NOTICE OF PUBLIC MEETING & AGENDA

UPPER VERDE RIVER WATERSHED PROTECTION COALITION BOARD MEETING

Wednesday, January 25, 2012 - 2:00 p.m.
City of Prescott City Hall, Council Chambers
201 South Cortez Street - Prescott, Arizona

ITEM NO 1. **Introductions, Awards, or Presentations**

ITEM NO 2. **Communications**

ITEM NO 3. **Call to Public**

Consideration and discussion of general unscheduled comments from the public: Those wishing to address the Coalition need not request permission in advance. Any such remarks shall be addressed to the Coalition as a whole and not to any member thereof. Such remarks shall be limited to three (3) minutes unless additional time is granted by the Chair.

At the conclusion of the unscheduled comments, individual members of the Coalition may respond to the item addressed at the discretion of the Chair, or they may ask Staff to review the matter or ask that the matter be placed on a future agenda.

ITEM NO 4. **Discussion & Possible Action - Approval of Board Meeting Minutes – September 28, 2011**

ITEM NO 5. **Discussion - TAC Meeting Summary for October 12, 2011, December 7, 2011, and January 4, 2012**

ITEM NO 6. **Discussion & Possible Action – Budget Update and FY 2012/2013 Dues**

ITEM NO 7. **Discussion – Grant Update**

ITEM NO 8. **Discussion & Possible Action – Potential Projects**

ITEM NO 9. **Discussion – Montgomery & Associates White Paper Summary and Talking Points**

ITEM NO 10. **Discussion & Possible Action - Next Meeting Time / Location / Agenda Items**

ITEM NO 11. **Adjourn Meeting**

AGENDA ITEM NO. 1
INTRODUCTIONS, AWARDS, OR PRESENTATIONS

- New Board Chair to recognize Mary Ann Suttles
- Welcome Steve Blair
- Past Project WET recipients to present projects the grants helped fund
  - Gail Pereira
  - Lynda Zanolli

AGENDA ITEM NO. 2
COMMUNICATIONS

Opportunity for Board members to communicate member updates

AGENDA ITEM NO. 4
DISCUSSION & POSSIBLE ACTION - APPROVAL OF BOARD MEETING MINUTES
SEPTEMBER 28, 2011

Approval of minutes for the previous Regular Board Meeting held on September 28, 2011.

AGENDA ITEM NO. 5
DISCUSSION - TAC MEETING SUMMARY FOR OCTOBER 12, 2011, DECEMBER 7, 2011, AND JANUARY 4, 2012

Brief summary of TAC Meetings.

AGENDA ITEM NO. 6
DISCUSSION & POSSIBLE ACTION – BUDGET UPDATE AND FY 2012/2013 DUES

Review current budget

- Review potential FY2012/2013 dues
- TAC Recommendation

AGENDA ITEM NO. 7
DISCUSSION – GRANT UPDATE

Discuss grant pursuits for current fiscal year

- National Science Foundation
- NRCS partnering discussion
- Private Foundations

AGENDA ITEM NO. 8
DISCUSSION & POSSIBLE ACTION - POTENTIAL PROJECTS

Review potential projects and proposal to implement Old Home Manor

- Project background
- Scale down strategy and proposed project implementation
  - Budget
  - Bidding
  - Procurement
  - Schedule

AGENDA ITEM NO. 9
DISCUSSION – MONTGOMERY & ASSOCIATES WHITE PAPER SUMMARY AND TALKING POINTS

Discuss white paper prepared by Montgomery & Associates

- Discussion – Mountain Front Recharge/Mountain Block Recharge
- Review Summary Points
- Future Actions

AGENDA ITEM NO. 10
DISCUSSION & POSSIBLE ACTION - NEXT MEETING TIME / LOCATION / AGENDA ITEMS

Board Meeting
The next regularly scheduled Board Meeting is on **March 28, 2012 at 2:00 p.m**. at the City of Prescott City Hall, Council Chambers, 201 South Cortez Street, Prescott, Arizona.

TAC Meetings

The next **TAC meeting will be Wednesday, February 1, 2012 at 1:00 p.m**. The meeting will be held at the City of Prescott City Hall, City Manager's Conference Room, 201 South Cortez Street, Prescott, Arizona.

AGENDA ITEM NO. 11
ACTION – ADJOURN MEETING

Meeting to be adjourned

UPPER VERDE RIVER WATERSHED PROTECTION COALITION
BOARD MEETING

A MEETING OF THE UPPER VERDE RIVER WATERSHED PROTECTION COALITION WAS HELD ON SEPTEMBER 28, 2011 in PRESCOTT CITY HALL, 201 South Cortez Street, Prescott, Arizona.

Chairman Suttles called the meeting to order at 2:03 p.m.

ITEM NO 1. **Introductions, Awards, or Presentations**

Members Present:
President Ernie Jones, Yavapai-Prescott Indian Tribe
Vice Mayor Carl Tenney, Town of Chino Valley
Supervisor Carol Springer, Yavapai County Board of Supervisors
Councilwoman Suttles, City of Prescott, Chairman
Councilwoman Lora Lee Nye, Town of Prescott Valley

Members Absent:
None

Staff Present:
Ed Mucillo, Program Manager
Shawn Bradford, Business Development
Rick Shroads, Assistant Program Manager
Kim Webb, City of Prescott
Leslie Graser, City of Prescott
John Munderlow, Town of Prescott Valley
Don Tjiema, Councilman, Prescott Valley, Alternate to Councilwoman Nye

ITEM NO 2. **Communications**
None

ITEM NO 3. **Call to Public**
Consideration and discussion of general unscheduled comments from the public: Those wishing to address the Coalition need not request permission in advance. Any such remarks shall be addressed to the Coalition as a whole and not to any member thereof. Such remarks shall be limited to three (3) minutes unless additional time is granted by the Chair.

At the conclusion of the unscheduled comments, individual members of the Coalition may respond to the item addressed at the discretion of the Chair, or they may ask Staff to review the matter or ask that the matter be placed on a future agenda.

Supervisor Springer said Kim Webb was shadowing her that day for the Prescott Area Leadership group.

ITEM NO 4. Discussion & Possible Action - Approval of Board Meeting Minutes – July 27, 2011

SUPERVISOR SPRINGER MOVED TO APPROVE THE BOARD MEETING MINUTES OF JULY 27, 2011; SECONDED BY COUNCILWOMAN NYE; APPROVED UNANIMOUSLY.

ITEM NO 5. Discussion - TAC Meeting Summary for September 12, 2011

Mr. Bradford noted that the summary was in the packet and there was an item concerning program management on the agenda.

ITEM NO 6. Discussion - Water Audit Update

Mr. Bradford showed a Water Audit PowerPoint that included:

- Information of an internal water audit by the Coalition on the Coalition's larger turf areas.
- Based on 2007 Larson Report
- Technical Advisory Committee (TAC) developing formal water audit program
- Prescott had eight locations
- Prescott Valley had 17 locations
- Benchmarks use best management practices
- WaterSmart guidelines
- Report will include summary of each location
- Recommendations for improvements (if any)

Mr. Bradford said the Coalition was doing everything it could to be water wise. He noted that Prescott was very proactive with internal water auditors who were certified and went out on a quarterly basis to audit the City's facilities. He said Prescott Valley made some changes in 2010 that had drastically reduced their water usage. He noted that the final report would be ready at next board meeting.

Supervisor Springer asked who was doing the work. Mr. Bradford said Burgess & Niple was putting the information together. They got meter reading data from the communities and worked with the TAC members to see how large the turf facilities were. He said the WaterSmart Guidelines laid out what the water usage should be.

Supervisor Springer asked if they only audited areas where large turf. Mr. Bradford said the first draft focused on large turf facilities. Supervisor Springer asked if the golf course was included. Mr. Bradford said that he did not believe so. Mr. Munderlow said that it was not potable water, it was treated effluent. Supervisor Springer said she understood that, but did not know if it was included in the study.

Mr. Bradford said the TAC discussed offering water audits to the general public and partnering with schools and golf courses on their water audits. Chairman Suttles asked if their work was repetitious of what the City was doing with their internal audits. Mr. Bradford said yes. They were trying to confirm the findings and develop a template and a process that they could roll out to schools and golf courses.

Supervisor Springer said she had heard that 50% of the water used was for outdoor purposes. She asked if that was a valid number. She said that the more they tried to work toward things like water harvesting and if they could reduce the amount of treated waste, the better off they would be. She said if the goal was to come to safe yield, she saw it as two pronged: harvesting water and recharging the aquifer and the second would be conservation in terms of taking less out of the aquifer to begin with, so that harvesting would become a significant part of the conservation effort. She said she was trying to get a better handle on how they could measure it and how they could portray it to the public.

Mr. Bradford said there were industry standards that worked on return flown. What they looked at was the amount of water delivered in gallons and inflow into the waste water treatment plant. That would give them a good flow rate. He noted the regional influences, but 50% was a reasonable number.

Vice Mayor Tenney asked if the services extended to Chino valley. Mr. Bradford said that they tried to get data from all of the members, but it was not available for Chino Valley. He said that there may be an opportunity to go outside the member agencies with the audits.

Councilwoman Nye noted that one of the conservation savings efforts Prescott Valley did was to put the artificial turf on the soccer fields and Mountain Valley Park. She said they did not realize what a good decision they made, not only for water conservation, but other savings as well. Mr. Bradford said the key was in educating the general public.

Chairman Suttles asked how often they would do the audit. Mr. Bradford said they would look for direction from the TAC. He thought it should be done at the large turf facilities on an annual basis. He said it was a win/win, even for people with wells. He noted that they could save money by not having to run their pump as often. Councilwoman Nye noted that people did not usually think about the electrical costs associated with wells.

The Board agreed that the audits should be done once a year.

ITEM NO 7. Discussion & Possible Action - Coalition Program Management

Mr. Bradford said part of the original contract with Burgess & Niple included a three year term and two, one year options for renewal. He said the first option was due to be exercised November of 2010. He said they did not notice that they needed to make an official action at the board level to approve the extension of the contract. He asked if they would like to approve the second extension. He said they created the renewal in the form of a resolution that would extend the contract from 2011 to November of 2012. He said that as a part of their contract with the Coalition, they wanted to add Montgomery and Associates to their team for grant pursuits.

SUPERVISOR SPRINGER MOVED TO EXTEND THE PROGRAM MANAGEMENT CONTRACT WITH BURGESS & NIPLE FROM NOVEMBER 8, 2010 UNTIL NOVEMBER 8, 2011; SECONDED BY COUNCILWOMAN NYE; PASSED UNANIMOUSLY.

SUPERVISOR SPRINGER MOVED TO EXTEND THE PROGRAM MANAGEMENT CONTRACT WITH BURGESS & NIPLE FROM NOVEMBER 9, 2011 TO NOVEMBER 8, 2012; SECONDED BY CHAIRMAN SUTTLES; PASSED UNANIMOUSLY.

SUPERVISOR SPRINGER MOVED TO APPROVE THE ADDITION OF MONTGOMERY AND ASSOCIATES TO THE BURGESS & NIPLE TEAM FOR THE CONTRACT TERM OF NOVEMBER 8, 2011 TO NOVEMBER 8, 2012; SECONDED BY COUNCILWOMAN NYE; PASSED UNANIMOUSLY.

ITEM NO 8. Discussion & Possible Action - Grant Update

Mr. Bradford said that as part of their efforts to find funding, the National Science Foundation (NSF) was attractive because there was no match required. He noted that there was an opportunity with Mountain Front and Mountain Block Recharge. He said the idea of how much water hit the mountain and got into the aquifer was subjective and the information was not conclusive. He wanted to do some additional research and create some modifications to implement ground water recharge. He noted that NSF had a two phase process. He said they were pursuing the first phase which was around $200,000 - $300,000. This would allow them to take a survey of the research that had been completed on the subject and bring stakeholders together in workshops. He said they could work on an agreement towards the next phase. The second phase of NSF monies could be up to one million dollars a year, up to a five year period. He said that it was highly competitive and bringing on a firm like Montgomery would bring a scientific approach to the study.

He said they were in the process of completing a Phase I grant application. They would identify additional research and action upon the research for a Phase II grant. He said it would be easier to get the Phase II money after they had done the work with Phase I.

Supervisor Springer asked where they were going to do the study. She said that the only area that came to mind was Big Chino.

Mr. Bradford said the goal was to do it in the region. The key component to the NSF grant was that the science that would be developed needed to be applicable anywhere. Supervisor Springer said that anywhere in the area, the surface water flows that contributed to groundwater recharge was generally water that came off the mountain in some sort of stream and went underground to theoretically recharge the aquifer. She said that all of that water was claimed by Salt River Project (SRP). She asked them if this type of grant application would have to include an agreement by SRP to approve of the project. Mr. Bradford said there was a science that supported that some of the water that fell within the mountain block was recharged into the aquifer, through the mountain. They were looking to quantify what that was, not to argue the quantity. They would like to firm up the science.

Supervisor Springer asked if he was saying that they did not need the approval from SRP. Mr. Bradford said that Phase I was a simple review of the literature and science that had been done to date and then identify an opportunity to develop a new approach to identify Mountain Block and how much it was.

Supervisor Springer asked where they would do the study. She said the mountains around Big Chino would be a logical place to do it, as opposed to some of the mountains around Prescott, where there were two different groundwater situations. She noted that there was no deficit In Big Chino. The ground water that went in there was already safe yield. She said the Prescott Active Management Area was in a deficit situation. She noted that they were trying to compare apples to oranges.

Mr. Bradford said the goal was to identify an approach to quantify the amount of water that was recharged. He noted that Phase II would identify some specific sites.

Mr. Munderloh said they had to go through a scientific progression of thought if they got the grant. He said they could not predetermine where their Category II Project would be, until they went through the progression.

Supervisor Springer said the study was similar to the study done in the San Pedro area. She noted that they were trying to find out how much water went into the aquifer from the mountain discharge. She asked if anyone had looked at that study.

Mr. Munderloh said that the Coalitions process was different. They looked at what they did not know. He said that Montgomery and Associates helped them look at the body of knowledge about Mountain Front and Mountain Recharge. He said that everyone tried to quantify that number. He noted that, to date, it was still a number that was developed as the derivative of everything else known. He said they assume that the unknown quantity at the end of their budget was recharge. No one really understood the process. He noted that it had never been approached scientifically. They wanted to look at it in a new light and present in to the NSF.

Supervisor Springer said if they were looking at a theory that would apply everywhere, the results would depend on the age of the body under the surface at that point of recharge. She asked if the results would be deeper if it was an older element, than from a newer geological formation where it did not have the depth.

Mr. Munderloh said that would have some impact but the primary impact would be around the root zone and above. He said what they knew was that 98% of the water received from precipitation was lost via evaporation and transpiration. He said those processes occurred at the surface of the ground or in the root zone. He noted that they had to be broad minded in their approach. He said that was where they had to focus the studies. If they could get the water past the root zone, before it evaporated, it would have a chance to move to the aquifer.

Mr. Bradford said the results would be different in different regions of the country. He said the approach they took to quantify the information would be universal. He noted that there would be many differing variables in different areas of the country.

Supervisor Springer said that it sound like an interesting study. She asked who else had studied it and what their results were.

Mr. Munderloh said it would be part of the process to do literature reviews. He said it had not been approached this way. He noted that the approaches, thus far, were to create more run off, which was a different process than how to create more recharge in the watershed.

He said they may look into the restoration of a plant species that was there prior to another species. He noted that non native plants may take water weeks earlier than native plants and the weeks may be critical to induce recharge. He noted that native plants may shorten growing periods.

Councilwoman Nye said that the potential body of knowledge they may gain from the studies was very exciting and they did not know how they may use the information in the future.

Chairman Suttles asked Mr. Bradford when they would know if the grant was awarded. Mr. Bradford said he thought it would be early 2012. He said that Phase I could lead to a dead end, but he did not think so. He wanted to have the information behind them for Phase II.

Chairman Suttles asked how many other groups applied for the grant. Mr. Bradford said that a lot of colleges went after that money. Supervisor Springer said that part of their Macro Water Harvesting Program was convincing the public that 98% of the water was lost through transpiration and evaporation.

ITEM NO 9. Discussion & Possible Action - Appointment of New Board Chairperson

Chairman Suttles said her last day in Council would be the day before the next meeting. She would try to find out who would take her place on the Board.

SUPERVISOR SPRINGER NOMINATED COUNCILWOMAN NYE AS CHAIRMAN OF THE BOARD; SECONDED BY CHAIRMAN SUTTLES; PASSED UNANIMOUSLY.

Councilwoman Nye noted that it might be her last tem of office and she was happy to put a lot of energy towards water issues.

ITEM NO 10. Discussion & Possible Action - Next Meeting Time / Location / Agenda Items

Mr. Bradford said the next regularly scheduled meeting would be Wednesday, November 23, 2011, which was the Wednesday before Thanksgiving. Supervisor Springer asked what action they would have to take at that meeting. Mr. Bradford said there would not be anything that they had to do. Supervisor Springer said she would rather cancel the meeting. Councilwoman Nye agreed.

Mr. Bradford said January would be the next meeting. He noted that the only thing on the schedule was a presentation from the Project Wet teachers, which could be moved to January. All members agreed to meet on January 25, 2012.

ITEM NO 11. Adjourn Meeting

The meeting adjourned at 2:59 p.m.

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Councilwoman Lora Lee Nye, Chairman

ATTEST:

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Kim Webb, Assistant Clerk

TAC Meeting – 12:00 p.m.

Attendees:

TAC Members: John Munderloh, Leslie Graser

Program Management Team: Shawn Bradford, Rick Shroads

- **Meeting called to order at 12:10 p.m.**

- **A quorum of TAC members was not in attendance. Meeting adjourned at 12:11 p.m.**

- **Next Meeting Time / Location / Agenda Items**
  - The next TAC meeting will be on Wednesday, November 9, 2011 at 1:00 p.m. at the Town of Prescott Valley, Community Room # 331; 7501 E. Civic Circle – Prescott Valley, Arizona
  - The next Board meeting is Wednesday January 25, 2012 at 2:00 p.m. at City of Prescott Council Chambers, 201 S. Cortez Street – Prescott, Arizona

UPPER VERDE RIVER WATERSHED PROTECTION COALITION
TECHNICAL ADVISORY COMMITTEE (TAC) MEETING

Wednesday, December 7, 2011 - 1:00 p.m.
Town of Prescott Valley, Community Room # 331
7501 E. Civic Circle - Prescott Valley, Arizona

TAC Meeting – 1:00 p.m.

Attendees:

TAC Members:	John Munderloh, Peter Bourgois, John Rasmussen
Program Management Team:	Ed Muccillo, Rick Shroads, Dana Biscan,
Guests:	Shaun Rydell

- **Meeting called to order at 1:02 p.m.**

- **Capital Projects**
  - Discussion and review of projects considered by UVRWPC for implementation, including Old Home Manor, Longview Ranch, Viewpoint Park, and rainwater harvesting at APS's solar facility
  - John and Shaun support Old Home Manor. It has been assessed and previously discussed with the Board and received their approval
  - Peter supports implementing more than one project to test multiple methods and to take a research oriented approach
  - Group decided a project will likely have to move forward without grant funding. It seems unlikely any of the projects will receive an award in the near future.
  - The TAC noted that the goal is not necessarily to construct a large project, but even a pilot site to show these methods can be implemented successfully
  - Longview ties back to some of the principles discussed in the M&A white paper. This project could be scaled back to have fewer areas (five currently proposed) or less expensive surface treatments.
  - The solar facility typically lacked support. UVRWPC never heard from APS regarding constructing a project on their site.
  - Suggest matrix development for the next TAC meeting to review likely costs and other pertinent project factors.

- **Water Conservation Program**
  - Shaun Rydell presented proposed WaterSmart projects and associated budgets. The TAC voted and approved providing funding to these endeavors.
  - John would like to make the WaterSmart materials more assessable and useful to those at lower elevations. Shaun said she could make her workbook more printer-friendly for download.
  - John mentioned the septic/well/irrigation educational materials. No action was proposed.

- Shaun to check the rights for the Anwall book so Prescott Valley can add it to their website.
- Dana to follow up with Edyssa regarding the status of her program. She had asked for posters, as did Shaun. Need to make sure not fulfilling the same request twice.
- UVRWPC/SRP letter was submitted.

- **Grant Pursuits**
  - National Science Foundation Grant application was submitted
  - Melody to look for potential fit with Department of Energy Grants
  - Melody is looking for eligible private grants. Nothing to date, but should review NRCS.

- **Recharge Literature Review**
  - Dana to add paragraph to talking points regarding finding on lack of research in the fields of Mountain Front and Mountain Block recharge and groundwater recharge.
  - Revised points will be presented at January TAC meeting. If approved, they will be provided to the board with the M&A white paper at the January Board meeting.

- **Media Outreach Efforts**
  - Should start developing a "bank" of releases for use when necessary/appropriate
    - Bring ideas for generating a bank to January's meeting
  - Will issue a release for project once underway

- **Budget Update**
  - Reviewed budget
  - Need to update to reflect potential changes – Chino paying no dues and a reduction in the conservation and management budgets.
  - Need to decide what dues will be next year at the January TAC
  - NO ACTION - $10,500 APPROVED BY PROGRAM MANAGER

- **January Board Meeting**
  - New Board Chair to recognize Mary Ann Suttles
  - Update on NSF grant
  - Water Audit report
  - Presentations from past Grant Award recipients
  - Welcome Steve Blair
  - Water Conservation Update - Shaun and Ed (in March)
  - White Paper summary and talking points
  - Potential projects

- **Public Comment**
  - None

- **Next Meeting Time / Location / Agenda Items**
  - The next TAC meeting will be on Wednesday, January 4, 2012 at 1:00 p.m. at the Town of Prescott Valley, Community Room # 331; 7501 E. Civic Circle – Prescott Valley, Arizona.
  - The next Board meeting is Wednesday, January 25, 2012 at 2:00 p.m. at City of Prescott Council Chambers, 201 S. Cortez Street – Prescott, Arizona.
  - TAC approved rescheduling meetings to the first Wednesday of the month.

UPPER VERDE RIVER WATERSHED PROTECTION COALITION
TECHNICAL ADVISORY COMMITTEE (TAC) MEETING

Wednesday, January 4, 2012 - 1:00 p.m.
Town of Prescott Valley, Community Room # 331
7501 E. Civic Circle - Prescott Valley, Arizona

TAC Meeting – 1:00 p.m.

Attendees:

TAC Members:	John Munderloh, John Rasmussen
Program Management Team:	Ed Muccillo, Rick Shroads, Dana Biscan
Guests:	John Zambrano

- **Meeting called to order at 1:02 p.m.**

- **A quorum of TAC members was not in attendance. Meeting adjourned at 1:11 p.m.**

- **Next Meeting Time / Location / Agenda Items**
  - The next TAC meeting will be on Wednesday, February 1, 2012 at 1:00 p.m. at the Town of Prescott Valley, Community Room # 331; 7501 E. Civic Circle – Prescott Valley, Arizona
  - The next Board meeting is Wednesday January 25, 2012 at 2:00 p.m. at City of Prescott Council Chambers, 201 S. Cortez Street – Prescott, Arizona

UPPER VERDE RIVER WATERSHED PROTECTION COALITION
BUDGET PROJECTION
January 3, 2012

	Actual	Actual	Actual	Actual	Through 11/20/2011	Projected (Dues Reduced 20% and No Chino Valley)	Projected (No Chino Valley)	Projected (Continue Dues Reduction of 20% and No Chino Valley)
	FY 2007/2008	FY 2008/2009	FY 2009/2010	FY 2010/2011	FY 2011/2012	FY 2011/2012	FY 2012/2013	FY 2012/2013
Beginning Fund Balance *	**$ -**	**$ 89,594**	**$ 178,222**	**$ 94,128**	**$ 153,398**	**$ 153,398**	**$ 17,798**	**$ 17,798**
Revenues								
Coalition Member Contributions **	$ 201,500	$ 201,500	$ 175,500	$ 202,167	$ 140,400	$ 140,400	$ 175,500	$ 140,400
Grant Receipts	$ -	$ 2,950	$ 12,307	$ -				
Other Revenues	$ -	$ -	$ -	$ -	$ -			
Total Revenues	**$ 201,500**	**$ 204,450**	**$ 187,807**	**$ 202,167**	**$ 140,400**	**$ 140,400**	**$ 175,500**	**$ 140,400**
Expenditures								
Tasks								
Task 1 - Program Management & Grant Research/Application (Ongoing)	$ 53,146	$ 83,601	$ 138,270	$ 100,838	$ 73,431	$ 115,000	$ 110,000	$ 110,000
Task 2 - Website Management (Ongoing)	$ 691	$ 2,450	$ 1,723	$ 181	$ -	$ 1,000	$ 1,000	$ 1,000
Task 3A - Water Conservation Program Development (Complete)	$ 35,894	$ 14,256	$ -	$ -	$ -			
Task 3B - Water Conservation Implementation (Ongoing)	$ -	$ -	$ 84,568	$ 41,878	$ 12,302	$ 35,000	$ 30,000	$ 30,000
Task 4 - Hydrologic Monitoring (Complete)	$ 14,000	$ 2,430	$ -	$ -	$ -			
Task 5A - Recharge Mapping (Complete)	$ 8,175	$ 13,085	$ -	$ -	$ -			
Task 5B - Recharge & Source Capture Pilot Projects Study/Design (Complete)	$ -	$ -	$ 47,340	$ -	$ -			
Capital Improvement Projects								
Recharge & Source Capture Pilot Project						$ 125,000		
Future Capital Improvement Project					$ -		$ 10,000	$ 10,000
Total Expenditures	**$ 111,906**	**$ 115,822**	**$ 271,901**	**$ 142,897**	**$ 85,733**	**$ 276,000**	**$ 151,000**	**$ 151,000**
Excess of Revenues Over Expenditures	$ 89,594	$ 88,628	$ (84,094)	$ 59,270	$ 54,667	$ (135,600)	$ 24,500	$ (10,600)
Ending Balance	**$ 89,594**	**$ 178,222**	**$ 94,128**	**$ 153,398**	**$ 208,065**	**$ 17,798**	**$ 42,298**	**$ 7,198**

* Fiscal Year Begins July 1 and ends June 30

** Coalition Member Contribution include Chino Valley Deferment Agreement

Montgomery & Associates
MOUNTAIN FRONT RECHARGE LITERATURE REVIEW IN SUPPORT OF UPPER VERDE RIVER WATERSHED PROTECTION COALITION APPLICATION
White Paper Review

The purpose of the white paper was to review existing research in the field of groundwater recharge to identify the current areas of knowledge and identify under investigated topics. The white paper focuses on mountain front recharge and mountain block recharge. This information is anticipated to help the Coalition prepare future applications to various public and private funding entities. This white paper formed the premise of the National Science Foundation (NSF) application.

The paper found that recharge in mountainous regions can be a significant portion of total recharge in semi-arid environments. Despite the relative importance of mountain recharge to the water balance in semi-arid regions, many of the processes that cause recharge on and near mountains remain poorly understood. The paper discussed these processes, as well as potential areas of research for each. They include:

- Precipitation
- Runoff
- Recharge
- Evapotranspiration (ET)

In general, there is a lack of research regarding Mountain Front and Mountain Block Recharge in semi-arid regions. In particular, research areas of interest presented in the paper include:

- How do tree canopies affect the relationship between ET and precipitation? Recharge? If this information was available, could recharge be increased through land management while still supporting wildlife?
- How long does it take for different plants to adapt to hydrologic changes? How does the timeframe, together with predicted changes in weather patterns, influence the future water balance in semi-arid watersheds?
- Can communities be designed to include plant communities that provide an optimal balance of habitat, efficient water use, and soil stability in semi-arid environments?

NSF Water, Sustainability and Climate (WSC) grants are available in three categories.

- Category 1 grants are for workshop-planning level projects. Typical awards for these grants range from $75,000 - $150,000.
- Category 2 grants are for observatories and modeling projects. In 2010, award amounts averaged $3.8 million.
- Category 3 grants are for modeling. In 2010, award amounts averaged $867,000.

Potential recommended NSF WSC application topics:

- Category 1 proposal to hold a workshop to draw experts to the region with the goal of generating their interest in developing future, site specific research projects.
- Category 2 proposal that makes use of existing hydrologic and economic analysis to prioritize data collection.

Note that all past NSF grants under the NSF WSC Program, which started one year ago, were awarded to universities.

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TUCSON PHOENIX SANTIAGO DE CHILE

August 15, 2011

MOUNTAIN FRONT RECHARGE LITERATURE REVIEW IN SUPPORT OF UPPER VERDE RIVER WATERSHED PROTECTION COALITION APPLICATION FOR NSF GRANT NSF 11-551

The purpose of this review is to define briefly and concisely the current state-of-the-art in research on recharge in semi-arid mountainous regions. In particular, we will define the commonly used terms: mountain front recharge and mountain block recharge. We will place these processes in a common context of basin-scale evaporation/runoff/infiltration processes. Finally, we will attempt to identify outstanding questions that could provide useful information for improved understanding and management of water resources in semi-arid environments.

Recharge in mountainous regions can be a significant portion of total recharge in semi-arid environments. Despite the relative importance of mountain recharge to the water balance in semi-arid regions, many of the processes that cause recharge on and near mountains remain poorly understood. Wilson and Guan (2004) provided an overview of recharge in mountainous regions. They use the term mountain front recharge (MFR) and suggest that it is made up of four components: near surface diffuse recharge; near surface focused recharge; subsurface diffuse recharge; and subsurface focused recharge. In their review, the term focused refers to infiltration and percolation into local high permeability regions, such as coarse-grained units and fractures. Diffuse recharge occurs through the matrix at some distance from these high permeability units. The two subsurface components of MFR are considered mountain block recharge (MBR). Since the publication of their paper, many scientists have conducted additional research in this area (see the reference list for a subset of these published studies in refereed journals). In this review, we summarize some of the more relevant findings of the research that has taken place since the publication of Wilson and Guan (2004).

Clear understanding of the importance of MFR/MBR to the water balance of a specific watershed depends on placing these processes in an appropriate local hydrologic context. Figure 1 (Aishlin and McNamara, 2011) provides a useful general image to guide this understanding. Typically, for water balance studies a hydrologic system is reduced to a partitioning of rainfall and snowmelt into evaporation, transpiration, infiltration, and runoff. However, these definitions can lead to some confusion because runoff may infiltrate at some location farther down slope. Similarly, infiltrated water, especially high-altitude infiltration, may resurface as springs; this water may then infiltrate farther down slope. To avoid some of these ambiguities, we use the term "infiltration" to refer to percolation beneath the root zone and beneath confining layers that form springs. That is, we consider infiltration to represent water that will, eventually, become recharge via exclusively subsurface flowpaths. In their review, Wilson and Guan (2004) paid particular attention to relatively fast and slow subsurface flowpaths. While this is important for understanding the dynamics of a hydrologic system, it is less important for understanding and for managing water resources. Therefore, we adopt slightly different definitions of MFR and MBR than suggested by Wilson and Guan (2004). Specifically, we propose that MBR refers to infiltration in mountainous regions at or near the location of precipitation or snowmelt; MFR is largely the product of runoff from the mountains that collects in more permeable regions near the base of the mountains. Because this definition is based on the location of infiltration, it provides a more direct link between hydrologic processes and management activities aimed at quantifying and modifying recharge rates.

The detailed sections of this report discuss five components of the water cycle that control the local water budget: precipitation; evaporation; transpiration; runoff (surface redistribution); and infiltration. For each section, we present the current state of knowledge, with particular emphasis on gaps in current knowledge that warrant research. Several common themes emerge: uncertainties regarding rates and, in particular, spatial variation in rates; development of technologies and approaches to measure fluxes; and methods to understand and quantify hydrologic processes based on more readily-measured states, fluxes, and properties. At the end of each section we provide several possible hypotheses that could be incorporated into an NSF coordinated science proposal or an NSF workshop proposal.

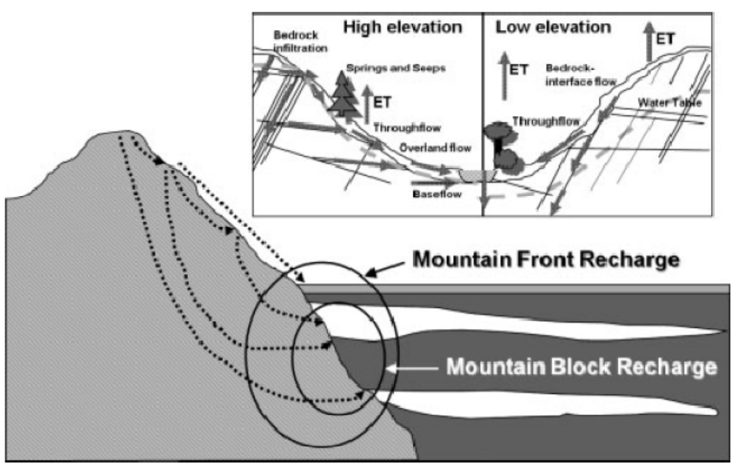

Figure 1. Conceptual diagram for MFR and MBR. Insert diagram depicts upland subcatchment routing of precipitation that may include discharge of groundwater to streamflow and subsequent streamflow loss to groundwater recharge via channel seepage

PRECIPITATION

Precipitation is a key hydrologic variable because it sets the upper limit of recharge to a mountain system. Recharge is often inferred as a residual in a water balance relationship (the difference between precipitation and the sum of evapotranspiration and runoff). As a result, uncertainties in precipitation estimates translate directly to uncertainties in recharge rates. Even in regions with relatively dense ground-based precipitation networks, differences in interpretations of precipitation patterns can lead to significant differences in hydrologic response (e.g. Tetzlaff and Uhlenbrook, 2005). While there have been major advances in technologies and methods to infer precipitation, rain gauges remain the gold standard for local precipitation measurement (Strangeways, 2007). Even over relatively flat landscapes and oceans, rainfall estimation algorithms can differ in their predictions by over 50 percent.

In many semi-arid watersheds, precipitation is largely limited to mountainous regions. Unfortunately, precipitation measurements are even more difficult mountainous regions, in particular in regions that experience localized, convective storms. For example, the most widely used precipitation model in the United States is PRISM (Daly et al., 1994). In *Guidelines For Assessing the Suitability of Spatial Climate Data Sets* (2006), Daly suggests that "regions having significant terrain features, and also significant coastal effects, rain shadows, or cold air drainage and inversions are best handled by sophisticated systems that are configured and evaluated by experienced climatologists. There is no one satisfactory method for quantitatively estimating errors in spatial climate data sets, because the field that is being estimated is unknown between data points." Smith and Barstad (2004) developed a new model to describe orographic precipitation. Their model considers air flow dynamics, condensed water advection, downslope evaporation, and complex terrain. The model was tested against three densely instrumented field sites (Barstad and Smith, 2005). But, mountainous precipitation estimation remains a challenging and active area of research.

Although both rain and snow represent inputs to the water budget, they must be treated entirely differently. In particular, most rainfall is converted rapidly to infiltration or runoff. As a result, measurement of precipitation above the ground surface can be used to model the timing and rate of these processes. In contrast, after snow falls its distribution modified by wind and vegetation. Snow transport models are only as good as the meteorological data that drives them and are particularly affected by wind speed and wind direction inputs (Bernhardt et al., 2010). The distribution of vegetation also provides control on snow accumulation and ablation. For example, Brooks et al. (2008) studied the affects of vegetation distribution on snow accumulation and ablation in mountainous forest in northern New Mexico. Results showed that snow water equivalent accumulation was 47 percent lower under the tree canopy than in the surrounding areas. Additionally, areas north of trees had 25 percent greater snow depth than southern areas. The authors suggested that this research opens the door to improved modeling of snowpack using remotely sensed vegetation data.

The non-uniformity of a snowpack distribution leads to difficulty in estimating the snow water equivalent (SWE), which in many mountainous regions can represent a majority of the water supply, such as for the Phoenix metropolitan area (City of Phoenix website). SnowModel (Liston and Elder, 2006) modified and compiled four sub-models to represent "snow accumulation; blowing snow redistribution and sublimation; forest canopy interception, unloading, and sublimation; snow density evolution; and snowpack melt". SnowModel produced reasonable correlations between measured and modeled SWE (r^2=0.92-0.99) and snow depth (r^2=0.85-0.95) at both forested and non-forested sites. However, deficiencies were noted in the models ability to represent sublimation of canopy intercepted snow, distribution of vegetation within model cells, percent cloud cover, distribution of air temperature and precipitation, and sub-canopy solar radiation. Bernhardt et al. (2010) used SnowModel with downscaled MM5 wind fields as model inputs. They found that the overall performance of SnowModel improved when using MM5 wind fields and particularly noted improved modeling of the spatial distribution of water stored as snow.

Interception refers to precipitation that does not reach the land surface, but is instead held above the land surface until it evaporates or flows along the stems and trunk to the ground surface. This process adds an additional challenge in relating precipitation measured above the canopy to potential infiltration at the ground surface. Several studies have been conducted that demonstrate the potential importance of interception on the water budget and on plant water availability in semi-arid lands (e.g. Carlyle-Moses, 2004). Model results of Love et al. (2010) estimated that interception in a year with typical precipitation represented 28 and 34 percent precipitation in each of two semi-arid basins in Zimbabwe. Additionally, they noted that during the drier than average 2006/2007 season, interception accounted for 56 percent of precipitation averaged over the two basins. Until recently, interception has been difficult to measure. Friesen et al. (2008) developed a new non-destructive stem compression method for measuring interception. The method is based on Hooke's law of elasticity and assumes that a tree trunk is a linear elastic material. Using this principal and an assumed modulus of elasticity, a vertical displacement in the tree trunk length is directly relatable to the addition/reduction of mass in the canopy. While this novel method could be used to improve understanding of interception at the single-tree scale, it is unlikely to provide large scale measurements than are necessary for watershed scale analyses.

Uncertainties related to precipitation still represent a major source of uncertainty in watershed scale water balance studies. The following questions would be highly relevant to a study aimed at improving the understanding and quantification of recharge in a semi-arid region:

- What are the key spatial scales of resolution of precipitation to quantify the partitioning of rainfall into infiltration and runoff? How do these scales depend on the spatial correlation length scales of hydrologic properties and features, topography, and rainfall intensity? Can instrumentation and methods be devised to target these key measurement scales?

- Can the impacts of interception and vegetation induce snowpack modification be upscaled based on satellite imagery? If so, can these vegetation impacts be used to better relate rain and snow inputs to inputs to the subsurface hydrologic system? In particular, can these vegetation impacts improve our ability to predict the timing of snowmelt and the subsequent partitioning of snowmelt to recharge and runoff?

- Can localized zones of rapid recharge (natural or engineered) act as efficient sinks of runoff? If so, how should they be designed for optimal, long term operation and can we predict their environmental impacts throughout a watershed?

RUNOFF

Water that flows overland from the location of precipitation is considered runoff. It is likely that flood managers are most interested in quantifying the portion of runoff that flows as surface water into the lower elevation regions beneath the mountain front. This includes both water that flows exclusively overland and water that infiltrates, but then flows along the bedrock and reemerges as surface water in springs (throughflow). Water supply managers are also interested in quantifying the portion of precipitation that becomes recharge, thereby contributing to long-term water stores.

There have been numerous studies of the "internal plumbing" of hillslopes to improve our understanding of throughflow processes. Tromp-van Meerveld and McDonnell (2006a) studied hillslope response to 147 storms in the Panola Mountain Research Watershed in north-central Georgia. The hillslope was trenched down to bedrock at the bottom of the slope and instrumented with soil moisture sensors and several tipping bucket rain gauges to capture "pipe flow". Pipe flow is focused subsurface flow through naturally occurring elongated cavities within the soil. In this case, the source of "pipes" was reported to be primarily decaying plant roots. The study showed that for this hillslope significant throughflow (>1 millimeter (mm)) occurred only during storms that were larger than 55 mm of rain. Tromp-van Meerveld and McDonnell (2006b) hypothesized that the 55 mm threshold was a function of microtopography of the bedrock surface: once bedrock depressions filled up, the rate of throughflow increased more than fivefold. While the specific results of the study are relevant only to the hillslope studied, they point to the idea that throughflow is generated when a threshold is exceeded. Additionally, the study found that for small rainfall events, areas that had small depths to bedrock delivered the largest portion of throughflow. However, during large rainfall events, areas with the largest depths to bedrock delivered the majority of throughflow. Few similar studies exist for arid and semi-arid regions. Newman et al. (2004) found that lateral subsurface flow in a semi-arid forest did not conform to the traditional model of soil-bedrock control of saturation and lateral subsurface flow. In their study, they observed lateral subsurface flow in a trenched hillslope under a melting snowpack. They observed that flow radiated outward following root macropores. This finding was surprising and suggests the need for additional studies on subsurface lateral flow in arid and semiarid lands. It is worth noting that the vast majority of hillslope hydrology studies like this have been done in humid regions. Hillslope dynamics in semi-arid and arid regions are a topic ripe for investigation.

There is also considerable interest in springs, both for hydrologic and ecological reasons. In 2009, Springer and Stevens formally defined 12 types of springs. A few of these types of springs had previously been defined, however, the majority of them were not. The definitions proposed by Springer and Stevens are largely based on the geological structures causing the release of water back to the land surface. Understanding of structures that can lead to spring discharge may be useful in MFR/MBR studies of flow paths and likely sources of discharge can be identified.

Despite the intense interest in understanding relatively rapid flow paths associated with throughflow and springs, there has been relatively little work done to relate these flow paths to recharge. The following are examples of questions that would be relevant to a more holistic examination of mountainous hydrologic systems with an eye to water management:

- Do the interesting threshold behaviors shown for "fill and spill" responses on bedrock surfaces have a parallel for recharge? For example, how does the partitioning of precipitation to recharge depend on the rate, timing, and periodicity of precipitation or snowmelt?

- Does subsurface, capillary-dominated flow moderate the importance of localized precipitation and infiltration? If so, what are the remaining scales of recharge variation? How can monitoring methods be developed to target these scales for improved watershed-scale recharge estimation?

- At what scale do vegetation patterns promote or inhibit recharge? If it can be shown that the density of trees and understory have predictable effects, can fire-mitigation culling efforts be modified to improve water retention as well?

RECHARGE

Quantifying recharge is often identified as a primary need for water supply planning. In this context, it is important to recognize the work of Alley and Leake (2007), who have been leaders in the effort to avoid simply equating recharge with available water. But, as for precipitation in the entire water cycle, recharge places a ceiling on the total water entering a closed subsurface hydrologic system. As a result, it is important to understand and quantify the processes that affect recharge.

Generally, recharge is a much slower process than throughflow. Both processes depend directly on topography, subsurface hydraulic properties, antecedent conditions, and vegetation (Tromp-van Meerveld and McDonnell, 2006c). In particular, the residence time of water in the subsurface depends on the flowpath, geologic material, presence of fractures, topography, and gradient (e.g. McGuire et al., 2005). The relatively slow movement of water through aquifers has led to the widespread use of chemical tracers to study recharge processes and rates. Aishlin and McNamara (2011) attempted to estimate MBR using the chloride mass balance approach in the Dry Creek Experimental Watershed near Boise, Idaho. Their results showed that MBR amounted to 14 percent of the gross precipitation. However, they note that their estimation of MBR was subject to the standard disclaimers associated with chloride mass balance plus the additional consideration of road salt adding chloride to the system. Ajami et al. (2011) used storage discharge relationships to estimate MBR. Initially isotopic data was used to determine that streamflow during dry periods is sourced from bedrock. Recession flow analysis was performed during bedrock flow periods following the method of Brutsaert and Nieber (1977) as a method of determining storage discharge relationships. These physical and chemical methods that are applied at the basin scale are particularly useful for estimating long-term average recharge rates and general patterns of recharge distribution.

Geophysical methods can be used to study a range of variables associated with mountain front recharge. Ferré et al. (USGS Professional Paper 1703, 2007) listed all available geophysical methods for studying recharge through approaches based on hydrogeologic framework, water mass balance, direct flux measurement, and vadose zone model calibration. The utility of each of these methods is limited to within a specific scale and the range of scales for these methods is between tenths and hundreds of meters. In general, geophysical methods are better suited to identifying shorter term variations in recharge rates and for comparing recharge rates within a basin.

Thermal methods have been used to identify infiltration and seepage out of or into stream beds, which is considered to be the primary mechanism of MFR. Constantz (2008) provides an excellent review of this approach. Blasch et al. (in USGS Professional Paper 1703, 2007) summarize recent advances in the use of thermal methods in particular for detailed understanding of the timing of ephemeral flows. More recent work has focused on the use of distributed temperature sensing (DTS) to provide very high resolution water temperature monitoring over km long stretches (e.g. Tyler et al., 2009).

Less work has been done on quantifying recharge related to snowmelt. Flint et al. (2008) studied infiltration of snowmelt into granite bedrock in Yosemite National Park. In their study, the soil on a mountainous hillslope was instrumented with water content and matric potential monitoring equipment. Throughout the season, snowpack, soil moisture, and matric potential data was collected. The data was then used to model infiltration into the bedrock using the numerical simulation software TOUGH2. Bedrock permeability was assumed in the model. Model results showed that all the snowmelt became direct recharge to the bedrock as long as melt rates did not greatly exceed the permeability of the bedrock. In this case, the melting rate was double the permeability of the bedrock in a few days of the year near the end of the season leading to lateral flow along the soil-bedrock interface.

Recharge remains an elusive process largely because it usually occurs far below the ground surface. This has led to two general approaches to quantifying recharge: model based residual estimation; and indirect inference with chemical and geophysical methods. There is much room for improvement in monitoring recharge. Some example questions that would be relevant to this work include:

- Walvoord et al. (2002) published groundbreaking work on recharge processes in deep vadose zones. They showed that very deep vadose zones in very arid regions can have significant subsurface cycling of water that can affect recharge estimation from shallow measurements. How are these processes modified in shallower vadose zones? In practice, what are the conditions that allow for recharge estimation from readily available near-surface measurements? Can geophysical and isotopic methods be targeted for appropriate, joint monitoring to best fit local conditions?

- How do shorter duration variations in recharge rates propagate through the vadose zone? What does this mean for long term impacts of short period climate fluctuations for water supply? How will this affect the response of recharge to longer term climate changes?

- How can models and measurements be merged to more accurately quantify recharge and to better characterize interactions among recharge, environmental water use, and to plan for societal water needs?

EVAPOTRANSPIRATION

Arid and semi-arid regions are water limited for most or all of a typical year. This means that the energetic potential to evaporate water and transpire water (PET) is not met by actual evapotranspiration. Desert plants have adapted to exist and thrive in these environments. In large part, these adaptations lead to effective capture, storage, and use of water. From the perspective of water management, it is important to understand how much water is "left" after evapotranspiration (ET) is removed from the total precipitation. In a simple sense, this represents the maximum amount of water that can be removed from the system without altering the natural ecosystem. Here, too, Alley and Leake (2007) provide a more detailed and considered discussion of the water budget in this context.

Regardless of how the water budget is applied, it is important that it be quantified as completely and accurately as possible. Quantification of ET is a large and growing field. Some of the more interesting recent studies have begun to relate ecological and hydrologic processes at smaller spatial and temporal scales. Brooks et al. (2010) hypothesized that plants and streams in the H.J. Andrews Experimental Forest (Oregon, USA) do not use the same water sources. In their conceptual model, autumn rains which have a strong isotopic signature, fill up soil pore space and become tightly bound within the soils. Rainy season water is mobile and flows quickly through preferential pathways or through pore space. This water contributes to stormflows. During the dry season, plants draw on the tightly bound water that was stored in autumn, while streams rely on discharges from the water table at depths beyond the root zone. In this hypothesis, the water used by plants in the dry season is water that is not available to streamflow or to recharge. Initial isotopic results from the H.J. Andrews watershed corroborate this hypothesis.

Studies have been aimed as semi-arid regions, as well. Springer et al. (2006) estimated the transpiration rates of fern-graminoid and graminoid plant communities (both herbaceous) near Flagstaff, Arizona by measuring volumetric water content differences between comparable plots of land with and without vegetation. Transpiration rates were estimated at between 0.63 and 2.4 millimeters per day (mm/d) in the fern graminoid and 0.57 and 1.1 mm/d in the graminoid community. Evaporation was estimated by measuring temporal changes in soil moisture at "clipped" plots where vegetation had been removed. Evaporation rates at these plots were between 54 and 474 percent of transpiration. The high evaporation rates were attributed to exposed soils and windy dry conditions. Springer et al. (2006) concluded that herbaceous plants transpire considerably more water than low density stands of ponderosa and limber pines which were found to use between 0.06 and 0.24 mm/d in a previous study (Fischer, 2001; Fischer et al., 2002). Potts et al. (2010) studied the impacts of mesquite canopy on variations in soil moisture in a mesquite savanna near Tucson, Arizona. They found that soils under mesquite canopies experienced significantly less variation in soil moisture at shallow depths <40 centimeters (cm) than soils not under tree canopies. Additionally, soils at depths >40 cm experienced significantly less variation in soil moisture regardless of whether they were under tree canopies.

Clear understanding of plant-level ET are critical for understanding root-water uptake processes and for predicting the effects of climate changes on plants. However, for watershed scale investigations aimed at water management, ET must be estimated at larger scales. Typically, models are used for this upscaling; often, these models are conditioned on remotely sensed data. For example, Magruder et al. (2009) used Biome-BGC to estimate MBR in the Tobacco Root Mountains in Montana. Biome-BGC is a process based model that simulates fluxes of water, carbon, nitrogen and energy through soil, atmosphere and plants. LANDSAT Thematic Mapper land cover types were used to identify vegetation groupings. Default Biome-BGC plant properties were used to determine plant properties. Resulting ET rates from Biome-BGC were then used as inputs to a MODFLOW groundwater model. A river basin water balance model by Duffy (2004) models the uptake of water into the root zone as ET and the passage of water beyond the root zone as recharge.

Active alteration of plant communities to reduce ET has also been attempted. Shafroth et al. (2005) conducted a review of attempts to reduce ET through salt cedar removal in desert riparian ecosystems. They found that reductions in ET were less than expected. The vegetation that replaces salt cedar significantly impacts ET rates and tends to increase ET through time. The authors stress that more complete hydro-ecological analysis is needed to predict the likely outcomes of active alterations. A similar finding was presented in a natural experiment due to tree die off in the Colorado River Basin (Guardiola-Claramonte et al., 2011).

Evapotranspiration is a topic that attracts both practical and scientific interest because it is the point of intersection of hydrology, meteorology, ecology, and societal planning. Because of this natural position amid disciplines, it could be an attractive platform to discuss a meeting to explore the future pathways for research under the NSF-11-551 call. Some possible overarching questions could include:

- What are the canopy-level feedbacks between ET and precipitation and how do they impact recharge? Can this information be used to better manage land to maintain ecological corridors while maximizing water availability for societal use?

- What are the time scales of adaptation to changing hydrologic regimes of different plant communities? How do these time scales, together with predicted changes in weather patterns, inform predictions of future water balances in semi-arid watersheds?

- Can communities be designed to include plant communities that provide an optimal balance of habitat, efficient water use, and soil stability in semi arid environments?

EXAMINATION OF SUCCESSFUL 2010 WSC GRANTS

The appendix to this document includes specific information about successful grant proposals funded by the National Science Foundation (NSF) Water, Sustainability and Climate (WSC) program in 2010. That was the first year of the program and the number of applicants was very large. According to personal conversations with NSF personnel, well over 200 proposals were submitted to the program. Some of the most relevant information about the grants that were awarded in each of the three proposal categories is summarized below.

Ten workshop-planning grants (Category 1) were funded in 2010. Broadly, the proposals examined the following topics: links between hydrology and ecosystem functioning and services (2 grants); ecological and economic impacts of changes in water management in response to climate change and urbanization (4 grants); and social and economic response to water conflicts (4 grants). There is a strong emphasis on ecological components and on merging natural sciences with sociological/economic analyses. All of the Principal Investigators (PIs) are from academic institutions: Florida International University; Utah State University; University of Texas at El Paso; Michigan State University; University of Minnesota Duluth; University of Illinois at Urbana-Champaign; University of Idaho; University of Northern Arizona; Michigan Technical University; and University of North Texas. The award amounts ranged from $75,000 to $150,000, with an average of $138,000.

Three observatories and modeling grants (Category 2) were funded in 2010. The proposals examined the following topics: impacts of extreme events on Great Lakes water quality under climate change; climate variability and urbanization impacts on water sustainability; and impacts of climate change and land use change on Midwestern agricultural water quality and quantity. There is a strong regional emphasis with preference for development of modeling and analysis approaches to document and plan for water management. All of the PIs are from academic institutions: University of Michigan, Ann Arbor; University of Maryland, Baltimore County; and University of Wisconsin-Madison. The award amounts were $5 million, $1.6 million, and $4.9 million, with an average of $3.8 million.

Three modeling grants (Category 3) were funded in 2010. The proposals examined the following topics: landscape, atmospheric and economic modeling of sustainability of the High Plains Aquifer; climate and population change impacts on dryland rivers; and water and climate influences on sustainability of Asian High Mountains. There is an emphasis on larger-scale systems and consideration was given to represent diverse environments. All of the PIs are from academic institutions: Michigan State University; University of Arizona; and University of New Hampshire. The award amounts were $1.2 million, $600,000, and $800,000, with an average of $867,000.

SUMMARY

Recharge is an important and elusive element of the hydrologic cycle. In water-limited areas, this flux to the groundwater system often places a critical maximum value on the total water resources that is available for environmental and human use without removal of groundwater stored in the aquifer. In addition, the rate of recharge imposes controls on the dynamic response of subsurface hydrologic systems to changing climate drivers. Recharge is difficult to quantify because it takes place below the ground surface and is often a relatively low flux distributed over large areas. It is particularly difficult to understand, characterize, and quantify recharge in mountainous regions. This difficulty is due to the mixture of relatively poorly quantified and highly localized inputs (rainfall and snowmelt), highly localized and poorly documented conductive pathways (e.g. faults and fractures), and complex subsurface conditions that can lead to modification of flow paths during percolation and subsequent groundwater flow.

There are many remaining challenges that make recharge quantification difficult, under both current and predicted future conditions. This presents many opportunities to propose research programs. In general, these efforts should include the following key elements: current limitations in measurements of and methods to measure key properties and fluxes; considerations of scale in propagating climate change to ecological and water resources changes; and full integration of socioeconomic and natural science analysis (with heavy emphasis on developing modeling platforms) to balance environmental and human water use under climate change and land use change. Some examples of scientific questions that relate to these topics are given in other sections of this document.

The National Science Foundation's WSC program is well suited to proposals for investigating the challenges of water planning for the Upper Verde River Watershed. A Category 1 proposal to hold a workshop could emphasize the use of competing hydrologic models within a socioeconomic analysis framework to plan hydrologic analysis. This would complement several funded proposals from 2010, while offering a unique perspective. The objective for the Upper Verde River Watershed Protection Coalition would be to draw experts to the region with the goal of generating their interest in developing future, site-specific research projects. Category 2 and 3 proposals are even more highly competitive, but offer larger budgets. A case could be made for a Category 2 proposal that makes use of existing hydrologic and economic analysis to prioritize data collection. This would likely be strengthened by first proposing (through the WSC program or another vehicle) a workshop that assembles diverse experts in hydrology, ecology, urban planning, and economics. It seems less likely that a Category 3 proposal would be competitive. Firstly, it would need to show a demonstrable added benefit over existing modeling that has been conducted for the region. Secondly, the University of Arizona award on a related subject would make it less likely that another grant dealing with Southwestern issues would be funded.

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Appendix

Full Listing of WSC Grants Awarded in 2010

The following information was downloaded from an NSF website (http://www.nsf.gov/news/news_summ.jsp?cntn_id=117819). Implications of these awards for a 2011 application are discussed in the body of the document.

October 6, 2010

CATEGORY 1: WORKSHOP PLANNING GRANTS
124k WSC-Category 1: Linking freshwater inputs to ecosystem functioning and services provided by a large mangrove estuary
PI (Principal Investigator): Michael C. Sukop, Florida International University
Summary: The objectives are to 1) generate an empirical and analytic approach to linking water balance and carbon budgets to ecosystem function and services in a mangrove estuary; and 2) develop a long-term plan for implementing the approach and integrating the results into decision-making forums for allocating water resources in the region. The study area is part of Everglades National Park.
150k WSC-Category 1: Hydrologic and Ecological Impacts of Changes in Human Water Resource Management in Response to Climate Change and Urbanization
PI: Douglas Jackson-Smith, Utah State University
Summary: What are the intended and unintended consequences of changes in water allocation and water use efficiency in response to anticipated climate change and urbanization? The project will build on the results of a co-located NSF-funded WATERS test bed watershed, a USDA Conservation Effects Assessment Program (CEAP) research watershed, and an EPA Targeted Watersheds Project in the Intermountain West.
150k WSC-Category 1: Sustainability on the Border: Water, Climate, and Social Change in a Fragile Landscape
PI: William Hargrove, University of Texas at El Paso
Summary: The project will conduct workshops to analyze the resilience, adaptability, and transformability of the ecological/social system in response to change. The system under study is the Middle Rio Grande River and the U.S./Mexico border at El Paso/Juarez, which presents unique challenges in a complex biophysical and socioeconomic environment complicated by violence, migration, and social inequities.
150k WSC-Category 1: Learning from Adaptable Water Systems
PI: Joan Rose, Michigan State University
Summary: This planning grant focuses on developing research procedures that integrate the observation and modeling of human water and wastewater systems as they adapt to environmental changes. The project will integrate existing initiatives to assess Michigan's Lake St. Claire and Grand River watersheds, to examine the changes and potential future changes through social science lenses, and explore the risks to water quality, public health and sustainability in the context of climate change.
137k WSC-Category 1: Water Sustainability and Climate in the Great Lakes Region of East Africa
PI: Thomas C. Johnson, University of Minnesota Duluth
Summary: The East African Rift lakes have seen increased occupation and settlement as a result of conditions favorable to agriculture, an abundance of fish, an apparent surplus of fresh water, relatively tolerable climate conditions, and an aesthetically pleasing landscape. This project will develop an interdisciplinary research plan for water sustainability and climate in the Lake Malawi basin, which typifies much of the great lakes region of tropical East Africa.
107k + 42k WSC-Category 1: Coupled Observation of the Water Environment: A National Survey Program
PI: John B. Braden, University of Illinois at Urbana-Champaign
Summary: Braden and colleagues will produce insights that improve our understanding of coupled water systems, lead to development of predictive scientific models that incorporate human behavior, and enable policies and institutions that improve environmental outcomes while also increasing the economic value of water. The researchers will engage in efforts with agencies such as NOAA, USEPA, USDA, USGS, and BLS to identify complementary sources of physical, biological, and social observations.
75k WSC-Category 1: Sustainability Dynamics for Water Resources in a Rapidly Urbanizing and Climatically Sensitive Region
PI: James R. Gosz, University of Idaho
Summary: This project will address water resources broadly: climate dynamics, water quantity/quality, landscape dynamics, distributed and renewable energy, social/economic factors, cultural and demographic change, natural resource law, built environment/engineering infrastructure, transportation planning/policies, urban-wildland/agriculture interface, and new threats in the Spokane, Washington-Coeur d'Alene, Idaho corridor.
150k WSC-Category 1: Building an economically sustainable restoration and monitoring plan for forested watersheds in Northern Arizona
PI: Abraham E. Springer, Northern Arizona University
Summary: Springer and others will link watershed and forest management metrics with ecological economics to devise a model for a watershed services market that offsets costs of large-scale ecological restoration of forested ponderosa pine (*Pinus ponderosa*) forest in northern Arizona. A successful water market with stakeholders paying for watershed management

benefits would support the maintenance, monitoring, and restoration of forest health while also providing sustainable water resources.

150k WSC-Category 1: Humans, Hydrology, Climate Change, and Ecosystems- An Integrated Analysis of Water Resources and Ecosystem Services in the Great Lakes Basin

PI: Alex S. Mayer, Michigan Technological University

Summary: The Great Lakes region of North America is water-rich, but concern exists that its water resources may be over-used. Scientists will conduct workshops to address this question with the plan to (a) develop integrated biophysical models for predicting ecosystem impacts due to future land and climate change and (b) develop an understanding of how the region's groups and individuals view the regions' aquatic resources.

150k WSC-Category 1: Integrated Biophysical-Social Research for Water and Ecosystem Sustainability in an Effluent-Driven Urbanizing Watershed

PI: David Hoeinghaus, University of North Texas

Summary: The upper Trinity River basin study area, including the Dallas - Fort Worth Metroplex, has great potential as a model system for the study of rapidly urbanizing watersheds that are increasingly reliant on surface water. Field research and public surveys will fill in gaps in available data and lead to human and natural systems modeling.

CATEGORY 2: OBSERVATORIES AND MODELLING

WSC-Category 2: Extreme events impacts on water quality in the Great Lakes: Prediction and management of nutrient loading in a changing climate

PI: Anna M. Michalak, University of Michigan Ann Arbor

Summary: The Great Lakes are a vital freshwater resource with chronic water quality problems. This research asks: What are the possible effects of climate-changed-induced extreme events on water quality and ecology in the Great Lakes system, and what management strategies will be effective in addressing these change

WSC-Category 2: Regional Climate Variability and Patterns of Urban Development - Impacts on the Urban Water Cycle and Nutrient Export

PI: Claire Welty, University of Maryland Baltimore County

Summary: The goal of the research is to evaluate the interactions between urban development patterns and the hydrologic cycle and its associated nutrient cycles, in the context of regional and local climate variability. The specific objective is to create a modeling system to simulate the feedback relationships that control urban water sustainability.

WSC-Category 2: Climate Change, Shifting Land Use, and Urbanization in a Midwestern Agricultural Landscape: Challenges for Water Quality and Quantity

PI: Christopher Kucharik, University of Wisconsin-Madison

Summary: How will ecosystem services vary and how can they be sustained in regional watersheds as climate, land use and land cover, the built environment and human demands change? The focus is the Yahara Watershed of Wisconsin, an exemplar of water-related issues in the Upper Midwest.

CATEGORY 3: MODELLING

WSC-Category 3: Toward Sustainability of the High Plains Aquifer Region: Coupled Landscape, Atmosphere, and Socioeconomic Systems

PI: David Hyndman, Michigan State University

Summary: The High Plains region boasts some of the most productive irrigated agricultural land in the United States, made possible by one of the largest contiguous aquifer systems in the world, the Ogallala-High Plains aquifer complex. The project will quantify different levels of sustainability for the region's agricultural practices in the face of increasing demand for agricultural products.

WSC-Category 3: Climate and Population Change and Thresholds of Peak Ecological Water: Integrated Synthesis for Dryland Rivers

PI: Thomas Meixner, University of Arizona

Summary: Meixner and colleagues will work on the San Pedro and Santa Cruz River basins in southern Arizona. Existing scientific and behavioral datasets will be integrated using process-based models, and linked to a public good market allocation model.

WSC-Category 3: Crops, Climate, Canals and the Cryosphere in Asia - Changing Water Resources around Earth's "Third Pole"

PI: Steve Frolking, University of New Hampshire

Summary: This project will generate an integrated assessment of the impacts of climate-driven changes in hydrology on agricultural production and land use in Central, South, East, and Southeast Asia, and their implications for the region's food security and economic welfare in the coming decades. It will assess current and projected water resources in the watersheds of the major rivers draining the Asian High Mountains (the Indus, Ganges, Brahmaputra, Salween, Mekong, Yangtze, Yellow, Amu Darya, Syr Darya and Irtysh Rivers).