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Sand Distribution in Pools along Six Reaches Downstream from the Little Colorado River, April to May 1994 Colorado River, in Grand Canyon, Arizona

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ABSTRACT

Geophysical surveys along 32 cross sections of the 11-kilometer reach below the Little Colorado River established baseline information about the distribution of sand and mixtures of sand with pebbles, cobbles and boulders on the river bed. The study utilized a part of the network of monumented cross sections established by Glen Canyon Environmental Study, and Water Resources Division of the United States Geological Survey. Profiles were collected between April and May of 1994. Each cross section was surveyed using a high-resolution seismic profiler, side scanning sonar, bathymetric profiler, and underwater video. Flags or brightly colored ribbon, set up as range markers in alignment with the monumented markers, or, a line marked at regular intervals strung across the river between the monuments, provided horizontal position control. This report describes the methods used to collect and interpret the data, with results and notes of subsequent work planned.

INTRODUCTION

This study is part of the work initiated by the U.S. Geological Survey (USGS) and funded by the Glen Canyon Environmental Study (GCES), to collect field data to monitor sediment response to water releases at Glen Canyon Dam (fig. 1). Graf, et. al. 1995 gives an excellent overview of the events leading to establishing GCES, and brief history of when and why Congress placed restrictions on releases through the dam. This report presents data collected as a cooperative field study between GCES, the USGS Office of Pacific Marine Geology, and Water Resources Division, between April 24 to May 13, 1994. The study collected bathymetric, side-scan sonar, high-resolution seismic profiling data, and underwater video along 18 reaches of the Colorado River. This report focuses on 32 cross sections located 11 kilometers below the LCR to

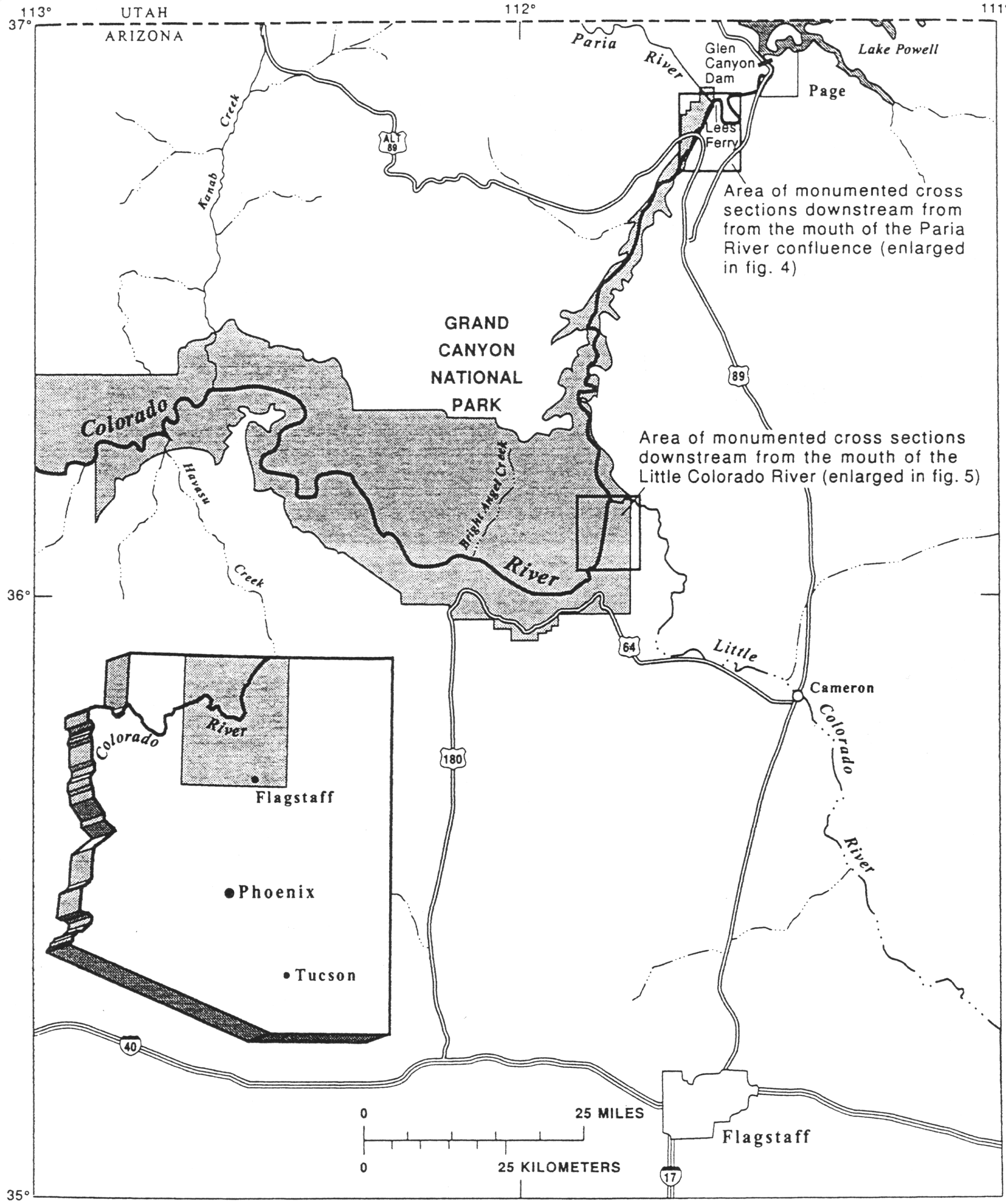

Figure 1 Location of the monitored reaches below the Little Colorado River. (Modified from Graf, et.al. 1995)

Tanner Rapid (figure 2). The study created a pre-experimental flood baseline of data to compare the effects of the experimental flood on the sediments trapped in the pools below the Little Colorado River (LCR).

METHODS

One obstacle of the survey was establishing navigation controls for the tracklines. Navigation control was established by conducting the surveys along predetermined reaches established by WRD (Graf et. al. 1994) for their bathymetric surveys, (figure 2). Surveying four reaches above the LCR allowed us to practice the surveying process before arriving at the LCR. The horizontal control used for all reaches surveyed consisted of stringing a line marked at 10 foot intervals across the river between previously surveyed monuments. The surveys were run in both a cross river and shore parallel orientation. For the shore parallel tracklines the marked line could not be utilized, instead flags were placed along the shore in-line with the monuments. The flags served as range markers that were annotated on the video, paper, and digitized records when passed during the shore parallel lines. The pre-surveyed monuments and the water's edge were well located in the GIS maps obtained from WRD and GCES and used as the base lines to hand digitize the geophysical and underwater video data (figure 3). The raft location was established by measuring from the shore line to the water's edge imaged on the side-scan record. The underwater camera navigation was established by audio marks on the video tape that oriented the camera location along the marked line stretched across the river or by range marks during shore parallel lines.

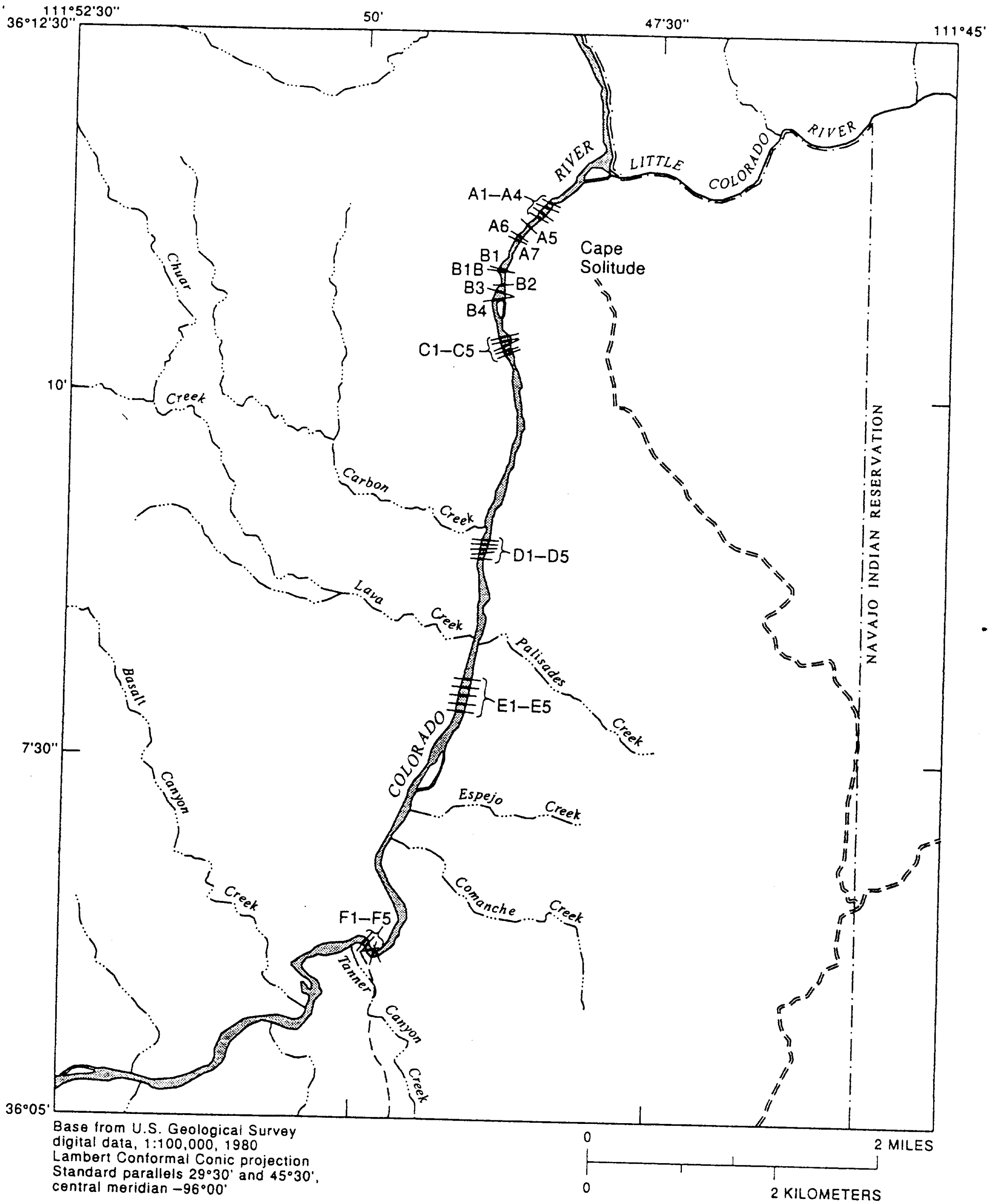

Figure 2 Location of monumented cross sections on the Colorado River downstream from the mouth of the Little Colorado River. (From Graf, et.al. 1995(

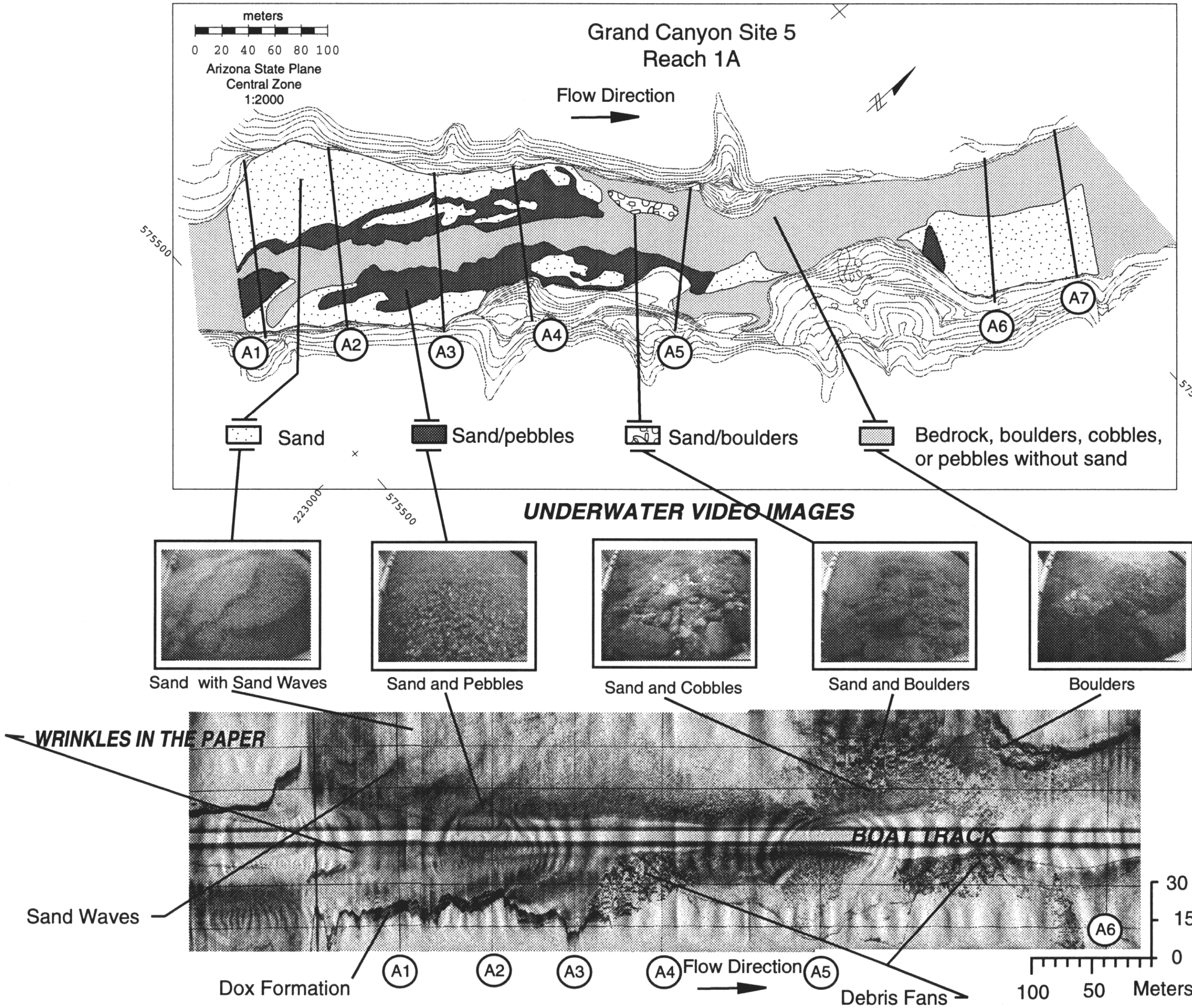

Figure 3 Map interpretation of reach"A" interpreted from both underwater video and side scan sonar r trackline data. The wrinkles in the side sonar records are the result of both the paper characteristics and the computer scanning method used. The boat track noted in the side scan record marks the origination point of the outgoing sonar signal which scan out to 45 meters on each side of the towed fish. The underwater video images displayed here were still framed using computer imaging software.

Geophysical Data

All systems and equipment were deployed from a 23 foot snout rig (figure 4). The seismic profiler consisted of one power supply, the sound source sled that produced 150 joules at a frequency 1 to 4 Khz, two streamers, a 3 element streamer, a 30 element streamer, and a recorder. The side-scan sonar equipment consisted of a 500 Khz fish, and recorder. The underwater video required a camera sled and video monitor. Two computer systems converted the analog signal to a digitizing signal and stored the data on optical disk. Water depth data was monitored constantly using a fathometer. Two generators mounted to the walking decks of the snout rig supplied the electrical power to run the all the electronic equipment. With the exception of the fathometer which did not require much space or power the actual surveying required the rigging and unrigging for each phase of the operation, as space and electrical power requirements did not allow the deployment of any two systems to be run simultaneously.

Both the side-scan sonar and seismic data were recorded as hard copy paper rolls and the analog signal was converted to a digitized signal and stored on optical laser disk. Heat proved to be a problem along some of the reaches that required a shut down of all systems to allow for cooling.

Data Interpretation

Using the maps provided by GCES and WRD as a guide, the shoreline was established on the side-scan record and measured from the shoreline on the maps. This gave the boats track along the reach. The reach was divided into 10 increments between surveyed lines and likewise the side-scan record was also divided into 10 segments between event marks put on the record to denote the crossing of the range marks. Features were then transferred to the map by measuring features from the boats track on the side scan to the measured distance from boats track on the map. The side scan tracklines were only run along shore parallel lines in both a downstream and upstream directions. Running side-scan sonar tracklines in shore normal orientation would not give good imagery due to the short duration of the trackline, the shallow water depths at both ends of the line and the fluctuation of the boat speed along the track. Shore parallel tracklines eliminated these problems.

Interpretations of riverbed composition for the reaches above and below the LCR mile 62 to Tanner Rapid were compiled on 1:50,000 scale topographic maps provided by GCES and Water Resources Division (J. Graf, 1994). These maps gave the river level for 5,000 cubic feet per second and the river level during this survey was between 8 to 15,000 cfs so that the overall error is between 3 to 8 meters horizontally, this is also taking into account the error that exist in the event marks, and the distance from shore interpreted from the side scan record. The underwater video was invaluable in decreasing the error due to the ability to match bottom texture to actual video images of the bottom. When measured in map view the error was decrease to within 2 meters.

The side-scan sonar record shows the ships track (fig. 3) with 15 meter line segments to each side of the record on a horizontal plane. The image is showing the reflectivity of bottom features. Where a very dark reflector is seen on the record with a light colored shadow behind or away from the fish, this is a large rock or some other large object on the bottom (fig. 3). Any sand areas are imaged as to medium tan (fig. 3). The darker and rougher the texture on the imaging the coarser the sediment type.

The high-resolution seismic profiles also show sediment textural variations in a vertical profile. The maximum depth of penetration along these profiles is 10 meters. The multiple is the dark image that runs parallel to the sediment surface (fig.5). The multiple is below the sediment surface at the same distance as the outgoing pulse is above the sediment surface, it is the second reflected image of the sediment surface (fig. 5). Due to the shallow depth this multiple obscures the actual data and makes interpretations difficult.

The underwater video camera sled system is a camera and two underwater lights suspended from the surface and controlled for depth changes by one person responsible for raising and lowering the camera based on what is seen on the video monitor in the boat. The video images in figure 5 are expamles of variations in bottom characteristics. The same features are plotted as they image on the side-scan sonar record. The results of the video imaging are combined with the imaging of the side-scan sonar imaging and plotted on the detailed maps provided by GCES to show the distribution of various combinations of sand along each reach. Each system augmented the other when interpreting the records. Often reaction time was slow and the camera sled hit rocks on the bottom or the sides of the channel. The video sled is well weighted to allow the sled to fly at a near vertical angle oriented in and upstream direction. Video sled lines were run in a shore normal and shore parallel orientation with careful attention to the range marks and the distance across the channel.

DESCRIPTION OF REACHES

Introduction

This report focuses on the reaches below the LCR to the pool above Tanner rapid (fig. 2). The reaches are designated as BLCR (Below the Little Colorado River) with the additional designation in sequence down-river starting with reach A, BLCRA, BLCRB,.......to BLCRF. The reaches average 348 meters in length with an average stream width of 115 meters. The reaches are all within pools between rapids or riffles. Onshore the reaches vary from sand beaches to extensive boulder fields to exposed bedrock of Dox formation. The video tracklines were run as close to shore as possible to ensure maximum coverage.

Underwater features ranged from extensive sand along reach BLCRB to increased amount of sand mixed with boulders and cobbles along reach BLCRA. The maps produced for this report are produced using the Arizona State Plane Central Zone grid, at a scale of 1:2000. Figures 6- 11, show the extent of sand with mixtures of boulders, cobbles, and pebbles. All interpretations are based on underwater video comparison to the side-scan sonar imagery with the variations in reflectivity noted in the side-scan matched the variations in sediment texture. The interpretative maps show only those areas with sand or mixtures of sand with other components. Areas whig grey shading can be areas of only bedrock, boulders or other components solely.

BLCRA

Reach BLCRA located directly below the LCR, at mile 62, has 7 crossing lines mapped by WRD (fig. 6). The reach is approximately 650 meters in length with the crossing lines averaging 106 meters in length. The right bank of reach BLCRA consists of bedrock ledges between lines 1, 2, 3, and midway to line 4. At the midway point between lines 3 and 4 the shore is compose of large boulders from a debris fan that continues to line 6. From line 6 to the end of he reach river right is composed of a sand bar. The left bank of BLCRA is composed of talus and sand with varying amount of Dox formation exposed along the shore.

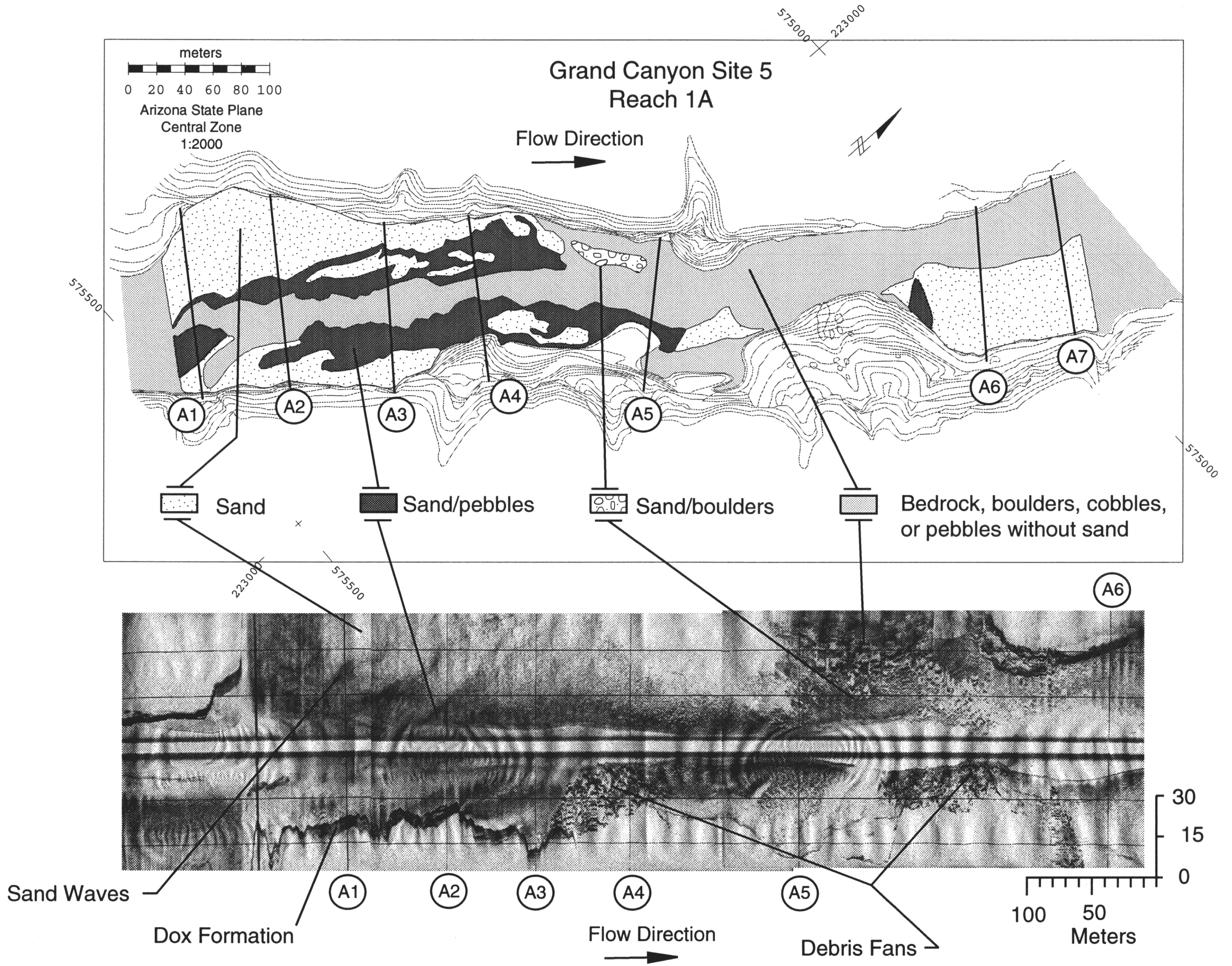

Figure 6 Map at top shows the distribution of sediment along reach "A" based on the interpretations of side-scan sonar imagary (below) with ground truthing using the underwater video (fig. 3). The numbers inside the circles indicate the crossing lines used to determine boat position.

The submerged features along this reach consist of pebbles and sand at the start of the line along center right of the channel. This becomes increasingly sandy downstream along river right. Before line two is reached the pebbles appear in the sand this continues to downstream of line 5 where sand again becomes predominant. Line 6 and 7 are composed entirely of sand to mid channel where pebbles, and pebbles with cobbles are found along the left side of the channel from less than mid channel.

River left is composed of sand with mixtures of pebbles to near mid channel. Sand interspersed with pebbles continues along to approximately 200 meters upstream from line 5 where sand and boulders are found. From line 5 to line 6 little to no sand is observed.

BLCRB

Reach BLCRB (fig. 7), is at the lower end of mile 62, is approximately 350 meters in length with 5 crossing lines averaging 143 meters in length. The reach has two debris fans that extend into the channel. The first downstream is located on river right between crossing lines B1b and B2. The second extends into the channel from river left and is smaller in size and lies directly down stream from the first debris fan with monument B2 located near the fan axis. The reach is predominantly sand the entire length of the reach. The exception to this is along the edges of the two debris fans where boulders and sand, and sand with pebbles are found. From the start of the reach at B1 to just upstream of the river left debris fan, are exposures of Dox formation along the shore. The reach shows good examples of sand waves between B1 and B1b and between B3 and B4. The area near B2 is an eddy pool with predomeinantly sand or bare rock. The small bar like feature on river left along line B4 appears to be a reattachment spit.

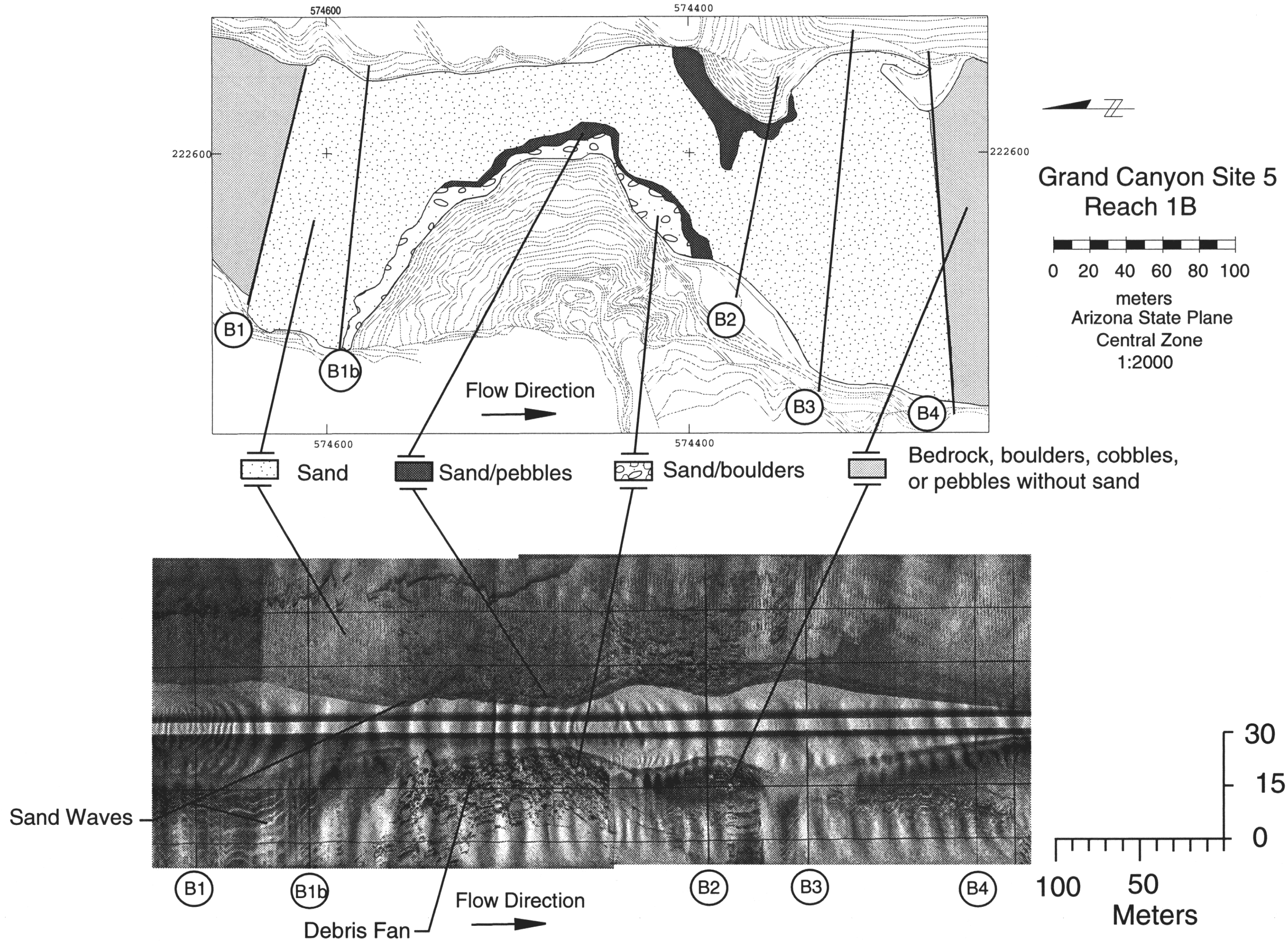

Figure 7 Map shows the distribution of sediment along reach "B" based on the interpretations of side-scan sonar imagary (below) with ground truthing using the underwater video. The concentration of boulders,sand and pebbles coensides with the location of the debris fan located between to control lines B2 and B3.

BLCRC

Reach BLCRC, mile 63, is a pool downstream of a large mid channel bar and debris fan extending from river left and upstream from two debris fans that extend from both sides of the river (not seen in figure 8). The reach is approximately 260 meters in length with 5 crossing lines averaging 174 meters in width, the widest of all the reaches in this report. The reach consist of an inter-fingering of sand along mid-channel and river left, with sand and pebbles beds that pinch out in an upstream direction oriented shore-parallel. Adjacent to the sand and pebble beds are beds of cobbles and sand along the entire reach on river right. Onshore the reach consist of boulders and talus along river right and exposures of Dox formation with boulders along river left. Large sand waves are seen beginning midway between C3 and C4 and extending to beyond C5 show good relief and extend across the ships track (fig. 8).

BLCRD

Reach BLCRD is located at mile 65 on the upper part of a large pool located down stream from the debris fan that formed at the mouth of Carbon Creek. The reach is approximately 240 meters in length with 5 crossing lines averaging 78 meters in length. This reach is covered with sand over most of its length. Dox formation is exposed along river-right from just above D4 to the end of the reach. Along river-left between the start of the reach to just downstream from D41 a combination of sand with boulders to sand with cobbles to sand with pebbles extends into the channel. The distribution of this material coesides with the small canyon located at the upstream end of D4 (fig 9).

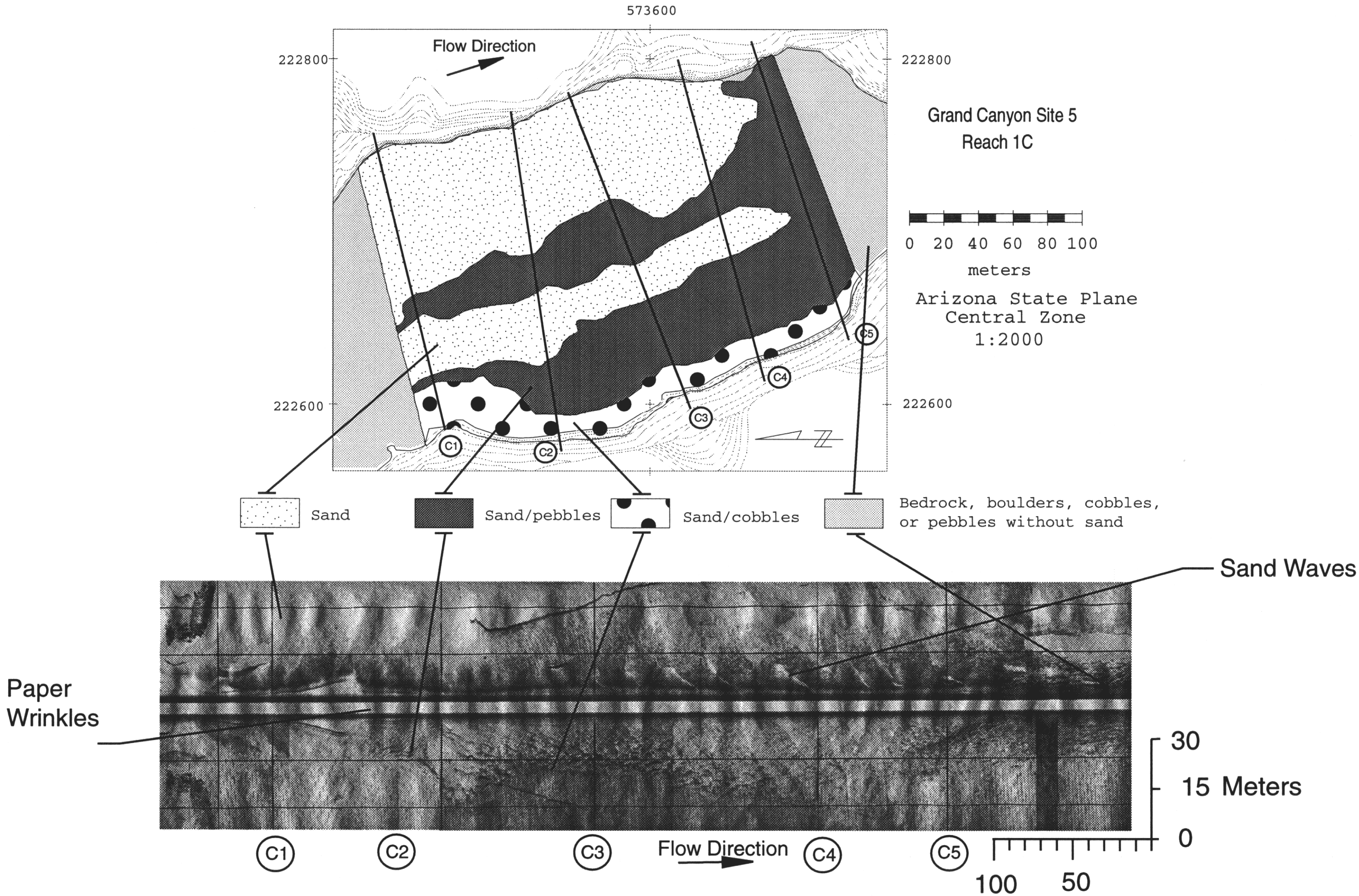

Figure 8 Map shows the distribution of sediment along reach "C" based on the interpretations of side-scan sonar imagary (below) with ground truthing using the underwater video.

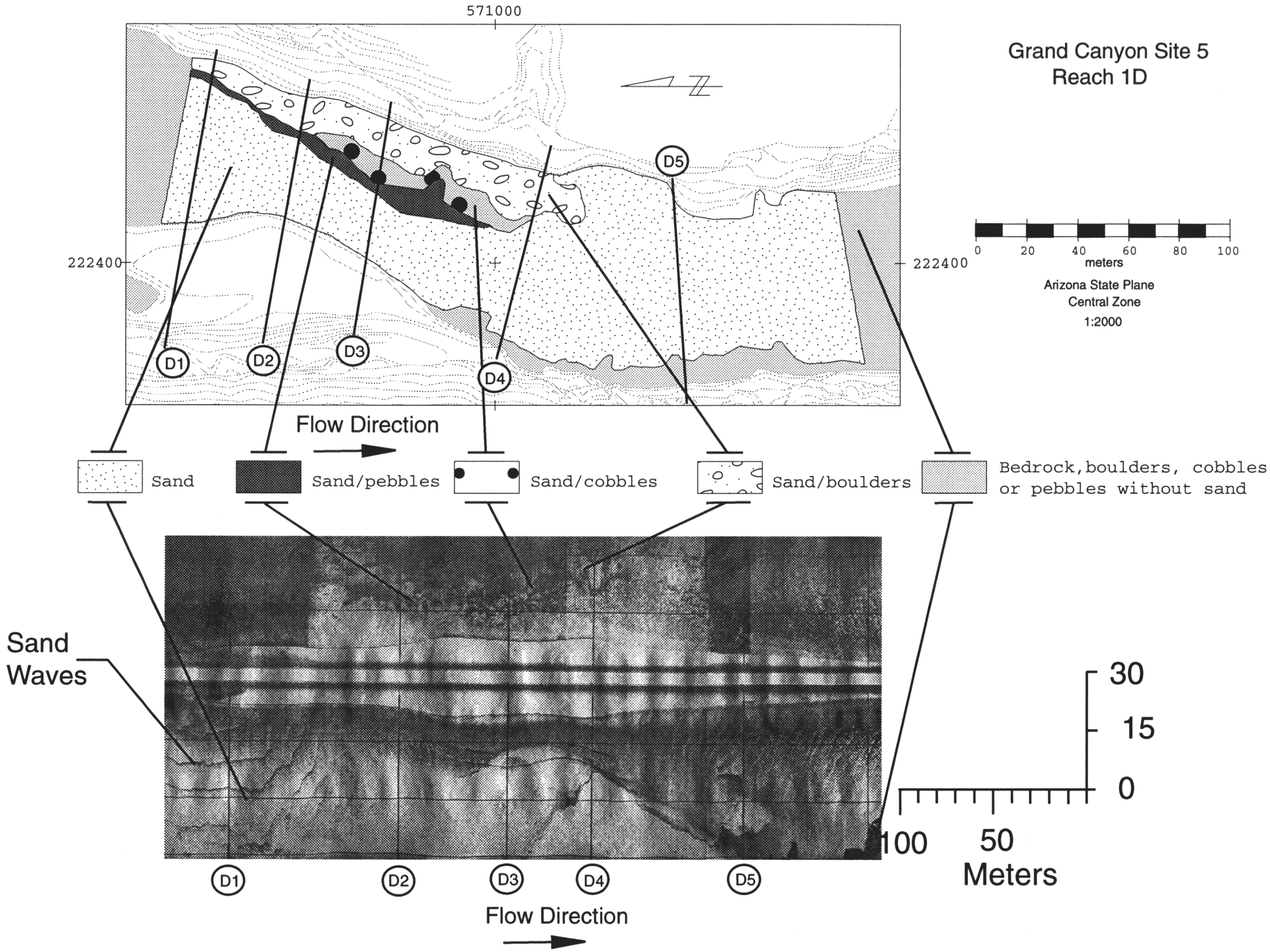

Figure 9 Map shows the distribution of sediment along reach "D" based on the interpretations of side-scan sonar imagary (below) with ground truthing using the underwater video. The concentration of boulders,sand and pebbles coensides with the location of the debris fan located between to control lines D2 and D4.

BLCRE

The next reach BLCRE is at mile 66, below Lava Rapids, approximately 300 meters in length with 5 crossing lines averaging 107 meters in length. The reach begins down stream form the constriction in the river caused by the debris fan formed at the mouth of Lava Canyon (figure 11). The reach consists predominantly of sand with very well formed current ripples along the central area of the reach. Along river right the shore line is dominated by Dox Formation that increases in the amount of boulders and cobble size material downstream. The submerged area of river right from line 2 is dominated by boulders along the entire reach. River left consist of sand to approximately midway between lines 2 and 3, where cobbles and pebbles dominate the left side of the channel. River left is composed of a boulders and sand with cobbles and pebbles (figure 10).

BLCRF

Reach BLCRF is the last reach of this section and is located above Tanner Rapid, mile 68 (figure 11). The reach is approximately 290 meters in length with 5 crossing lines averaging 85 meters in length. This is the only reach that is located along a river bend. River right consists of a very large reattachment bar with extensive vegetation along the entire reach. The submerged area along river right reflects the same sediment texture as the subaerial part of the reach. River left in contrast consist of Dox Formation outcropping from the start of the reach to line F2. Beyond line F2 the reach consist of boulders and cobbles with sand. The boulders and cobbles extend midway into the channel from line F3 to the end of the reach. The amount of boulders and cobbles decrease upstream along river left where the submerge part of the reach is predominantly sand with outcrops of Dox Formation at line

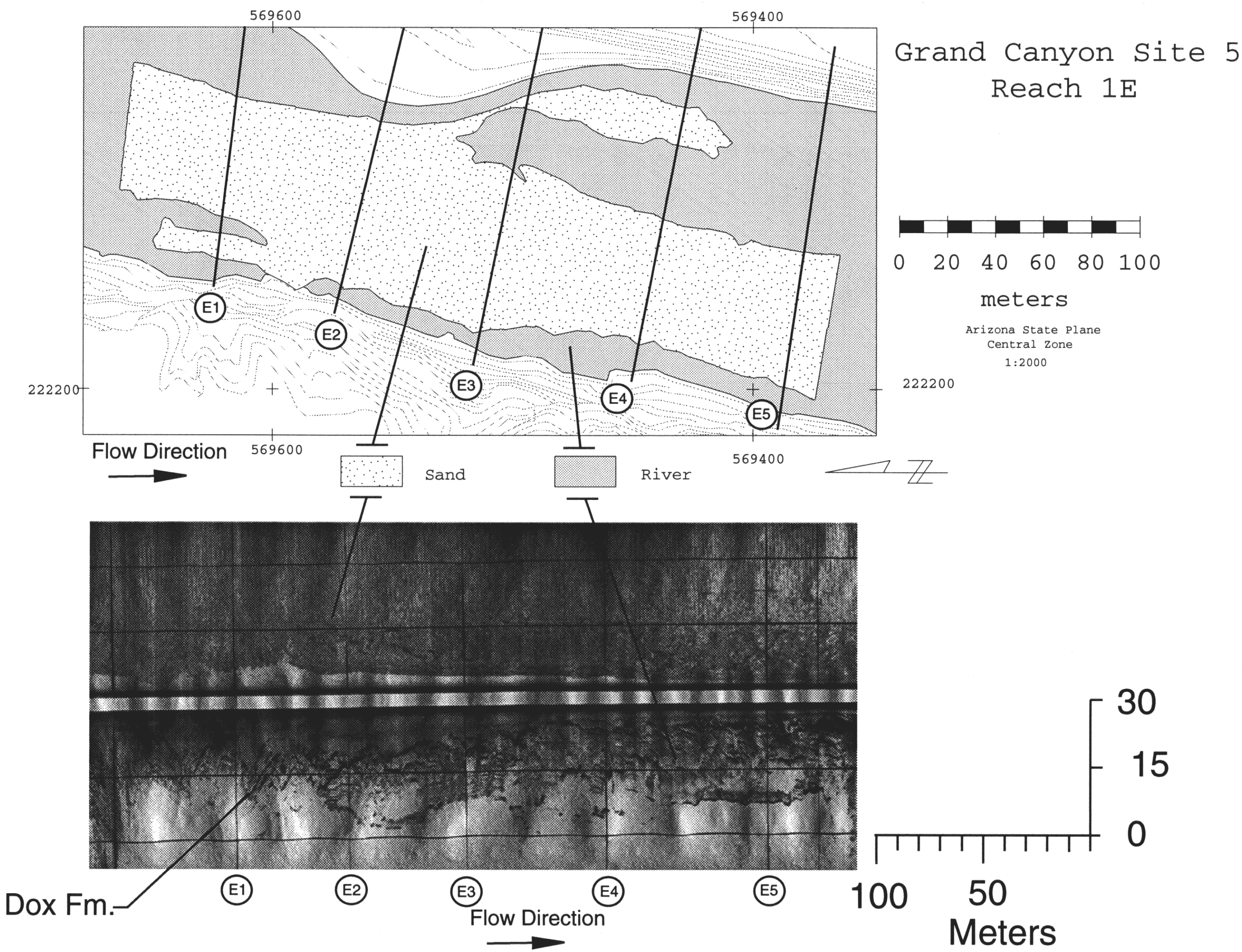

Figure 10 Map shows the distribution of sediment along reach "E" based on the interpretations of side-scan sonar imagary (below) with ground truthing using the underwater video.

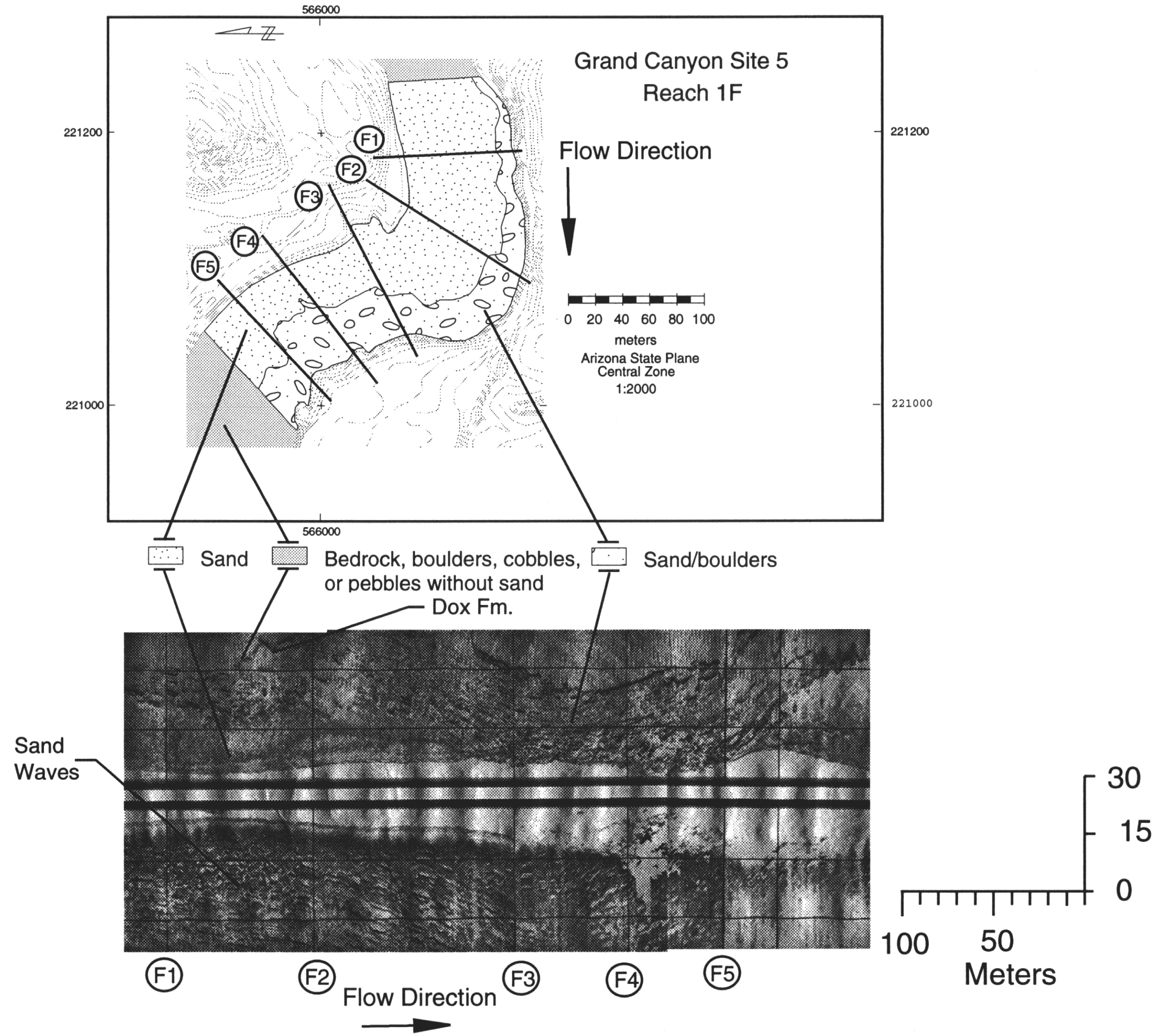

Figure 11 Map shows the distribution of sediment along reach "F" based on the interpretations of side-scan sonar imagary (below) with ground truthing using the underwater video.

F1 to the start of the reach. This reach lies along the east flank of the debris fan at the base of Tanner Canyon. This is likely the source of the large amounts of large boulders and cobbles.

DISCUSSION AND CONCLUSION

The use of geophysical surveying equipment along the Colorado River gave excellent results despite the limited space available for equipment set up and deployment, the labor intensive rigging problems, and the heat related electronic problems. Both the side-scanning sonar and underwater video proved to be excellent tools when used in conjunction with one another to image the bottom features. The high-resolution subbottom seismic-reflection profiles were limited by a shallow air-water multiple, but did show areas where sand overlies talus or bedrock (figure 4). The extent of sand cover over the bottom in most reaches varied according the proximity of the sand body to the constriction of the river. Very good reattachment bar morphology was seen along lines BLCRA and BLCRC. The bedforms noted along many of the reaches attest to the effects of stream velocity on bottom features and texture. The variation of pebbles and cobbles also reflect the variation in stream velocities along sections of the same reach. Boulders were more concentrated near debris fans or near exposed rock outcrops. The transition from boulders to cobbles to pebbles was well imaged along sections A,D, and F. A bedform feature noted along many of the lines suggest ridges formed at an oblique angle to the river flow, these ridges are composed of texturally sorted sediments with sand ridges overlying pebble and cobbles (Section A and C, figs. 7 & 9). These ridges appear to be at a transition between a large sand body and a pebble or cobble lag deposit.

Also noted were sand waves oriented normal to the flow at the base of reattachment bars. The sand waves are part of the reattachment bar system reported by Rubin et. al. (1990) and Schmidt and Rubin (1995) as being part of the recirculation eddy pattern noted in their work on reattachment bars. The work accomplished to date is an extension of the work of other investigators along the reaches focused on in this report.

FINAL NOTE

The side-scan sonar and underwater video profiles allowed the imaging of bottom features along the Colorado River with an acceptable degree of precision. It is hoped that the systems used in this report, with the exception of the high-resolution seismic profiler, will be utilized to repeat the surveys following the March 1996 flood experiment. A repeat of this initial survey will image changes in bed roughness, showing variations in sediment texture that will help determine the amount of sediment removed from or transported into the pools. Much was learned from the initial survey that will be used to improve the techniques used on the first survey. The subsequent survey will use what was learned to, decrease the error factor and ease the interpretative aspect of the survey.

References

Graf, J.B., Marlow, J.E., Fisk, G.G., Jansen S.M.D., 1994, Sand storage changes in the Colorado River downstream from the Paria and Little Colorado Rivers, June 1992 to February 1994, U.S. Geological Survey Open-File Report 95-446, 61 pages