
# Sinuosity and Sand Waves of the Cooper River, SC


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BEAMS

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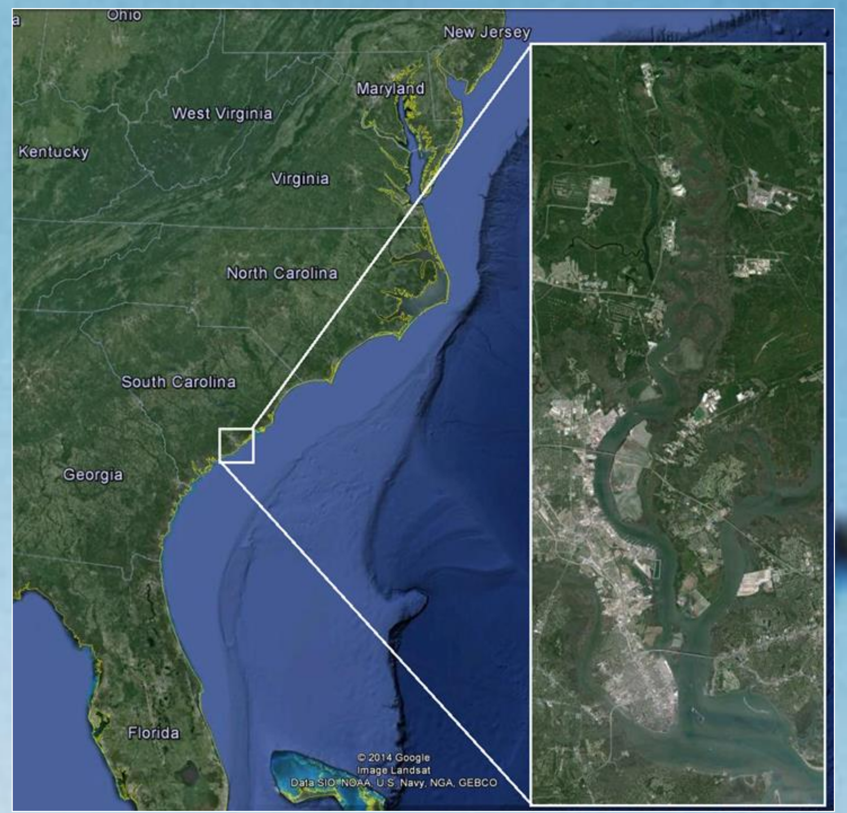


Figure 1: The white box highlights the location of the Cooper River in South Carolina, the focus for this study (Images from Google Earth)

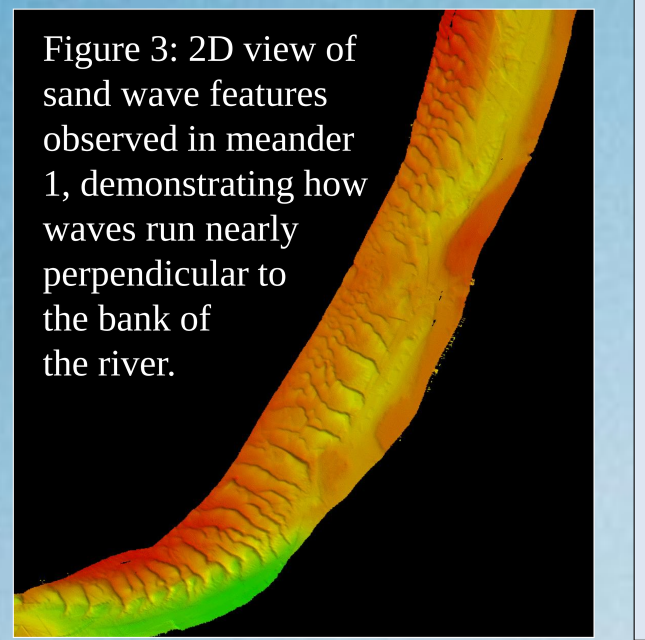


Figure 3: 2D view of sand wave features observed in meander 1, demonstrating how waves run nearly perpendicular to the bank of the river.


## Abstract

In March of 2014, the College of Charleston's BEAMS students collected bathymetric data of the Cooper River, SC to observe the river's sinuosity and its numerous sand wave and scour features that occur throughout its length. This river flows into the Charleston Harbor estuary and is subjected to a semi-diurnal tide with range of 6 to 8 feet, and has areas of significant development along its banks. Of the 20 meanders that were studied in detail, 14 had measurable sand waves. Of these 14 meanders, only the two located closest to the harbor entrance exhibited symmetric sand waves. The majority of sand waves occur farther up the river, and exhibit asymmetrical wave orientation directed downstream. The Cooper River appears to have organized itself into an ordered state versus a chaotic state based on its calculated average value for the sinuosity of its meanders, and from the area known as the "T," it is dominated by a unidirectional flow of water.


## Introduction

Undergraduate students in the College of Charleston's BEAMS Program sailed aboard the R/V *Savannah* of the Skidaway Institute of Oceanography in March 2014, to collect bathymetric data on the Cooper River. The Cooper River (Figure 1) is one of the three rivers, along with the Ashley and Wando Rivers, which flow into the Charleston Harbor Estuary (Levisen and Van Dolah, 1997). This river is described as a meandering river, meaning it is not laterally confided by bordering valley walls (Howard, 2009). A meandering system is characterized by two opposing processes: lateral migration of the river's flow which increases the sinuosity, and the cutoffs which can form ox bow lakes as the river reorganizes the channel's flow (Stølum, 1996). This study will be a focus of the sinuosity of the Cooper River and the sand wave features that occur throughout the length of the area studied.

## Methods

- Cooper River data collected by the R/V *Savannah* using Kongsberg EM2040C
- CARIS HIPS 8.1 used as post processing software
- Utilized Google Earth to measure lengths of river meanders
- Sinuosity values measured using equation: $s= L / l$, where $s$ is the unitless value for sinuosity, $L$ is the actual length of a river meander between 2 points, and $l$ is the shortest distance between those same two points

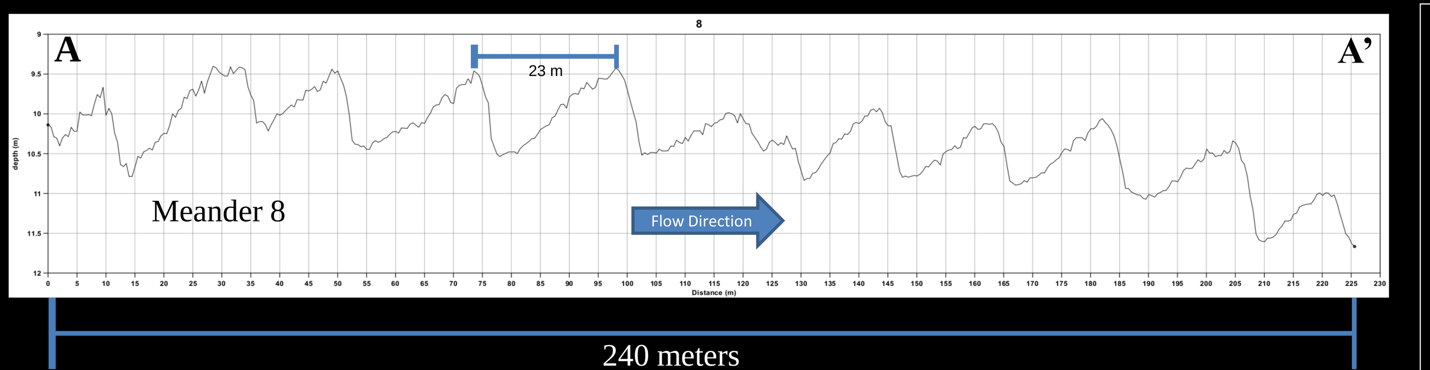



Figure 4a: Profile of Meander 8 displaying asymmetrical sand waves which are typical where water has a unidirectional flow. The line which this figure was made is on Figure 4b

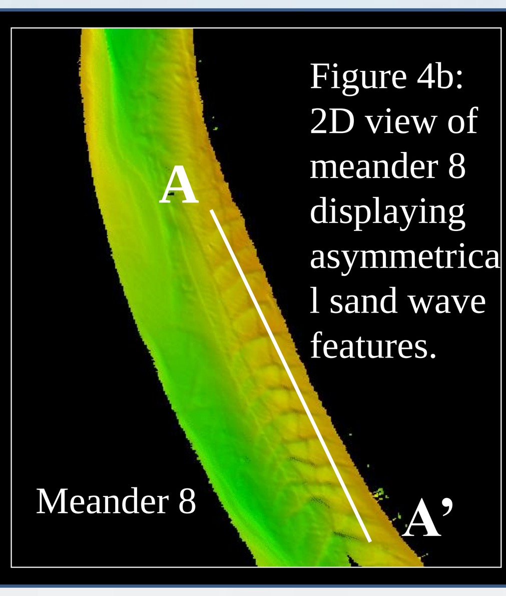



Figure 4b: 2D view of meander 8 displaying asymmetrical sand wave features.

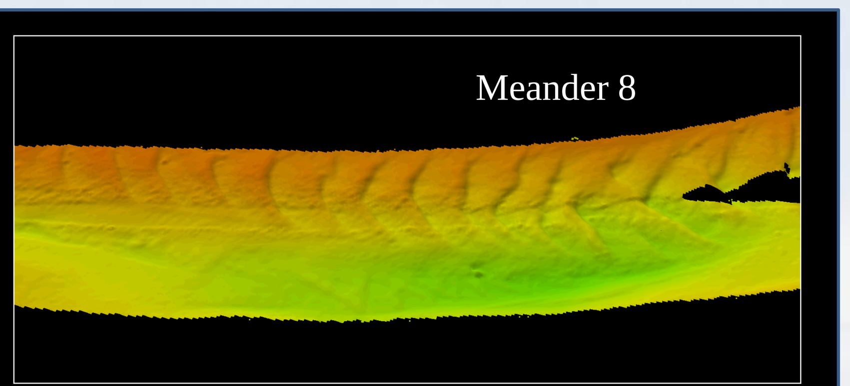



Figure 4c (above): 3D view of sand waves in meander 8, exhibiting asymmetrical patterns indicative of a unidirectional flow. (VE=2x)

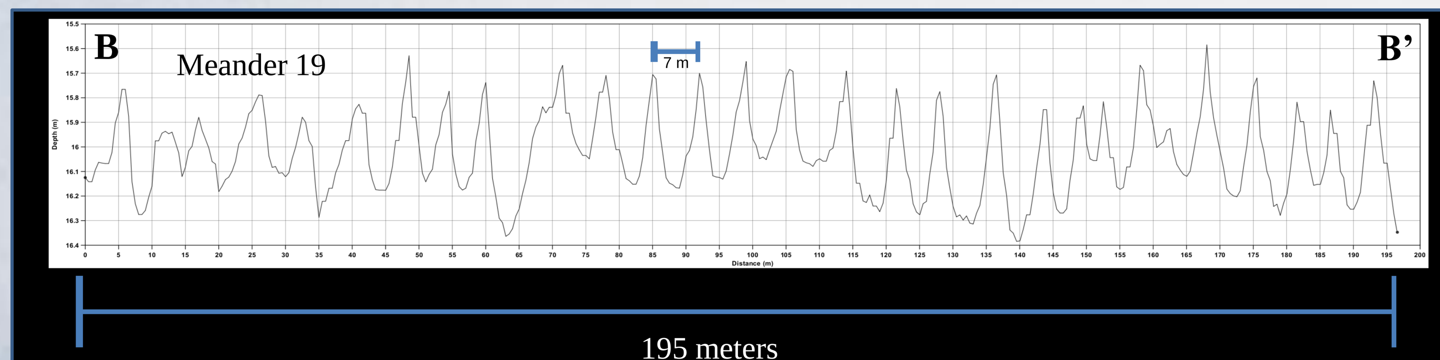



Figure 5a: Profile of Meander 19 displaying symmetrical sand waves which are typical where water is more influenced by tides. This figure was generated by line on figure 5b

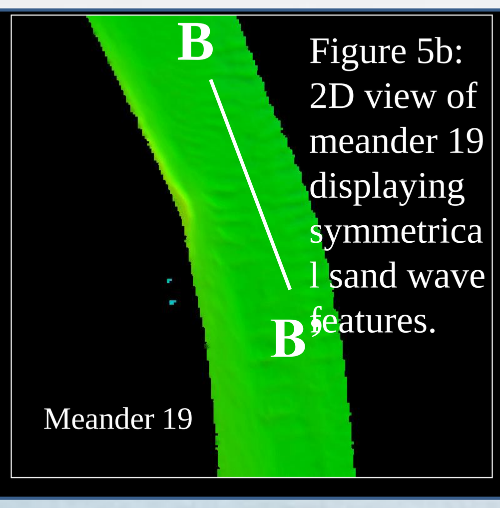



Figure 5b: 2D view of meander 19 displaying symmetrical sand wave features.

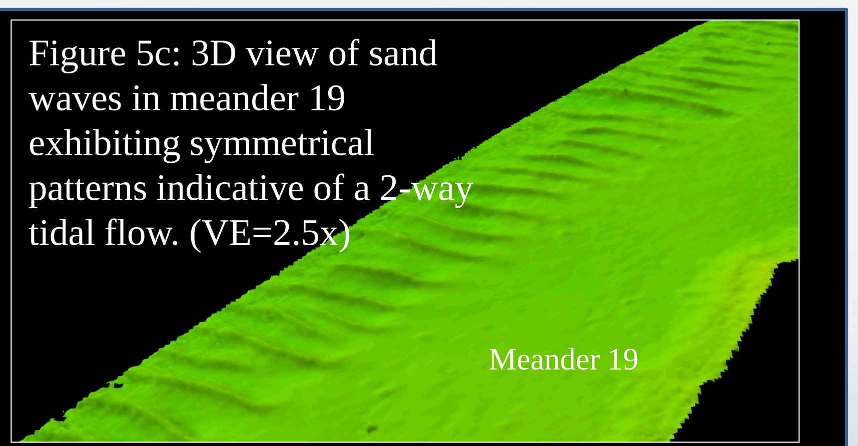
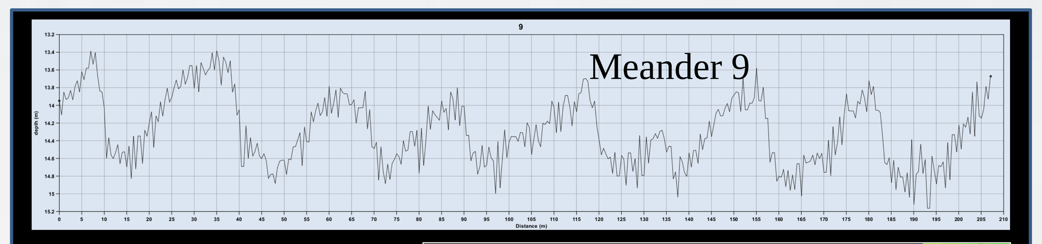



Figure 5c: 3D view of sand waves in meander 19 exhibiting symmetrical patterns indicative of a 2-way tidal flow. (VE=2.5x)



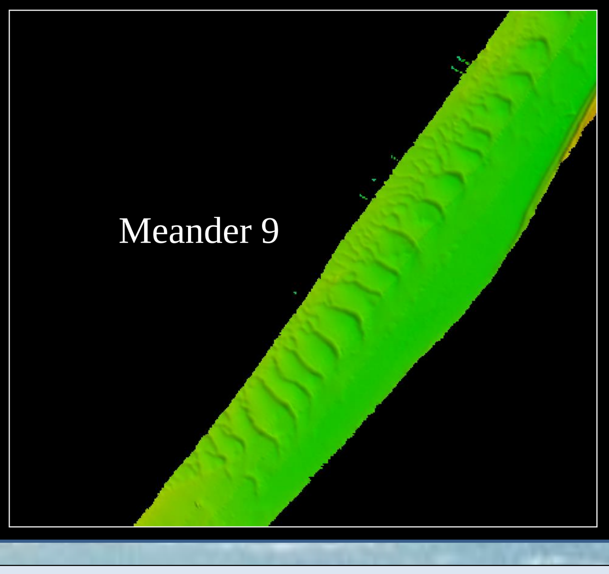




Figure 6: (Above) An asymmetrical profile taken of meander 9 which is also represented in the 2D view (right). There can be variation in the asymmetrical wavelengths but they follow the same general morphology

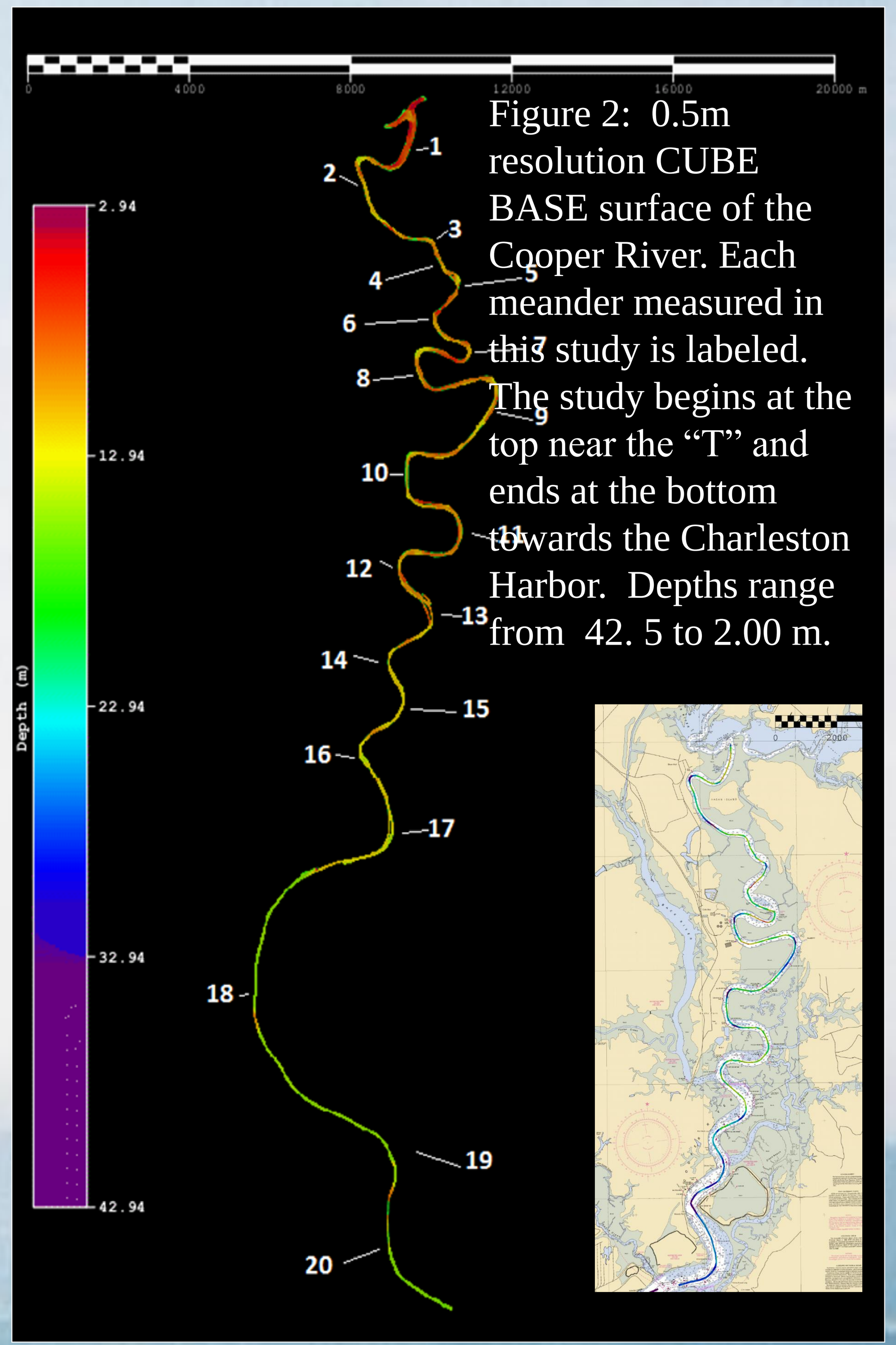



Figure 2: 0.5m resolution CUBE BASE surface of the Cooper River. Each meander measured in this study is labeled. The study begins at the top near the "T" and ends at the bottom towards the Charleston Harbor. Depths range from 42. 5 to 2.00 m.

Table 1: Data representing the 20 meanders that were examined in this study and their quantitative and qualitative features that were calculated and observed. The Meander Number column correlates to those labeled on Figure 2. NA indicates that no sand waves were observed and measured in the meander.

| Meander Number | True Length (m) | Shortest Length (m) | Sinuosity Value | Sandwave symmetry | Average Wavelength |
|---|---|---|---|---|---|
| 1 | 2416.41 | 1731.73 | 1.395 | Asymmetrical | 31.1 |
| 2 | 4586.16 | 2241.70 | 2.046 | Asymmetrical | 30.0 |
| 3 | 2004.32 | 2858.20 | 1.078 | Asymmetrical | 50.4 |
| 4 | 1341.71 | 1225.48 | 1.095 | Asymmetrical | 10.3 |
| 5 | 2020.97 | 1400.28 | 1.443 | Asymmetrical | 20.6 |
| 6 | 2327.07 | 1630.75 | 1.427 | Asymmetrical | 15.2 |
| 7 | 3001.24 | 1203.20 | 2.494 | Asymmetrical | 35.3 |
| 8 | 5573.75 | 1163.35 | 4.791 | Asymmetrical | 25.8 |
| 9 | 5848.71 | 2578.40 | 2.268 | Asymmetrical | 20.4 |
| 10 | 5594.20 | 3325.53 | 1.682 | Asymmetrical | 40.0 |
| 11 | 4209.69 | 2045.43 | 2.058 | Asymmetrical | 19.9 |
| 12 | 3729.26 | 2086.55 | 1.787 | Asymmetrical | 25.1 |
| 13 | 3273.89 | 2338.61 | 1.399 | NA | NA |
| 14 | 2979.83 | 2232.63 | 1.317 | NA | NA |
| 15 | 2939.37 | 2472.26 | 1.189 | NA | NA |
| 16 | 4214.27 | 3213.88 | 1.311 | NA | NA |
| 17 | 6633.20 | 5239.60 | 1.266 | NA | NA |
| 18 | 11777.06 | 7811.77 | 1.508 | Symmetrical | 26.2 |
| 19 | 8607.92 | 7464.69 | 1.153 | Symmetrical | 7.3 |
| 20 | 5290.62 | 4185.65 | 1.264 | NA | NA |

## Results

- Total length of the Cooper River starting from the "T" is approximately 46,799.81 meters while the shortest distance between the same 2 points is 30,960.85 meters.
- The overall sinuosity value for the Cooper River is 15.11.
- The average sinuosity value for all 20 meanders is 1.698 (Table 1).
- Sand waves had an average crest to crest wave length of 25.14 meters.
- 14 of the 20 meanders had measurable sand wave features present.
- All but 3 of the 14 measured sand waves had an asymmetric shape. Symmetric sand waves occur closest to the river's entrance into the Charleston Harbor.
- Sand waves are always nearly perpendicular to the bank of the river (Figure 3).


## Acknowledgments

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## Literature Cited


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Levisen, Martin V., and Robert F. Van Dolah, 1997, Spatial Distribution of Sediments within the Charleston Harbor Estuary Following Drainage Modification: Journal of Coastal Research v. 13.1, p. 141-46.

Stolum, Henrik H, 1996, River Meandering as a Self-Organization Process: *Science* v.271.5256 , p. 1710-713.


## Discussion and Conclusions

When Stølum conducted his experiment performing over 200 simulations of meandering river formation and self organization, he discovered that the average sinuosity value was 3.14. This result is conducive to the idea that the river's planform experiences fractal geometry throughout it (Stølum 1996). The average sinuosity measured throughout the Cooper River's 20 different meanders was 1.698, which is below Stølum' average. This lower number indicates that the self organization processes in the Cooper have reached a more ordered state versus a chaotic state, as the value is closer to 1.000, which would be representative of a straight-flowing river. The ordered state in meandering rivers can indicate that it has reached a more mature state where the bends are quite symmetrical around the axis which would represent the linear flow of the river (Stølum 1996). Comparing the sinuosity values calculated to the sand wave features and their wavelengths, however does not seem to have any correlation as the numbers exhibit large variations with no seemingly obvious pattern.

In this portion of the Cooper River, 11 of the 14 meanders contain sand waves that exhibit asymmetrical wave formation (Figure 4), a result of unidirectional flow. The majority of these types of waves occurred starting from the "T" and continued to show the same orientation with varying wavelengths and heights. Comparison of the asymmetric sand wave profile of meander 8 (Figure 4) to that of the symmetric sand wave of meander 19 (Figure 7), indicates that the meanders with tidally influenced symmetrical sand waves are more peaked. In the two 3-dimensional images of both meanders (Figures 6 and 9), it can be seen that the wave forms still run perpendicular to the banks of the river. Starting at meander 13, sand waves are far less common as the river approaches the Charleston Harbor estuary. The few observed were at meanders 18 and 19, and exhibited symmetrical patterns in their wavelengths. This is reasonable as it is closer to the harbor and thus more likely to be influenced by tidal forces which are responsible for symmetrical geometry.

While there may not be a direct correlation with sinuosity and the wavelengths of sand wave features in the Cooper River based off of this study, conclusions can be drawn based on the data collected (Table 1). The meanders in which sand waves were measured mainly are subjected to a unidirectional flow of water based off the fact that the geometry of the waves were asymmetrical in nature. This type of geometry is more apparent as it is further up the river, and as it approaches the Charleston Harbor there is a change in water flow to affect the deposition of sand wave features, however those which are measurable exhibit a symmetrical, tidal influenced geometry. The Cooper River thus appears to be a mature river in an ordered state of self organization with a primarily unidirectional flow starting from the "T" until it approaches the Charleston Harbor.