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Taking out the jacks : issues of jetty jack removal in bosque and river restoration planning

Kathy Grassel

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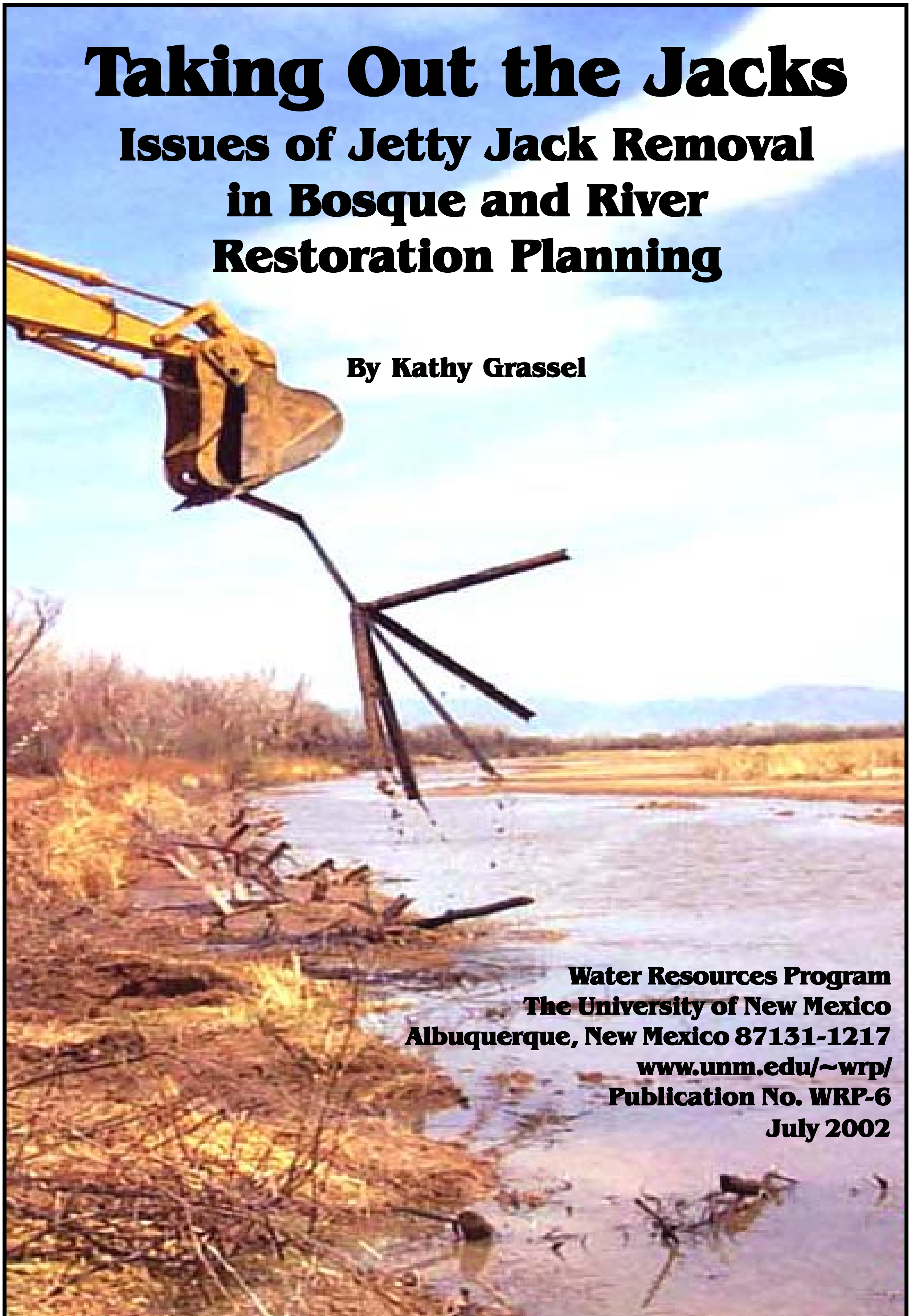

By Kathy Grassel

Water Resources Program
The University of New Mexico
Albuquerque, New Mexico 87131-1217
www.unm.edu/~wrp/
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Acknowledgments

I would like to thank my committee chairman Michael Campana for his prodding and patience and friendship, Bill Fleming for his unswerving support of students, and Cliff Crawford to whom I credit my abiding interest in the bosque.

I would also like to thank Scott Anderholm at the U.S. Geological Survey for his support, patience, and mentoring through the last two years, and for cutting me some slack while I finished this report.

I am grateful to my parents for their genes and their steadiness, some of both of which were passed down to me, and for standing by through my many years of "higher education."

I would like to acknowledge all the people who won't give up on restoration, no matter what.

And then there's my dog Chuck who for the last 12 years has enthusiastically run hundreds of miles by my side in the bosque. I haven't been able to get anyone else to do that.

Abstract

This professional project report presents a history of jetty jacks from the 1940s to the present, and offers some comments and recommendations on what the future has in store for jetty jacks based on the past. This history will trace how:

- jetty jacks contributed to the success of the massive human undertaking of re-shaping the Rio Grande for the protection of property, levees, and riverbanks from flooding;
- the role of jetty jacks was expanded to the establishment of a straight channel in the Middle Rio Grande Valley;
- jetty jacks in a post-dam era have lost their function, and finally
- present-day managers are grappling with balancing past technology with present demands.

End-users of a jetty-jack analysis value information relating to their specific mission. To provide context for that edification, this paper reviews not only the history of jetty jacks and their role in flood and erosion control, but also discusses the issues surrounding their former usefulness, present redundancy, and potential stumbling blocks to their removal based on varying positions of the resource agencies.

This paper is qualitiative, to be used as a starting point for further discussion. I will look at three restoration projects that are either in the study or implementation phase and that include jetty jack removal, a prism through which a sharper picture will hopefully be illumined.

Introduction

Jetty jacks have outlived their usefulness. So agree those agencies responsible for the installation and/or eventual removal of these large, crossed steel structures that served to trap sediment to stabilize the banks of the Rio Grande. These agencies include the U.S. Fish and Wildlife Service, the Bureau of Reclamation, the U.S. Army Corps of Engineers, and the Middle Rio Grande Conservancy District. These agencies, among many others, are involved in ecosystem improvement projects that may entail the removal of all or a portion of jetty jacks that line the riverbank and crosshatch the river's riparian zones.

According to one official at the U.S. Army Corps of Engineers (Blake, pers com.), there are "a zillion studies" about how to improve the river. A few of these studies mention jetty jacks, but none contains details about their function, or if and how their removal should be accomplished, or how much it should cost. They are a subset in the shadow of the larger effort of non-native vegetation removal, or they are a minor player in the uncertain climate of water allocation in an era of endangered species recovery and impending drought conditions.

No single document exists presenting the locations of the jacks. The installations were accomplished by different agencies at different times and for different reasons. Installations in the Rio Grande began in earnest in the 1950s and continued through the 60s. Additional spot installations occurred as late as the 1980s and 90s (Baird, pers. com.).

Today, as agencies consider removal of all or some portion of jetty jacks, some analysis of their continued function or obsolescence is needed. A discussion of the role of jetty jacks, historically, now, and for the future, is intended to be a useful informational tool for end-users and the public, providing a context for inclusion of jetty jacks in restoration decision-making. To date, analysis on a case-by-case basis has been expedient since plans for jetty jack removal is project-driven. As projects are proposed and implemented, a plan for removal and disposition of jetty jacks becomes essential.

Objectives and Scope

This is a simple but important paper.

My ulterior motive in presenting this history is a wish that it serve as a resource to agencies, project managers, consultants, government divisions, restoration biologists, and anyone with an interest in a functioning riverine and riparian ecosystem— end users wishing to add more to their information base about jetty jacks to further their particular restoration goals. Bringing the past up to the present, I wish to add to the historical database of the rise and fall of jetty jacks in the context of the times.

A further objective is to highlight certain restoration projects in the making whose results will no doubt provide invaluable know-how and data for future projects that are sure to come and sure to involve decisions about jetty jack removal.

A final objective is to illustrate restoration constraints in light of differing agency missions, but how collaborative effort and decision-making (in other words, working together), while painstaking, is the appropriate vehicle for present and future gains in the shifting sands of restoration ecology management.

For now, nothing is known of methods, nor thus benefits and/or consequences of removing jetty fields because they have yet to be removed on a large scale. Since restoration projects tend to occur in phases, with each phase often yielding stand-alone results, I would wish that the jetty jack removal gain status as an object of meaningful study in its own right to be eventually added the pantheon of solvable restoration issues. By bringing information together into one document, I hope to advance that objective.

This report offers an opportunity for advancing knowledge for more study and creating incentive to do the hard work of finding alternatives to a bank protection system that no longer functions.

On the advice of Dr. Cliff Crawford who has had many years of experience in the field of restoration, I have limited the scope of this report to jetty jacks alone, resisting the temptation to get tangled in the imbroglios that restoration issues present. For this advice I am deeply grateful.

History of Development

H.F. Kellner was responsible for the first jetty jack, and while the name "Kellner jack" is still found in the literature, his name has been largely dropped in favor of the more colloquial moniker “jetty jacks.” We don’t even know if Mr. Kellner was a construction engineer, but we do know that he founded the Kellner Jetties Company in the early 1920s (U.S. Army Corps of Engineers 1953). The company’s product was a permeable form of bank protection did the job at a lower cost than the nonpermeable types of bank protection then in use. Mr. Kellner started his experiments on a small stream near his home in Topeka, Kansas. He made his first jack with three willow poles tied together at the mid-point. To

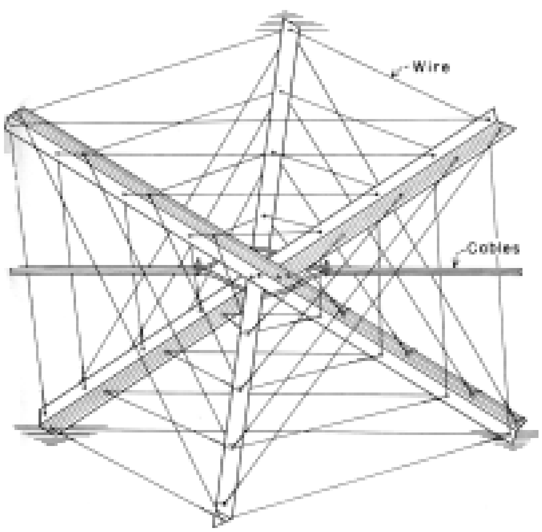


Fig. 1: Standard jack design

Fig. 2: Intact jack in the bosque

keep the willow poles extended, he laced them with wire. He replaced the willows with the steel angle design that is the standard today and has changed very little since these early days, as seen above in Fig. 1. The company continued to do research in both design improvements and installation methods, and kept its patent rights current while doing so. The company's competitive advantage was its ability to design effective layouts of jetty systems that gave the end user the desired protection, and to come up with methods of shop fabrication to simplify shipping and assembly. The price was also competitive (U.S. Army Corps of Engineers 1953).

These days we observe a Kellner jetty in less than mint condition and it is most often tangled with vegetation, underwater, detached from its original line, or partly exposed. Occasionally we see a fairly intact high-and-dry jetty line as in the Fig. 2 above that gives us an idea of how it might go together. It is prudent to know how it goes together to effectively remove it, repair or retrofit it. The structural unit of the system is called a jack. It is a standard unit; they all look alike, no variations. It is composed of three 16-foot long 4 in. x 4 in. x ¼ in. steel angles. These three angles are bolted together at their midpoints. The angles are placed back to back with their longitudinal axes at right angles to each other. The angles are fastened into place and form three sets of intersecting planes, their common point at the center. The planes are maintained by lacing them with wire at 15-inch intervals. Then they are linked together in a line with thick cable to form a jetty.

The cables extend in a continuous line through the units and are fastened at each end of the jetty to what are called deadman anchors. These are standard creosoted 8-foot railroad ties buried about halfway into the ground. Usually about 16 units are assembled and positioned at a time.

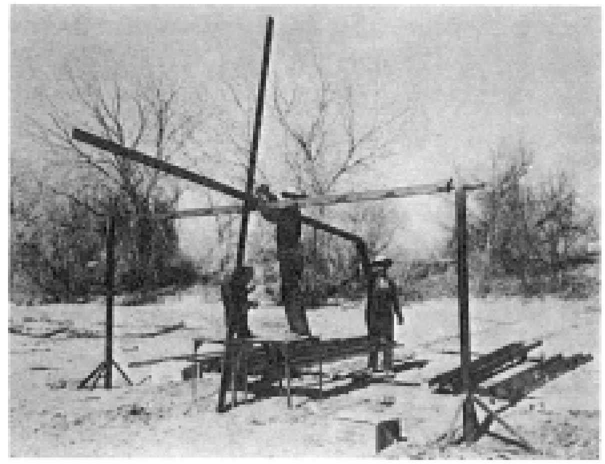


Fig. 3: Workers assemble a jack on site. Casa Colorada area, Middle Rio Grande Project, NM. Photo:Herman E. Carter, Bureau of Reclamation (Carlson and Enger 1956).

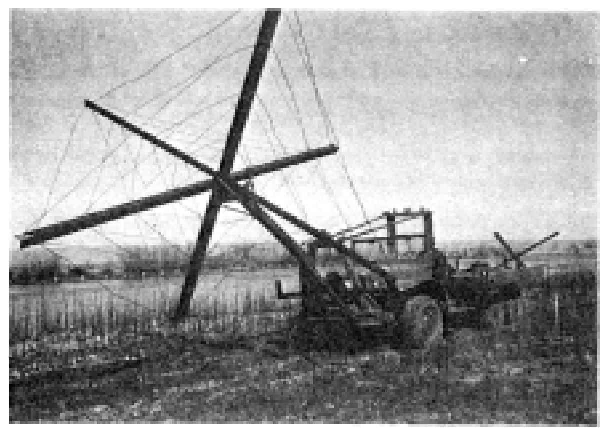


Fig. 4: Jack unit is moved to position in jetty field by a winch controlled lift. Casa Colorada area, Middle Rio Grande Project, NM. Photo:Herman E. Carter, Bureau of Reclamation (Carlson and Enger 1956).

Out of the Factory, Into the River: Assembly and Installation

The angles were set at the factory, after which connection holes and lacing holes were punched into the angles. At this point, the parts were ready to ship to the user. From the Topeka factory, the Kellner Jetties Company would send out crates full of steel angles, lacing wire, cable, cable clamps, and railroad ties. The shipment would be hauled to the job site for assembly. The company also furnished a construction supervisor who employed a crew of 12 laborers—12 was optimum—using hand tools. The crew assembled the units (see Fig. 3), then carried, hauled (see Fig. 4), rolled, or rafted them into place, 12 ½ feet apart. They then threaded the units together with double lines of thick ¾-inch diameter cable and clamped the cables together at the unit center points. Excavation was rarely required to position the jacks (U.S. Army Corps of Engineers 1953). See a schematic of a jetty field in Fig. 5.

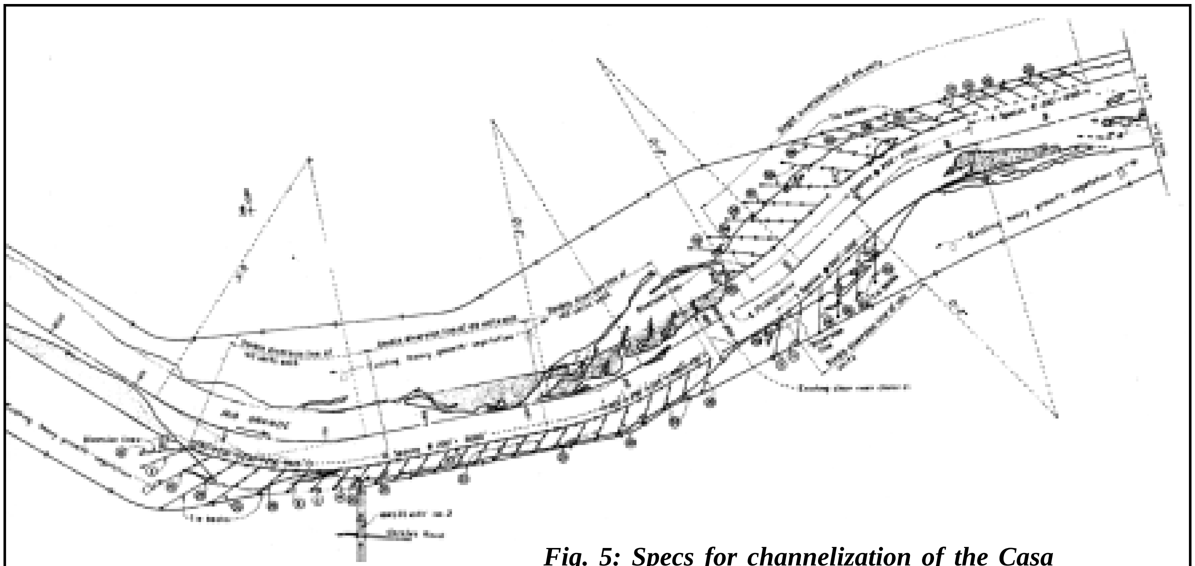


Fig. 5: Specs for channelization of the Casa Colorada reach, Rio Grande (Carlson and Enger 1956)

How Do Jetty Jacks Work?

If correctly installed, a jetty jack field will trap sediment and debris during flood events and essentially build up its own levee to confine the river channel. A jetty system is designed to conform to the existing regime of the river. The system prefers a concave bank of a meandering channel. The usual design employs variations on a theme of diversion lines paralleling the bank and backup retard lines, alternatively called tieback lines (see Fig. 5 above). They are called diversion lines because they provide diversion of the river current. The number of front lines varies from one to three (or more) depending on the angle of attack by the current. If the angle of the current is greater than 45 degrees, there is potential for damage of individual jacks in the line. At 20 degrees, the current can be trained around the curve (U.S. Army Corps of Engineers 1953). The sharper the angle, the more diversion lines are needed. Effective silt deposition can be achieved with one line but is vulnerable to damage by floods carrying heavy debris. The backup retard lines extend from the diversion lines in the river channel to the bank and are anchored at the bank line. Their spacing varies from 75 feet to 200 feet depending on the current's angle of attack, the more severe the angle the closer the spacing. They are called retard lines because they further retard the velocity of the current passing the diversion lines, thus inducing sediment deposition. As a rule of design, if the angle of attack is 20 degrees, the current should cut at least four lines; if the attack is 45 degrees, it should cut at least six lines.

The Early Days of Jetty Jack Installations

The Arkansas River saw the first installations of jetty systems by the Albuquerque District of the U.S. Corps of Engineers, with five on the Arkansas and two on the Rio Grande completed in the early 1950s. Seven additional installations on the Rio Grande were completed by 1953. Two of the completed jetty projects—one on the Purgatorie River in Higbee, Colorado, and the other on the Arkansas River in Manzanola, Colorado—experienced high flows soon after installation so the efficacy of the jetty system was verified. In both cases, there was damage to impermeable cribcell deflector dikes but not to the permeable jetty systems.

Bank protection was the original purpose of jetty jacks, and not just those federal agencies responsible for flood control availed themselves of the new technology. In fact, railroad and highway departments, as well as cities and counties, were the first public entities to successfully use Mr. Kellner's technology. They sought, as railroad and highway departments have always sought, to protect vulnerable areas in river systems that threatened their infrastructure.

In **Kansas**, the state highway department installed jetties to protect the bridge across the Cimarron River at Sitka. Before the jetty installation in 1950, the bridge abutment washed out twice and both times the bridge was extended. After the installation, the Department was able to remove the extensions.

In **Nebraska**, the Santa Fe Railway bridge protection project of 1947 demonstrated how jetties were used to establish a bank on a curve that matched the natural curve of the river. See Fig. 6 and Fig. 7 on the next page for what the area looked like before and after the installation. The system used a total of 980 jack units, consisting of 40 feet of retards, 1800 feet of double diversion lines, and 14 backup retard lines to achieve the new bank.

In **Oklahoma**, the railroad company in 1942 installed jetties to stabilize a high bank in a deep channel, a deviation from the recommended use of the system for low-to-moderate height banks. They graded the slope to 1:2 and then placed the jacks in the usual pattern except for tightly-spaced retard lines to form a gridiron of resistance.

In **New Mexico**, the Santa Fe Railroad used the jetty system several times with success starting in 1936. The embankment next to the banks of the Rio Galisteo had been protected by heavy riprap that was consistently washed out during floods. A jetty field was installed to build up an auxiliary bank.

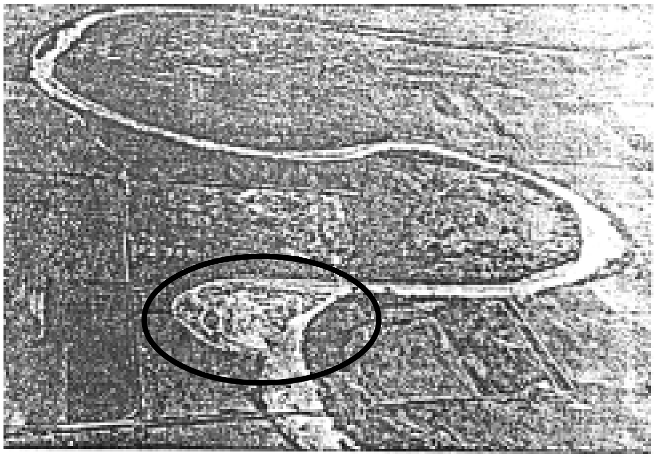


Fig. 6: Republican River in Superior, Nebraska, prior to installation in 1946. The work was performed on the large curve above the rail track.

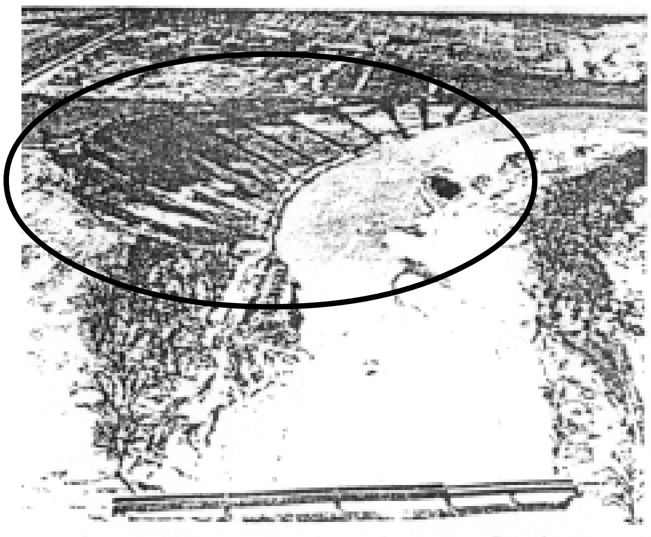


Fig. 7: A jetty field was installed in 1947 by the A.T. & S.F. Railway Co. The photo left is from 1949 and shows the results of the jetty project. The system used a total of 980 jack units: 40 feet of retards, 1800 feet of double diversion lines, and 14 backup retard lines. The jetty field is still visible on the upper bank of the river (U.S. Army Corps of Engineers 1953).

Another row of jacks were installed later where the attack of the river was directly against the embankment (U.S. Army Corps of Engineers 1953).

How Much Did a Jetty Field Cost ?

Jetty installations were quite inexpensive, and at the time, competed favorably against traditional structures that, besides being more costly, didn't work as well. One unit—a jack complete with lacing, cables, and anchors–cost $67.58. This figure was multiplied by the number of units and then divided by the lineal feet of bank protected. The average cost per lineal foot of protection for seven locations in the

Table 1: Costs of the Kellner jetty system in 1953
(based on bid prices received in March 1953)

Location	**No.Units**	**Unit cost**	**Lineal ft. bank protected**	**Cost/lineal ft. bank protected**
Santo Domingo	374	$67.58	1410	$17.93
Opposite Jemez Creek	1,149	$67.58	4475	$17.35
Bernalillo Sawmill	1,086	$67.58	4250	$17.27
Sandia Pueblo	1,142	$67.58	3625	$21.29
Chical area	435	$67.58	1900	$15.47
Los Lentes	978	$67.58	3700	$17.86
Below Los Lunas	432	$67.58	1880	$15.53
Average		**$67.58**		**$17.80**

Source: U.S. Army Corps of Engineers, Albuquerque District, 1953

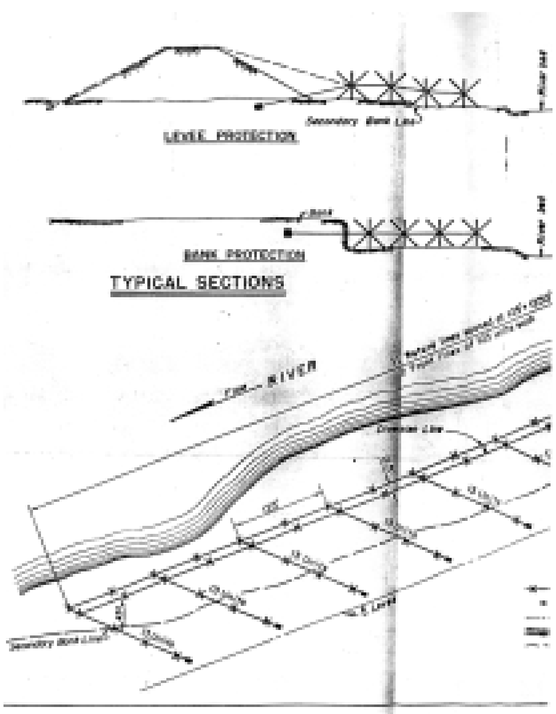


Fig. 8: How jetty jacks protect levees (top), banks (middle), and how the jetty field is configured for bank stabilization and levee protection (bottom). Source: U.S. Army Corps of Engineers 1953.

Albuquerque area was $17.80. A table reconstructed from the Civil Investigations paper by the U.S. Corps of Engineers is shown in Table 1.

What Was a Jetty System Used For?

The original purpose of jetties was bank protection. Jetties were used to hold existing riverbanks in place, restore degraded ones, or extend existing ones. They kept water away from the banks and caught silt, which builds up in front of the banks and is deposited within the jetty system. They proved to be ideal because they were permeable and flexible, which means they retain their protective value even when undermined by scour. The system was considered to be most effective in (what were at the time of installation) moderately sinuous and sediment-laden streams such as the Arkansas River and the Rio Grande.

Fig. 9: Installation of jetty field on the Rio Grande near Bernalillo, NM.
Aerial photos by the Corps of Engineers.

Fig. 9(a): Location of the jetty installation. Photo: Dec. 12, 1952.

Fig. 9(b): Jetty field installed. Photo: Aug. 12, 1953.

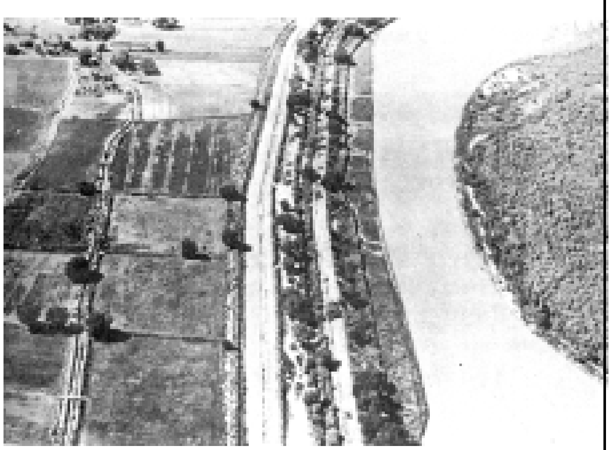


Fig. 9(c): Vegetation dominates in the mature jetty field. Photo Sept. 2, 1955.

They were also used for protection of flood control structures such as levees (see Fig. 8). Levees are rarely engineered and rather consist of dirt piled up from the excavation of the riverside drains and so are vulnerable to undermining by scour (Soards, pers. com.; Grogan, pers. com.). The jetty system was also used much like riprap for bank sloping where high banks are subjected to scour be varying river stage.

In the days of flood events before Cochiti Dam was built, jetty jacks were put to use in fighting floods (U.S. Army Corps of Engineers 1953). Because the unit parts were so easily stockpiled and quickly assembled, lines of jacks would be assembled on top of a threatened levee and then tipped over along the scoured area, providing instant resistance to erosion of the levee. Sometimes a second line would be tipped over on top of the first for further protection.

The Making of a Bosque

The flexible jetty jack system conforms to channel scour and allows sediment-laden water to penetrate an area of low kinetic energy where sediment drops out, thereby building a bank (Carlson and Enger1956, Lagasse 1980). A successful installation makes sediment beds at a rate of about one foot per year. These depositions make new ground for vegetation growth. Vegetation grows rapidly, usually within two years of installation of the jetty system. Vegetation increases the protective value of the jetty system as it greatly increases the resistance of the system to displacement during floods. Vegetation also locks in the new bank line. Fig. 9(a) illustrates the reach of the Rio Grand before jetty jack installation, in Fig. 9(b) how the field appeared in the river before vegetation, and in Fig. 9(c) how the area appeared after vegetation was established. Early reports noted growths of native vegetation such as cottonwood, willow, and grass, and also the non-native salt cedar (U.S. Army Corps of Engineers 1953).

Channelization in Vogue

Considering how successful the jetty system was in straightening out a meander, Mr. Kellner should not have been surprised when someone got the idea to use jetties to straighten out an entire river, in this case the reach comprising the entire middle Rio Grande Valley. It was in the mid-1950s when the Rio Grande Project was in full swing with massive excavations to construct conveyance channels and levees (Bureau of Reclamation 1952, 1953). A group of hydraulic engineers employed by the Bureau of Reclamation in Denver, CO, selected a prototype test reach in the Casa Colorada area of the Middle Rio Grande Valley south of Belen. Jetty fields were installed for the experimental purposes of establishing a channel. At the same time, the engineers developed a hydraulic model to duplicate scour and deposition in the prototype and to predict performance for higher discharges (Carlson and Enger1956). The Corps had already been installing jetty fields for some years; it is not known if the Bureau had higher performance standards such that it constructed a model and built and monitored a test site in the field.

Several things conspired to make channelization a reality. These were pre-dam days and the floodway of the Rio Grande was aggrading two feet every 50 years around Albuquerque and up to 16 feet near San Marcial (Lagasse 1980). Then during the high-flow years of 1941 and 1942, the channel underwent considerable scour and the overbank was raised by sediment overflow. Then the reverse happened during low-flow years that followed. Clearly channel rectification and stabilization were on people's minds. The jetty jack system had proven itself well adapted to silt-laden streams and readily conformed to channel scour. As discussed above, both the parallel diversion lines and perpendicular tieback lines reduce the velocity of the flow, allowing deposition of sediment within the jetty field, in a short time forming a stabilized bank on which rapid growth of vegetation further strengthens the area (Lagasse 1980). So jetty installation by the Corps of Engineers began in earnest in 1954. Two years later the Bureau of Reclamation joined in. By 1956, 17,000 jacks had been installed. In 1959, 83,000

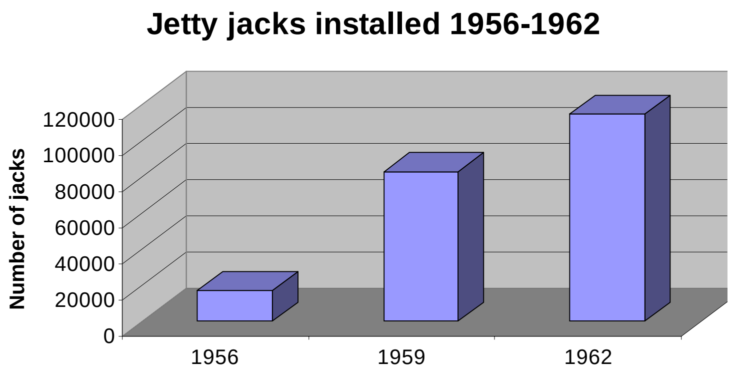


Fig. 10: Straightening the channel with jetty jacks

more units were installed. By 1962, a total of 115,000 jacks were in place (Lagasse 1980). Fig. 10 illustrates the rapidity of jetty jack installation between 1956 and 1962. These same years were years of low flow, so conditions were perfect both for rapid installation and subsequent stabilization of the jetty fields. The jetty fields did their work throughout the decade. They filled in; trees grew on the new banks created by the jetties; the new banks protected the new levees. From Cochiti to Bernardo the river was a well-defined stable channel with widths of 990 feet at Cochiti narrowing to 550 feet at Bernardo. During this same time and for a decade after, the dams were built and brought into operation.

But first, why all this fuss about straightening the channel? Back before jetty jacks and before the dams and before any works at all was a river with many thousands of irrigated acres. Toward the end of the 19th century, several things conspired to cause a massive crash in irrigated acreage, among them high sedimentation rates that caused a rising riverbed and flooding. These days also marked the beginning of big federal engineering projects, and the problem on the Rio Grande was deemed to have engineering solutions. A congressional authorization called the Rio Grande Reclamation Project marked the beginning of water diversion and delivery facility construction. The Middle Rio Grande Conservancy District (MRGCD) was formed in 1925 and in 10 years had constructed five diversion dams, miles of drainage canals, and levees. Both the U.S. Army Corps of Engineers and the Bureau of Reclamation were heavily involved. The Corps built the Jemez Canyon Dam in 1953, Abiquiu Dam and reservoir in 1963, Galisteo Dam in 1970, and Cochiti Dam and reservoir in 1973. Cochiti Dam was intended for flood and sediment control, and later for also arresting flood flows and retaining sediment. The intended effect was a halt to aggradation (channel bed raising through sediment accumulation) of the downstream channel and a return to degradation (channel bed lowering due to reduced sediment load). The Bureau of Reclamation as part of the Rio Grande Channelization Project was busy rehabilitating the MRGCD's irrigation and drainage systems, rectifying channels that included levee as well as channel improvements, and, importantly, installing jetty jack fields covering the 100 miles of the reach below Cochiti (U.S. Army Corps of Engineers and Bureau of Reclamation 2002, Crawford et al.1993, Lagasse 1980,

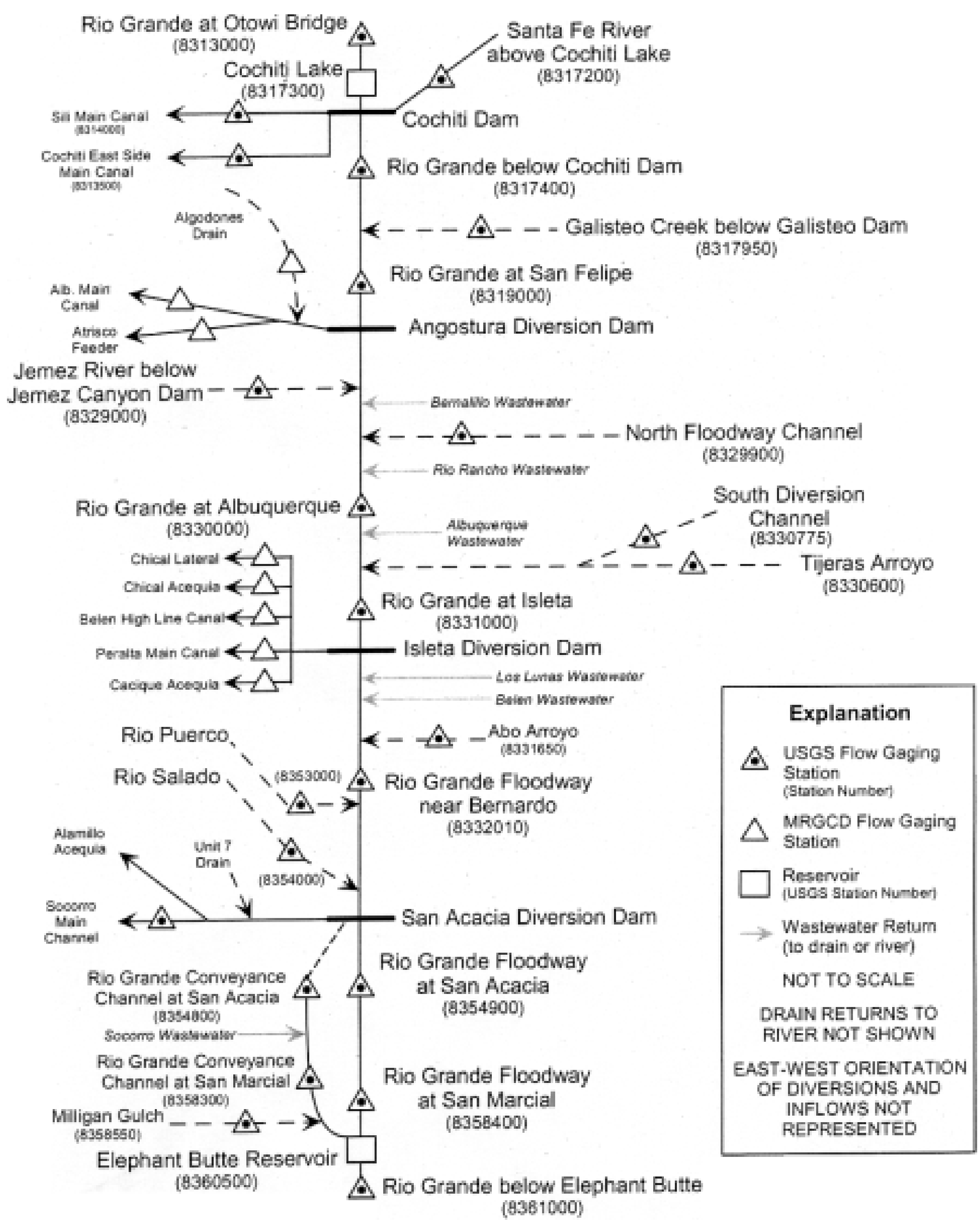
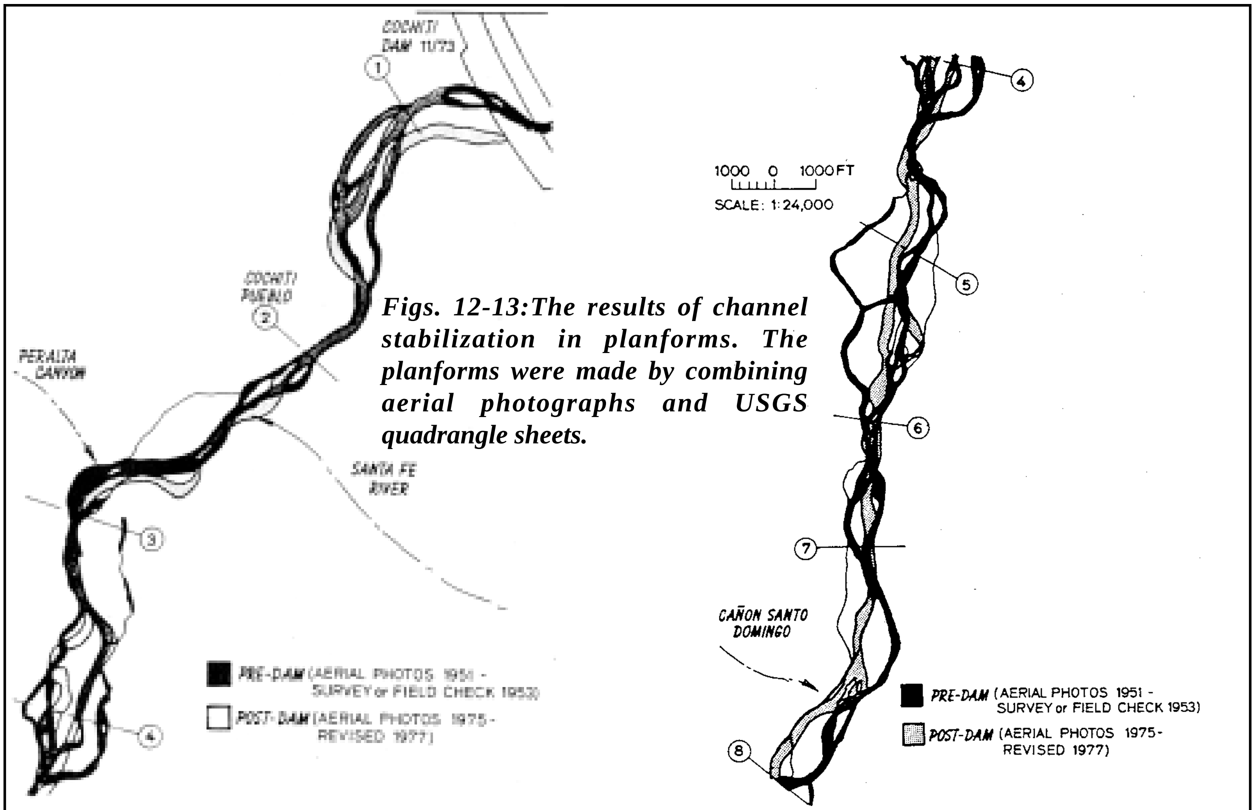


Fig 11: Inflows and Outflows of the Middle Rio Grande Valley. Source: S.S. Papadopulos & Associates, 2000. **Middle Rio Grande Water Supply Study.**



Figs. 12-13:The results of channel stabilization in planforms. The planforms were made by combining aerial photographs and USGS quadrangle sheets.

Najmi 2001). The Espanola floodway also saw extensive levee rehabilitation and channel straightening with jetty fields.

When it was all done, the Rio Grande was no longer a natural stream, but rather a highly modified water storage and water conveyance system with extensive flood control structures. See the Fig. 11 schematic above for a snapshot of the altered Rio Grande. Natural processes were sacrificed on the altar of a predictable, relatively risk-free platform for human activity and habitation. River regime and morphology were altered indelibly. See the planforms in Figs. 12 and 13 below to see the differences in the channel between the pre- and post-Cochiti Dam. Was this level of river management exaggerated? Was there an awareness that unintended consequences might follow such massive alterations? It depends on your point of view.

In 1960 in Albuquerque, the channel was eight feet above the urban area beyond the levees. (Aggradation occurs when the sediment added to the river exceeds the sediment being transported.) It's easy to understand how an aggraded riverbed creates a flood risk. It's easy to understand people's concern about the vulnerability of the levees. Also, the faith of the country at the time in engineering solutions to any physical problem should not be underestimated. The deep pockets of the federal government to further the development of the West should not be underestimated. So the channel was modified so people could live in the floodplain and farmers could irrigate their acres. The age of biology and ecosystem awareness was to come later. Meanwhile, the public good was served. Everybody was happy.

Rather than post-dam response, the jetty fields and bosque vegetation are attributed as largely responsible for the stable channel position observed in the planforms. Interestingly, the stabilization and rectification of the floodway channel between 1954 and 1962 had, by the early 1970s, begun to accomplish the desired effect of reversing the long-term aggradational trend and lowering bed elevations.(Lagasse 1980). But that's water over the dam, as they say.

The Post-Dam Era and the Kiss of Death for Jetty Jacks

Cochiti Dam went into operation in 1973. With Jemez Canyon, Galisteo, and Cochiti dams in operation, an estimated 80 percent of the sediment inflow to the Rio Grande above Albuquerque was controlled (Lagasse 1980).

The key word here in determining the future and fate of jetty jacks is sediment. It was perhaps an unintended consequence that Cochiti Dam, constructed for flood control and sediment control, would starve the jetty fields of the very substance that allowed them to function so well. Without a sediment supply accompanied by adequate flow, the jetty jacks don't work. Bank protection again becomes an issue, which means fortification of bank lines using vegetation becomes increasingly important. Lagasse summarizes the problem in his 1980 study:

"…processes set in motion by … Cochiti dam … may dictate against the installation of any new jetty fields for channel stabilization. Permeable jetties are effective only if there is a significant amount of debris carried by the stream, and the suspended sediment concentration must be large so that there will be deposition in the jetty field. The general tendency toward post-dam degradation in the Cochiti to Isleta reach and the development of armored reaches below the dam are strong indicators of a changing sediment regime below the dam and less favorable conditions for jetty stabilization. Less frequent inundation of flood plain area and depriving the main stem of such major sediment source areas as the Jemez River will also reduce the effectiveness of the jetty fields. A degradational environment and reduced sediment supply will induce scour in the jetty fields, and the existing lines of jetties could eventually be undercut and buried." (1980)

Comparison of cross section data from 1975 to 1995 showed that the Santa Ana reach had been losing 140,000 tons of sediment per year. Riverbed material became coarser over time as fine sediments were trapped by the dam. Prior to dam construction, the median bed material was fine sand of 0.2 mm in size. Recent bed material samples were in the gravel range, measuring on the order of 7 to 20 mm (U.S. Army Corps of Engineers 2002).

Photographs below (see Figures 14, 15 and 16) of the present condition of random jacks in the Middle Valley indicate that Lagasse's calculation that then existing lines could be undercut and buried has been borne out.

Whether or not it was considered that the bank stabilization that jetty jacks provided would be less crucial with the dam's ability to control the flow regime is not reflected in the literature, but logic would dictate that dam function would supersede the major role heretofore performed by jetty field installations, and that loss of jetty function would be an acceptable consequence of superior development techniques represented by the dams.

The Present: The Rise of Environmentalism and Fall of Jetty Jacks

The present is differentiated from the past by an awareness of the decline of the condition of the river and its bosque. The engineering feats of the 1950s and 1960s are seen to be a culprit inasmuch as their dam-building and channelization successes produced unintended consequences.

Some authorities attribute a part of this decline to jetty jacks freezing river banks in place, interrupting natural processes of the river, disturbing habitats of species now extirpated or endangered, and promoting exotic species at the expense of native vegetation (Tashjian, AWRA Abstract Proceedings 2001; Hoagstrom, pers.com.). Others are less disposed to ascribe so much credit to jetty jacks for ecosystem decline, but overall awareness of this decline has resulted over a short period of time in a shifting paradigm of thought about water management and policy, combined with action on the ground in the form of restoration projects. Some of these projects include jetty jack removal. I will discuss these projects in some detail, but first I would like to present some characteristic points of view of those directly involved in these and future projects and others who may be affected by removal of the jetty system that has been keeping river banks in place for almost a half century.

The Players

Potential end-users of a document about jetty jacks are not interested in the same thing; there is no uniform agreement about the need for the ubiquitous jetty jack and how it is viewed. In light of constrictions of agency missions, it is not surprising that viewpoints are conflicting.

To illustrate, the following agencies are potential end-users of information about use of jetty jacks in certain locations and associated environmental data. Each, with differing missions and concerns, should be able to use the same information to satisfy their end uses.

• The U.S. Fish and Wildlife Service views jetty jack removal as key to restoring river function. An actively cutting bank would result in a sediment supply for the river and reconnect the channel to its floodplain. The jetty jacks most important for removal would be those paralleling the river, removal that would lower the banks and allow the river to form its own banks again. This would include active erosion along the banks in certain places, such as meander bends (Tashjian, pers. com., Hoagstrom, pers. com). This agency maintains the jetty jack lines against the levees are serving an important purpose, that is additional protection for the levee in the event of flooding.

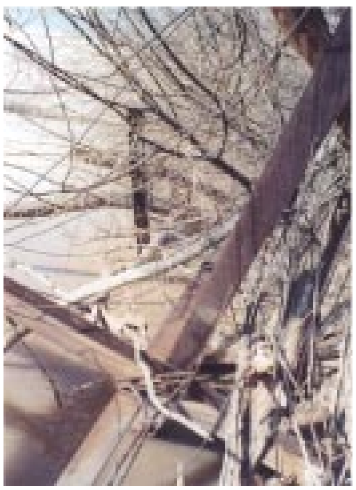


Fig. 14: The MRGCD wants riverbank jacks to stay in place for levee protection

• The U.S. Army Corps of Engineers will remove jetty jacks, too, but its purpose varies depending on the project. The Rio Grande Valley State Park enhancement project does not include any consideration of active erosion. As part of Sen. Pete Domenici's 2001 initiative to apply restoration measures in the bosque, the Corps plans to spend $10 million over the next decade (Blake, pers. com.). Its first task is to remove as-yet-unselected jetty jacks from the bosque west of the levee from Tingley Beach near the Old Town Bridge and the National Hispanic Cultural Center near Barelas Bridge. The non-federal cooperators, the City of Albuquerque Open Space Division and the MRGCD, view jetty jack thinning as a precursor to recreation enhancement and native vegetation restoration. The Corps will leave in place jacks running parallel in the channel; only a portion of the tieback jacks are slated for removal. The lines parallel to the riverbank are considered essential for levee protection. Consultants are contracted to determine the most efficient and cost-effective way to remove jacks, and to what distance the tieback units may be removed without jeopardizing the integrity of the riverbank lines (Walhood, Bohannan Houston, pers. com.; Lewiecki, Sites Southwest, pers. com.).

• The Office of the State Engineer (OSE) and the Interstate Stream Commission (ISC), responsible for water deliveries downstream, are bound by law to deliver a specified quantity of water. Jetty jack removal, especially those lodged in the banks that created a narrow channel for efficient water delivery, would result in bank sloughing, widening of the channel, reduced velocity, and greater surface evaporative potential. Jetty removal without corresponding non-native phreatophyte replacement could compromise the amount and efficiency of water deliveries. The ISC is also reluctant to accept another agency's data, and equally reluctant to share its own data, especially with those agencies considered to be working at cross purposes, such as the Fish and Wildlife Service (Tashjian, pers. com.).

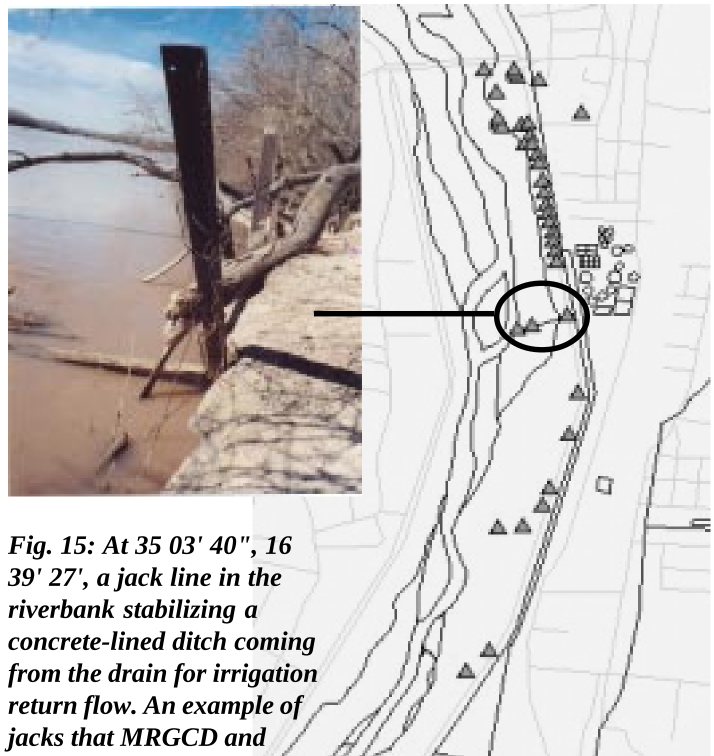


Fig. 15: At 35 03' 40", 16 39' 27', a jack line in the riverbank stabilizing a concrete-lined ditch coming from the drain for irrigation return flow. An example of jacks that MRGCD and others would oppose removing.

Photo and GIS: Kgrassel

• People in support of the Domenici rehabilitation initiative for a revitalized bosque to create an urban park will consider the aesthetic value of jack removal and how cleanup contributes to an area where people will want to recreate. For these parties, consideration of restoration of dynamic river function is secondary.

• The Middle Rio Grande Conservancy District (MRGCD) is a cooperator in the City of Albuquerque Tingley Beach restoration, a project that includes construction and maintenance of ponds and wetlands construction on the west side of Tingley Drive. The area is currently overgrown with exotic vegetation and snarled with jetty jacks. The MRGCD is supportive of jetty jack removal to accomplish the goals of the project, but not those jacks that define the river channel whose removal could threaten the levees in the event of flood events. The MRGCD is responsible for levee maintenance. Its position is that it can't afford to remove protective jacks until the levees have been reinforced. Levees in their current condition, made by piling up dirt from the excavation of the riverside drains, would not withstand a major flood event. (Grogan, pers. com).

• The U.S. Fish and Wildlife Service in its mission of floodplain restoration within the levees understands the need for the levees and protection for those levees (Tashjian, pers. com.). If the channel bank is free of jacks and vegetation, the Service favors leaving or placing jacks along the levees to protect them and prevent flooding, the same jacks that the Corps of Engineers, in cooperation with the City of Albuquerque Open Space Division and the MRGCD, proposes to remove in the Rio Grande Valley State Park restoration project.

The above comprise just a sample of the total number of stakeholders in the middle Rio Grande reach. In total they include counties (four), towns and cities (nine including Albuquerque), pueblos (six), federal agencies (four), state agencies (five), flood control authorities, irrigation districts, environmentalist groups, recreationists, urban water users, endangered species, Texans, individual concerned citizens, and farmers, each with their respective interests, perspectives, and missions comprising a complex political ecology (Crawford et al. 1993).

What can be found in common among these interests is a desire to protect the levees, which means that in areas where levees and jetty jack co-exist, jetty jacks are the first and second lines of defense. Much of the discussion of which jetty jacks the bosque and river can live without is driven by this exigency. This means, just as in real estate, only three things are important when designing a removal plan: location, location, and location.

Fig. 16: In the Rio Grande facing west at the Los Lunas restoration site, west bank. Note the buried jack in the foreground center bottom. The jetty line in the bank respresents the landward diversion line installed behind the riverward line. Both lines will be removed.

Jetty Jack Removal in the Rio Grande Habitat Restoration Project in Los Lunas, NM

This project is a collaborative effort of the U.S. Army Corps of Engineers and the Bureau of Reclamation with the Middle Rio Grande Conservancy District a non-federal cooperator. The Los Lunas project, 6,000 feet in length and 40 acres in area, is expected to cost $1.5 million (Gorbach, pers. com.) over three years. The overall goal is to widen the river channel and lower river banks to produce shallow water habitats, overbank flooding, and stands of willows and cottonwoods. The first of three phases is the permanent removal of 1,355 jetty jacks (U.S. Army Corps of Engineers and Bureau of Reclamation 2002). This is the first real experience with extensive jetty jack removal (Gorbach, pers.com.). Other aspects of the project are also untested. The restoration project is considered to be an effort to gain knowledge and experience in the applications of channel expansion, with the goals of the project in line with the recommendations in the *Bosque Biological Management Plan* (U.S. Army Corps of Engineers and Bureau of Reclamation 2002, Crawford et al., 1993). Great numbers of people are looking to the Los Lunas project to set a precedent for extensive restoration efforts in the Middle Rio Grande Valley (U.S. Army Corps of Engineers and Bureau of Reclamation 2002). The removal of 1,355 jetty jacks and the activities around it are expected to take from one to several months. (Gorbach, pers.com.). The reasons for their removal are threefold: (1) they've done their job and Cochiti is continuing its work; (2) the U.S. Fish and Wildlife Service wants to restore river function; and (3) the Corps/BOR/MRGCD wants to make a better bosque (Gorbach, pers. com). The overall goal of the project is to produce inundation of the area at flows of 2,500 cubic feet per second or greater. To accomplish this, once the jetties are removed,

Fig. 17: Los Lunas, west bank. The first day of jetty jack removal, Apr. 9, 2002. Bankline jacks are the first to be removed. The job of removing 1,355 jacks is expected to take one to several months. Photo by Mark Horner, U.S. Army Corps of Engineers.

bank elevation will be lowered by moving tons of bank material away and up against the levees. The result will be 40 acres lowered and designed to take advantage of higher flows.

As noted above, the jacks were placed to establish a bank and as a buffer to protect the levees. As lowering riverbanks and cutting channels into the area may be the only way to reconnect the river to the bosque, removal of the jacks holding those banks is the first step. Unlike in the Cochiti area below the dam where the paucity of sediment supply has caused erosion behind the jetty lines and rendered them useless, the second tier of jacks in the Los Lunas area has maintained the bank line. The vegetation built up behind the bank line provides a buffer between the river and the levee (see Fig. 16 above).

The original jetty jack installation in the current project area consisted of two front diversion lines paralleling the bank line, 480 jacks in each row to make a total of 960, to establish the riverbank with 395 tieback lines to the levee. The riverward row is positioned on the toe of the bank and is mostly buried except for one-to-three feet of upward facing limbs (see Fig. 17). An excavator will pull the jacks toward the land to remove what can be pulled out; the rest will be dug out. The landward row is positioned along the bank itself and is also buried except for four-to-six feet of the upward facing limbs exposed (see Fig. 18). After the jacks are removed, any excavated area will be allowed to fill naturally from sloughing along the bank. The tieback jacks slated for removal are on land above ordinary high water; the tiebacks left behind will serve to arrest unwanted bank erosion (U.S. Corps of Engineers and Bureau of Reclamation 2002).

Fig. 18: Dense dead vegetation dominates the post-fire Los Lunas bosque. Heavy equipment is used to pull out this landward diversion line parallel to the river. Photo by Mark Horner, U.S. Army Corps of Engineers.

While this much is known, no analysis was conducted to assess feasibility of removal or to predict the effects of removal of the jetties. The mostly buried river jacks were expected to crumble when pressure was applied to extract them, but the jacks came out much easier than expected (Tashjian, pers. com.). The tieback lines are expected to come out fairly easily, even though interspersed with dense vegetation.

The cost of removing the jetties is not known, but rather built into the package that includes constructing the staging area and clearing access to the site. The figures below correspond to the unit costs of jetty jack removal in 2000 for the ongoing Santa Ana Restoration Project. The numbers are based on the removal of 1,600 jacks at Santa Ana, comparable to 1,355 at Los Lunas. Hence, costs of total removal would total $259,000. If accurate, the cost of jetty jack removal will total 17.3 percent of a total $1.5 million project budget (see Table 2 below).

Table 2: Estimated costs of removing jetty jacks, by category

Type	Removal/unit	No. jacks/ 6,000 ft.	Total
Unburied jacks	$140	395	$ 55,300
Partially buried	$180	480	$ 86,400
Buried in river bank line	$225	480	$118,000
Total		**1,355**	**$259,700**

The Conservancy District intends to salvage them and use them for check structures (Gorbach, pers. com.). Beyond the experience of three Indian pueblos—Santa Ana, Sandia, and Isleta—which selectively have removed a small number of jacks, Los Lunas is thought to be the first opportunity to observe and monitor the effects of extensive removal.

Because of heavy equipment needing access in the entire site area, and storage and refueling staging areas, construction impacts are many, involving the removal of almost all vegetation, but because the restoration site suffered a severe burn in April 2000, excavation avoids impacting a non-burned area. Throughout the burn area, the standing trees are black and the mature canopy is a skeleton. The understory has turned into a mass of dense herbaceous growth. The area is a highly degraded system.

Collaboration: the Hard Part of the Los Lunas Project

This is the era of mandatory collaboration. The Los Lunas project is being done as part of the agreement that was reached in the summer of 2001 in the Minnow vs. Keys case, the lawsuit brought by environmental groups against the U.S. Army Corps of Engineers, the Bureau of Reclamation, and interveners, the MRGCD, the State of New Mexico and others. The project partly satisfies the requirements of the Reasonable and Prudent Alternatives (RPA) for the Biological Opinion (BO) delivered to the Corps and Reclamation by the U.S. Fish & Wildlife Service. The BO requires eight projects; Los Lunas is the first of the eight (U.S. Army Corps of Engineers and Bureau of Reclamation 2002). The Bureau of Reclamation and others are engaged in trying to develop an authorized program that will be funded federally and by non-federal entities. This requires developing an agreement to pursue a collaborative program to engage in restoration to address river management, a formalized program called the Middle Rio Grande ESA Collaborative Program (U.S. Fish and Wildlife Service 2001). It is largely driven by the need for water users to comply with the Endangered Species Act. The aim of the collaborative program is to navigate the field of issues and provide the wherewithal to conserve the species as well as meet the needs of the cultural community and the cities (Gorbach, pers. com). This came up after the BO evaluated the implications of the Bureau of Reclamation's water management practices and the U.S. Army Corps of Engineers' ordinary water operations on the middle Rio Grande and concluded that their practices jeopardize the silvery minnow and the willow flycatcher. The U.S. Fish and Wildlife Service developed the RPA, which resulted in the Los Lunas project. The BO will cover the next two years and beyond that the agencies must have in place a collaborative program and hence funding for implementation both from federal and non-federal sources (Gorbach, pers. com.).

The Los Lunas project was scheduled to begin in December 2001, and after experiencing delays, got underway in mid-April 2002. The holdups were bureaucratic, a source of frustration for those who had been trying to get to work. As in any collaborative effort, a typical process that defines natural resource management decision-making in contemporary times, many competing needs and cumbersome processes have to be served. The front-end work needing to be done before the point of letting the contracts can be daunting. The legal requirements, which include National Environmental Policy Act of 1969 (NEPA) compliance and endangered species consultations, are stringent. NEPA requires federal agencies to consider the environment when making decisions regarding their programs. Compliance requires an Environmental Assessment and a Finding of No Significant Impact (FONSI). The endangered species consultations are tiered into the Biological Assessment and the BO.

The complexity of the collaborative process has been working out the conflicts of different parties around the table and hammering out an agreement on some course of action that will conserve species and still allow other activities to continue. Its purpose is to protect and improve the status of listed species while existing and future water uses are protected and proceed in compliance with all applicable laws. Applicable laws run the gamut from the ESA, NEPA, the Safe Drinking Water Act, the Clean Water Act, Indian trust responsibilities, tribal laws, state water laws, and interstate compacts to international treaties governing the allocation of water. Collaboration is in essence a law in that the funding mechanisms require it, and the benefits accrue to all the program participants. Participants can number into the dozens. This process goes on as people try to grapple with the needs of resource management in a way that is respectful of all the different interests involved. On a smaller scale, federal agencies have certain authorities that define a continuum depending on the nature of the work so a job can be done relatively easily and quickly. A collaborative program is complex, composed of a lot of players, and has been a large challenge for people not accustomed to working across agency parameters and missions (Gorbach, pers.com.).

According to the Bureau of Reclamation's Chris Gorbach, a participant in the collaborative program work group,

"Science is the easy part. To me, the human factor, the politics, getting people to collaborate and work together, is endlessly frustrating and fascinating. The management part of it is more challenging and interesting than the science aspects of it. Not that those things don't overlap, but the real challenge in resource management and water management is getting people to sit down and plow through the very difficult job of working out their competing interests. If anyone thinks that the management and policy aspects of water management is soft, they're invited to sit in on ESA work group sessions."

Breaking the Cycle of Talking in the Rio Grande Valley State Park

Similar management issues beleaguer project players responsible for the the Rio Grande Valley State Park project. It's a 10-year program budgeted for $20 million to revitalize 500 acres of bosque from Paseo del Norte to Rio Bravo Blvd. The U.S. Army Corps of Engineers is the lead agency with the MRGCD and Albuquerque Open Space cooperating. When Sen. Pete Domenici succeeded in securing federal funding to initiate a revitalized bosque project in Albuquerque, it turned out that Congress intended the money to be more "study money." Fritz Blake, project manager with the Corps, wants to use jetty jack removal as a way to get on the ground and break the cycle of talking. The Corps has hired the consulting firms Bohannan Houston Inc. and Sites Southwest to do planning studies and engineering. As Sen. Domenici expressed a wish to see something on the ground quickly, the Corps is paying consultants to perform a study to determine the best way to remove jetty jacks (Blake, pers. com.). Whether to rip them out, cut them up, pull them out straight, pull them out sideways, excavate around them, torch them off at the base, build a trail on top, or pile over them and vegetate on top are several options being looked at by the consulting firms (Walhood, pers. com). The firms are also taking a wait-and-see stance to see how the Los Lunas project jetty jack removal progresses and they will then proceed on a lessons-learned basis (Walhood, Lewiecki, pers. com.). There is also a question of how many to take out. At more than 1,000 jacks per mile (Grogan, pers. com), at upwards of $200 to

$300 a jack (Walhood, pers. com), many considerations need to be weighed for a feasibility study before work can start.

Fig. 19: Dead and down wood tangled in jetty jacks in the bosque, slated for removal as part of the Rio Grande Valley State Park restoration project. Jetty jacks armor the river banks and prevent overbank flooding, so wood litter can't decompose, making it ready fuel for fires.

It's a big undertaking but may not accomplish riverine restoration as much as a healthier bosque. After selective jetty jack thinning, the plan is to clear out dead and down trees (see Fig. 19), improve habitat for species in the bosque by removing non-native trees, offer salvage wood to the public to get it off the premises, put in passive recreation, and formalize the trails. While it is agreed that jetty jacks are not serving a purpose any more, that the actual trees and shrubs in the bosque serve the same purpose as the jacks did by slowing down the water, there is no plan so far to remove any jacks that run parallel along the channel, rather only the tieback jacks. There is concern that the State Engineer would disapprove because removal there would make the bank slough off, widen the channel, and decrease the efficiency of the water deliveries. The project can't lose any water (Blake, pers. com.), though to date there is no way to accurately measure actual water loss by ET and widening of the channel.

As part of one of the three parts of this study, jacks are slated to come out near the Hispanic Cultural Center and near Tingley Beach. Figures 20 and 21 include maps of the two restoration areas, respectively, with an overlay of select jetty jack locations.

Fig. 22: Results of jetty jack removal and exotic vegetation removal. Todd Caplan, project engineer for the Pueblo and the Bureau of Reclamation, gives a tour in the cottonwood bosque at Santa Ana restoration project area, 1999.

Santa Ana: The Power of Diesel and Money

Santa Ana Pueblo, located about 25 miles down from Cochiti Dam, had experienced the full range of federal water resource management activities such as diversions, dams, levees, drains, channelization, and jetty jacks when it

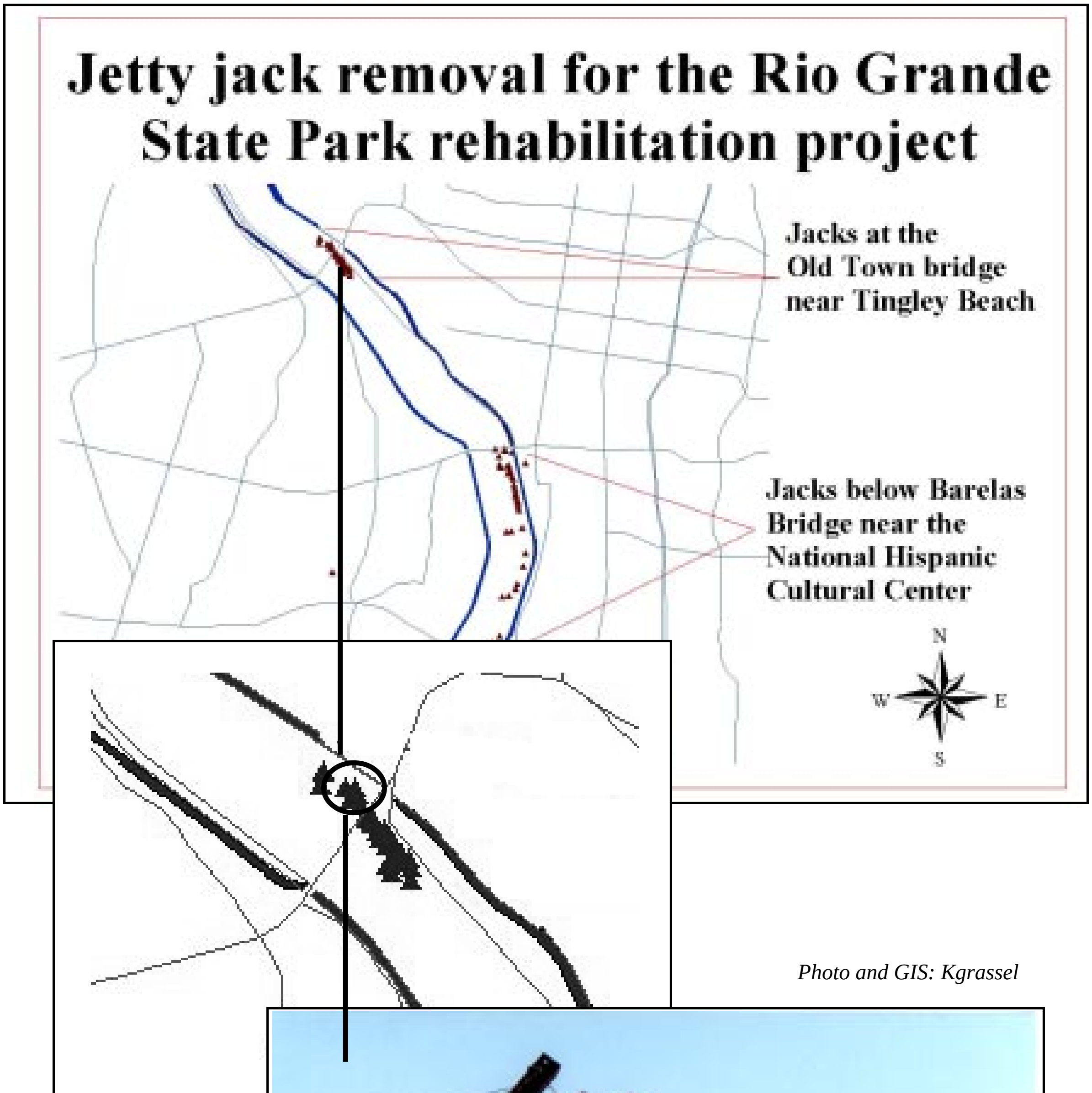


Photo and GIS: Kgrassel

Fig. 20: Jetty jacks dominate the bosque near the levees. Many of these will stay in place in the Rio Grande Valley State Park. Note the BioPark in the background. The endangered silvery minnow is being bred in captivity in the facility's aquarium.

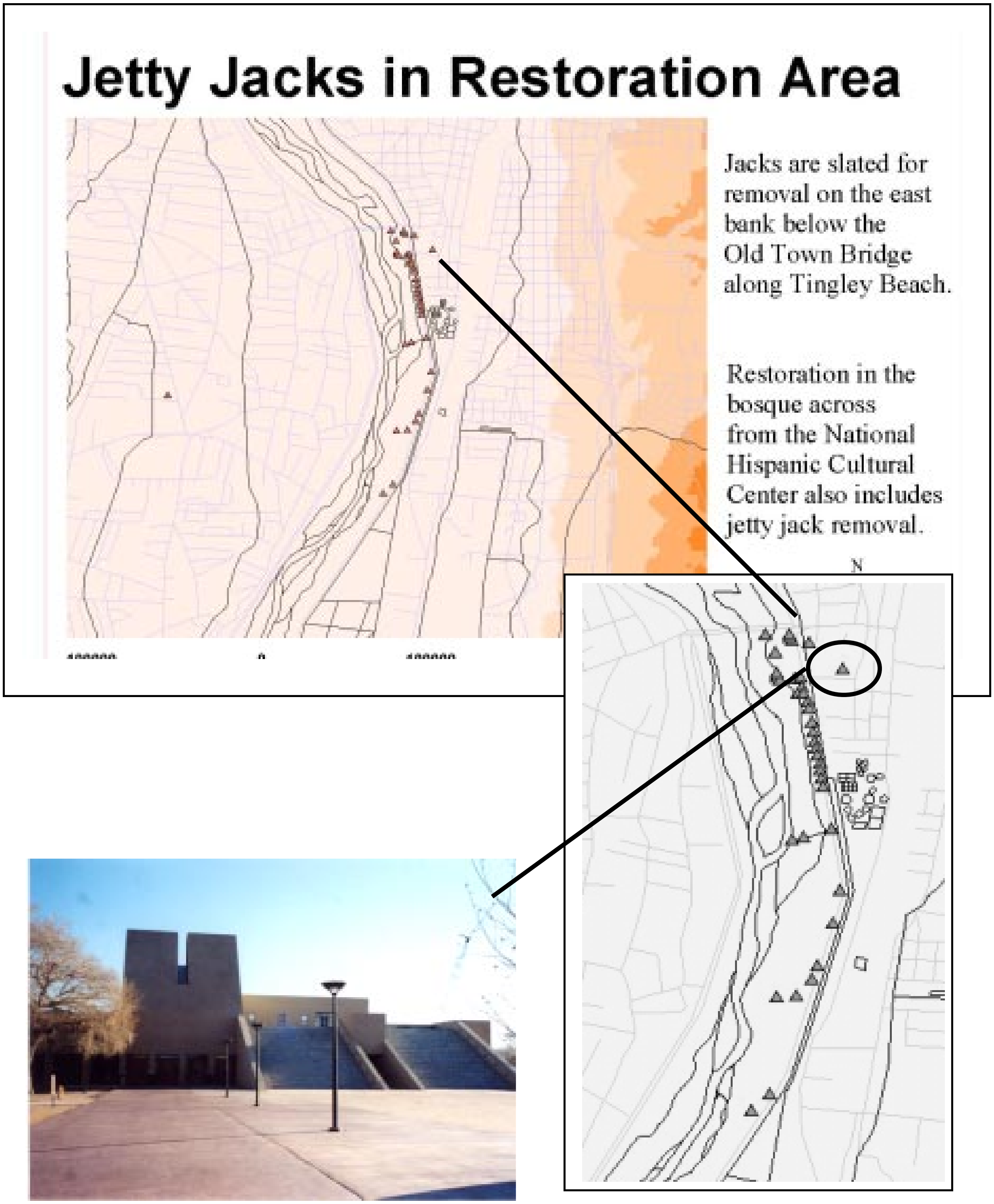


Fig. 21: Barelas Bridge bosque will be cleaned up to adjoin the National Hispanic Cultural Center.

Photo and GIS: Kgrassel

initiated in 1996 a restoration plan covering 1,200 acres of riparian land. The results have been impressive. The project is ongoing; so far 480 acres has been cleared of salt cedar and Russian olive (see Fig. 22 below). Revegetation with native trees and shrubs is completed on 30 acres to be expanded to additional acreage over the next several years. Soil remediation of 115 acres of saline soils had to be done before planting of native grassland. Finally, the Pueblo removed 1,600 jetty jacks from the abandoned floodplain adjacent to the river (see Fig. 23). Following clearing, part the channel was rebuilt to redirect flow away from a Bureau levee and bioengineering techniques were employed to build a new bank (see Fig. 24). The project is ongoing, well-funded, and successful.

Figures 23-24: Before and After: At left is a jetty jack installation at Santa Ana, photo 1974 (Lagasse 1980). Below is the result of bank restoration using bio-engineering methods and native willow planting.

The Future of Jetty Jacks in Water Management Planning

Fig. 25: Tiffany Site, river-mile 71.2 west bank. Bank jetty line and tiebacks circled. Aerial photo: Bureau of Reclamation March 1994.

Where jetty jacks lose their function in riverbank protection, their landlocked role in levee protection increases in importance. In other locations, where adequate sediment supply exists to support jetty jack efficacy, new installations are still feasible. Recent installations would indicate that jetty jacks are reverting to their original purpose, i.e., to protect vulnerable areas in river systems that threaten infrastructure.

- The U.S. Fish and Wildlife Service in Phoenix, AZ, recently transmitted a Biological Opinion to the Natural Resources Conservation Service, USDA, proposing to protect some cropland and buildings from bank erosion along the Verde River with the use of jetty jacks (Harlow 2001). The Conservation Service proposed installing 23 jacks extending 350 feet to be placed at the base of high bank bend. As a reader may conclude from having read the previous extent of jetty jack projects, this one is insignificant. A small project with a big name, the Verde River Bayless Bank Stabilization Project was given the go-ahead by the U.S. Fish and Wildlife Service, which found that the project is not likely to jeopardize the continued existence or critical habitat of a number of threatened fish (Harlow 2001).
- As recently as 1993, the Bureau of Reclamation installed seven jetty jack fields at different locations along the Middle Rio Grande. Most of these sites are south of the Highway 60 bridge at Bernardo, NM; the reason for their selection that far down the reach is that the concentration of river sediment is higher and thus there is greater likelihood of successful bank line stabilization (Bureau of Reclamation 1994). Sites were chosen based on problem areas where there existed fewer than 100 feet of established bosque fringe between the river bank and drains and/or levees. At the Tiffany site, a total of 314 jetty jacks were installed and anchored with six deadman anchors (see Fig. 25). The length of bank protected is1200 feet. The number of jetties installed at the other sites ranged from 155 to 409 (Bureau of Reclamation 1994). It is unclear from the document whether the compiler of the memo mistakenly used the word jetties to describe jacks. Jetties are the lines made up of jacks.
- The Bureau also repairs failed jetty lines, the rationale being to attempt to restore historic bank lines thus narrowing the floodway and increasing sediment and water transport efficiencies.
- It also appears that the jack role in levee protection is here to stay, at least until levees are engineered to withstand potential flooding (Grogan, pers. com., Tashjian, pers. com.).

Conclusions

Processes set in motion by Cochiti Dam in 1973 limit the effectiveness of the existing jetty fields. Less frequent inundation of floodplain area, a reduction in sediment supply from major source areas, and degradation and armoring the upstream channel all dictate against the installation of new jetty fields for channel stabilization. The current debate, then, centers around what should be the fate of the current jetty systems, some of which are functioning marginally, others not at all, others having once functioned to armor riverbanks now viewed as protectors of levees.

Because a degradation environment and reduced sediment supply has induced scour across some jetty lines, undercutting and burying them, the time is ripe to remove non-functioning jacks to enhance the success of river and riparian restoration projects. Resource managers, having to grapple with the necessity to provide greater certainty for the survival of endangered species while honoring the water needs/rights of people and entities in accordance with many laws, has resulted in the implementation of several riverine and riparian restoration projects that include, among other things, removal of jetty jacks. This paper described three of of those projects, two of which are successfully removing jetty jacks.

The past enormous success of jetty jacks in flood and erosion control has made it problematic for water managers to accept their present redundancy, even with an understanding of the change in river function due to the effects of Cochiti Dam. Many of the stumbling blocks to their removal are still based on varying positions of the resource agencies, combined with the necessity for those same agencies to agree on restoration design before implementation.

The U.S. Fish and Wildlife Service view jetty jacks as armoring the river's banks and their removal imperative to restoring river function. It thus favors removal of jetty lines in river banks. The Rio Grande Valley State Park bosque project does not include removal of riverside jacks due to prevailing thought that these jacks are necessary to protect the levees (MRGCD), that their removal could decrease water deliveries to farmers and to Texas (MRGCD, OSE, ISC), and that the goals of the project are unrelated to riverine function, but rather are to improve the bosque, enhance recreation, and make an urban park (City of Albuquerque Open Space Division). These same entities favor thinning jetty jacks in the bosque, some of which the U.S. Fish and Wildlife Service would contend are important for levee protection.

Recommendations

Common ground

The one point of agreement among all the agencies with a stake in the fate of river and bosque in the face of jetty jack removal is that the levees must be protected and that jetty jacks can do that. That there is disagreement about what constellation of jetty jacks can best serve that purpose is secondary to the common ground on which people can meet and agree, especially since some jetty lines are already non-functional and can be removed on a case-by-case basis without concern for bank failure or bank erosion. While the above-described restoration projects (Los Lunas, Rio Grande Valley State Park, and Santa Ana) are in progress because biological opinions mandated and/or facilitated those efforts, I would further recommend that these same involved agencies use this common ground of levee protection to continue to experiment with jetty jack removal with the overall result of bosque improvement as well as riverine restoration in accordance with the recommendations outlined in the Bosque Management Plan (Crawford et al. 1993) and endorsed by Sen. Pete Domenici.

Disseminate this report

While a qualitative or descriptive report such as this one does not provide sufficient basis for making engineering decisions requiring changes in development techniques, it is useful in bringing problem areas into focus to supplement the information base of federal and non-federal agencies in designing their restoration plans. This report will be online at www.unm.edu/~wrp/.

Design alternative systems

As dams hold back sediment, and sediment is crucial for jetty field function, dependence on jetty jacks for bank stabilization is being reevaluated. If bank line stability is desired, new systems for bank line protection such as vegetation growth and bio-engineered banks must be devised and implemented. While Russian olive has served this purpose, there are drawbacks. Coyote willow has been used successfully in Santa Ana and should be tried in more places.

Data collection and monitoring

Since jetty jack removal is a new idea, it will be useful to record results of removal and monitor impacts over time. Such monitoring will aid in determining the most efficient and cost-effective methods to remove jetty jacks. This effort would include monitoring the physical (i.e., hydrological, topographical, and soil-related) and biological (i.e., process- and population-related) changes over time on the ground.

GIS

Devise an interactive, flexible Geographical Information System using Arc Macro Language or Avenue Script with pull-down menus that can be easily used by all end users. Create a book of maps containing point coverages of existing jetty fields, create attribute data with historical information, make buffers to isolate selected data, and combine technical and political data into one interface (Morain 1999).

Public education

Let the governor or mayor declare a "Jetty Jack Awareness Week." Few in the public know what jetty jacks are or what they do. Use jetty jack awareness as a gateway to bring people into the larger issues of bosque restoration, river restoration, levee repair, endangered species recovery, agriculture, native cultures, groundwater connections, and pollution.

Have guided tours of the Rio Grande Valley State Park restoration in progress. Have guided tours of the Los Lunas restoration project in progress. Tours of the Santa Ana project have been very successful.

History meets science

As usual with most research and analysis, one outcome is always the recognition that more study is needed, in this case comprehensive study going back and forward many years.

Afterword: Constraints to Progress

Cause and effect

A watershed analysis of past and present bank stabilization efforts is sorely needed. Whether a small discrete project for a specific outcome or a large scale channel engineering project, whether policy decisions favor leaving jetty jacks in place or in removing them and replacing them with alternative stabilization measures, effects from channel constraint on channel morphology will continue. Bank stabilization projects, excluding the fact that they provide non-ecosystem benefits, have consequences for the river upstream and downstream from the sites. The need for a particular project downstream may have been a direct result of a previous bank stabilization upstream. Installation of jetty jacks in one location may lead to the need for more jetty jacks downstream. Effects continue to move downstream as the river continues to lose natural function (Fleming, Watershed Management 527 notes, 1994).

“In nature there are neither rewards nor punishments—there are consequences.” —R.D. Ingersoll

So many alterations have occurred over so much time from so many different actions—dams, diversions, channelizations, stabilizations—that it is impossible to say with certainly how any one action, say jetty jack installation, has contributed to the overall loss of channel form, river function, and ecological health. Currently, project proposals must undergo extensive evaluations to determine biological and other impacts of the project, but separating effects of the present from effects of the past is impossible without comprehensive data on the extent to which the river has been affected (Hoagstrom, pers. com.).

"We live in an age where people expect immediate results," says Hoagstrom. "If you postulate that an action will be negative, they expect that you are able to show it. The Endangered Species Act is about saving a species rather than saving the river. One comes back to the concept of trying to improve the overall ecology. Even if the minnow is lost, if you have improved the overall environment, you have still gained."

Ode to "Bridge Man," who lives here

Living here along the river, jetty jacks are your walls, the river your picture window, the sky your ceiling. Your bed is made of silt from the north, long ago deposited and caught in the jetty jack that is your hut.

THE END

Glossary

Aggradation – bed raising through sediment accumulation

Bosque – the riparian forest along the Rio Grande

Collaborative program – the intergovernmental program established to implement the Middle Rio Grande Endangered Species Collaborative Program, the purpose of which is to provide a framework for coordinated actions to enhance habitat, increase populations, and contribute to the recovery of listed species in the Middle Rio Grande

Degradation – channel bed lowering due to reduced sediment load

Ecosystem – the combination of interrelated life forms that share a geographic area. The interaction of components of air, land, water and living organisms essential to life within a defined area.

Flood control – methods or facilities for reducing flood flows

Floodplain – areas adjacent to a channel

Jack – a single structural unit of the system

Jetty – a number of jacks connected

Jetty jacks – misnomer for jacks but is the description in use, not to be confused with a jetty, the line made by a series of jacks fastened together

Kellner jack, Kellner jetties – original designation for jetty jacks

Middle Rio Grande - the Rio Grade channel from the outlet of Cochiti Dam to the headwaters of Elephant Butte Reservoir, a distance of approximately 175 miles

Middle Rio Grande Project - the federal reclamation project authorized by the Flood Control Act of 1948 and Flood Control Act of 1950

Riparian area – the transition zone between the flowing waters and terrestrial ecosystems, possessing its own distinctive organisms and ecosystem

Streambank erosion – the carrying away of individual soil particles at the bank's surface

Streambank failure – the loss of a large section of a bank when it fails and slides into the channel

Unit – an assembled jack complete with lacing, cables, and anchors

Watershed – the entire physical area or basin drained by a distinct stream

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Appendix 1: Abbreviations and Acronyms

For reasons of style, I have used the following abbreviations and acronyms for the below agencies and environmental documents.

The U.S. Army Corps of Engineers	The Corps
The Bureau of Reclamation, U.S. Department of Interior	The Bureau
The U.S. Fish and Wildlife Service	The Service
The Middle Rio Grande Conservancy District	MRGCD
Biological Opinion	BO
Biological Assessment	BA
Environmental Assessment	EA
Endangered Species Act	ESA
Environmental Impact Statement	EIS
Finding of No Significant Impact	FONSI
Interstate Stream Commission	ISC
National Environmental Policy Act	NEPA
Natural Resources Conservation Service	NRCS
Office of the State Engineer	OSE