PROVISIONAL
Subject to revision

Chaco Culture National Historical Park

Monitoring Chaco Wash Using Monumented and Surveyed Cross-sections

Introduction – Chaco Wash may have some of the most extensive erosion control efforts for any stream of its size, however, a long-term channel erosion monitoring program is lacking. This paper documents a monitoring project initiated by Paul Whitefield of CHCU and Rick Inglis of WRD. The program is designed to monitor long term trends through low frequency measurement over a long duration and needing only low to moderate data analysis (MacDonald 1991). The specific monitoring objective is to identify trends of aggradation and degradation (erosion and deposition) and lateral migration of key locations in Chaco Wash within the boundaries of the park.

Background – Chaco Wash and its tributaries drain 398,240 acres of overgrazed, sparsely vegetated land upstream of the park. Since the mid-1930's various erosion control projects were undertaken to minimize erosion damage to cultural resources. Studies of the history of soil erosion control and a review of the existing situation by the park staff in 1979 and 1980 alerted management to continued threats to park resources. Three major ruins are threatened by erosion. Soil pipes and gullies have developed within 10 feet of Pueblo Del Arroyo. Chaco Wash has cut to within 40 feet of Kin Kletso and is at the edge of the road between the wash and the ruin. Soil pipes and large gullies have developed to within 75 yards of Wijiji Ruin (Simons, Li & Associates, Inc. 1982).

Bill Jackson and William Werrell wrote a July 1994 memorandum to the Southwest Regional Director noting that the park has a long history of erosion control, however, some significant cultural sites still may not be adequately protected against extreme hydrologic events. They recommended designing and implementing an arroyo monitoring program, among other things (see appendix). A follow-up memorandum dated September 1995 from Gary Smillie to the Field Director, Intermountain Field Area also recommended to develop an erosion program and make an initial survey.

Methods – Thirteen cross-sections were selected with a specific purpose as detailed in the field work plan (see appendix) and the following site descriptions. Permanent end point monuments were constructed according to the design drawing except where archeological features were encountered. At these features, a unique, unmovable location are used and described in detail. To survey elevations near perfect alignment between monuments, temporary flagging is tied about 50-feet apart in a straight line between the endpoints. One person stands at a monument and aligns the other person in order to tie flagging on the sight line with the opposite monument. An instrument station is located nearby were all the flagging is seen. Use of an extended survey rod is sometimes needed. A total station is used to collect the distance/depth measurements along the cross-sections. A reading is taken to a survey rod at each monument and to the ground surface along the flagging line at every major topographic break. Additional measurements are made about 25 feet apart along flat or unbroken ground. Key features such as rim and channel edges are noted in the survey notes. Distance and elevation data is later

July 21, 1994

L54 (479)
CHCU/General

Memorandum

To: Regional Director, Southwest Region

From: Dan B. Kimball, Chief, Water Resources Division

Subject: Trip Report for Travel by Bill Jackson and William Werrell to Chaco Culture Nation Historical Park, May 16-19, 1994

The attached trip report by Bill Jackson and William Werrell present their findings concerning erosion issues at Pueblo del Arroyo, as well as other cultural sites potentially affected by arroyo erosion processes. Sam Kunkle and Bob Krumenaker of your staff participated in this field assessment.

The park has a long history of erosion control; however, some significant cultural sites still may not be adequately protected against extreme hydrologic events.

Recommendations include: develop detailed stabilization designs for Pueblo del Arroyo and Kin Kletso ruins; design and implement an arroyo monitoring program; prepare a project statement for the development of a comprehensive long-term erosion control program plan for the park; prepare a project statement for a geomorphic assessment of the evolutionary status of Chaco Wash Arroyo, including the influences of Escavada Wash and vegetation plantings on arroyo evolution; and develop an interpretive display about the Chaco Wash arroyo, with an emphasis on historic evolution and modern-day process geomorphology.

If you have any questions or if we can be of further assistance, please call Bill Jackson or me at (303) 225-3502.

DAN B. KIMBALL

Attachment

cc: CHCU-Superintendent, Ford, Saino
SWR-Kunkle, Krumenaker
479-Jackson, Werrell, Smillie, Hanson, Flora

July 21, 1994

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July 21, 1994

L54 (479)
CHCU/General

Memorandum

To: Chief, Water Resources Division

From: William Jackson, Chief, Water Operations Branch
William Werrell, Hydrologist, Water Operations Branch

Subject: Trip Report for Travel to Chaco Culture National Historical Park, May 16-19, 1994

PURPOSE: The purpose of this trip was to respond to a previous recommendation by Water Resources Division staff for additional assessment of the arroyo erosion situation at Pueblo del Arroyo ruin. In addition, we reviewed erosion issues at several other cultural sites within the park.

ITINERARY: We travelled from Fort Collins, Colorado, to Chaco Culture National Historical Park (CHCU) on May 16, 1994, and returned on May 19, 1994.

CONTACTS:

Sam Kunkle, Chief, Natural Resources Division, Southwest Region
Bob Krumenaker, Branch Chief, Resource Management, Southwest Region
Dabney Ford, Archeologist, CHCU
Carolyn Saino, CHCU

DISCUSSION:

During a visit to Chaco Culture National Historical Park (CHCU) in 1993, Water Resources Division staff expressed concern about the adequacy of flood and erosion protection efforts at Pueblo del Arroyo ruin, located on the edge of Chaco Wash. At that time, it was recommended that additional professional perspective on the situation be sought. This trip, coordinated with the park through Sam Kunkle and Bob Krumenaker of the Southwest Region, was designed to respond to the recommendation for further assessment of flood protection and erosion issues at Pueblo del Arroyo. In addition to Krumenaker and Kunkle, we were joined in the field by Dabney Ford and Carolyn Saino of CHCU.

In preparing for the visit, we invested considerable time reviewing the 1982 report by Simons and Li Associates, entitled Erosion Study at Chaco Culture National Historical Park. From that report, we learned that at least a dozen other ruins have been impacted or threatened by arroyo/gully erosion and/or soil piping, and that there have been extensive efforts, dating back to the 1930's to manage runoff and erosion throughout the park. Thus, we expanded the scope of our visit to include a broader overview of erosion (primarily arroyo/gully erosion) processes and historic efforts to manage runoff and erosion issues throughout the park.

Arroyo Evolution at Chaco Wash

Simons and Li Associates (1982) draw heavily from the geologic and geomorphic accounts of Hall (1977) and Love (1977, 1979) to reconstruct the geomorphic evolution of Chaco Wash over the past 10,000 years. In addition, Simons and Li Associates (1982) draw from numerous historic accounts, beginning in about 1850, to describe the evolution of modern-day Chaco Wash arroyo. Several points are relevant to the current assessment of arroyo erosion issues.

1. Chaco Canyon has undergone numerous (perhaps seven) cycles of arroyo cutting and refilling over the past 10,000 years. As many as five cut and fill cycles have occurred over the past 2,500 years. This evolution is consistent with patterns observed for other southwest arroyo systems.

2. Most documentation suggests that the valley was flat (unincised) and at a slightly lower elevation at the time the pueblos were built. This is not what we see today. The arroyo incision which coincided with the abandonment of the valley by the Anasazi is not the modern-day arroyo, and was not at the same location as the modern-day arroyo. Between about 1200 A.D. and the early 1800's the valley filled to elevations which existed prior to 1000 A.D., and Chaco Wash was not incised. A major episode of downcutting commenced in the early-to-mid 1800's. By the 1920,s the maximum depth of arroyo cutting was achieved - approximately 34 feet in the vicinity of Pueblo del Arroyo. The present-day arroyo is a partly filled remnant of the period of downcutting in the late 1800's and early 1900's. It is interesting to note that arroyo downcutting was pervasive in the Southwest United States during this period (Harvey, et.al., 1985).

4. Following the early 1930's, Chaco Arroyo began a period of filling. By 1963, the arroyo had reduced its depth at Pueblo del Arroyo from 34 feet to 16 feet. Arroyo filling, as well as widening, following episodes of downcutting is consistent with the geologic evolution of Chaco Wash, and is believed to be part of the natural arroyo dynamics.

5. Also by the 1960's, a new "inner channel" was cut into the partially-filled arroyo floor. However, even the floor of this recent inner channel is elevated at least 10 feet over the elevation of the arroyo floor in 1927. This "inner" channel now conveys

most normal flows. Larger floods spill over the main arroyo floor and can impinge on the main arroyo walls. In addition, the inner channel is undergoing some meandering and at places the outer banks of the inner channel are causing additional erosion of the main arroyo walls.

In summary, the Chaco Wash arroyo is a dynamic system, undergoing repeating episodes of cutting, widening and filling. Knowing the status and direction of arroyo evolution is necessary for designing management actions which work with, not against, natural arroyo processes to the extent practical.

Erosion Issues Associated With Arroyo Processes

Several significant cultural ruins are located on or very near to the edge of the modern arroyo, and are threatened by further erosion of the arroyo walls. For example, both the Bradley Site and Pueblo del Arroyo already have lost part of their structure to arroyo widening, and are subject to additional erosion damage. Both Kin Kletso and Lizard House are located very near the edge of the arroyo system, and could be damaged if further arroyo widening occurs. The road between Kin Kletso and Chaco Wash arroyo already has been directly threatened by arroyo processes. Other ruins, for example Chetro Ketl, have been threatened by local drainage and the possibility of headward extension of gullies which are tributary to the main arroyo system.

Ironically, when these structures now threatened by arroyo processes were built, they likely were not in close proximity to an active drainage, and there was no arroyo incision. Rather, they have become victim of the somewhat random locating of the 19th century episode of arroyo downcutting.

While we believe that the present arroyo has completed its most active phase of downcutting and widening, and is presently undergoing filling, four mechanisms remain which could result in further arroyo widening and erosion of archeological sites.

1. Arroyo Widening Due To Extreme Floods: While we did not quantify the conveyance capacity of the inner channel, clearly floods of large magnitude (e.g., 100-year or greater return period floods) will greatly exceed the capacity of the inner channel and will spread across the entire arroyo from wall-to-wall. These large floods will be capable of further eroding and widening the main arroyo walls.

2. Arroyo Widening Due to Evolution of the Inner Channel: The "inner" channel, cut in the arroyo floor, has a meander ratio which exceeds that of the main wash. At points the inner channel meanders up against the walls of the main arroyo. In these places, even modest flows confined to the inner channel can directly impinge upon the arroyo walls and cause further erosion and widening. We expect continued meander migrations to make other points of the arroyo subject to lateral erosion in the future, even under conditions where flows are confined to the inner channel.

3. Arroyo Widening Due to Piping: The soils of the Chaco Wash valley are highly subject to piping. Piping, driven by local surface runoff, is a major mechanism contributing to the erosion of the main arroyo walls. In some locations (e.g., the Bradley Site) piping may dominate over main-channel flow as the major arroyo erosion mechanism threatening cultural sites.

4. Arroyo Widening or Lengthening Due to Local Rainfall and Runoff: In addition to soil piping, raindrop splash and local surface runoff can contribute to the erosion of arroyo walls. Where surface runoff concentrates in small tributary channels, the channels become very susceptible to downcutting and headcutting. Further headward advance of arroyo tributaries is still possible - especially in locations where headcutting has been controlled by engineered drop structures. If currently-functioning structures (e.g., Mockingbird) fail or are not maintained, rapid headward advancement of the arroyo system will occur.

Field Inspection of Erosion Issues

We had the opportunity to inspect some of the most critical issues involving the erosion of cultural sites as identified by Simons and Li Associates (1982). Summary observations follow.

Mockingbird Diversion Dam/Drop-Structure - This large masonry drop structure was built on a main tributary arroyo and apparently was intended to halt further headward erosion of the channel. Smaller, dirt diversion structures direct all surface flows to the main structure, in an attempt to avoid gully erosion around the structure by tributaries. Subsequent to its initial construction, the arroyo downstream from the structure continued to downcut, requiring modifications to the structure to extend it deeper. We do not know if the drop structure contributed to further downstream cutting, or if that occurred independently of the structure. The toe of the structure has been undercut in the past and repaired. Further repairs may be warranted now. The structure has succeeded in keeping Mockingbird Valley unincised, but must be maintained to remain effective.

Chetro Ketl - The small tributary channel east of the ruin has been straightened and directed away from the ruin. Thus flows presently don't threaten the ruin. Some armoring was placed where flows drop to the main channel. This has reduced the tendency for headcutting to work upstream - something which otherwise could have been induced by channel straightening and realignment. The drainage should be inspected periodically to insure that any tendency to headcut remains controlled.

Kin Kletso - A main park road is tightly fitted between the main arroyo walls and the Kin Kletso ruin. Chaco Wash erosion threatens the road at this point. Riprap and flow deflectors have been placed along the base of the arroyo wall at this location in an attempt to increase its resistance to erosion and to deflect erosive flows away from the arroyo walls. In addition, numerous trees now offer further erosion protection at this site. As the arroyo floor has filled, some of the bank protection structures have been buried, and new ones

We think that a well-engineered "hardening" or protecting of the arroyo walls around the ruin is the best approach to long term stability of the site. The ruin protection should be based upon sound hydrologic criteria (probably an "extreme" or "probable maximum" flood) and engineering design. Among other things, we recommend footings penetrating well below the depth of maximum arroyo downcutting - possibly to bedrock, and as effective anchoring as possible of the structure in upstream and downstream banks. While we generally supported recommendations in the Simons and Li Associates (1982) report, we did not concur with their recommendation for inner channel straightening and realignment in the vicinity of Pueblo del Arroyo (see discussion of Kin Kletso). Also, we thought that possibly they were proposing less substantial engineering solutions (e.g., gabions, jacks) than what we are contemplating for protecting this priceless cultural resource.

Casa Chiquita - We inspected the Chaco Wash channel downstream of the ruin for about 2000 feet. Cottonwood trees in this reach are in much better condition than those upstream. The inner channel is wider but not as deep as further upstream. The overall channel pattern is more sinuous here, and the main arroyo is much less deeply incised. We discussed what effect the confluence of Escavada Wash, immediately downstream, might be having on Chaco Wash, and how the two washes have interacted geomorphically over time. Escavada Wash is unincised and steeper than Chaco Wash, and appears to convey enormous sediment loads in comparison to Chaco Wash. We wondered if Escavada Wash might function as a base control to Chaco Wash, which periodically might be breached when extremely large flows in Chaco Wash occurred in absence of concurrent large flows in Escavada Wash.

Lizard House - Lizard House is located near the head of a tributary arroyo to Chaco Wash, near the base of a sandstone cliff. The arroyo in this area has soft sandy walls. The ruin, in places, is within 5-10 feet of the arroyo walls. While this tributary is small, we see no reason why further erosion of the arroyo walls will not occur during infrequent periods of unusually high runoff. Protection might involve hardening the arroyo walls with gabions, as recommended by Simons and Li Associates (1982) or, possibly, re-routing the channel away from the ruin and filling in the existing channel. Because the tributary at Lizard House is so much smaller than Chaco Wash, it might be possible to use less-rigorously engineered protection, such as gabions and loose rock fences, than what is recommended for Pueblo del Arroyo.

Bradley Site - This ruin already has suffered structural loss, perhaps to a substantial degree, due to erosion of Chaco Wash arroyo. What remains of the ruin is on the immediate edge of the arroyo, and is being impacted substantially by soil piping. There is no evidence of man-made manipulation within the incised channel. However, as we walked from the overflow camping area to the ruin, we observed several long dikes. We hypothesized that these contour dikes were intended to reduce overland flow and piping in the vicinity of the arroyo.

<u>The History of Watershed Management at Chaco Wash: Is there more to learn?</u>

The Simons and Li Associates (1982) report summarizes from the literature the history of the extensive erosion control efforts at CHCU. Much of what follows is drawn from the Simons and Li Associates Report.

The history of erosion control at CHCU extends back to the early 1900's when flow diversion structures were built along the east side of Pueblo Bonito. From 1934-1952 an extensive erosion control program was implemented. During that period, the monument was fenced and most livestock grazing was terminated. From 150,000-700,000 (depending upon the account) cottonwoods, willows and other vegetation were planted in the arroyo. Over five miles of channel were realigned. Twenty miles of dikes and seventy basket dams, spillways, and check-dams were constructed. Woven wire fences and steel dikes also were constructed at Kin Kletso and Pueblo del Arroyo to encourage sediment deposition. Other projects/techniques included spider jetties, rock jetties, brush bundle jetties, cable rail fences, earth dams, contour furrowing, and post and wire dams.

As far as can be determined, erosion control efforts at CHCU never have been guided by comprehensive long-term plans - either for construction, or for inspection and maintenance. In 1977-1978, Dennis M. McAuliffe, a volunteer, compiled all available information on park erosion control efforts during the period up to 1968. Twenty volumes were produced by this effort, of which we were able to review two. Simons and Li Associates (1982), drawing from the McAuliffe works, attempted to identify the purposes and relative effectiveness of the various classes of erosion control strategies employed at the park. They concluded that many of the erosion control techniques implemented at CHCU were effective, but that many others were ineffective or even the causes of problems - either because they were ill-conceived, poorly designed, or not maintained.

Simons and Li Associates (1982), recognizing the fragmented and piecemeal nature of past erosion control efforts and CHCU, strongly advocate development of a comprehensive erosion control program plan for CHCU. They note that the Soil Conservation Service attempted to develop a comprehensive structural stabilization program in the 1970's. However, funds for that program never were appropriated. Furthermore, the program was keyed to the construction of numerous large drop structures in the main wash - an approach which Simons and Li and Associates (1982) did not support in concept. We concur with the Simons and Li Associates (1982) recommendation that a comprehensive erosion control plan: (1) be driven by clearly stated objectives; (2) identify and work with the dominant erosion processes and controlling variables; and (3) draw from the lessons of past erosion control work at CHCU. In addition, a comprehensive erosion control program should include long-term plans for monitoring resource response to management actions, periodic inspection and maintenance of project structures, and overall evaluations and documentation of program effectiveness.

We, frankly, were surprised/amazed at the extent of the park's past watershed management and erosion control activities. It seemed that almost every mile of drainage network and acre of land surface had, in one way or another, been manipulated to control surface runoff and erosion. Furthermore, an enormous number of watershed "stabilization" techniques had

been employed in one context or another. We're not sure we can think of anywhere else in the western United States where there is such a large concentration of rangeland watershed stabilization efforts. While we did not have the opportunity to review the vast majority of the McAuliffe works, we suspect that there is still more to learn and to share (in a professional context) about the effectiveness of the historic erosion control program at CHCU.

Conclusions:

1. The arroyo system associated with Chaco Wash is extremely dynamic and is undergoing a complex morphologic evolution. Both interpreting the cultural resource and managing erosion issues associated with arroyo processes requires a better understanding of the long-term dynamics of the arroyo, and a quantification of its modern day status and evolutionary trend.

2. Arroyo erosion threatens numerous archaeologic resources at CHCU. The most significant (and in our view, priceless) of these threatened resources are Kin Kletso and Pueblo del Arroyo. We do not think present stabilization is adequate to protect either site against extreme runoff events. In these two cases, we advocate heavy-handed, properly designed structural stabilization of the immediate site. We discourage interfering with "natural" arroyo evolutionary processes any more than is absolutely necessary.

3. The first step in providing permanent stabilization at Kin Kletso and Pueblo del Arroyo is to contract for detailed engineering designs, based upon contemporary hydrologic and hydraulic criteria and a clear understanding of long-term arroyo dynamics. At Kin Kletso and Pueblo del Arroyo we advocate hardening arroyo walls and deflecting flood flows from arroyo walls over manipulating the inner channel, or using softer technologies (vegetation plantings, jacks) in an attempt to tame flows and induce sediment deposition. We recognize that the entire Chaco valley is composed of highly erodible sediments, and that almost any structure in effect will be "floating" in erodible sediments and subject to failure. However, a properly-designed revetment, anchored to bedrock, is less likely to failure during catastrophic floods than are randomly-placed gabion baskets, rock sausages, wire fences, or steel jacks.

4. The Bradley site and Lizard House also are threatened by further arroyo widening. At the Bradley site, so much cultural resource already has been lost that the significance of what remains may not justify the level of engineered stability recommended for Kin Kletso and Pueblo del Arroyo. Lizard House is on a much smaller tributary wash and may respond to a less heavily engineered stabilization approach.

5. Erosion control at CHCU has occurred opportunistically, in a fairly fragmented and piecemeal fashion, and has not been guided by a comprehensive, long-term erosion control program plan. Development and implementation of such a program plan, as described by Simons and Li Associates (1982) is recommended.

6. The scale and breadth of past erosion control efforts at CHCU is remarkable. Greater effort is needed to learn from that experience and to communicate it to the watershed management profession.

7. The Simons and Li Associates (1982) report, though not without its shortcomings, is extremely well done and provides an excellent documentation of contemporary erosion issues at CHCU. That report should serve as a starting point for future management efforts.

Recommendations:

1. Initiate a long-term arroyo morphology monitoring program. This program needs to be carefully designed, but at a minimum should include monumented cross-sections.

2. Contract for detailed professional engineering designs for stabilization of the arroyo at Kin Kletso and Pueblo del Arroyo ruins.

3. Develop a fundable project statement to implement an Intergovernmental Personal Appointment (or some other kind of "sabbatical-type" appointment) with the objectives of preparing a review of all existing erosion control structures and developing a comprehensive long-term erosion control program plan for the park. All existing projects need to be inventoried, original project objectives identified, and current project status and effectiveness evaluated. Recommendations should be made to passively abandon, actively abandon, maintain, or enhance all existing structures. Additional erosion control efforts should be identified and prioritized.

4. Develop a fundable project statement for a geomorphic assessment of the evolutionary status of Chaco Wash arroyo, including the interactions with Escavada Wash and the influences of vegetation plantings on arroyo evolution.

5. Develop a fundable project statement to develop an interpretive display on the Chaco Wash arroyo, with an emphasis on historic evolution and modern-day process geomorphology.

ACTION ITEMS:

Assist the Region and Park in implementing any of the above recommendations, as requested. Responsible Party: Jackson, Werrell, Smillie. Target Date: As Requested.

William L. Jackson

Literature Cited

Hall, S.A., 1977. Late Quaternary sedimentation and paleogeologic history of Chaco Canyon, New Mexico. Geologic Society of America Bulletin, Vol. 88, pp. 1593-1618.

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L54(479)
CHCU/MEVE

SEP 2 2 1995

Smillie
Jackson
Kimball

Memorandum

To: Field Director, Intermountain Field Area

From: Chief, Water Resources Division

Subject: Trip Report for Travel by Gary Smillie to Chaco Culture National Historical Park and Mesa Verde National Park from September 5 - 9, 1995

The attached trip report by Gary Smillie of my staff concerns his recent trip to Chaco Culture National Historical Park (CHCU) and Mesa Verde National Park (MEVE). The visit to CHCU was made to meet with park and SSO staff regarding development of a scope of work for a WRD funded project. This project will be conducted in fiscal years 1996 and 1997, and is intended to provide protection to cultural sites that are threatened by water erosion. Gary's trip to MEVE was made to inspect flood hazard associated with a location that has been proposed for a new visitor center near the park entrance. His comments regarding these activities can be found in the trip report.

If you have any questions, please call Bill Jackson or Gary at (970) 225-3503 or (970) 225-8528, respectively.

DAN B. KIMBALL

Attachment
cc: CHCU - Superintendent, Schultz, Ford
MEVE - Superintendent, Colyer
IMFA - CP - S - Wise
IMFA - SW - S - Kunkle
479 - Jackson, Smillie, Wagner

FNP:SMILLIE:AP:09/21/95:S:\WOB\SMILLIE\CMVTR

September 20, 1995

L54(479)
CHCU/MEVE

Memorandum

To: Chief, Water Resources Division

Through: Chief, Water Operations Branch

From: Gary M. Smillie, Hydrologist, Water Operations Branch

Subject: Trip Report for Travel to Chaco Culture National Historical Park and Mesa Verde National Park, September 5 - 9, 1995

PURPOSE: The purpose of this trip was to participate in a meeting to develop a scope of work for a WRD-funded erosion mitigation project for CHCU and to assess potential floodplain hazards near the entrance of MEVE.

ITINERARY: I departed Fort Collins on September 5 and arrived at CHCU the next day. I travelled MEVE on September 8 and returned to Fort Collins on the 9th.

CONTACTS:

Superintendent, CHCU
Dabney Ford, CHCU
Herschel Shultz, CHCU
Sam Kunkle, IMFA - SW-S
Janet Wise, IMFA - CP-S
Marilyn Colyer, MEVE

DISCUSSION:

Chaco Culture National Historical Park

Chaco Culture National Historic Park (CHCU) successfully competed for project funding from the Water Resources Division (WRD) for fiscal year 1996. The funded project is intended to provide for protection of cultural resources at CHCU that are threatened by water erosion. The project statement submitted for funding competition briefly describes the problems related to arroyo erosion and piping that threaten cultural resources and provides broad recommendations for a course of action for mitigation. The primary purpose of this meeting was to develop a more detailed scope of work that can be used as the basis

for soliciting and selecting a contractor to perform the work. Additional reasons for meeting were to assign responsibilities to involved NPS staff and to discuss mechanisms of funding transfer and other administrative details.

An extensive description of erosion-related conditions at CHCU can be found in the WRD trip report by Jackson and Werrell (July 21, 1994), a report by Simons, Li and Associates, Inc. (June, 1982), and numerous other reports. Such a discussion will not be repeated here except to note that many efforts (some successful and some not) have been made in the past to remedy erosion near cultural sites at CHCU and to study the complex geomorphic history of the area. The approach to be utilized in this project is to use the considerable knowledge gained by earlier studies and attempts at erosion control. The goals of this study are: 1) identify useful existing structures and prescribe a maintenance regimen, 2) recommend removal of existing structures that adversely affect the stability of important cultural sites, 3) develop detailed construction plans for new structures needed to protect resources presently at risk, and 4) develop a monitoring program to quantify arroyo evolution and erosion rates at selected locations, and to assess the effectiveness of erosion control structures. Implementation of new construction is beyond funding capabilities of this project.

The following project responsibilities were agreed to at the meeting. The WRD will write a generic scope of work describing the tasks and products associated with the project. The scope of work will be merged with site priorities developed by CHCU staff to ensure that the appropriate sites are included. This prioritization is particularly important since funding constraints dictate that all sites cannot be addressed by this project. CHCU staff will provide contract administration, on-site support and coordination with the contractor, and perform necessary environmental compliance-related tasks. The mechanics of fund transfer are somewhat uncertain due to the NPS reorganization but the group agreed to work cooperatively to find means that are acceptable to all. WRD will develop the erroyo and erosion monitoring program and make the initial topographic survey.

Mesa Verde National Park

Mesa Verde National Park (MEVE) is considering constructing a new visitor center just east of the entrance kiosks near the north boundary of the park. WRD was requested by MEVE staff to inspect the area and provide advice regarding the suitability of the site with respect to compliance with the NPS Floodplain Management Guideline. The following are my thoughts on this subject.

The area proposed for development is a drainage for several small catchments. However, the area is swale-like and does not have a discernable channel throughout much of its length. No evidence was found suggesting water floods occur in this area except sheet flow associated with heavy precipitation events or perhaps snowmelt. For these reasons, I don't believe this area needs to be considered a floodplain subject to NPS guidelines.

While compliance with floodplain regulations may not be an issue here, there are some flood-related and other water-related concerns of relevance to the site. A large stock pond is located upstream and failure of the dam could result in hazardous flooding downstream for a short distance. This pond has been observed to remain dry in recent years and I don't know if there is a potential for filling and failure. Any development in this area should provide for removal of the impoundment, or at a minimum, surveillance of conditions associated with this structure. The hill slopes surrounding the site are prone to fail as mudslides. Evidence for this can be seen in the exposed scarp faces on the hills and the hummocky terrain at the base of the hills. I don't know if there are areas in the proposed site that are safely outside of the runout zone of mudflows and recommend that an expert in this field provide advice to the park regarding this. The soils in this area are extremely erodible. A large development with paved surfaces will generate relatively large stormwater flows that may cause extensive erosion if not properly handled. And finally, some portion of the area may be classified as wetland and subject to NPS Wetlands Guidelines.

ACTION ITEMS:

1. Write generic scope of work for project and consult with park staff regarding selection of contractor. Responsible party: Smillie. Target date: December, 1995.

2. Develop erosion monitoring program and make initial survey. Responsible parties: Smillie, M. Martin. Target date: To be determined.

3. Reconvene the participants in this meeting to develop a funding strategy involving cooperation between cultural and natural resources programs. Responsible parties: Smillie and group. Target date: To be determined.

Gary M. Smillie

Gary M. Smillie
GMS
William L. Jackson
WLJ - acting

May 6, 1999

L54(2380)
CHCU/General

To: Superintendent, Chaco Culture National Historical Park

From: Gary Smillie, Hydrologist, Water Operations Branch
Bill Jackson, Chief, Water Operations Branch

Subject: Trip Report for Travel to Participate in the Pueblo del Arroyo Erosion Protection Meeting, April 7, 1999

In this trip report we will reiterate and expand upon our professional assessment of the risk to Pueblo del Arroyo from erosion of Chaco Wash. In light of this assessment we will review potential management strategies as well as the Bureau of Reclamation's proposed alternative for structural protection of the site. We left the April 7th meeting with the sense that there was not uniform understanding of the risk to the structure from future erosion and geomorphic evolution of Chaco Wash.

Erosion Risk at Pueblo del Arroyo

First and foremost, the Water Resources Division believes that a real and present threat to Pueblo del Arroyo exists from likely future erosion of the right bank (looking downstream) of Chaco Wash. Our assessment is shared and confirmed by other hydrologists, hydraulic engineers, and civil engineers, including professionals from Simons, Li and Associates, the Bureau of Reclamation, and the Corps of Engineers. Risk to Pueblo del Arroyo stems from potential failure of the right bank of the wash rather than from possible inundation by flood waters. This fact makes precise quantification of risk more difficult than for more traditional flood inundation analysis. However, we will try to provide you with our best quantification of that risk.

While several mechanisms could result in the undermining and failure of the right bank of Chaco Wash at Pueblo del Arroyo, the most probable cause of failure would be an extremely large flood. We think that floods of roughly a 50-year magnitude would threaten the structure, and we feel pretty confident in saying that a 100-year return period (or greater) flood would be extremely destructive to the site. If you recall from our discussions, a 100-year flood would just about fill the wash in its present configuration, have extremely high velocities (15-20 ft. per second), and possess considerable erosive power. A flood of this magnitude is difficult to imagine; however, the risk of a 100-year flood occurring is greater than is commonly appreciated.

A "100-year" flood is, statistically, a flood magnitude that has only a 1% probability (one chance in a hundred) of being equaled or exceeded **in any <u>one</u> year**. However, the probability of a flood of this magnitude or greater occurring over timeframes longer than one year increases considerably. For example, over a 50-year timeframe the probability of experiencing a 100-year flood increases to 39% (or almost 4 chances in 10). Over a 100-year timeframe that probability increases to 63%. That means that there is a 63% probability that a 100-year or greater flood will occur in Chaco Wash sometime during the next century. This is not an insignificant risk. Amazingly, there actually exists a 12% chance that 3 or more 100-year or greater floods could occur during the next 100 years.

It is logical to ask why Pueblo del Arroyo still exists at all if the risk of flood-induced arroyo erosion is so great. First of all, we think that the present arroyo is an artifact of processes that occurred over the past 100-150 years. Arroyos in the southwest United States are thought to respond to many factors, including both anthropogenic and natural, and are known to go through "cycles" of downcutting, widening, and refilling. We think that Chaco Wash, like other arroyos in the region, has undergone significant adjustment since the late 19th century in response to grazing practices, possible climate influences, and/or changes in downstream base levels. Therefore, the present location and condition of Chaco Wash is relatively new and in a more threatening setting than possible previous arroyos that may have existed subsequent to construction of the building. It is our understanding that several previous floods this past century in the "modern" arroyo have resulted in significant damage and loss to both the south side of the building and to the "tri-wall" structure. This seems to lend credence to the concept that while very large floods are rare in any single year they are very common over longer timeframes and are very capable of causing damage to the building.

<u>Discussion of Alternative Management Strategies</u>

Clearly, it is not our role to recommend management strategies or priorities for resource protection at CHCU. However, we do want to point out the general alternatives available to park management. If it is accepted that the long-term threat to the structure from flood-induced arroyo processes is relatively high, management would have to accept that loss of or damage to the structure could occur at any time and be prepared for this eventuality. Another possible management strategy would be to take actions to protect the site up to some pre-determined (and reduced) level of risk. The park, with funding support from WRD, contracted with the Bureau of Reclamation to evaluate alternatives and to recommend a structure that would protect the site from the largest possible flood that could be contained within the present arroyo. As mentioned above, this would protect the site from roughly the 100-year magnitude flood. While larger floods might overtop the arroyo banks and possibly inundate parts of the building, we believe they would spread across the valley and, in general, would be only marginally more destructive than flows contained within the wash proper.

<u>Evaluation of the Structural Alternative Recommended by the Bureau of Reclamation</u>

If park management chooses a strategy to protect Pueblo del Arroyo from arroyo erosion, we think that the general structure design developed by the Bureau of Reclamation is good and is the

most feasible and realistic option available to you. We thought it was reassuring that the Corps of Engineers representatives at the April 7th meeting not only concurred with the general sense of risk to the site but also concurred with the structure concept and design developed by BOR. Any remaining work on the BOR design represent structural, material, and logistical details that need to be worked out only if park management chooses the arroyo erosion protection strategy. Like you, we are sensitive to and regret the fact that meaningful erosion protection requires such a large and heavy-handed approach. All involved with this project have tried very hard to identify and evaluate "softer" approaches to erosion control, but this is a difficult situation which simply does not lend itself well to less intrusive approaches. With creativity and careful planning, we think that erosion protection can be implemented in a way that will be minimally intrusive from an aesthetic standpoint and that will provide minimum interference with natural arroyo evolution.

Summary and Conclusions

It is very difficult to contemplate or "visualize" large floods that only occur with frequencies of several decades or centuries. This is especially true for large floods in arid landscapes and in streams that generally experience either no flow or very low flows. However, these relatively rare events are critical to the evolution of fluvial landscape features such as streams and arroyos. There is a substantial (63%) likelihood that a flood will occur over the next 100 years that will be large enough to completely fill Chaco Wash in its present configuration at Pueblo del Arroyo. A flood of this magnitude will initiate substantial arroyo erosion and evolution and will very likely cause major damage to Pueblo del Arroyo.

Management alternatives are to accept to present level of risk or to implement meaningful protection to reduce the risk level. The structure designed by the Bureau of Reclamation under contract to NPS represents the best alternative for achieving protection from roughly a 100-year magnitude flood. Smaller, more piecemeal, or "softer" approaches to erosion control would prove ineffective during extremely large flood events.

We understand that it is difficult to embrace such a "heavy handed" approach to resource protection and we would not normally advocate this level of interference with natural processes were it not for the park's previously communicated interest in preserving the Pueblo del Arroyo site.

Please call Gary Smillie (970 225-3522) or Bill Jackson (970 225-3503) if you have any questions or if we can in any way help facilitate additional assessment of either the hydrologic risk to the site or the protection strategy proposed by the Bureau of Reclamation.

cc:

CHCU – Whitefield, Ford
IMR – Reber
Corps of Engineers – Edson, Selano
2380 – Kimball, Flora

Field Work Plan:
Establishing a Network of Surveyed and Monumented Cross-sections Across Chaco Wash, Chaco Culture National Historical Park

Contact: Paul Whitefield (505) 786-7014 ext.223

Introduction. Chaco Culture National Historical Park, originally designated as Chaco Canyon National Monument in 1907, was established to preserve the significant archaeological features located in Chaco Canyon. The park lies west of the Continental Divide within the San Juan River Basin. Other than a few small seeps, sandstone catchments, and small tributary drainages within the side canyons, surface water is limited to intermittent flows in Chaco Wash and short reaches of the Fajada Wash and Gallo Wash tributaries. A 20 km segment of Chaco Wash courses through the park, which typically has flowing or standing water for 3 - 6 months of the year.

The condition of the Chaco Canyon watershed and Chaco Wash remains paramount to preserving the canyon floor alluvial units and the thousands of cultural sites they contain. Beginning in the mid-1800's, livestock overgrazing seriously impacted grassland and riparian vegetation within the region. The loss of vegetation cover and topsoil likely contributed to the onset of severe erosion within the drainage system. By 1935, Chaco Wash incised into an arroyo averaging 100 feet wide by as much as 30 feet deep throughout the length of the canyon, and headcuts migrated upstream along the tributary drainages. Numerous archaeological sites were damaged by streambank erosion or altogether collapsed into the arroyo. In order to protect threatened sites, the National Park Service, Soil Conservation Service, and Civilian Conservation Corps implemented extensive erosion control projects between the 1930's and 1960's. These efforts, combined with fencing the park boundary between 1934 and 1948 and improved range management practices, have led to measurable recovery within the drainage system, and the arroyo has been aggrading during the last 60 years.

In addition to preserving the park's cultural features, the park's water resources are also important for: (1) continuing archaeological research into "Chacoan" water control structures; (2) interpreting the Chacoan and early historic environments to the visiting public; and (3) conserving the park's inherent biodiversity. The park's cultural and natural resources are certain to be threatened by external development and land-use pressure within the watershed (e.g. overgrazing, development of groundwater resources, oil and gas exploration and production, and coal and uranium mining).

In 1977, the NPS filed groundwater rights claims to the park's primary water supply well (945 meters deep), and to a shallow well in the arroyo floor of Chaco Wash. The Water Rights Branch of the NPS Water Resources Division is currently relying upon these original claims to secure adequate water to meet projected park operational needs for the next 30 years. In addition, park resource managers are collaborating with the Water Rights Branch to secure adequate surface flows and groundwater within Chaco Wash as necessary to preserve, interpret, and support continued scientific inquiry into

the unique "Chacoan" archaeological sites and environment found within the park. As part of this strategy, in 1998 the Water Rights Branch assisted the park with installing a network of groundwater monitoring wells and stream gauges at 3 locations along the wash. Data from the wells and gauges will be used to correlate water table levels with surface flows in the wash.

A considerable amount of descriptive environmental and technical hydrological information is currently available for Chaco Wash and the canyon watershed, but the park is also in need of a long-term approach to monitoring stream channel morphology in order to: (1) understand long term changes in base stream level and drainage channel shape; (2) assess erosion rates and threats to archaeological sites in critical reaches; and, (3) establish elevation datum points to accurately measure water table fluctuations within the canyon's shallow aquifer. Information on stream channel morphology, timing and frequency of flows, and groundwater levels is also critical for planning riparian restoration projects to control invasive tamarisk thickets and stabilize stream channels with native riparian plant species (many of which were utilized by the Chacoan civilization for construction materials and other products). A program to monitor chanell morphology would best be accomplished by establishing a network of surveyed and permanently-monumented, cross-sectional profiles at selected reaches along Chaco Wash. Information from the profile network would be used monitor for stream base level changes (including the detection of headcuts originating from downstream locations) and secure water rights appropriate to meeting the park's legislated purpose.

Cross-section Network Objectives.

(1) Establish profile sites at selected known "critical cultural resources protection reaches" along Chaco Wash within the park, as described in the *Erosion study at Chaco Culture National Historical Park, New Mexico* (Simons *et al.* 1982), including:
   (a) Wijiji
   (b) Zorro-Bradley
   (c) Chaco Wash - Gallo Wash "Narrows"
   (d) Pueblo del Arroyo - Kin Kletso reach
   (e) Penasco Blanco Trail Crossing site
   (f) Possibly as many as three other exemplary threatened sites as recommended by the Chief Archaeologist

(2) Tie into existing elevation datum points near each of the three groundwater monitoring well transects along Chaco Wash.

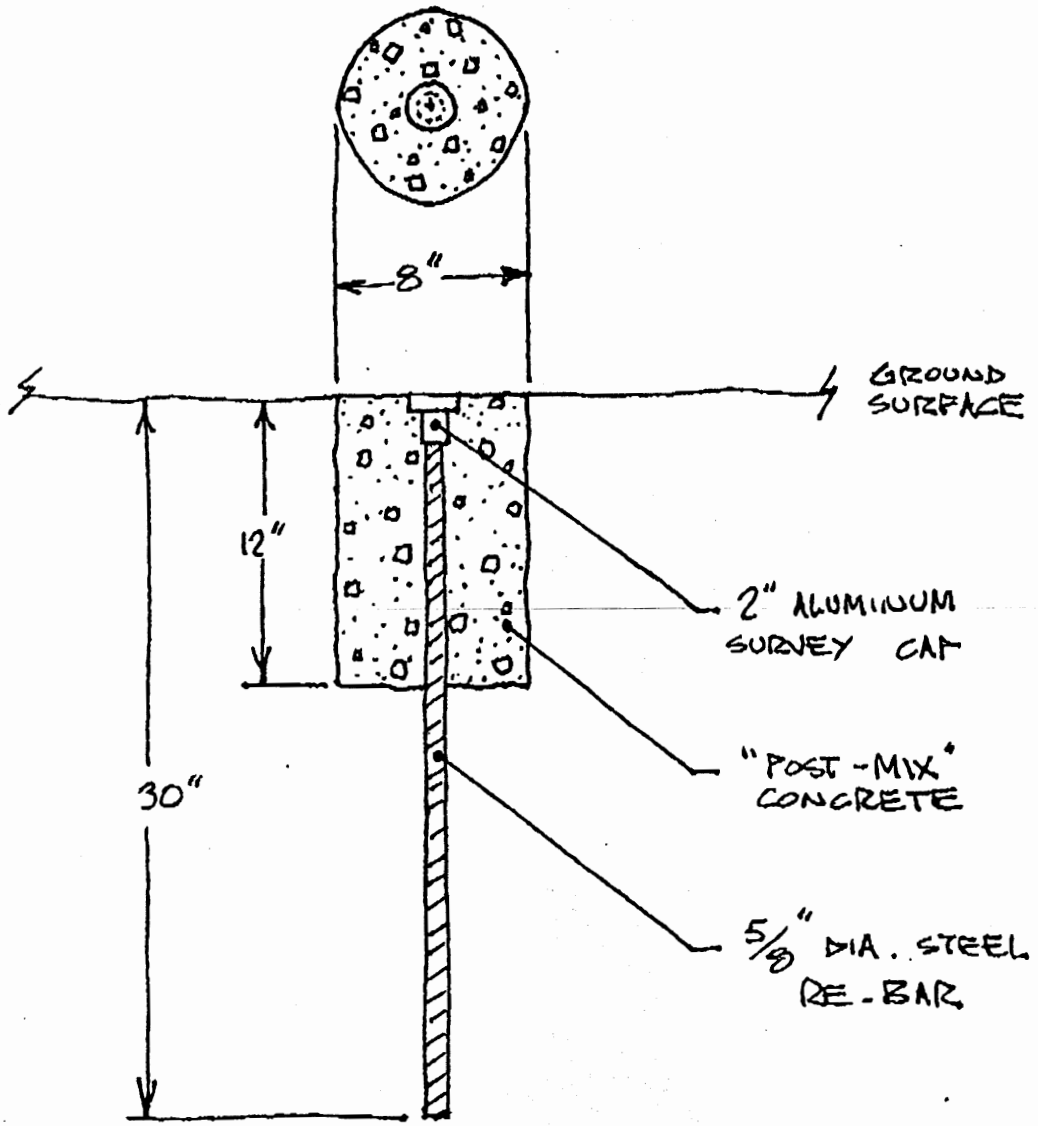
(4) Establish a profile near the confluence of Chaco Wash and Escavada Wash in order to detect potential downstream base level drops and head-cut initiation.

(5) As field time allows, prioritize and select additional profile sites in key reaches

which would contribute to an understanding of stream base level aggradation/degradation within the entire canyon drainage system, including important tributaries (Gallo Wash, Fajada Wash, Mockingbird Canyon, South Gap, and Clys Canyon).

(6) All cross-section profiles would be installed for long-term monitoring purposes and appropriately monumented in a secure location above the 100 year floodplain (i.e. on the canyon floor above the arroyo walls or the talus slopes beneath the canyon cliff faces).

Park CHACO CULTURE N.H.P.	NATIONAL PARK SERVICE SOUTHWEST REGION		Sheet
Area SAN JUAN CO., NM			of
Project CHACO WASH X.S. NETWORK	By MAW	Checked	Pkg.
Feature SURVEY END-POINT BENCHMARKS	Date 3/17/99	Date	Account



Channel Cross Section # XS-1
Location: 1980 East Boundary

Date: 5/11/99
Crew: K R Inglis
Instr Loc: ✓ Right ___ Left

Mon Elev Rod
Lx ___ + ___ = ___
Rx ___ + ___ = ___

Left Monument Pin Ht: 110.41
Condition: New

Right Monument Pin Ht: 110.35
Condition: New

K eye piece rew. = 5.15

Reference Dist: ___
Recent Survey Dist: ___

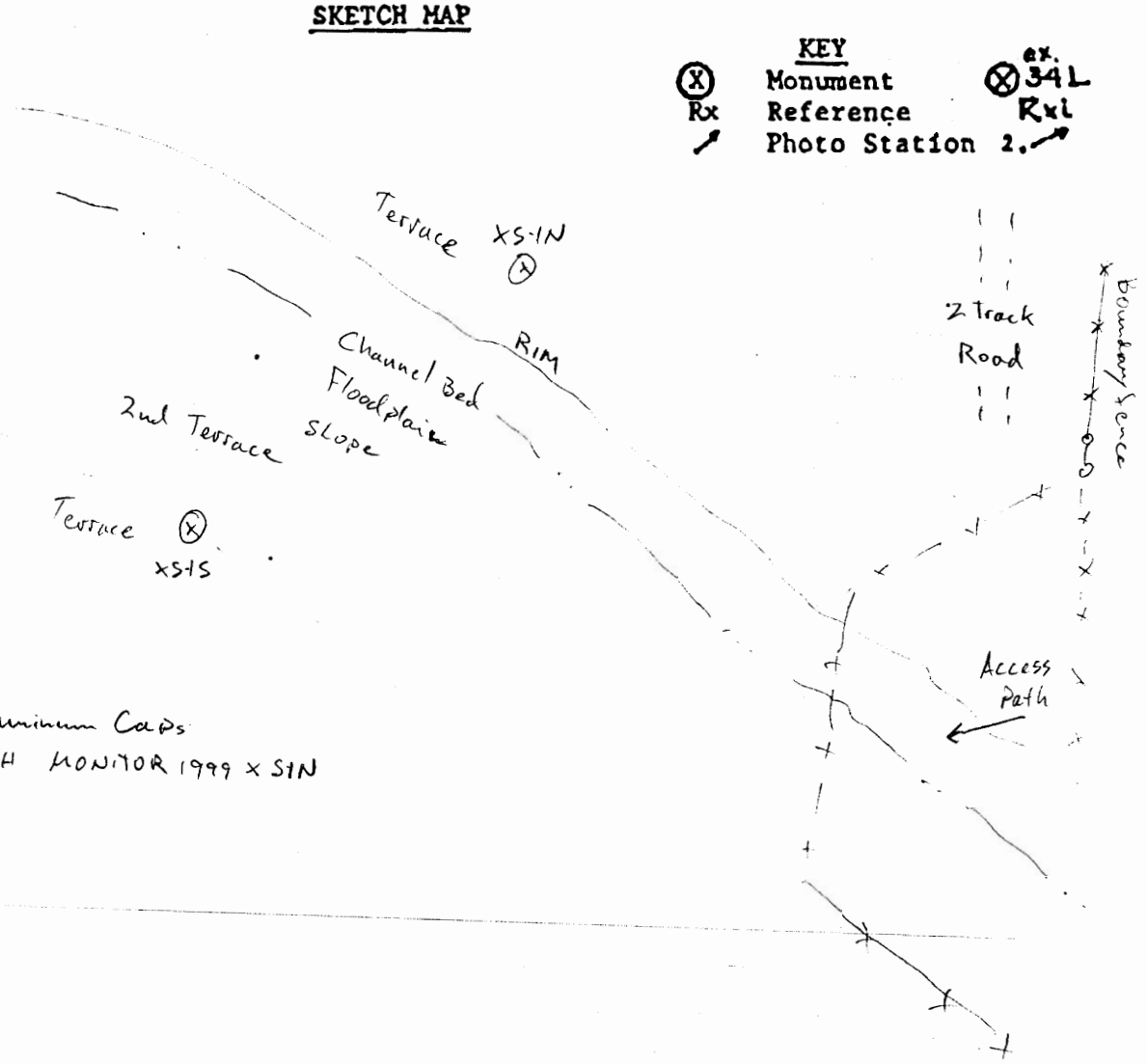
Recorded in: ___ m ✓ ft

Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		110.41				BM 1 South
	11.15		110.16				TERRACE
	22.29		109.50				TER
	33.50		106.80				SLOPE
	54.13		105.46				SLOPE
	65.89		102.09				2nd TERRACE
	94.78		100.00				2 TER
	102.33		95.00				SLOPE
	114.94		92.40				SLOPE
	123.71		90.85				Flood PlAIN
	134.15		89.90				FP
	141.84		90.94				FP
	149.20		90.33				FP
	156.50		88.69				FP
	161.32		82.45				CH BED
	166.33		82.74				CH BED
	168.86		84.20				Right Bankfull
	170.26		88.28				FP
	179.98		90.26				FP
	190.16		94.05				SLOPE
	192.00		108.96				SLOPE
	197.08		110.32				RIM
	223.20		110.17				TER
	245.31		110.12				TER
	270.66		110.35				BM 1 North

CROSS SECTION # XS-1 at 1980 East Boundary Date: May 11, 1999

RIGHT/LEFT) Bank Monument

SKETCH MAP



MONUMENT DESCRIPTION:

X : Cemented Aluminum Caps
"CHACO WASH MONITOR 1999 X SIN

REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

S X ⟶ N X

Bearing: N 26°E Mag. N

Distance: 270.66'

COMMENTS:

Channel Cross Section # XS-2
Location: Shabikeschee Wells

Date: 5/11/99
Crew: K Inglis Whitef.
Instr Loc: ___ Right ___ Left

Mon Elev Rod
Lx ____ + ____ = ____
Rx ____ + ____ = ____

Left Monument Pin Ht: ____
Condition: New

Right Monument Pin Ht: ____
Condition: New

$\Delta_{use\ price\ elev.}$ = 5.0'

Recorded in: ___ m X ft

Reference Dist: ____
Recent Survey Dist: ____

Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		119.92				BM 2 South
	23.81		119.80				TERRACE
	40.56		118.92				TER
	48.40		113.07				SLOPE
	57.53		111.76				SLOPE
	59.77		110.11				SLOPE
	63.16		102.75				SLOPE
	71.38		99.85				FLOODPLAIN
	87.48		99.03				FP
	98.66		100.31				FP
	111.67		98.69				FP
	122.47		98.93				FP
	136.07		98.46				FP
	149.11		99.60				FP
	154.19		97.69				FP
	162.91		98.96				FP
	171.64		97.58				FP
	179.73		91.72				Left Bank Full
	182.90		91.38				CH BED
	191.28		97.40				Right Bankfull ?
	191.92		98.89				FP
	201.69		99.36				FP
	212.81		101.33				SLOPE
	214.39		107.82				SLOPE
	216.43		109.79				SLOPE
	222.10		112.73				SLOPE
	241.10		115.29				SLOPE
	264.85		119.84				TER
	272.09		119.91				BM 2 North

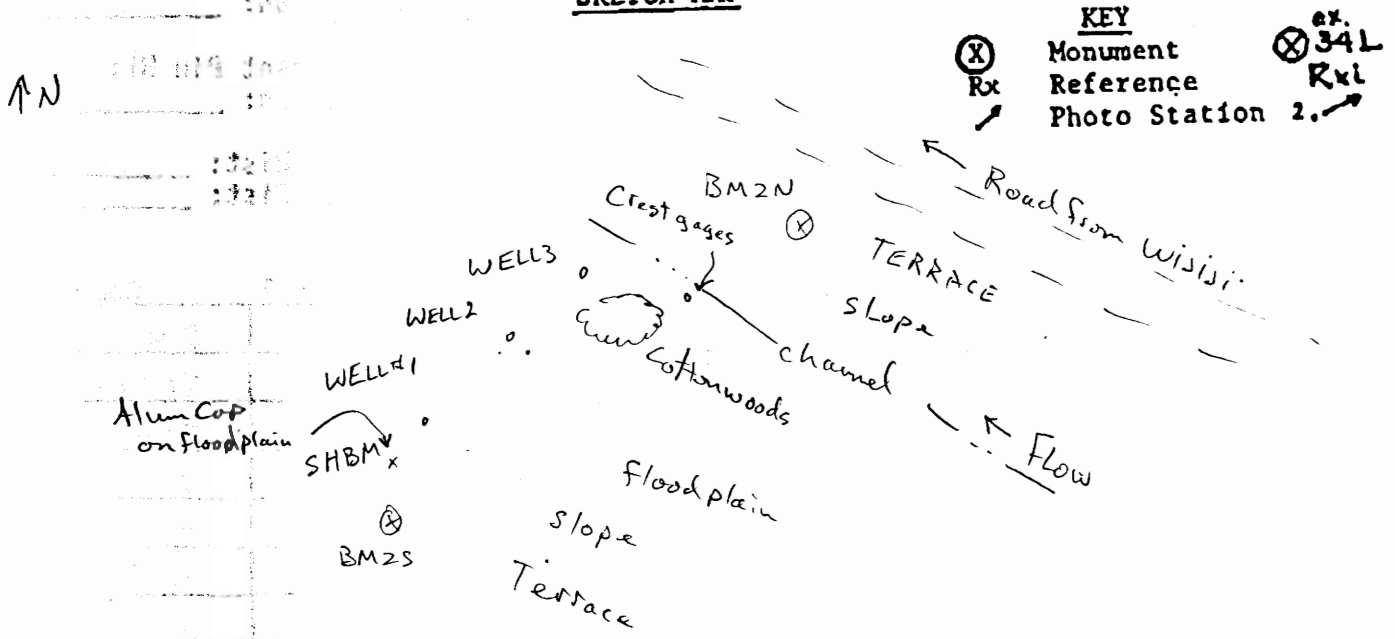
CROSS SECTION # XS-2 Shabi Keschee Wells

Date: May 11, 1999

Bank Monument

RIGHT/LEFT)

SKETCH MAP



MONUMENT DESCRIPTION:

X : cemented Aluminum Caps
"Chaco Wash Monitor XS-2S 1999"

REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

~~S~~ X ⟶ ~~N~~ X

Bearing: N 18° E Mag

Distance: 272.09

COMMENTS:

Channel Cross Section # XS-3

Location: [illegible]

Date: 5/11/99

Crew: Inglis, Whitefie[illegible]

Instr Loc: ___ Right ___ Left

	Mon Elev		Rod	
Lx		+		=
Rx		+		=

Eye piece elev. = 5.10'

Recorded in: ___ m X ft

Left Monument Pin Ht: 117.65
Condition: New

Right Monument Pin Ht: 117.33
Condition: New

Reference Dist: ______

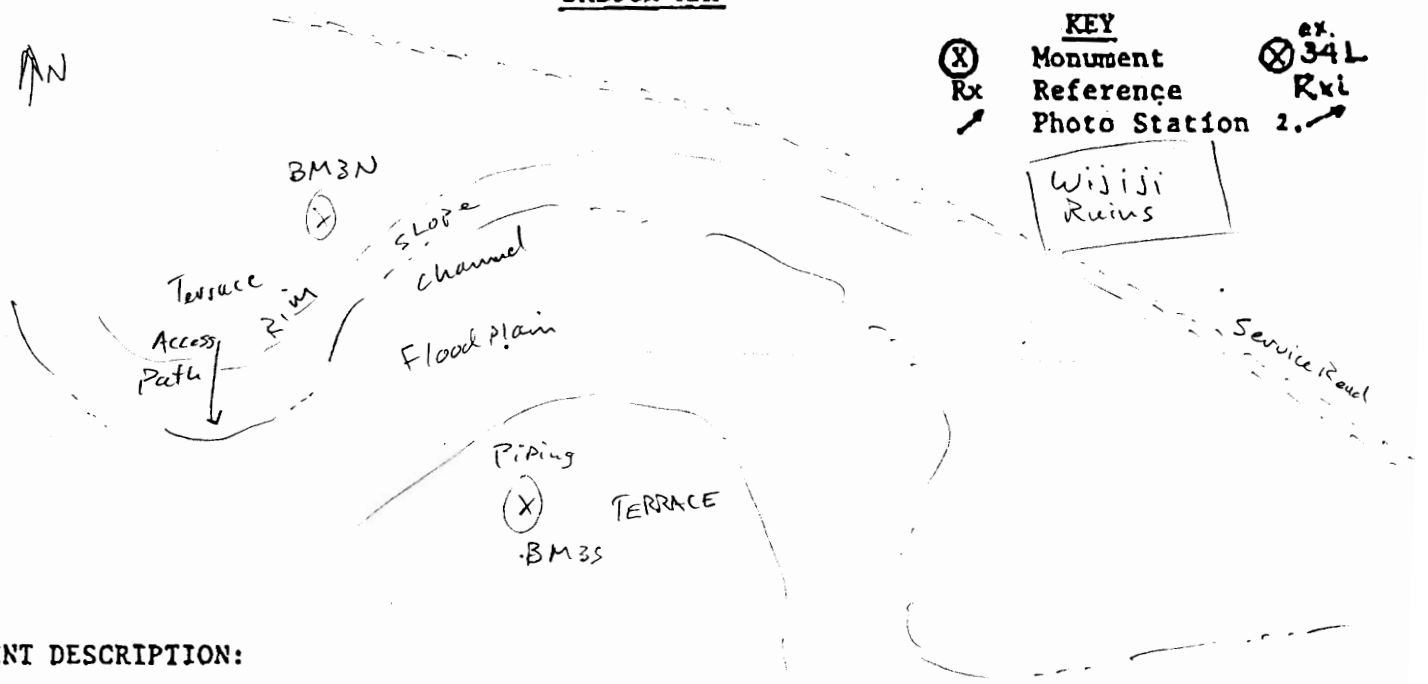
Recent Survey Dist: ______

Sta	Dist	Top	Mid	Bot	H2O Depth	Bed Mat'l	Comments
	0.00		117.65				BM 3 South
	16.37		117.42				TERRACE
	37.34		117.20				TER
	48.96		115.47				PIPE
	51.80		103.78				SLOPE
	55.42		101.98				SLOPE
	72.42		100.62				SLOPE
	86.97		100.42				FLOOD PLAIN
	97.24		100.67				FP
	108.07		100.07				FP
	123.26		100.03				FP
	138.10		99.55				FP
	154.84		100.18				FP
	169.33		100.37				FP
	183.51		99.15				FP
	199.75		100.65				FP
	218.73		100.49				FP
	228.10		93.75				CH BED
	232.43		93.75				CH BED
	240.68		99.46				FP
	247.72		101.85				FP
	250.39		101.13				SLOPE
	254.12		116.70				RIM
	299.20		117.23				TER
	323.61		117.22				TER
	354.73		117.33				BM 3 North

CROSS SECTION # XS-3 wijiji Date: May 11, 1999

RIGHT/LEFT Bank Monument

SKETCH MAP



MONUMENT DESCRIPTION:

X : Cemented Aluminum Caps
"CHACO WASH Monitor XS-3S 1999"

REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

S X ⟶ N X

Bearing: N 33 W Mag

Distance: 354.73'

COMMENTS:

Channel Cross Section # XS-4
Location: Narrows

Date: 5/13/99
Crew: TI, KH, [illegible] Schaffer
Instr Loc: ___ Right ___ Left

	Mon Elev		Rod
Lx		+	=
Rx		+	=

Left Monument Pin Ht: ____
Condition: New

Right Monument Pin Ht: ____
Condition: New

$\pi_{use\ place\ elev.}$ = 4.7'

Reference Dist: ____
Recent Survey Dist: ____

Recorded in: ____ m ____ ft

Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		98.58				BM 4 North
	22.43		98.33				TER
	57.37		98.22				TER
	85.16		95.61				SLOPE
	87.49		89.99				CHAN
	98.72		86.70				CHAN
	114.94		84.21				CHAN
	129.40		87.06				CHAN
	141.13		95.43				TER
	169.18		100.13				TER Berm
	177.22		98.45				TER
	199.61		98.39				TER
	219.43		98.01				TER
	254.25		97.70				PIPE
	285.48		97.51				PIPE
	297.32		96.46				RIM
	298.80		78.46				SLOPE
	310.39		75.89				FP
	328.08		73.62				FP
	334.73		71.84				FP
	348.82		71.53				FP
	353.27		69.65				RAIL Fence
	353.75		67.52				RAIL
	355.78		66.65				CHBED
	358.82		67.06				CHBED
	365.69		69.64				Left Bankfull
	372.50		74.06				BANK
	381.95		75.29				BANK
	404.47		75.75				FP
	421.55		74.96				FP
	Cont'		Cont'				cont'

S-4 cont

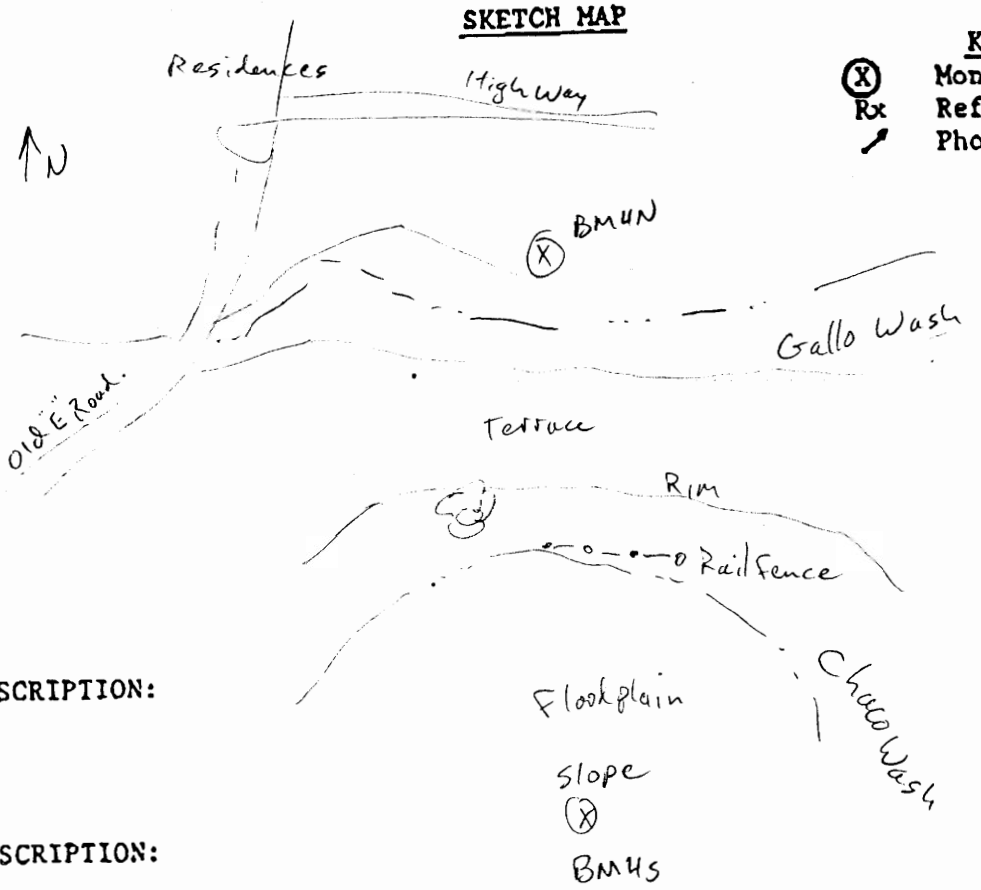
	442.90		75.36				FP
	472.18		75.30				FP
	500.72		74.31				FP
	524.49		75.28				FP
	549.95		76.50				FP
	567.80		78.94				SLOPE
	591.06		79.98				SLOPE
	610.66		81.65				SLOPE
	638.72		90.27				SLOPE
	699.42		90.75				SLOPE
	744.51		96.77				TER
	806.86		97.96				BM 4 South

CROSS SECTION # XS-4 Narrows

Date: _____

_____ Bank Monument
RIGHT/LEFT)

SKETCH MAP



KEY
X Monument
Rx Reference
Photo Station 2.
ex. 34L Rxi

MONUMENT DESCRIPTION:

X :

REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

S X ⟶ N X

Bearing: N 1°E Mag

Distance: 806.86

COMMENTS:

Channel Cross Section # XS-5
Location: Fajada Wash Confluence

Date: 5/14/99
Crew: TEnglis Swhitefield
Instr Loc: ___ Right ___ Left

Mon Elev Rod
Lx ____ + ____ = ____
Rx ____ + ____ = ____

Left Monument Pin Ht: ____
Condition: New

Right Monument Pin Ht: ____
Condition: New

$\pi_{\text{use place elev.}}$ = 4.95

Reference Dist: ____
Recent Survey Dist: ____

Recorded in: ___ m X ft

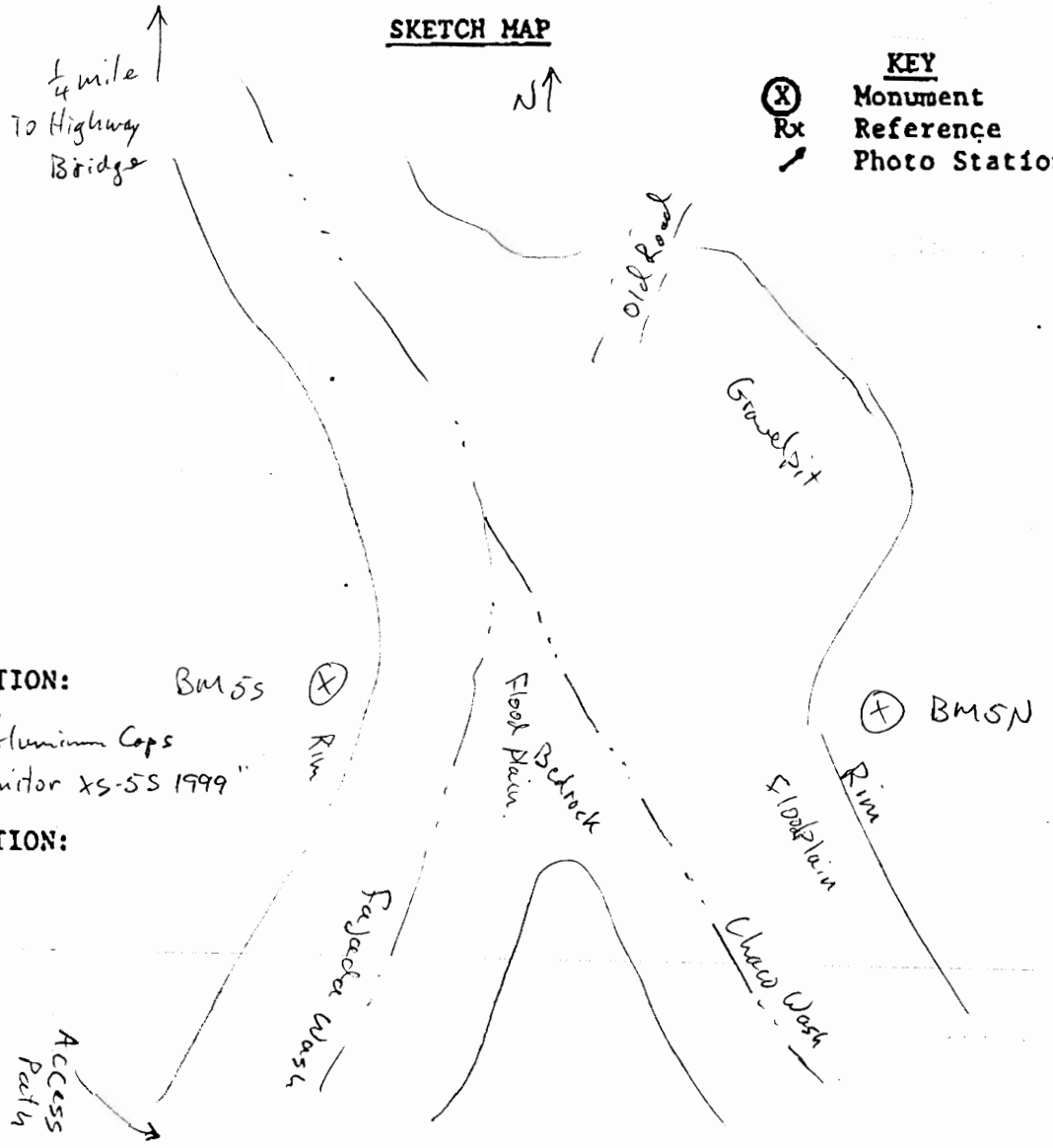
Sta	Dist	Top	Mid	Bot	H2O Depth	Bed Mat'l	Comments
	0.00		120.68				BM S North
	21.81		120.52				TER
	54.77		120.31				TFR
	68.00		118.74				RIM
	74.36		97.95				SLOPE
	80.70		95.47				FP
	98.39		94.93				FP
	116.62		95.59				FP
	131.04		95.16				FP
	147.53		94.40				FP
	162.05		92.29				BANK
	166.63		90.52				Right Bankfull
	169.79		89.52				CHAN
	171.33		89.28				CHAN
	173.99		88.00				CHAN
	175.32		89.56				CHAN
	178.33		90.54				Left Bankfull
	185.18		93.61				BANK
	200.34		94.00				FP
	222.57		94.85				FP
	227.06		92.58				FP
	234.00		92.83				FP
	242.17		90.38				BANK
	242.87		89.10				Left Bankfull
	245.67		89.11				CHAN
	247.19		90.72				Right Bankfull
	256.12		92.48				BANK
	263.76		95.11				BANK
	277.07		95.65				FP
	290.86		102.65				SLOPE
	Con't						

XS=5	1	295.72		121.64			RIM
Con't		320.41		121.52			TER
		344.19		121.51			BM 5 South

CROSS SECTION # XS-5 Fajada Wash Confluence Date: May 14, 1999

RIGHT/LEFT Bank Monument

SKETCH MAP



MONUMENT DESCRIPTION: BM5S

X : Cemented Aluminum Caps "Chaco Wash Monitor XS-5S 1999"

REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

S X ⟶ N X

Bearing: S 60°E

Distance: 344.19

COMMENTS:

Channel Cross Section # XS-6
Location: Historic Masonry Wells

Date: 5/11/99
Crew: K INGLIS [illegible]
Instr Loc: ___ Right ___ Left

Mon Elev Rod
Lx ____ + ____ = ____
Rx ____ + ____ = ____

Left Monument Pin Ht: ____
Condition: New

Right Monument Pin Ht: ____
Condition: New

K eye piece elev. = ____

Reference Dist: ____
Recent Survey Dist: ____

Recorded in: ____ m ____ ft

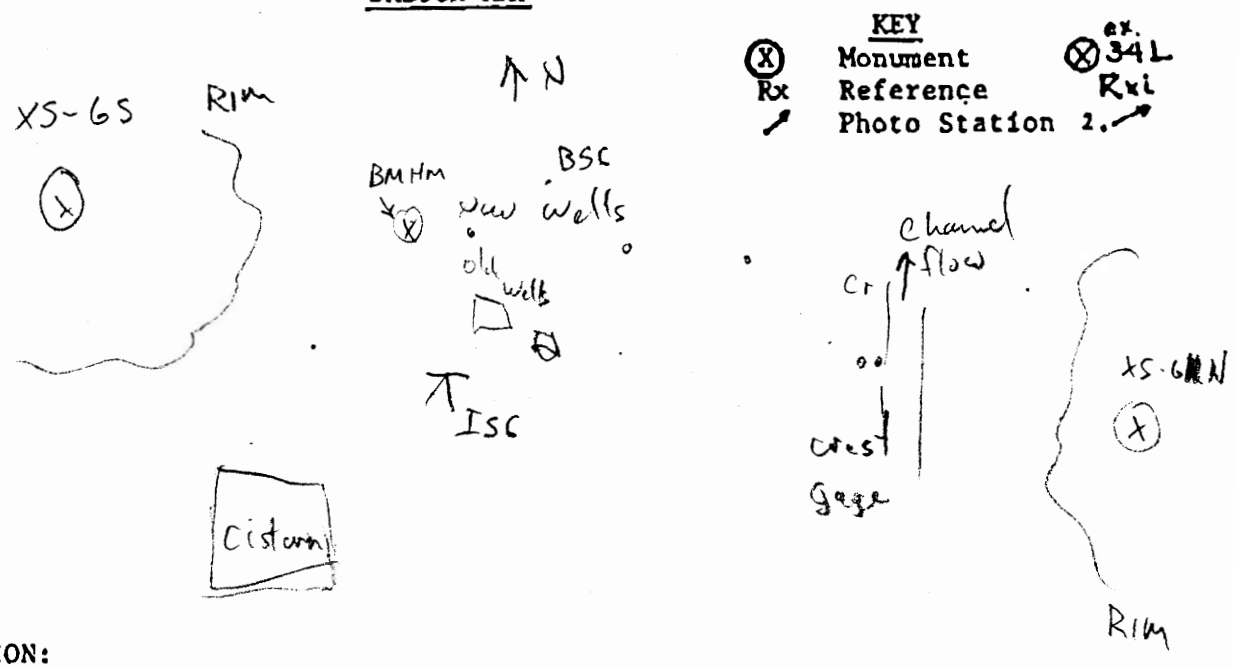
Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		128.34				BM 6 South
	11.23		128.21				TER
	22.16		127.54				RIM
	23.02		124.01				SLOPE
	33.27		118.41				SLOPE
	47.68		115.28				SLOPE
	57.80		113.64				SLOPE
	65.02		111.56				SLOPE
	84.73		101.76				FP
	95.96		101.02				FP
	107.24		100.85				FP
	152.11		99.39				FP
	165.54		99.27				FP
	177.84		98.97				FP
	184.61		99.52				FP
	191.00		98.73				FP
	202.85		98.71				FP
	217.56		97.00				BANK
	226.40		95.27				CHAN
	229.22		94.06				Left Bankfull
	232.64		91.92				CHBED
	237.08		91.90				CHBED
	240.92		93.95				Right Bankfull
	248.67		97.03				BANK
	261.25		98.87				FP
	273.64		100.26				SLOPE
	277.14		102.07				SLOPE
	283.95		123.97				SLOPE
	290.92		126.07				TER
	307.86		126.29				TER
	327.76		126.48				BM 6 North

CROSS SECTION # 6 Historic Masonary Well

Date: 5/11/99

(RIGHT/LEFT) Bank Monument

SKETCH MAP



MONUMENT DESCRIPTION:

X : Aluminum Cap flush in Ground Stamped NPS CACO XS-6

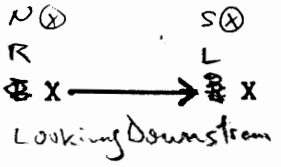
REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		



S 69E MagN

Bearing: S 65 E MagN.

Distance: 126.48'

COMMENTS:

Channel Cross Section # XS-7
Location: Gallo Wash confluence

Date: 5/14/99
Crew: T Inglis, Pwh. Fetch
Instr Loc: ___ Right ___ Left

	Mon Elev		Rod
Lx		+	=
Rx		+	=

Left Monument Pin Ht: ____
Condition: New

Right Monument Pin Ht: ____
Condition: New

$\Delta_{\text{use price elev.}}$ = 4.9

Reference Dist: ____
Recent Survey Dist: ____

Recorded in: ____ m ____ ft

Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		101.15				BM 7 North
	19.13		100.82				TER
	46.73		100.48				TER
	80.58		99.25				RIM
	84.91		75.70				SLOPE
	96.33		72.69				FP
	112.21		71.56				FP
	133.71		71.45				FP
	152.70		71.64				FP
	173.14		70.68				CHAN
	180.80		70.42				CHAN
	181.92		69.16				Headcut
	184.55		69.55				CHAN
	186.86		71.01				FP
	203.10		72.19				FP
	209.62		72.25				FP
	215.39		70.93				BANK
	220.33		67.97				Right Bank Full
	223.79		64.69				CHBED
	230.89		65.01				CHBED
	234.33		66.76				Left Bank Full
	244.21		72.12				BANK
	261.22		72.89				FP
	277.58		74.28				FP
	285.94		72.94				FP
	296.24		74.35				FP
	309.87		73.36				FP
	325.49		74.39				FP
	342.34		74.11				FP
	355.98		73.62				FP
	Con't						

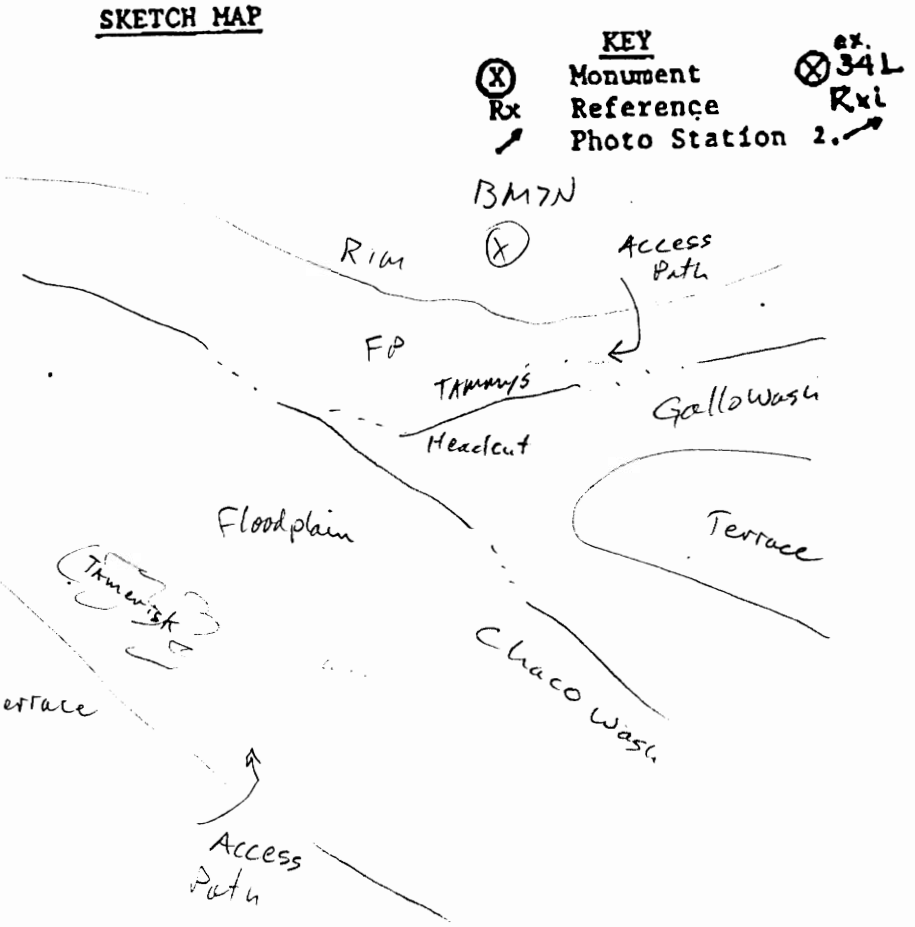
	394.83		72.80				FP
	416.19		73.06				FP
	416.21		73.06				FP
	437.85		73.89				FP
	460.44		76.19				SLOPE
	461.60		98.70				RIM
	461.75		98.55				RIM
	487.12		100.83				TER
	515.88		100.79				TER
	547.75		101.39				BM 7 South

CROSS SECTION # XS-7 Gallo Wash Confluence

Date: May 14 1999

_____ Bank Monument
RIGHT/LEFT)

SKETCH MAP



MONUMENT DESCRIPTION:

X : cemented Aluminum Cap
"Chaco Wash Monitor XS-7S 1999"

REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

S N
L X ⟶ R X

Bearing: N 54° E

Distance: 547.75

COMMENTS:

Channel Cross Section # XS-8
Location: Mockingbird Confluence

Date: 5/14/99
Crew: T Inglis, White fe
Instr Loc: ___ Right ___ Left

	Mon Elev		Rod
Lx		+	=
Rx		+	=

Left Monument Pin Ht: ____
Condition: New

Right Monument Pin Ht: ____
Condition: New

T use = 4.9
pole elev.

Recorded in: ____ m ✓ ft

Reference Dist: ____
Recent Survey Dist: ____

Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		102.32				BM & North
	23.48		102.23				TER
	54.21		101.84				TER
	76.60		100.64				RIM
	86.83		83.07				SLOPE
	100.86		76.70				SLOPE
	113.27		73.64				SLOPE
	129.66		73.03				CHAN Mockingbird Wash
	141.27		73.06				CHAN
	151.96		73.54				FP
	156.54		73.15				BANK
	164.92		68.69				Right Bank Full
	168.17		65.23				CHAN
	172.82		65.30				CHAN
	179.06		67.31				Left Bank Full
	184.05		69.70				BANK
	202.74		73.56				BANK
	220.63		73.09				FP
	241.26		73.26				FP
	262.62		73.82				FP
	284.05		72.69				FP
	304.99		72.36				FP
	326.27		72.23				FP
	345.99		72.22				FP
	353.66		73.04				FP
	378.19		72.76				FP
	409.98		73.29				FP
	421.10		77.59				SLOPE
	424.89		85.46				SLOPE
	433.50		87.25				SLOPE
	cont		Cont				

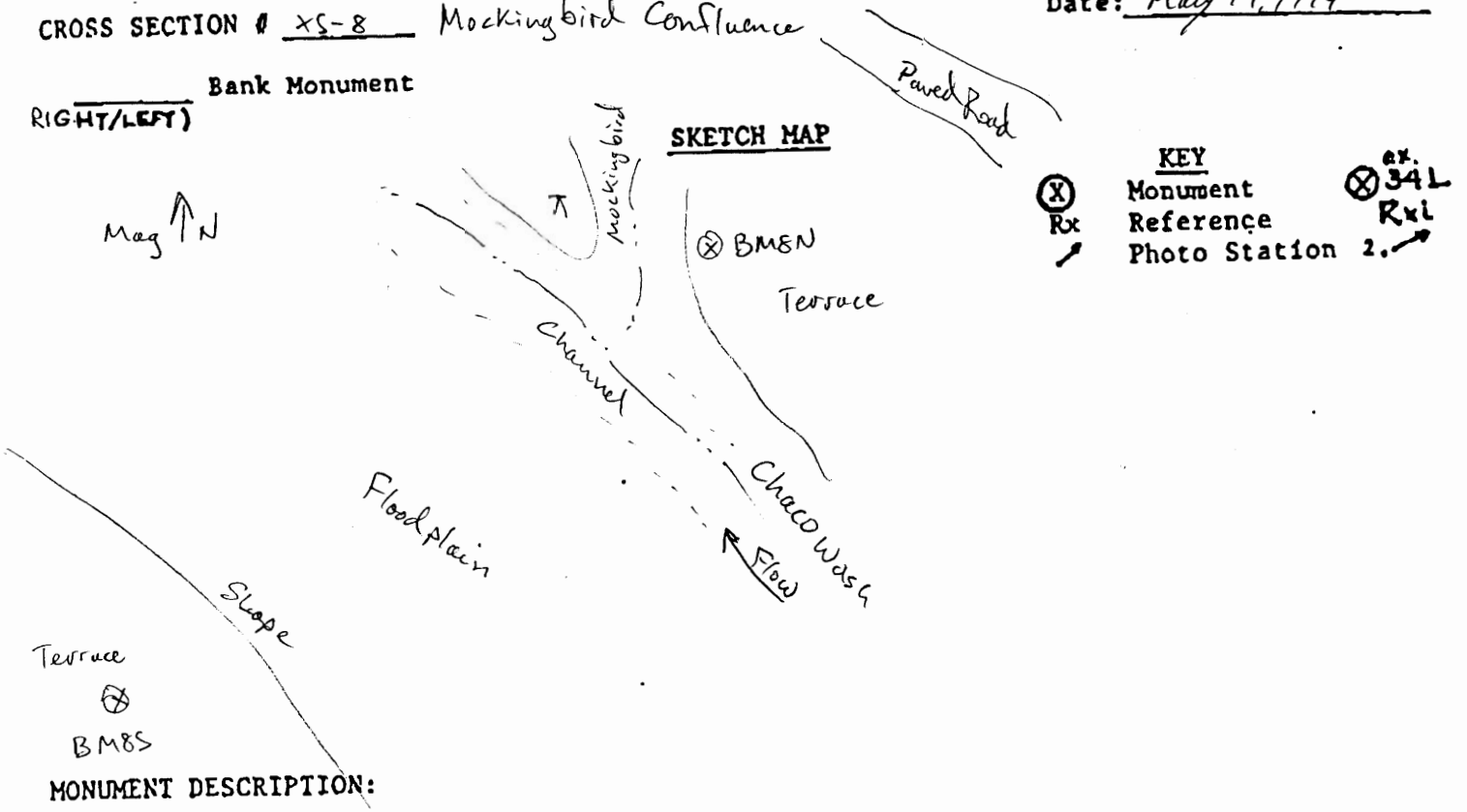
XS-8. con't	447.62		9/42				SLOPE
	460.21		100.07				RIM
	481.51		101,37				TER
	498.22		101.32				BM 8 South

CROSS SECTION # XS-8 Mockingbird Confluence

Date: May 14, 1999

RIGHT/LEFT) Bank Monument

SKETCH MAP



KEY
- ⊗ Monument
- Rx Reference
- ⊗ ex. 34L Rxl Photo Station 2.

MONUMENT DESCRIPTION:

X : Cemented Aluminum Cap
"Chaco Wash Monitor XS-8N 1999"

REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

S ~~X~~ X ⟶ N ~~X~~ X

Bearing: N 36° E

Distance: 498.22

COMMENTS:

Channel Cross Section # XS-9
Location: Pueblo Del Arroyo

Date: 5/12/97
Crew: T Inglis
Instr Loc: ___ Right ___ Left

CHCU Staff

Mon Elev Rod

Lx ___ + ___ = ___
Rx ___ + ___ = ___

Left Monument Pin Ht: ___
Condition: New

Right Monument Pin Ht: ___
Condition: See Note on other side

$\pi_{\text{upper pilot slew.}}$ = 5.1'

Reference Dist: ___
Recent Survey Dist: ___

Recorded in: ___ m X ft

Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		104.03				COR
	0.45		100.57				Ground
	21.55		96.07				Path Edge
	24.73		95.97				Path Center Line
	25.05		92.29				Wall
	39.73		87.48				GABION
	51.63		88.25				FP
	54.38		95.95				TER
	60.43		97.05				TER
	73.98		97.83				TER
	96.07		98.86				TER
	112.49		99.58				TER
	132.32		96.92				TER
	136.21		95.44				RIM
	150.13		85.76				SLOPE
	155.00		84.14				FP
	182.03		82.45				FP
	202.80		81.32				FP
	225.86		80.05				FP
	231.49		78.98				BANK
	236.08		76.37				Right Bank full
	239.63		74.95				CH BED
	244.92		74.66				CH BED
	252.94		80.01				BANK
	260.63		82.30				FP
	276.99		82.07				FP
	291.50		83.01				FP
	317.98		81.31				FP
	331.92		82.69				SLOPE
	344.44		88.79				SLOPE
	Con't						

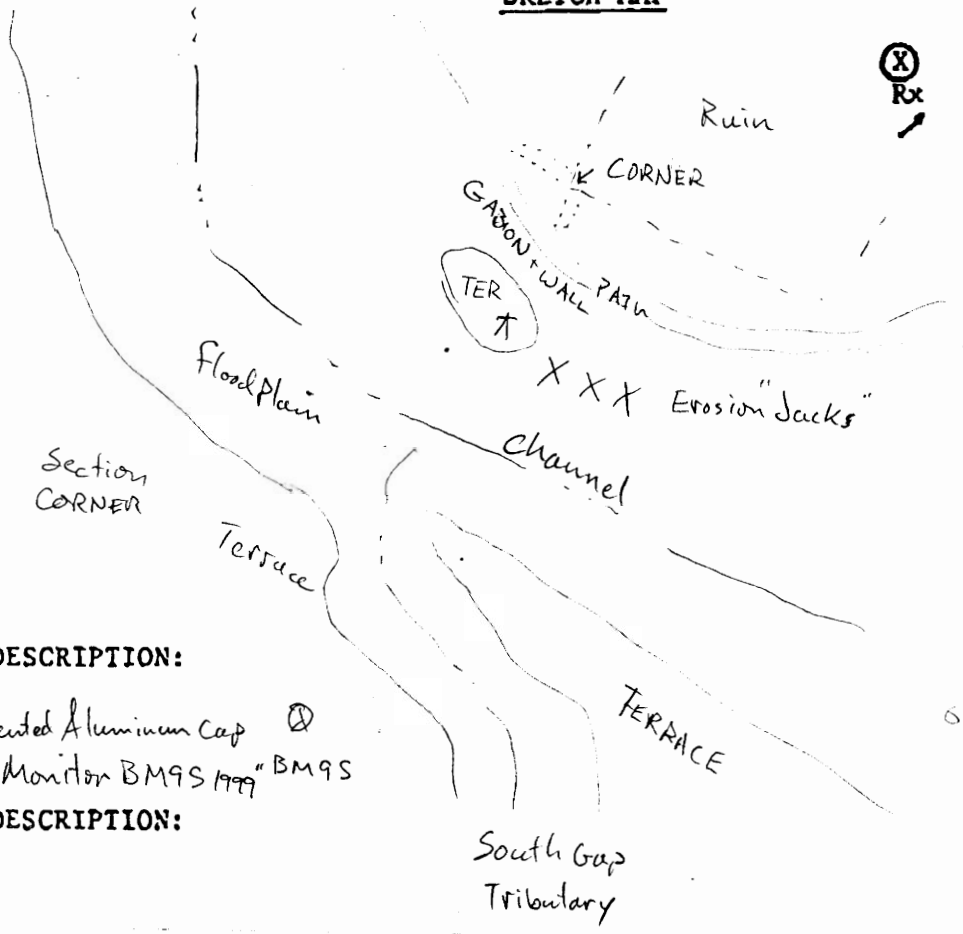
XS-9

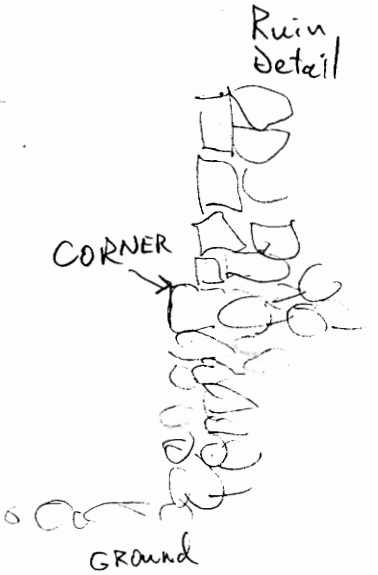
	352.38		87.23				SLOPE
	368.47		82.02				CHAN
	385.49		80.33				CHBEN
	398.11		82.15				CHAN
	404.80		84.50				SLOPE
	422.26		99.47				RIM
	434.37		100.11				TER
	448.54		100.21				BM 9 South

CROSS SECTION # XS-9 Pueblo Del Arroyo Date: May 12, 1999

RIGHT/LEFT) Bank Monument

SKETCH MAP





MONUMENT DESCRIPTION:

X : Cemented Aluminum Cap ⊗ Chaco Wash Monitor BM9S 1999" BM9S

REFERENCE DESCRIPTION:

xi :

xii :

The 6.3' Rod was placed on the "CORNER" along the side of the wall. The Rod was Not Vertical because the Wall is Not Plumb.

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

S N

X ⟶ X Bearing: N 22°E Mag

Distance: _____

COMMENTS:

Channel Cross Section # XS-10
Location: Kin Kletso

Date: 5/12/99
Crew: T Inglis Wittef
Instr Loc: ___ Right ___ Left

	Mon Elev		Rod	
Lx		+		=
Rx		+		=

Left Monument Pin Ht: ____
Condition: New

Right Monument Pin Ht: ____
Condition: See Note on other Side

$T_{\text{use price elev.}}$ = 4.9'

Reference Dist: ____
Recent Survey Dist: ____

Recorded in: ___ m X ft

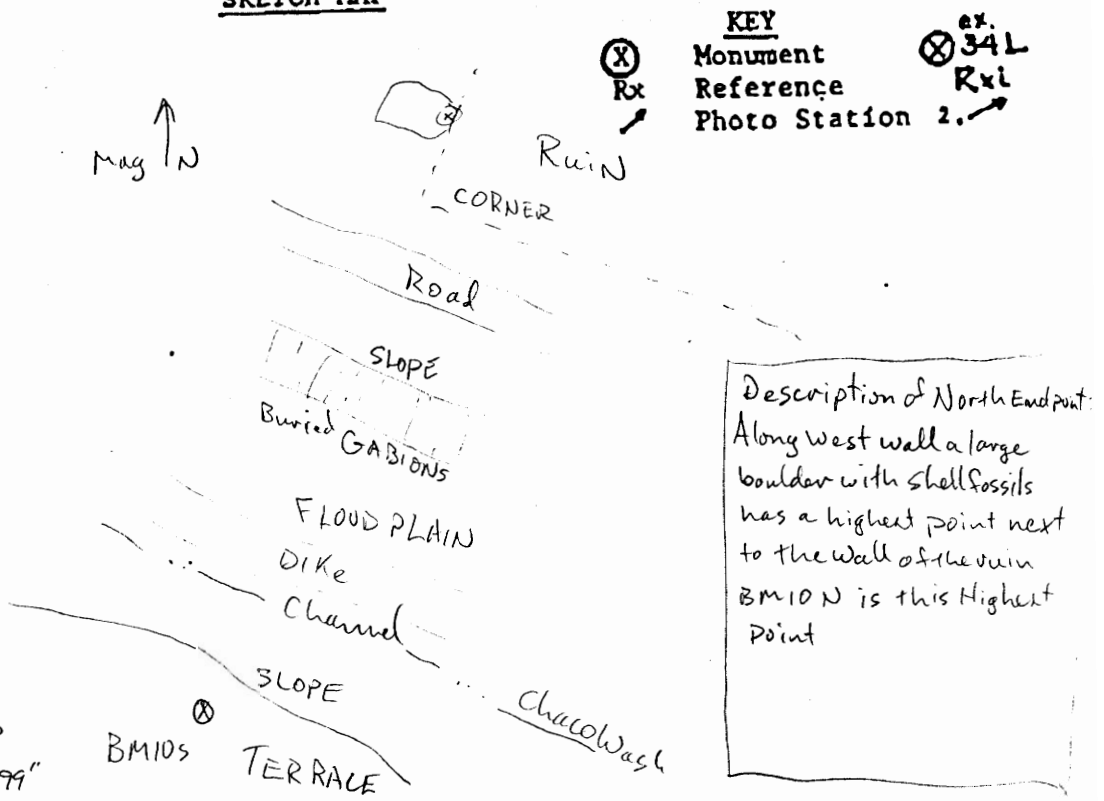
Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		113.21				BM 10 South
	16.03		113.10				TER
	36.09		113.73				TER
	57.96		113.40				TER
	86.48		109.49				RIM
	88.18		101.22				SLOPE
	92.82		99.92				FP
	103.60		98.73				FP
	119.29		97.72				FP
	129.14		100.63				FP
	139.95		100.17				FP
	155.42		97.17				BANK
	169.34		88.76				CHBED
	173.36		88.65				CHBED
	178.96		92.11				Right Bank full
	179.29		93.37				BANK
	189.76		98.47				DIKE
	202.45		100.16				DIKE
	214.81		99.93				DIKE
	229.43		97.10				DIKE
	242.10		96.00				FP
	250.14		95.98				FP
	262.09		95.34				FP
	279.17		95.06				FP
	293.45		96.79				FP
	308.15		96.53				FP
	319.83		97.89				GAB
	348.53		117.41				RIM
	355.76		118.17				SLOPE
	364.42		116.93				Road
	Con't						

	391.20		117.21				ROAD
	395.32		120.46				TER
	403.64		121.14				TER
	416.10		122.67				CORner
	419.54		122.82				Run
	434.16		128.59				BM ION

CROSS SECTION # _____ Date: _____

_____ Bank Monument
RIGHT/LEFT)

SKETCH MAP



MONUMENT DESCRIPTION:

X : Cemented Aluminum Cap "Chaco Wash Monitor BM10S 1999"

REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

S N
X X ⟶ X X

Bearing: N 16°E Mag

Distance: 434.16

COMMENTS:

Channel Cross Section # XS-11
Location: Casa Chiquita Wells

Date: 5/14/99
Crew: T Inglis, WhiteSie
Instr Loc: ___ Right ___ Left

	Mon Elev		Rod
Lx		+	=
Rx		+	=

Left Monument Pin Ht: ____
Condition: New

Right Monument Pin Ht: ____
Condition: New

$\pi_{use\ price\ elev.}$ = 5.0

Reference Dist: ____
Recent Survey Dist: ____

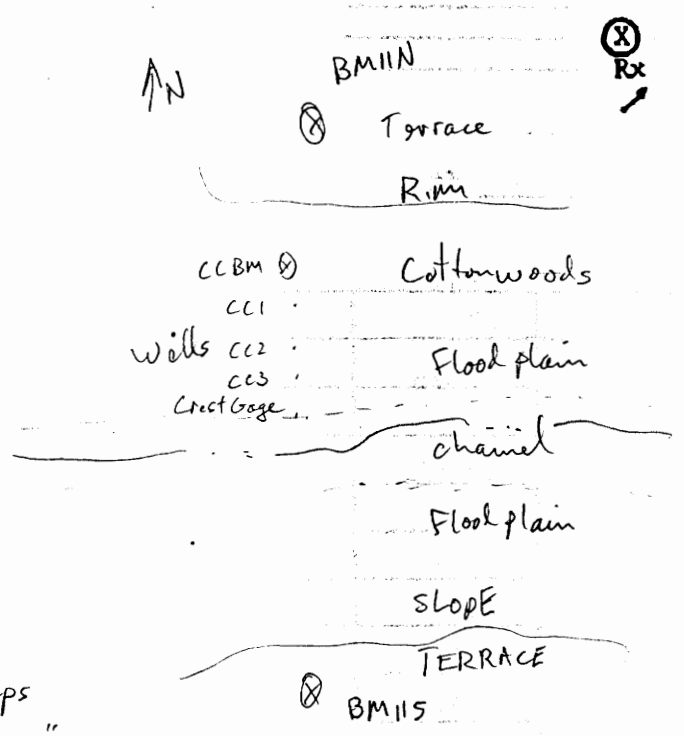
Recorded in: ___ m X ft

Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		112.72				BM 11 South
	15.90		112.52				TER
	30.58		110.99				RIM
	47.25		100.34				FP
	65.17		99.17				FP
	88.58		98.85				FP
	117.28		98.62				FP
	139.11		98.47				FP
	165.36		99.67				FP
	182.32		100.12				FP
	233.39		100.24				FP
	241.07		100.29				FP
	246.69		98.92				BANK
	251.94		95.01				CHAN
	258.02		93.65				BED
	262.67		93.05				BED
	266.92		92.96				CHAN
	273.44		97.55				BANK
	281.89		99.52				FP
	302.64		99.92				FP
	317.35		98.57				FP
	330.62		99.65				FP
	349.77		100.05				FP
	365.55		99.89				FP
	376.86		99.20				FP
	382.92		99.15				FP
	398.44		102.92				SLOPE
	400.56		113.66				RIM
	402.90		113.85				TER
	424.03		113.81				TER
	442.47		113.73				BM 11 North

CROSS SECTION # XS-11 Casa Chiquita Wells Date: May 14, 1999

RIGHT/LEFT Bank Monument

SKETCH MAP



KEY
X Rx — Monument Reference
ex. 34L Rxi 2. — Photo Station

MONUMENT DESCRIPTION:

X : Cemented Aluminum Caps "Chaco Wash Monitor XS11S 1999"

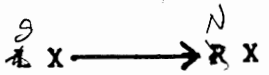
REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		



Bearing: N 1°W Mag

Distance: 442.47

COMMENTS:

Channel Cross Section # XS-12
Location: Penasco Trail Crossing

Date: 5/13/99
Crew: TInglis, [illegible]
Instr Loc: ___ Right ___ Left

	Mon Elev		Rod
Lx		+	=
Rx		+	=

Left Monument Pin Ht: ____
Condition: New

Right Monument Pin Ht: ____
Condition: New

$\pi_{\text{use price elev.}}$ = 4.9

Recorded in: ____ m X ft

Reference Dist: ____
Recent Survey Dist: ____

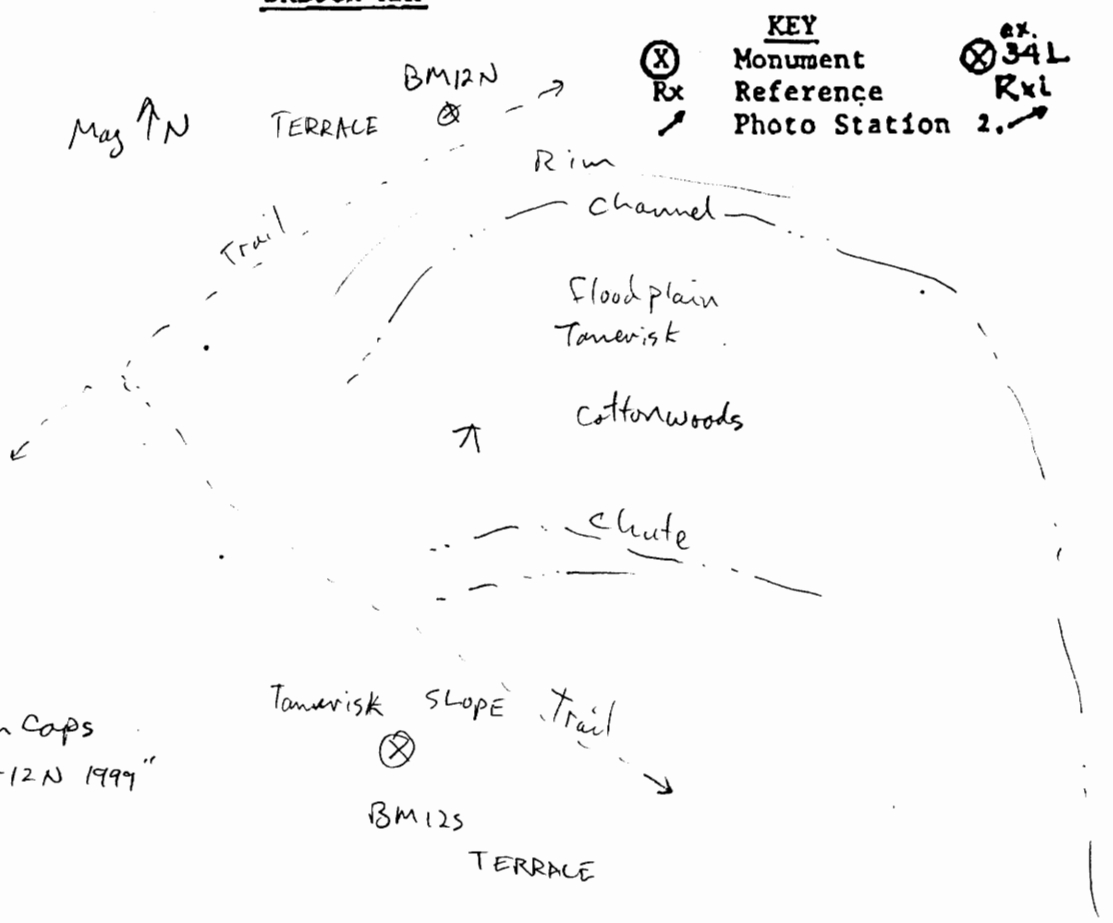
Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		111.60				BM 12 South
	17.60		110.41				TER
	38.51		108.65				SLOPE
	48.29		106.99				FP
	58.39		103.24				FP
	75.85		101.48				FP
	92.64		100.44				FP
	115.04		99.36				FP
	131.36		99.08				FP
	147.96		99.07				FP
	160.90		98.98				FP
	175.03		99.18				FP
	185.16		99.58				CHUTE
	186.39		98.73				CHUTE
	192.84		97.93				TRAIL
	200.57		97.28				CHUTE
	203.93		97.81				CHUTE
	209.43		95.98				CHUTE
	216.60		97.62				CHUTE
	219.80		97.77				CHUTE
	225.40		99.17				FP
	239.69		98.83				FP
	248.56		98.91				FP
	260.93		99.04				FP
	285.09		100.20				FP
	296.95		99.27				FP
	308.04		97.42				FP
	320.23		96.73				FP
	327.06		96.99				FP
	339.67		95.49				FP
	Cont						

	346.25		96.24				FP
	355.31		95.72				FP
	368.93		96.42				FP
	382.40		95.80				FP
	395.13		96.55				FP
	403.09		95.66				FP
	412.93		97.06				FP
	424.64		96.14				FP
	434.37		97.06				FP
	447.41		95.63				FP
	468.15		95.98				BANK
	474.59		94.01				CHAN
	479.70		92.92				CHAN
	480.94		91.66				CHAN BED
	483.16		91.64				CHAN BED
	483.90		92.61				CHAN
	498.14		93.31				CHAN
	510.11		92.31				CHAN
	518.78		94.06				CHAN
	526.12		97.60				WALL
	530.72		110.77				RIM
	560.49		110.88				TER
	583.43		110.61				TER Trail
	637.21		111.06				BM2N

CROSS SECTION # XS-12 Peñasco Trail Crossing Date: May 13, 1999

RIGHT/LEFT Bank Monument

SKETCH MAP



MONUMENT DESCRIPTION:

X : Cemented Aluminum Caps
"Chaco Wash Monitor XS-12N 1999"

REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

S N
L X ⟶ R X

Bearing: N 5° E Mag

Distance: _____

COMMENTS:

Channel Cross Section # XS-13
Location: Near Escavada Wash

Date: 5/13/99
Crew: T Inglis [book] Pwhitefo
Instr Loc: ___ Right ___ Left

Mon Elev Rod
Lx _____ + _____ = _____
Rx _____ + _____ = _____

Left Monument Pin Ht: _____
Condition: _____

Right Monument Pin Ht: _____
Condition: _____

T use = _____
pole elev.

Reference Dist: _____
Recent Survey Dist: _____

Recorded in: _____ m _____ ft

Sta	Dist	Top	Mid	Bot	H20 Depth	Bed Mat'l	Comments
	0.00		103.49				BM 13 South
	6.78		103.00				SLOPE
	21.37		100.54				SLOPE
	31.17		99.58				SLOPE
	31.42		90.07				SLOPE
	41.94		87.68				SLOPE
	52.70		83.67				SLOPE
	66.34		82.00				FP
	70.21		82.26				FP
	71.66		81.68				FP
	77.12		80.87				BANK
	82.49		79.49				CHAN
	90.24		78.73				CHAN
	93.01		78.23				CHAN
	98.08		78.32				CHAN
	99.84		78.77				CHAN
	107.10		78.89				CHAN
	111.09		82.01				BANK
	115.25		83.17				BANK
	120.00		85.56				FP
	132.53		86.69				FP
	140.38		85.81				FP
	150.03		87.17				FP
	163.60		86.46				FP
	176.77		86.81				FP
	191.81		87.44				FP
	206.36		88.56				FP
	231.49		90.61				FP
	251.71		95.57				SLOPE
	265.36		96.01				TER
	275.05		96.55				BM 13 North

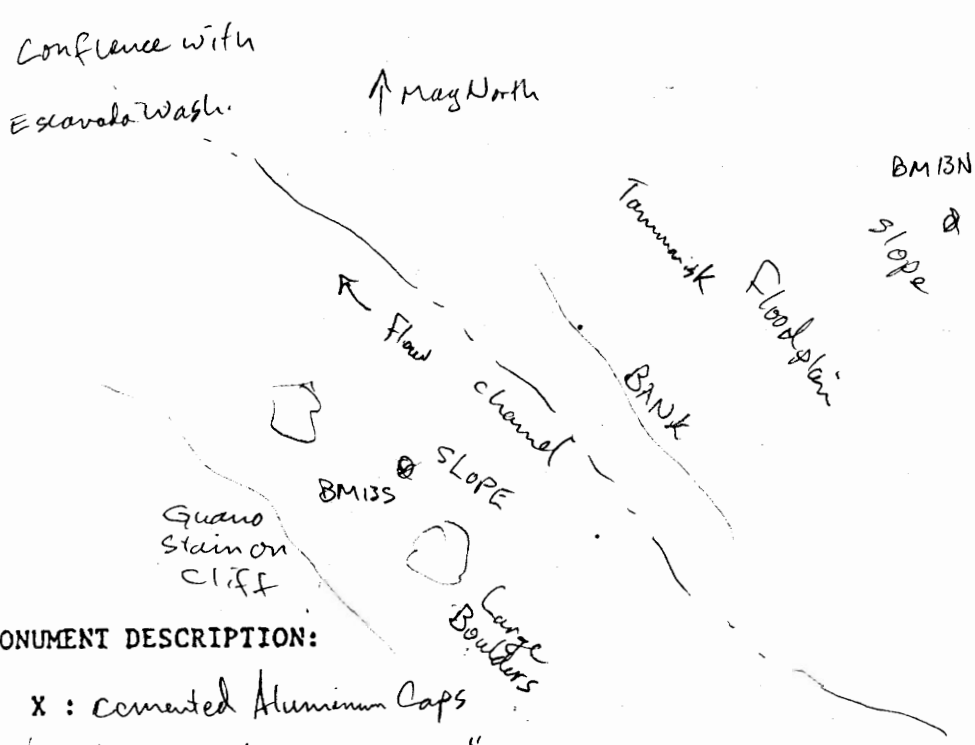
CROSS SECTION # XS-13 Near Escavada Wash

Date: May 13, 1999

RIGHT/LEFT) Bank Monument

SKETCH MAP

KEY
(X) Monument
Rx Reference
Photo Station 2.
ex. (X) 34L Rx1



MONUMENT DESCRIPTION:

X : cemented Aluminum Caps
"ChacoWash Monitor XS-13N 1999"

REFERENCE DESCRIPTION:

xi :

xii :

INSTRUMENT SETUP:

Station	Center Hair Reading	Elevation ( )
X :		
xi :		
xii :		

N ← X ——→ S X

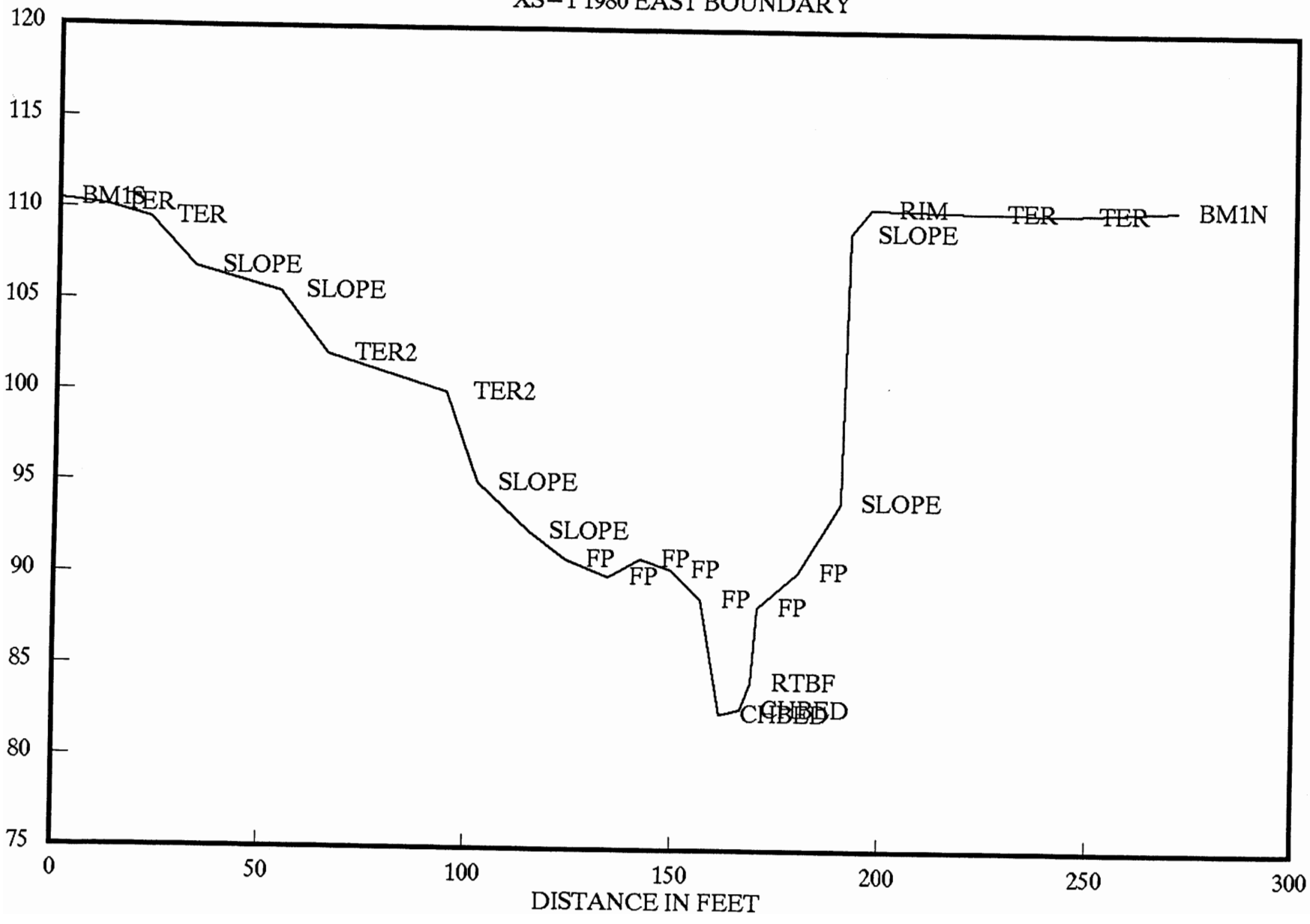
Bearing: N 82° E Mag

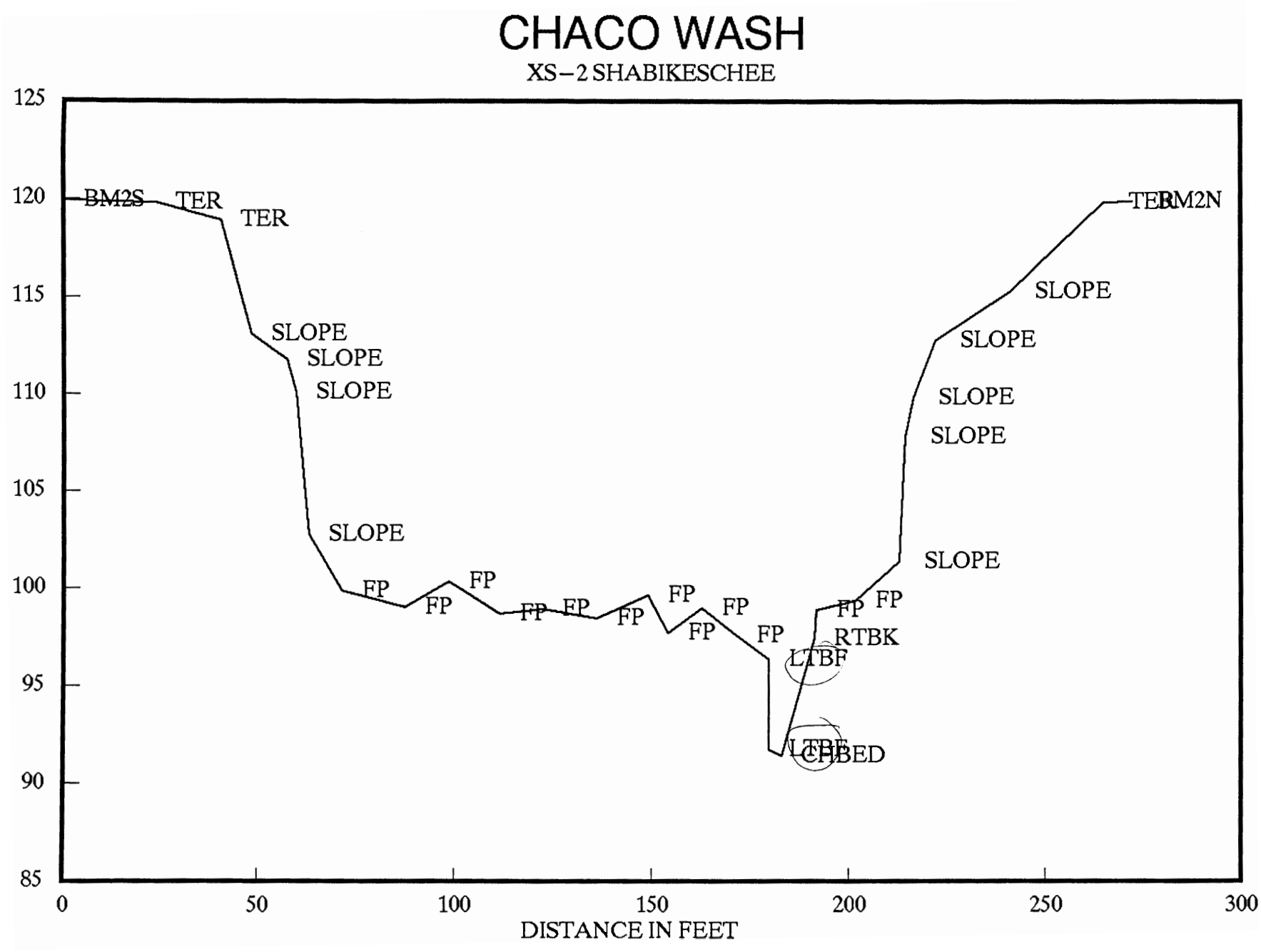
Distance: 274.77' straight line
275.05' sum of Segments

COMMENTS:

CHACO WASH

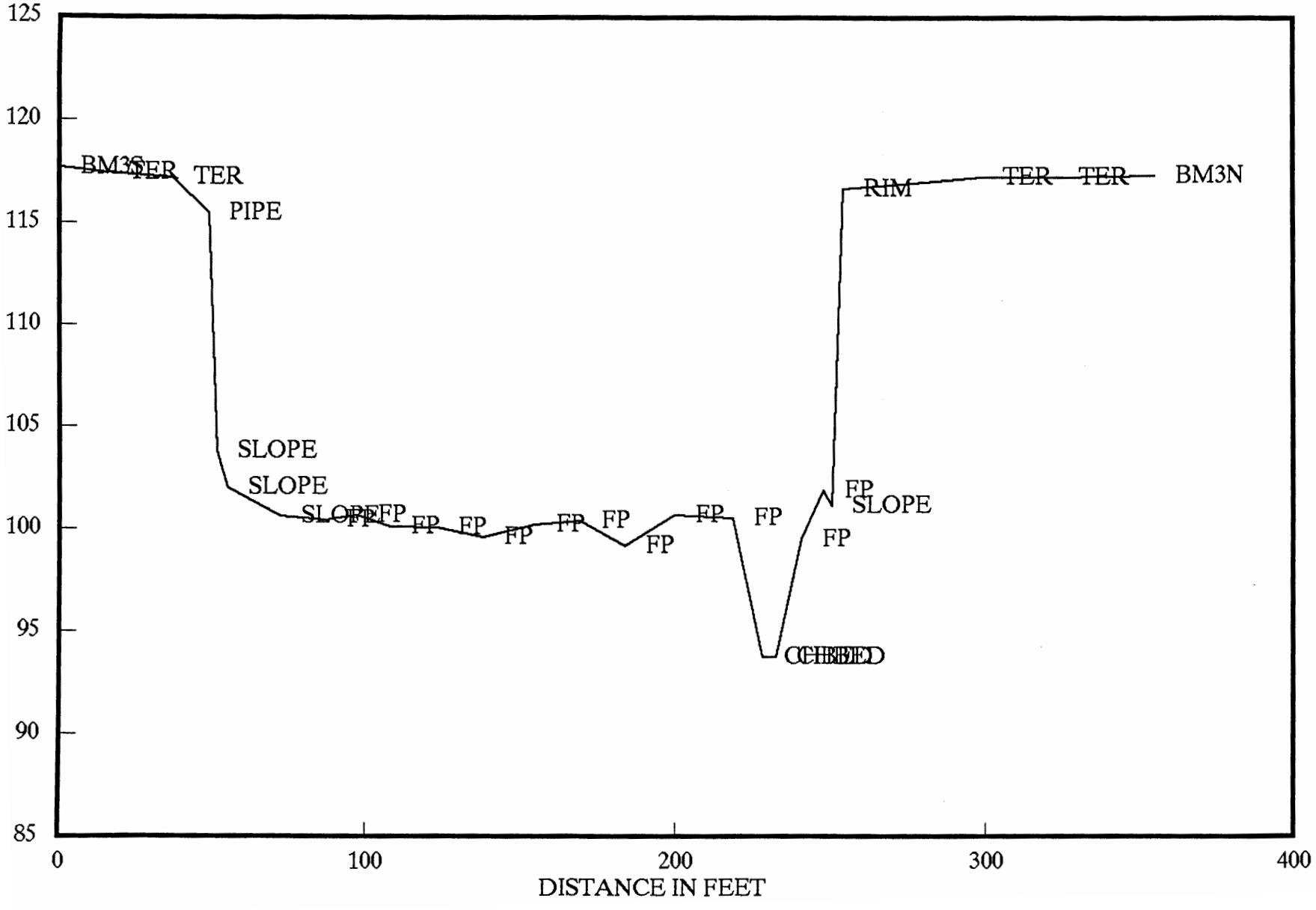
XS–1 1980 EAST BOUNDARY

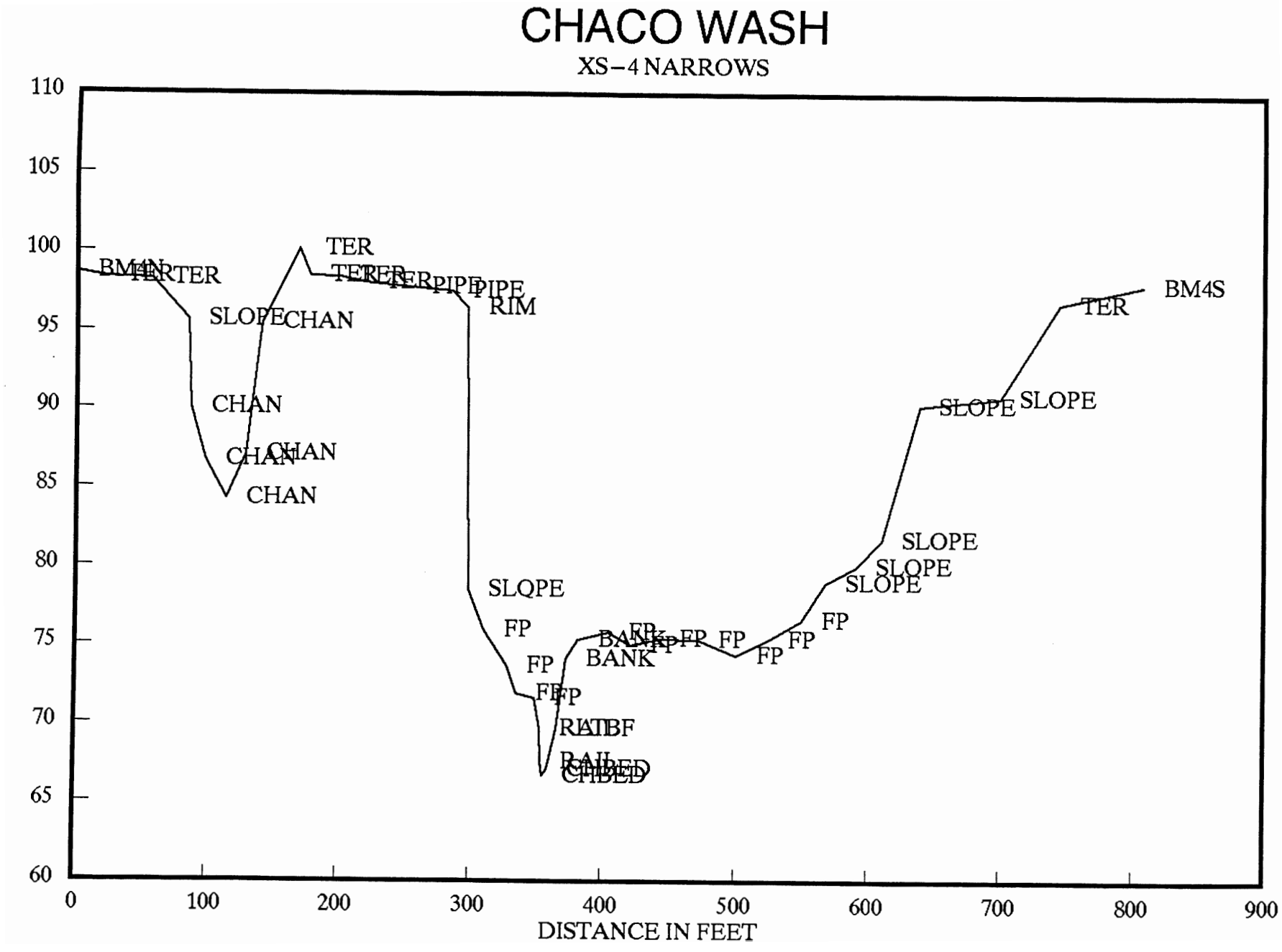



CHACO WASH
XS–2 SHABIKESCHEE
125
120
115
110
105
100
95
90
85
0
50
100
150
200
250
300
DISTANCE IN FEET
BM2S
TER
TER
SLOPE
SLOPE
SLOPE
SLOPE
FP
FP
FP
FP
FP
FP
FP
FP
FP
FP
FP
FP
LTBF
RTBK
LTBF
CHBED
SLOPE
SLOPE
SLOPE
SLOPE
TER
BM2N

CHACO WASH

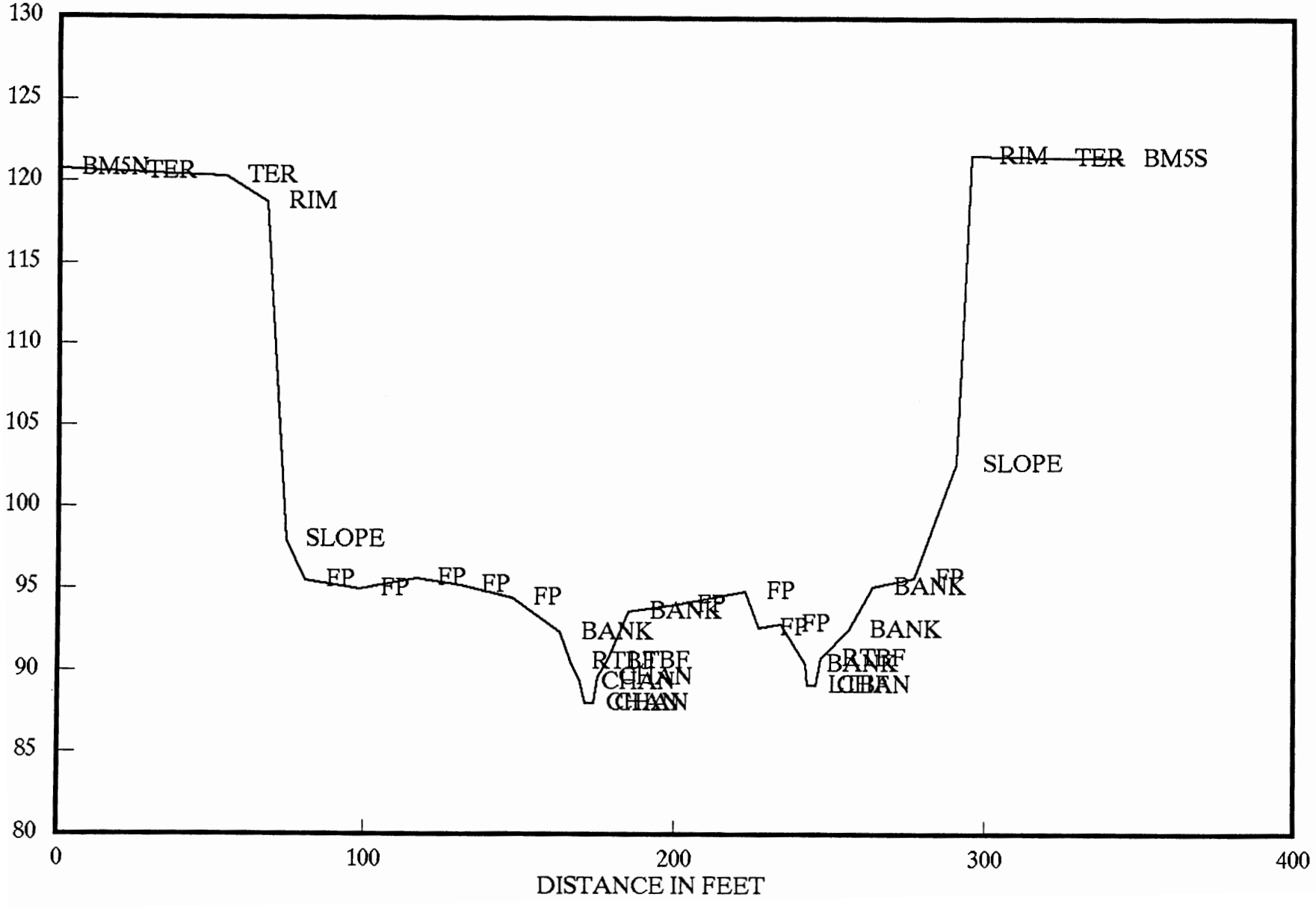
XS-3 WIJIJI




CHACO WASH
XS-4 NARROWS
110
105
100
95
90
85
80
75
70
65
60
0
100
200
300
400
500
600
700
800
900
DISTANCE IN FEET
BM4N
TER
TER
SLOPE
CHAN
TER
TER
TER
PIPE
PIPE
RIM
CHAN
CHAN
CHAN
CHAN
SLQPE
FP
FP
FP
BANK
FP
FP
FP
FP
FP
FP
FP
SLOPE
SLOPE
SLOPE
SLOPE
SLOPE
TER
BM4S

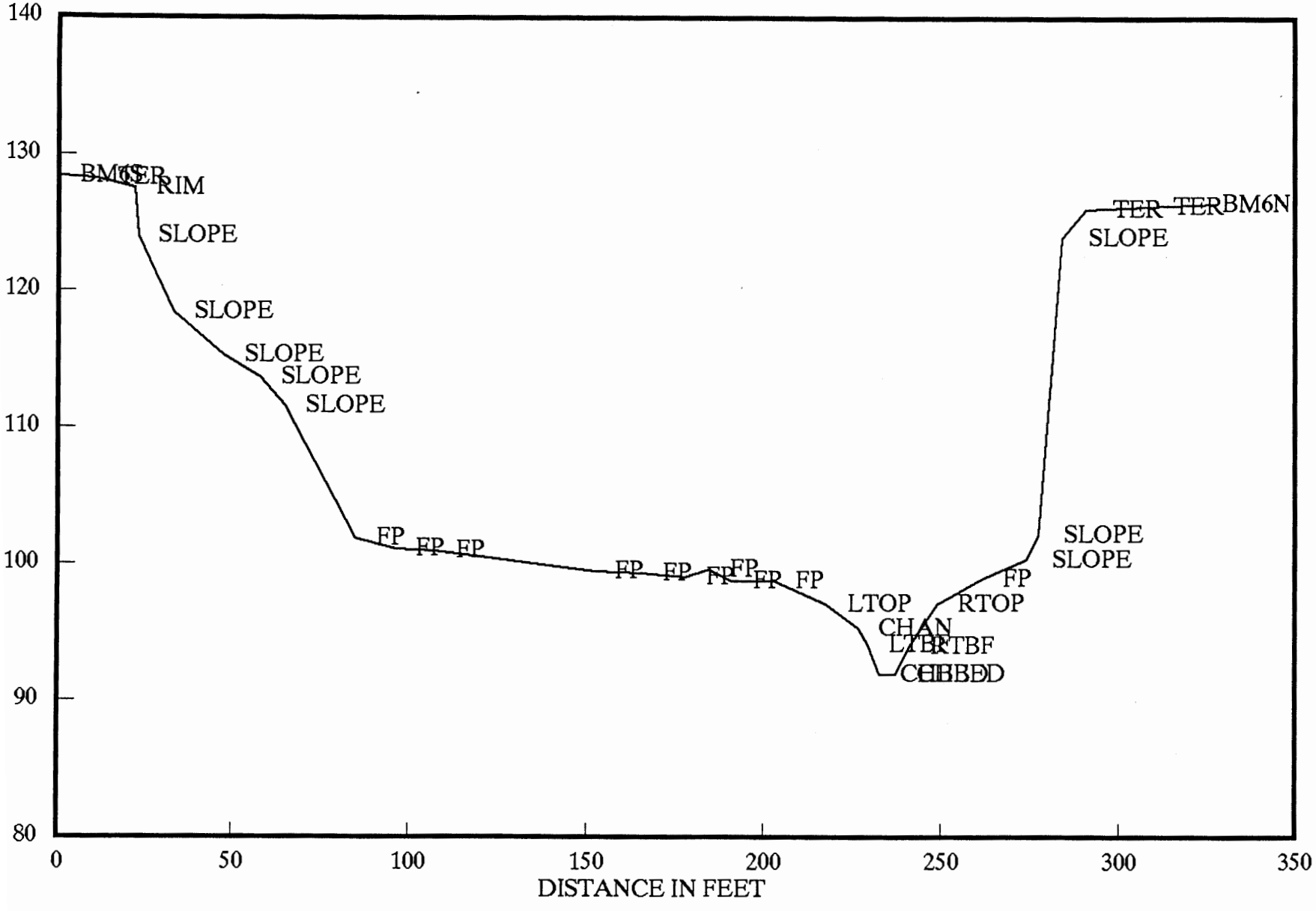
CHACO WASH

XS–5 FAJADA WASH CONFLUENCE



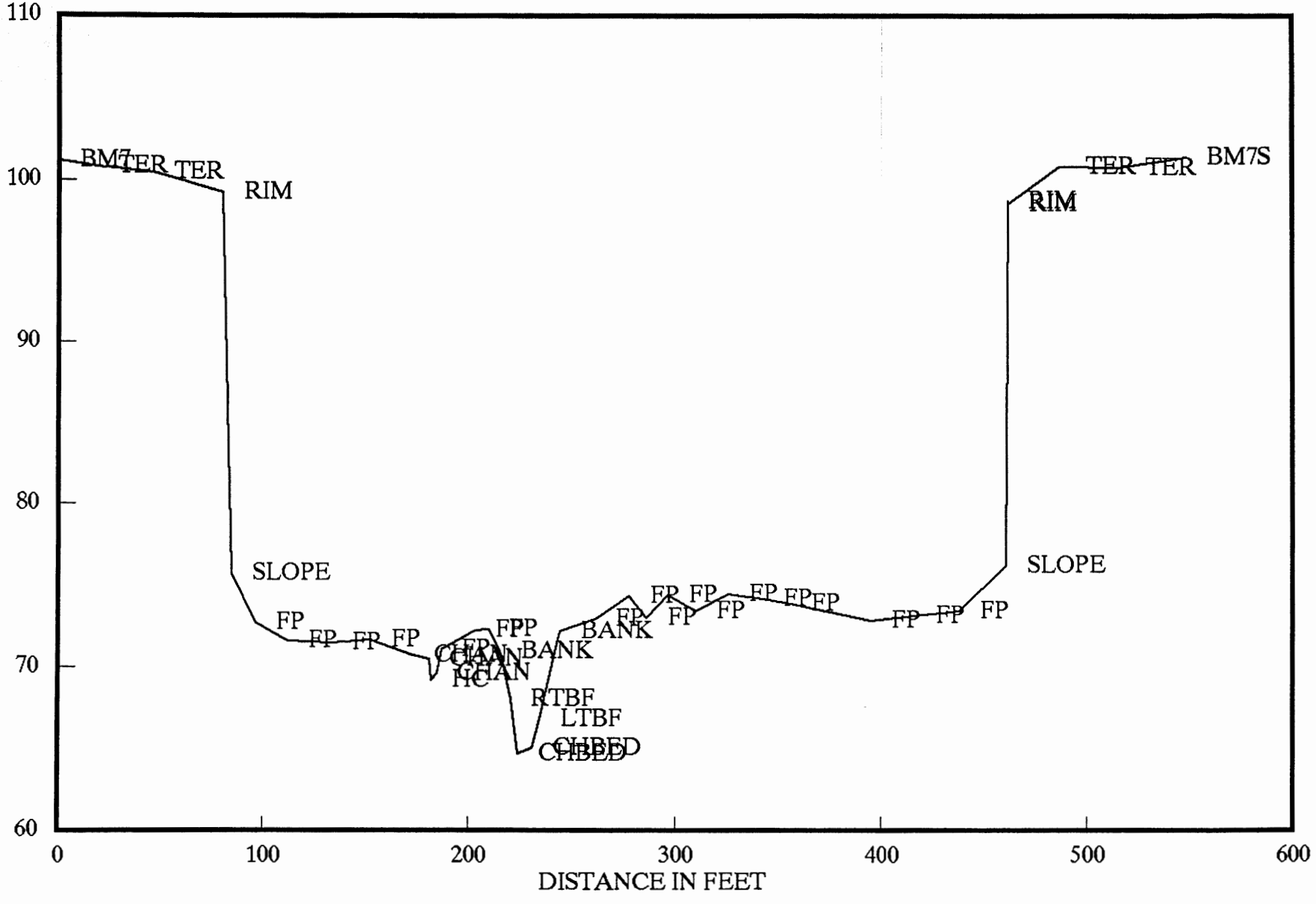
CHACO WASH

HISTORIC MASONARY WELLS



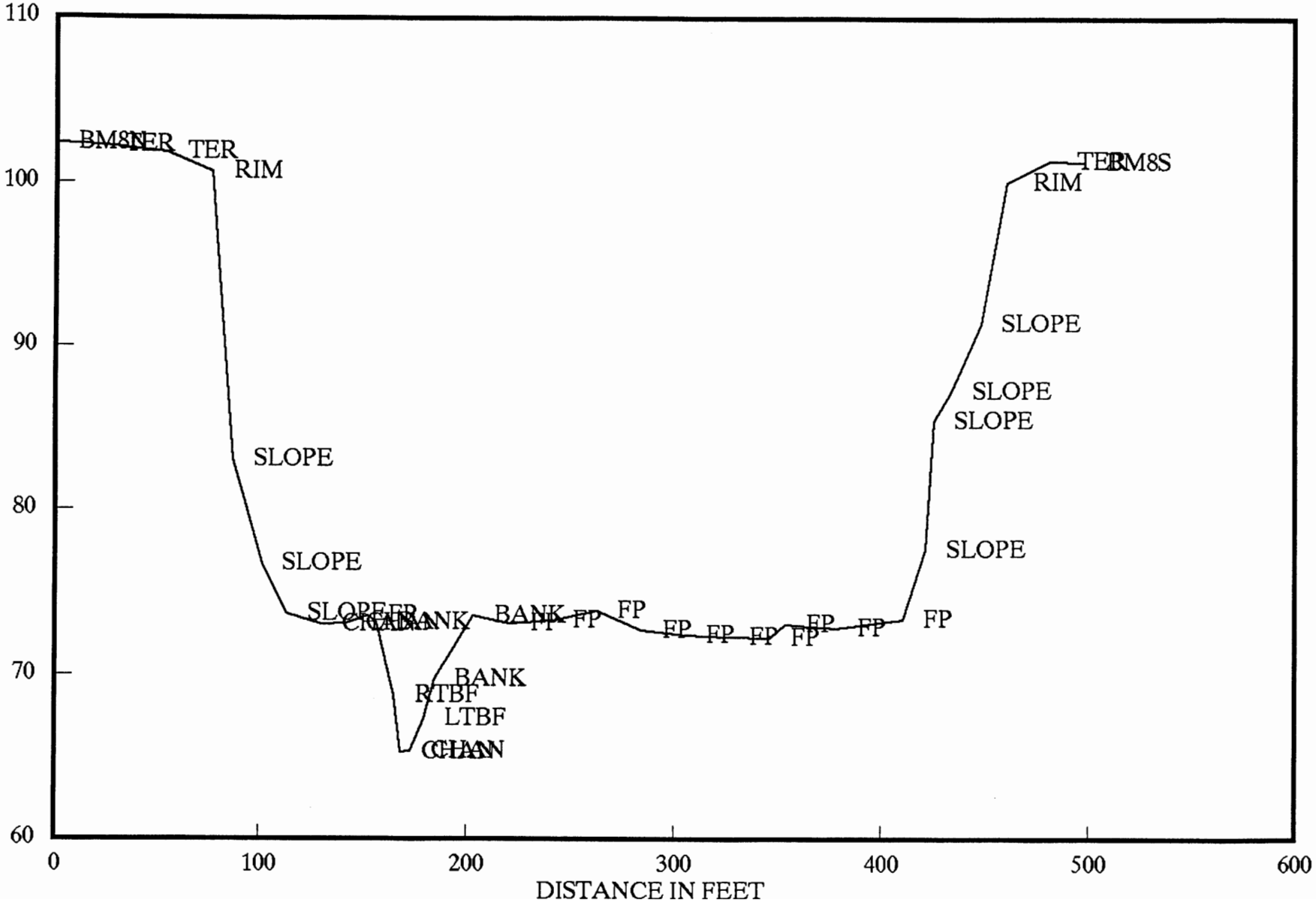
CHACO WASH

XS–7 GALLO WASH CONFLUENCE



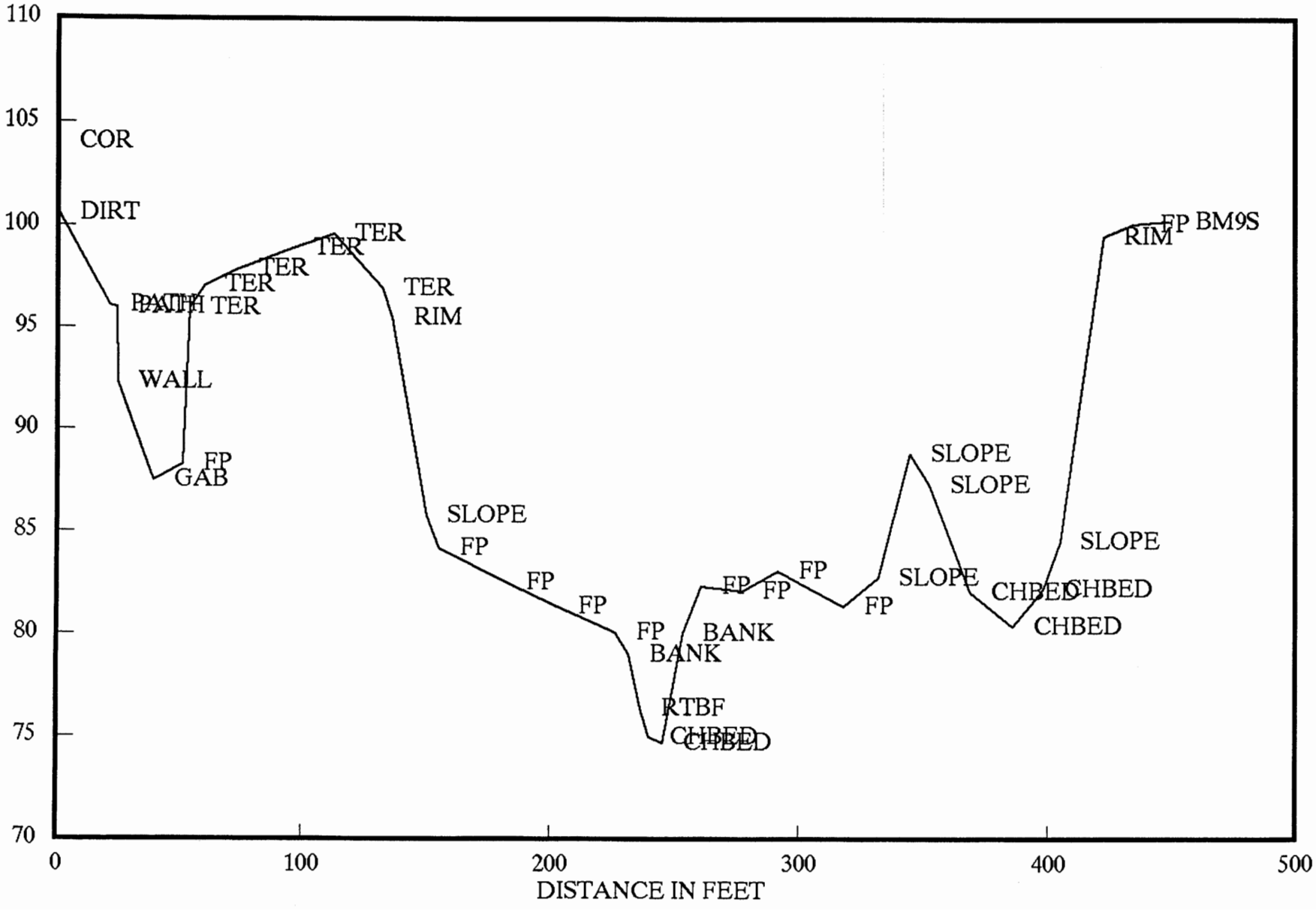
CHACO WASH

XS–8 MOCKINGBIRD



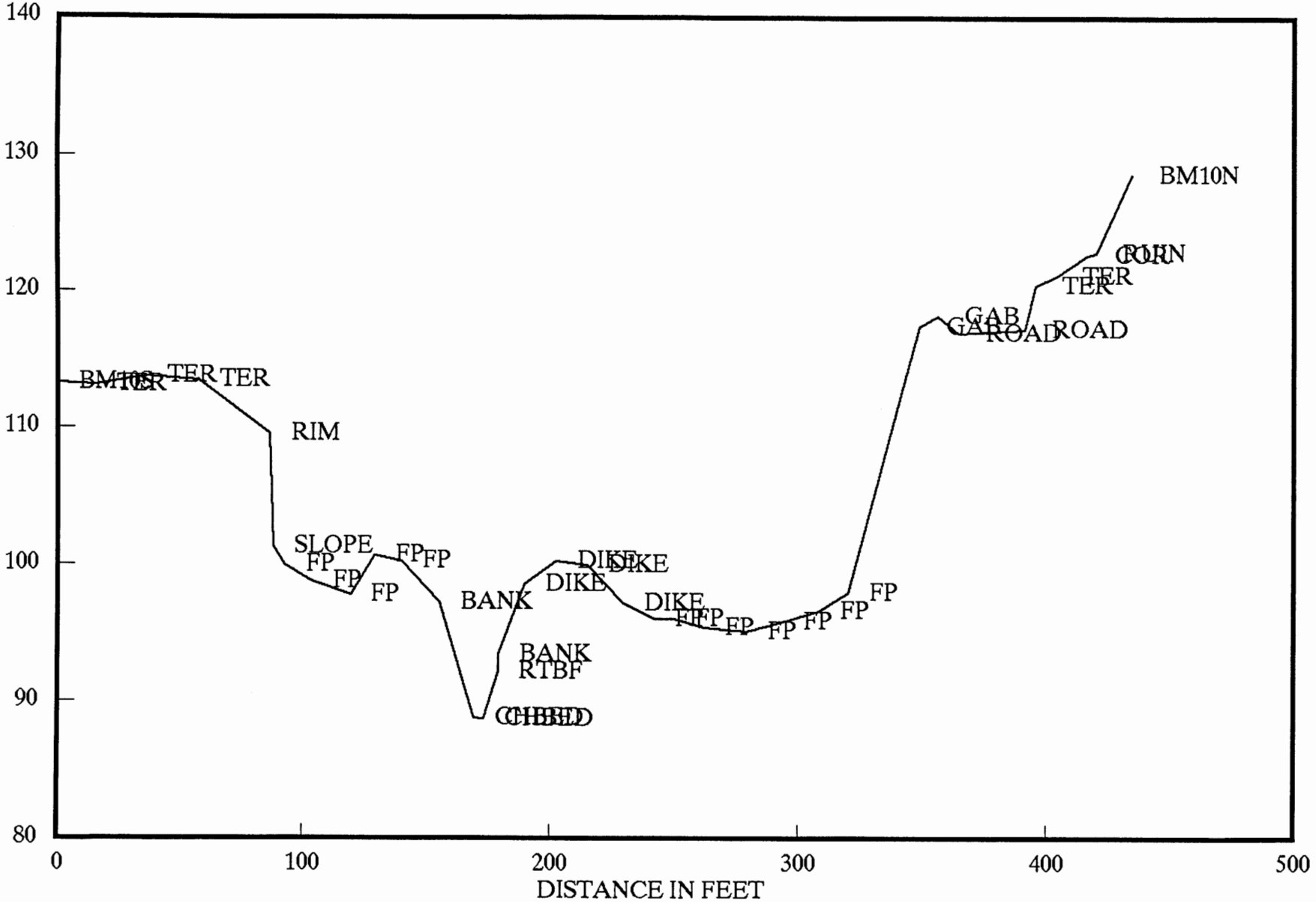
CHACO WASH

XS–9 PUEBLO DEL ARROYO



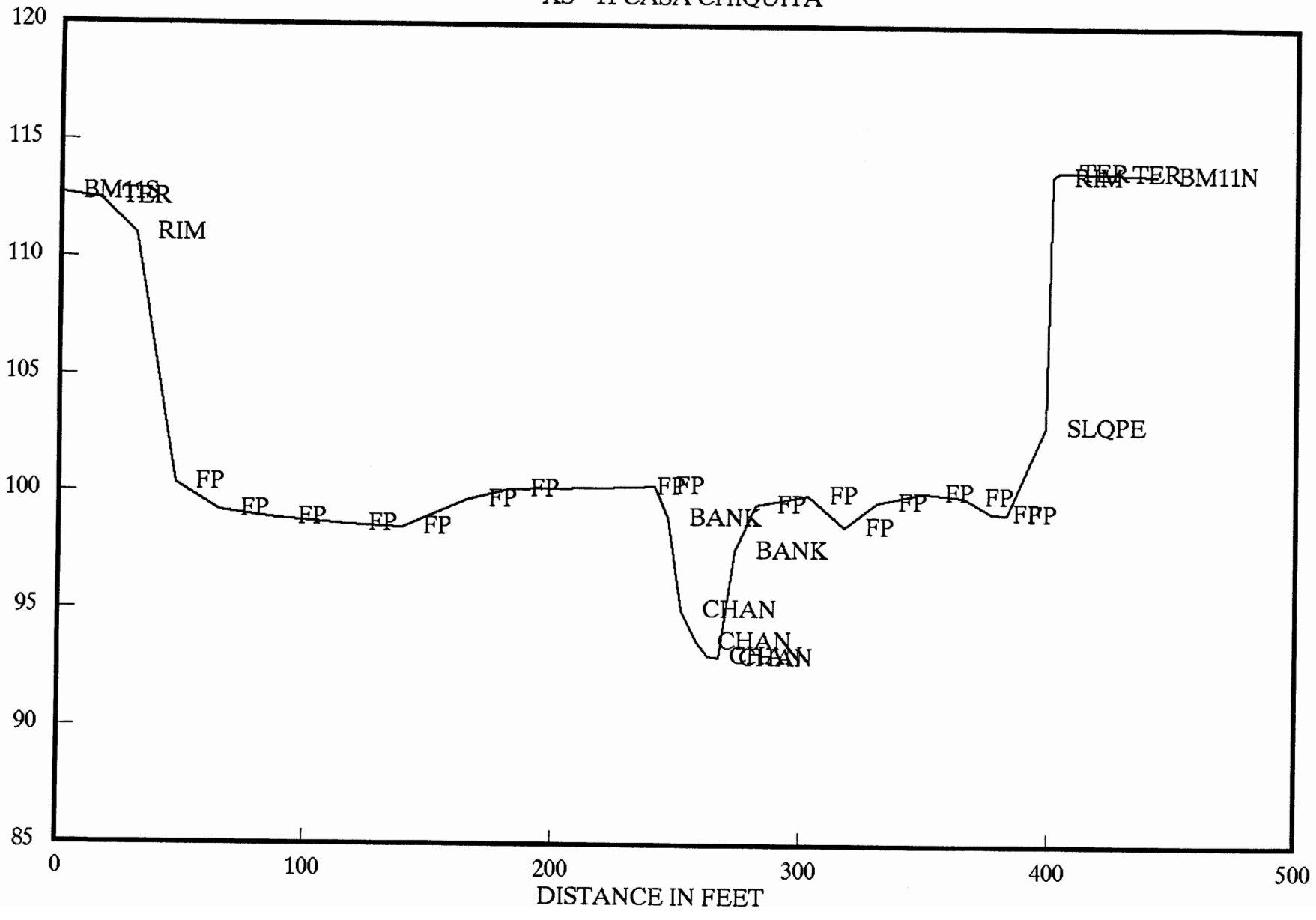
CHACO WASH

XS–10 KIN KLETSO



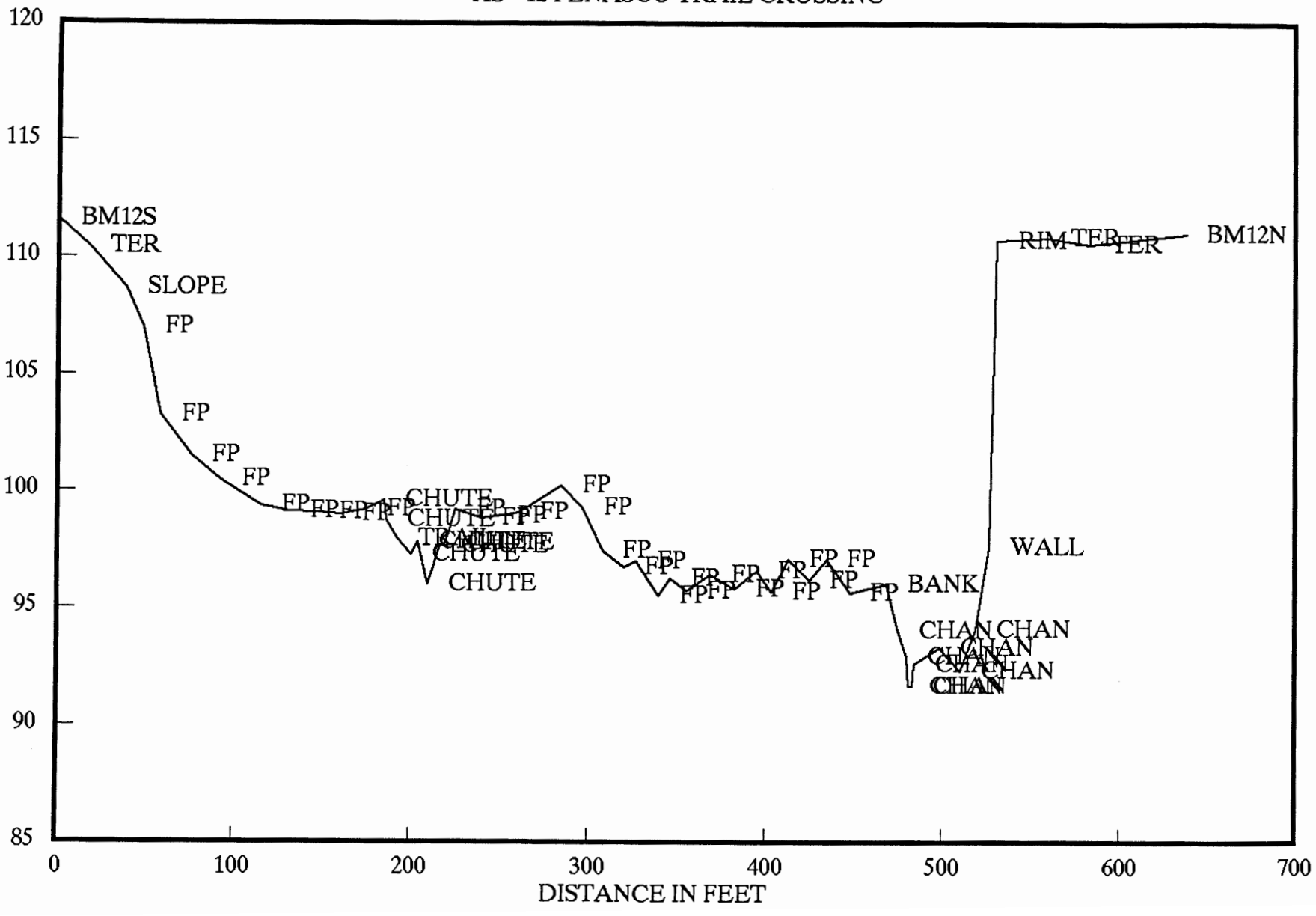
CHACO WASH

XS–11 CASA CHIQUITA



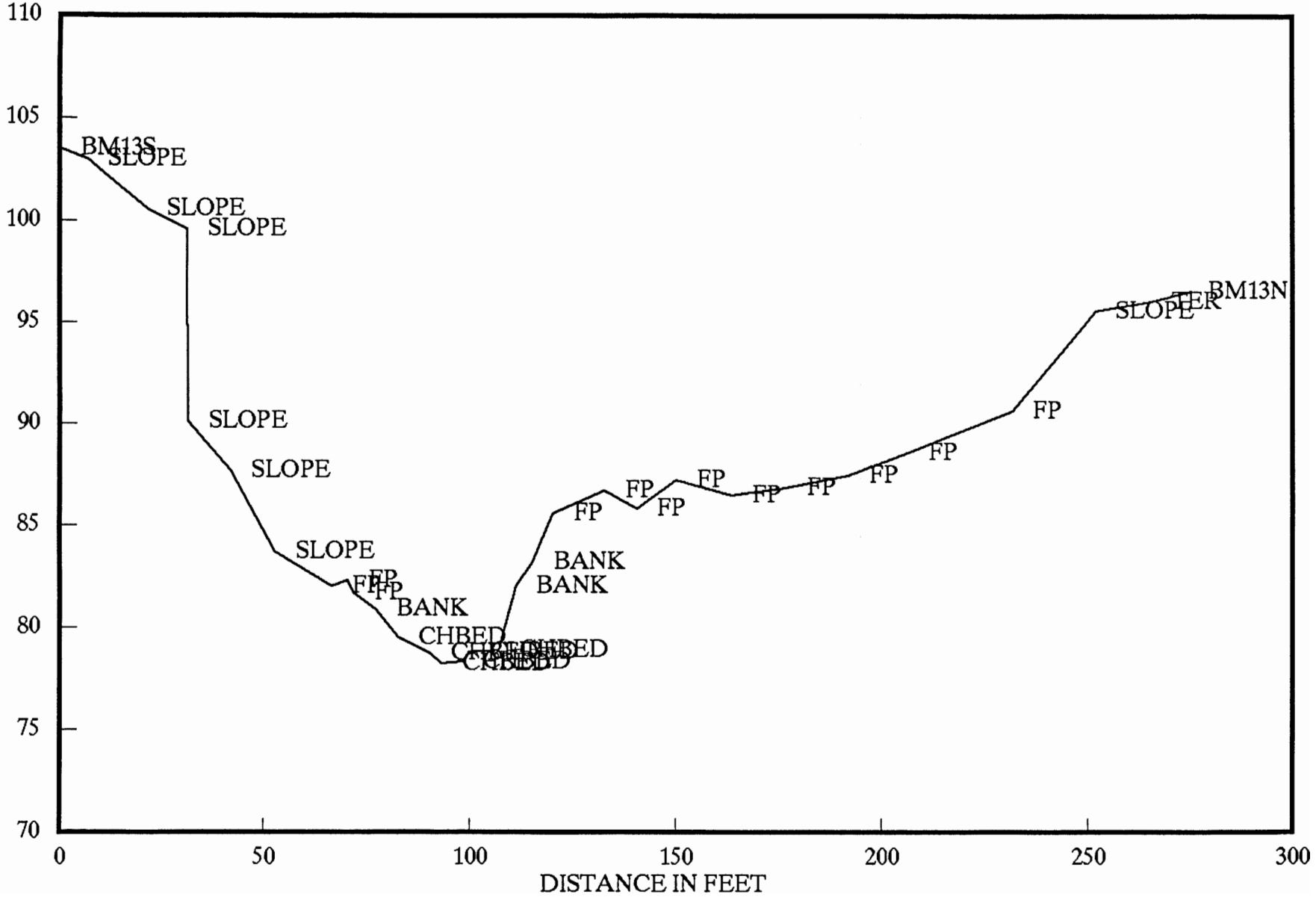
CHACO WASH

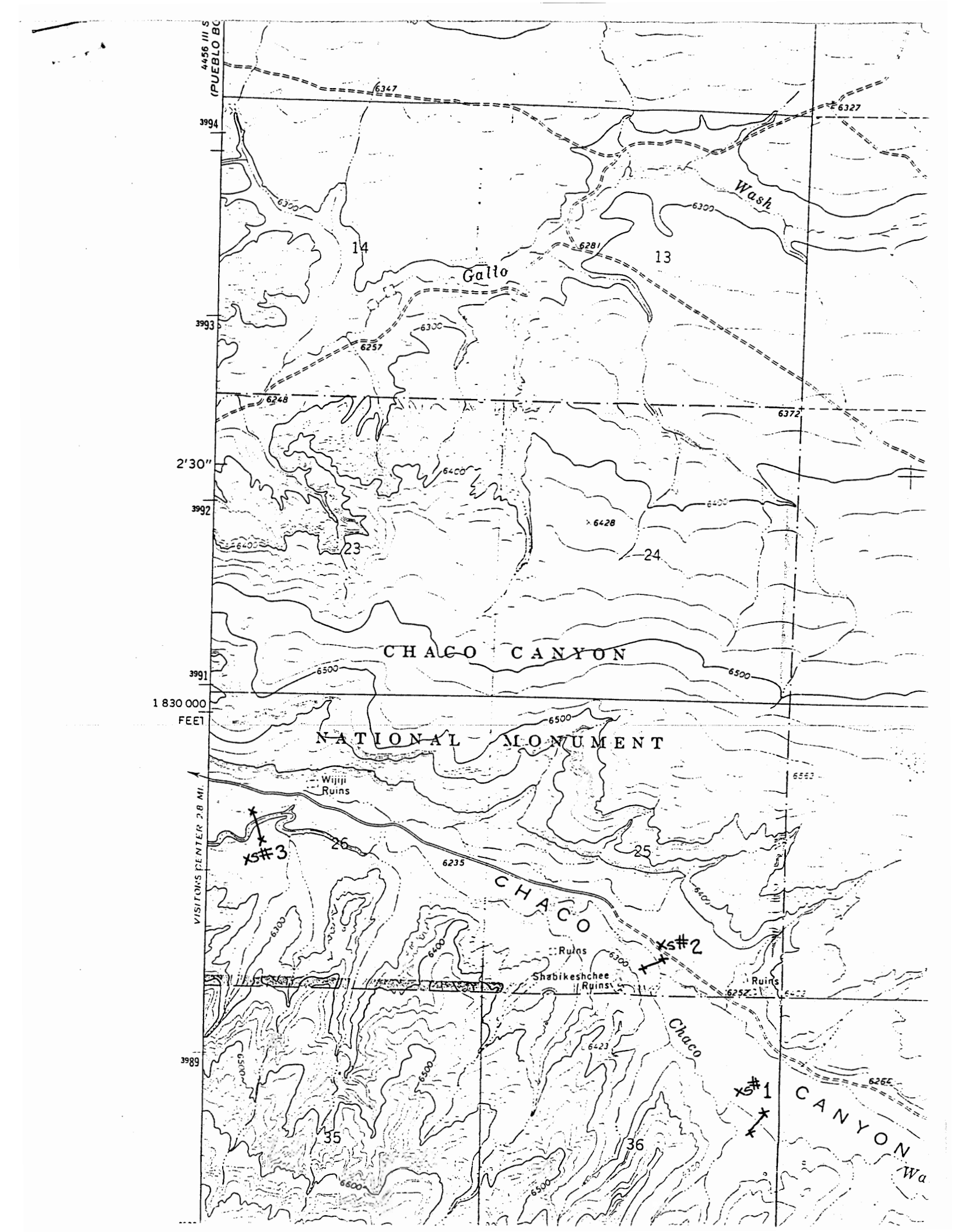
XS–12 PENASCO TRAIL CROSSING

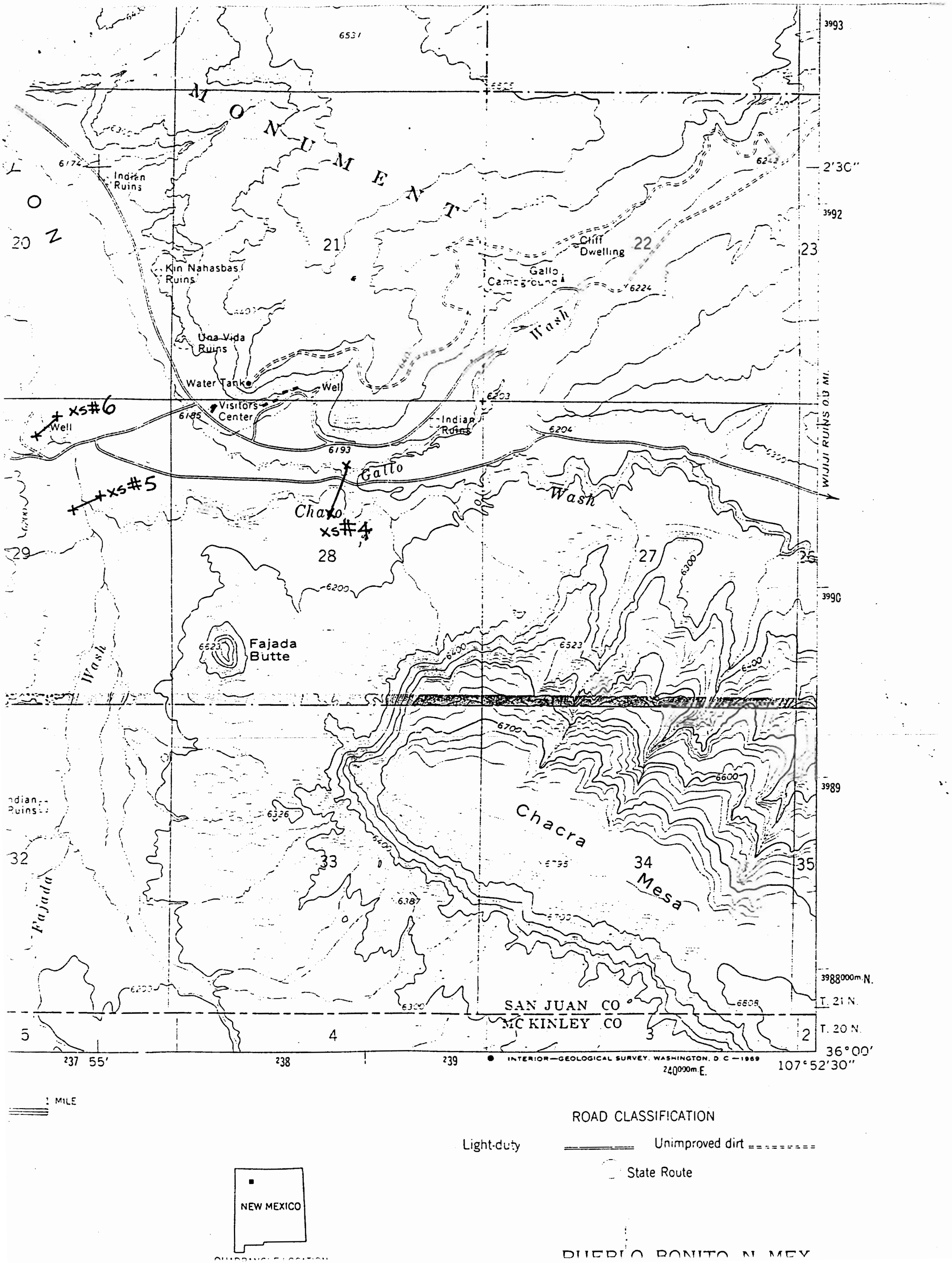


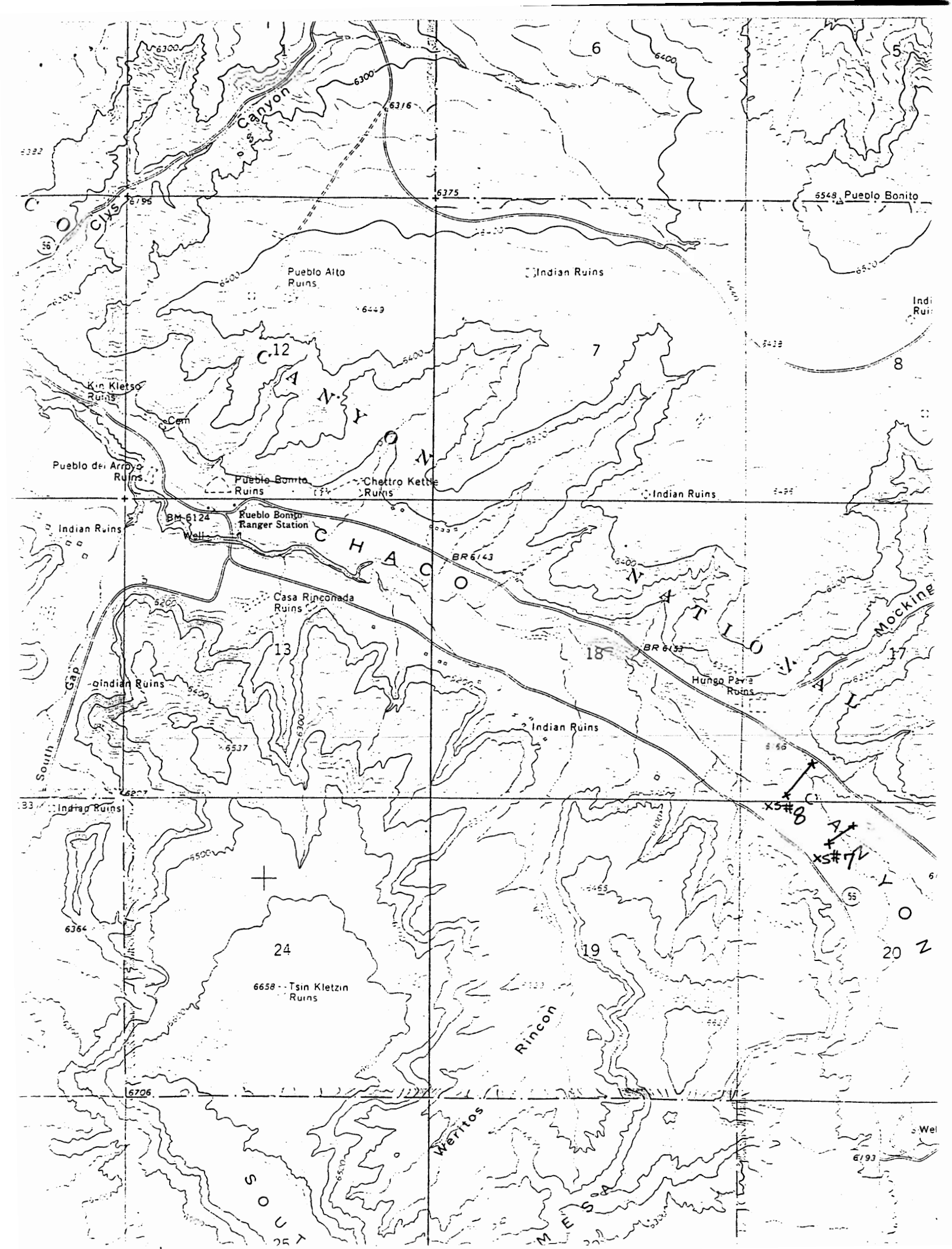
CHACO WASH

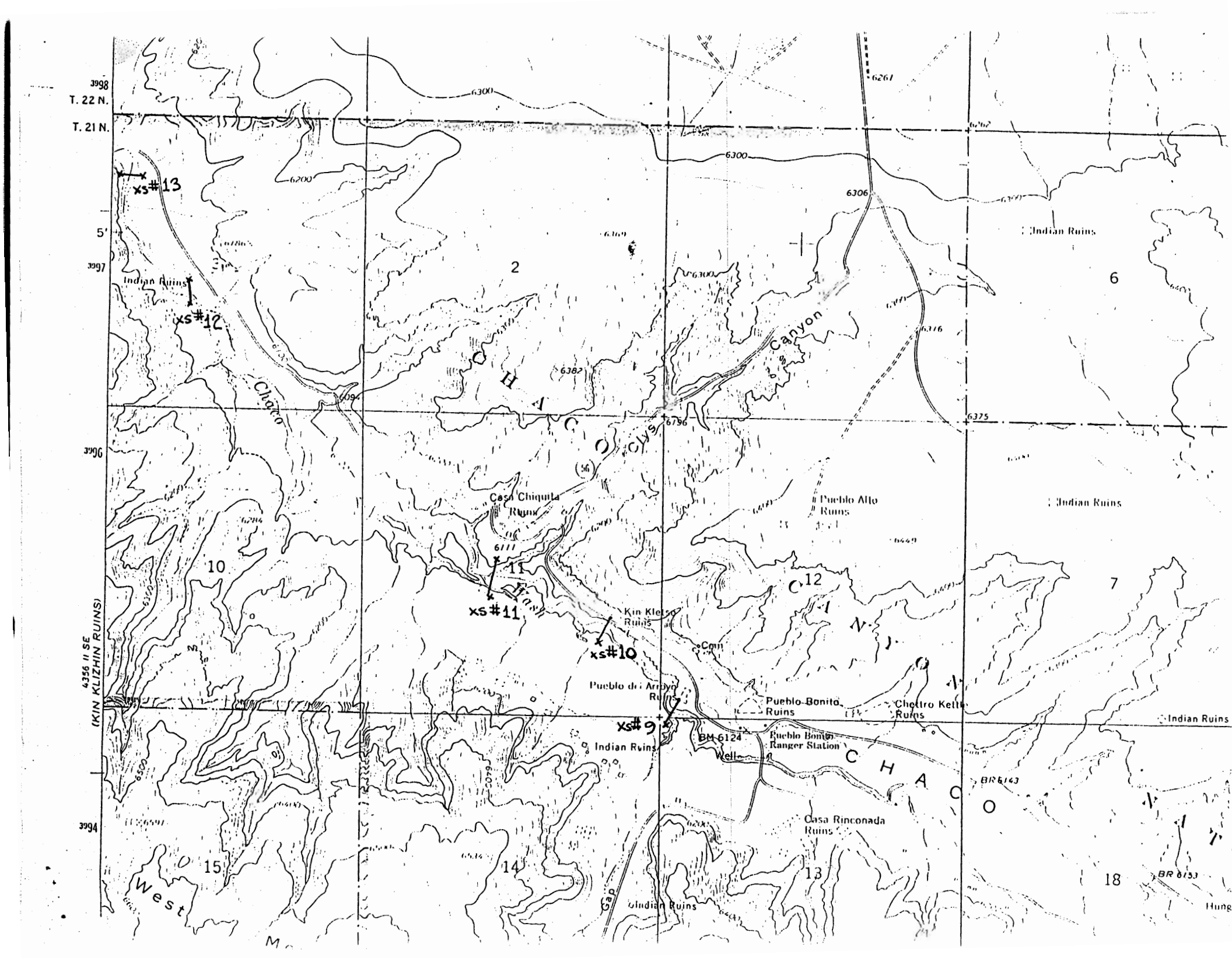
XS–13 NEAR ESCAVADA WASH




4456 III S
(PUEBLO BO
6347
6327
3994
6300
Wash
14
6281
13
Gallo
3993
6300
6257
6248
6372
2'30"
6400
3992
6428
23
24
CHACO CANYON
3991
6500
1 830 000
FEET
NATIONAL MONUMENT
Wijiji
Ruins
6563
VISITORS CENTER 2.8 MI.
XS#3
26
6235
25
CHACO
6400
Ruins
XS#2
Shabikeshchee
Ruins
Ruins
6252
6423
Chaco
3989
6500
XS#1
6265
CANYON
35
36
6600
6500
Wa


MONUMENT
Indian Ruins
Kin Nahasbas Ruins
Una Vida Ruins
Water Tank
Well
Visitors Center
Indian Ruins
Cliff Dwelling
Gallo Campground
Wash
Gallo Wash
Chaco
xs#6
xs#5
xs#4
Fajada Butte
Wash
Fajada
Chacra Mesa
Indian Ruins
20
21
22
23
27
28
29
32
33
34
35
5
4
3
2
6531
6174
6185
6193
6203
6204
6224
6243
6200
6300
6400
6523
6600
6700
6326
6387
6795
6605
3993
3992
3990
3989
3988000m. N.
2'30"
WIJIJI RUINS 0.3 MI.
SAN JUAN CO
McKINLEY CO
T. 21 N.
T. 20 N.
36°00'
107°52'30"
237 55'
238
239
240000m. E.
INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D C —1969
1 MILE
ROAD CLASSIFICATION
Light-duty
Unimproved dirt
State Route
NEW MEXICO
PUEBLO BONITO, N. MEX.


Canyon
6316
6375
Pueblo Bonito
6548
Pueblo Alto Ruins
Indian Ruins
6449
12
7
8
CANYON
Kin Kletso Ruins
Cem
Pueblo del Arroyo Ruins
Pueblo Bonito Ruins
Chettro Kettle Ruins
Indian Ruins
BM 6124
Well
Pueblo Bonito Ranger Station
CHACO
BR 6143
NATIONAL
Mocking
Casa Rinconada Ruins
13
18
17
BR 6133
Hungo Pavie Ruins
Indian Ruins
6537
South Gap
Indian Ruins
6207
XS#8
XS#7
55
6364
24
19
20
6658 Tsin Kletzin Ruins
Rincon
6706
Weritos
MESA
SOUT
6193


T. 22 N.
T. 21 N.
xs#13
xs#12
xs#11
xs#10
xs#9
Indian Ruins
Chaco Canyon
Casa Chiquita Ruins
Pueblo Alto Ruins
Kin Kletso Ruins
Pueblo del Arroyo Ruins
Pueblo Bonito Ruins
Chetro Ketl Ruins
Pueblo Bonito Ranger Station
BM 6124
Well
Casa Rinconada Ruins
Gap
West
CHACO CANYON
4356 II SE (KIN KLIZHIN RUINS)
BR 6143
BR 6153