclamation to use the Trico Powerline
road as an access route during construction etc of a pilot recharge project in the SCR. Have you had a
chance to get a response to this request?

Also, what type of ROE/ROW permit does Trico have from the Arizona State Land Department? Is Trico
permitted to do road maintenance under their ROE/ROW permit?

If you require further information or have questions, please contact me.

Thank you,

Deborah Tosline, R.G.
Hydrologist/Assistant Program Manager
U.S. Department of Interior
Bureau of Reclamation
300 W. Congress Rm 1L (FB-37)
Tucson, AZ 85701
Office: 520-670-4806
Fax: 520-670-4745
Cell: 520-404-1083
dtosline@usbr.gov
www.usbr.gov

From: Tosline, Deborah J
Sent: Monday, January 04, 2010 12:18 PM
To: 'cwilcox@trico.coop'
Cc: Holler, Frank (Eric) E; bridlebitranch@triconet.org
Subject: Trico Powerline Access Road

Chuck,

Reclamation would like to conduct a pilot research project in the Santa Cruz River immediately north of
the Trico Powerline. I am writing to request permission for Reclamation to use the Trico Powerline
road as an access route during construction, maintenance, and break-down of the pilot project.
Attached is a map of the potential access route along the Trico Powerline road. It is our understanding
that Trico plans to install a culvert in the oxbow to provide a vehicle crossing. What is the timeframe
for completion of installation of the culvert?

The pilot research project involves enhancing recharge in the Santa Cruz River by creating a diversion
and spreading flows across the channel to increase infiltration rates. The pilot would take about a
week to construct and would require maintenance following any potential flood flows in the SCR.
 Vehicles utilizing the access road include an excavator, a 10-wheel truck, and field vehicles. The pilot
could last from 6 months to 2 years. The pilot would be conducted under existing permits and
agreements for the Lower Santa Cruz River Managed Recharge Project underground storage facility.

If you have questions or require further information, please contact me.

Thank you,

Deborah Tosline, R.G.
Hydrologist/Assistant Program Manager
U.S. Department of Interior
Bureau of Reclamation
300 W. Congress Rm 1L (FB-37)
Tucson, AZ 85701
Office: 520-670-4806
Fax: 520-670-4745
Cell: 520-404-1083
dtosline@usbr.gov
www.usbr.gov

Appendix C3

ASLD Lessee John Kai Permission

Phone conversation with John Kai 990-8888

John asked that I send him info about the ERP to his email address at kaifarms@earthlink.net. John gave verbal permission to cross his land during construction and maintenance of the ERP.

Deborah Tosline 3/19/10

Appendix D

Pima County Regional Flood Control District License Agreement

Pima County Regional
FLOOD CONTROL
DISTRICT

PIMA COUNTY
REGIONAL FLOOD CONTROL DISTRICT
97 EAST CONGRESS STREET, THIRD FLOOR
TUCSON, ARIZONA 85701-1797

SUZANNE SHIELDS, P.E.
DIRECTOR

(520) 243-1800
FAX (520) 243-1821

JUL 16 '10

July 14, 2010

US Dept of Interior
Bureau of Reclamation
Phoenix Area Office
6150 W. Thunderbird Rd.
Glendale, AZ 85306-4001

Mr. Deyle:

Enclosed you will find two original licenses signed by our Board of Supervisors' Chair at their meeting on June 15, 2010. I am also sending a copy of the recorded document. It was recorded at Docket 13837 Page 2881 on June 24, 2010 in the office of the Pima County Recorder.

If you have any questions, either Bill Zimmerman or I should be able to answer them. Both of us can be reached at (520) 243-1800. Thank you in advance for your prompt attention to this matter.

Sincerely,

Connie Maraschiello

Connie Maraschiello
Program Manager
Regional Flood Control District

CCM\yo

c: Bill Zimmerman, Planning and Development Division Manager

CONTRACT
NO. 12-59-U-142981-0610
AMENDMENT NO. ____
This number must appear on all invoices, correspondence and documents pertaining to this contract.

For Recorder's Use Only

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
LICENSE AGREEMENT

THIS AGREEMENT is entered into by the Pima County Regional Flood Control District, a special taxing subdivision of the State of Arizona ("District"), and the U.S. Department of the Interior, Bureau of Reclamation ("Licensee"), for the temporary use of District property.

RECITALS

A. The Licensee recharges Southern Arizona Water Rights Settlement Act (SAWRSA) effluent at the Santa Cruz River at the Lower Santa Cruz River Managed Recharge Project, Phase II, Permit No. 71-591928.

B. A managed recharge permit allows for treated effluent to be discharged to a streambed to percolate into the aquifer without the assistance of a constructed device to accrue Long-Term Storage Credits (LTSC) for one-half of the volume of water recharged.

C. The Licensee intends to conduct pilot tests to enhance recharge at the Phase II facility which is permitted to recharge 43,000 acre-feet per year but has historically recharged less than 50% of the permitted recharge volume.

D. The Licensee desires to enhance the recharge at the Phase II facility and has selected a potential location [identified as Powerline Gravel Bar Site] to be located on District owned tax parcels 215-03-011C, 217-53-0460, 217-53-042B.

E. The Town of Marana has granted Licensee permission to use access routes across Heritage Park to get to the District parcels involved.

F. The Town of Marana has also given Licensee a floodplain use permit since the proposed recharge site is subject to the Town's floodplain regulations.

NOW THEREFORE, the parties agree to the following:

LICENSE

1. Grant of Permission. The District hereby grants permission, revocable and terminable as provided herein, to the Licensee to use District tax parcels 215-03-011C, 217-53-0460 and 217-53-042B for the purpose of constructing, operating and maintaining the Managed Recharge Phase II- Enhanced Recharge Project ("MRII ERP"). The District parcels are more specifically described and depicted in **Exhibit A.**

2. Project Description. The MRII ERP involves installing a structure to divert and raise surface water onto the west bank of the river. The water surface would be raised a maximum of two feet four inches in the vicinity of the former thalweg. The diversion structure, in conjunction with an inlet channel, reduces the required water surface increase in the SCR. A flow measurement device will be installed in the inlet channel to monitor and control flow. A diversion structure located transversely in the SCR will provide the necessary water surface increase needed to divert the water. An inlet channel will provide the necessary hydraulic connection to the SCR. Hydraulic modeling indicates a flow of one (1) cubic foot per second (CFS) is possible. Work for the Project will be conducted under 404 Nation Wide Permit 33, Temporary Construction, Access and Dewatering. All material excavated from District property shall be stockpiled on site at a suitable location or transported to another site by approval of the District. Licensee shall pay all costs to permit, design, construct and operate the Project.

3. Privilege Assignable. Licensee's privileges hereunder are assignable only upon written approval of the District.

4. Hold Harmless. All costs associated with this license shall be at the sole expense of Licensee. Licensee assumes responsibility and liability for any injury or damage to the pilot recharge facility caused by or arising out of the exercise of this License. To the fullest extent allowed by law, Licensee indemnifies, defends, and holds harmless District, its officers, departments, employees, and agents from and against any and all suits, actions, legal or administrative proceedings, claims, demands, or damages of any kind or nature arising out of this License, which are

attributed, in whole or in part to Licensee's use of the District property, or to any act or omission of the Licensee, its agents, employees, or anyone acting under its direction, control or on its behalf, whether intentional or negligent in connection with or incident to this License. Licensee's responsibilities shall not extend to the negligence of District, its officers, departments, employees and agents. This indemnification shall survive the termination of this License.

5. Insurance. The Licensee shall acquire and maintain worker's compensation, automobile, accident, property damage, and liability coverage or a program of self insurance for the specified areas. The policy shall be maintained throughout the term of this License by the Licensee or Licensee's assignees. This License shall immediately terminate if said insurance lapses for any reason.

6. Annual Fee. There is no fee required for this License.

7. Permits. This License is not a right of way use permit. Following the granting of this License by District, Licensee shall obtain all applicable permits necessary for any constructed improvements, which may include a Right-of-Way Use Permit, Building Permit or Floodplain Use Permit from the appropriate jurisdiction.

8. Safety. The construction and maintenance of any improvements shall not interfere with the general health, safety and welfare of the citizens of Pima County.

9. Term. This License shall run for a period of 25 years from the date this License is executed by the Pima County Flood Control District Board of Directors. Notwithstanding any other condition, this License may be terminated by either party or revoked by District upon providing ninety days' written notice to the other. District may terminate or revoke this License at any time by recording a termination or revocation statement executed by the District Engineer.

10. Licensee Has No Interest or Estate. Licensee agrees that it has no claim, interest, or estate at any time in the subject real property or its use hereunder. Upon termination or revocation of this License, Licensee shall have no right of entry upon District property.

11. Removal of Recharge Facilities and Associated Improvements. Upon termination or revocation of this License for any reason or in the event partial or total removal of the improvements are required by District, Licensee shall promptly remove all or part of the pilot project as required by District at Licensee's sole expense and to the satisfaction of District. Licensee shall not seek compensation or

financial reimbursement for any and all costs associated with the removal or relocation of the improvements from District. In the event the improvements are not promptly removed by Licensee as directed by District, District shall have the right to remove the improvements and Licensee hereby agrees to reimburse the total amount of District's costs incurred for the partial or complete removal of the improvements within sixty (60) days of receipt of an invoice from District for said costs.

12. Conflict of Interest. This Agreement is subject to A.R.S. § 38-511 which provides for cancellation of contracts for certain conflicts of interest.

LICENSEE:

U.S. Department of Interior, Bureau of Reclamation

By: ______________________

Title: Area Manager

Date: May 10, 2010

GRANTEE:

Pima County Flood Control District

____

Chairman, Board of Directors

JUN 15 2010

ATTEST:

____

Clerk of the Board

Approved as to form:

____

Deputy County Attorney

EXHIBIT A

(4 pages)

MRII ERP

Book-Map-Parcel: 215-03-011C **Oblique Image** Tax Year: Tax Area: **0616**

Taxpayer Information:
PIMA COUNTY
FLOOD CONTROL DISTRICT

Property Description:
PTN N2 LYG W & ADJ SANDARIO RD 42.39 AC
AVID 42.38 AC SEC 3-12-11

00000- 0000

Valuation Data:

	2010				2011		
	LEGAL CLASS VALUE	ASMT RATIO	ASSESSED VALUE	LEGAL CLASS VALUE	ASMT RATIO	ASSESSED VALUE	
LAND FCV	VACANT/AG (2) $55,107	16.0	$8,817	VACANT/AG (2) $55,107	16.0	$8,817	
IMPR FCV	$0			$0			
TOTAL FCV	VACANT/AG (2) $55,107	16.0	$8,817	VACANT/AG (2) $55,107	16.0	$8,817	
LIMITED VALUE	VACANT/AG (2) $55,107	16.0	$8,817	VACANT/AG (2) $55,107	16.0	$8,817	

Property Information:

Section:	3
Town:	12.0
Range:	11.0E
Map & Plat:	/
Block:	
Tract:	
Rule B District:	1
Land Measure:	42.39A
Group Code:	000
Census Tract:	4408
Use Code:	9640 (COUNTY AGRICULTURAL PROPERTY)
File Id:	1
Date of Last Change:	1/5/2006

Valuation Area:

Condo Market:	410
DOR Market:	14
MFR Neighborhood:	UnDefined
SFR Neighborhood:	20442006
SFR District:	2

Recording Information

Docket	Page	Date Recorded	Type
10878	3200	1998-09-10	

Book-Map-Parcel: 217-53-042B | **Oblique Image** | Tax Year: | Tax Area: **0656**

Taxpayer Information:
PIMA COUNTY
FLOOD CONTROL DISTRICT

00000- 0000

Property Description:
GLADDEN FARMS SWLY PTN OF BLKS B & C

Valuation Data:

	2010				2011		
	LEGAL CLASS VALUE	ASMT RATIO	ASSESSED VALUE		LEGAL CLASS VALUE	ASMT RATIO	ASSESSED VALUE
LAND FCV	VACANT/AG (2) $11,223	16.0	$1,796		VACANT/AG (2) $11,223	16.0	$1,796
IMPR FCV	$0				$0		
TOTAL FCV	VACANT/AG (2) $11,223	16.0	$1,796		VACANT/AG (2) $11,223	16.0	$1,796
LIMITED VALUE	VACANT/AG (2) $11,223	16.0	$1,796		VACANT/AG (2) $11,223	16.0	$1,796

Property Information:

Section:	34
Town:	11.0
Range:	11.0E
Map & Plat:	55/60
Block:	00B
Tract:	
Rule B District:	1
Land Measure:	22.05A
Group Code:	000
Census Tract:	4406
Use Code:	9600 (COUNTY VACANT LAND)
File Id:	1
Date of Last Change:	8/31/2005

Valuation Area:

Condo Market:	411
DOR Market:	14
MFR Neighborhood:	UnDefined
SFR Neighborhood:	20442006
SFR District:	2

Recording Information

Docket	Page	Date Recorded	Type
12514	2171	2005-03-22	QUIT CLAIM DEED
12487	548	2005-02-10	

Book-Map-Parcel: 217-53-0460 **Oblique Image** Tax Year: Tax Area: 0612

Taxpayer Information:
PIMA COUNTY
FLOOD CONTROL DISTRICT

00000- 0000

Property Description:
GLADDEN FARMS BLOCK D

Valuation Data:

	2010				2011			
	LEGAL CLASS	VALUE	ASMT RATIO	ASSESSED VALUE	LEGAL CLASS	VALUE	ASMT RATIO	ASSESSED VALUE
LAND FCV	VACANT/AG (2)	$500	16.0	$80	VACANT/AG (2)	$500	16.0	$80
IMPR FCV		$0				$0		
TOTAL FCV	VACANT/AG (2)	$500	16.0	$80	VACANT/AG (2)	$500	16.0	$80
LIMITED VALUE	VACANT/AG (2)	$500	16.0	$80	VACANT/AG (2)	$500	16.0	$80

Property Information:

Section:	34
Town:	11.0
Range:	11.0E
Map & Plat:	55/60
Block:	00D
Tract:	
Rule B District:	1
Land Measure:	0.10S
Group Code:	000
Census Tract:	4408
Use Code:	9600 (COUNTY VACANT LAND)
File Id:	1
Date of Last Change:	7/12/2005

Valuation Area:

Condo Market:	411
DOR Market:	14
MFR Neighborhood:	UnDefined
SFR Neighborhood:	20442006
SFR District:	2

Recording Information

Docket	Page	Date Recorded	Type
12514	2171	2005-03-22	QUIT CLAIM DEED
12487	548	2005-02-10	QUIT CLAIM DEED

Appendix E

Town of Marana License Agreement

LICENSE AGREEMENT

LICENSOR: Town of Marana
11555 W. Civic Center Drive
Marana, AZ 85653

LICENSEE: U.S. Department of Interior
Bureau of Reclamation
Phoenix Area Office
6150 West Thunderbird Road
Glendale, AZ 85306-4001
Attn: Ms. Carol Lynn Erwin, Area Manager

In consideration of Licensee's promises in this Agreement, Licensor hereby gives permission to the Licensee to temporarily use Licensor's property (the "Heritage Park") located in Section 34, Township 11 South, Range 11 East, Quadrant 3 of the Gila and Salt River Meridian, Pima County, Arizona described as follows:

> **That certain real property owned by the Licensor and depicted in Exhibit "A", location and access map, and incorporated by reference herein.**

Beginning on the effective date of this Agreement, Licensee may use **those particular access routes across the Heritage Park that are designated in writing by the Marana Director of Parks and Recreation** for access to Licensee's Enhanced Recharge Project located in the Santa Cruz River (the "ERP") and access maintenance purposes only. Access maintenance materials may include natural stone such as decomposed granite, asphalt or any other hardscape or surface material approved by the Marana Director of Parks and Recreation for use within conservation or park lands. For the purposes of this Agreement, "hardscape" includes natural stone or other paving materials used for walking paths and roadways as approved by Licensor. Licensee, its representatives, assignees or designees may use the land for access and access maintenance purposes temporarily as permitted by this Agreement, subject to the terms and conditions set forth below:

1. This Agreement is revocable and shall be binding upon Licensee, its representatives, assignees and designees, and every reference to Licensee in this Agreement shall include and bind Licensee's heirs, assignees and designees.

2. Permission is revocable and given to Licensee for temporary access and access maintenance across the Heritage Park to the ERP.

3. All access and access maintenance performed under this License shall be in compliance with plans approved by the Marana Director of Parks & Recreation. Any modification or relocation of access shall be in accordance with plans approved in writing by the Marana Director of Parks & Recreation, whose written approval shall be obtained before any access changes commence.

4. Licensee is aware and agrees that in the event of a future roadway, conservation or park construction project, Licensee bears the sole cost for removal of any improvements (if any) placed by Licensee, restoration of any Heritage Park landscaping damaged or destroyed as a result of Licensee's activities, and Licensee's costs related to the relocation of access.

5. Licensee, its representatives, assignees and designees covenant that it shall defend, indemnify and hold harmless Licensor, its officers, agents, and employees from any and all claims, demands, causes of action, complaints, suits, losses, damages, injuries, and liabilities whatsoever (including those for costs, expenses, and attorneys' fees) to any person, persons, or property arising out of either (1) the maintenance and use of the Heritage Park by Licensee, or (2) the negligent acts or omissions of Licensee.

6. This License shall become effective when this fully executed License is delivered to the Marana Town Clerk.

7. Licensor retains the right to modify, terminate or revoke this License at any time.

8. From the effective date, this License shall be temporary and shall remain in effect unless and until it is (a) modified or terminated by written agreement of the parties or (b) revoked by and at the sole discretion of Licensor.

9. Revocation of this License is at Licensor's discretion. Licensor's decision shall be based on, but not limited to, future progress or construction of the right-of-way, conservation or park improvements and any traffic control and public safety concerns.

10. Except in cases of imminent hazards or emergency or by agreement of the parties, Licensee shall give Licensor written notice of any access modification or relocation at least 60 calendar days prior to the effective date of modification or access relocation.

11. If Licensee causes any damage to the Heritage Park or other Town property, Licensee shall promptly make and pay for the repairs necessary to restore the property to its pre-damaged condition. At the discretion of Licensor, if repairs are not initiated and completed within a reasonable length of time, but in any event within 14 calendar days after Licensor gives written notice of damage to Licensee, Licensor may make the repairs and bill Licensee for all costs. Licensee shall pay the bill within ten calendar days of receipt.

12. All access improvements installed by Licensee shall be maintained by Licensee.

13. Licensee shall abide by all existing laws and regulations of the United States of America, State of Arizona, County of Pima and Town of Marana, as they may be amended from time to time.

14. This Agreement is subject to cancellation in certain instances involving conflict of interest pursuant to A.R.S. § 38-511.

IN WITNESS WHEREOF, the parties have executed this License Agreement on the last signature date set forth below.

TOWN OF MARANA (LICENSOR)	U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION (LICENSEE)
BY: ______________ Tom Ellis, Director Parks & Recreation	BY: ______________ Acting For Carol Lynn Erwin, Area Manager

APPROVED AS TO FORM:

____
Town Attorney

STATE OF ARIZONA)
) ss.
COUNTY OF PIMA)

The foregoing instrument was acknowledged before me on this 20th day of February, 2010 by Tom Ellis, Marana Parks & Recreation Director, on behalf of the Town of Marana, an Arizona municipal corporation.

My commission expires:
1/19/2011

______________ Notary Public

Barbra L. Bourne
Notary Public - Arizona
Pima County
My Commission Expires
January 19, 2011

STATE OF ARIZONA)
) ss.
COUNTY OF Maricopa)

The foregoing instrument was acknowledged before me this 8th day of March, 2010 by ~~Carol Lynn Erwin,~~ Richard E. Dent Acting Area Manager of the U.S. Department of the Interior, Bureau of Reclamation (Licensee), on behalf of Licensee.

My commission expires:
August 2, 2011

____
Notary Public

ELLEN L. STENDER
Notary Public - Arizona
Maricopa County
My Comm. Expires Aug 2, 2011

EXHIBIT "A"

HERITAGE PARK DR
GLADDEN FARMS DR
BOSCOMBE DR
TANGERINE FARMS RD
GRANVILLE DR
FOXBERRY DR
SCHOOLDAY DR
WILLOWVALE DR
STONERING DR
SANDBY GREEN DR
BONEY GATE DR
COTTONSEED LN
HARVESTER DR
BEACHFIELD DR
FERNSBURY DR
STARTHROAT DR
RUDDY DR
BUFFLEHEAD DR
DUNLIN DR
LAZY RIVER DR
DAWNLIGHT DR
FOUNTAINVIEW DR
FLYCATCHER DR
PARULA DR
COPPERTAIL DR
GALLINULE DR
MORNINGTIDE DR
RIVERTON DR
WALZ DR
GADWALL DR
EFP Location
Access Point
Marana Owned Land
400 200 0 400
Feet
Town of Marana
Technical Services Department

Appendix F

Town of Marana Floodplain Use Permit Application

TOWN OF MARANA
FLOODPLAIN USE PERMIT APPLICATION

MARANA
TOWN OF MARANA

11555 W Civic Center Drive
Marana, AZ 85653
Phone: (520) 382-2600/Fax: (520) 382-2643

ENG 1004-001

APPLICANT INFORMATION		PROPERTY INFORMATION	
Name	Andrew Ashby	Address:	SCR (Lat 32°25'27.78"N Long 111°12'50.40W)
Company Name	U.S. DOI - Bureau of Reclamation	Tax Code:	
Mailing Address	6150 West Thunderbird Road Glendale AZ, 85306-4001	Township: 11 S	Range: 11 E Section: 34
Phone Number	(623) 773-6452	Legal Description	The project site is located on the main channel of the Santa Cruz River along the southern boundary of Section 34, Township 11 South Range 11 East, Gila & Salt River Base and Meridian.
Fax Number	(623) 773-6481		

CONTRACTOR INFORMATION (if applicable)

Business Name		Contractor Lic	
Address		Marana Bus Lic	
Phone Number		Fax Number	

PROPERTY OWNER INFORMATION

Name	Pima County Regional Flood Control District	Information Submitted With Application	Powerline Gravel Bar, Hydraulic Analysis and Project Details, For the Town of Marana, Department of Public Works.
Address	97 East Congress, 3rd Floor Tucson, AZ 85701		
Phone No	(520) 243-1800		

Description of work to be performed. Excavation along the alignment of the historic thalweg of the Santa Cruz River to produce a receiving channel for enhanced effluent recharge.

Will fill or the storage of of fill take place on the property? ☐ YES ☒ NO

By signing this permit application, the undersigned applies for a permit pursuant and subject to the requirements of the FLOODPLAINAND EROSION HAZARD MANAGEMENT CODE (Title 21 of the Marana Land Development Code), and herby agrees to faithfully abide by all the Covenents, Conditions and Restrictions contained or referred to herein and to indemnify, defend, and hold harmless the Town of Marana and their agents from and against any and all suits, claims or demands associated with the approval of this application. This application becomes a valid permit only when completed and signed by the Town of Marana below and accepted by the applicant. Validated permit is subject to the conditions and restrictions attached (IF ANY)

APPLICANT SIGNATURE Andrew Ashby DATE 4/15/2010

Print Form

THIS PORTION TO BE FILLED OUT BY TOWN OF MARANA FLOODPLAIN MANAGEMENT DEPARTMENT

Rec'd By GM Date 27 APR 10 Map Panel 0990 Zone AE Effective Date 8 FEB 1999

Floodplain Map superceded by LOMR? ☐ NO ☒ YES LOMR Case # 02-09-1039 P LOMR Effective Date 16 SEPT 2004

Floodplain Permit # FP1004-004 Building Permit # NA Conditions & Restrictions # C&R FP1004-001

Elevation Certificate Required? ☐ YES NO Elevation Certificate Completed? ☐ YES

APPROVED BY GUS MYERS CFM DATE 3 MAY 2010

Form Revised Mar 2010

TOWN OF MARANA

Floodplain Use Permit
CONDITIONS & RESTRICTIONS

FLOOD PLAIN USE PERMIT #: FP1004-001

ENG # ENG1004-001

TAX CODE #____

LOCATION: Main Channel of the Santa Cruz River along the southern boundary of Section 34, T11S, R11E GSRBM

The Town of Marana has determined that the above-mentioned property upon which you are requesting to construct a receiving channel and associated flow control/measuring facility is located within the Federal Emergency Management Agency (FEMA) map designated floodplain zone AE per Flood Insurance Rate Map (FIRM) Panel 04019C0990. The property is subject to any and all conditions of a regulated wash and flood plain proposed by Town staff.

GENERAL CONDITIONS *(applicable to all floodplain use permits)*

A. Applicant agrees to comply with all conditions and restrictions as stated in Title 21 of the Town of Marana Land Development Code

B. This Floodplain Use Permit shall be valid for one (1) year from the date of approval. This permit can be revoked subject to the provisions of Title 21.

C. This Floodplain Use Permit applies only to those matters regulated under the Floodplain and Erosion Hazard Management Code, and does not intend, nor should it be construed to approve the establishment of any use or uses prohibited or also regulated by Federal, State or local laws or regulations.

D. Prior to the establishment of any use under this Floodplain Use Permit, the property owner must obtain all necessary permits and approvals required under any Federal, State and local laws and regulations, as well as all permits required under the Clean Water Act. Applicant assumes the responsibility for engineering, design, construction, inspection and maintenance associated with all improvements and facilities covered by this permit.

E. By the issuance of this permit, Town of Marana makes no representation regarding applicant's authority or permission to enter into and upon the lands of third parties. It is the responsibility of the applicant to obtain any and all rights of entry or easements from any or all third party landowners which may be necessary to effectuate the conditions of this permit.

F. Uses allowed under this permit shall be confined to those described in the application and shall conform to the limits shown on the plot plan, ***EXHIBIT A***, attached hereto and incorporated by reference herein.

The following conditions are in compliance with Title 21.

1. **Allowed Storage.** Storage of other material or equipment may be allowed if it is not subject to major damage by floods and is firmly anchored to prevent flotation or is readily removable from the area within the limited time available after flood warnings.

2. The storage and/or processing of materials that are buoyant, flammable, and explosive or that could be injurious to human, animal or plant life in time of flooding is prohibited.

3. Structures shall be constructed so as to offer the minimum obstruction to the flow of flood waters. Whenever possible, structures shall be constructed with the same alignment as the direction of flood flow and so far as practicable, shall be placed approximately on the same alignment as those of adjoining structures.

4. All structures shall be firmly anchored to prevent their flotation, which might otherwise result in damage to other structures or restriction of bridge openings and other narrow sections of the watercourse.

5. Enclosed areas within the regulatory floodplain and below the regulatory flood elevation shall be designed to equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters.

6. Construction (installation) shall not cause floodplain drainage to be altered, disturbed or obstructed other than as approved by the Town of Marana Floodplain Administrator.

SPECIAL CONDITIONS *(applicable to this specific permit)*

1. Not Applicable

These conditions must be observed for Floodplain Use Permit to be valid.

Approved By: GUS MYERS CFM Date Approved: 3 MAY 2010

Permitted To: DOI - BUREAU OF RECLAIMATION

APPLICANT ACCEPTANCE SIGNITURE ***DATE***

TOWN OF MARANA
11555 WEST CIVIC CENTER DRIVE
MARANA AZ 85653

Payee: BUREAU OF RECLAMATION
Date: 05/03/2010 Time: 9:19am
Receipt Number: DSVCS/ 10137
Clerk: SHANNON

Gus

ITEM	REFERENCE	AMOUNT
40020	FP1004-004	
	Floodplain Use	100.00
40060	T21005-001	
	T2 Grading Pe	600.00
	Total:	700.00
Check	1188	700.00
	Change:	0.00

LESLIE WHITE
BUREAU OF RECLAMATION
6150 W THUNDERBIRD RD.
PXAO9000
GLENDALE AZ 85306

For Official Use Only
US Government Tax Exempt
Not Valid For Cash

1188

DATE 4-28-2010

56-1551/441

PAY TO THE ORDER OF TOWN OF MARANA $ 700.00

SEVEN HUNDRED AND NO/100 DOLLARS

Security Features Included. Details on Back.

© DELUXE WALLET OR DUPLICATE

J.P.Morgan
JPMorgan Chase Bank, N.A.
Columbus, OH
Commercial Credit Card Convenience Check

Not Valid For Amount Over $3000
Not Valid After 60 Days
Tax ID# 14-0001849

MEMO PERMIT FEES - D. FALCON

Leslie White

MP

⑆044115511⑆ 5272800002260⑈ 1188

FP1004-004 ~~Fdo~~ T21005-001

SPECIALTY GRAY

Appendix F2

Town of Marana Permit Application for Construction of Public Improvement in the Town of Marana Type II Grading Permit

PERMIT APPLICATION FOR CONSTRUCTION OF PUBLIC IMPROVEMENTS IN THE TOWN OF MARANA

TYPE II GRADING PERMIT

Date of Application:	04/15/2010	**PERMIT NO. ISSUED**	T21005-001
Project Name:	SCR Managed Recharge Phase II, Enhanced Recharge Demonstration		
Project Location/Address:	Main channel of the SCR (Lat 32°25'27.78"N Long 111°12'50.40W)		

Description of Work (In accordance with Title 19, Town of Marana Land Development Code and Resolution 90-05):

Excavation along the alignment of the historic thalweg of the Santa Cruz River to produce a receiving channel for enhanced effluent recharge.

☐ The permit includes private streets.

Applicant/Owner	U.S. Department of the Interior - Bureau of Reclamation				
Contact Name	Andrew Ashby				
Address	6150 West Thunderbird Road				
City	Glendale	State	AZ	Zip	85306
Telephone No.	623-773-6452		Fax No.	623-773-6481	
Applicant's Signature	(If Applicant is not the Owner, the Applicant guarantees they are acting on behalf of the Owner) Andrew Ashby				

Contractor					
Contact Name					
Address					
City		State		Zip	
Telephone No.		Fax Number			
State License No.		Expiration Date			
Town Business License No.		Expiration Date			

A COPY OF THIS PERMIT SHALL BE ON THE JOB AT ALL TIMES.

PERMIT NO. T21005-001

For Official Use Only

PERMIT FEES	
Base Fee	**$100.00**
Construction Cost Fee	
Greater of $500.00	$ 500.00
OR	
Construction Cost $ *1% of Construction Cost* - An agreement for inspection of public improvements has been executed, and Applicant hereby agrees to retain an Engineer of Record and pay the costs of all tests of materials and performance as required by the Town Engineer.	$ Ø
OR	
Construction Cost * $ *3 ½% of Construction Cost* - An agreement for inspection of public improvements has been executed, and Applicant hereby agrees to retain the Town of Marana or his/her designated representative as an Engineer of Record and pay the costs of all tests of materials and performance as required by the Town Engineer. * At the Town's Discretion	$ Ø
AT-RISK Grading Fee	$ Ø
Violation Fee (Double permit fee)	$ Ø
TOTAL FEES DUE Check No. 1188 Receipt No. DSVCS 10137	$600.00

Work performed under this permit shall comply with the Town of Marana Standards, Regulations, Requirements and Federal Permits.

BONDS (AS REQUIRED)	
Bond Amount	
Re-seeding Bond Cost: $0.05 per sq ft of area Area Performance Bond Cost of returning the site to the previous condition plus 15% Contingency Construction Cost: $ Contingency: $	$ Ø
TOTAL FEES DUE Check No. Receipt No. Bond No.	$ Ø

Accepted for the Town of Marana By:	GUS MYERS
Date of Issuance:	3 MAY 2010
THIS PERMIT SHALL BECOME NULL AND VOID IF WORK IS NOT COMPLETED BY:	30 OCT 2010

AH **OWNERS INITIALS**

Revised 8 June 2009

PERMIT NO. T21005-001

TOWN OF MARANA
AGREEMENT FOR CONSTRUCTION OF PUBLIC IMPROVEMENTS

TYPE II GRADING PERMIT: SUBDIVISION AND/OR DEVELOPMENT

In consideration of mutual covenants herein contained, and for other good and valuable consideration, the receipt of sufficiency of which is hereby acknowledged by each party to the other, this AGREEMENT, made and entered into this 3rd ~~15th~~ day of ~~April~~ May, 20 10 , by and between the Town of Marana, a municipal corporation, hereinafter called the Town, and:

U.S. Department of the Interior - Bureau of Reclamation
Name

6150 West Thunderbird Road
Address

Glendale, AZ, 85306-4001
City, State, Zip Code

hereinafter called the Applicant.

WITNESSETH:

WHEREAS, the Applicant desires to make improvement(s) within the Town of Marana, Arizona at:

SCR Managed Recharge Phase II, Enhanced Recharge Demonstration
Project Name (as depicted on the plans)

Main channel of the SCR (Lat 32°25'27.78"N Long 111°12'50.40W)
Location

Santa Cruz River along the southern boundary of Sect 34, R 11 E, T 11 S
Legal Description of the Property

within the public right-of-way, easement, or other property of the Town of Marana. (If the project is within a subdivision, the map or plat is recorded in the office of the Pima County Recorder in Book ____ of Maps and Plats at Page _____ thereof); and

WHEREAS, the required reports, plans, specifications and soil tests for said work have been approved by the Town Engineer, and the officials of the appropriate water and wastewater, or other agencies, as applicable; and

AA **OWNERS INITIALS**

WHEREAS, the Applicant desires that the Town approve the construction of said improvement(s); and

WHEREAS, the Town is willing to approve said improvement(s), provided it/they meet Town Standards and the work is completed in accordance with Town requirements; and

WHEREAS, the Town requires that such improvements in Town rights-of-way be constructed in accordance with Town standards, regulations, and requirements;

NOW, THEREFORE, IT IS AGREED AS FOLLOWS:

1. That the Applicant shall install and construct or cause to have constructed, at the Applicant's sole expense, the improvements set forth in the plans and specifications, Santa Cruz River Managed Recharge Phase II, Enhanced Recharge Demonstration ENG 1004-001, which plans and specifications have been prepared by a Professional Engineer registered to practice in Arizona, and which have been reviewed and approved by the Town Engineer, as well as by the appropriate owner/agency. Construction shall also comply with the conditions for improvements as specified herein.

2. That said work shall be done in conformance to all applicable regulations, permits, standards, and requirements of the Town; and that all required permits shall be obtained by the Applicant prior to the commencement of any work under this Agreement.

3. That a Professional Engineer, registered to practice in Arizona, shall be retained by the Applicant as "Engineer of Record", and said Engineer shall lay out and establish the lines and grades for the work as it progresses, shall be responsible for the surveillance of the construction, and shall order tests to verify the compliance of materials incorporated into the work with the specifications.

4. That the Applicant shall notify, in writing, the Owners of all properties abutting the periphery of the development. Notification shall include a description of the work, the approximate dates the construction will take place, and a telephone number and name of the individual to contact if further information is required. Notification shall be accomplished a minimum of seven (7) calendar days prior to the commencement of any construction activities. A copy of such notice shall be submitted to the Town Engineer.

5. That the Applicant shall pay any and all inspection fees as may be charged to the Applicant by the Town.

6. That the Applicant shall be solely responsible for the cost of material tests required by the Town as well as securing all applicable materials compliance documents and certifications.

dd **OWNERS INITIALS**

7. That the work shall be subject to the inspection and the approval of the Town as the work progresses. The Engineer of Record shall provide at the end of each month a written report as to the progress of the construction together with inspection reports, materials test reports, and any other supplemental data pertinent to the work. Deviations from the approved plans shall be shown on the "As-Built" mylars of the plans. All changes or deviations in the approved plans and/or specifications, other than those of a minor nature, shall be submitted to the Town Engineer for review and approval prior to execution in the field.

8. That the Town Engineer or his/her designated representative shall be present at the final on-site inspection of the improvements. Deficiencies in the work noted during the final inspection shall be corrected to the satisfaction of the Town prior to approval of the improvement by the Town and/or prior to release of assurances.

9. That within thirty (30) calendar days of the completion of construction, the Applicant shall furnish the Town Engineer a closeout package that includes all applicable items from Section 06-06 of Title 6 of the Marana Land Development Code. A certified listing of all items and quantities installed and associated costs will be required to verify permit fees.

10. That the Applicant shall guarantee the work against defective materials or workmanship for a period of at least one (1) year from the final acceptance of the improvements by the Town. Upon discovery of defects, any repair or replacement by the Town pursuant to said guarantee shall be undertaken immediately to the satisfaction of and at no cost to the Town.

11. We the undersigned, our successors and assigns, do hereby save the Town of Marana, its successors and assigns, their employees, officers and agents harmless and indemnify same from any and all claims for damage to persons or property related to the improvements/installations as set forth in the accepted plans and specifications first mentioned above, to the fullest extent permitted by law.

12. During the construction of said improvements, the applicant shall maintain policies of liability insurance, issued by companies licensed to do business in Arizona, in amounts not less than $1,000,000.00, and the Town of Marana shall be an additional insured. The policy limit shall not be construed to limit the scope of indemnity above.

13. The property owner must obtain all necessary permits and approvals required under any Federal, State and local laws and regulations, as well as all permits required. Applicant assumes the responsibility for compliance, engineering, design, construction, inspection and maintenance associated with all improvements and facilities required by such permits.

IN WITNESS WHEREOF, the Applicant has executed or has caused this Agreement to be executed by its proper and duly authorized officer and the Town has caused this Agreement to be executed by the Town Engineer or authorized representative as of the day and year first written above.

AA **OWNERS INITIALS**

PERMIT NO. TZ1005-004

OWNER, TRUST HOLDER OR AUTHORIZED AGENT (APPLICANT):			
Print or Type Company Name	U.S. Department of the Interior - Bureau of Reclamation		
Address	6150 West Thunderbird Road Glendale AZ 85306-4001		
Telephone Number	623-773-6452	Fax Number	623-773-6481
Signature of Owner, Trust Holder or Authorized Agent	Andrew Ashby		Date 4/15/2010
Print or Type Name and Title of Owner, Trust Holder or Authorized Agent	Andrew Ashby, PE Senior Engineer		

The terms and conditions of this Agreement have been read and are hereby agreed to and accepted by the following:

ENGINEER OF RECORD:			
Print or Type Company Name	U.S. Department of the Interior - Bureau of Reclamation		
Address	6150 West Thunderbird Road Glendale AZ 85306-4001		
Telephone Number	623-773-6452	Fax Number	623-773-6481
Signature of Owner, Trust Holder or Authorized Agent	Andrew Ashby		Date 4/15/2010
Print or Type Name and Title of Owner, Trust Holder or Authorized Agent	Andrew Ashby, PE Senior Engineer		

CONTRACTOR:			
Print or Type Company Name			
Address			
Telephone Number		Fax Number	
Signature of Owner, Trust Holder or Authorized Agent			Date
Print or Type Name and Title of Owner, Trust Holder or Authorized Agent			

TOWN OF MARANA:		
Signature of Town Engineer or Authorized Representative	GUS MYERS	Date 3 MAY 2010

AA **OWNERS INITIALS**

TOWN OF MARANA
11555 WEST CIVIC CENTER DRIVE
MARANA AZ 85653

Payee: BUREAU OF RECLAMATION
Date: 05/03/2010 Time: 9:19am
Receipt Number: DSVCS/ 10137
Clerk: SHANNON

Gus

ITEM	REFERENCE		AMOUNT
40020	FP1004-004		
	Floodplain Use		100.00
40060	T21005-001		
	T2 Grading Pe		600.00
	Total:		700.00
Check		1188	700.00
	Change:		0.00

LESLIE WHITE
BUREAU OF RECLAMATION
6150 W THUNDERBIRD RD.
PXAO9000
GLENDALE AZ 85306

For Official Use Only
US Government Tax Exempt
Not Valid For Cash

1188

DATE 4-28-2010

56-1551/441

PAY TO THE ORDER OF TOWN OF MARANA $ 700.00

SEVEN HUNDRED AND 00/100 DOLLARS

Security Features Included Details on Back.

© DELUXE WALLET OR DUPLICATE

J.P.Morgan
JPMorgan Chase Bank, N.A.
Columbus, OH
Commercial Credit Card Convenience Check

Not Valid For Amount Over $3000
Not Valid After 60 Days
Tax ID# 14-0001849

MEMO PERMIT FEES - D. FALCON

Leslie White

MP

⑆044115511⑆5272800002260⑈1188

FP1004-004 ~~Fdo~~ T21005-001

SPECIALTY GRAY

Appendix F3

Town of Marana Santa Cruz River Managed Recharge Phase II, Enhanced Demonstration Project. CLO1111-001 / ENG1004-001 / Permit No’s. T21005-001 / FP1004-001

TOWN OF MARANA
DEVELOPMENT SERVICES

14 Nov 2011

Mr. Andrew Ashby, P.E.
Bureau of Reclamation
Lower Colorado Region, Phoenix Area Office
6150 W Thunderbird Rd
Glendale, Arizona 853085-4001
Via E-Mail

Re: Santa Cruz River Managed Recharge Phase II, Enhanced Demonstration Project. CLO1111-001 / ENG1004-001 / Permit No's. T21005-001 / FP1004-001

Dear Mr. Ashby,

The Town of Marana has reviewed the submitted closeout package for the above referenced permit(s). The closeout package has been accepted. As the referenced commercial project is private and contains no public streets for maintenance; the Town of Marana will not maintain the site improvements and therefore the release from the Private Improvement Agreement will not require council action. The permit(s) listed above are hereby closed.

If you have any questions please feel free to contact me at (520)382-2600.

Sincerely,

Gus Myers

Gus Myers CFM
Engineering Technician
Development Engineering Division
Town of Marana

cc: file

11555 W. CIVIC CENTER DRIVE, BLDG. A2 MARANA, ARIZONA 85653-7003 TELEPHONE: (520) 382-2600 FAX: 382-2641

Appendix G

Pima County Department of Environmental Quality Air Program – Air Quality Activity Permit: Fugitive Dust

PIMA COUNTY DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR PROGRAM
33 N STONE AVE, SUITE 700
TUCSON, ARIZONA 85701
PHONE: (520) 243-7400 FAX: (520) 243-7370
www.deq.pima.gov

AIR QUALITY ACTIVITY PERMIT: FUGITIVE DUST

Permit Number	6353
Effective Date	4/8/2010
Expiration Date	4/7/2011

Permittee	US DOI - Bureau of Reclamation
Address	6150 W. Thunderbird Rd.
	Glendale AZ 85306-

Project Address	(Latitude 32°25'27.78"N Longitude 111°12'50.40"W)
Subdivision	Tangerine Farms Road through the Marana Heritage River Park (via Heritage Park Drive)
Cross Streets	Tangerine Farms Road through the Marana Heritage River Park (via Heritage Park Drive)

THIS PERMIT WAS ISSUED FOR THE FOLLOWING ACTIVITIES

Landstripping/Earthmoving	*- none -*
Trenching	*- none -*
Road Construction	*- none -*
Blasting	*- none -*
Multiple Activities	*1+ to 10 acres*

Please read and abide by the Pima County Code that regulates Air Quality Permits and Fugitive Dust Control.
http://www.deq.pima.gov/air/pdf/DustRegs.pdf

Authorized by: Barbara Dery

4/8/2010 1:12:12 PM

PIMA COUNTY DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR PROGRAM
33 N STONE AVE, SUITE 700
TUCSON, ARIZONA 85701
PHONE: (520) 243-7400 FAX: (520) 243-7370
www.deq.pima.gov

Air Quality Activity Permit Receipt

Issued To	US DOI - Bureau of Reclamation 6150 W. Thunderbird Rd. Glendale AZ 85306-	Account Number	0
		Check Number	1011

Permit Number	6353	Effective Date	4/8/2010
Site Location	(Latitude 32°25'27.78"N Longitude 111°12'50.40"W) Tangerine Farms Road through the Marana Heritage River Park (vi Tangerine Farms Road through the Marana Heritage River Park (vi		

Activity	Amount	Fee
Landstripping (ac)	- none -	$0.00
Trenching (ft)	- none -	$0.00
Road Construction (ft)	- none -	$0.00
Blasting	- none -	$0.00
Multiple Activities (ac)	1+ to 10 acres	$625.00
	Amount Paid	**$625.00**

Appendix H

Arizona Department of Water Resources – Lower Santa Cruz River Managed Recharge Project, Enhanced Recharge Project Meeting April 21, 2010

ARIZONA DEPARTMENT OF WATER RESOURCES
3550 North Central Avenue, Phoenix, Arizona 85012
Telephone: 602 771-8535
Fax: 602 771-8685

JANET NAPOLITANO
Governor

HERB GUENTHER
Director

April 21, 2010

Ms. Deborah Tosline
Bureau of Reclamation
300 W. Congress Street
Room 1L (FB-37)
Tucson, AZ 85701-1371

SUBJECT: Lower Santa Cruz River Managed Recharge Project, Enhanced Recharge Project Meeting April 21, 2010

Dear Ms. Tosline:

The Arizona Department of Water Resources (Department) met to discuss a recharge enhancement demonstration project at the Lower Santa Cruz River Managed Recharge Facility that the permittees would like to pursue under the existing managed USF Permit (No. 71-591928) on April 21, 2010.

Based on the information provided at the meeting, the Department has determined that the demonstration project proposed by the permittees may be carried out under the existing managed USF Permit No. 71-591928. Further, the Department has determined that the USF permit does not need to be modified. The Department would like to request that the permittee provide periodic updates on the project progress and the final results of the demonstration project as a courtesy.

Sincerely,

Doug Dunham, Manager
Assured Water and Recharge Section

Appendix I

Arizona Department of Environmental Quality – ERP under APP 100630

From: Mason Bolitho [Bolitho.Mason@azdeq.gov]
Sent: Monday, June 14, 2010 10:22 AM
To: Tosline, Deborah J
Cc: James Dubois; Holler, Frank (Eric) E; Mike Block; Asia Philbin; Bill Zimmerman; Dorothy O'Brien; Anthony Cuaron; Dave Crockett; Ashby, Andrew S; Lehman, Nathan L; Tracey L. Carpenter; Michele I. Robertson
Subject: RE: ERP under APP 100630

Deborah,

Thank you very much for the information you submitted concerning the planned demonstration project associated with the Lower Santa Cruz River Managed Recharge Project. Based upon this information, we have determined that there is no requirement to amend existing Aquifer Protection Permit (APP) No. P-100630 for the purposes of the described demonstration project. If any changes to the demonstration project are planned, please contact me.

Please call me if you have any questions.

Mason

Mason R. Bolitho, R.G.
Hydrologist
Groundwater Section
(602) 771-4434
mb10@azdeq.gov

From: Tosline, Deborah J [mailto:DTosline@usbr.gov]
Sent: Wednesday, June 09, 2010 2:11 PM
To: Mason Bolitho
Cc: 'James Dubois'; Holler, Frank (Eric) E; Mike Block; Asia Philbin; Bill Zimmerman; Dorothy O'Brien; Anthony Cuaron; Dave Crockett; Ashby, Andrew S; Lehman, Nathan L
Subject: ERP under APP 100630

Mason,

I am writing to provide information to ADEQ regarding a demonstration project that Reclamation and partners are planning under our current Underground Storage Facility permit and to request approval from ADEQ to conduct the project under the existing Aquifer Protection Permit. The primary purpose of the Enhanced Recharge Project is to increase infiltration rates by spreading surface water flows (treated effluent) across the Santa Cruz River channel. A description of the demonstration project is attached. ADWR provided approval for the ERP in the attached correspondence.

ADEQ and ADWR permit information:
APP: 100630
USF Permit Number: 71-591928
USF Name: Lower Santa Cruz River Managed Recharge Project

If you have questions or require additional information, please contact me.

Best regards,

Deborah Tosline, R.G.
Hydrologist/Assistant Program Manager

U.S. Department of the Interior
Bureau of Reclamation
300 W. Congress Rm 1L (FB-37)
Tucson, AZ 85701
Office: 520-670-4806
Fax: 520-670-4745
Cell: 520-404-1083
dtosline@usbr.gov
www.usbr.gov

Appendix J

ELM Locating & Utility Services

ELM Locating & Utilit[illegible] Services

NOTIFICATION OF INCOMPLETE BLUES[illegible]

Fax #: **623.773.6481** **Date Faxed** **January 25, 2011** [illegible] **Time** ________

Blue Stake Ticket # **2011012000177.001** **Orig[illegible] Due Date:** **JAN. [illegible]4, 2011**

Location: **N SANDERS RD**

To Whom It May Concern: **ANDREW ASHBY with US BUREAU [illegible] RECLAIMATION**

ARIZONA REVISED STATUTE 6.3[illegible]

Sec. 40-360.22 Paragraph "J"

"An excavator that requests facility markings shall limit the [illegible] est to an area that can reasonably be excavated within the validity period of the markin[illegible] person who violates this subsection is liable to the one-call notification center and to all [illegible]ed underground facilities operators for any damages proximately caused by the violation, [illegible]ding economic loss."

Sec.40-360.22 Paragraph "B"

"The owner of the facility shall respond as promptly as practical, [illegible] n no event later than two working days. No person shall begin excavating before the locatio[illegible] markings are complete or the excavator is notified that marking is unnecessary."

Sec. 40-360.22 Paragraph "I"

"If an underground facility operator is unable to complete the locat[illegible]d marking within the time period provided by subsection B of this section, the facility operator [illegible] satisfy the requirements of this section by proving prompt notice of these facts to the excava[illegible]nd assigning one or more representatives to be present on the excavation site at all pertin[illegible]mes as requested by the excavator to provide facility location services until the facilities have [illegible] located and marked or the excavator is notified that marking is unnecessary pursuant to any [illegible]ally agreeable method. A person that receives notice from the underground facility operato[illegible]ese facts shall not begin excavating before the underground facility operator has completed [illegible]g the underground facility or the excavator is notified that marking is unnecessary. Except as [illegible]ed in subsection "J" of this section, the underground facility operator shall bear all of its own exp[illegible] associated with assigning representatives.

As allowed by these sections, we are notifying you ELM Locating & [illegible] Services, responsible for marking __Qwest _ _SWG __TRICO were unable to complete ou[illegible]kings on your Blue Stake ticket (see specifics above) within the required two working days due [illegible]

X Other Ticket is not complete due to...NO ACC[illegible] TODAY...ACCESS AVAILABLE TOMORROW. WILL LOCATE 1/26/2011.

Please contact us IMMEDIATELY to set-up a site meet to discus[illegible]tinent times and locations where you will be excavating so we can avoid damage to these facili[illegible] You can reach us by calling the following numbers:

Area Locator:	**Jason Summerkamp**	**Phone #:**	**[illegible]20.349.6834**
Fax#:	**520.740.9949**	**Area Supervisor:**	**[illegible]ll Stubblefield**

Appendix K

Job Hazard Analysis Enhanced Recharge Channel Excavation Bureau of Reclamation Phoenix Area Office January 3, 2011

Job Hazard Analysis
Enhanced Recharge Channel Excavation
Bureau of Reclamation
Phoenix Area Office
January 3, 2011

Participants:

Reclamation:
Andrew Ashby
Tosline Deborah
Carol Hanson

Flowing Wells Irrigation District:
Dave Crockett
Geoff Caron

Tucson Water:

Metro Water:

Pima County WW:
Joe Gonzales

Operations to be Performed:

- Perform channel excavation on approximately 2000 linear feet of channel using front end loaders and dump trucks.
- Place and smooth excavated material on haul roads and at stockpile locations using loaders and trucks.
- Apply construction water to haul roads and piles utilizing 5000 gallon off highway water pull.
- Extract water from "Ox Bow" irrigation ditch at the culvert crossing utilizing a 4" diesel pump.

Safety Equipment Required:

Appropriate personal protective equipment includes long sleeve shirts and long pants, hard hat, safety boots, ear and eye protection, safety vest, dust protection, gloves, fluids, first aid kit, camera, and cell phone. Additionally, a life ring with rope will be available onsite for use around the Santa Cruz River and the diversion channel.

Hazards and Solutions:

Specific Hazard	*Solution*
Heavy Equipment Delivery and Offloading	Provide for proper clearances near and around equipment. Utilize signage and traffic control where near public roads. Those not involved in the offload should remain at a safe distance from the equipment.
Heavy Equipment	Ensure all equipment is equipped with the proper safety equipment including fire extinguishers, back up alarm, etc. Perform safety inspections and brake tests. Ground crews shall wear hi visibility clothing and avoid working in areas near equipment that may be hard to see by the operator.
Petroleum Spill	In case of release of petroleum absorptive booms and towels will be onsite. Work shall cease in the area and all effort shall focus on cleanup of the spill. Soil that has come in contact with the fluid shall be removed and disposed of at an approved facility. If the spill is large enough local hazmat crews shall be notified.
Pumps and Pipes	Pump supplier shall give instructions on the proper operation of the pump and load-stand piping. Only those that have been instructed should operate the pumps. Make certain that all pipes are secure before pressurizing to avoid unexpected movement.
Dust	Haul roads and excavation limits will be water to reduce dust emissions.
Overhead Powerlines	Ensure that buckets and booms are lowered to allow for proper clearances around powerlines. Use a spotter as necessary when working nearby to ensure that no contact will occur.
Ongoing Construction (Visitors)	Visitors shall report in with inspector prior to entering construction area. Be aware of location of construction equipment. Use personal protective equipment.
Transportation, driver fatigue	Keep vehicle maintenance current. Stop often to avoid fatigue

Weather conditions	Be prepared for the current weather conditions. Use rain gear, sun screen, hat, long-sleeved shirt and pants, and jacket as needed. Monitor stream gauges on the Santa Cruz River to alert crews to possible high water in the channel.
Dehydration	Come prepared with plenty of liquids and drink frequently; recommend one gallon per day. When lightheaded or nauseated, proceed to a shady area, sit down and cool the body off.

Safety Standards Requirements:

Reclamation Safety and Health Standards
Safety and Health for Field Operations
Brief personnel on specific safety issues

Emergency Services:

In the event of an emergency situation contact emergency services by dialing 911.

Reclamation shall be notified, both Onsite Representative and Office Engineer (623-773-6452) should be contacted as soon as possible after appropriate response has been issued.

Job Hazard Analysis Prepared By: Andrew Ashby (signature) — Andrew Ashby — 12/27/10 — Date

Job Hazard Analysis Reviewed By: (signature) — John Gusich — 12-27-12 — Date

Note: MAKE SURE A LIFE RING + ATTACHED LINE IS AVAILABLE

Signatures of the team members listed below indicate that they have been instructed in and understand the requirements and hazards associated with the excavation work.

Signatures of the team members listed below indicate that they have been instructed in and understand the requirements and hazards associated with the excavation work.

__________________ __________
Date

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Date

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Date

Date

CITY	HOSPITAL	ADDRESS	PHONE NUMBER
Tucson	University Medical Center	1501 North Campbell Avenue; Tucson, AZ	520-694-0111
	Northwest Medical Center	6200 N La Cholla; Tucson, AZ 85741	520-742-9000
	St. Mary's Hospital	1601 W Saint Mary's Road; Tucson, AZ 85745	520-872-3000
	Kino Community Hospital	2800 E Ajo Way; Tucson, AZ 85713	520-294-4471
	University Physicians Hospital	2800 E Ajo Way; Tucson, AZ 85713	520-874-2000
	St. Joseph Hospital	350 N Wilmot Road; Tucson, AZ 85711	520-873-3000

Appendix K2

Job Hazard Analysis - Addendum Enhanced Recharge Channel Excavation Bureau of Reclamation Phoenix Area Office January 13, 2011

Job Hazard Analysis - Addendum
Enhanced Recharge Channel Excavation
Bureau of Reclamation
Phoenix Area Office
January 13, 2011

Participants:

Reclamation:
Andrew Ashby
Tosline Deborah
Danny Falcon
Jeff Reichelt

Tucson Water:

Operations Completed:

- Perform channel excavation on approximately 2000 linear feet of channel using front end loaders and dump trucks.
- Place and smooth excavated material on haul roads and at stockpile locations using loaders and trucks.
- Apply construction water to haul roads and piles utilizing 5000 gallon off highway water pull.
- Extract water from "Ox Bow" irrigation ditch at the culvert crossing utilizing a 4" diesel pump.

Operations to be Performed:

- Install two galvanized steel flumes in the main channel
- Excavate anchor trench for concrete anchor
- Construct and place concrete anchor in trenches, backfill trenches and rig anchors to flumes with steel cable.
- Excavate remaining 75'-100' feet of channel at the upstream and downstream ends of the main channel, thus establishing flow in the channel.

Work Sequence and Hazards.

Flumes shall be installed level in the excavated channel requiring heavy equipment to smooth a five foot section. Final grading will be accomplished with hand tools. The flumes will be unloaded from the truck and carried a short distance to the proposed location. Do not attempt to carry the flume into the excavation. First place the flume on the bank then enter the channel and remove the flume from the bank into its final location.

Individuals will be required to work around heavy equipment while preparation is underway and are advised to review heavy equipment safety found in the original JHA. Final grading work with hand tools shall be conducted to minimize the chances of injury by employing such techniques as using the legs for leverage and not the back, wear gloves and other PPE to minimize blisters and injury.

Pre-mix concrete will be used to construct anchors for the flume installations. The concrete will be mixed onsite using water from the river. Eye and hand protection is important when working around the wet concrete. The anchors will be allowed to set-up overnight then will be placed into holes excavated with a backhoe. These holes will be approximately 10 feet deep. Under no circumstances shall anyone enter the excavated hole. The anchor blocks will be lowered using the attached steel cable rigging that will later be attached to the flume. The anchor will be lowered and placed using the backhoe.

Finally the upstream plug will be excavated allowing water to flow in the new channel.

Job Hazard Analysis
Enhanced Recharge Channel Excavation
Bureau of Reclamation
Phoenix Area Office
January 3, 2011

Participants:

Reclamation:
Andrew Ashby
Tosline Deborah
Carol Hanson

Flowing Wells Irrigation District:
Dave Crockett
Geoff Caron

Tucson Water:

Metro Water:

Pima County WW:
Joe Gonzales

Operations to be Performed:

- Perform channel excavation on approximately 2000 linear feet of channel using front end loaders and dump trucks.
- Place and smooth excavated material on haul roads and at stockpile locations using loaders and trucks.
- Apply construction water to haul roads and piles utilizing 5000 gallon off highway water pull.
- Extract water from “Ox Bow” irrigation ditch at the culvert crossing utilizing a 4” diesel pump.

Safety Equipment Required:

Appropriate personal protective equipment includes long sleeve shirts and long pants, hard hat, safety boots, ear and eye protection, safety vest, dust protection, gloves, fluids, first aid kit, camera, and cell phone. Additionally, a life ring with rope will be available onsite for use around the Santa Cruz River and the diversion channel.

Hazards and Solutions:

Specific Hazard	*Solution*
Heavy Equipment Delivery and Offloading	Provide for proper clearances near and around equipment. Utilize signage and traffic control where near public roads. Those not involved in the offload should remain at a safe distance from the equipment.
Heavy Equipment	Ensure all equipment is equipped with the proper safety equipment including fire extinguishers, back up alarm, etc. Perform safety inspections and brake tests. Ground crews shall wear hi visibility clothing and avoid working in areas near equipment that may be hard to see by the operator.
Petroleum Spill	In case of release of petroleum absorptive booms and towels will be onsite. Work shall cease in the area and all effort shall focus on cleanup of the spill. Soil that has come in contact with the fluid shall be removed and disposed of at an approved facility. If the spill is large enough local hazmat crews shall be notified.
Pumps and Pipes	Pump supplier shall give instructions on the proper operation of the pump and load-stand piping. Only those that have been instructed should operate the pumps. Make certain that all pipes are secure before pressurizing to avoid unexpected movement.
Dust	Haul roads and excavation limits will be water to reduce dust emissions.
Overhead Powerlines	Ensure that buckets and booms are lowered to allow for proper clearances around powerlines. Use a spotter as necessary when working nearby to ensure that no contact will occur.

Ongoing Construction (Visitors)	Visitors shall report in with inspector prior to entering construction area. Be aware of location of construction equipment. Use personal protective equipment.
Transportation, driver fatigue	Keep vehicle maintenance current. Stop often to avoid fatigue
Road hazards	Use caution, be alert to traffic, use vehicle emergency flashers or other appropriate warning devices.
Weather conditions	Be prepared for the current weather conditions. Use rain gear, sun screen, hat, long-sleeved shirt and pants, and jacket as needed. Monitor stream gauges on the Santa Cruz River to alert crews to possible high water in the channel.
Dehydration	Come prepared with plenty of liquids and drink frequently; recommend one gallon per day. When lightheaded or nauseated, proceed to a shady area, sit down and cool the body off.

Safety Standards Requirements:

Reclamation Safety and Health Standards
Safety and Health for Field Operations
Brief personnel on specific safety issues

Emergency Services:

In the event of an emergency situation contact emergency services by dialing 911.

Reclamation shall be notified, both Onsite Representative and Office Engineer (623-773-6452) should be contacted as soon as possible after appropriate response has been issued.

Job Hazard Analysis Prepared By: ______________________ ________
Andrew Ashby Date

Job Hazard Analysis Reviewed By: ______________________ ________

John Gusich Date

Signatures of the team members listed below indicate that they have been instructed in and understand the requirements and hazards associated with the excavation work.

____________________ ____________
Date

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Date

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Date

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Date

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Date

____________________ ____________

Date

Date

Date

CITY	HOSPITAL	ADDRESS	PHONE NUMBER
Tucson	University Medical Center	1501 North Campbell Avenue; Tucson, AZ	520-694-0111
	Northwest Medical Center	6200 N La Cholla; Tucson, AZ 85741	520-742-9000
	St. Mary's Hospital	1601 W Saint Mary's Road; Tucson, AZ 85745	520-872-3000
	Kino Community Hospital	2800 E Ajo Way; Tucson, AZ 85713	520-294-4471
	University Physicians Hospital	2800 E Ajo Way; Tucson, AZ 85713	520-874-2000
	St. Joseph Hospital	350 N Wilmot Road; Tucson, AZ 85711	520-873-3000

Appendix K3

Job Hazard Analysis – Addendum #2 Enhanced Recharge Channel Excavation Bureau of Reclamation Phoenix Area Office October 27th, 2011

Job Hazard Analysis – Addendum#2
Enhanced Recharge Channel Excavation
Bureau of Reclamation
Phoenix Area Office
October 27th, 2011

Participants:

Reclamation:
- Danny Falcon
- David Trimm
- Henry Corretjer
- Nathan Lehman

Optional:
- Deborah Tosline
- Gina Derosa
- Sarabeth Schuman

Operations Completed:

- Perform channel excavation on approximately 2000 linear feet of channel using front end loaders and dump trucks.
- Place and smooth excavated material on haul roads and at stockpile locations using loaders and trucks.
- Apply construction water to haul roads and piles utilizing 5000 gallon off highway water pull.
- Extract water from "Ox Bow" irrigation ditch at the culvert crossing utilizing a 4" diesel pump.
- Install two galvanized steel flumes in the main channel
- Excavate anchor trench for concrete anchor
- Construct and place concrete anchor in trenches, backfill trenches and rig anchors to flumes with steel cable.
- Excavate remaining 75'-100' feet of channel at the upstream and downstream ends of the main channel, thus establishing flow in the channel.

Operations to be Performed:
- Excavate and Remove two galvanized steel flumes from the main channel.
- Removal of steel cable and any visible sandbags leftover from the project.

Work Sequence and Hazards.

Flumes shall be excavated with hand tools such as shovels and picks. Using bolt cutters, the steel cables will be cut from the flumes and recycled here at PXAO. Any visible sandbags leftover from the project site will also be removed and disposed of properly. After excavation the flumes will be carried a short distance and loaded onto a truck. The flumes will be delivered to Reclamation's storage yard at the San Xavier District.

Excavation work with hand tools shall be conducted to minimize the chances of injury by employing such techniques as using the legs for leverage and not the back, wear gloves, steel toes and hard hats to minimize blisters and injury.

Job Hazard Analysis – Addendum#1
Enhanced Recharge Channel Excavation
Bureau of Reclamation
Phoenix Area Office
January 13, 2011

Participants:

Reclamation:
Andrew Ashby
Tosline Deborah
Danny Falcon
Jeff Reichelt

Tucson Water:

Operations Completed:

- Perform channel excavation on approximately 2000 linear feet of channel using front end loaders and dump trucks.
- Place and smooth excavated material on haul roads and at stockpile locations using loaders and trucks.
- Apply construction water to haul roads and piles utilizing 5000 gallon off highway water pull.
- Extract water from "Ox Bow" irrigation ditch at the culvert crossing utilizing a 4" diesel pump.

Operations to be Performed:

- Install two galvanized steel flumes in the main channel
- Excavate anchor trench for concrete anchor
- Construct and place concrete anchor in trenches, backfill trenches and rig anchors to flumes with steel cable.
- Excavate remaining 75'-100' feet of channel at the upstream and downstream ends of the main channel, thus establishing flow in the channel.

Work Sequence and Hazards.

Flumes shall be installed level in the excavated channel requiring heavy equipment to smooth a five foot section. Final grading will be accomplished with hand tools. The flumes will be unloaded from the truck and carried a short distance to the proposed location. Do not attempt to carry the flume into the excavation. First place the flume on the bank then enter the channel and remove the flume from the bank into its final location.

Individuals will be required to work around heavy equipment while preparation is underway and are advised to review heavy equipment safety found in the original JHA. Final grading work with hand tools shall be conducted to minimize the chances of injury by employing such techniques as using the legs for leverage and not the back, wear gloves and other PPE to minimize blisters and injury.

Pre-mix concrete will be used to construct anchors for the flume installations. The concrete will be mixed onsite using water from the river. Eye and hand protection is important when working around the wet concrete. The anchors will be allowed to set-up overnight then will be placed into holes excavated with a backhoe. These holes will be approximately 10 feet deep. Under no circumstances shall anyone enter the excavated hole. The anchor blocks will be lowered using the attached steel cable rigging that will later be attached to the flume. The anchor will be lowered and placed using the backhoe.

Finally the upstream plug will be excavated allowing water to flow in the new channel.

Job Hazard Analysis
Enhanced Recharge Channel Excavation
Bureau of Reclamation
Phoenix Area Office
January 3, 2011

Participants:

Reclamation:
Andrew Ashby
Tosline Deborah
Carol Hanson

Flowing Wells Irrigation District:
Dave Crockett
Geoff Caron

Tucson Water:

Metro Water:

Pima County WW:
Joe Gonzales

Operations to be Performed:

- Perform channel excavation on approximately 2000 linear feet of channel using front end loaders and dump trucks.
- Place and smooth excavated material on haul roads and at stockpile locations using loaders and trucks.
- Apply construction water to haul roads and piles utilizing 5000 gallon off highway water pull.
- Extract water from "Ox Bow" irrigation ditch at the culvert crossing utilizing a 4" diesel pump.

Safety Equipment Required:

Appropriate personal protective equipment includes long sleeve shirts and long pants, hard hat, safety boots, ear and eye protection, safety vest, dust protection, gloves, fluids, first aid kit, camera, and cell phone. Additionally, a life ring with rope will be available onsite for use around the Santa Cruz River and the diversion channel.

Hazards and Solutions:

Specific Hazard	***Solution***
Heavy Equipment Delivery and Offloading	Provide for proper clearances near and around equipment. Utilize signage and traffic control where near public roads. Those not involved in the offload should remain at a safe distance from the equipment.
Heavy Equipment	Ensure all equipment is equipped with the proper safety equipment including fire extinguishers, back up alarm, etc. Perform safety inspections and brake tests. Ground crews shall wear hi visibility clothing and avoid working in areas near equipment that may be hard to see by the operator.
Petroleum Spill	In case of release of petroleum absorptive booms and towels will be onsite. Work shall cease in the area and all effort shall focus on cleanup of the spill. Soil that has come in contact with the fluid shall be removed and disposed of at an approved facility. If the spill is large enough local hazmat crews shall be notified.
Pumps and Pipes	Pump supplier shall give instructions on the proper operation of the pump and load-stand piping. Only those that have been instructed should operate the pumps. Make certain that all pipes are secure before pressurizing to avoid unexpected movement.
Dust	Haul roads and excavation limits will be water to reduce dust emissions.
Overhead Powerlines	Ensure that buckets and booms are lowered to allow for proper clearances around powerlines. Use a spotter as necessary when working nearby to ensure that no contact will occur.
Ongoing Construction (Visitors)	Visitors shall report in with inspector prior to entering construction area. Be aware of location of construction equipment. Use personal protective equipment.

Transportation, driver fatigue	Keep vehicle maintenance current. Stop often to avoid fatigue
Road hazards	Use caution, be alert to traffic, use vehicle emergency flashers or other appropriate warning devices.
Weather conditions	Be prepared for the current weather conditions. Use rain gear, sun screen, hat, long-sleeved shirt and pants, and jacket as needed. Monitor stream gauges on the Santa Cruz River to alert crews to possible high water in the channel.
Dehydration	Come prepared with plenty of liquids and drink frequently; recommend one gallon per day. When lightheaded or nauseated, proceed to a shady area, sit down and cool the body off.

Safety Standards Requirements:

Reclamation Safety and Health Standards
Safety and Health for Field Operations
Brief personnel on specific safety issues

Emergency Services:

In the event of an emergency situation contact emergency services by dialing 911.

Reclamation shall be notified, both Onsite Representative and Office Engineer (623-773-6452) should be contacted as soon as possible after appropriate response has been issued.

Job Hazard Analysis Addendum Prepared By: ______ Danny Falcon ______ 10/11/11 Date

Job Hazard Analysis Reviewed By: ______ John Gusich ______ 10-11-11 Date

Signatures of the team members listed below indicate that they have been instructed in and understand the requirements and hazards associated with the excavation work.

[illegible]	10/27/11 Date
[illegible]	10/27/11 Date
David [illegible]	10-27-11 Date
[illegible]	10/27/11 Date
[illegible]	10/27/11 Date
	Date
	Date
	Date
	Date

CITY	HOSPITAL	ADDRESS	PHONE NUMBER
Tucson	University Medical Center	1501 North Campbell Avenue; Tucson, AZ	520-694-0111
	Northwest Medical Center	6200 N La Cholla; Tucson, AZ 85741	520-742-9000
	St. Mary's Hospital	1601 W Saint Mary's Road; Tucson, AZ 85745	520-872-3000
	Kino Community Hospital	2800 E Ajo Way; Tucson, AZ 85713	520-294-4471
	University Physicians Hospital	2800 E Ajo Way; Tucson, AZ 85713	520-874-2000
	St. Joseph Hospital	350 N Wilmot Road; Tucson, AZ 85711	520-873-3000

Appendix L

Reclamation Daily Inspection Report Managed Recharge Phase II Enhanced Recharge Project

ENHANCED RECHARGE
DAILY REPORT

DAY OF WEEK: Monday
DATE: January 3, 2011
Hours: 7:00 am to 3:30 pm

SOLICITATION NO.: NA

CONTRACTOR: NA
Work performed by representatives from Tucson Water, Pima County Regional Wastewater, Flowing Wells ID and Metro Water.

SUBCONTRACTOR(s):

WEATHER: clear, cold GROUND CONDITION: damp

TEMPERATURE: MIN:20s MAX: 40s

SAFETY:

Acceptable: Andrew Ashby with the oversight of John Gusich performed safety briefing and review of JHA.

WORK PERFORMED AND REMARKS:

Arrived onsite at 0700 to find Empire and Tucson Tractor delivering equipment and offloading along Sanders Road. Empire supplied a water pull and Tucson Tractor supplied a FEL. Tucson will deliver their own equipment and were not expected onsite until 10:30. A safety meeting was conducted near the entry gate to the access route and staging area. Equipment was driven to the culvert crossing on the diversion channel where work began. The FE loader operated by FWID began placing stockpiled material over the culvert crossing to allow equipment to cross. The culvert crossing will be used to stage a pump to extract water from the diversion for construction. The previous week a load stand had been delivered to the site by Pima County.

At about 0900 both TW and Pima County arrived onsite. A FEL from TW arrived onsite at about 0930 and began assisting with the crossing and pad. Pima County arrived with the pump and piping intended to fill the water pull. The crew waited around until about 1000 when the crossing and pump pad was finished, allowing them to cross and set up.

TW took the FEL to the river site at 1030 to begin clearing the alignment. FWID continued leveling a turnaround for the water pull near the pump. At 1200 both loaders were working on channel excavation. Excavated material was hauled from the channel a spread on the existing road.

The water pull was unable to water the roads since a fitting was needed that did not arrive with the pump. However, the damp condition of the roads and channel material made this possible.

Equipment was moved back to the coral area at 1500 for overnight storage.

The following equipment is onsite:
Cat 613 Water Pull, Cat 950 loader, Case 721 loader, Power Prime diesel pump.

Field Engineer: Andrew S. Ashby

ENHANCED RECHARGE
DAILY REPORT

DAY OF WEEK: Tuesday
DATE: January 4, 2011
Hours: 7:00 am to 3:30 pm

SOLICITATION NO.: NA

CONTRACTOR: NA
Work performed by representatives from Tucson Water, Pima County Regional Wastewater, Flowing Wells ID and Metro Water.

SUBCONTRACTOR(s):

WEATHER: clear, cold GROUND CONDITION: damp

TEMPERATURE: MIN:20s MAX: 40s

SAFETY:

Acceptable: Andrew Ashby with the oversight of John Gusich performed safety briefing and review of JHA.

WORK PERFORMED AND REMARKS:

Arrived onsite at 0700 just prior to the operators from TW, FWID and PC who began warming up equipment. The ground is frozen. The PC operator stopped by their shop and made up a fitting for the water pull. Should be able to get some water on the roads today.

The FEL went to work in the channel. At 0800 an end dump from Metro Water arrived onsite. The dump was sent to work with the FEL’s near the river with a plan to spread material on the existing road by chaining the gate on the dump. This process worked well and with the exception of two incidents of being stuck the truck speeded production. Turnarounds were improved with excavated material to keep the dump from getting stuck.

Roads where watered using the water pull. Only need to make a couple passes per day to keep the dust down on the portion west of the crossing. The fill comes out of the river damp and doesn’t need much water. When not watering the driver assists with checking grade in the river.

Equipment was moved back to the coral area at 1500 for overnight storage.

The following equipment is onsite:
Cat 613 Water Pull, Cat 950 loader, Case 721 loader, Power Prime diesel pump.

Field Engineer: Andrew S. Ashby

ENHANCED RECHARGE
DAILY REPORT

DAY OF WEEK: Tuesday
DATE: January 5, 2011
Hours: 7:00 am to 3:30 pm

SOLICITATION NO.: NA

CONTRACTOR: NA
Work performed by representatives from Tucson Water, Pima County Regional Wastewater, Flowing Wells ID and Metro Water.

SUBCONTRACTOR(s):

WEATHER: clear, cold GROUND CONDITION: damp

TEMPERATURE: MIN:20s MAX: 40s

SAFETY:

Acceptable: Andrew Ashby with the oversight of John Gusich performed safety briefing and review of JHA.

WORK PERFORMED AND REMARKS:

Arrived onsite at 0700 just after the operators from TW, FWID and PC who began warming up equipment. The ground is frozen. Today Carol Hansen from LC Region is onsite to take over as inspector for the duration of work.

The FEL went to work in the channel. At 0800 an end dump from Metro Water arrived onsite. The dump was sent to work with the FEL's near the river with a plan to spread material on the existing road by chaining the gate on the dump. This process continued to work well. Two lifts had been placed on the road and it was discussed that after one more we would not put more on the road. The truck will then haul material to the crossing for stockpile.

Roads where watered using the water pull. Only need to make a couple passes per day to keep the dust down on the portion west of the crossing. The fill comes out of the river damp and doesn't need much water. When not watering the driver assists with checking grade in the river.

I briefed Carol on the work and transferred equipment, including survey and safety, to her. She was introduced to all the operators and started out by checking grade with me. I left the site for a couple hours to get an invert cut sheet copied and pick up NWP in Tucson. Upon my return we reviewed some of the grade that was shot. It appeared they still needed to cut two feet in the downstream section from about 2+50 to 6+00 the rest of the main channel was at or near grade.

I left the site at 1300 to return to the Phoenix Area Office.

The following equipment is onsite:
Cat 613 Water Pull, Cat 950 loader, Case 721 loader, Power Prime diesel pump.

Field Engineer: Andrew S. Ashby

Managed Recharged Phase II
Daily Inspection Report

Day, Date:	Wednesday, January 5, 2011	**Shift**	0700 hrs to 1530 hours	
Project Location:	Santa Cruiz River	**Temperature:**	H 44°f	L:18˚f
Project No.:		**Precipitation:**	0.0	
Feature:	Enhanced Recharged Channel Excavation	**Weather:**	Partly Cloudy and Cool	
Contractor:	Flowing Wells Irrigation District	**Representative:**	Al Chealano	
Contractor:	Tucson Water	**Representative:**	Julian Pallanes	
Contractor:	Metro Waters	**Representative:**	Steve	
Contractor:	Pima County WW	**Representative:**	Joe Gonzales	

Major Features of Work

A crew of two operators, one dump truck driver, and one water truck driver arrived onsite to continue removing the material from approximately station 0+50 to 11+00 on the main channel. Surveying was taken several times throughout the day to verify the excavated material. The equipment on site was One Case front end loader, one Caterpillar front end loader, one Caterpillar water truck and one Mac Dump truck. The two loaders filled the dump truck with the excavated material. The material then was spread along the roadway to fill in any depressions and to improve the roadway. The roadways were watered throughout the day for dust abatement.

SAFETY

Significant Discussions (Contractor, Owner, Area Office, Region, or TSC)

Bureau of Reclamation representative Andrew Ashby was onsite to oversee the start of the day and to go over the job with construction inspector, Carol Jean Hansen. Photos were taken of the job progress.

PERSONNEL			
Name	**Task**	**Description**	**Worked**
Flowing Wells Irrigation District			
Al Chealano	Operator	Operated the Case Front End loader	8
Tucson Water			
Julian Pallanes	Operator	Operated the Caterpillar Front End Loader	8
Metro Water			
Steve	Truck Driver	Operated the Dump Truck	4
Pima County WW			
Don	Truck Driver	Operated the Water Truck	8

Equipment on Site					
Type / Capacity	**Make/Model**	**Activity**	**Usage**	**Idle**	**Repairs**
Front End Loader	Case 721D	Excavated Channels	8	0	0
Front End Loader	Caterpillar 950G	Excavated Channel	8	0	0
Dump Truck		Hauled excavated material	4	4	0
Water Truck	Caterpillar Water wagon	Dust Abatement	6	0	2

Attachment – 8 photographs

Construction Representative	**Date**
Carol Jean Hansen	1/05/2011
Supervisory Representative or Field Engineer	**Date**
Andrew Ashby	

Photo Number: 00101052011 Date Photo Taken on: 1-5-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Caterpillar Water truck used for Dust abatement.

Photo Number: 00201052011 Date Photo Taken on: 1-5-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Case front-end loader used to excavate the channels.

Photo Number: 00301052011 Date Photo Taken on: 1-5-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Start of the exaction on the main channel.

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Photo Number: 00401052011 Date Photo Taken on: 1-5-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Excavation of the main channel.

Daily Inspection Report, Wednesday, January 5, 2011

Photo Number: 0001052011 Date Photo Taken on: 1-5-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Caterpillar Front-end loader excavating the main channel.

Photo Number: 00601052011 Date Photo Taken on: 1-5-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The two front end loaders working together to get the material out of the main channel.

Photo Number: 00701052011 Date Photo Taken on: 1-5-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Progress of the Main Channel excavated, at station 5+50, looking East.

Photo Number: 00801062011 Date Photo Taken on: 1-6-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Progress of the Main Channel looking West around station 5+00.

Managed Recharged Phase II
Daily Inspection Report

Day, Date:	Thursday, January 06, 2011	**Shift**	0700 hrs to 1530 hours	
Project Location:	Santa Cruiz River	**Temperature:**	H: 64°f	L: 39˚f
Project No.:		**Precipitation:**	0.0	
Feature:	Enhanced Recharged Channel Excavation	**Weather:**	Partly Cloudy Skies	
Contractor:	Flowing Wells Irrigation District	**Representative:**	Al Chealano	
Contractor:	Tucson Water	**Representative:**	Julian Pallanes	
Contractor:	Metro Waters	**Representative:**	Steve	
Contractor:	Pima County WW	**Representative:**	Joe Gonzales	

Major Features of Work

A crew of two operators, one dump truck driver, and one water truck driver arrived onsite to continue removing the material from approximately station 0+50 to 11+00 on the main channel. The dump truck driver arrived on the job site at 1100 hours due to other commitments. The excavation crew stockpiled the material and was hauled away from the channel area once the dump truck arrived on the job site. The crew started on the secondary channel, while the main channel was being resurveyed. Surveying measurements were taken several times throughout the day to verify the bottom elevation of the channel. The equipment on site was one Case front-end loader, one Caterpillar front-end loader, one Caterpillar water truck, and one Mac Dump truck. The two front-end loaders used their buckets to remove the material. The excavated material was placed into the dump truck. The excavated material was spread along the roadway to fill in any depressions and to improve the roadways and placed in a stockpile. The roadways were watered throughout the day for dust abatement.

SAFETY

No safety violations were noted.

Significant Discussions (Contractor, Owner, Area Office, Region, or TSC)

PERSONNEL			
Name	**Task**	**Description**	**Worked**
Flowing Wells Irrigation District			
Al Chealano	Operator	Operated the Case Front End loader	8
Tucson Water			
Julian Pallanes	Operator	Operated the Caterpillar Front End Loader	8
Metro Water			
Steve	Truck Driver	Operated the Dump Truck	4
Pima County WW			
Don	Truck Driver	Operated the Water Truck	8

Equipment on Site					
Type / Capacity	**Make/Model**	**Activity**	**Usage**	**Idle**	**Repairs**
Front End Loader	Case 721D	Excavated Channels	7	0	1
Front End Loader	Caterpillar 950G	Excavated Channel	8	0	0
Dump Truck		Hauled excavated material	4	4	0
Water Truck	Caterpillar Water wagon	Dust Abatement	8	0	0

Attachment – 6 photographs

Construction Representative	**Date**
Carol Jean Hansen	1/06/2011
Supervisory Representative or Field Engineer	**Date**
Andrew Ashby	

Photo Number: 00101062011 Date Photo Taken on: 1-6-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The two Front End Loaders working together to gather the material out of the main channel.

Photo Number: 00201062011 Date Photo Taken on: 1-6-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Caterpillar front end loader starting to remove the material from the secondary channel.

Photo Number: 00301062011 Date Photo Taken on: 1-6-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The main channel at the final grading on the bottom of the channel. Looking west from station 5+50.

Photo Number: 00401062011 Date Photo Taken on: 1-6-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The main channel at the final grading on the bottom of the channel. Looking east from station 5+50.

Photo Number: 00501062011 Date Photo Taken on: 1-6-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Case front end loader cleaning out the bottom of the main channel.

Photo Number: 00601062011 Date Photo Taken on: 1-6-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: A view of the west end of the main channel with the secondary channel.

RECLAMATION
Managing Water in the West

Managed Recharged Phase II
Daily Inspection Report

Day, Date:	Friday, January 7, 2011	**Shift**	0700 hrs to 1530 hours	
Project Location:	Santa Cruiz River	**Temperature:**	H: 62°f	L: 36˚f
Project No.:		**Precipitation:**	0.0	
Feature:	Enhanced Recharged Channel Excavation	**Weather:**	Mostly Sunny Skies	
Contractor:	Flowing Wells Irrigation District	**Representative:**	Al Chealano	
Contractor:	Tucson Water	**Representative:**	Julian Pallanes	
Contractor:	Metro Waters	**Representative:**	Steve Woolridge	
Contractor:	Pima County WW	**Representative:**	Joe Gonzales	

Major Features of Work

A crew of two operators, one dump truck driver, and one water truck driver arrived onsite to continue removing the material from approximately station 2+50 to 6+00 on the main channel. The crew finished the main channel and then continued removing the material from the secondary channel, while the main channel was being resurveyed. The crew removed the material from station 0+00 to 4+00 on the secondary channel. Surveying measurements were taken several times throughout the day to verify the bottom elevation of the channel. The equipment on site was one Case front-end loader (which was replaced by a Komatsu front-end loader), one Caterpillar front-end loader, one Caterpillar water truck, and one Mac Dump truck. The two front-end loaders used their buckets to remove the material. The excavated material was placed into the dump truck. The excavated material was placed in a stockpile by the creak crossing. The driver of the dump truck did not feel comfortable driving a full load over the culvert. The excavation crew stated they would use the front-end loaders to move the material over the culvert. The roadways were watered throughout the day for dust abatement.

SAFETY

No safety violations were noted.

Significant Discussions (Contractor, Owner, Area Office, Region, or TSC)

The following people were on the job site today:
Bureau of Reclamation:
Debra Tosline
Erick Holler
Nathan Leham

City of Tucson
Harold Maxwell-System Maintenance Manager
Sergio Cordova-Safety Specialist
George Cruz-Property Management Supervisor
Lane West-Operator

Flowing Wells Irrigation District:
Geoff Caron-Assistant Superintendent
David Crockell-Superintendent

PERSONNEL			
Name	**Task**	**Description**	**Worked**
Flowing Wells Irrigation District			
Al Chealano	Operator	Operated the Case Front End loader	8
Tucson Water			
Julian Pallanes	Operator	Operated the Caterpillar Front End Loader	8
Metro Water			
Steve Woolridge	Truck Driver	Operated the Dump Truck	8
Pima County WW			
Don Ervin	Truck Driver	Operated the Water Truck	0
Luis Burruel	Truck Driver	Operated the Water truck	8

Equipment on Site					
Type / Capacity	**Make/Model**	**Activity**	**Usage**	**Idle**	**Repairs**
Front End Loader	Case 721D	Excavated Channels	5	0	3
Front-End Loader	Komatsu	Excavated Channels	3	0	0
Front End Loader	Caterpillar 950G	Excavated Channels	8	0	0
Dump Truck		Hauled excavated material	8	0	0
Water Truck	Caterpillar Water wagon	Dust Abatement	8	0	0

Attachment : Photographs

Construction Representative	**Date**
Carol Jean Hansen	1/07/2011
Supervisory Representative or Field Engineer	**Date**
Andrew Ashby	

Photo Number: 00101072011 Date Photo Taken on: 1-7-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Case Front End Loader removing the material from the secondary channel.
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Photo Number: 00201072011 Date Photo Taken on: 1-7-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Caterpillar front end loader removing the material from the secondary channel.

Daily Inspection Report, Friday, January 7, 2011

Photo Number: 00301072011 Date Photo Taken on: 1-7-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Metro Water dump truck.

Photo Number: 00401072011 Date Photo Taken on: 1-7-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Case front end loader loading the Metro Water District dump truck.

Photo Number: 00501072011 Date Photo Taken on: 1-7-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Caterpillar front end loader stockpiling the excavated material in the secondary channel area.

Photo Number: 00601072011 Date Photo Taken on: 1-7-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: A view of both the front-end loaders removing the stockpile of material from the secondary channel.

RECLAMATION
Managing Water in the West

Managed Recharged Phase II
Daily Inspection Report

Day, Date:	Monday, January 10, 2011	**Shift**	0700 hrs to 1530 hours	
Project Location:	Santa Cruiz River	**Temperature:**	H: 59°f	L: 35˚f
Project No.:		**Precipitation:**	0.0	
Feature:	Enhanced Recharged Channel Excavation	**Weather:**	Mostly Sunny Skies	
Contractor:	Flowing Wells Irrigation District	**Representative:**	Al Chealano	
Contractor:	Tucson Water	**Representative:**	Julian Pallanes	
Contractor:	Metro Waters	**Representative:**	Steve Woolridge	
Contractor:	Pima County WW	**Representative:**	Joe Gonzales	

Major Features of Work

A crew of two operator and one water truck driver arrived onsite to continue removing the material from approximately station 4+00 to 7+00 on the secondary channel. The crew did not finish removing the material from the secondary channel. The secondary channel had been surveyed to verify the bottom elevation of the channel. The equipment on site was one Kawasaki front-end, one Caterpillar front-end loader, and one Caterpillar water truck. The two front-end loaders used their buckets to remove the material. The excavated material was placed into the dump truck. The excavated material was placed in a stockpile. The roadways were watered throughout the day for dust abatement.

The secondary channel is almost complete. Final bottom elevations would be taken on Wednesday when Bureau of Reclamation Andrew Ashby arrives onsite.

SAFETY

No safety violations were noted.

Significant Discussions (Contractor, Owner, Area Office, Region, or TSC)

Metro Waters, Steve Woolridge, called and stated they would not be back on site until Wednesday. A call was placed to Andrew Ashby to see if another dump truck could come out to the site.

PERSONNEL			
Name	**Task**	**Description**	**Worked**
Flowing Wells Irrigation District			
Al Chealano	Operator	Operated the Case Front End loader	8
Tucson Water			
Julian Pallanes	Operator	Operated the Caterpillar Front End Loader	8
Metro Water			
Steve Woolridge	Truck Driver	Operated the Dump Truck	0
Pima County WW			
Don Ervin	Truck Driver	Operated the Water Truck	6
Luis Burruel	Truck Driver	Operated the Water truck	0

Equipment on Site					
Type / Capacity	**Make/Model**	**Activity**	**Usage**	**Idle**	**Repairs**
Front End Loader	Case 721D	Excavated Channels	0	0	0
Front-End Loader	Komatsu	Excavated Channels	8	0	0
Front End Loader	Caterpillar 950G	Excavated Channels	8	0	0
Dump Truck		Hauled excavated material	0	8	0
Water Truck	Caterpillar Water wagon	Dust Abatement	6	2	0

Attachment : Photographs

Construction Representative	**Date**
Carol Jean Hansen	1/10/2011
Supervisory Representative or Field Engineer	**Date**
Andrew Ashby	

Daily Inspection Report, Monday January 10, 2011

Photo Number: 00101102011 Date Photo Taken on: 1-10-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: A look West on the Secondary Channel from station 5+00.

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Photo Number: 00201102011 Date Photo Taken on: 1-10-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Secondary Channel looking East from station 5+00.

Photo Number: 00301102011 Date Photo Taken on: 1-10-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Caterpillar front-end loader cleaning out the bottom of the secondary channel.

Managed Recharged Phase II
Daily Inspection Report

Day, Date:	Tuesday, January 11, 2011	**Shift**	0700 hrs to 1530 hours	
Project Location:	Santa Cruiz River	**Temperature:**	H: 66°f	L: 32˚f
Project No.:		**Precipitation:**	0.0	
Feature:	Enhanced Recharged Channel Excavation	**Weather:**	Mostly Sunny Skies	
Contractor:	Flowing Wells Irrigation District	**Representative:**	Al Chealano	
Contractor:	City of Tucson Water	**Representative:**	Julian Pallanes	
Contractor:	Metro Waters	**Representative:**	Steve Woolridge	
Contractor:	Pima County WW	**Representative:**	Joe Gonzales	

Major Features of Work

A crew of two operator and one water truck driver arrived onsite to continue removing the material from approximately station 6+50 to 7+00 on the secondary channel. At 1030 hours, the driver for the dump truck arrived on site to assist in removing the temporary stockpiles and placed this material on the roadway and other areas. The crew finished removing all of the material from the secondary channel. The secondary channel had been surveyed to verify the bottom elevation of the channel. The equipment on site was one Kawasaki front-end, one Caterpillar front-end loader, Mac dump truck, one Caterpillar grader and one Caterpillar water truck. The two front-end loaders used their buckets to remove the material. The excavated material was placed into the dump truck. The Caterpillar grader and the water truck graded and watered the roadways. The roadways were watered throughout the day for dust abatement.

Both of the channels are completed at this time. A final survey for the bottom elevations of both channels will be taken on Wednesday, when Bureau of Reclamation Andrew Ashby arrives onsite.

SAFETY

No safety violations were noted.

Significant Discussions (Contractor, Owner, Area Office, Region, or TSC)

Metro Waters, Steve Woolridge, arrived onsite at 1030 hours today to assist in removing the material and stockpiling the material out of the channel.
Visitors and new employees: City of Tucson:
George Cruz-Property Management Supervisor
Lane West-Operator
Mark Garcia- Operator

PERSONNEL			
Name	**Task**	**Description**	**Worked**
Flowing Wells Irrigation District			
Al Chealano	Operator	Operated the Case Front End loader	8
Tucson Water			
Julian Pallanes	Operator	Showing Mark Garcia the area	1
Mark Garcia	Operator	Grader	6
Lane West	Operator	Operated the Caterpillar Front End Loader	8
Metro Water			
Steve Woolridge	Truck Driver	Operated the Dump Truck	0
Pima County WW			
Don Irvin	Truck Driver	Operated the Water Truck	6
Luis Burruel	Truck Driver	Operated the Water truck	0

Equipment on Site					
Type / Capacity	**Make/Model**	**Activity**	**Usage**	**Idle**	**Repairs**
Front End Loader	Case 721D	Excavated Channels	0	0	0
Front-End Loader	Kawasaki	Excavated Channels	8	0	0
Front End Loader	Caterpillar 950G	Excavated Channels	8	0	0
Grader	Caterpillar	Haul Roads	6	2	0
Dump Truck		Hauled excavated material	4	4	0
Water Truck	Caterpillar Water wagon	Dust Abatement	6	2	0

Attachment : Photographs

Construction Representative	**Date**
Carol Jean Hansen	1/11/2011
Supervisory Representative or Field Engineer	**Date**
Andrew Ashby	

Photo Number: 00101112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The crew working on the end of secondary channel, with the crew removing the material.

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Photo Number: 00201112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Secondary Channel looking West from station 7+50, with the crew cleaning out the channel.

Photo Number: 00301112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Kawasaki front-end loader placing material that was removed from the channel to the temporary stockpile.

Photo Number: 00401112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Kawasaki front-end loader removing the last of the material from the secondary channel.

Photo Number: 00501112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The end of the primary channel cleaned out.

Photo Number: 00601112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: View of the temporary stockpile as it being removed.

Photo Number: 00701112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Kawasaki front-end loader removing material from the temporary stockpile.

Photo Number: 00801112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Pima county employee (Don Irvin) filling up the.Catperillar water wagon for applying dust abatement on the roadways.

Photo Number: 00901112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: A secondary temporary stockpile.

Photo Number: 01001112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The temporary stockpile almost gone!

Photo Number: 01101112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Caterpillar 14GH grader that was used to grade the roadways.

Photo Number: 01201112011 Date Photo Taken on: 1-11-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Kawasaki front end loader that was operated by the Flowing Water Irrigation District, Al Chealano.

RECLAMATION
Managing Water in the West

Managed Recharged Phase II
Daily Inspection Report

Day, Date:	Wednesday, January 12, 2011	**Shift**	0700 hrs to 1530 hours	
Project Location:	Santa Cruiz River	**Temperature:**	H: 69°f	L: 37˚f
Project No.:		**Precipitation:**	0.0	
Feature:	Enhanced Recharged Channel Excavation	**Weather:**	Mostly Sunny Skies	
Contractor:	Flowing Wells Irrigation District	**Representative:**	Al Catalano	
Contractor:	City of Tucson Water	**Representative:**	Lane West	
Contractor:	Metro Waters	**Representative:**	Steve Woolridge	
Contractor:	Pima County WW	**Representative:**	Joe Gonzales	

Major Features of Work

A crew of thee operators one dump truck driver, and one water truck driver arrived onsite to remove continue the temporary stockpiles. The equipment on site was one Kawasaki front-end, one Caterpillar front-end loader, Mac dump truck, one Caterpillar grader and one Caterpillar water truck. The two front-end loaders used their buckets to work on the temporary stockpiles. The Caterpillar grader and the water truck graded and watered the roadways. The roadways were watered throughout the day for dust abatement.

Both of the channels had the final survey for the bottom elevations of both channels will be taken on by Bureau of Reclamation Andrew Ashby and Carol Jean Hansen. There were three problem areas that were too high. The three areas were taken care by the operator on the Caterpillar Front-End loader. The areas were resurveyed and they were just under the bottom elevations. The operator also cleaned up the bottom area and put in small berm to separate the primary and the secondary channels, the berm is approximately 3-inches high. Photos were taken of the final channels.

The crews discussed demobilization and the Caterpillar Front-end loader and the Caterpillar grader will be removed by the City of Tucson on Thursday. The Caterpillar water wagon will also be removed on Thursday from the Rental Company, after the City of Tucson fills it with fuel. The Kawasaki Front-End loader will be removed on Friday. Flowing Water Irrigation District will perform some extra jobs for the rancher Brad. Pima County will remove the water pump at the creek on Thursday.

SAFETY

No safety violations were noted.

Significant Discussions (Contractor, Owner, Area Office, Region, or TSC)

Visitors: City of Tucson:
Harold Maxwell
Sergio Cordova

Flowing Water Irrigation District
David Crockwell

Bureau of Reclamation
Andrew Ashby
Deborah Tosline

When Deborah Tosline and Andrew Ashby were onsite and were discussing the extension of the primary channel. Surveying was done to see how much material needed to be taken out. While looking over the site, Mr. Ashby noticed that the water by the end of the original primary channel had a ripple. After further investigation it was determined that the main telephone line to the airport was unburied in the water and excavation in the area would be possible. The crew did not excavate in extended area, and due to that the crew finished the rest of the cleanup form the original excavation and by the end of the shift ready to demobilize the equipment.

PERSONNEL			
Name	**Task**	**Description**	**Worked**
Flowing Wells Irrigation District			
Al Catalano	Operator	Operated the Case Front End loader	8
Tucson Water			
Julian Pallanes	Operator	Showing Mark Garcia the area	0
Mark Garcia	Operator	Grader	6
Lane West	Operator	Operated the Caterpillar Front End Loader	8
Metro Water			
Steve Woolridge	Truck Driver	Operated the Dump Truck	6
Pima County WW			
Don Irvin	Truck Driver	Operated the Water Truck	8
Luis Burruel	Truck Driver	Operated the Water truck	0

Equipment on Site					
Type / Capacity	**Make/Model**	**Activity**	**Usage**	**Idle**	**Repairs**
Front End Loader	Case 721D	Excavated Channels	0	0	0
Front-End Loader	Kawasaki	Excavated Channels	8	0	0
Front End Loader	Caterpillar 950G	Excavated Channels	8	0	0
Grader	Caterpillar	Haul Roads	6	2	0
Dump Truck		Hauled excavated material	6	2	0
Water Truck	Caterpillar Water wagon	Dust Abatement	8	0	0

Attachment : Photographs

Construction Representative	**Date**
Carol Jean Hansen	1/12/2011
Supervisory Representative or Field Engineer	**Date**
Andrew Ashby	

Photo Number: 00101122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The crew: Albert Catalano, Flowing Water Irrigation District (Kawasaki Front End Loader operator), Don Irvin Pima County WW (Caterpillar Water wagon driver), Steve Woolridge Metro Water, (Mac dump truck driver), and Lane West with the City of Tucson, (Caterpillar Front-End loader operator).

Photo Number: 00201122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Kawasaki Front end loader finishing leveling the stockpile from the excavated material from the channels.

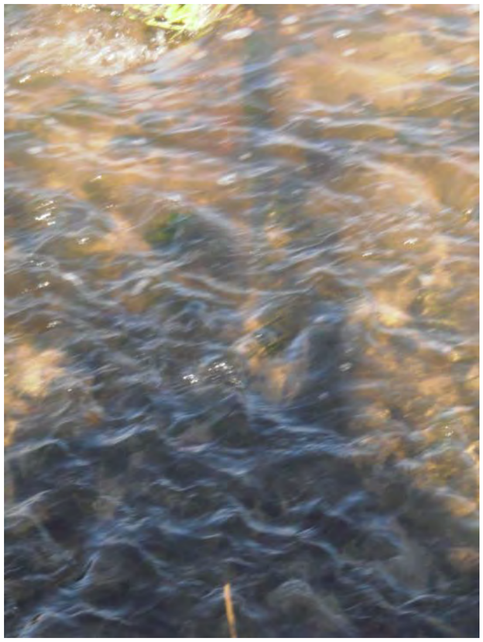

Photo Number: 00301122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The Santa Cruiz River with the telephone cable in the river.

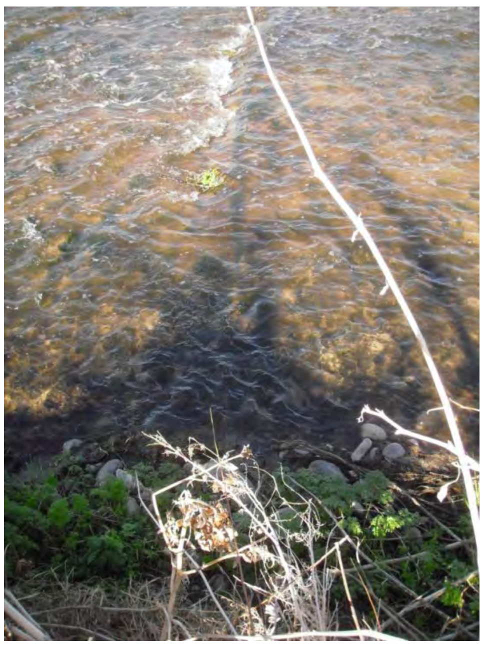

Photo Number: 00401122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Another view of the Santa Cruiz River with the telephone cable in the river.

Photo Number: 00501122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: The west end of the primary channel, stations 0+00 to 0+75+/-.

Photo Number: 00601122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Primary channel, looking east, from station 0+75 to 1+00.

Photo Number: 00701122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Primary channel, looking east, from station 1+00 to 3+00.

Photo Number: 00801122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Primary channel, looking east, from station 1+50 to 3+00, with the secondary channel to the left.

Photo Number: 00901122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Primary channel, looking east, from station3+00 to 5+00.

Photo Number: 01001122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Primary channel, looking east, from station 5+00 to 6+50.

Photo Number: 01101122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Primary channel, looking east, from station 6+00 to 8+00.

Photo Number: 01201122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Primary channel, looking east, from station 9+00 to 11+00.

Photo Number: 01301122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Primary channel, looking east, from station 10+00 to end.

Photo Number: 01401122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Primary channel, looking west, from station end to 10+00.

Photo Number: 01501122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Primary channel, looking east, from end station to the river.

Photo Number: 01601122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Start of the Secondary Channel from station 0+00 to 2+00.

Photo Number: 01701122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Secondary Channel from station 0+00 to 2+00.

Photo Number: 01801122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Secondary Channel from station 2+00 to 4+00.

Photo Number: 01901122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Secondary Channel from station 3+00 to 5+00. Note sides are collapsing.

Photo Number: 02001122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Secondary Channel from station 4+00 to 6+00.

Photo Number: 02101122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Secondary Channel from station 6+00 to the end.

Photo Number: 02201122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Secondary Channel from station end of the channel.

Photo Number: 02301122011 Date Photo Taken on: 1-12-11
Photo Taken by: Carol Jean Hansen Project Enhanced Recharged Channel Excavation
Narrative: Area were the extra channel was to be placed.

Appendix M

Biological Clogging on the Enhanced Recharge Project, Arizona State University

Biological Clogging on the Enhanced Recharge Project

Natalie Case and Dr. Julie Stromberg
School of Life Sciences, Arizona State University, Tempe AZ
December, 2011

Abstract. This research was designed to capture trends and highlight contributing factors to riverbed clogging in the Enhanced Recharge Project (ERP) channel along the Santa Cruz River. Clogging is a general term for the reduction of permeability in a porous medium. While physical clogging results from suspended particles that become entrapped in sediments, biological clogging refers to the buildup of microbial biomass, exopolysaccharide or biofilm matrix, and metabolic gases. The ERP provides a unique setting to study this phenomenon by providing a natural field experiment that would not be feasible in the main channel of the river. Our goals were to measure physiochemical and biological parameters during the ERP cycles to increase our understanding of what variables play a role in the clogging process. We hypothesized that the constant supply of warm, high-nutrient effluent that feeds the river and ERP channel would promote biological clogging. We measured conductivity, sediment bacteria, sediment texture, and water quality in-stream to investigate this hypothesis. We found that conductivity in the sediments was low at the start of the project, declined over the first month, and was restored after channel disturbance. Sediment texture of the ERP contained higher percentages of fines, resembling the river bank, and sediment bacterial counts increased exponentially, while algal mats and sludge layers accumulated on the surface. While our hypothesis that ERP channel conditions promote biological activity was supported, bacterial abundance was not strongly correlated with reduced infiltration rates, nor was there a strong correlation between fine sediments and infiltration rates. Given the small sample size, additional measurements may yield stronger conclusions. Low surface flow appeared to be a critical driver for these variables, so we propose that increasing flow rates may reduce fines and surface mats, extending the time between drying and ripping cycles.

Background

There is evidence of reduced infiltration of surface water in waterways that receive nutrient-enriched water, including the Santa Cruz River in southern Arizona (Galyean 1996; Lacher 1996). However, the causal agents of the 'clogging layers' that impede infiltration, and the environmental factors that regulate their dynamics, remain virtually unknown for these rivers. Reduced infiltration may be a result of biotic processes (growth of microbial biofilms or algae), abiotic processes (siltation of interstitial spaces in the channel bed) or both. The net result is reduced exchange of water and dissolved compounds between the surface stream and aquifer, causing stream water to flow longitudinally (downstream) rather than laterally (towards the floodplain). This disruption of hydrologic connectivity is of societal concern because it can reduce survivorship of valued floodplain riparian vegetation, reduce local recharge of groundwater intended for re-use, and induce surface flow where it is not desired.

Growth of bacteria and algae is one potential cause of reduced infiltration of water into channel bed sediments (Battin and Sengschmitt 1999). Microbial growth and particulates are well known to clog surfaces utilized for wastewater treatment (Iliuta and Larachi 2005) and may do the same in natural stream beds. Where steady flows of nutrient-enriched waters occur, such as downstream of wastewater treatment facilities, biofilms may become sufficiently abundant to reduce infiltration rates. Biofilms are multi-species aggregations of bacteria and other microorganisms that are present on any surface that is regularly exposed to water, such as hyporheic zones (the ecotone nested between the river's surface waters above and the ground water below). The bacteria attach themselves to larger particles (such as sand grains) and begin dividing and excreting a polysaccharide matrix. The biofilm can quickly develop into a cooperative, complex microecosystem within which nutrients and organic matter can be stored, transformed, and released back to the surface waters (Boulton et al. 1998).

Biofilms can develop on the channel bed and be composed mostly of photosynthetic algae and cyanobacteria, but also can form deep in the sediments, out of reach of sunlight, and be composed of heterotrophic bacteria (Pusch et al. 1998). Biofilms can form continuous, impenetrable layers through the sediment, or can form isolated conglomerates that fill interstitial spaces between the sediments. Either form can reduce the ability of surface water to infiltrate outwards and downwards from the channel, effectively forcing more water to flow downstream. Consequently, less water becomes available to floodplain vegetation and the soil surrounding the river, and less water is recharged to groundwater.

The composition, activity, and extent of a biofilm is influenced by environmental parameters such as dissolved oxygen, organic carbon, nutrients, and ions (Storey et al. 1999). These parameters, in turn, vary with the characteristics and flow paths of the inflowing source waters and also are influenced by on-site biologic activities such as macrophyte growth in the streambed. Large floods can mobilize sediments and disrupt biofilms (Hancock and Boulton, 2005), and biofilms also may be disrupted if the river dries for a sufficient period of time. However, once river flow returns the clogging layer may rapidly redevelop (Eisenmann et al. 1999). Biofilms can be disrupted through bioturbation of aquatic invertebrates (Nogaro et al. 2006), but where water quality is poor, diversity of invertebrates can decline.

Abiotic factors also can be a cause of reduced infiltration. Fine sediment particles can settle out of the water column and fill in surface pores or interstitial spaces, thereby reducing infiltration (Brunke 1999). Biotic interactions can influence this process of colmation. For example, dense growth of macrophytes may enhance accumulation of fine sediments (Wharton et al. 2006), as may dense growth of bacteria, with the sediments becoming embedded in the polysaccharide matrix of the biofilm (Vandevivere and Baveye 1992). Precipitates and gases produced by bacteria also can fill in interstitial pores (Lozada et al. 1994).

Objectives:

- Monitor the ERP channel from its initial construction, development, and disturbance regime to capture trends in infiltration and sediment biology.
- Pinpoint factors that may contribute to reduced infiltration.

Methods

Study site: The Bureau of Reclamation's Enhanced Recharge Project (ERP) site is located in the main channel of the Santa Cruz River (SCR) near the town of Marana, AZ (Latitude

32°25'27.78"N and Longitude 111°12'50.40"W). The goal of the ERP project was to spread out the flow of the river and increase infiltration rates and thereby accrue more long-term storage credits for recharging the surface water. To accomplish this, the Bureau excavated two secondary low flow channels along a bend in the main channel. Water was added to the newly excavated channels through a flume system on January 28, 2011. We established three transects, approximately 100 meters (m) apart, on the southern-most low flow channel, and a fourth reference transect was set on the SCR main channel (Figure 1). Two sites were established along the SCR transect; one along the bank and one along the thalweg, or center of the channel. The SCR bank and thalweg were used to establish minimum and maximum infiltration conditions for the area. The ERP did not have a distinct thalweg, so the center and bank sites were considered replicates. Sampling events were initially planned to occur monthly, but this was changed to occur around treatment times (before and after drying/ripping). Measurements on hydrology, sediment, and water quality were taken on January 29, 2011, at the start of the project; February 26, after one month of development; and April 16, after the first drying, ripping, and rewetting treatment. Sampling was not conducted in May and June due to scheduling conflicts. The project ended in July after strong flooding.

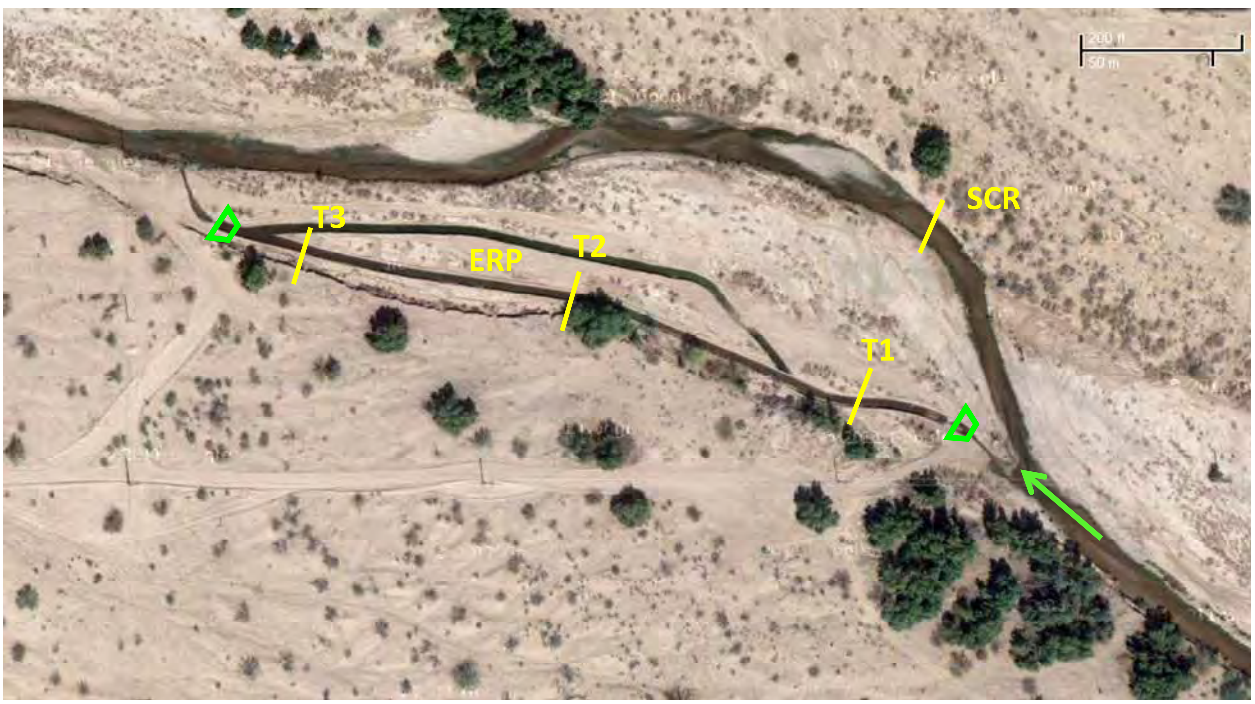

Figure 1. SCR and 2 previously abandoned low flow ERP channels. Yellow lines indicate locations of transects, and green boxes are the flumes used to measure flow diverted from the main channel into and out of the secondary channels. Image from Google Maps, 8/2011.

Hydrology: Flow rates were measured with a flow meter, with average velocity recorded at several vertical points along each transect. When flow was too slow for the meter to detect (<0.3 feet per second (f/s) the float method was utilized (Gordon et al. 1992).

Hydraulic conductivity (K) was calculated as a measure of infiltration, as they are directly related (conductivity measures the resistance to the flow of water through interstitial spaces).

Shallow in-stream peizometers (modified from Chen 2004) were installed each trip to measure vertical hydraulic conductivity of the sediments using a falling head test (Chen 2004). The piezometers were constructed of clear, four cm inner diameter pvc pipe cut to 122cm lengths. Piezometers were installed in sets of three at depths of 10, 15, and 20cm below the sediment surface at each site (thalweg and bank) totaling 18 piezometers on the ERP and 6 on the SCR. Though clogging is often observed as a surface phenomenon within the first few centimeters, previous research on the Santa Cruz had detected clogging layers developing below 10cm (Treese, Meixner, and Hogan 2009), these methods allowed us to differentiate between 0-10, 10-15, and 15-20cm. Piezometers were installed manually with a mallet and left to equilibrate for approximately an hour. After this, the distances from the top of the pipe to the water level inside and outside the pipe were recorded and clean surface water was slowly added to fill the pipe full. The time it took for the water level in the pipe to fall one cm was recorded. This measurement was repeated a total of three times and the value averaged. In places of low infiltration this measurement was abbreviated by setting a cut-off time of 10 minutes and the time recorded as >10 minutes.

Sediment characterization: Following infiltration measurements, the 20cm pipe was carefully removed from the sediments to provide a sediment core sample. The sediments were collected in a bag and kept on ice (~4C) until analysis. Notes of visual observations such as dark iron-reducing layers, gas bubbles, or high organic matter were recorded.

The presence of surface algal biofilms was noted and sediment bacteria were counted as an indication of biological clogging. A homogenous subsample of the sediment core was used for biological analysis within a week of collection. Heterotrophic plate counts were conducted using Standard Methods Spread Plate Method 9215C (American Public Health Association 2005). In preparation, wet sediments were packed into 50ml sterile centrifuge tubes and left to stand overnight so excess water could be poured off. Next, 50g of sediment were transferred into sterile 500ml plastic bottles. For a 1:10 dilution, 450ml of sterile phosphate buffered solution were added to each bottle which was vigorously agitated by hand for five minutes to dislodge attached cells. Promptly after agitation, 100 µl of the suspension was transferred aseptically to a set of serial dilution tubes containing 900 µl of sterile phosphate buffer. Corresponding duplicate plates of R2A agar received 100 µl from the dilution tubes and were spread dry with sterile glass rods. Inoculated plates were incubated at room temperature for 72h, or until colonies were easily countable. Plates containing 30-300 colonies were counted and recorded. Initial wet sediments were weighed, oven dried, and re-weighed to determine the number of colony forming units (CFUs) per gram of dry sediment.

The remaining portion of the core sample was oven dried and sieved to conduct texture analysis (modified from Gee and Or 2002). Sediment texture (further described in Addendum) was monitored throughout the study as a physical factor that regulates hydraulic conductivity. At each sampling time, the % gravel (> 2mm) fraction was determined and 75g of soil (< 2mm) was reserved to determine silt and clay content using the hydrometer method. Sand fractions were determined after hydrometer measurements by wet sieving the sample through a 63 µm sieve. The sample was oven dried and then sieved through a stack of sieves to yield very coarse (1000 µm), coarse (500 µm), medium (250 µm), fine (125 µm), and very fine (63 µm) sand fractions.

Water chemistry: Water chemistry from surface water and porewater was examined as an indication of biological activity in the sediments. A surface water grab sample was collected in the center of each transect and a sediment water sample was collected at each cluster of piezometers using a pore water extractor. The pore water extractor (M.H.E Products) had a screened zone at one end and a sampling port at the other, and after being pushed into the sediment to the 20cm depth, pore water was extracted with a peristaltic pump. Dissolved oxygen (DO), pH, oxidation-reduction potential (ORP), and temperature were measured on site using portable multi-parameter meters (Oakton DO6, and Hanna Combo pH & ORP). Water samples were collected in acid washed plastic bottles for further laboratory analyses. In accordance with Environmental Protection Agency regulations (40 Pt. 136.3), samples were transported on ice, stored at 4C, and analyzed for nutrients within 48h. Prior to analysis, the bottles were centrifuged at 5000rpm for 10m to remove particles. Subsamples for ammonium, nitrite/nitrate, and phosphate (as orthophosphate) were frozen until analysis, and non-purgeable organic carbon (NPOC) subsamples were acidified with hydrochloric acid to a pH of 2 and stored at 4C until analysis. Analyses were performed by ASU Goldwater Environmental Lab research specialists.

Data analyses: Data were log or square root transformed prior to statistical analysis. Pearson's correlations (further described in Addendum) were used to show the relationships of conductivity data with bacterial and texture variables. Welch's analysis of variance (ANOVA) was applied to test for differences in sediment depth and conductivity (alpha level of 0.05). A repeated measures ANOVA was used to test for differences in bacterial abundance, followed by Tukey's Honestly Significant Difference post-hoc test, with a Bonferroni correction. Analyses were performed with the software SPSS (Release 19.0, SPSS Inc.).

Results

Did hydraulic conductivity change over time with treatment?

Conductivity declined over time, as expected, but was restored after drying and scraping treatments. At the start of the project, conductivity in the ERP was low, similar to a clogged bank on the main channel of the Santa Cruz (Figure 2). The SCR thalweg, representing a maximum of infiltration, was two orders of magnitude higher than the bank and ERP channel. However, over the first month, conductivity in the ERP declined even lower than the bank. In April, the ERP channel was dried and the surface scraped to remove a 3.8cm thick layer of fines. After water was released back to the channel, conductivity measurements returned to levels slightly higher than January. There was a significant difference in conductivity between months ($F(2, 45) = 7.882$, $p = .001$), and a Tukey post-hoc test revealed that conductivity was statistically significantly higher in April after the channel was dried and scraped (0.0033 ± 0.003 cm/s, $P = 0.001$) than in February (0.0005 ± 0.0005 cm/s, $P = 0.249$). There were no significant differences detected between January and February or January and April.

While an ANOVA showed no significant difference between the different depths sampled during the study (results not shown), a more detailed examination of the ERP conductivity profile shows interesting patterns (Figure 3). In January the sediments were so compacted that it was difficult to install the piezometers. This compaction may have contributed to restricted water movement through the top 20cm. The higher conductivity at T2 20cm in January may have been due to larger gravel, and T3 was not measured due to delays caused by gravelly and compacted sediments. After the drying treatment in April the sediments became loose and soft, and conductivity was greatly improved at all depths measured. However, residual spots of low conductivity remained (Figure 3: T2, T3). *Did sediment biomass change over time with treatment?*

Sediment bacteria counts increased exponentially during the first three months of the project (Figure 4), though exponential growth was not seen in the SCR. The ERP growth pattern was surprising because in January the sediment bacteria had only one day between water addition and sample collection to establish, yet their numbers were slightly greater than the SCR thalweg, and slightly less than then SCR bank. Also, at the end of March, the ERP was dried over a period of two weeks and scraped, but this disturbance did not cause a decline in bacteria counts. During April sampling, the channel had only been wetted for a few days before sample collection. The large error bars in April should also be noted; only half of the samples had increased above February while the remaining half was in the range of February counts. A repeated measures ANOVA found a statistically significant difference in bacterial counts between sampling times ($F(2, 10) = 6.252$, $P = 0.017$), and a post hoc test determined that the difference between January and April was the only significant difference ($p=0.013$). Though correlations between bacteria and conductivity get stronger over time, they show only a very weak negative association (Table 1).

Qualitative measures of sediment biomass were also noticeable in the ERP. In January, the ERP had no signs of biological activity, but by February, nonfilamentous algal mats were growing and thick sludge layers were building up on the sediment surface, increasingly so towards the downstream flume . Sediment cores were showing black layers as well (metal sulfide deposits from bacterial metabolic byproducts). At this point the primary production was sufficient to support an abundant community of amphipods (scuds) and chironomid larvae (blood worms), both pollution tolerant invertebrates. In April, photosynthetic mats were growing back, indicating that the biotic community recovers quickly after disturbance in the ERP.

Were there trends in physiochemical parameters?

<u>Soil texture</u>

The ERP sediment texture more closely resembled the SCR bank with its finer textures (Figure 5). In contrast, the ERP had a higher percentage of gravel than the SCR. The drying, scraping, and ripping treatment in April resulted in a decrease in the percentage of fines in the ERP. Variations in the SCR bank texture are likely due to the heterogeneous morphology of banks and smaller sample size (only one transect and core). Similar to biomass, the correlation between percent fines and conductivity grew over time, but it was a very weak negative association (Table 1).

<u>Flow</u>

In contrast to the Santa Cruz River, flow in the ERP channel was too low to measure during this study (Figure 6B). An average flow of 4cfs was measured in the flume, as the river is subject to a diurnal flux in flow. Later in the project flow rates were increased.

<u>Water chemistry</u>

In many respects, the physical and chemical profile of ERP channel resembled the SCR, with some interesting exceptions. Dissolved oxygen (DO) decreased in the SCR over the three months as temperatures warmed, but in the ERP surface water, DO readings were extremely high (Figure 6A, and additionally discussed in Addendum). These readings coincided with low stream flow and high algal photosynthetic activity. In the ERP sediment porewater, DO was high in January, but dropped over the months, indicating that oxygen was either being consumed by bacteria or not being delivered into the deeper sediments. From the water quality results (Table 2) there were a few trends of note. Oxidation-reduction potential (ORP) stayed unexpectedly high in the ERP sediments, never dropping below 140mV. NPOC, a measure of organic carbon, decreased from 17 to 13mg/L in February, and then to 8mg/L after the April drying. Nitrates, however, did not decrease in the ERP sediments as they did in the SCR sediments.

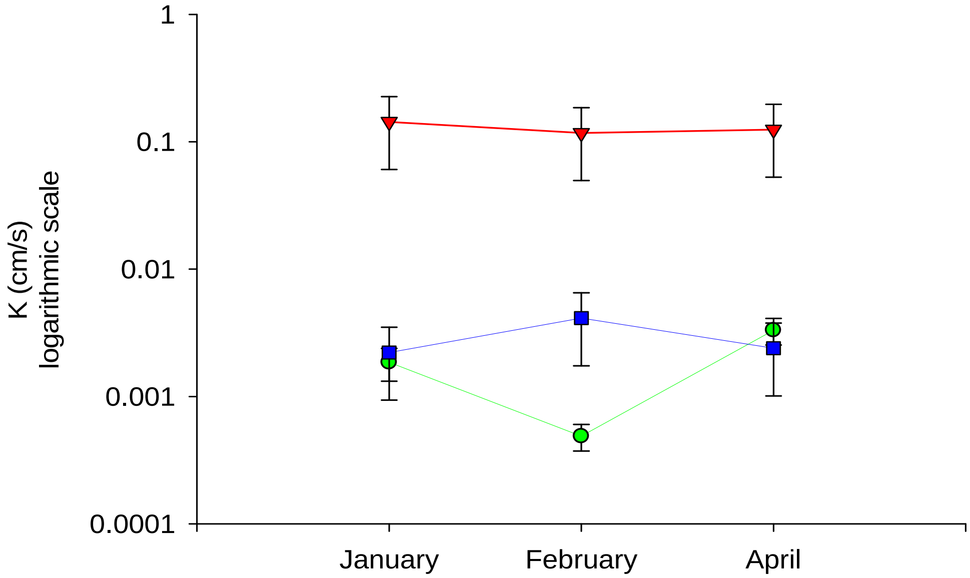

Figure 2. Average hydraulic conductivity of the ERP channel , SCR bank , and SCR thalweg . Log scale is used because the thalweg conductivity was much larger than the bank and ERP. Error bars ± 1 standard error.

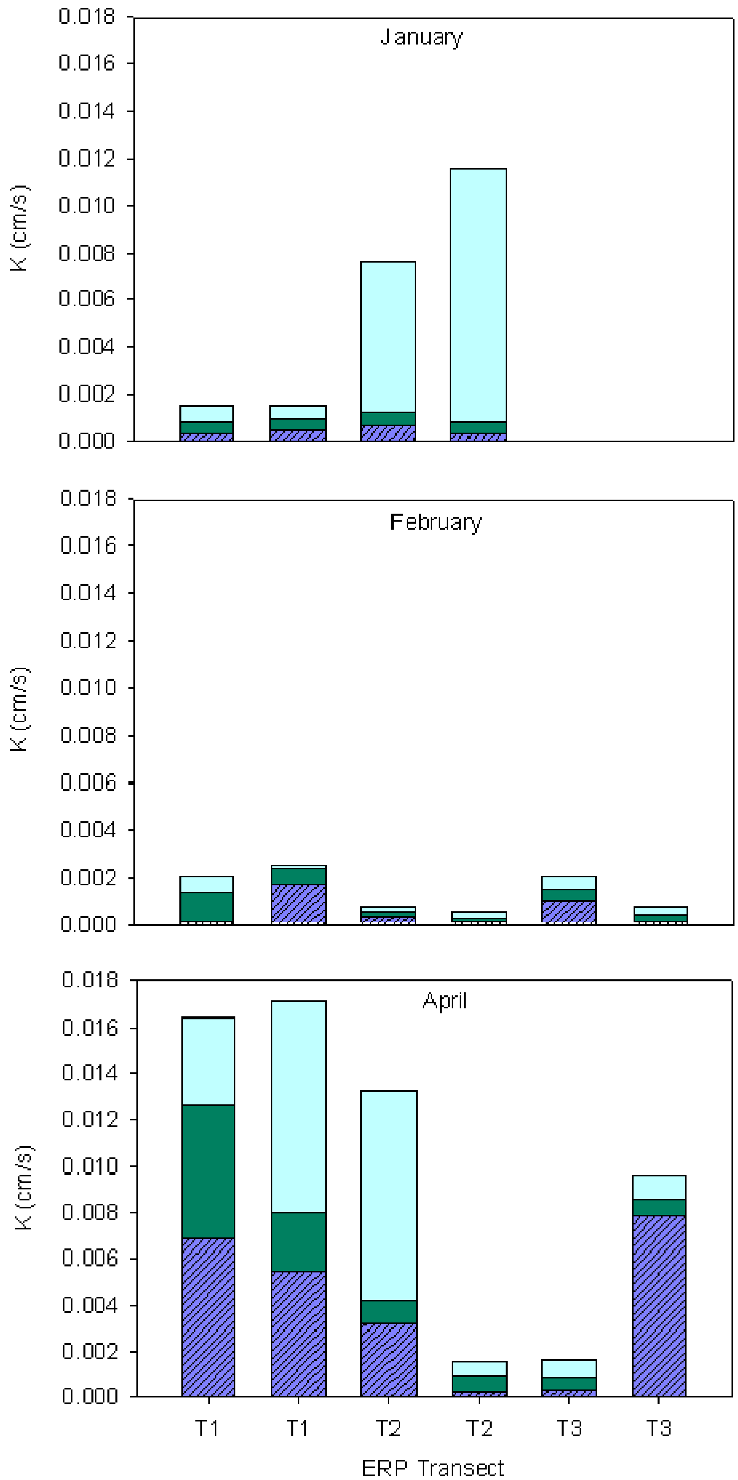

Figure 3. Hydraulic conductivity (K) measured at 6 points along the 300m ERP channel. At each location piezometers were installed at 10cm deep, 15cm, and 20cm. January data were collected after construction of the ERP, February represents one month of undisturbed development, and April measurements were conducted after drying, ripping, and rewetting the channel.

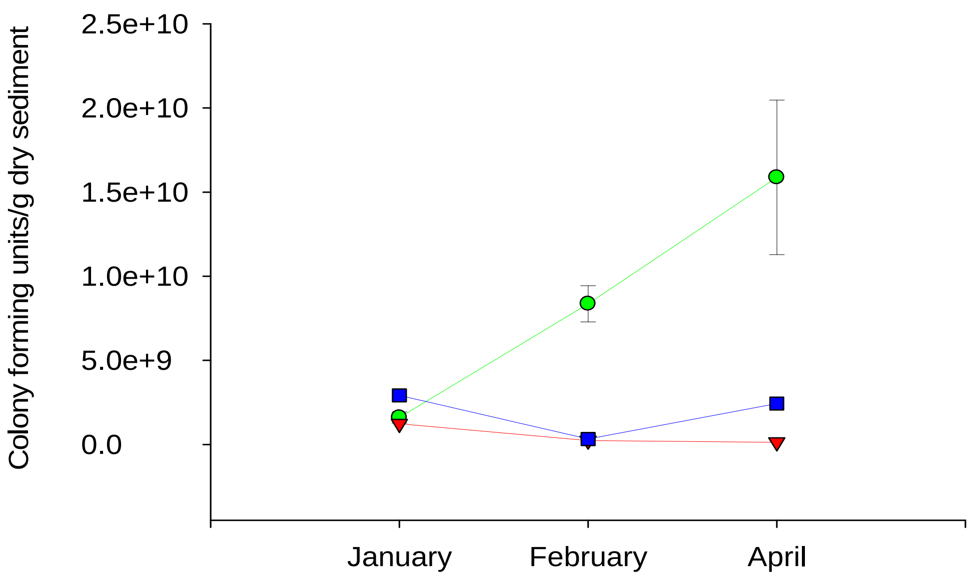

Figure 4. Plate counts of colony forming units of sediment bacteria from the ERP channel, SCR bank, and SCR thalweg. ERP is averaged from six 20cm sediment cores spanning the three transects, while one core was taken for each SCR site. Error bars ± 1 standard error.

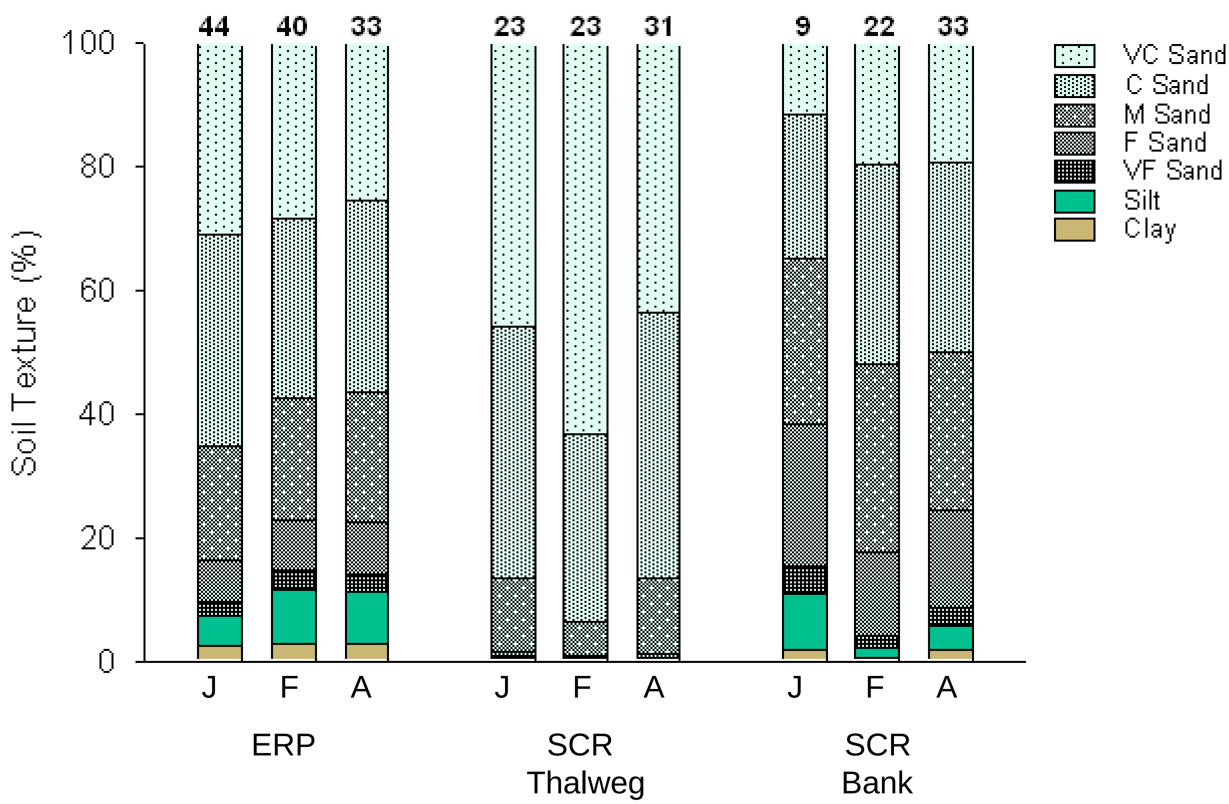

Figure 5. Sediment texture composition from the three sites during January (J), February (F), and April (A). Numbers above each bar represent percent gravel of the unseived sample.

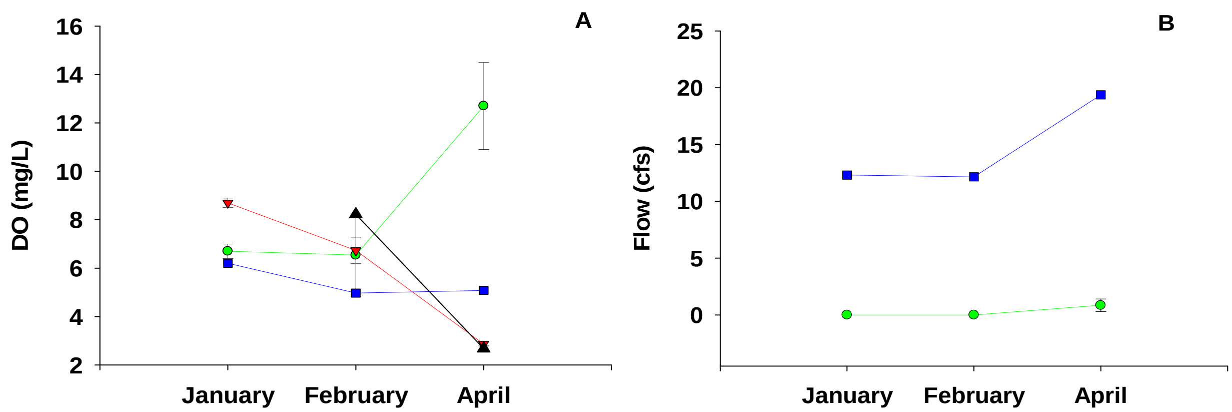

Figure 6. Dissolved oxygen (A) and stream flow (B) of the ERP surface water , ERP pore water , SCR surface water , and SCR bank pore water . Error bars ± 1 standard error.

Table 1. Pearson's Correlation results for conductivity, bacteria counts, and fine texture sediments during the study.

	r value	p value	Sample size
Conductivity vs Bacteria			
January	-0.103	0.900	4
February	-0.565	0.327	5
April	-0.596	0.215	6
Conductivity vs %Fines			
January	-0.091	0.911	4
February	-0.436	0.467	5
April	-0.542	0.270	6

Table 2. Physical and chemical parameters of surface and sediment porewater for the ERP channel and the Santa Cruz River

Date	Site	Location	**Temp. (C)**	**DO [1] (mg/L)**	**pH**	**ORP [2] (mV)**	**Flow (cfs)**	**NH3 [3] (mg/L)**	**NO3 [4] (mg/L)**	**TN [5] (mg/L)**	**NPOC [6] (mg/L)**	**PO4 [7] (mg/L)**
Jan	ERP	Surface	18.50	6.70		151.00	0.00	21.80	6.77	33.23	11.77	
Jan	ERP	Sediment	17.65	8.70		146.50		20.75	6.69	33.79	17.53	
Jan	SCR	Surface	17.30	6.20		155.00	12.4	19.90	5.95	32.97	11.69	
Feb	ERP	Surface	14.87	6.54		142.33	0.00			32.02	13.83	3.26
Feb	ERP	Sediment	13.30	6.73		141.50				30.70	13.89	2.73
Feb	SCR	Surface	13.40	4.97		144.00	12.0			31.57	12.08	3.31
Feb	SCR	sediment*	13.30	6.29		162.00				32.46	20.89	3.00
Feb	SCR	sediment**	13.20	8.22		139.00				29.98	12.77	3.11
Apr	ERP	surface	29.73	12.72	8.51	278.00	0.71	12.13	4.54		10.50	2.48
Apr	ERP	sediment	28.38	2.87	7.48	277.00		15.13	4.47		8.53	2.90
Apr	SCR	surface	28.60	5.08	7.89	256.00	19.4	13.00	5.21		9.77	2.59
Apr	SCR	sediment*	27.40	3.02	7.61	95.00		15.00	1.59		6.42	3.12
Apr	SCR	sediment**	25.60	2.70	7.51	-92.00		16.00	0.10		7.14	4.02

*Thalweg sediments
**Bank sediments
[1] Dissolved Oxygen
[2] Oxidation Reduction Potential, measures the ability of the system to either accept electrons (reduce) or donate electrons (oxidize). Values less than -150 mV indicate an anaerobic zone, while anoxic zones range from -100 to 100 mV.
[3] Ammonia
[4] Nitrate-Nitrite
[5] Total Nitrogen (the sum of organic and reduced nitrogen, ammonia, and nitrate-nitrite)
[6] Non-Purgeable Organic Carbon (the portion of organic carbon left in the sample after the volatile carbon has been purged with air)
[7] Phosphate

Discussion

Did hydraulic conductivity change over time with treatment?

Hydraulic conductivity on the ERP was relatively low to start, matching that of the stagnant SCR bank, but over the course of the first month it continued to decline. The drying and ripping treatment effectively restored conductivity to rates greater than the initial levels. Physical processes were evidently responsible for the low initial conductivity. The ERP channel had been constructed by heavy machinery, rather than flowing water, leaving the sediments densely packed from the weight. Pitt et al. (1999) found that infiltration rates in sandy soils were greatly reduced after compaction by construction activity. Fortunately, the drying and ripping treatment in April was very effective at loosening the compacted sediments and restoring conductivity. The difference in conductivity patterns of February and April indicate that the top 10 cm were highly clogged, with slow water movement through the subsequent depths. The drying treatment left the sediments permeable to the 20cm depth, though there were residual clogged areas that did not seem to be affected by the treatment. Even though infiltration was improved on the ERP, April conductivity rates were still comparable to the SCR bank and far below the thalweg. There were clearly other variables limiting the conductivity of the project.

Did sediment biomass change over time with treatment?

Bacterial numbers rose exponentially during the course of the study and were not inhibited by the drying and ripping process. The newly constructed ERP channel had clean, bare sediments, but bacterial counts were surprisingly high for these newly wetted sediments. This suggests that sediments are rapidly colonized with the addition of effluent. After one month, the ERP sediments were no longer barren. Like the SCR bank, the sediments had built up considerable amounts of algal mats, organic sludge layers, and black metal oxide deposits. Bacterial abundance had reached levels much higher than the SCR, however. While bacteria counts rose sharply in the ERP, there was not a similar trend in the SCR. It was clear that conditions in the ERP were promoting biological growth. The lack of scouring flow appeared to be the main influence, as it allowed the extensive buildup of algal mats and sludge in the ERP. Bacteria are known to feed off of exudates released by algae (Haack and McFeters. 1982) so the algal mats and sludge could serve as additional sources of carbon to fuel bacterial growth. After the disturbance in April, sediments had the highest bacterial counts of the study, indicating that drying did not inhibit bacterial abundance. McKew et al. (2011) studied the bacterial community of a salt marsh by extending the normal tidal desiccation period to several weeks. After rewetting the site, they found bacterial activity increased sharply. They also discovered a change in the bacterial community, where particular species were able to increase their abundance under the new disturbance pattern. Drying the ERP may allow desiccation-resistant species to dominate the sediments and drive bacterial counts higher.

The biological developments over the first month coincided with a drop in conductivity. While there was also a slight buildup of silt over the first month, biology was the main variable that had changed during this period. This pattern supports the hypothesis that biological clogging would be promoted in the ERP. However, the disruption in April presents a more complicated picture; after the channel is dried and rewetted, conductivity was at its highest, yet bacteria were also at their greatest abundance. It appears the relationship between bacterial abundance and conductivity rates in the ERP is not straight forward. Laboratory column experiments have demonstrated that increased biomass decreases conductivity rates (Mitchell and Nevo 1964;

Vandevivere and Baveye 1992; Wu et al. 1997). While biological clogging is well-studied under laboratory conditions, it is rarely studied in the field setting where a multitude of other variables are interacting. It is possible that after water was added back to the channel in April, the loosened sediments allowed more nutrients and oxygen to be delivered deeper, allowing more bacteria to grow. Drying can also affect the quality of organic matter. One study reported that after wetlands were allowed to dry, the organic matter fractured into smaller components were more easily utilized by the bacteria upon rewetting (Sommer 2006). Ripping could have introduced organic matter deeper into the sediments to be decomposed by bacteria, allowing more growth. Finally, temperature may have been a confounding variable; algal and microbial growth rates are temperature dependent, and April was approximately 10ºC warmer than the previous months. These conditions can explain why bacteria grew so well after the disturbance, but not why the relationship to conductivity changed after drying. The correlation between bacteria and conductivity was not strong, but of the variables considered, biological clogging is the most likely cause of the decrease in conductivity. Given the small sample size and only sampling one post-drying event, it is premature to make strong conclusions about the bacterial counts, but they may not be the most informative measure of biological clogging for the ERP. Other measures of biological activity that could be investigated include chlorophyll a to quantify algal abundance in the sediment, polysaccharide determination to quantify biofilm development, or extracellular enzyme activity of sediment bacteria.

Were there trends in physiochemical parameters?

Fine-textured sediments are another physical variable that can lead to clogging. Though the fine sediments did not change much throughout the study, the ERP channel had a higher percentage of clay and silt than the SCR bank. The ERP channel was constructed in the active floodplain of the SCR, where fine sediments are deposited during floods but are not continuously scoured like the active channel. Fine-textured sediments fill in the pore spaces that water must move through to infiltrate downwards, so fines lead to lower infiltration rates (Brunke 1999). The fines probably worsened the effects of compaction, and over the first month silt increased slightly. In the SCR, fines only tend to build up in slow moving banks, while the thalweg maintains a corridor of scoured sand and high conductivity. The ERP channel lacked a thalweg, having uniformly distributed fines and conductivity. Ripping and scraping the channel successfully restored and improved conductivity, but did not measurably decrease the percentages of fines. The ERP may not be capable of attaining the higher infiltration rates seen in the SCR thalweg until flooding scours out more of the silts and clays. The ERP also had a higher percentage of gravel than the SCR, and while texture size tends to be directly related to conductivity, Brakensiek and Rawls (1994) concluded that rock fragments in soil will reduce conductivity Rocks are assumed to have low porosity, or zero conductivity, so soils containing high percentages of gravel will have less volume for more porous soils, leading to lower conductivity. This may help explain why the higher gravel content in the ERP did not have higher conductivities.

As previously mentioned, flow rates were an important reason that conductivity rates in the ERP declined. This study and our previous findings (unpublished) on the SCR show that thalwegs, with strong flow and scoured sandy sediments, usually have the highest conductivity measurements. Flow in the ERP channel was usually not measurable during low flow conditions. While the effluent discharge cycles through low and high flows through the day, the high flows must not have been strong enough during the first three months to scour out fines and prevent buildup of material on the sediment surface. While low flow rates could potentially allow the surface water more time to infiltrate, conductivity rates dropped lower than the bank of the SCR during the first month. Low flow promotes biological activity, such as photosynthetic mats and anaerobic sediments that entrap metabolic gasses, as well as physical properties like the buildup of sludge layers and retention of fines. These can act as barriers at the sediment surface, preventing water from entering the sediments. Flume experiments have determined that sheer stress values less than 0.056 accelerate clogging (Schalchli 1992). For river regulating projects, Schalchli also suggests that areas with varied geomorphology help reduce clogging layers.

Finally, water quality parameters indicated that some biological processes in the ERP differed from the SCR. Even though ERP surface water DO readings were quite high in April (due to algal photosynthesis), readings were low in the sediments; because this coincides with high bacterial counts, it reflects high metabolic activity in the sediments. Interestingly, high ORP readings are maintained in the sediments throughout the study, indicating that anaerobic metabolisms would not be favored. The SCR banks usually maintain much lower ORP readings than surface water, as they promote anaerobic conditions and metabolisms. Nitrates declined in the SCR sediments as temperatures warmed in April, but they did not decline in the ERP. Under low oxygen conditions, bacteria convert $NO3^-$ into nitrogen gas, where it is lost from the system. Denitrification and other anaerobic processes would be inhibited by sediment disturbance that introduces oxygen. The drying and scraping combined with a large increase in the amount of oxygen-rich water moving through the sediment may explain why nitrates remained high in ERP sediments. The use of effluent and drying cycles could alter sediment water chemistry, but further research would help clarify the effects.

Conclusions

While the duration of the ERP pilot study was short, we found a number of patterns that may be useful in guiding future studies in improving infiltration:

- Low flow conditions in the ERP promoted high biological activity and retention of fine particles, leading to declines in hydraulic conductivity.
- Texture may be a limiting factor on conductivity - flooding or flushing the ERP may help reduce fines and improve overall conductivity.
- Low conductivity can be overcome by drying and ripping, but the time between channel disruptions could potentially be extended if flow in the channel were increased.
- There was evidence for biological clogging before treatment/maintenance events, but not after treatment. Further research is needed to clarify this relationship.
- The small sample size and short sampling period of this study increase uncertainty, leaving these as preliminary conclusions.

Conclusions from this study could be applied to future scenarios for the Santa Cruz River. Water use projections indicate that treated wastewater will be increasingly utilized in the urban setting, leaving less volume available for discharge to the river. If projections that the amount of water discharged to the Santa Cruz is significantly reduced in the near future, then low flow conditions in the channel could become the norm. In this case, we would expect to see more clogging conditions and poor infiltration in the river. If future infiltration studies are conducted with the ERP, it would be interesting to use the two ERP channels as separate treatments over the same period to determine if one combination of drying, scraping, and ripping is more effective than another. Examining treatments over the same time period would reduce interfering variables like temperature increases or changes in the water quality being discharged.

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Addendum

Sediment texture analysis

Texture analysis was conducted in 3 stages. In the first stage, the dried, raw sediment sample was weighed and sieved into two fractions, >2mm and <2mm. The >2mm fraction was defined as gravel, according to USDA and CSSC systems. The upper limit of gravel size in these samples would be ~40mm, the diameter of the pipe used to collect the sediment core sample. The gravel fraction was weighed and the percent gravel for the sample was calculated by dividing it by the total sample weight. The advantage of calculating gravel from the original sediment sample was that it provided a larger (usually ~200g), more representative sample. In the second stage, a 75gram subsample was weighed out from the <2mm fraction, which was classified as soil. According to the Soil Ecology lab at ASU, 75grams is the recommended sample weight for sandy samples. The 75g sample was processed and analyzed using the hydrometer method with one 7 hr reading (Soil Ecology lab at ASU). This analysis yielded the clay and silt fraction of the soil sample. However, determining the sand fraction from the hydrometer method is considered inaccurate, so for the third stage, the hydrometer sample was washed through a 63 µm sieve to retain only sand. The sand fraction was dried, weighed, and then sieved into the 5 sand fractions (USDA/CSSC): very coarse (1000 µm), coarse (500 µm), medium (250 µm), fine (125 µm), and very fine (63 µm).

Because texture was analyzed in three stages with different sample weights, the final percentages will not add up to 100. The sand percentages were adjusted so that they, with the silt and clay, total 100, but the gravel could not be included in this total. For example, a sample of sediment that contains 44% gravel would have 56% soil. The 56% soil was broken into 7 fractions that add up to 100%. The gravel remains a distinct percentage from the soil, so its value is shown on the graph as a number above the bar representing the soil. Gravel can be compared across sites by these percentages, where we see ERP does contain the highest gravel content.

Dissolved oxygen

DO was measured after installation and equilibration of the piezometers at each transect. The same routine was followed each trip, so measurements would fall in the 11:30am-5:30pm range. In the main channel of the Santa Cruz, surface water samples were collected from the thalweg (the deepest, strongest flowing part), but in the ERP there was no apparent thalweg and so samples were collected at the center of the channel. Due to the relationship between DO and temperature, a decline in DO from January to April was fully expected. Also, the slower flow in the ERP compared to the main channel would result in less mixing and warmer water temperatures, which would also predictably lower DO. However, ERP DO readings in April were unexpectedly high, and this was best explained by high photosynthetic activity, shallow water, and low flow allowing DO to build up in the water. High readings were checked a second time to ensure accuracy. The Oakton DO6 Dissolved Oxygen Meter used in this study has an Automatic Temperature Compensation system and the meter was calibrated at the start of each sampling event. The meter also automatically compensates for pressure based on factory calibration at 760mm Hg or 101.3 kPa barometric pressure (sea level), so pressure would be a constant throughout this study. Flow readings across the ERP channel only increased to 0.71

CFS in April, and this would not likely have a large measureable effect on DO readings, which had doubled over the same period (Table 2).

Pearson’s Correlation

Pearson’s correlation coefficient (r) measures the strength of a linear relationship between two or more variables. The correlation coefficient always lies between -1 and +1. A positive r value implies a positive association and a negative r value implies a negative or inverse association. The closer the correlation is to +1 or -1, means it is closer to being a perfect linear relationship. It is somewhat arbitrary, but the r value can be interpreted as such:

-1.0 to -0.7 strong negative association
-0.7 to -0.3 weak negative association
-0.3 to +0.3 little or no association
+0.3 to +0.7 weak positive association
+0.7 to +1.0 strong positive association

For another way of looking at the results, the r value can be squared and multiplied by 100 to give the percentage that one variable is explaining the other. Sample size is also important to note. When flipping a coin, you would expect to get heads half the time. If you only flip the coin a 5 times, you may get heads 4 of the times (80% chance). With smaller sample sizes, it is easy to produce a strong correlation by chance and you must pay attention to significance.

Finally, to determine whether the correlation is simply a chance occurrence, a p value is calculated. If this probability is lower than the standardized 5% ($p < 0.05$), the correlation coefficient is considered statistically significant and not likely the result of chance.

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Appendix N

Monitoring Enhanced Stream-Bed Recharge Using Time Lapse Gravity, University of Arizona

Monitoring Enhanced Stream-Bed Recharge Using Time Lapse Gravity

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The following is a report of activities undertaken by Dr. Ferré and his students at the University of Arizona under cooperative agreement number R11AC32022 entitled "Gravity Monitoring of the Lower Santa Cruz River Enhanced Potential Recharge Study" through the Bureau of Reclamation (BOR). Under the agreement, gravity monitoring was conducted at the Enhanced Recharge Demonstration Project (ERDP). Authority for this agreement is under Public Law 111-11, Omnibus Public Land Management Act of 2009, Section 9504(b) and in accordance with the Desert Southwest Cooperative Ecosystems Studies Unit Agreement No. R10AC40042. The overall goal of the project was to evaluate the effectiveness of rerouting flow from an active river channel to an inactive channel to increase the rate of infiltration through a stream section. Deborah Tosline (BOR) coordinated the overall project, including construction of the channel, monitoring of surface water flow into and out of the constructed reach, and contracting of complementary measurements by university researchers. Our objective was to quantify changes in subsurface water storage in response to enhanced recharge using time-lapse gravity.

HYDROLOGIC CONCEPTUAL MODEL

A losing river that is in hydrologic connection with an underlying, unconfined aquifer will show a mounding of the water table beneath the river. This is shown schematically in Figure 1. The mound occurs because water is infiltrating vertically faster than it can be transported laterally in the saturated zone. As a result, mounds will tend to be higher if the aquifer has lower permeability and if the infiltration rate is increased. A similar mound will form above less permeable units within the vadose zone, even for a river that is disconnected from the water table.

The enhanced recharge project excavated a previously inactive channel close to and parallel to an active channel. The exact distribution of the mound beneath the active channel is unknown. Given the depth of the water table beneath the channel, it is unlikely that a mound like that shown in Figure 1 exists. But, given the heterogeneous nature of the deposits beneath the channel, it is likely that a mound has formed on one or more low permeability units in the subsurface. If such a mound exists, it is further likely that the excavated channel was located on one limb of the mound. Once water was introduced into the excavated channel, it is likely that a mound would have formed beneath this channel as well, possibly above the same low permeability unit(s). The two mounds would then interact, forming a joint mound on the water table.

The mound that formed due to the addition of the second channel will be similar to that of the active channel, with four potentially important differences. First, the sediments in the excavated region may be different than those in the active channel. However, the proximity of the active and excavated channels, both of which are located in a common floodplain, makes this less likely. Second, the infiltration rate into the excavated channel may have been different than that of the active channel. As a result, the mound beneath the excavated channel could have been smaller or larger than that of the active channel. Third, the active channel is considerably wider than the excavated channel. This would tend to make the mound beneath the active channel both wider and higher than that of the excavated channel. Finally, the presence of the active channel affects the shape of the second mound.

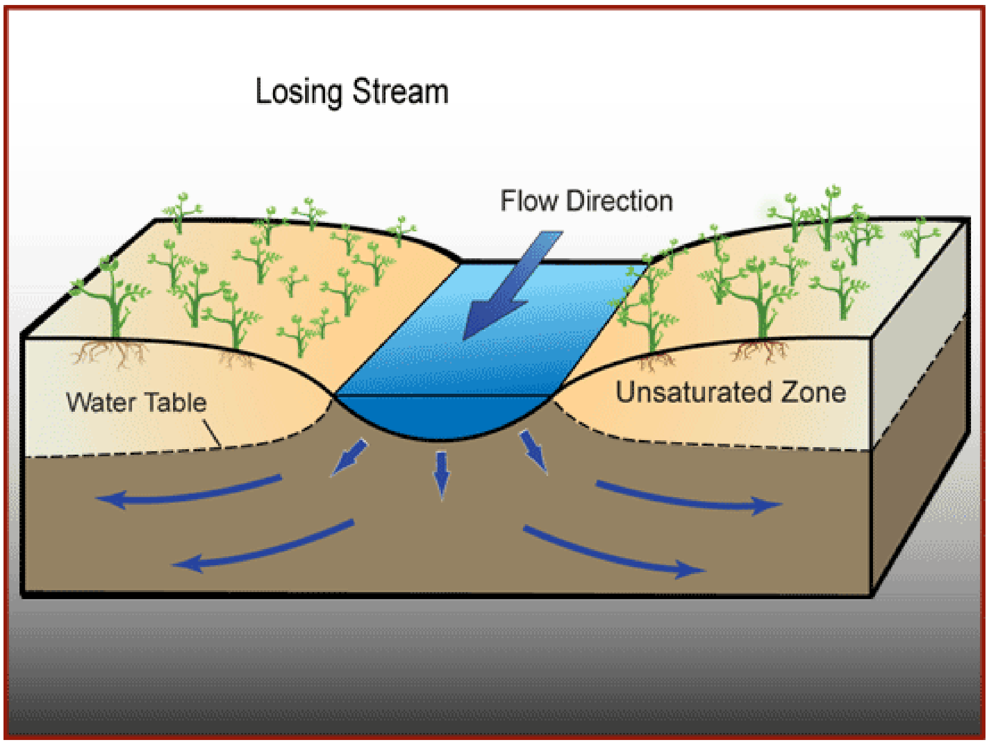

Figure 1: hydrologic conceptual model of a stream connected to an underlying aquifer. Original source: http://www.connectedwater.gov.au/processes/connectivity_cat.html

The interaction of two mounds is shown in Figure 2 for a simplified representation of the Enhanced Recharge Project. Consider a low permeability unit within the vadose zone, above the water table (dotted blue line). Buildup associated with infiltration in the active channel alone would likely result in a broad mound on the low permeability unit (solid blue line). The smaller excavated channel would have a secondary mound that combines with the mound from the active channel (dashed blue line). The result would be an asymmetric 'added mound' due to infiltration into the excavated channel.

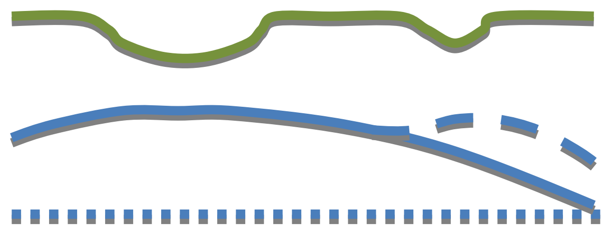

Figure 2: schematic representation of mounded water beneath the ground surface (green) on a low permeability layer (dotted blue) for: infiltration in the active channel only (solid blue); and infiltration in both the active and excavated channels (dashed blue).

HYDRO-GRAVIMETRY

A gravity meter (or gravimeter) measures the total vertical gravitational attraction at a point in space.   Every mass within several hundreds of feet contributes to the total gravitational attraction. But, its contribution decreases with the inverse of the square of the distance between the mass and the gravimeter. In addition, because the instrument measures the vertical component of gravity, the contribution of each mass decreases with increasing angle from vertical of a line between the mass and the gravimeter.

Our application of hydrogravimetry is based on time-lapse gravity monitoring. Essentially, we assume that any changes in mass through time at a given location are only due to changes in water storage. That is, no other masses (soil solids, vegetation, infrastructure, etc.) change significantly over the course of the experiment. With this assumption, we can relate measured gravity changes to water storage changes.

Water in the shallow subsurface represents a small fraction of the total mass of the Earth. Therefore, to monitor water storage changes, gravimeters must make very precise measurements. In addition, all other sources of noise must be minimized. In practice, a major source of noise is changes in the placement of the instrument among measurement times. For this reason, we built stable gravity measurement pads with specific characteristics that allow for repeatable instrument placement. Figure 3 is a series of photographs of the gravity-monitoring pad installations. Each pad is constructed of concrete that has been poured around a 4-foot length of rebar that was driven into the ground. A plastic sleeve around the rebar allows the concrete pad to move independently of the rebar. This design provides a precise measurement point at the top of the rebar and a relatively stable, level platform to rest the instrument. The pads are painted orange for ease of location in the field. The instrument sits on the pad and can be placed at the same location and in the same orientation for each measurement.

There are several different types of gravimeters. They can generally be divided into two groups: absolute meters and relative meters. Absolute meters measure the value of gravity at a location. Relative meters measure the difference in gravity between two points. Absolute meters are more expensive and less portable than relative meters. As a result, relative meters are used more often for field surveys. We used an automated Burris relative gravity meter for this investigation. This instrument, is produced by the ZLS Corporation, Austin, TX. The Burris meter is a metal, zero-length spring meter with a reported measurement accuracy of 3 microGals. The instrument shows very low drift (1 mGal per month) and is designed for use in rugged environments. It is designed to operate in temperatures ranging from -15 to 50 ^{o}C. Further information about this meter can be obtained at: http://www.zlscorp.com/index.html.

Figure 3: top left, gravity monitoring pad; top right, transect of gravity stations; bottom gravimeter placed on a monitoring pad.

To infer gravity change through time at a location using a relative meter, a survey must relate all measurements to a single, stable base station at which the gravity is not expected to change with time. Each field day consisted of multiple 'loops' through the gravity stations. Tidal corrections, to account for changes in the location of the moon and sun during each loop, were applied. Then, the measurements at each station were averaged over the loops for that day.

GRAVITY MONITORING NETWORK DESIGN

Figure 2 represents our hydrologic conceptual model, which formed the basis for our gravity monitoring network design. Specifically, we expect to see relatively smaller changes in water stored in response to flow in the excavated channel in the region between the active and excavated channels. We expect to see no change in storage on the side of the active channel farthest from the excavated channel. The largest changes should take place beneath the excavated channel or on the side of the excavated channel that is farthest from the active channel. Finally, some distance away from the excavated channel, in the direction away from the active channel, there should be little or no change in storage.

To capture the expected spatial variations in water storage due to flow in the excavated channel, we installed a transect of gravity stations perpendicular to both channels. The transect extended from a point between the excavated and active channels, across the excavated channel, onto the plateau in a direction away from the active channel. Figure 4 shows the gravimeter station locations and Table 1 lists their GPS coordinates. However, the GPS coordinates lack sufficient accuracy to locate the stations. Therefore, we will rely on the field measured station locations (also listed in Table 1). These distances are referenced to the North and South banks of the excavated channel. We measured the excavated channel to be 5 m wide at our transect. Based on these field measurements, we have the following distances, in meters, to stations 5 through 1 and background from a point between the active and excavated channels: 0; 10; 15; 30; 35; and 75. This compares with our nominal proposed distances, in feet, of 0; 50; 100; 250; 500. This alteration was made to fit the field conditions including the channel locations and a location for a stable, yet accessible, background measurement location. The station locations were selected to capture both vertical infiltration and lateral subsurface water movement away from the excavated channel.

Each gravity station was comprised of a circular concrete pad with a 4' rebar section inserted through the pad. The rebar was driven into the soil and a short 1" diameter section of PVC tube was placed over it. Then, a circular form, approximately 2' in diameter, was placed such that the rebar was near one edge and within the form. Then, concrete was filled within the form to make a 6" deep base that was leveled at the surface. This provided a stable base for the instrument that could move independently of the measurement point at the top of the rebar. This design has been found to minimize heave associated with connecting the measurement point to the base. Each station was painted bright orange for safety and for ease of location in the field.

Figure 4: Map of gravity station locations relative to active and excavated channels.

Station	Latitude	Longitude	Distance from Wetted Area
Background	32° 25'5.8"	111° 12' 53.0"	50 m South
1	no data	no data	10 m South
2	32° 25' 29.5"	111° 12' 51.2"	5 m South
3	32° 25' 28.3"	111° 12' 51.7"	5 m North
4	32° 25' 28.8"	111° 12' 51.5"	10 m North
5	32° 25' 29.0"	111° 12' 51.4"	20 m North

Table 1: Gravity station locations as measured by Deborah Tosline with a Garmin GPS.

MONITORING SCHEDULE

The original plan included four phases: installation of gravity meters; background measurements; initial flood monitoring; an opportunistic measurement during flooding or another event of interest. We completed our work as follows:

Installation: as described above, gravimeters were installed in a transect perpendicular to the active and excavated channels.

Background: background measurements were made repeatedly until a stable set of background gravity values was achieved. Only the two final gravity background values were used for analysis.

Initial flooding: measurements were collected 3, 6, 24, 58, and 64 days after water was diverted into Channel 1 (the excavated channel) on January 28, 2011. These measurements comprised the majority of the study, which was aimed at characterizing changes in infiltration rates during flow.

Opportunistic measurement: one round of measurements was collected, 72 days after flow initiation, to characterize the impact of draining the excavated channel. Unfortunately, the instrument was not available for our use after this time. But, these measurements proved crucial for testing the performance of the channel. The experiment was terminated on July 6, when a natural flooding event buried the ERDP flumes.

GRAVITY RESULTS

Gravity was measured on 12 days between January 25 and April 12. The first four trips (Jan. 25, 26, 27, and 28) were used for pre-flooding background. There appeared to be a trend in gravity at several stations over the first two days, which may have been related to settling of the gravity pads. But, the last two days provided repeatable background measurements. We used the average gravity measured at each station on these two days as our background value. Water was released into the excavated channel on Jan. 28th, after our background measurements were collected. For our analyses, we use Jan. 29 as day zero.

Data were not reliable for April 3rd, leaving six days of monitoring throughout the initial flooded period (Jan. 29 – March 29, 2011). The results are shown on Figure 5. There are four significant characteristics to the plots. First, the gravity change pattern is highly consistent at all four monitoring locations. Second, the gravity change reached a peak value after six days of flooding, on Feb. 4th. Third, after this peak, there was a gradual and continual decline in the gravity change until 64 elapsed days, on April 2nd. Fourth, there is a clear spatial trend in the magnitude of the gravity change with distance from the active channel (Station 5 to Station 1). The smallest changes were seen closest to the active channel (Station 5) and the largest changes were seen farther from the channel (Stations 1 and 2). The two stations that were farthest from the active channel (Stations 1 and 2) showed very similar results through time. The corresponding data are shown in tabular form in Table 2.

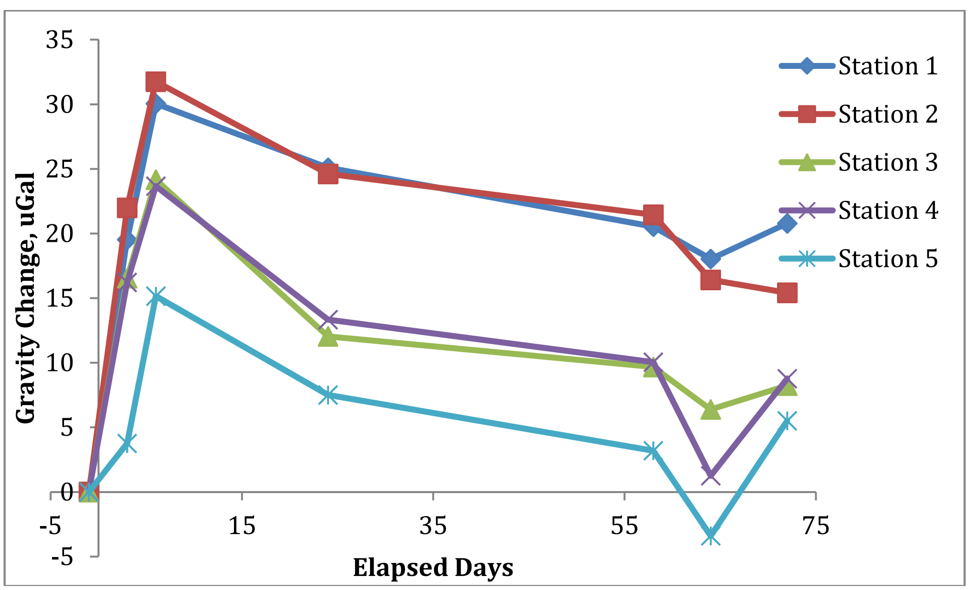

Figure 5: Relative gravity changes through time following the initial flooding of the excavated channel on January 29th.

Date	El. Days	1	2	3	4	5
Jan.25	-4	193	748	918	901	961
Jan. 26	-3	204	723	884	873	937
Jan. 27	-2	199	720	875	866	943
Jan. 28	-1	191	713	878	871	946
Feb. 1	3	215	738	893	885	948
Feb. 4	6	226	748	901	892	960
Feb. 22	24	221	741	889	882	952
Mar. 28	58	216	738	886	878	948
Apr. 2	64	213	733	883	870	941
Apr.12	72	216	732	885	877	950

Table 2: Gravity, relative to background station, in microGals. Each measurement is the result of multiple closed loops on the measurement day. The averages of measurements made on January 27 and 28 were used as background.

An accurate estimation of the change in water storage based on the gravity measurements requires estimation of the soil hydraulic properties and coupled hydrologic and gravity modeling. However, an estimate of the change in water storage can be made based on a commonly applied simplification of gravity response: assuming that the water table is relatively flat relative to the size of the measured volume. Based on this assumption, 1 μGal corresponds to 2.5 cm of water storage. Our results indicate that the maximum change in water storage at the two farthest stations was as much as 79 cm of water. (Note that this would represent a much larger change in water table elevation for a connected stream or mounding height above an impermeable unit, approximately equal to this length divided by the specific yield.)

Using our simplifying assumption to convert gravity signal to water storage change, we can show the change in water storage with distance from the active channel at each measurement time (Figure 6). Here, we assume that Station 1 is 20 m from the active channel (located midway between the active and excavated channels). These results can be overlain on Figure 4 to visualize storage change in the context of the field map. The results show a continuous increase in water storage across the location of the excavated channel (located between stations 35 and 50 m distance). This suggests that the mound from the active channel reached to and beyond the excavated channel, consistent with the conceptual model shown in Figure 2. As a result, the maximum change in storage that could have been achieved was more limited than it would have been farther from the active channel. However, it should also be noted that (Station 1) our most distant station from the floodplain, not including the background station, showed the largest storage change. As a result, the gravity monitoring likely *underestimates* the total change in water storage.

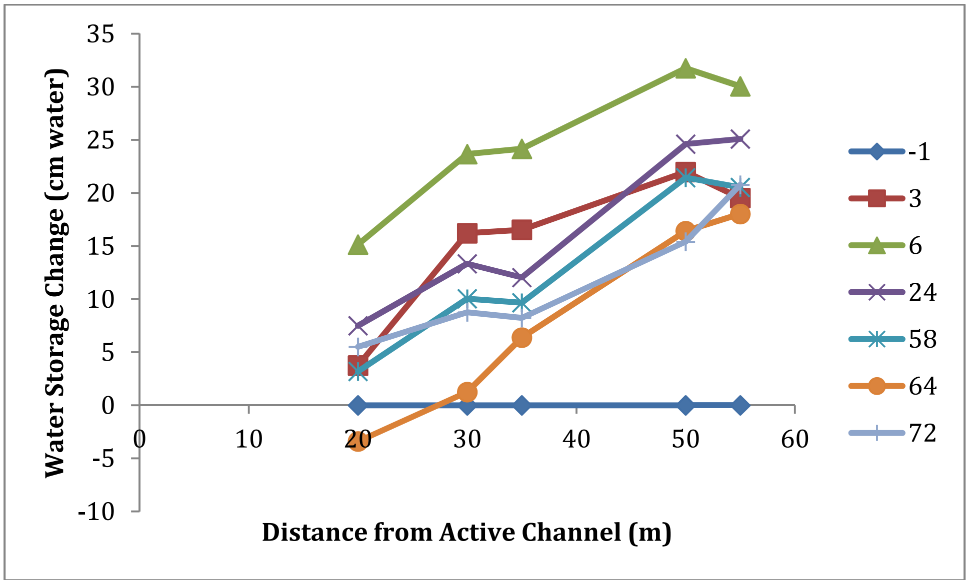

Figure 6: Relative gravity changes through time following the initial flooding of the excavated channel on January 29th. Each series is labeled with the elapsed time, in days, since release of water into the excavated channel. These times correspond to those given in Table 2.

Because of the possibility of changes in hydrogeology and infiltration in both channels with location, it is highly tenuous to extend our 1D transect results to estimate total water storage change. However, we can calculate the storage change per unit length along the monitored section. The results are compared with direct measurements of seepage loss, integrated through time, on Figure 7. Note that the vertical axes are different because seepage loss occurs over the entire excavated channel, while the gravity change is only measured on a transect. But, the trends are very interesting. First, at early time, both gravity-estimated storage change and cumulative seepage loss increase rapidly. This is consistent with water infiltrating from the excavated channel and forming a secondary water table mound. Through time, the seepage results show a decrease in infiltration rate with time. The gravity shows a corresponding decrease in storage change, which is consistent with the partial dissipation of the secondary mound due to reduced infiltration. The final period, with no seepage in the excavated channel during the period of servicing (day 60-75), shows essentially constant gravity response. The nearly constant gravity response suggests minimal loss in stored mass during this period, which may indicate that the infiltration rate had slowed sufficiently to allow most of the mound to dissipate by this time. If the mound were truly stable through this period, variations in gravity measurements during this period could be used to place error bounds on the gravity estimates. However, this would require independent measurements of subsurface water storage or a more highly time-resolved measurement set.

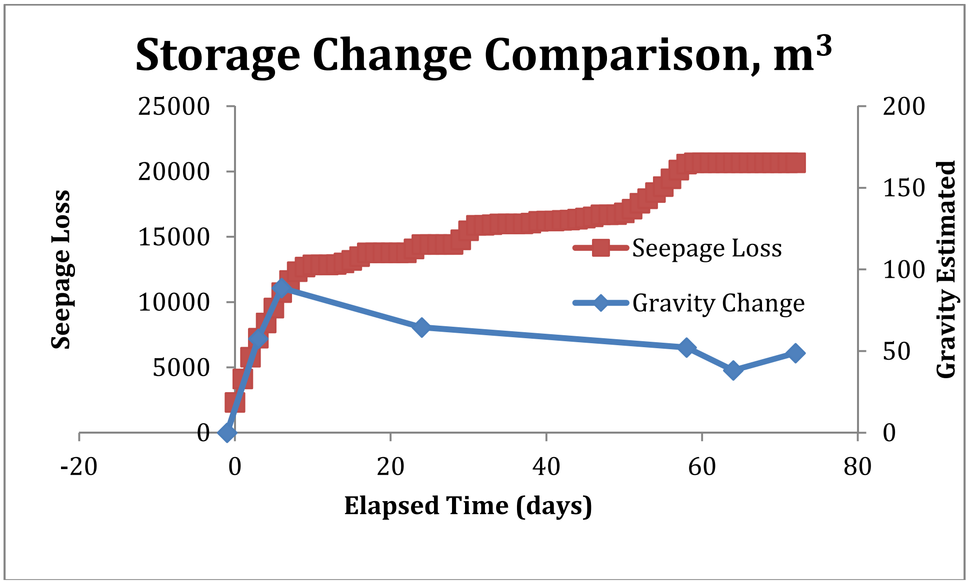

Figure 7: Calculated change in water storage per unit area (blue) and cumulative seepage loss between the gauges (red) through time following the initial flooding of the excavated channel on January 29th. Both y-axes have units of m^3.

CONCLUSIONS

Time-lapse gravity measurements provided insight into changes in storage due to infiltration into the excavated channel. The gravity change time series is consistent with a conceptual model of infiltration and mounding in two adjacent streams, suggesting that this could form the basis for more quantitative hydrologic modeling, where necessary. Gravity results showed significant water movement laterally from the excavated channel, in the direction away from the active channel. Similar monitoring efforts could be very useful in determining the potential for water and solute movement laterally from active channels.