# BOSQUE LANDSCAPE ALTERATION STRATEGY

## OBJECTIVES, BASIC REQUIREMENTS, and GUIDELINES


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Many people contributed their valuable time, energy, and ideas to help realize this Bosque Landscape Alteration Strategy. All of them, particularly those who participated in the 2004 and 2005 workshops, deserve more credit than can be expressed here. Some individuals contributed in special ways. State Senator Dede Feldman, along with State Forestry officials Greg Fitch and Tony Delfin got us the funds that made the whole project possible. Director Marilyn O'Leary, Assistant Director Susan Kelly, and the staff and graduate students of the Utton Transboundary Resources Center at the University of New Mexico School of Law organized and hosted the two very productive workshops. Chris Garcia kept the notes and made a valuable record of the proceedings. Subhas Shah, Chief Engineer of the Middle Rio Grande Conservancy District, made time available for Yasmeen Najmi and Sterling Grogan to participate. Of course, mere thanks are not enough for Cliff "Dr. Bosque" Crawford, who planted the original seed and nourished it with his kind heart, creativity, tenacity, and passion that will forever inspire those who are lucky enough to work in the bosque.

# INTRODUCTION

This Bosque Landscape Alteration Strategy evolved from a May, 2004 proposal developed by Dr. Cliff Crawford (University of New Mexico) and Sterling Grogan (Middle Rio Grande Conservancy District) entitled "Bosque Landscape Alteration Will Reduce Fires and Conserve Water: A Proposal" (see p. 17). That proposal was intended to be a point of departure for discussion and debate by those concerned with the management of fire and water in the middle Rio Grande riparian forest, the bosque. In August, 2004 and again in May, 2005, the Utton Transboundary Resources Center at the University of New Mexico School of Law organized and facilitated two workshops designed to stimulate that discussion and debate among scientists, managers, advocates, and citizens concerned with the bosque. The results of those workshops and several subsequent discussions were combined to create the "Objectives, Basic Requirements, and Guidelines" for implementation of bosque landscape alteration that constitute this Strategy.

The concepts presented here may seem radical at first, but they have been evolving for a decade or more. This vision of bosque landscape alteration centers on re-creating a patchy mosaic of native riparian trees and open spaces along the narrow active floodplain of the middle Rio Grande, between the outfall of Cochiti Dam and the upper end of the Elephant Butte Reservoir high-water pool. Although the present straightened and levee-bordered river will require that the mosaic be somewhat linear, it will otherwise resemble the pattern of scattered cottonwood groves interspersed by open spaces that once characterized the wider historic floodplain (Horgan 1984).

The Objectives, Basic Requirements, and Guidelines describe in some detail how to achieve this vision of the bosque. However, this Strategy is intended to be guidance only, and will have to be supplemented by site-specific details that are beyond the scope of this Strategy to create rehabilitation/remediation/restoration plans. In essence, this Strategy amounts to a guide for rehabilitation/remediation/restoration of the Rio Grande's riparian zone between the levees — actions that will both diminish the potential for frequent and intense bosque wildfires, and reduce water loss due to evapotranspiration (ET). This Strategy assumes that these actions will involve the removal of most of the bosque's invasive trees, and some senescent native trees, while retaining some dense patches and creating new native vegetation communities for habitat. They will also create savanna-like woodland patches with an understory of native grasses and shrubs. Open areas between the patches will also support grasses and shrubs, and perhaps small numbers of widely spaced individual trees or groves useful for animals moving between the patchy woodlands. This combination of tree reduction and increased open space will reduce overall ET in the altered landscape and increase water in its shallow aquifer.

This Strategy assumes that the contemplated actions will be carefully monitored and evaluated before, during, and following the proposed alteration of the bosque landscape. Carefully supervised citizen volunteers, along with scientists and managers, will participate in all phases of bosque landscape alteration. To achieve the Objectives of this Strategy, the authors believe implementation must be coordinated on both the landscape and project scale, possibly through reach-wide or larger-scale plans.

This Strategy is a living document, to be revised occasionally as we gain new knowledge from the many ongoing and planned efforts in bosque landscape alteration.

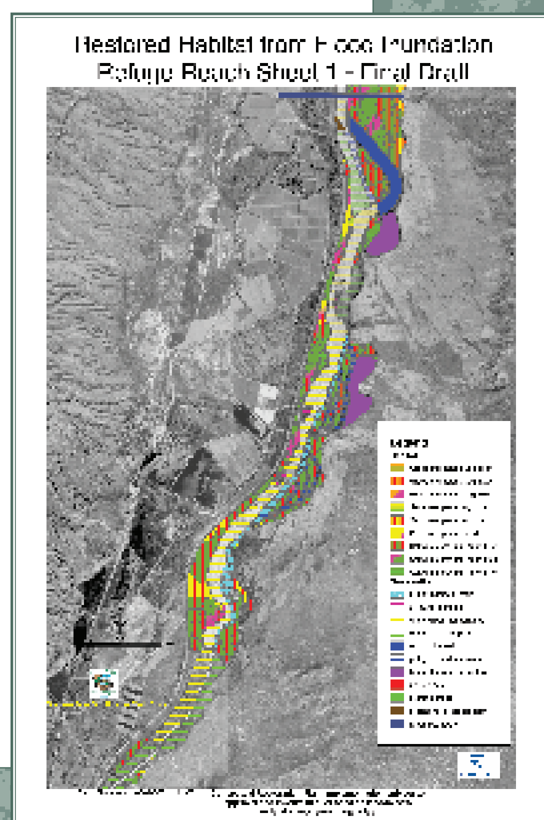
# I
# OBJECTIVES

Example of Mosaic in Restored Area

Bosque del Apache National Wildlife Refuge

Photo by: Gina Dello Russo, BDANWR

1. To reorganize the Rio Grande bosque's landscape to retain, within current constraints, including institutional and water supply constraints, its historical processes and wildlife communities.
2. To recreate, by doing this, its former patchy mosaic of native trees and open spaces along the present-day river's narrow floodplain, while containing the distribution of invasive species.
3. To reduce, by having created this mosaic, the intensity of bosque wildfires both at the wildland-urban interface and within the rest of the bosque, and water depletion by the bosque landscape.



# II
# BASIC REQUIREMENTS

1. Become familiar with the present condition of the bosque landscape (hydrology, soils, flora, fauna), including existing water depletion rates and fire danger in different reaches, and with the management practices that affect it.
2. Develop flexible hydrological management options, including the ability to mimic the natural hydrograph, in order to maintain wet soils at appropriate seasons for native tree recruitment and maintenance.
3. Recognize that historical flooding is being replaced by wildfire as the driving disturbance in bosque landscape dynamics, and implement flexible responses to both flood and fire to maximize the benefits and minimize the damages of these disturbances.
4. Manage the river and the anticipated patchy riparian mosaic for habitat diversity; biological diversity will follow.
5. Adaptively manage the bosque landscape in an ecosystem-based manner that integrates recreation uses with fire protection.
6. Construct wetlands inside – and where possible outside – the levee system, (with reference to available wetland models) where hydrologic conditions are likely to support wetlands.
7. Maintain the altered bosque landscape with measures that provide for a goal of no increase in net depletions of water by the riparian ecosystem.
8. Ensure a sustained program of bosque research and monitoring.

Bosque Post-Fire
Veguita, New Mexico
Photo by: New Mexico Forestry Division

Constructed Wetland
Los Lunas, New Mexico
Photo by: Yasmeen Najmi, MRGCD

# III
# GUIDELINES

Willow swale at I-40 Burn
Albuquerque, New Mexico

Before thinning, revegetation, or other bosque landscape alteration, goals must be clearly articulated and agreed upon by those involved. Goals should reflect an understanding of three elements that should be part of any process for planning and implementation of bosque landscape alteration: First, describe what is known about the bosque, or part of the bosque, where the work will take place. Second, implement bosque landscape alteration using an adaptive management approach, whereby new knowledge gained from monitoring during or after the work will be incorporated as soon as practical into the bosque landscape alteration. Third, describe how the altered bosque landscape will be maintained and monitored.

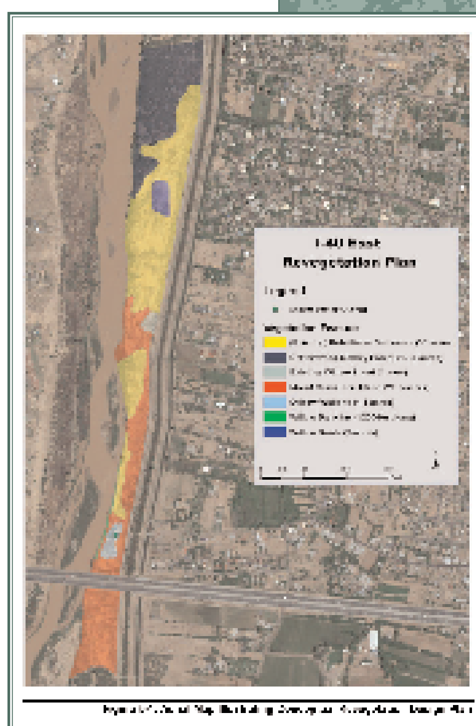
**A. Describe what is known about the bosque and what additional information is required to implement the Bosque Landscape Alteration Strategy**

1. Before implementing projects:

   a. Describe the goals of the project;

   b. Identify and describe the area that will be impacted, including size and location;

   c. Describe how the project site relates to the bosque overall;



I-40 East Revegetation Plan

Photo and map courtesy of U.S. Army Corps of Engineers, Albuquerque District

d. Describe how the project objectives relate to the BLAS objectives;

e. Document existing site conditions (vegetation, hydrology, soils, surrounding habitats, etc.);

f. Describe the process necessary to achieve objectives.

2. Use the historical vegetation community types and acreages from the Bosque Biological Management Plan, the updated Hink & Ohmart vegetation classifications, and other sources of information as a basis for landscape mosaic planning.

3. Collect and periodically review data on pre and post-treatment fuel loads, the effects of fire, and the results of other ecosystem monitoring, so that prescriptions for thinning exotics and the dead/down/mulch component can be revised to incorporate current knowledge.

4. Define a target range of vegetation patch sizes and optimal stem densities within patches to leave or create for wildlife. To determine patch sizes and types:

   a. Identify optimal site conditions for patch(es);

   b. Identify nearest patches and their conditions/qualities;

   c. Determine habitat needs to be met in patch(es);

   d. Determine how patch(es) will be established;

   e. Define expected vegetation community dynamics (succession);

   f. Determine needs for monitoring and maintenance.

**B. Implement bosque landscape alteration with adaptive management and coordinate alteration activities on the project and landscape level.**

A decision key or matrix could be a useful tool to identify appropriate goals for a particular project, providing some context for when these goals are likely to be conflicting or complementary, and, at the most detailed level of planning, to guide the selection of specific rehabilitation projects. A matrix should also address type, frequency and intensity of maintenance and a monitoring protocol to address objectives. A website link to a decision support model used in developing water management alternatives on the Rio Grande is provided in the References Section of this document as an example to consider.

1. Remove dead-and-down and invasive trees to meet the established goals.

2. Depending upon the width of the bosque, site conditions and management objectives, leave or create a buffer strip of relatively dense vegetation along the river, of 5 to 15 meters in width, for habitat. Water availability and animal use is generally higher in this zone, making it harder to maintain and better suited for riparian shrubs. Considerations include: Bank stability; type and density of existing vegetation to leave as a buffer; proximity to other desirable species or infrastructure; and, other objectives, such as river bank access.

3. In river reaches where the hydrology does not support periodic flooding or water tables to create sufficient size or number of young dense stands of native vegetation, leave relatively dense remnant patches of cottonwoods and exotic understory (especially Russian olive), not to exceed 20 hectares in extent, as interim habitat and as controls for monitoring the effects of landscape alteration. First priority sites in this category would be sites designated as suitable or potentially suitable habitat for the southwestern willow flycatcher and/or other species of concern. Some removal or rearrangement of dead-and-down can occur within these stands if dead-and-down fuel loads exceed 10 tons/acre, or where conditions such as fuel depth warrant. Dead-and-down wood, as well as snags and decomposing logs greater than 12 inches in diameter, should be left for wildlife cover. Dead and down wood removal should be focused on the edges of dense patches. These patches should

Fire Management and Recreation

Socorro, New Mexico

Photo by: Doug Boykin, NMSF

Fire Management and Water Salvage

Belen, New Mexico

Photo by: Marcel Reynolds, VSWCD

Habitat Restoration

Bosque del Apache NWR, New Mexico

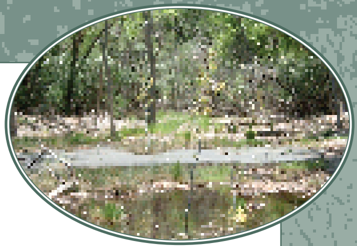
Photo by: BDANWR staff

be surrounded by thinned woodland, shrub/grasslands, or other areas defensible against fire. Defensible space areas should have vegetation that supports only low intensity fires (flames lengths less than 8 feet) that allow direct attack using ground crews and heavy equipment, where required. Dense patches should not be retained adjacent to (within 50 meters of) bridges or other structures, or designated recreation access points, unless requirements for wildlife habitat or flood control dictate otherwise.

4. Thin existing stands of native trees, while retaining sufficient dense young-growth native forest patches for habitat, leaving enough standing dead trees for wildlife. First priority is to convert burned areas to desirable vegetation communities, depending on site conditions and potential, leaving sufficient dead-and-down wood and snags for wildlife. In patches of decadent stands of cottonwoods greater than 20 hectares, thin cottonwoods to a minimum distance of 12-15 meters between trunks. Thin decadent trees in recreation areas.

5. Create uneven-aged stands of native trees by overbank flooding, pole planting, selective watering, landscape lowering, side-channel construction, and/or other appropriate techniques. Take advantage of flood prone areas and higher runoff periods. Choose areas with water tables less than 2 meters below the surface to create willow swales, for tree and shrub plantings, and for landscape lowering or side channel construction. Where feasible, use alternate sources of water such as drains and wasteways for seasonal artificial flooding. Wetlands can be created in seasonally flooded areas and areas with water tables sufficient to support hydric soils.

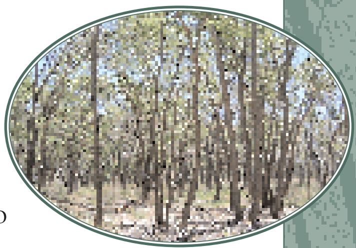
6. Create an irregular and internally thinned woodland patch mosaic of varying density with relatively large, interspersed open spaces of native grasses and shrubs. Variables that determine optimal patch size include, but are not limited to: Access, nearest similar patch, corridors/ connections with other patches, wildlife habitat



Dense Bosque Left for Habitat Adjacent to Treated Site

Belen, New Mexico

Photo by: Yasmeen Najmi



Dense Stand of Cottonwoods

Los Lunas, New Mexico

Photo by: Yasmeen Najmi

Post-Burn Rehabilitation

Belen, New Mexico

Photo by: Yasmeen Najmi

Landscape Lowering and Side Channel Development

Endangered Species Habitat Restoration

Los Lunas, New Mexico

Photo by: Yasmeen Najmi

requirements, fire risk, and water depletions. Native grass and shrublands should be prioritized for dry terraces where flooding occurs only with infrequent, high flows, as well as at bridges and recreation/emergency access points. Flood potential and levels must be determined for different river reaches. For example, areas that flood in the bosque south of San Acacia, New Mexico above 5660 cfs would generally support a more open bosque with grasses and grass/shrublands depending on groundwater and other factors. Salt grass meadows can be prioritized for areas where an open vegetation community is desired and the hydrology and soils support it – generally where water tables are less than 1-1.5 meters below the soil surface.

7. Create grasslands with sparse, low growing shrubs (less than 2 meters in height), or a thinned cottonwood canopy of 5 to 15 hectares in extent, adjacent to bridges and recreation/emergency access areas. Create a buffer zone approximately 50 meters wide adjacent to powerlines where overstory is thinned to 12-15 meters between trees, and shrub canopies are not touching or forming ladder fuels. Treat dead-and-down fuel loads in these areas to less than 10 tons per acre.

Wetland Revegetation
Belen, New Mexico
Photo by: Yasmeen Najmi

Variable Thinning with Russian olive Retention
Corrales, New Mexico
Photo by: Yasmeen Najmi

Burn Rehabilitation and Recreation Access at Montano Bridge
Albuquerque, New Mexico
Photo by: Yasmeen Najmi

Native Grass and Shrub Community
Tome, New Mexico
Photo by: Yasmeen Najmi

**C. Describe how the altered bosque landscape will be maintained and monitored**

1. Utilize controlled grazing/browsing animals, and/or other maintenance tools, seasonally to meet established goals.

2. Conduct periodic reviews and external evaluations of the ecological outcomes of bosque landscape alteration, as determined by monitoring.

3. Establish and implement basic and consistent monitoring protocols soon after, if not before, landscape alteration activities. Protocols should address objectives tied to a list of appropriate monitoring techniques, as well as the scale, frequency, and timing of measurements. At a minimum, a basic monitoring protocol for bosque landscape alteration should address changes in the vegetation community, including changes in fuels and fire intensity, as well as changes in surface and ground water hydrology. With additional financial support, the BEMP (Bosque Ecosystem Monitoring Program; see www. bosqueschool.org) model could be used to establish additional monitoring sites. BEMP sites are currently monitored for fuel loading, ground and canopy cover, vegetation diversity and other biotic and abiotic variables, including groundwater depth and chemistry, but they are not specifically monitored for resprouting woody native and non-native vegetation. Support and expand efforts to monitor all water depletions associated with bosque landscape alteration.

4. Evaluate monitoring programs for effectiveness, and to ensure that information gaps are being filled. Current information gaps for the middle Rio Grande bosque include the interaction between the river channel, shallow ground water aquifer, the canal/drain system, and the deep aquifer; the bosque's vegetation potential; and, the location and extent of invasive plants.

5. Expand the use of citizen volunteers with training, supervision, and management, to assist with various aspects of bosque landscape alteration, monitoring, and maintenance.

Goat Vegetation Management Study

San Acacia, New Mexico

Photo by: Sandy Tartowski, Jornada ARS

Bosque Fuels Reduction Study Monitoring

Middle Rio Grande Bosque

Photo by: USDA Forest Service Research Station

Volunteers Enhancing Wetland

Belen, New Mexico

Photo by: Yasmeen Najmi

6. Create communication and teamwork opportunities among the many groups working on the bosque. Create a bosque advisory committee to increase coordination, expand communications, and advise managers by reviewing and evaluating plans, projects, and monitoring programs, evaluating the results of landscape alteration, and making recommendations for adaptive management. The committee should include, among others, scientists expert in the scientific disciplines relevant to bosque landscape alteration. Develop outreach programs that will enhance decision-makers' understanding of bosque processes. Utilize forums and workshops such as the Arid Lands Research Station at Bosque del Apache National Wildlife Refuge, and the Bosque Hydrology Group, to publicly discuss bosque management issues at least twice a year, including such topics as fire season updates and planning. Invite agency heads and policy makers to workshops and forums or hold special update sessions for policymakers on bosque management.

# IV
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# Other relevant publications:


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# Other sources of information

(Some sources are listed once but may apply to more than one category):

**General information, vegetation and soils**

1. Hink & Ohmart veg. maps + 2004 update URGWOPS/US Army Corps shape files (Hawks Aloft transects provide a good comparison – see below)
2. NM Natural Heritage Program http://nmnhp.unm.edu/publications/pub_nhnm.php. Hink and Ohmart, river bars, wetlands, riparian vegetation
3. Albuquerque Overbank Project final report Bureau of Reclamation (Nancy Umbright), NMNHP
4. BEMP http://www.bosqueschool.org/Environmental%20Science%20Programs/data_sets.htm
5. Save Our Bosque Task Force Conceptual Restoration Plan San Acacia - San Marcial, NM. http://mrgbi.fws.gov/ Projects/2002/Table/Index.html
6. U.S. Army Corps of Engineers Bosque Planning http://www.bosquerevive.com; Ondrea Hummel 342-3375 and restoration projects; revegetation plans/lists
7. Bosque (Initiative) Improve-ment Group projects http://mrgbi.fws.gov/Projects/index.html
8. Pueblo of Santa Ana projects www.santaana.org, Brian Bader
9. Mosaic grass study Rio Grande Nature Center, Doug Shaw 345-0364
10. Seeding/Monitoring Study Ciudad S&WCD See 2001 Report by R. Garner @ Plant Materials Center, 865-4684.
11. Friends of Rio Rancho Open Spacehttp://www.forros.org/restoration.html.
12. Fuel Reduction, Wildfire Effects Studies http://www.fs.fed.us/rm/ USFS RMRS 724-3660
13. Rio Grande Valley State Park studies/plans www.cabq.gov/openspace/Open Space 452-5200
14. New Mexico Rare Plants Technical Council Robert Sivinski http://nmrareplants.unm.edu/index.html
15. Weed management with goats http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=174885
16. NM Forest & Watershed Health Plan http://www.emnrd.state.nm.us/Forestry/NMForestHealthPlan/docs/FWHPlan033005.pdf
17. NM Tamarisk & Watersheds Strategic Plan http://nmdaweb.nmsu.edu/DIVISIONS/APR/TAMARISK/tamariskhome.html
18. USDA/NRCS Los Lunas Plant Materials Center Greg Fenchel or Dave Dreesen 865-4684

**Reports on riparian plant propagation and planting methods**

**Wildlife**

1. Songbird study, raptor study Hawks Aloft http://www.hawksaloft.org/
2. Wildlife rescue http://www.wrinm.org/
3. Bird banding Steve and Nancy Cox ay Rio Grande Bird Research lgorbet@unm.edu
4. Fuel Reduction and Wildfire Effects Studies: www.fs.fed.us/rm/albuq/; USFS RMRS (see above)

**birds, herptiles, bats, arthropods**

5. Southwestern willow flycatcher (WFFL) surveys http://arizonaes.fws.gov/ Nancy Baczek USFWS 505 346-2525
6. BEMP http://www.bosqueschool.org/Environmental%20Science%20Programs/data_sets.htm
7. Arthropods: Hubbel Oxbow Farm, Candelaria Farm preserve, Ondrea Hummel USACE, 342-3375
8. Herptiles New Mexico Herpetological Society, Department of Biology, University of New Mexico, Albuquerque, NM 87131
9. Partners in Flight, NM Bird conservation plan http://www.partnersinflight.org/WatchListNeeds/default.htm http://www.blm.gov/wildlife/pl_85sum.htm
10. Rio Grande Valley State Park: mammals, birds www.cabq.gov/openspace/ Open Space 452-5210.
11. N.M. Department of Game and Fish Share with Wildlife http://www.wildlife.state.nm.us/conservation/share_with_wildlife/
12. UNM + NM Tech studies Search by animal, author, e.g., Hira Walker, Peter Stacy
13. Collaborative Forest Restoration Program http://www.fs.fed.us/r3/spf/cfrp/index.shtml
14. USFWS & BOR 2002-2003 Fish monitoring http://www.usbr.gov/uc/albuq/envprog/mrg/index.html
15. Fish Health Assessment http://mrgesacp.fws.gov/
16. MRG Endangered Species Collaborative Program: http://mrgesacp.fws.gov/

**Restoration projects, techniques, research, monitoring**

17. UNM Biol. / Sevilleta National Wildlife Refuge http://sev.lternet.edu/
18. Bosque del Apache National Wildlife Refuge http://www.fws.gov/southwest/refuges/newmex/bosque/

**Water**

1. BEMP precipitation, ground & surface water http://www.bosqueschool.org/Environmental%20Science%20Programs/data_sets.htm
2. Groundwater data in ABQ reach www.cabq.gov/openspace/
3. NM Interstate Stream Commission (ISC) www.ose.state.nm.us/
4. Upper Rio Grande Water Operations (URGWOPS) http://www.spa.usace.army.mil/urgwops/
5. NMED Surface Water Quality Bureau TMDL (Total Maximum Daily Load) http://www.nmenv.state.nm.us/swqb/links.html#TMDL_Library
6. USFWS Water Quality data, 2002-2003 http://mrgesacp.fws.gov/
7. Bosque Evapotranspiration Research See description on J. Cleverly's website, http://sevilleta.unm. edu/~cleverly/bosqueET.html ; See ET Toolbox at http://www.usbr.gov/ pmts/rivers/awards/Nm/riogrande.html
8. Bosque weather stations http://www.mrgcd.com;www.usbr.gov/pmts/rivers/awards/Nm/rg/RioG/indexhour.html; http://raws.wrh.noaa.gov/cgi-bin/roman/raws_ca_monitor.cgi?state=SWCC&rawsflag=2

9. River flow data http://nm.water.usgs.gov; (see also USBR in #8 above)

10. Fuels Reduction, Wildfire Effects Studies http://www.fs.fed.us/rm/ USFS RMRS (see above)

11. ISC/NM Tech Socorro Reach Groundwater Study http://www.ees.nmt.edu/bowman/research/RioGrandeProject/

12. Bosque Hydrology Group http://www.fws.gov/bhg/

13. Decision support model used by URGWOPS http://www.infoharvest.com

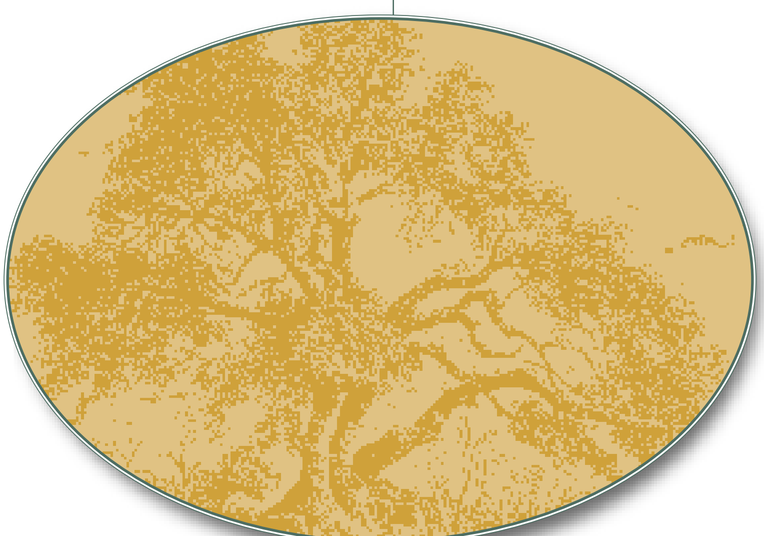
**The following information will be developed or completed within the next six months:**

1. Updated Hink and Ohmart vegetation classifications for Bosque Farms to Bernardo, New Mexico - MRGCD

2. MRGESCP Albuquerque reach-specific plan for habitat restoration – MRG Endangered Species Collaborative Program

3. Update to the Bosque Biological Management Plan – Lisa Robert

4. Update to the Middle Rio Grande Bosque Prescription Guide - MRGCD



# BOSQUE LANDSCAPE ALTERATION WILL REDUCE FIRES AND CONSERVE WATER: A PROPOSAL

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## Introduction

This proposal is intended as a point of departure for discussion and debate by those concerned with the management of fire and water in the Rio Grande's riparian forest, the bosque. The concepts we present here may seem radical at first, but they have been evolving for a decade or more (e.g. Crawford et al. 1993, 1994; also personal communications from Paul Tashjian and other members of the Bosque Hydrology Group). Specifically, our prescription for bosque landscape alteration centers on re-creating a patchy mosaic of native riparian trees and open spaces along the narrow active floodplain of the Middle Rio Grande. Although the present straightened and levee-bordered river will require that the mosaic be somewhat linear, it will otherwise resemble the pattern of scattered cottonwood groves interspersed by open spaces that once characterized the wider historic floodplain (Horgan 1984).

We present this picture in more detail below. In essence, it amounts to a restoration of the Rio Grande's riparian zone between the levees – an action that will both diminish the potential for frequent and intense bosque wildfires and reduce water loss due to evapotranspiration (ET). The operation will involve the removal of most of the bosque's invasive trees, and some senescent native species as well. It will also create savanna-like woodland patches that can retain or be planted with an understory of native grasses and shrubs. Open areas between the patches will also support grasses and shrubs, and perhaps small numbers of widely spaced individual trees or groves useful for animals moving between the patchy woodlands. This combination of tree reduction and increased open space will reduce overall ET in the altered landscape and increase water in its shallow aquifer.

Landscape manipulations will be carefully monitored and evaluated before, during, and following the proposed bosque transformation. Carefully supervised citizen volunteers will be used as much as possible in all phases of the operation.

# Background

Naturally occurring overbank floods were responsible for the historic establishment, maintenance, and at times the destruction of the Rio Grande's riparian forests. In the past half-century, however, wildfires have begun to replace floods as the driving force behind the changing bosque's organization and appearance. The fires were and are still caused mostly by humans. Since the great floods of the early 1940s the effects of bosque fires have been intensified by the spread of invasive woody species and the accumulation of fallen and standing dead wood – all during a period when peak flows were being progressively reduced by river regulation (Stuever et al. 1997).

Prior to regulation, the Rio Grande's flow regime was controlled by regional climate, basin geology, and floodplain geomorphology. The combined influence of these features was especially evident in the early growing season, when melting winter snows in the basin's upper watersheds produced a swollen river that often overflowed its banks. Those floods coincided with the release of wind blown cottonwood and willow seeds. They also prepared scoured banks for eventual seedling germination, and brought on avulsion events leading to new channel formation that in turn left trees on abandoned banks lacking significant hydrologic connectivity with the river (Crawford et al. 1994, 1996). Depending on the distance and elevation change between the new and old channels, average water table depths at the abandoned banks would at times have been well below their previous levels. Trees on those banks would then have been at risk, as water table depths exceeding ~3 meters result in cottonwood and willow water stress and eventual canopy dieback (Horton et al. 2001). Also impacted would have been seedling recruitment and nutrient uptake when soils beneath and around abandoned stands remained dry during the growing season.

Because of the apparent climatic uncertainty of the Holocene in what is now the U.S. Southwest (Graf 1994, Pearse and Kelson 2003), we speculate that the above scenario would have characterized a floodplain in which cottonwood and willow stands differed markedly in size, configuration, age, and health. We also assume that open spaces varying in size in the floodplain would have supported dryland grasses and shrubs as they do now – for example, in power line clearings. In other words, the riparian landscape on the whole would have been structurally complex, with an extensive diversity of habitats and species.

Compare such a picture with today's Middle Rio Grande riparian zone. The two are strikingly different. Following the entry of large numbers of humans into the valley, the old cottonwood groves were progressively cleared for agriculture and dwellings, or subjected to various forms of disturbance such as livestock foraging. By the mid-1800s beaver extirpation in the basin's upper watersheds led to the disrepair of their dams and subsequent soil erosion by heavy summer rains (Findley 1987). Heavy grazing and lumbering in the watersheds later in the century also added sediment to the river downstream (Wozniak 1995), raising its bed and causing severe flooding and eventual salinity problems in farm fields, as well as much damage to human communities (Scurlock 1998).

Pressures to make the floodplain more livable inevitably mounted and resulted in the formation of the Middle Rio Grande Conservancy District in 1925 (Scurlock 1998). The MRGCD, in cooperation with the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, drained the floodplain, improved irrigation, and instituted flood controls. By late century, river damming and other forms of flow regulation had reduced peak discharges to the point where overbank flooding had become rare in a river now greatly straightened, and positioned by levees. Within that new "active floodplain," stands of the no longer discontinuous bosque were then invaded by extensive spreads of invasive saltcedar, Russian olive, Siberian elm, and a variety of lesser species (Crawford et al. 1993). Competing with aging and infrequently reproducing cottonwood and willow trees for diminished water and flood-deposited nutrients, the invaders contributed enormously to the densely wooded, linear gallery stucture of today's bosque.

The crowded riparian forest's increasing use of water is bad news not only for the native bosque trees, but also for the inhabitants of rural and municipal communities in the middle valley. Meanwhile, New Mexico's southern Rio Grande valley, the states of Colorado and Texas, and the country of Mexico also have well-established claims to Rio Grande water. This combination of pressures, together with the present-day reduction of river discharge and a bosque becoming ever more vulnerable to wildfire, symbolizes the gravity of an issue that needs to be understood and faced realistically by the basin's rapidly growing human population.

# How to reduce bosque fires and save water

It is estimated that the average annual water loss due to evapotranspiration (ET) in the Middle Rio Grande riparian corridor is 20-35% of that reach's total water depletion (Dahm et al. 2002). Most of the cottonwoods contributing to the depletion are relatively old, and are stressed by low water availability (Leffler et al. 2000, Eichhorst et al. 2002) and leaf beetle outbreaks (Eichhorst 1999). Many cottonwoods dating back to the 1941-1942 floods and earlier (P. Jacobson, unpublished tree coring data) now regularly drop dead branches, as do many shade-tolerant Russian olives in the understory. Thick accumulations of nearly impenetrable dead branches are common on the floor of the bosque. During most of the year the fallen wood and a surrounding layer of dead, dry leaves become highly combustible fuels, especially on dry, windy spring days. When the fuels do catch fire, the dense living and dead woody understory then becomes a conduit that ignites the canopy above (Stuever et al. 1997). It is true that intermittent overbank floods can still deter fires because they clear out much of the fuel on the ground and cover what remains with sediment, creating a moist environment for decomposition (Ellis et al. 1998). However, with the reduction of overbank flooding those effects now seldom take place.

Our proposed solution to the twin problems of the bosque's potential depletion of river water via ET and the increasing frequency of bosque fires, lies in reorganizing the riparian landscape to resemble its historic condition, but doing so within the current constraints on the bosque's active floodplain. Because of the major spatial change that regulation has imposed on the system, attempts to fully "restore" the bosque can never be totally successful. That accepted, we propose that a more realistic way of sustaining the bosque's ecosystem integrity should include the following: (1) carefully controlled overbank flooding or other means of soil moistening, both of which can be accompanied by bank or soil surface lowering; (2) management leading to improved habitat diversity; (3) wetland construction inside and outside the levees; and (4) a sustained program of research and monitoring. Those goals are consistent with the objectives of the U.S. Army Corps of Engineers Middle Rio Grande Restoration Project, the City of Albuquerque Open Space Division projects; and with those of other planned and ongoing restoration-related programs in the Middle Rio Grande Valley. These include the San Juan, Santa Ana, and Sandia Pueblo restoration projects, and the Save our Bosque Task Force's San Acacia-San Marcial Conceptual Restoration Plan project.

Implementation of the proposed solution will involve selective removal of large numbers of bosque trees so that ET depletions and fire probability are reduced to acceptable levels. Bosque ET appears to be higher in dense stands of saltcedar, and in mature stands of cottonwood containing extensive understories of saltcedar and Russian olive, than it is in less dense saltcedar stands and mature cottonwood stands with few understory trees (Cleverly et al. 2002; Dahm et al. 2002). Thus reduction of tree densities, especially those of invasive species occurring either in monospecific stands or in the subcanopies of mature cottonwood stands, is basic to the proposed solution. Considering that bosque wildfires are fueled both by live trees and dead wood, it will be imperative to remove large portions of both. Given these realities, how does one design and implement an ecologically and socially acceptable plan for such a reorganization of the riparian landscape?

Here is our suggested approach, much of which we have alluded to above. First, we feel it essential to recognize the following four essential components of the proposed reorganization process, and note that some are already part of ongoing or planned restoration activities along the Middle Rio Grande: The four components are (1) removal of most standing and down dead wood of any species, other than small numbers of large cottonwood snags for use mainly by birds; (2) retention but occasional thinning of most native trees; (3) creation of uneven-aged stands of native trees to ensure their long-term sustainable replacement (such stands can be established by combinations of well-timed overbank flooding, pole planting, watering cleared and often lowered areas in late spring with pumped groundwater and/or drainwater, and constructing side channels from the river or drains into partially cleared forest); (4) creation of an irregular and internally thinned mosaic of woodland patches separated by relatively large open spaces.

The reorganization just described will be the rough equivalent of "restoration" in that the proposed woodland patches, even though confined to today's nearly linear active floodplain, will resemble those of the much wider active floodplain of the past (see discussion above). Stands separated by open areas of native grasses and shrubs over distances up to, say, half a mile, will delay the movement of fire and enable firefighting equipment to be brought in rapidly. (Lines of jetty jacks probably will have to be removed first.) The open spaces will therefore act as firebreaks. Application of all four of the restoration components listed above will, in our opinion, result in a savanna-like architecture of mostly native, uneven-aged stands that are much less vulnerable to combustion and more restrictive of water loss than is the gallery forest that constitutes the present bosque.

# Monitoring the Landscape Alteration

Monitoring the altered landscape before, during, and long after its creation will be key to evaluating its success. Use of the ongoing Bosque Ecosystem Monitoring Program (BEMP) is suggested as a means of tracking hydrologic and ecologic change in the bosque through time. Engaging many hundreds of K-12 students and other volunteers ensures a quality controlled and highly educational activity (Eichhorst et al. 2002). An added benefit of using BEMP is financial: the program relies mainly on volunteers to do most of the monitoring. Expenses will also be greatly reduced by using adult volunteers, under supervision, in clearing and various other tasks during the reorganization.

# Concluding Remarks

We conclude by urging that the entire project be well integrated and ecosystem-based. We feel it should take advantage of present and past river and riparian research along the Rio Grande, and that it should coordinate with other relevant projects and programs in the basin. We also suggest that it incorporate a seldom discussed but potentially catastrophic situation, namely major flooding of the Rio Grande. This could happen even with the river's present flood control devices in place – witness the extensive flooding of the upper Mississippi in 1993. Setting aside large tracts of remaining open space, possibly even including farmland, as sumps to receive direct overflows or water diverted through culverts or other openings in levees, could create temporary wetlands such as wet meadows and marshlands that were once common in the valley (Crawford et al. 1993).

In addition, we also strongly suggest that external assessment of both planning and progress – resembling, for example, the assessment employed by the Kissimee River Restoration Evaluation Program (Dahm et al. 1995) -- will add credibility to the project and flexibility to its operation over time. Finally, we note that many of the recommendations detailed in the Middle Rio Grande Bosque Biological Management Plan (Crawford et al. 1993) are nested in our proposal, and if seriously considered by resource managers will add historical consistency to the proposal's implementation.

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