Final Report

Morefield Canyon Reservoir Paleohydrology
Mesa Verde National Park; Site 5MV1931
Project # 96-02-090

By

Mesa Verde Paleohydrological Survey
Wright Water Engineers
Denver, Colorado

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# Table of Contents

Preface ........................................................................................................................................... iii
Morefield Canyon Reservoir Paleohydrology ................................................................. 1
Introduction ................................................................................................................................. 1
Site Location .................................................................................................................................. 2
Topography ..................................................................................................................................... 4
Geologic Framework ...................................................................................................................... 4
Soils ............................................................................................................................................... 10
Prehistoric Precipitation .............................................................................................................. 11
Prehistoric Runoff Characteristics ............................................................................................. 13
Paleoflood Hydrology ................................................................................................................... 14
Trench Excavation ......................................................................................................................... 15
Artifacts ......................................................................................................................................... 21
Intake Canal ................................................................................................................................. 22
Sediment Inflow and Deposition ................................................................................................. 25
Maps and Profiles ......................................................................................................................... 27
Summary ....................................................................................................................................... 28
Mesa Verde Paleohydrological Survey Team ............................................................................. 30
Figures and Drawings

Figure 1 Morefield Canyon Drainage Basin Tributary to Site 5MV1931

Figure 2 Overlay Sketch of Figure 2A showing the valley bottom, Site 5MV1931, channel, and access road.

Figure 2A View looking north up-channel of Morefield Canyon. Note the wide flat bottom of the canyon.

Figure 3 September 20, 1899 Infrared aerial photo of Morefield Canyon

Figure 4 Morefield Canyon Profile

Figure 5 Prater Canyon Profile

Figure 6 Mesa Verde Dendroclimatic Reconstruction of Annual Precipitation

Figure 7 View looking westerly of Site 5MV1931 showing the May 1997 trench excavation laterally across the reservoir mound.

Figure 8 May 1997, documentation of Site 5MV1931 trench wall using a 5 foot grid system.

Figure 9 Deposited sediment size analysis of the Morefield Canyon Reservoir.

Figure 10 View looking north toward the mound of Site 5MV1931 showing the flat top and steeply sloping side of the mound.

Figure 11 Large anomalous flagstone shaped boulders along the dike-like ridge which extends north from the mound.

Drawing 1 Site 5MV1931 Morefield Canyon Plan and Profile Not Included

Drawing 2 1997 Excavation at Site 5MV1931 Not Included

Drawing 3 1967 Excavations at Site 5MV1931 Not Included
Preface
The engineering and geologic study of Site 5MV1931 was aimed at resolving the enigma of the Morefield Mound, to determine whether or not the mound was an Ancestral Puebloan ceremonial platform, an erosional remnant, or an ancient reservoir built by the Early People. The Wright Water Engineers 1995-1997 investigation proved that it was a reservoir.

The project was undertaken by the Mesa Verde Paleohydrological Survey team made up of a broad range of civil engineers, geologists, archaeologists and related professionals. Dr. Jack Smith, former Chief Archaeologist for Mesa Verde, provided unparalleled assistance while serving as chief archaeologist for the team.

Field investigations were conducted in October 1995, May 1996, and May 1997. The appreciation of the survey team is extended to Mr. Larry Nordby and the entire staff of Mesa Verde National Park for their cooperation and support throughout the project period. Without their assistance in obtaining the necessary permits and without Mr. Nordby’s guidance the Site 5MV1931 project by WWE would not have occurred.

The financial support of the Colorado Historical Society is gratefully acknowledged. The WWE team is particularly proud to have received the Society’s Stephen Hart Award for outstanding performance in historic preservation.

Kenneth R. Wright
Project Director
Morefield Canyon Reservoir Paleohydrology
Mesa Verde National Park, Site 5MV1931
Project # 96-02-090
Mesa Verde Paleohydrological Survey Team
Wright Water Engineers, Inc.

Introduction

The relatively large Ancestral Puebloan domestic water supply reservoir of Morefield Canyon was situated amongst one of the densest ancient settlement areas of Mesa Verde National Park (MVNP). The reservoir and feeder canal represent a “public works” undertaking by these early people demonstrating good water management and an understanding of hydrological phenomena.

The reservoir mound and canal sit on the canyon floor as shown on Drawing 1 in a manner inconsistent with how one would expect an ancient reservoir to look.

The Morefield Canyon Mound (Site 5MV1931), long an enigma to archeologists and National Park Rangers at Mesa Verde, was selected for paleohydrological research by the authors in 1995. Working under a U. S. Department of Interior archeological permit, Wright Water Engineers, Inc. (WWE) conducted engineering and scientific studies in Morefield Canyon to determine the reason for, and function of, the mound which is 200 feet in diameter, rises 15 feet above the valley floor, has a long berm-like structure extending northward to the valley thalweg, and is shaped like an inverted frying pan.

Dr. Jack Smith of the University of Colorado Department of Anthropology had studied the Morefield site in 1967 and prepared an excellent preliminary draft technical paper concluding that the “Morefield Mound” was the remains of an ancient reservoir. However, scientific disagreement persisted in regard to interpretation of the data which resulted in the paper being mothballed. As of 1995, the Morefield Mound was still judged by the scientific community to be either a ceremonial mound, an erosional remnant of a Pleistocene valley terrace, or a reservoir as Dr. Smith had concluded.

The 1995–1997 WWE team field and office research in Morefield Canyon was aimed at not only the mound’s purpose and function, but also at the canyon geomorphology, geology, hydrology and rainfall-runoff characteristics in ancient times. The Early People settlement patterns during the Pueblo I and II periods of occupation were reviewed in the MVNP library so that WWE could better evaluate the reservoir functions.

Detailed field surficial investigations were conducted by the WWE team in 1995 and 1996 to define canyon physical and hydrological characteristics, to perform topographic surveys for mapping, examine the settlement ruins, and to study the configuration of the mound and the
basin extending to the north. Stone placement along the berm top was also analyzed. Following the 1996 field season, it was evident that an excavation was necessary to finally determine the origin and function of the mound.

The May 1997 field effort included a 125 foot long excavation across the mound to a depth of 15 feet. The trench walls were string-lined to define the sediment bedding of the mound and the location of potsherds and other buried artifacts were documented for permanent record. The excavation results were compared with Dr. Smith’s 1967 shallower trench documentation as shown in Drawing 2.

The WWE research team included twenty-three technical personnel ranging from archaeologists, geologists and hydrologists to water attorneys familiar with the southwest. To assist with documentation efforts three professional video specialists and experienced photographers were included. Fortunately for the scientific validity of the excavation and cultural interpretation of the site work, Dr. Jack Smith (University of Colorado and former Chief Archaeologist for Mesa Verde) served the research team as chief archaeologist. Dr. Smith brought a detailed knowledge of the Early People and the canyon characteristics to the effort without which the project would have suffered.

The 1995-97 WWE research effort proved that the site was a Pueblo II domestic water supply reservoir likely dating from about 750 to 1100 AD. The berm extending northward was the route of the ancient feeder canal to the reservoir.

**Site Location**

The Morefield Canyon research site is officially known as 5MV1931 in the archaeological records of Mesa Verde National Park. Morefield Canyon is closed to the public to preserve its extensive, abundant and valuable ruins for future study when funds are available to permit a thorough scientific evaluation of the canyon. The canyon held a larger Early People population than any other portion of the Mesa Verde area.

Site 5MV1931 of Mesa Verde National Park in Morefield Canyon is in the southwest quarter, Section 33, Township 35 North, Range 14 West of the New Mexico Meridian. It is approximately 12.8 miles southeast of Cortez in Montezuma County at an elevation of 7,200 feet.

The Morefield Canyon watershed above Site 5MV1931 is 4.2 square miles in size. Figure 1 shows the delineated watershed upstream of the site. The canyon drains in a southerly direction through a broad flat valley with mesas running north to south on both sides. The drainage basin ranges from 7,200 feet to 8,300 feet in elevation, with a mean elevation of 7,800 feet. The valley floor is composed of Hesperus loam soil and has a fair covering of sage and other types of grass and brush (Cortez Soil Survey Area, Water Canyon, Mesa Verde National Park, 1993). The sides of the canyon are steep, leading up to the mesas with piñons and junipers interspersed with rock outcroppings. The current land use is characterized as ungrazed rangeland.
Site 5MV1931 lies roughly one quarter mile north of a Pueblo I and II settlement ruin containing the largest kiva found in Mesa Verde, which lies immediately across the valley bottom from a small spring as shown in Figure 1.

**Topography**

Morefield Canyon is a broad valley with the side ridges rising 400 to 600 feet on each side of the nearly flat bottom which ranges from 600 feet to 1,100 feet in width. The WWE survey indicated an upstream valley bottom cross-slope to the west of approximately one percent, flattening out further upstream. Downstream of the mound, the valley bottom flattens and the stream channel swings to the east. At the 5MV1931 archaeological site, the valley bottom is approximately 800 feet wide (Figures 2 and 2A).

A nearly flat-bottomed channel six to eight feet deep eroded into the broad valley floor has formed flanking terraces on each side of the channel. No active erosion was observed in the floor of Morefield Canyon except at the few intermittent headcuts in the channel; even these appeared to be healing. The channel edges form vegetated well-healed, gentle slopes. Grass, mature big sage, and occasional Gamble’s oak thickets cover the channel bottom and its well-rounded banks. About one-half mile north of the 5MV1931 site, this channel drifts from the normal central location in the valley toward a position near the west flank of the valley. Normally, channels tend to drift into a valley’s curve rather than away from it. Approximately a quarter mile south of the site, the channel drifts eastward back to the more normal location on the outside bend of the curve as shown in Figure 3.

The Morefield channel gradient slopes to the south at approximately 135 feet per mile for a slope of .025 ft/ft. Approximately 2,000 feet north of Site 5MV1931, a decrease in gradient coincides with the change in bedrock from Mancos Shale to the Point Lookout Sandstone. Further down valley, another flattening of gradient occurs where the channel encounters the Menefee Formation. The variation in the Morefield Canyon profile slope is illustrated in Figure 4, and can be compared with that of the adjacent Prater Canyon in Figure 5.

**Geologic Framework**

The Mesa Verde plateau is held up by the sandstones of the Cretaceous Age Mesaverde Formation which are more erosion resistant that the surrounding Mancos Shales. The top of the plateau is essentially a dip slope lying on the Cliff House Sandstone in the upper Mesaverde group. The numerous north/south-trending canyons—of which Morefield Canyon is only one example—have cut through the Cliff House Sandstone and are floored in the sands and shales of the Menefee Formation. The basal Point Lookout Sandstone only outcrops around the edges of the plateau. The gentle south dip of the bedrock of 235 feet per mile (0.044 percent) into the San Juan Basin to the south only slightly exceeds the south slope of the valley floors.
Figure 2—Overlay Sketch of Figure 2A showing the valley bottom, Site 5MV1931, channel, and access road.
Figure 2A—View looking north up-channel of Morefield Canyon. Note the wide flat bottom of the canyon.
Figure 3—September 20, 1988 infrared aerial photo of Morefield Canyon
FIGURE 4
MOREFIELD CANYON PROFILE

Plotted by Ernie Pemberton
GEOLOGIC FORMATIONS
Plotted by J.W. Rold
from USGS geologic map

Note: 5x vertical exaggeration of channel slope and formation dips.
The Recent or Holocene deposits underlay the broad, flat valley floors. No bedrock outcrops were observed along the valley bottom. No data has been found to establish the thickness of the deposits in Morefield Canyon.

**Soils**

The soil present in the bottom of Morefield Canyon and adjacent canyons has been identified as the Hesperus series. The Hesperus soil was sampled by the National Soil Survey Laboratory (NSSL) in Waters Canyon, approximately three-quarters of a mile east of Site 5MV1931. This soil sample location is very similar in location and development when compared to samples taken in the vicinity of this site.

The soils present on the steep sideslopes of Morefield Canyon and adjacent canyons have been identified in several different series. The predominate soil has been placed into the Prater series. This soil is very deep and is forming in colluvium and local slope material from the Menefee Formation. The NSSL sampled this soil on the west side of Morefield Canyon approximately one-half mile from this site.

Site 5MV1931 sits in the bottom of Morefield Canyon on the valley floor. During previous times, geologic erosion has cut the base rock of the canyon to form Morefield Canyon. During recent millennia, the valley is no longer down cutting, but has slowly been filling with soil material from the surrounding canyon walls. These deposits consist of alluvial material generally ranging from fine sand to clay. These deposits contain limited amounts of gravel and larger material. This larger material grades from very little present in the center of the valley to increasingly more moving toward the canyon sides. Most rock fragments found in the deposits are from the Cliffhouse and Menefee Sandstones and are predominantly cobble sized and smaller. Very few coarse fragments larger than cobbles are found in the material of the valley floor.

The Hesperus soil is located in the valley bottom of Morefield Canyon. It extends from the slope break from the canyon slope across the valley bottom to the slope break on the opposite side of the canyon, approximately 800 feet at this site. The parent material is colluvium and alluvium from the Mesaverde Group. Particle size distribution is predominantly fine sand and smaller. Small amounts of sandstone gravels occur in the soil profile, sometimes as thin horizontal lines. Textures are generally loamy with 25 to 30 percent clay. It is judged to be a Hydrologic B type soil with a curve number of 51.

Evidence of this developing soil is present. The primary evidence of development is the argillic horizon. This horizon occurs from 0.5 to 6.5 feet (13 cm to 198 cm). It is characterized by the movement of clay within the soil profile and development of structure through physical and chemical alteration of the parent material over time. The presence of clay films on the faces of peds and in pores is strong evidence of development. The leaching of calcium carbonate from
the 0 to 0.5 feet (0 to 13 cm) layer into the lower horizons usually only occur in a stable soil environment.

The Prater series soil occurs on the canyon sideslopes of the major canyons in the eastern parts of Mesa Verde National Park. It occurs with several other soils series on the gently sloping to steep canyon sides. The Prater Series soil is Hydrologic C type soil with a curve number of 73. The parent material consists mainly of material from the Mesaverde group. These include the material from the Cliffhouse Sandstone, Menefee Formation of inter-bedded sandstone and shale, and the Point Lookout Sandstone. These formations are weakly cemented, and consist of material that is fine sand and smaller. As these geologic formations weather and erode, the material generally moves downslope in water by gravity at a very slow rate. Because of the weak cementation, coarse fragments tend to weather rapidly and few large stones and boulder occur other than very near to their place of origin.

**Prehistoric Precipitation**

Dendroclimatic reconstructions for the Mesa Verde area were studied to estimate average annual precipitation during the ca. 800 to 1100 A.D. period of Anasazi occupation of Morefield Canyon and to contrast the prehistoric precipitation with modern records. Dr. Jeffrey Dean of the University of Arizona’s Laboratory of Tree-Ring Research in Tucson, Arizona provided the reconstruction data. Data for the Mesa Verde area from A.D. 481 through 1988 were evaluated. The long-term average annual precipitation for the period of record was estimated to be 18.1 inches. The period of record from 1922-1988 had an average annual precipitation of 18.3 inches. This is in agreement with the 74 years of modern record from Chapin Mesa. The average annual precipitation from A.D. 800 through 1100 (the approximate period of occupation in Morefield Canyon by the Anasazi) was 18.0 inches (Figure 6). For this reason, precipitation records from modern times were considered suitable for use in analyses of the ancient period.

It is not possible to extrapolate daily precipitation data from the reconstructions. For this analysis, it has been assumed that the frequency and magnitude of prehistoric events were probably similar to the modern records. It is suitable to make this assumption for flow modeling given the lack of data to confirm or show it was different and because the prehistoric and modern average annual precipitation depths are similar.
Figure 6 Mesa Verde Dendroclimatic Reconstruction of Annual Precipitation

18.0 inch long-term average (800-1100)
Prehistoric Runoff Characteristics

It is evident from the study of modern hydrology that fires and human activities can significantly change the runoff potential of a watershed. When a forested watershed is converted to an agricultural watershed, runoff increases. When an agricultural watershed is converted to an urban watershed, runoff increases. Further, with environmental changes such as burns, runoff will increase.

Archaeological evidence provided by Dr. Smith indicates that up to 500 Early People lived in Morefield Canyon. Farming was practiced, and there was removal of trees and brush for cooking, construction, and heat. Rough estimates suggest that it is likely that 125 acres were farmed (one acre for every four people). In addition, the Early People may have denuded a quarter of the watershed (one square mile) by gathering firewood. Forest fires did occur in the canyon, as evidenced by layers of charcoal in the reservoir excavation.

Using the above land use/type estimates, the NRCS curve number procedure was applied to these potential prehistoric conditions to determine runoff magnitude. It was assumed that 125 acres of farm land occurred upstream of Site 5MV1931 on the canyon floor. The “B” soils would have been altered by the Anasazi and acted more like “C” soils (similar to the compacted dirt roads currently used by the National Park Service). Thus, the likely runoff curve number of only the potential farmed area was estimated to be:

Canyon bottom (crops, poor condition, C soil) → 88.

Under these hydrologic conditions, a rainfall of 0.5 inches would produce a runoff of 0.033 inches from the 125 acres of farmland. The volume of runoff that results from this is:

\[
\text{Runoff Volume} = (0.033 \text{ in.}) \times (125 \text{ acres}) \times (1 \text{ ft/12 in.})
\]

\[
= 0.34 \text{ acre-feet.}
\]

This would have been adequate water to fill the reservoir at Site 5MV1931. The estimated runoff does not consider the area that would have been denuded for fuel or by forest fires. If these denuded areas were upstream of Site 5MV1931, then additional runoff would have been generated that could have been stored. For instance, it was estimated that the 1996 Chapin #5 Fire in Mesa Verde temporarily changed runoff characteristics so as to increase the peak runoff potential some 500 to 600 percent because of hydrophobic soil conditions resulting from the fire. The Buffalo Creek fire of 1996 resulted in twelve 100-year floods in the first month following the fire. Forest fires cause a significant increase in runoff characteristics.

The Chapin Mesa rainfall records were again evaluated to determine the frequency of rainfall events 0.5 inches or greater. In the 48 years of record analyzed, there have been approximately
200 days of recorded precipitation greater than 0.5 inches per day during the summer months. Under the prehistoric hydrologic conditions (farming, fires, and human activity), these 200 events would likely have produced reasonable runoff. This suggests that direct runoff water would have occurred and would have been available for capture and storage about four to five times each summer. The water diversion canal route was defined in the field using instrument surveys. It would have been able to intercept the canyon flow and deliver the water to the reservoir for storage.

**Paleoflood Hydrology**

Accurately estimating the magnitude and frequency of flooding is difficult when hydro-meteorologic data are limited. A regional interdisciplinary paleoflood study is being conducted to help assess past hydrologic conditions in Morefield Canyon. The approach, which includes analyses of paleoflood, flood, and extreme-rainfall data of many sites in southwestern Colorado, provides a more complete and accurate assessment of past and potential future flooding. A lack of flood evidence in one basin could result from pure chance. Thus, it is essential to ascertain the flood history for other basins in the region.

Paleoflood hydrology is the study of past or ancient floods. Floods leave distinctive deposits and landforms in and along stream channels, as well as botanic evidence. Slack-water deposits of sand-sized particles, flood scars on trees, erosion scars, and bouldery flood-bar deposits commonly are used as indicators of past flood levels called paleostage indicators (PSIs). Paleoflood discharge is determined from estimates of flood width and depth corresponding to the elevation of PSIs using engineering-hydraulic analyses. Relative age-dating techniques (dendrochronology, soils, lichenometry, boulder burial) are used to determine the age of paleofloods.

Paleoflood estimates were made at 12 sites along Morefield Canyon by the WWE team in 1997 from Morefield campground to Site 5MV1931. Maximum paleoflood discharges range from about 250 to 350 cubic feet per second (unit discharges range from about 60 to 80 cubic feet per second per square mile) near Site 5MV1931. The PSIs are at least 100 years old and likely reflect the largest flooding in several hundred years. The lack of flooding in upper Morefield Canyon (4.2 square miles) is likely due to a combination of: 1) thick, pervious soils; 2) dense vegetation; and 3) infrequent, localized rainstorms in western Colorado. Most of Morefield Canyon basin (upstream from 5MV1931) is above an elevation that is subject to substantial rainfall-produced flooding in southwestern Colorado (Jarrett, 1990).

One of the largest flash-flood producing rainstorms during the past century in southwestern Colorado was recorded at Mesa Verde National Park. On August 3, 1924, 3.50 inches of rain fell in 1 to 2 hours at the U.S. Weather Bureau gage. The gage was located near the head of Spruce Tree Canyon near the present location of Park Headquarters. Mary Ellen Hendrick,
MVNP helped survey paleoflood data for three sites in Spruce Tree Canyon and Spruce Canyon. Although trees (Douglas Fir, Gambel Oak, Utah Juniper) growing on flood deposits were not cored, the diameter of most of these trees suggests an age of about 60 to 80 years old. Thus, it is most likely that the trees germinated on the 1924 flood-deposited sediments. The estimated paleoflood discharge for Spruce Canyon is about 1,000 cubic feet per second and the drainage area is about 2 square miles. The unit discharge is about 500 cubic feet per second per square mile.

Regional envelope curves encompassing maximum rainfall and flooding are being developed to assess maximum flood potential for the present climatic regime. The 1924 rainfall amount and associated unit discharge define the maximum envelope values for southwestern Colorado.

**Trench Excavation**

The 1997 excavation of the Morefield Reservoir mound penetrated to the original ground surface on the east and west portions of the trench (Drawing 2). In the trench’s mid-section the original ground surface was reached by auger at about 4.3 feet below the trench bottom. This deeper bottom elevation likely represents the original pond dug by the Anasazi for groundwater and surface water collection prior to the reservoir building. The trench relationship to the mound configuration is illustrated in Figures 2 and 2A.

Long horizontal layers of alluvial sediments were exposed throughout the trench walls, along with gently upward sloping layers at the edges where the reservoir embankment existed. At two locations, evidence of embankment slope failure were evident.

The 125-foot-long, 15-foot-deep trench was excavated in a manner to meet federal regulations for trench safety as shown in Figure 7. This meant that the trench faces were stepped, which resulted in three levels: a lower, middle, and upper trench face. A 5-foot grid system was established over the entire south trench face (Figure 8). Experienced geologists were assigned as trench safety officers to watch for hazards. Intensive study of the soil depositional patterns, sediment layering, and artifact type and location was made jointly by archeologists, physical scientists, engineers, and soil specialists. Then the trench wall was inspected by archeologists of the National Park Service.

The natural soil of the original canyon floor was readily identified, not only by the team soil scientist but by other team members. The underlying Hesperus Soil Series existed in sharp contrast to the overlay water-borne sediment.
Figure 7 View looking westerly of Site 5MV1931 showing the May 1997 trench excavation laterally across the reservoir mound.
Figure 8 May 1997, documentation of Site 5MV1931 trench wall using a 5 foot grid system.
The distinct layers, while initially considered to be fine sand, were found to be mostly sandy clay or sandy silt. Approximately 20 thin continuous layers of charcoal deposits were found, likely representing fluvial transported charcoal from forest fires. Four Carbon-14 tests of the charcoal layers taken from the bottom, mid-section, and upper layers were tested. Ages of the layers ranged from 41,000 to 1500 years before present (BP) indicating that three of the charcoal layers contained coal—likely particles from the upstream coal seams that would have been carried in the occasional flood waters directed into the reservoir and thereby contaminating the carbon 14 samples.

Analyses of the trench walls are still underway; however, initial observations include:

a) The 1997 trench face contained approximately 1,900 square feet of surface area, of which 65 percent was a densely compacted clay matrix. The clay was judged to be impermeable with a permeability in the range of $1 \times 10^{-6}$ to $10^{-7}$ centimeters per second. The tightness of the clay would have obviated any measurable reservoir storage seepage losses. The clay deposits would have been deposited in the reservoir during small rates of water diversion from the thalweg of Morefield Canyon and from wind-blown sediment.

b) Over the life of the reservoir, there were about 21 instances of measurable sand to sandy clay depositional occurrences that would have represented larger (and likely uncontrolled) diversions to the reservoir during canyon flooding periods. This would represent an average of one sediment-carrying flood each 17 years, when the inlet canal likely would have been overtopped and damaged or perhaps washed out in one or more places. An analysis of eight sandy clay depositional samples is given in Figure 9. The material is 30 percent clay, 55 percent silt and 15 percent sand. One sample not included in the average contained 60 percent sand. Detailed sediment analyses of each layer is in process by the NSSL.

c) Fill sediments consist of “couplets” with a lower layer of very fine sand (locally silt) and a thicker upper layer of dense clay. Generally, the lower layer is ripple-bedded and has a smooth lower contact, although some beds have undulating lower contacts that fill irregularities in underlying clay beds. In a few places, the sandy layers contain thin inter-beds of clay and the clay layers include fine laminations of sand. In cross section, the couplets have concave shapes that rise toward the edges of the fill. Toward these edges, the sandy layers thin, become silty, and may become discontinuous or pinch-out.

d) Near the middle of the trench, the lower part of the fill contains a disconformity with several feet of relief. Slump blocks overlying this disconformity probably moved toward a void created by removal of sediment from the lower middle area. Because the lowest part of the detachment surface is tangential to lower, undisturbed couplets, the void was probably created by manual excavation.
e) Some six outside berm structures were exposed in the 1997 reservoir trench. The overall distribution of berm and fill sediments suggests that the width of the water surface varied with time, as the reservoir rose progressively upward. In the lower tier, near the east end of the trench, a berm consists of two layers that are distinguished by the presence of small clay fragments, several centimeters in diameter in the lower layer. This layer also contains crude internal stratification, in the form of off-lapping layers that contain higher proportions of sand in irregular masses. The upper layer is relatively uniform, but browner and slightly coarser than overlapping fill sediments. At both ends of the trench, very weakly bedded clayey material overlaps the berm sediments and is overlain by well-bedded fill sediments. Some parts of this clayey material contain thin or discontinuous beds of silt or fine sand. This unit may consist of peripheral fill sediments in which bedding was mostly destroyed during Anasazi maintenance work on the berm. Overlapping, well-bedded fill sediments are consistent with this interpretation.

f) Potsherds were found throughout the trench walls. They were more common in the berm material or in fill sediments near the berm, than near the middle of the fill. All of the sherds in the trench were found in the clay matrix with none in the sandy silt or sand deposits. A broken deer antler is presently being carbon dated.

g) A detailed comparison was made between the 1997 WWE excavation and the 1967 Smith excavation. The Smith excavation was typically 8 feet deep; however, three test pits carried the Smith field observations an additional 2 to 5 feet below the trench bottom. Correlation between the 1967 and 1997 excavations was good as determined from Drawing 2.

h) The volume of storage would have varied considerably over the years; however, an approximate storage estimate would place the volume of maximum active storage at about 120,000 gallons. The storage volume at other times is estimated to range down to about 40,000 gallons.
Figure 9 Deposited sediment size analysis of the Morefield Canyon Reservoir.
Artifacts

Pottery

Fragments of pottery vessels (potsherds) were found throughout the excavation. While not abundant, these were found in sufficient quantities and distributed in such manner as to leave no doubt as to the contemporaneity of the site with prehistoric potters of the Anasazi Cultural Tradition. Thirty-one potsherds\(^1\) were found in situ in the profile exposed in the south wall of the trench. These were recorded by horizontal and vertical position relative to the strata in which they occurred and to the five-foot grid placed on the trench wall. Seven other potsherds were found within the trench but not in their original position. All recovered pottery was catalogued into the system used at Mesa Verde National Park and was identified to the extent possible by type and/or ware. Although only two of the in situ potsherds could be reasonably ascribed to a particular type, all except one could be classified as belonging to one of the white or gray wares common in Mesa Verde ceramics. The exception was a brownish sherd which may have come from one of the areas outside the Mesa Verde culture area where brown ware pottery was commonly manufactured.

The excavated pottery places the site within the Pueblo II period of occupation of the canyon by the prehistoric Mesa Verde people, further confirming that placement based on the earlier (1967) excavations. This suggests an absolute time range of around A.D. 900 to around A.D. 1100. The two sherds identified by type are both Cortez black-on-white, a type securely placed in the earlier half of the Pueblo II occupation on the Mesa Verde. Two others, both out of context and found in the back dirt during the back-hoe excavation, are either carbon-painted Mancos black-on-white or McElmo black-on-white, indicating a time late in the Pueblo II period or possibly early in the succeeding Pueblo III period. With the exception of the above mentioned brownware sherd, all of the remainder are of general plainwares common throughout most of the prehistory of the Mesa Verde and abundant in the Pueblo II period.

The excavated pottery was also analyzed as to probable vessel type. Most fragments came from jars that have been presumed to have functioned for carrying and storing water; these accounted for 76 percent of the recovered potsherds. Bowls accounted for another 21 percent, although in some instances their identification was somewhat borderline. The remaining 3 percent were either too fragmentary or too eroded, or both, to be identified as falling into either of these or any other functional category.

The preponderance of jars suggests that water collecting was the primary purpose of most of the pottery found in the site. The more frequent occurrence toward the eastern and western edges of the

\(^1\) Where more than one potsherd was found and could be joined together with another they were counted as one.
site, presumably near the edge of a fluctuating pool area, also lends support to a hypothesis that people were collecting water in large vessels used to carry and probably store water.

More intensive analysis of the pottery from the site is in progress, but these preliminary results are entirely consistent with what would be expected in a site which functioned for water diversion and catchment.

**Other Artifacts:**

While pottery makes up the bulk of artifactual evidence of human use of the site, a few non-pottery items also indicate that use. A broken deer antler found deep within the clay layers may have been part of a digging implement; it occurred in isolation, no other bone or antler fragments were found with it. A small roughly-shaped disk of tabular sandstone was probably a lid for one of the above mentioned pottery jars, and another roughly rectangular piece of tabular sandstone appears to have been intentionally shaped but of an unknown use.

**Intake Canal**

The Morefield Reservoir evolved into an off-stream reservoir during its early life after the original excavated pond filled with sediment and was mucked out to form a perimeter berm. A view looking north of the reservoir mound is shown in Figure 10. An off-stream reservoir requires an intake canal for water delivery. The existing route of the intake canal represents the final canal alignment at the time the reservoir was abandoned.

The final canal route was laid out in the field via the remaining canal stones and field instrument route surveys. The canal was 1,425 feet long with an average slope of 1.0 percent—the slope ranging between 0.5 and 2.0 percent, not unlike modern farm irrigation systems in the Cortez area.

This canal is recognizable today as a long ridge extending from the north edge of the reservoir mound to a point where it gradually blends into the canyon floor. This ridge was tested with a cross-trench in 1967 and the subsoil was shown to be largely composed of numerous layers of silts, sands, and gravels. A line of shaped stones parallel to the east edge of the ridge formed a line of demarcation between these layers to the west and undifferentiated silts to the east. The stones marked the east edge of a canal which had been cut into the undifferentiated silts and which gradually silted in during the life of the site. The aligned stones were mapped from near the northern extreme of the mound to where they gradually disappeared about 500 feet to the north. No excavation was attempted during the 1997 season, but the exposed stones were defined using whisk brooms and pointing trowels so they could be mapped and photographed. Their alignment agreed well with a topographic survey, which defined a constant slope from north to south sufficient to have carried water to the main reservoir area.
The stones marking this canal were intentionally shaped and resembled those used to lay up village walls elsewhere in the canyon as shown in Figure 11. Whether these stones were shaped for use in defining the canal or whether they were robbed from abandoned villages for reuse here could not be determined. Their uniformity of size and shape, typically about 13 inches in length, 8 inches in width, and 3-5 inches in thickness, distinguished them from local outcrop stones. No similar stones occur in the immediate vicinity, they were too large to have been washed in by flood events, and their presence can only be explained by their having been intentionally brought in and placed in their present locations.

The west side of the canal was not as clearly defined by aligned stones, but numerous stones were found where the ridge sloped sharply into the present drainage channel immediately west and about ten feet below. These showed indications of having formed a retaining wall, probably to prevent the canal from being breached during flood events.

Analyses of the 1967 Smith excavation of the canal ridge provided evidence of the earlier canal alignments at depth and that the east-west location of the canal varied from time-to-time by some 18 feet at the excavation. The sediment layering was consistent with former canal cross-section silting. Over the course of the estimated 150 years of reservoir operation, the canal would have had several points of diversion, slopes and cross-sections as it was reshaped, rebuilt and realigned.

Evaluation of the field data, coupled with engineering computations and judgment, resulted in an estimate of the final canal capacity of 19 cubic feet per second (cfs). The bank full velocity of water in the canal was about 3.8 feet per second (fps).

The southerly 163-foot reach of the intake canal earthen berm leading to Morefield Reservoir was studied for man-placed stones. The analysis consisted of measuring and locating stones observed on the surface and larger than five pounds, that may have been part of the canal(s) that led to the reservoir. Reasons for the canal stone lining would likely have been to prevent erosion from excess flow velocities, maintain high velocities to keep sediment from depositing in the channel, and to reduce animal damage to the sides of the canal. There were 286 stones examined in this 163 foot reach. The average stone measured 12.6 inches x 8.5 inches x 3.9 inches and weighed 36 pounds. Some of the stones served a retaining-wall function.
Figure 10 View looking north toward the mound of Site 5MV1931 showing the flat top and steeply sloping side of the mound.

Figure 11 Large anomalous flagstone shaped boulders along the dike-like ridge which extends north from the mound.
Twenty-seven percent of the stones were at the final grade line of the canal, 37 percent were between the grade line and 3 feet below grade line, 16 percent were between 3 and 6 feet, and 10 percent were below 6 feet. Ninety-four percent of the stones were between the center line of the canal and Morefield Creek. Almost all of the observed stones were rectangular in shape. The stones were from Menefee sandstone. There were three places in the section studied where there appeared to be a group of stones remaining in their original alignment. From Station 80 to 130, there was a series of aligned rocks at an elevation about 1-foot between the top of the assumed final grade of the canal. From Station 150 to 155, there was a set of aligned rocks three feet below the top of the berm. From Station 80 to 130, there were 32 stones near the center line on top of the berm.

The canal and the reservoir were integrated into a single operating structure for the diversion, transport, and storage of water.

**Sediment Inflow and Deposition**

An evaluation has been made of sediment associated with peak runoff from assumed ancient thunderstorm events. For this evaluation of sediment, analyses developed by the U.S. Bureau of Reclamation were utilized. They represent standard and accepted practices of the engineering profession.

For purposes of the sediment inflow and deposition analyses effort, it was necessary to determine the typical size and carrying capacity of the inlet canal. Two methods were used:

1) The capacity and hydraulics along with the width and approximate depth were determined from Smith’s canal 1967 cross-section excavation as shown in Drawing 3, and

2) The volume of sediment deposited in a specific layer was used to determine of the water discharge required to move that sediment volume at a given concentration.

The results of the computations are given below:

Method 1: Based on a bottom width of 3 feet, 2:1 side slopes, hydraulic slope of .01, an “n” of .03, and a maximum depth of 1 foot, the canal velocity is 3.79 fps and the discharge is 19 cfs. A check was made on the critical velocity and discharge.

Method 2: Two layers of sediment were used to compute a canal discharge. The first layer at the bottom of the trench, was 60 feet long, 4 inches thick, and had bottom elevation of 7210.4 feet. The second layer was 40 feet long, 3 inches thick, and had a bottom elevation of 7214.7 feet.
The application of Method 2 requires an estimate of the sediment concentration of the peak flow and the assumed time of runoff. Based on prior experience with flood flows for arroyos in the New Mexico and Arizona areas, sediment concentration for the 50 to 100-year events of 10,000 parts per million (ppm) was assumed. In this case the flood concentration was checked by use of bed material transport equations. Two of the better known equations that gave acceptable results were the formulas by Laursen and Yang (using size fractions). The size gradation for the bed material was assumed to be the same as the size of deposited sediments shown in Figure 9. With the channel hydraulics from Method 2, the computed concentration for the Laursen Formula was 11,800 ppm and the Yang Formula was 15,700 ppm for an average of 14,000 ppm. The time of runoff was assumed to be one hour, equal to the time for arroyo type flow.

In the first test of a deposited layer under Method 2, the topography of the mound was examined. A circular pattern of sediment deposits was assumed, resulting in a computed sediment volume of 932 cubic feet. At a sediment concentration of 14,000 ppm, this results in a volume of water of 1.5 acre feet or about 486,000 gallons if the entire volume was stored in the reservoir. For a 1-hour flood flow this test gave a canal inflow of 18 cfs. In actuality, the reservoir would have over-topped, perhaps causing a breach.

For the second test of a deposited layer under Method 2, and because of a narrower, 40 foot long layer, the assumed deposition would have a length of about 100 feet. With these dimensions the volume of sediment was 1000 cubic feet. At a concentration of 14,000 ppm, the volume of water was 1.6 acre feet. This gave a water storage volume of about 520,000 gallons and inflow discharge for a 1-hour duration flow of 19 cfs, again causing a reservoir overtopping.

These computations would support an inlet canal with a capacity of about 19 cfs. The two selected sediment transport formulas showed an average concentration of 14,000 ppm and an instantaneous transport rate of about 700 tons/day. It is concluded that the sandy layers represent erosion at the higher elevations of the drainage area. The heavy clay material would represent materials eroded from the channel banks in the upstream valley alluvium representing previously deposited materials from the Mancos Shales.

Examination of the reservoir deposits indicates that the diversion structure in the Morefield Canyon channel was built to cause a complete diversion of the streamflow, except when the dam was overtopped due to excessive storm flow. The number of times the diversion dam was moved upstream is unknown but is subject to study using the elevation of the sediment layers and the necessary slope of the inlet canal.
Maps and Profiles

The large size drawings are enclosed with this report. They are:

**Drawing 1**  The plan and profile of Site 5MV1931 includes the apparent final canal route, the existing eroded channel of Morefield Canyon and the estimated ancient channel bottom. It should be noted that Site 5MV2818 represents a portion of the canal route stones.

**Drawing 2**  The south faces of the 1997 and 1967 excavations are illustrated in detail as described by the field measurements data. Special note should be taken of the 1997 trench as follows:

- The slip plane at station 20 which represents an ancient berm failure;
- Auger hole which penetrated to the ground surface at the bottom of a likely original pond;
- A large sandy deposit at elevation 7220 ft.;
- Location of sherds; and
- Long horizontal layers from station 75 to 100.

**Drawing 3**  The main south trench face (Test Cut III-IV) is repeated here from Drawing 2 for reference purposes. Test Cut II represents the inlet area of the reservoir where heavier sandy material tended to settle first. The narrower upper layers between stations 16 and 25 likely represent extensions of the canal into the mound during late periods.

Test Cut I represents the intake canal. It shows the canal form from time-to-time. Approximately 17 canal deposits are illustrated. The form of the canal ridge is apparent.

The profile of Test Cut D shows three distinct canal sediment deposits over a range of 19 horizontal feet.
Summary

The examination of the trench walls and approach berm proved that the site was not an Anasazi ceremonial platform and not an erosional remnant of a valley terrace. The trench wall data and configuration of the canal and mound demonstrated that the Morefield Mound Site 5MV1931 was a reservoir based on the following:

1. Sand/clay couplets are typical in the fills of modern reservoirs with similar sizes. The basal sandy layers represent bed material size sediments moving in suspension deposited during flood events, whereas the upper clayey layers represent suspended load from the same events and from later, smaller flow events. Such bedding does not occur in the natural alluvium of through-flowing streams observed at many other locations in the region.

2. Secondary iron-oxide stains in the fill beds indicate that they were sometimes covered with standing water for a considerable period of time.

3. The berm material contains stratification that suggests periodic maintenance. Parts of the berm consist of randomly arranged fragments of natural sediments. Crude off-lapping layers have moderate dips that are too steep for natural alluvial sedimentation.

4. The height and slope of the reservoir and intake canal differ from natural land forms and alluvial features of this and other valleys. The reservoir rests on and rises above natural alluvium that slopes westward toward the axis (modern stream profile) of Morefield Canyon. The top of the reservoir is above the toe of a dissected alluvial fan that slopes eastward toward the valley axis, so the reservoir sediment cannot be an erosional remnant of the alluvial fan. The intake canal has a down-valley gradient which is much lower than those of the natural alluvium and ephemeral stream channel, so the canal cannot have been constructed by natural down-valley alluvial processes. Finally, the uniqueness of the reservoir (only one exists in many miles of similar valleys in Mesa Verde) suggests that it is not a natural feature.

5. The canal’s location and estimated size, shape, and route are consistent with a reservoir-filling purpose. The canal represents good engineering skills.

6. The arrangement of sandstone slabs along the intake canal is consistent with manual reinforcement, but inconsistent with natural alluvial deposition.

The reservoir was situated close to extensive Early People settlements having a population of about 500. The reservoir “grew-up” from the canyon bottom over a likely period of about 150 years; each inflow of sediment raising the active storage zone until finally at the time of abandonment the reservoir mound was some 15 feet high. With each significant reservoir rise,
the feeder canal would also be raised in elevation and extended upstream for water diversion and capture.

The Early People demonstrated the ability to construct and maintain a significant public works project over an extended time involving many generations. This example of water management speaks well for these ancient Native Americans who were able to work with nature to harvest water and to help overcome water shortages.
Mesa Verde Paleohydrological Survey Team

Ken Wright, Project Leader/Paleohydrologist, Wright Water Engineers, Inc.
Jack Smith, Chief Archaeologist, Former Mesa Verde National Park Archaeologist

Dave Baysinger, Video Production, Denver Museum of Natural History
Eric Bikis, Hydrogeologist, Wright Water Engineers, Inc.
Ted Brown, Water Resources Engineer, Wright Water Engineers, Inc.
Chris Crowley, Forest Hydrologist, Wright Water Engineers, Inc.
John Ewy, Civil Engineer, Wright Water Engineers, Inc.
Michael Frachetti, Archaeological Graphics, Wright Water Engineers, Inc.
Mary Gillam, Quarternary Sedimentologist, University of Colorado
Robert Houghtalen, Hydraulic Engineer, Professor, Rose-Hulman Institute of Technology
Sean Larmore, Archaeologist, Fort Lewis College
Rita Lavato, Video Production, Former Channel 9 Newperson
Kurt Loptien, Geologist/Soil Scientist, Wright Water Engineers, Inc.
William Lorah, Hydraulic Engineer, Wright Water Engineers, Inc.
Scott Marshall, Civil Engineer, Wright Water Engineers, Inc.
Gordon McEwan, Scientific Advisor, Former Curator New World Department, Denver Art Museum
David Mehan, Forest Hydrologist, Wright Water Engineers, Inc.
Ernest Pemberton, Sedimentologist, Former Sediment Head, Bureau of Reclamation
Doug Ramsey, Soils Scientist, U.S. Natural Resources Conservation Service
John Rold, Geologist, Former Colorado State Geologist
Janice Sheftel, Water Attorney, Maynes Bradford Shipps & Sheftel
Jeri Smalley, Archaeologist, Fort Lewis College
Gary Witt, Hydrogeologist, Wright Water Engineers, Inc.
Ruth Wright, Attorney/Photographer, Former Colorado State Representative