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**SOUTH BLUFF EROSION ASSESSMENT,
ST. CROIX ISLAND NATIONAL MONUMENT**

by

Dr. James R. Allen
Coastal Geomorphologist

National Biological Service
North Atlantic Field Station
c/o National Park Service
15 State St.
Boston, MA 02109

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St. Croix Island N.M., south bluff erosion

Problem:

In the 1970's it was recognised by management and staff that the south bluff of St. Croix Island N.M. was unvegetated and unstable. Furthermore, continued retreat of the bluff would lead to the potential loss of archeological resources dating to the site's occupation by the expeditionary company of Sieur de Monts, as recorded by Samuel de Champlain, from June, 1604 to June, 1605 (see Fig. 1). Some of these had been revealed in a reconnaissance excavation in 1972-73.

Existing historical maps, although of variable quality regarding features, scale, and accuracy, depict the loss of land in the southern portion of the island (c.f. Fig. 1 and 2). The present "rubbles" are the rock cores of former upland promontories. Preferential retreat of the south side results from 1) elsewhere there is a more erosional resistant, contiguous rock core for the island with only a thin veneer of glacially deposited sediment above the zone of wave attack in recent times of similar sea level stands, 2) greater erosional susceptibility of the much thicker layer of glacially deposited sediment onto small rock cores on the south side, and 3) a long wind-wave fetch to the south whereby large storm waves can attack the toe of the bluff, with subsequent gravity-driven adjustment of the oversteepened slope. There was some speculation, never supported strongly, that activities of bank swallows nesting just beneath the turf layer capping the bluff contributed to sediment disturbance.

Quantifying the retreat rates of various bluff aspects would allow for a projection of the threat to archeological sites, especially the burial ground on the south grounds, but the maps are too crude to provide adequate quantitative data. To confound the issue even further, the erosional processes were not fully natural in that substantial sand and turf mining took place, apparently in the late 19th century, by Canadians (source unknown). The sandy sediment composing the steep (angle of repose) bluff face is also not very conducive to vegetational colonization because it is easily eroded by rainfall, runoff, mass-wasting, and human traffic.

Monitoring design and data:

In the summer of 1978 the Regional Archeologist (Frank McManamon) and Regional Aquatic Management Biologist (Mike Soukup) visited the site and established a triple transect, horizontal displacement monitoring system based upon distances from benchmark STCI-9 (see Fig. 3 and 4). The benchmark's elevation has been reported as both 39.30' (NPS files) and 38.30' (DSC map) NGVD. Each transect was established as a maximum or minimum distance between the benchmark and the south bluff and they obtained a compass bearing for each (d^1 is minimum distance to bluff east of point (130°); d^2 is maximum distance out to point (170°); and d^3 minimum distance to bluff west of point (220°). However, it is unknown as to whether the magnetic bearing was corrected for magnetic declination ($21^\circ 7'W$ in 1980, $+0.5'$ annually) to true north. All data for the monitoring program are presented in Table 1. On May 20, Acadia NP Chief of Maintenance (Dick Young) remeasured the distances using a hand-held compass, again

it is unknown whether the orientation was relative to magnetic or true north. His results indicated that the point had retreated 3.3 feet and the sides had retreated less.

On September 25, 1981 the Regional Coastal Geomorphologist (Jim Allen) visited the site with Acadia Chief of Resource Management (Carrol Schell) to assess the situation. Using a Brunton compass corrected for magnetic declination, it was found that d^1 and d^2 bearings continued to define the minimum and maximum distances but that d^3 was problematic. The minimum distance orientation was 210° and a longer distance of 36.5' was taped along azimuth 220° . The difference was considered to be due to a "typo" and not that the minimum distance location had migrated. Stakes were emplaced along the transect lines to aid in future orientation measurements. It was also observed that the turf edge at the blufftop was curved vertically to add a small uncertainty (ca. 0.5') to measurements of the distance to the "edge" and that it was horizontally serrated so that even very small differences in transect orientation intercept at the blufftop would also result in an measurement error on the order of $\pm 0.5'$.

Allen returned on October 18, 1983, could not recover the stakes, and was forced to remeasure the transects using a SUUNTO compass uncorrected for magnetic declination. The east bank top had retreated 1.44' and the point retreated 1.32' since 1981. The west bank minimum was at $d^3 = 220^\circ$ again but had a distance of 31.5'--about the same as measured along 210° previously but shorter than measured along 220° . It was estimated that the technique had a measurement precision of $\pm 0.5'$ due to a "fuzzy" bluff top edge and transect orientation inconsistencies. It was suggested that more permanent markers for replication of a constant and accurate transect orientation would improve study design but either nothing was done or these "subdatums" were lost.

Accordingly, Allen's remeasurements on November 7, 1985 showed "no change" on the lateral transects but a further retreat of about 2' at the point. The seven-year record of change was thus established as having problems due to remeasuring the same transect bearing exactly hence the irregular outer edge of the bank top contributes error. Nevertheless, the lateral bank distances had decreased but only by about 1.3'. Significant change occurred at the point which retreated by 6.3'. In reviewing the monitoring data, available photography, and discussions with maintenance crew, it was suggested that recent erosion was most likely due to the activities of summer visitors who climb and jump off the cliff. Of only secondary importance were the more "natural" processes of basal erosion during storms leading to bluff retreat and turf undercutting by bank swallows. Accordingly, it was suggested that posting some type of informational signs regarding erosional impacts might help in that people management may be more effective than engineering structures in stabilizing the bluff.

During a field review of the site on May 11, 1995, using magnetic bearings for the transects, Allen measured 2.2' of erosion on the east and 1.5' on the west over the ten-year period. The point orientation was now about 189° , and it had retreated only about 1.6' in ten years. If this orientation is corrected for magnetic declination it is close to past

orientations to maximum distance. An alder shrub immediately south of the benchmark has grown much and is now interfering with taping distances to the point. Monitoring has been plagued by orientation inconsistencies in measuring the lateral transects arising from different and unknown equipment and human error. As a result, the lateral transect data suggest that while retreat has been measured over the 17 years ($d^1 = -3.5'$, $d^2 = -8.2'$, $d^3 = -2.7'$), there is some doubt as to the accuracy of measurement and the magnitude of error probably is a couple of feet. About 8' of retreat at the point is clearly demonstrated because the point is a sufficiently recognisable feature to remeasure accurately. Straightening of the shoreline would accentuate retreat of this feature beyond the rates for the side areas and thus the retreat rate for the point is the upper bound for anything off to the side. The side transect measurements are more problematic and may not really record what the blufftop is doing further away from the point. Although some instability of the eastern side of the bluff is suggested by the large expanse of bare sand, measured loss is not much different from the estimated error. More important to the resource manager is retreat on the western side, adjacent to the gravesites, where there is reasonably dense vegetation on the slope and recorded retreat is again within the estimated error.

Recognising some of the difficulties in past study design, Allen experimented with using the satellite-based Global Positioning System (GPS) technology to add more spatial information to the data set developed from the 3-transect program. The entire bluff crest was walked along the south side and northwards along the east side. The benchmark and a few other points were also located. A Trimble GeoExplorer was used and its files were differentially corrected using a base station at the University of Rhode Island. This technology and processing level has an (manufacturer's stated) locational accuracy of 2-5 m (6-16 ft.). The GPS-calculated position of BM 9 is 8.4' (2.56 m) away from the published position. Which methodology contains the majority of the locational error is unknown but the coordinate system for the topographic surveys should not be fully trusted to their implied precision of expression because they would have had to be tied into the mainland datums nearly 1 mile away, across the river. Whatever, the GPS technique is likely to illuminate much geomorphic change only on longer time scales (> 5 years) according to the existing database. Visual comparison of this "baseline" GPS data with the reduced copy of a 1976 topographic map (NPS Denver Service Center) suggests that retreat along the south bluff occurred only at the point (Figure 3). Although the blufftops elsewhere are closely coincident, the point retreat *may* be more apparent than real because its scaled value of approximately 15' is within the margin of instrument error. The two plots are only approximately of the same scale due to photocopying difficulties--note that the benchmark location is much more than 8' away from the indicated triangle and that the iron rod 6' south of the southwest corner of the bathhouse is plotted within the structure!

Comparison of site photography from 1978 through 1995 (available from Allen) indicates that many of the original blufftop features are still present (the only obvious change is that the then undercut birch tree adjacent to d_3 has finally collapsed) and that even bluff toe

features are surprisingly stable as a large log is present just to the east of the point since 1983. The photography also supports substantial progress in natural revegetation of the bluff face since 1985. Discussion with the site's maintenance worker indicated that human disturbance ended in the late 1980's and people have been obeying the posted signs.

Temporary Conclusions:

Little to no retreat of the south bluff at St. Croix National Monument has occurred over the past 17 years with the likely exception of only at the point. Although monitoring has been plagued with inconsistency in personnel and (sometimes) unidentified equipment for measuring survey direction, the quantitative program has sufficient accuracy to support such a conclusion. The available ground photography also lends subjective support to minimal geomorphic change other than at the point and some revegetation between 1978 and 1995, with most this taking place in the past five years, or so.

The variation in observational data does pose a problem for any strategy for conservation of the resources: is the inaccuracy in retreat rate sufficient to pose a threat? In order to redefine all data, one more trip to exhaustively review all field possibilities of orientation and subjective/objective definitions and measurement would reduce the present level of uncertainty. Otherwise one is left with a data set which suggests that erosion does not appear to be ongoing at a sufficient rate to present a problem unless archeological resources exist very close to the bluff edge now. One must assume the dataset is fully believable on erosion and cultural resource richness to accept such a statement. I suggest a future, detailed resurvey of both topography and cultural resources, in that priority to fully clarify the variability in the data describing the threat.

Table 1. South bluff crest retreat, 1978-1995.

<u>transect/ true bearing</u>	<u>horizontal distance from STCI benchmark #9 (ft.)</u>					
	<u>8/9/78</u>	<u>5/20/81</u>	<u>9/25/81</u>	<u>10/18/83</u>	<u>11/7/85</u>	<u>5/11/95</u>
d ¹ (130°) <i>mag. 151</i>	24.0	23.0	23.6	22.1	22.7	20.5
d ² (170°) <i>mag. 191</i> <i>"point" (189°)</i>	47.8	44.5	44.6	43.3	41.5	28.7* 39.6
d ₃ (210°) <i>mag. 231</i>	32.5	32.0	31.3	31.5	31.3	29.8

*likely "bad" data

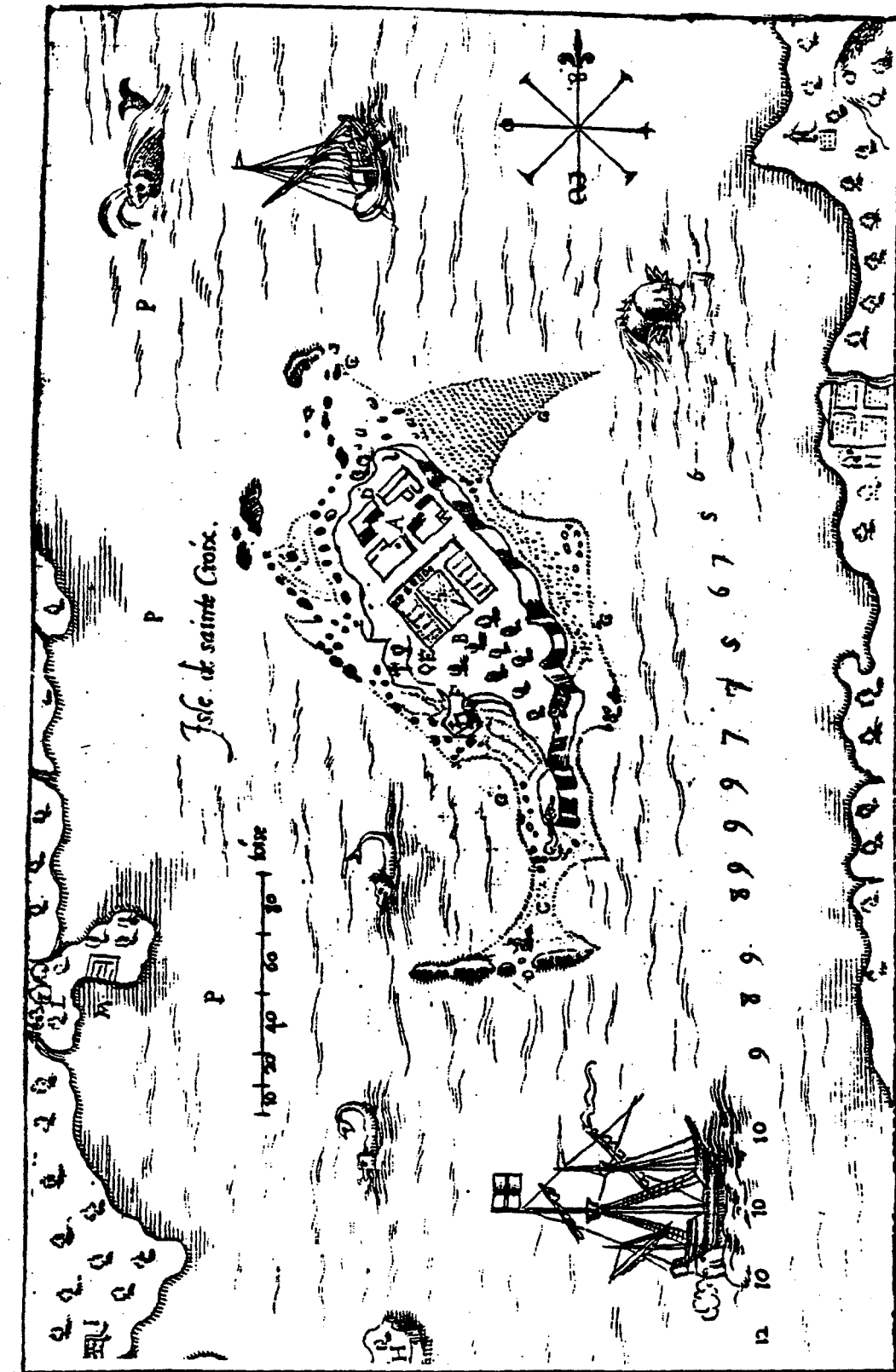


Figure 1. Copy of Champlain's sketch map (ca. 1607) of St. Croix Island.

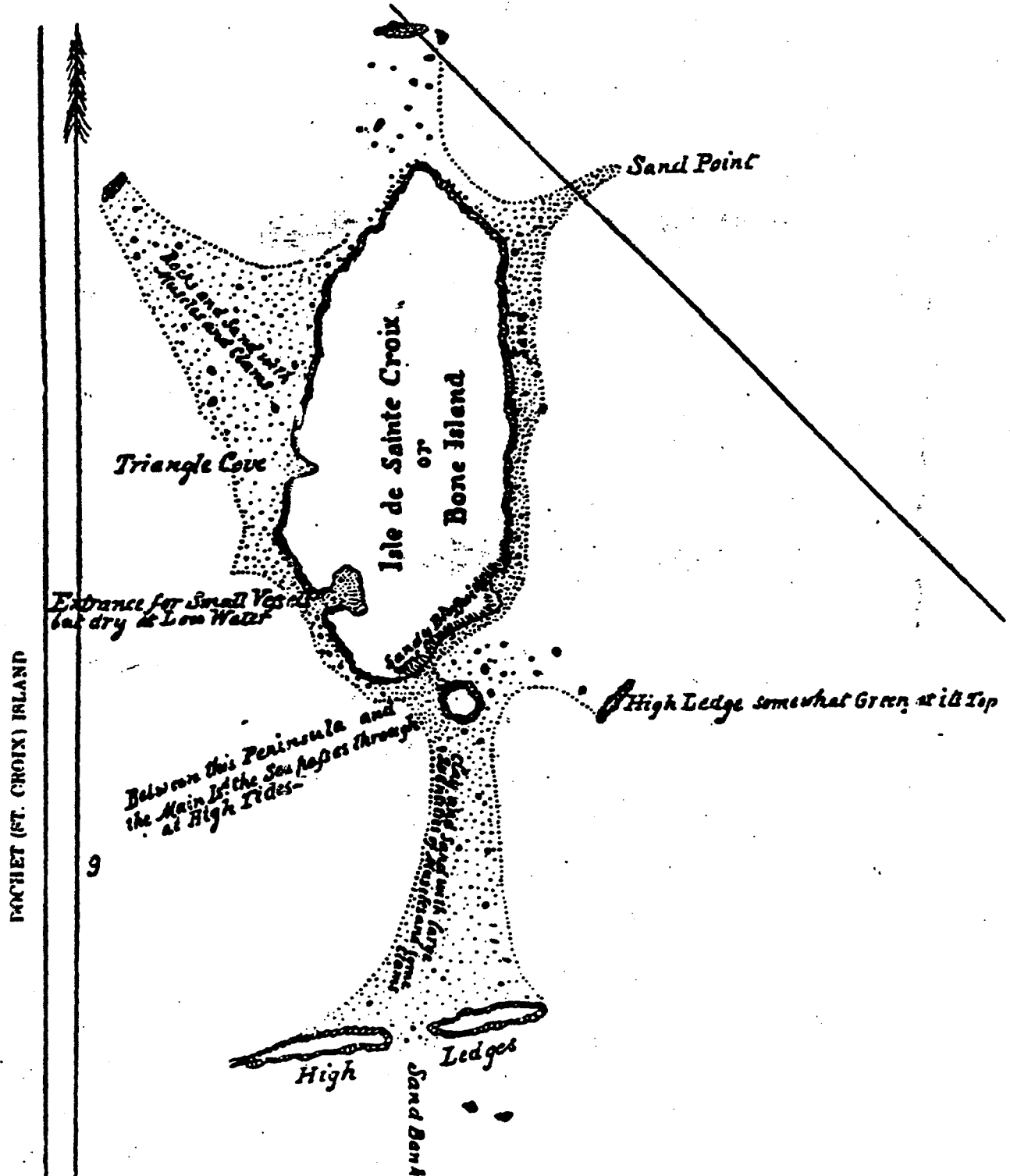


Figure 2. Copy of Wright's 1797 map of St. Croix Island. Such features as the northeastern "Sand Point", the rocky intertidal point to the northwest, and the "Triangle Cove" and "Entrance for Small Vessels" along the west side are still present--and the latter is still used for boat landings from the US mainland.

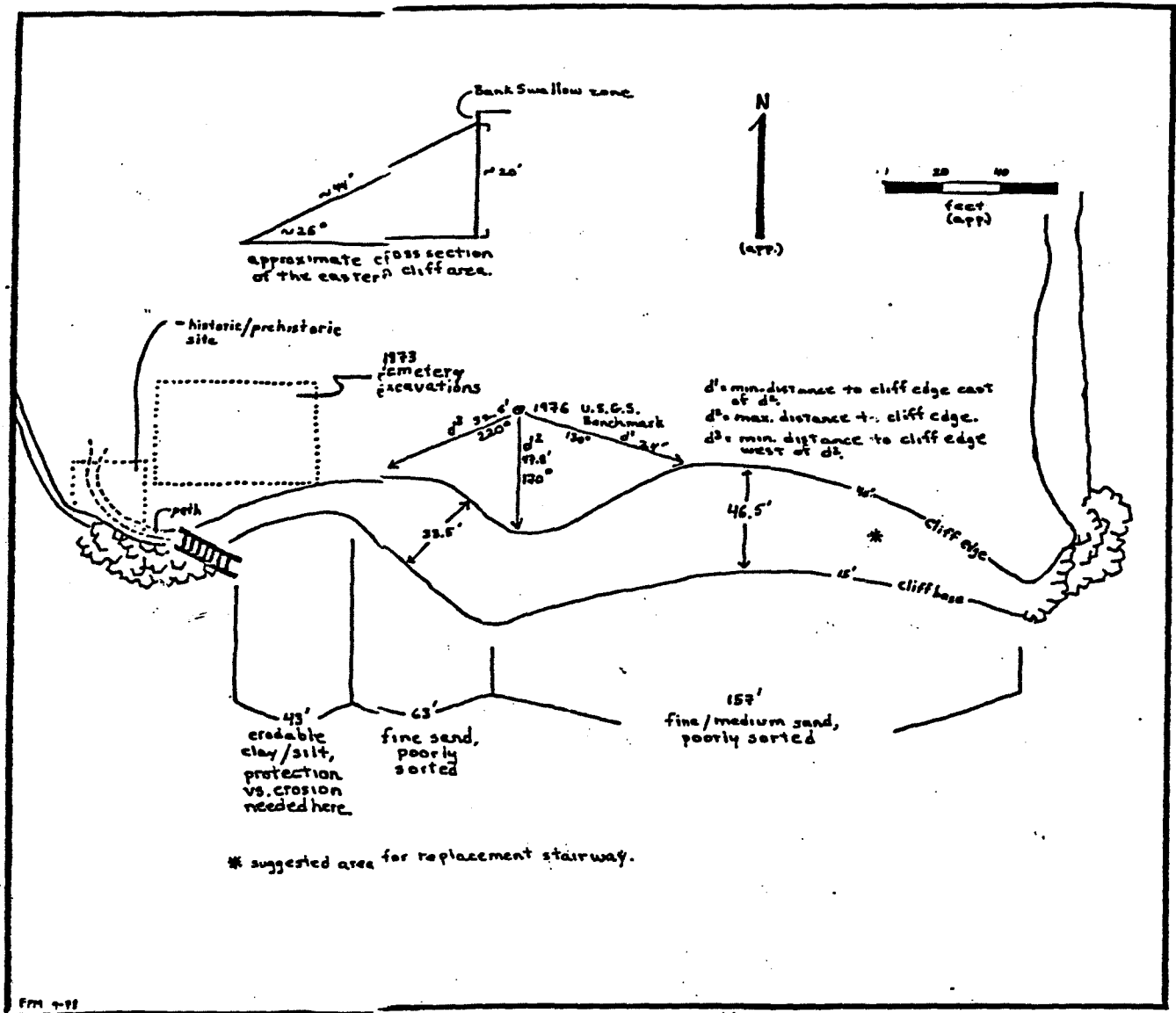


Figure 3. Initial field sketch of south bluff conditions and measurements taken by McManamon and Soukup (1978).