TIER-1 APPLICATION TO THE NEW MEXICO INTERSTATE STREAM COMMISSION FOR NEW MEXICO UNIT OR WATER UTILIZATION ALTERNATIVE

APPLICANT INFORMATION (PRINT **DATE:**

1. Legal Name: VAN D. Clothier	2. Organization: Stream Dynamics, INC.
3. Address (street, city, county, state, and zip code): **Stream Dynamics, Inc.** PO Box 2721 Silver City, NM 88062	4. Name, email, and phone number of contract person: VAN Clothier streamdynamics@AZNex.Net
5. ~~TYPE~~ OF APPLICATION (check one): [✓] Final [ ] Preliminary for review [ ]	6. TYPE OF APPLICANT (CHECK BOX): [ ] local governments or municipalities [ ] soil and water conservation districts, irrigation districts or commissions, acequias, or other political subdivision of the State of New Mexico [ ] institutions of higher education or a consortium of such institutions [ ] non-profit organizations or associations [ ] private individual/s [ ] federal agency (ies) [✓] Other (specify) Corporation
7. BRIEF PROJECT DESCRIPTION: A large number of small water harvesting projects	
8. AREAS AFFECTED (describe by county, municipality, township, etc. as applicable): MANY homes, businesses and public spaces in all four counties	

9. TOTAL FUNDING REQUESTED ~~(in $1,000)~~:

2012: 6,600,000	2013: 6,600,000	2014: 6,600,000	2015: 6,600,000	2016: 6,600,000
2017: 6,600,000	2018: 6,600,000	2019: 6,600,000	2020: 6,600,000	2021: 6,600,000

10a. TO THE BEST OF MY KNOWLEDGE AND BELIEF, ALL DATA IN THIS APPLICATION ARE TRUE AND CORRECT, THE DOCUMENT HAS BEEN DULY AUTHORIZED BY THE GOVERNI9NG BODY OF THE APPLICANT AND THE APPLICANT WILL COMPLY WITH THE ATTACHED REQUIREMENTS AND ASSURANCES IF THE

10b. TYPED OR PRINTED NAME OF AUTHORIZED REPRESENTATIVE: VAN Clothier	11. TITLE: Director	12. PHONE NUMBER: (575) 388-5296
13. SIGNATURE: [signature]		DATE: July 14, 2011

AWSA - TIER I APPLICATION

for

WATER HARVESTING

submitted July 14, 2011
by

Van Clothier

Stream Dynamics, Inc.

1. State whether the proposal is for the "New Mexico Unit," a "water utilization alternative," or both.

This is for a water utilization alternative.

2. Describe how the proposal will meet a "water supply demand" in the Southwest New Mexico Water Planning Region, comprised of Catron, Grant, Hidalgo and Luna Counties.

Executive Summary for the Water Harvesting Proposal

Stream Dynamics, Inc. is hereby putting forth what we feel is a critical component of the overall best solution to the AWSA, one that will provide abundant and cost effective water resources, and great long term benefits to the residents of the four county area. This idea is intended to be implemented by qualified individuals, firms, or agencies, including but certainly not limited to Stream Dynamics, Inc.

This proposal will meet a water supply demand for thousands of homes and businesses in the four county area. It will create the largest overall benefit for the people of our four county region from our water resources and the funds that have been appropriated to properly utilize them, and this benefit will be equitably distributed.

The next largest demand for water in this region after agriculture and mining is water for commercial and residential use. Currently, the supply is mostly met through groundwater pumped from municipal and private wells. Harvesting rainwater and greywater on a large scale would dramatically increase the effective supply of water available while decreasing the depletion of our precious groundwater resources.

The Water Harvesting Concept

Imagine if you poured a five gallon bucket of rainwater out in the middle of a dirt parking lot on a hot day. It would spread out 10 feet wide and wet the earth ½ inch deep. By the next day, most of the water would be lost to evaporation. The whole game changes if you dump the same five gallon bucket of water into a ten gallon hole. Most of the water would then soak deeply into the subsoil where it would be available for tree roots to utilize during the entire dry season. This is the basis of water harvesting.

People need food, and food production requires water. Water harvesting employs a suite of techniques that direct concentrated runoff from hardscape surfaces (such as the roof of your house), towards shallow permeable basins where it will soak into the ground. Water harvesting also includes roof catchment cisterns, and greywater recycling (both are legal in New Mexico, see page 14). Note that a cistern is not required to do water harvesting: a simple water harvesting earth basin stores water in the soil where it can be used to deeply irrigate vegetable gardens, and the roots of trees – fruit trees, shade trees, windbreaks, etc. We propose repeat application of these astonishingly simple concepts. Read on.

Earth basin soaks water into the subsoil where it cannot evaporate

For water harvesting to be an effective component of our region's water supply, it must be implemented in thousands of widespread locations where a concentrated flow of water is adjacent to a point of demand. This has been pointed out by some as a weakness of the proposal. Consider it now as a great strength. The population of the four county area lives widely spread out in households that number a score of thousands. We are living on remote ranches, widely scattered homes and rural subdivisions, and a smattering of towns, villages and cities. We are distributed thinly over a vast and mountainous geographical area. It would be difficult to supply us all from one giant water project. Fortunately this is not necessary, because each of these homes has a roof. The roof can create for each home an individual supply of water located uphill from each point of demand. This is marvelously convenient, wouldn't you say?

Each dwelling is adjacent to a road or driveway, which is another potential source of water after a precipitation event, one which is advantageously located near landscaping areas that need water. Bingo! Here is a perfect solution for turning nuisance stormwater runoff into a beneficial resource for the people, wherever they live in the four county area. Water harvesting can be done along roads to grow trees and create green corridors along the right of way for us all to enjoy.

Our homes are already served by pressurized potable water flowing in a pipe inside the house. The wastewater from sinks, tubs, showers, and the washing machine normally gets mixed with the wastewater from the toilet before going to the sewer or septic system.

A minor correction to this unfortunate plumbing convention is easily made by separating all other drains from the toilet. This is called greywater recycling, and creates a reliable supply of irrigation water adjacent to and uphill from the home's landscaping demands. Approximately 78 percent of the average household's wastewater can be recycled in this way. This is a huge savings! Greywater use vastly decreases our need for water pumping and sewage treatment, saving a bunch of electricity at the same time. This is entirely legal, and so simple, so cost effective. What could be better?

How much will this cost?

Implementation of this proposal is very flexible. Construction of any number of these small projects is feasible: the more water harvesting sites, the more benefits for the people and environment of the four county area. The ultimate goal is for each person in the four county area have access to the benefits created by a free a source of harvested rainwater, if not at their home, then at their work, or along their street or in the local park, or in a store parking lot so they can park in the shade on a hot day.

A small water harvesting curb cut, including a mulched, stone lined basin planted with a tree costs $200 - $500. Water harvesting earth basins that capture roof runoff can be built for free with a hand shovel by a knowledgeable homeowner. An installation by a certified water harvester may cost $500 or more. The cost of a whole house greywater installation varies depending on the arrangement of the plumbing within the house. A simple installation, including all plumbing ranges upwards from $810. (source: Create an Oasis with Greywater by Art Ludwig, page 16). Cisterns cost $0.75 - 1.50 per gallon of storage, and the accompanying installation package, (including rain gutters, basic filtration, and downspouts) is in the vicinity of $1000 for a simple roof.

On the average, let us suppose it will cost approximately $1000 per person for water harvesting infrastructure. There will likely be 66,000 people in the area by the time this is implemented. Therefore the full implementation of this proposal will cost:

66,000 people x $1000/person = $66,000,000

It will take ten years to complete this scenario, which will cost $6,600,000 per year (plus the interest from the account to adjust for inflation. For this price we will be creating a fabulous water resource the AWSA money, and create jobs for a hundred people for ten years.

Jumping ahead to the water supply issue (addressed in question II of the AWSA application form below), a combination of greywater recycling and rainwater harvesting can create a water resource of 50,000 gallons per year for a four person household. This would cost of $4000. For a average project cost of $1000 per person, everyone who wants this can have a free lifetime supply of water!

Note that water harvesting from roofs and greywater is not in conflict with downstream users. The additional runoff created by urban hardscape is a liability which water harvesting responsibly handles.. No payments will be demanded from downstream water users if we do this thing that benefits everyone and harms nobody.

Sounds amazing, but how could this be implemented?

The energy audits being conducted in the Silver City area by the Silver City / Grant County Joint Office of Sustainability could serve as an example. The Office of Sustainability has secured funding to do minor energy efficiency improvements for local area homes. People can call them up and ask to schedule an energy audit. Trained personnel visit the home and perform minor insulation and weather stripping tasks at no charge to the resident. This simple model could be used to implement widespread water harvesting retrofits for people's homes and businesses.

There should also be a provision for a tax or some other type of credit, or a reimbursement or payment (ultimately paid by the AWSA funds) for homeowners who apply to do the work themselves as long as it meets specifications. Not every homeowner or commercial building owner will be interested in saving money on their water bill with this free government-funded program. This will allow a significant portion of the funding to be expended to build water harvesting infrastructure along public rights of way, parks and green spaces. It will all balance out.

Doing all the work to retrofit our region's infrastructure for water efficiency and self-reliance is a huge task. It would take much time, and the dedicated work of many people. Fabulous! We have many people living here that need meaningful jobs so that we can not only feed our families, but also do something to make our world a better place.

How awesome would it be if the AWSA money was used to transform the four county area into a beautiful example of how people in the drylands can live in balance with our water supply?

Water harvesting from a city street irrigates the Silva Creek Botanical Gardens

Rainwater Harvesting Supply
Below are a few basic calculations to demonstrate that water harvesting represents a significant supply, one located adjacent to important points of demand, such as your house. These calculations are written out longhand so that everyone can follow along. Some of the inputs are approximations, yet this serves to illustrate that we are talking about significant water resources.

The four county area has a population close to 63,228 (2010 census). Divide this by approximately 3.5 people per house, multiply by 1700 square feet of roof area per house, multiply by 1.2 feet of rain annually, and finally divide by 43,560 cubic feet per acre foot to arrive at over 800 acre feet of water that falls on the roofs of our homes in the four county area. A calculation of the roof area of all commercial and municipal buildings would significantly add to this.

Let's say that the average house in the four county area has approximately 1700 square feet of roof; this times 1.2 feet of rain annually, times 90% runoff coefficient, times 7.48 gallons per cubic foot equals: over 13,000 gallons of water that goes down the downspouts of an average house annually. For many homes, this water goes past the landscaping (which must therefore be watered with the hose), down the driveway, down the street, and then into the nearest arroyo, contributing to traffic safety hazards, and erosion, as well as flooding problems for downstream landowners.

Water harvesting turns this nuisance runoff directly into a water supply - potentially for the majority of homes in the four county area! This water could grow a vegetable garden or fruit trees instead of creating a public liability for the municipal and county streets departments. The annual water needs of a mulched vegetable garden planted in a sunken bed (ideal for water harvesting roof runoff) is 64 gallons per square foot of vegetable garden per year (This figure is for Tucson, Arizona). This equates to over 200 square feet of vegetable garden for the average home that will be watered for free, without depleting our precious groundwater resources, and without using electricity to pump it. Alternatively, the rainwater could be used to grow shade trees in strategic locations around the house to provide shade in the summer, which would reduce summer temperatures around the building, reducing the need to run the evaporative cooler, thus reducing the demand on our municipal and local water systems, and also reducing the need for electricity, which uses even more water in its generation.

Commercial and municipal establishments could use the water from their roofs and parking areas to irrigate shade trees and windbreaks, while eliminating their contribution to nuisance storm water runoff.

Greywater Harvesting Supply

The available supply of greywater is located very close to the point of demand for many houses. Typical household water use, in gallons per week (gpw), for two adults and two kids, is calculated in the table below. (from Create an Oasis with Greywater, by Art Ludwig):

Washer	5 loads/week x 32 gal/load		= 160 gpw
Shower	1 shower/day/person x 8 min x 2 gpm x 4 people x 7 days		= 448 gpw
Bathroom Sink	2 gal/day/person x 4 people x 7 days		= 56 gpw
Tub	2 baths/wk x 30 gal		= 60 gpw
	Greywater Total		= 724 gpw
		Times 52 weeks/year	x 52
			37,648 gal/year

According to New Mexico law, kitchen sink water and toilet water are considered blackwater which must still go to the sewage treatment plant

Toilet	3 flushes/day/person x 1.6 gal/flush x 4 people x 7 days		= 126 gpw
Kitchen Sink	3 gal/day/person x 4 people x 7 days		= 84 gpw
	Black Water Total		= 210 gpw
		Times 52 weeks/year	x 52
			10,920 gal/year

In this example, 78% of indoor use water is recycled for the landscaping, and previous outdoor water use is drastically cut. As soon as we start to do this simple retrofit in significant numbers, we will be extending the water supply for the whole community.

This is 37,000 gallons per house per year that does not have to be treated by the sewage treatment plant, resulting in a cost savings for municipalities, mostly labor and electricity. Since the greywater recycled does double duty by irrigating the landscaping and garden, this also represents 37,000 gallons of water saved at the well. This will save electricity and protect the groundwater resource from depletion. Note that water is used for electrical energy generation, so by saving electricity, we are also saving more water!

Adding it All Up

By combining rainwater harvesting with greywater recycling, a home can expect to receive a significant new water resource:

Rainwater Harvesting	13,000 gallons/year
Greywater Recycling	37,000 gallons/year
TOTAL PER HOUSE	50,000 gallons/year

Wouldn't you like your house to receive this free resource? Why don't you calculate how much money you could save on your water bill?

Water Harvesting Project Examples

Since this idea may be new to some people, included here are several examples that demonstrate the variety, beauty, simplicity and utility of water harvesting options. Water Harvesting includes cistern installation, curb cuts, and earth basins. A "Laundry to Landscape" installation is featured as a good example of Greywater Harvesting. The examples follow in the order mentioned above.

Cisterns

Water Supply and Demand illustrated: In the photo below, the hose is used to water the garden (demand) using the rainwater collected from the roof and stored in the cistern (supply). This supply of water is located adjacent to the point of demand, and requires no electricity to access, making it more reliable than any other water supply during emergencies such as fire or electricity outage (which often happen at the same time).

Galvanized culvert cistern irrigates a backyard garden

Curb Cuts
Curb cuts, where appropriate, allow water from the street gutter to flow into a small basin on the back side of the curb within the public right of way. The rim of the basin is designed to be at a higher elevation than the curb itself, so that it will not overflow except back to the street. The basin is lined with rock, and mulched. This works well for existing as well as newly planted trees. This water harvesting technique requires modifying public infrastructure, which is regulated by the municipality or department that owns and maintains the streets and curbs. In Tucson, AZ, water harvesting curb cuts are a routine procedure. A permit is applied for, and the work must meet design and workmanship standards. This is becoming quite popular, and is tied into the complete streets program. Studies have shown that shady tree lined streets are known to have a traffic calming effect and encourage people to walk and engage with their neighbors.

A tidy example of a bore hole curb cut with tree basin is seen in the photo below. This is on the small side, perhaps 100 gallon capacity. Depending on the runoff duration and intensity and the soil percolation rate, this feature could harvest much more water during a storm. A larger curb cut and basin system could harvest 600 gallons per storm or even more.

Urban stormwater runoff (supply) is used to irrigate a tree (demand). The tree provides shade, food, windbreak, visual screening, and beauty. All these benefits are free with rain that falls from the sky.

Bore hole in curb, Tucson, Arizona

Below is a local example of a newly constructed water harvesting bore hole installed on April 16, 2011 by Patricia Pawlicki's sustainable design class at Western New Mexico University. The photo shows the feature working perfectly during its first real test. In the photo, the basin has filled to the maximum, which equals the water level in the street gutter. Now the WNMU Garden Club can plant landscaping to beautify the entrance to the university. This is exciting stuff!

Bore hole in curb during a rainstorm, Silver City NM July 11, 2011

A supply of water from Swan Street in Silver City meets the demands of grass and wildflowers along the public right of way. In the photo below, the basin is hidden by lush vegetation.

Curb cut converts nuisance stormwater runoff into wildflowers.

Water Harvesting Basins

A variety of water harvesting basins can be constructed to receive roof runoff (as well as street runoff), and cause the water to soak deeply into the ground where tree roots can utilize the moisture during the entire dry season. Gardens can benefit from the huge increase in soil moisture during monsoon. This will also keep the runoff from going into the street, where during large rainstorms, it often causes a safety hazard.

In the example below, roof runoff from two houses was previously going down the driveway, down the street, and out of town in the Big Ditch. Sediment from the driveway was going into a city street, causing a safety hazard for kids on bikes, and costing the city a bit of extra street sweeping. Simple earthworks have turned this into a water resource for the property. The supply is coming from roof runoff, and the demand is the vegetable garden that has just started to grow. The sunflowers are volunteers.

Earth basin, Cheyenne Street, Silver City

February 1, 2011

July 11, 2011

In the picture below, a concrete basin fills with roof runoff from the downspout. This creates a supply of water for the demands of wildlife habitat in the desert just outside a friend's window in Rodeo, NM. The overflow goes to a native plant garden. Keeping things green is a good way to be fire safe.

Concrete garden basin for wildlife

Laundry to Landscape

The photo below shows a straightforward installation of new plumbing to route greywater from the washing machine to the landscaping. These people are students of the Water Harvesting Certification course taught by Watershed Management Group in Tucson.

Greywater pipes must slope ¼" per foot.

The newly created supply of greywater flows by gravity to a mulched basin next to a fruit tree in the yard (demand) instead going into the sewer system. This simple and legal plumbing project turns wastewater into a water supply at the point of demand. Six thousand households in the four county area could have this very simple system installed using funds from AWSA. This would permanently reduce the need for developing additional water infrastructure.

This greywater is free, and perfectly suited for irrigation of trees.

A Note on Greywater Law
Greywater recycling has been fully legal in New Mexico since 2003. Details of this can be found at http://www.oasisdesign.net/greywater/law/#newmexico. This is a well considered law, which requires the installation of a convenient Y-valve that can direct laundry water to the sewer when required, such as when washing greasy coveralls from an auto repair, or washing diapers.

As an example of how a large municipality in our region is dealing with its water resource issues, the City of Tucson has a recently adopted water harvesting ordinance that requires greywater stub outs on all new construction, as well as water harvesting basins to infiltrate any new runoff caused by new construction. The text of the ordinance is in the appendix of this application. It was obtained from:
www.tucsonaz.gov/water/docs/rainwaterord.pdf

A Note on Water Harvesting in New Mexico
The office of the State Engineer has issued a statement encouraging "the harvesting, collection and use of rainwater from residential and commercial roof surfaces for on-site landscape irrigation and other domestic uses." The office also has how-to water harvesting information on its website:
http://www.ose.state.nm.us/wucp_waterwise_building.html

3. Describe how the proposal considers the Gila environment and describe how any negative impacts might be mitigated.

This proposal is specifically formulated to derive maximum water resource benefit for residents of the four county area without causing any harm whatsoever to the environment of the greater Gila area. Instead, the implementation of this proposal will have many positive impacts on the Gila environment.

Urban Stormwater Runoff
"The best solution to the urban runoff problem is to detain this stormwater in small volumes as near to its source as possible, and then to release it slowly to natural stream channels or to the groundwater system," Dunne and Leopold, Water and Environmental Planning. Water harvesting from impervious roads and rooftops creates a vegetated filter that protects our water quality, and reduces storm water runoff and downstream erosion and sedimentation problems.

Water going to waste,
unfiltered street runoff goes directly into a stream.

Extending limited resources
Doing water harvesting to add to our available water resources is preferable to groundwater pumping, which depletes aquifers and dries up and degrades streams, rivers and riparian habitats. By reducing the need for pumping, we are reducing electricity consumption, with its concommitant air pollution and groundwater depletion. (A huge amount of water is used to cool electrical generating stations. This relationship between water and energy in modern society is now called the water/energy nexus.) Greywater harvesting reduces the amount of water that must be treated at the wastewater treatment plant, a huge electrical energy consumer. The air pollution from distant energy generation stations may already be affecting air quality in the Gila, so we must do our small part to minimize this, and to set a good example.

The Gila - a High Quality Environment for Human Beings
Precipitation is naturally distilled through evaporation prior to cloud formation and thus is one of our purest sources of water. Rain is considered *soft* due to the lack of carbonate or magnesium in solution, and is excellent for cooking, washing, and growing plants. With modern water harvesting technology, rainwater stored in cisterns can easily be filtered to meet the highest water quality standards for drinking and cooking. We can save on water treatment systems, which consume electricity (and therefore use water and create air pollution - the water/energy nexus).

Rainwater is a natural fertilizer and has the lowest salt content of all natural fresh water sources, so it is a superior water source for plants. By irrigating our gardens and fruit trees with rainwater we will be reducing the need for imported fertilizers, which can leach undesirable chemicals into the groundwater (and also have environmental transportation costs, such as smog). We will also be eating higher quality food.

Rainwater, the highest quality water, comes to each of us free of charge. It is the most democratic of all water sources, falling on rich and poor alike. This proposal will use the funding provided by the settlement act to provide water harvesting infrastructure for thousands of area residents. This improves the human environment, an important part of the equation.

4. Describe how the proposal considers the historic uses of and future demands for water in the Southwest New Mexico Water Planning Region and the traditions, cultures and customs affecting those uses.

Historic Uses

Historically, the Gila River flowed from the mountains in New Mexico, all the way across Arizona and into the Colorado River, which flowed to the Gulf of Mexico. Aldo Leopold described this as a fantastic and highly productive delta zone. Water supply and demand were balanced naturally. Water manipulation through dams and large-scale irrigation diversion created a false impression of increased supply, resulting in an unsustainable demand over the long term, e.g., water hungry alfalfa grown with diverted river water. The balance has been tipped to the degree that the river now goes dry more frequently and rarely, if ever, completes its flow to the Gulf.

A thriving agricultural economy has now existed for a very short time frame in the historical sense, but the traditions, cultures and customs established during that 200-year timeframe have become sacred to some, to be preserved at all costs. Agriculture for profit in the Southwest is now struggling to survive, and is decreasingly cost-effective as the cost to run such operations increases and the production profit decreases. The demand for water has surpassed the supply, and contradictory uses vie for control.

Implementation of this proposal on any scale would move us toward a more natural balance of water supply and demand.

Future Demands

To meet future demands, we must do something intelligent to extend our limited supply. In the domestic greywater recycling example above, 78% of indoor water use, or 37,646 gallons a year, was recycled as greywater to the garden and landscaping trees, drastically cutting the need for outside irrigation. In the rainwater harvesting example 13,000 gallons of water from the roof of the average home can be put to beneficial use by the residents (i.e. meet a "water supply demand"). These two items add up to a water savings of approximately 50,000 gallons per year per average household. Multiply this by an estimated 18,700 households in the four county area and you get 935,000,000 gallons, or

2,800 acre feet of water savings. This is water that we don't have to pump out of the ground. It can be stored there to meet future demands. (This is not including water harvesting from roads using curb cuts, which can add thousands of gallons more per household to irrigate street trees within the public right of way. In concert, these practices add up to a significant decrease in the strain on existing water infrastructure and resources.

We must also find a way to carefully address the human population issue. Unless this is done, all increases in supply or efficiency will be quickly overcome by additional demand. Let us not continue to abrogate our responsibility to pay attention to these important matters.

Traditions, Cultures, and Customs
The Desert Southwest has a long tradition of water harvesting. Before the advent of modern irrigation technology, peoples of the American Southwest relied on water harvesting techniques for drinking water and to grow their food. Check dams were built for many hundreds of years across small ephemeral drainages to catch soil and water and to provide irrigation for crops. Terraces and linear borders were built along contour lines to catch soil, nutrients and water. Sunken beds were built to catch and infiltrate water and grow valuable crops. Plantings were often situated advantageously at the base of cliffs and rock outcrops where water would run off and become concentrated. Brush weirs were used to spread water across floodplains.
(from August 1994 article in Permaculture Drylands Journal by Joel Glansburg)

Many old homesteads in New Mexico had kitchen gardens that were irrigated in part by greywater. Rain barrels and cisterns were an important water source back in the day. The traditional self-sustaining hacienda was, out of necessity, a study in wise use of resources. It's exciting to see these important traditions being revived with the recent popularity in water harvesting. Growing your own garden and fruit trees with harvested rainwater in an urban or rural setting can again become the norm.

Appendices

1) Silver City Water Harvesting Projects - this is a report by Van Clothier on recent projects by Stream Dynamics, Inc. within the Town of Silver City.
2) Santa Fe Water Harvesting Projects - report by Van clothier on water harvesting demonstration projects in Santa Fe designed in part by Stream Dynamics, Inc.
3) Swale Treatment of Parking Lot Runoff
4) Urban Stormwater Management
5) Tucson Rainwater Ordinance

6) A set of useful links to water harvesting references:

A) Fabulous article on Stream Dynamics, Inc. Silver City water harvesting projects in the July edition of Desert Exposure:
http://www.desertexposure.com/201107/201107_van_clothier_water.php

B) A Prototype Analysis for Determining the Stormwater Retention and Water Supply Benefits of Cisterns, by Evan Canfield and Lisa Shipek:
http://www.watershedmg.org/sites/default/files/publications/canfielde_paper.pdf

C) see attached "nrc_stormwaterreport.pdf" - a publication by National Research Council, 2008 focused on urban stormwater management. Suggest a coupling of flow proxies like impervious cover to better evaluate potential pollution loading issues

D) City of Tucson and Pima County Water Study and recommendations - focus on lot-scale water harvesting practices for most efficient use of rainwater and to benefit infrastructure:
http://www.tucsonpimawaterstudy.com/

E) Conference proceedings and good places to look for examples and related contacts for more info:
http://www.aridlid.org/

F) EPA resource links:
http://cfpub.epa.gov/npdes/docs.cfm?program_id=6&view=allprog&sort=name --> related presentation listed on page: http://www.epa.gov/npdes/pubs/ginm13.pdf

Van Clothier, Stream Dynamics, Inc.

Local Silver City Water Harvesting Demonstration Projects
Designed and built by Van Clothier

I Flow limiter - Silva Creek Botanical Gardens

This was my first water harvesting project in an urban setting, and it was inspired by Brad Lancaster. I met Brad when I introduced him at his presentation at the 2006 Gila River Festival. His presentation got a bunch of us fired up about urban storm water harvesting.

The Silva Creek Botanical Gardens site is a one acre city-owned property on Virginia Street at the edge of a tributary of the Big Ditch in Silver City. The Big Ditch is where the historic San Vicente Marsh cut to bedrock as a result of cattle grazing, wood cutting, and roads that set the stage for a horrendous erosion event in 1895. Floodwaters "12 feet high and 300 across" ran through the heart of town. When the waters receded the next day, Silver City was left with a ditch 35 feet below street level where Main Street used to be. A second flood in 1903 deepened the ditch to 55 feet, and widened it to take property on both sides of the street. A section of the ditch through downtown has now become a park with paths, picnicking areas, and foot bridges.

Silva Creek, a tributary of the Big Ditch, has cut to 20 feet deep. At the project site, runoff from a 75 acre urban neighborhood goes in a drainage ditch and off a steep eroding bank into Silva Creek. Flood flows from a two inch rain in a 75 acre urban sub-watershed with 60% impervious surface and a .6 routing factor equal 4.5 acre feet of water. This is a one acre site, and to prevent flooding the neighboring house, I needed to limit the maximum amount of water that would be diverted into the park. The solution was a cap rock flow limiter that had a 1/4 square foot aperture for water to enter the diversion system. The grade of the original drainage ditch was raised slightly to insure that base flow would enter the diversion, and the cap rock flow limiter prevents excess flow from entering the diversion during an extremely large runoff event.

The project received approval from the town community development director. It was built in July of 2006 under my direction by the Youth Conservation Corps and Aldo Leopold High School students. All of my time for design, oversight, monitoring and maintenance was donated to the project.

Construction of water harvesting basin

Once water gets past the flow limiter, it enters a short diversion channel with a rock rundown into a three foot deep cobble lined basin about 10 feet across. The overflow from this basin travels as sheet flow and gets trapped behind a series of two raised path banana berms, creating temporary ponding approximately 6" deep. The overflows from the banana berms are protected with stone work to prevent erosion. At the downstream end of the park, a collector channel gathers all of the return flow to prevent it from entering the neighbor's property. The collector channel goes down the bank of the Big Ditch in a series of rock lined step pools, thus responsibly returning any overflow back to the Big Ditch.

Back to the original drainage ditch and the site of the water harvesting diversions: There is actually a second diversion intercepting water from the drainage ditch a bit downstream of the first diversion. The first diversion takes all of the base flow, and when the stage in the ditch gets a bit higher, the second diversion (which also has a cap rock flow limiter) goes to another three foot deep by ten foot wide cobble lined basin. The entire rim of this basin is higher than the bank of the drainage ditch, so it is an oxbow diversion that does not overflow to the park. Instead, the excess water simply bypasses it and stays in the drainage ditch.

I have monitored this diversion's performance during several runoff events. The porosity of the soil in the basin is so high that it takes a long time to fill the basins during a runoff event because water soaks into the ground so rapidly. At last, the first basin overflows, and sheet flow travels across the park, getting trapped behind the two banana berms. For an afternoon thundershower, this water will be standing behind the banana berms until some time the next morning.

The result of all this is a phenomenal change in the ecology of the site. A local gardener who is active in the Gila Native Plant Society has devoted his spare time to planting hundreds of native plants, and the growth and beauty of this vegetation is astounding.

Filling cycle of water harvesting diversion. Blue arrow pointing left is flow in drainage ditch. Water must flow through an 8 inch by 4 inch opening under a boulder to flow to the diversion.   The top of the boulder is as high as and keyed into the bank of the ditch to keep high flows in the ditch. Note yellow arrow pointing to fence post, which is in the next photo.

Looking upstream toward basin now that it is overflowing. Yellow arrow at fence post is same location as preceding photo.

The next morning. Banana berm path is visible in center of photo. At this point almost all of the water has soaked into the ground, facilitating the transformation of what once was a parking lot for city trucks into a botanical garden.

II Street Reshaping at a cul-de-sac:
Frances Trotta Fig Tree Project

At the north end of Grant Street in Silver City a ½ acre urban sub-watershed drains erosively over a steep bank and into the Big Ditch. Over the years, city maintenance crews have dumped dirt and rocks off the bank in an effort to stem the erosion. My friend Frances Trotta wrote a grant to the Town and Country Garden Club to turn this area of city land into a fig and jujube tree grove for the neighborhood. The grant paid for trees and the rental of a backhoe. I donated my time to design and build the project. Grant Street turns to dirt at the end of this deadend street, and the city officials allowed that we could make changes to the drainage here to correct the erosion problem and put the water to beneficial use.

Photo point looking south prior to construction, showing haphazard arrangement of berm with eroding bank and no water retention.

Basins constructed and fig and jujube trees being planted.

Completed earthworks, planted and mulched. Rock overflow drop structure is to right of people. This lets overflow down steep bank without erosion.

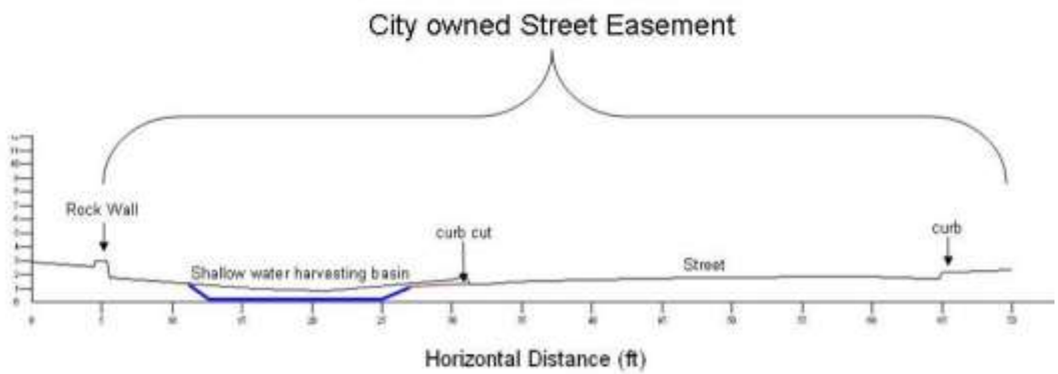
Looking north during runoff event.
The basins are full of water and the chip mulch is floating.

III Through-Flow Curb Cut Basin -
The first water harvesting curb cut in Silver City, New Mexico.

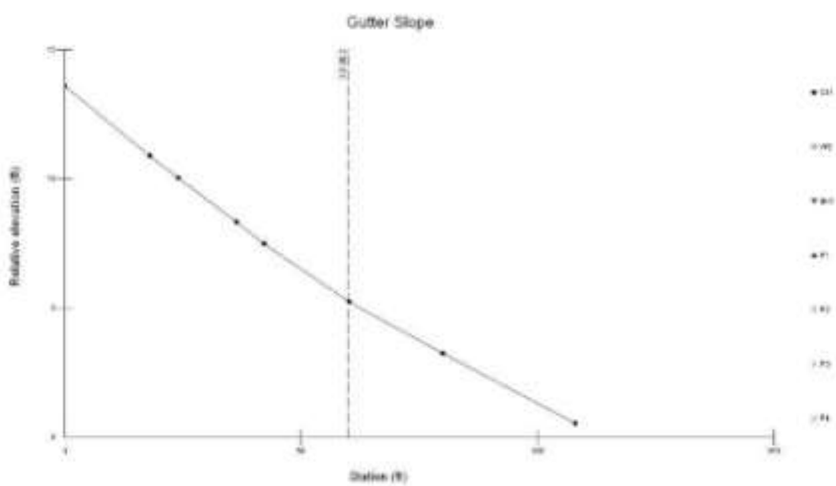
My client was willing to be a guinea pig for this experiment. I met with the Mayor to give him a water harvesting presentation and asked for his support to do the first city approved water harvesting curb cut in our town. He asked the city manager to allow this. I then met with the floodplain manager and the community development director to discuss my plan. I next met with the public works director who is in charge of the streets department and received his permission to cut a city owned concrete curb for water harvesting.

This site presented design challenges because the street and landform slope was 10%. It seemed a bit steep to create an oxbow style water harvesting diversion without terracing the hillside, which would have destroyed a nice patch of native grass. I also wanted to maximize the area of land irrigated from one curb cut, so I decided to create a through-flow diversion. This is a good technique for water harvesting in small, shallow gullies in a broadlands setting. The critical feature for this to work is a landform wide enough to route the flow, which is lower than the bank of the gully, or in this case, the curb. Note that this design would allow the downslope neighbor to excavate basins and move the return flow down slope, harvesting more water from the single curb cut.

Panorama of site, showing location of street and gutter cross section,
which follows in the next illustration.



Cross section of city owned easement, looking downstream,
showing the swale landform behind curb. The basin is illustrated in blue.
Farther down the street, the grassy landscape slopes toward the street,
providing a stabilized return flow over the curb to the gutter.



The slope of the street and adjoining landform is 10%. This is very steep,
but the watershed area is small, and the swale is relatively broad and well vegetated.

Day of construction, showing completed curb cut, diversion channel and water harvesting basin. Note how concrete diversion gutter is still "green." All basins and channels were raked, seeded, and mulched before rock work was done, i.e. the mulch is <u>under</u> the cobblestones. This is because this is a through flow basin and I don't want the mulch to float away before the grass seeds sprout

The next morning Silver City received 1.6 inches of rain. Here is the diversion with water flowing. The rock work was not completed because I was waiting for the concrete to cure. Note how there is a diversion channel, a shallow fore-basin, and a deep water harvesting basin that overflows to the swale at top right of photo, before flowing over the curb to return to the street gutter.

20 days and several monsoon storms after construction. Note vigor of grass in upper right of photo where return flow jumps the curb to go back into the gutter. This surface protection prevents sediment from departing the project site.
Note also sandy sediment collected at beginning of diversion channel.
This can be shoveled out to maintain the capacity of the system.
We are cleaning the street of sediment as we harvest water!

Almost two months after construction, and many rainstorms later.
Native grass and wildflowers flourish.

IV	Revamping street drainage for water harvesting and flood control - Yankie Street right of way.

At this site my client was experiencing run-on coming onto her property from Yankie Street in Silver City. Water was flowing into a small side yard, damaging the foundation of a building, and flowing under the red gate in the photo below and into a concrete and tile patio. She had attempted to stop this with hay bales and bags of concrete. My first thought was to send the water to her upstream neighbor, who has an apple orchard. He was not interested in this, so after discussing many other options, and meeting with the streets department, who was very supportive of what we were trying to do, we came up with a plan.

There was not enough room between the driveable portion of the street right of way and the old property-line rock wall to build a system that would capture all the flow from this two acre urban sub-watershed. The design objective was to prevent erosion and property damage, capture as much water as feasible, and use this to grow native shrubs for beauty and habitat along the public right of way. The property owner had wanted to build a wall for the side yard for privacy and flood protection, but now it would be 4 feet inside her property line, allowing enough room for a water harvesting basin that would be partly on city property (with their full knowledge and approval) and planted with native shrubs to beautify the neighborhood. To prevent frost heave from the basin, the wall has a deep foundation and the cinder blocks were filled with concrete.

A rolling dip road drain was built on this dirt section of Yankie Street to direct all of the street runoff into the basin system. A first flush oxbow type basin was designed and built to catch the first runoff and then be bypassed by the overflow when filled. It is as deep as the space allows and lined with 18 inch boulders. The advantage of having an oxbow basin in this through-flow system is that the basin will retain its mulch. The inlet elevation is controlled with a stone rundown into the basin, and the outlet elevation is controlled by burying large flat stones flush with the bottom of the drainage channel downslope.

After: Cinder block wall built 4 feet inside property line and integrated into existing wall to create a private space for storage and a public space for oxbow water harvesting basin. Landform and path to new gate is now shaped uphill towards wall. To capture first flow, inlet of basin is 3" below high point in outlet channel. Planting shelf is two inches above this outlet elevation, and planted with native shrubs to beautify the public right of way.

Continuing down the north side of the property, there is a drainage channel with three connected shallow basins, all lined with small cobblestones to form a little streetside creek. Native shrubs are planted on the property line side of the channel. A "last chance" stone lined oxbow basin was installed within the property and integrated into the beginning of the city's concrete curb at the corner of Yankie and Cheyenne Street. This was built to sub-irrigate a very large Arizona Cypress on the northeast corner of the property.

After completion of the project, the public works director and the head of the streets department inspected the work and gave it their apporval. There have been two snowmelt runoff events since then. The critical elevations in the drainage plan were correct, and the basins filled, overflowing once. There was a bit of maintenance needed where an errant driver drove down the shallow water conveyance for 10 feet, messing up an inadequately compacted bank of the channel. This was fixed with a rake, and should become more compacted over time.

Looking up slope on Yankie Street, showing rolling dip road drain, and the layout of the water harvesting basins.


Stone lined oxbow basin is a "last chance" water harvesting feature, before the overflow from this system returns to the street gutter. Note how stones feather into concrete curb.

"First Chance" oxbow basin filled during runoff from an 8 inch snow on Dec 30, 2010. It was very cold for several days after that. This basin is on the north side of the property and shaded by the new wall. This photo, taken on January 12, reveals that the mulched basin had filled to capacity with melt water, then froze at the surface before percolating into the soil. Newly planted native trees and shrubs will do well this spring

V Eroding Driveway Between Houses, Cheyenne Street

Roof runoff from two houses and the neighbor's yard flowed down a dirt driveway, carrying water and sediment out to the street. My client didn't want a cistern in this narrow side yard, but wanted to grow herbs and shrubs here on the south side of the house. This area is shaded by the neighbor's house. My client wanted to park cars in her driveway, but allowed we could shorten the driveway to the minimum length for parking two cars. She wanted this smaller parking area to be gravel, because the soil turns to muck in the wet. Since the houses were less than 20 feet apart, having a deep and wide earth basin might endanger the foundation from frost heave in this mountain climate. Both buildings have very deep concrete foundations, so I built a very small and shallow basin that overflows under the new gravel driveway. The entire area drains to the basin, including an out-sloped gravel path. The entire area was mulched, as well, which will decrease the runoff coefficient. The homeowner intends to use the basin and surrounding beds as an herb garden in the spring and summer.

December 1, 2010 prior to construction.
Green spray paint lines mark the basin location.

December 1, 2010 during construction

February 2, 2011 the day after a 2" snowstorm. Due to constraints in the site and landowner preferences, the overflow, if any, will go under the gravel in the driveway to the street gutter, greatly diminished by the basin and sediment-free.

Stream Dynamics

Earthworks Institute Stormwater Harvesting Demonstration Project on the Arroyo Chamisos for the City of Santa Fe
by
Van Clothier and Steve Vrooman

Executive Summary

For Earthworks Institute and the City of Santa Fe, Van and Steve designed 11 urban stormwater retrofits to demonstrate a variety of techniques geared toward modulating the flood pulse and cleaning pollutants out of the water before it enters the receiving arroyos. These sites are all on City lands and were chosen for cost effectiveness, distance from at-risk infrastructure, and easy access for public viewing. Custom designs for water harvesting earthworks were produced for each site, taking a balanced account of many variables. This report details four of the sites that best illustrate the variety of problems solved. All photos are by Van Clothier unless otherwise noted.

These projects were constructed by the Earthworks Institute youth crew, with oversight and training from the project designers. Two sites required excavation with a backhoe to create shallow basins and swales. These were finished with hand labor. The other sites were treated exclusively with hand labor, including planting with native vegetation, and watering to insure survival. Interpretive signage was installed to educate the public about the benefits of this water harvesting strategy. Earthworks Institute has solicited neighborhood "adopt an arroyo" volunteers to monitor and maintain these sites.

Urban Watershed Reconnaissance

The selected sites are on both sides of Arroyo Chamisos, where neighborhood street runoff is delivered to the arroyo via culverts and concrete conveyance channels. After initial site visits, we looked at satellite photos of these neighborhoods and took a few measurements to get a good approximation of the percent of the area that is impervious to rainfall infiltration. Streets, sidewalks, driveways and rooftops represent close to 70% of the surface area of these urban sub-watersheds.

The next step was to measure the watershed area that drains to each culvert. To do this we patrolled the streets with a GPS and a builder's level looking for watershed divides. Most of the streets are crowned with a concrete gutter on each side. Each road junction was carefully examined to determine which way the gutters flowed, by using the level and by analyzing the flow tracks of leaves and other debris left by the most recent runoff event. In several places the micro-topography of the streets and gutters at intersections suggested that water would flow several ways during a runoff event. The best way to determine the watershed area in this case would be to walk the streets in the rain, which we were able to do for several sub-watersheds.

Design Runoff Calculations

Upon returning to the office, we put the GPS watershed divide points in a GIS map and calculated the area of each urban sub-watershed. The next step was to estimate the target temporary storage volume for water quality and channel protection from flooding. Since these two parameters are usually close to the same volume, we used the channel protection volume equation below:

$$V_t = P/12 * IC/100 * A * .6$$

Where: V_t = Target Storage Volume (acre feet)
P = 1-Year 24-hour storm depth (inches)
12 = Conversion factor (inches to feet)
IC = Impervious Cover (%)
A = Drainage area (acres)
0.6 = Pond routing factor

The above equation is from Urban Stormwater Retrofit Practices, by the Center for Watershed Protection.

The sites were then revisited to complete the designs. There were several limitations to the total detention volume for some sites: the size of basins that can be reasonably dug by hand, available area at each site for detention basins, slope, and areas to put the soil from the basins. Taking all of this into account, several sites will have less detention storage than the calculated target, yet considerably more than the present situation affords. The water harvesting from these sub-watersheds can still be improved by doing water harvesting curb cuts and other measures before the storm water runs down the culvert and out of town in the arroyo.

Project Reach -West Half

Project Reach - East Half

Urbanite Site Urban sub-watershed area: 3 acres

This site is named for the large amount of broken pieces of concrete (urbanite) littering the immediate vicinity. Urbanite is a good substitute for stone building material, being free and locally available. Stormwater arrives in a one foot diameter concrete culvert and proceeds through a narrow 1-3 foot deep gully for 93 feet to the arroyo. Some well meaning individual had built up a berm out of urbanite right at the end of the culvert, which may have caused the culvert to plug one day.

The treatment was to remove the blockage in front of the culvert and dig a fore-basin here instead. This will serve to dissipate energy, and also function as a sediment and trash trap. The long swale was broken into a series of ponds, using large chunks of urbanite to control the grade. A sledgehammer was used to custom cut the large unmovable chunks into manageable pieces for use in building pour-overs for the interconnected ponds. Upstream of each grade control, the swale was widened with hand shovel work, placing the material upstream of the grade control structures. The fill was compacted and then topped with cobble sized urbanite stones to provide surface protection.

This design greatly increased the storm surge volume of the swale by deepening and widening it, and converting it to a series of shallow basins. The tail end of the swale has a constructed Zuni Bowl (rock lined water harvesting basin) which overflows over the vegetated bank of the Arroyo Chamisos. The swale portions between the shallow ponds were sloped at between 2-4%.

Urbanite site, showing culvert outlet and fore-basin. Photo by Kina Murphy.

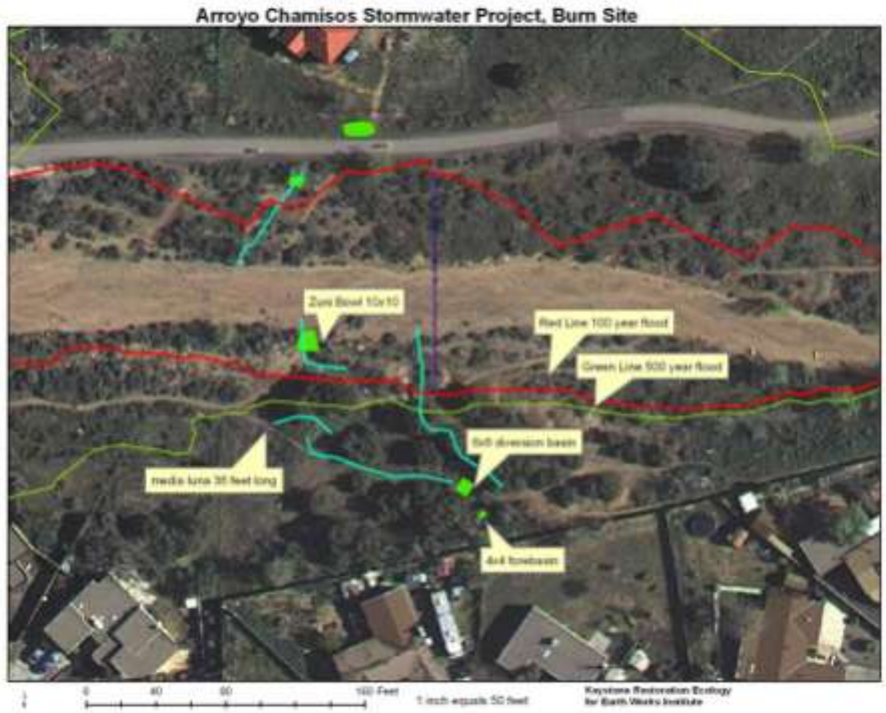
Urbanite was arranged to create an outdoor seating area adjacent to the basin, converting a brown fields area to a pocket park for the community.

Looking upstream. Overflow from fore-basin goes through two sequences of swale and basin before it is released to the Arroyo Chamisos.

Last chance to harvest water before the arroyo: Overflow from Urbanite site must fill a Zuni Bowl with a very porous sand bottom and flow over the bank of Arroyo Chamisos to enter the arroyo as surface flow. While this is happening, the arroyo itself will be flowing at bankfull, so the confluence will not have an erosive drop off.

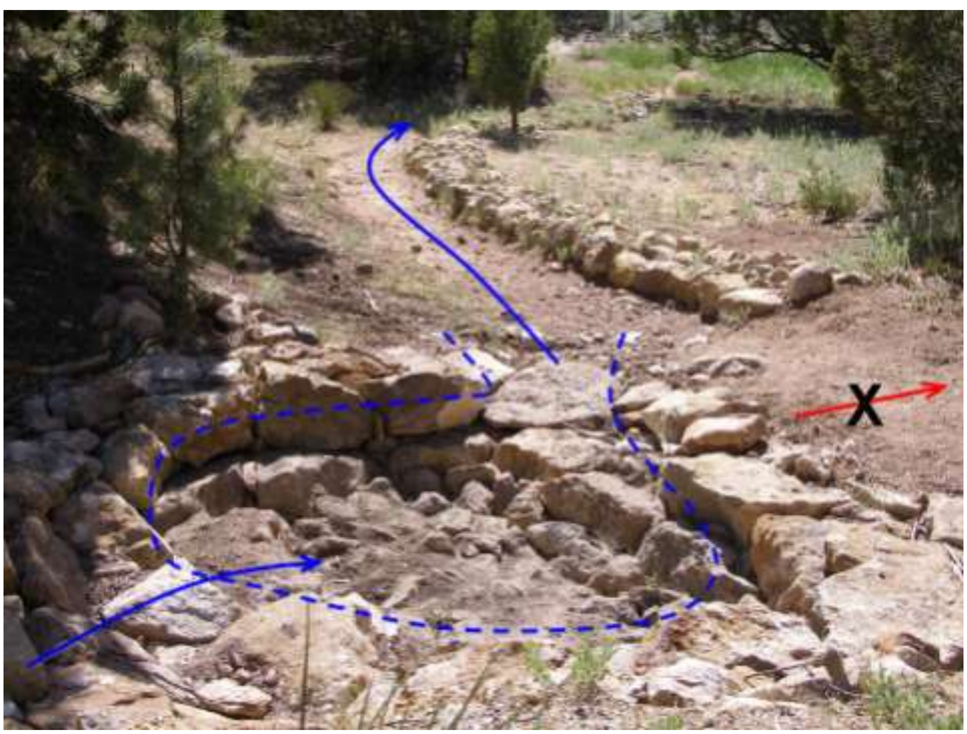
Burn Site Urban sub-watershed area: 1 acre

Before treatment, stormwater from this sub-watershed arrived as open channel flow and went down a steep, incised, and eroding channel for 116 feet, going straight down slope, and over several headcutting terrace drops on its way to the arroyo. It looks like a neighborhood resident had built some one rock dams in the channel above the drop offs, raising the grade. High flows could jump the channel and go down an overflow channel that heads diagonally down the high terrace and fans out in the vicinity of a recent burn where junipers were killed by a fire. This area has abundant plant growth, including a thicket of Golden Currant, *Ribes aureum*. This suggested an easy way to optimize water harvesting at this site: to direct <u>all</u> of the flow towards the burn site, where the vegetation is very thick, and the permeability is very high.



Burn site. Digging the fore-basin.

Completed fore-basin



The next basin is this Diversion Basin. The gully down the steep bank is blocked, and water now takes a longer, wider, flatter path. Large flows can overbank the curved stone channel bank to the right of the blue arrow and irrigate the land in the upper right of the photo. Base flows continue down channel to Media Luna.

Immediately after construction, showing a rock Media Luna (Spanish for half moon).
It is a cobble mulch placed on contour to maximize the spreading of water.

Burn site after several runoff events. Note increased vigor of grass.

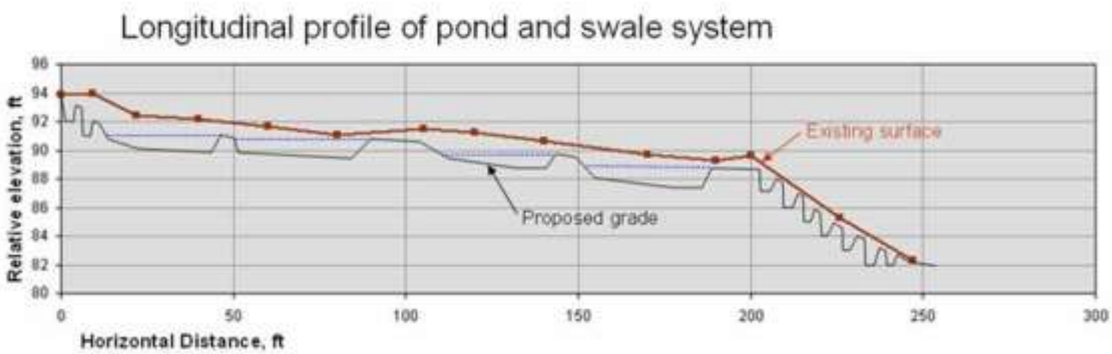
Since there is very little sediment in this impermeable urban sub-watershed, and our swales will quickly become well vegetated, we didn't have to design a system to route sediment. This is true for all of the sites in this pilot project. The small amount of sediment that will arrive from the culvert over time will be sequestered in an alluvial fan created by the Media Luna at the Burn site.

Bosque Site #1 Urban Sub-watershed area: 5 acres

Stormwater from this five acre urban sub-watershed went down an open asphalt channel, then a shallow gully before dropping over the edge of an 8 foot terrace cut bank into the arroyo where it was eroding at the base of a large Siberian elm. This open channel was diverted by the project down a wide swath on the high terrace of the Arroyo Chamisos to a series of ponds and swales before being stepped down over the edge of the terrace to the receiving arroyo with a series of rock lined step pools.

This site features a diversion berm that directs storm water along a new flow path. The first basin is a small cleanable fore-basin to collect any sediment and trash prior to entering the system of ponds and swales. Stormwater then flows into a two pool step-pool system to drop the grade of the channel to the elevation of the terrace. Thereafter, three long shallow ponds snake along the terrace for 150 feet, separated by short stone and earth swales that keep the water level in the ponds at the desired depth during a runoff event One pond is kidney shaped, and the layout goes around large beautiful Chamisa bushes, etc. in order to preserve the existing vegetation as much as possible.

At the end of the water harvesting earthworks on the terrace, there is a designed low water crossing for the emergency fire road which runs along the edge of the terrace, then a series of seven step pools to dissipate energy as the overflow is dropped 8 feet down to the left bank of Arroyo de los Chamisos. The ponds and swales were dug with a backhoe, and the finish smoothing and rock work was done by human labor. During construction, many plants were saved and replanted around the new basins. The spoils from digging the ponds were used to fill in the old gully, build the diversion berm, and eliminate a troublesome dip in the fire road at this juncture. All disturbed areas were raked, seeded, mulched and planted with native xeriscaping. The project budget included providing irrigation for all the plantings to insure survival and rapid growth so that the site will quickly achieve full demonstration potential. This site was surveyed with a GPS and laser level. The graph below shows the swale alignment in longitudinal profile:



Bosque site #1 Longitudinal profile of original surface in red, with new grades for the stormwater basin and swale system in grey.

Bosque site 1, two days after construction.
Everything worked out pretty well, including the rainbow!

Bellamah Site #1 Urban Sub-watershed area: 2.5 acres

Stormwater from a 2.5 acre urban sub-watershed went down a 12 foot wide concrete channel and poured over the brink of this channel into the arroyo. This site was ideal for an oxbow basin, with a very flat non-vegetated area adjacent to the concrete channel.

The basin was designed with a shoreline that is higher than the curb of the channel. This was easy because the ground level around the concrete channel was ½ foot higher than the curb of the channel. Because of this, no water could ever leave the pond except through the inlet. A curb cut was made to let water into the oxbow basin. Still, a diversion berm was needed to shunt the water towards the inlet. Originally envisioned as a concrete berm, this was made more easily by bolting a low (2") plastic speed bump to the concrete, aligned diagonally across the wide concrete channel. This insures that sufficient stormwater will flow into the oxbow basin without significantly decreasing the existing channel capacity.

Stormwater first fills the basin, then bypasses the basin and continues along the originally designed stormwater system. This oxbow design feature could be used in yards in the city as well, as no outlet is needed and the system is very simple. The first flush of pollutants in the watershed will always be caught in the pond, and clean water will flow past into the channel of the arroyo. During a runoff event, the basin will be continuously topped off to maximize water harvesting volume.

A backhoe was used to dig this basin. The finishing work and planting will be done by hand. The backhoe entered off Bellamah Street, and drove down the 12 foot wide channel between two houses. The dirt from the pond was placed against the toe of a steep hill behind a house. This was banked to a 4:1 slope (much less steep than before), raked and seeded with native grass seed.

Mapping the urban sub-watershed.

Flat bottom concrete drainage channel was originally designed to send any storm water quickly to Arroyo Chamisos.

After oxbow basin was excavated, but before curb was cut.

Plastic speed bump was bolted to the drainage channel diagonally to capture all of the base flow, yet allow peak flow to bypass the diversion. Photo by Steve Vrooman.

Look at all this fabulous water! Basin is very sandy and has a high percolation rate. All the water from the monsoon storms soaked into the ground within 24 hours. This site still needs to have trees planted. Photo by Steve Vrooman.