

Article



Adopting a Reference Standard Port for Nigeria

Oliver C. Ojinnaka and Ndukwe K. Ndukwe, University of Nigeria (Nigeria)



Abstract

Nigeria has a coastline of about 800km which is covered by only two Standard ports located at Bonny in Nigeria and Takoradi in Ghana. Tidal analyses were carried out to verify the rational in referencing some secondary port in Nigeria to the standard port in Ghana. Result showed that, for all locations in Nigeria, analysis made with reference to Bonny gives either better or similar accuracy when compared with analysis made with reference to Takoradi. It is therefore concluded that, depending on the availability of the needed tidal data, referred to Bonny, the use of Takoradi as the reference port for some locations in Nigeria may not be necessary.



Résumé

Le Nigéria possède une ligne de côte d'environ 800km qui est seulement couverte par deux ports principaux situés à Bonny au Nigéria et Takoradi au Ghana. Des analyses de marée ont été menées pour justifier les relations référentielles de certains ports secondaires au Nigéria par rapport au port principal au Ghana. Les résultats ont montré que, pour l'ensemble des lieux situés au Nigéria, l'analyse conduite en référence à Bonny donne une précision meilleure ou similaire comparée à l'analyse fait en référence à Takoradi. Il est en conséquence conclu que, selon la disponibilité des données de marée nécessaires, l'utilisation de Takoradi comme port de référence pour certains lieux au Nigéria pourrait ne pas être nécessaire.



Resumen

Nigeria tiene una línea de costa de cerca de 800km que esta cubierta por solo dos puertos principales ubicados en Bonny, Nigeria y Takoradi en Ghana. Se llevaron a cabo análisis de la marea para verificar la relación referencial de algunos puertos secundarios en Nigeria respecto del puerto principal en Ghana. Los resultados mostraron que, para todas las localidades en Nigeria, los análisis hecho con referencia a Bonny entregan ya sea una mejor o similar precisión cuando se comparan con los análisis hechos con referencia a Takoradi. Por lo tanto se concluye en que, dependiendo de la disponibilidad de los necesarios datos de marea, referidos a Bonny, el uso de Takoradi como puerto de referencia puede no ser necesario para ciertas localidades en Nigeria.

The Admiralty Tide Tables (ATT) volume II on the Atlantic and Indian Oceans publishes information on tide and tidal stream for the coastal nations bounded by these oceans. Some of the information published includes the locations of the standard and secondary ports, high and low water times and heights at the standard ports, time and height differences of tides between the standard and secondary ports, etc. The records also contain the dates of establishment of the standard port, when data is available. An overview of the standard ports and extent of the secondary ports covered by each standard port is shown in figure 1 for the African Coastline.

data obtained within this zone.

The use of standard ports as references for tidal operation in other locations is a frequent requirement in tides and tidal stream studies. Under the existing condition in Nigeria, it follows that for all operations between Lagos and Forcados, observations and data reduction should be referenced to the standard port in Takoradi. A situation where survey operation is executed in one country (Nigeria) and reference data is needed from another country (Ghana) may create some logistic problems especially in absence of full international cooperation.

Objective and Scope of Work

The paper tends to address the following problems:

1. To verify which of the reference standard ports, that is Bonny or Takoradi, that should be used for locations lying between Akassa and Forcados in Nigeria.
2. To verify whether it is possible to refer all the tidal studies in Nigeria to one Standard port which should preferably be located in Nigeria. If this is feasible, then the issue of using Takoradi as the reference standard port for any work in Nigeria may no longer be necessary.
3. On the interim, while the search for the location of the appropriate standard port is on, is it feasible to use Bonny as the reference for all stations in Nigeria without introducing serious errors in obtained results?

A positive result to the second objective will certainly obviate the need to address the first question. Similarly, a positive result to the third objective will

be a welcome relief, for a fairly long period of time, to all those involved in hydrographic operations in Nigeria pending the establishment of more standard ports in the nation.

Standard Port for Nigeria

Standard ports are locations where tidal analysis have been made from tide observations lasting for

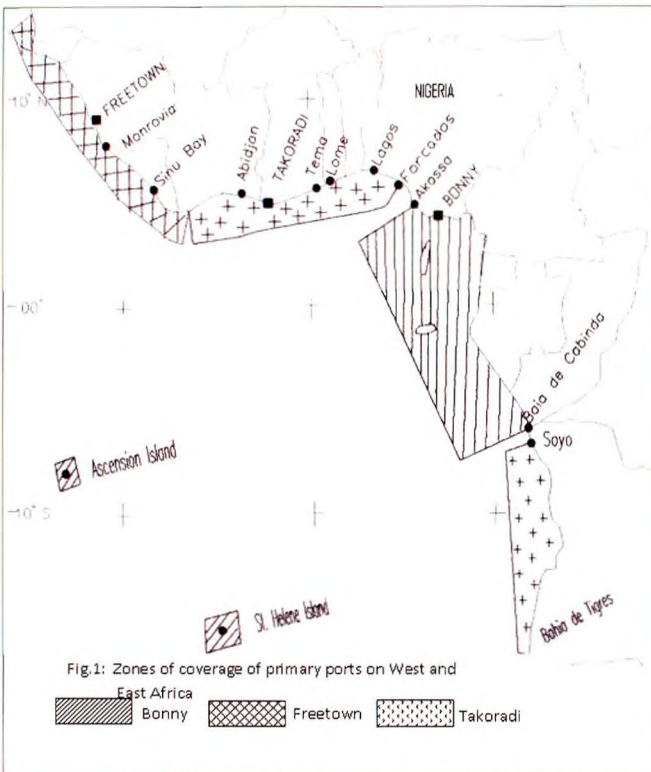


Figure 1: The Nigerian Coastline.

From figure 1, it can be observed that the Nigerian coastline is covered by two primary ports namely Takoradi and Bonny. The secondary ports covered by Takoradi extend from Lagos to Forcados while those covered by Bonny extend westwards to Akassa and eastwards to the Nigeria/Cameroun border. Since no information is given for the area between Akassa and Forcados, an uncertainty exists as to which of the two standard ports (Takoradi or Bonny) should be used as reference for reduction of hydrographic

at least one year, while secondary ports are locations where analysis have been made from observations lasting for a relatively short duration, usually between seven days and one month. Tidal analyses at standard ports are made by direct application of astronomic theory. In the ideal situation, tidal analysis should be carried out from observation made over a period of 18.61 years (approximately 19 years) which is the period of the moon's node. The number of tidal constituents which can be separated from tidal analysis depends on the duration of the observations. For observations lasting up to one year, 100 constituents can be separated while more than 300 constituents can be separated in observations lasting up to 19 years.

In the case of secondary ports, in which short-period analysis is made, the only constituents that can be reliably separated are the four principal constituents (usually M2 , S2, K1, O1). The constituent N2 is however sometimes included by some scholars. Observations made for short-period analysis do not actually provide enough data for complete separation of the above constituents, they are therefore separated by making reference to available standard ports. For this purpose, the theory of regional relationship is employed. The theory states that 'over a considerable stretch of any coastline, the ratios H_{o1}/H_{k1} and H_{s2}/H_{M2} and the differences $g_{o1}-g_{k1}$ and $g_{s2}-g_{M2}$ are approximately constant [6].

This does not however hold true near amphidromic points since at such points, each constituent has its own amphidromic distribution and the relationship between the various constituents will vary greatly near such locations [3].

Evaluation of Tidal Characteristics

The tidal constants for the above four major constituent (M2 , S2, K1, O1) are published for several locations in the ATT. The published values were used in this research to compute the mean spring range

for the tidal stations on the West African coastline. Figure 2 shows the curve of mean spring range for the locations between Free Town and the ports lying the extreme east of Nigeria. Note that the plot is not according to any scale but is simply intended to depict the variation of tidal range from East to West of this coastline. From the plot, it can be observed that the tide range decreases from the east in Nigeria westwards to minimum at Lagos and increases from there westwards towards Takoradi and FreeTown. Consequently, Bonny and Takoradi apparently lie on opposite sides of an amphidromic point. It also shows that Bonny and all the other locations in Nigeria lie on the same side of this amphidromic point. The effect of this, if any, for the Nigerian tidal stations which are referred to Takoradi is yet to be determined.

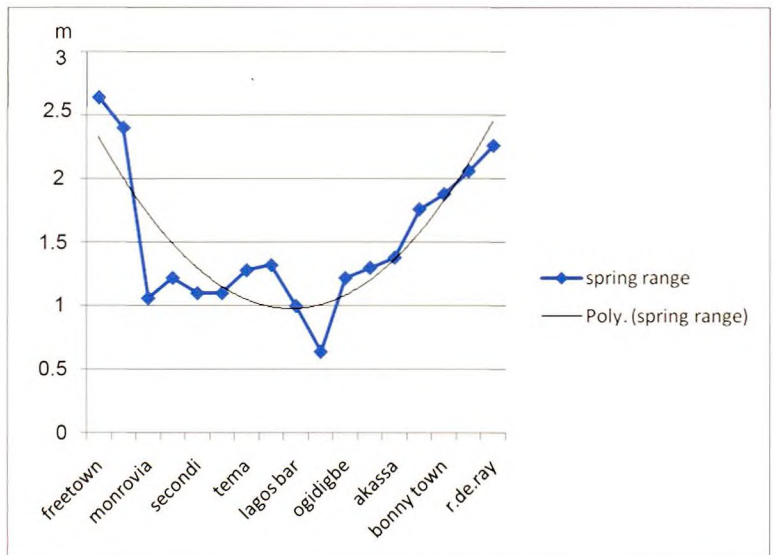


Figure 2: Spring range values on West-African coastline.

Historical Review of Standard Ports in West Africa

The colonial masters landed first on the shores of the then Gold Coast (Ghana) and, encouraged by the abundance of gold, settled and used it as base for further activities in West Africa. From here, they moved eastwards up to Forcados and continued their journey across the Bight of Biafra to East Africa where a more conducive climate encouraged them to settle. Therefore, as early as 1927, a tidal station has been established at Takoradi in Ghana. Water level observations were made at this location for a

period of two years and subsequently used for analysis. Consequently, all the secondary ports located along the coast of West Africa and part of East Africa were referenced to Takoradi [8]. This extended to Forcados on the west part of the Niger Delta in Nigeria and Bahai-de-Tigres in Angola. It was in the wake of oil prospecting in the old Eastern Nigeria, and the discovery of oil at Oloibiri in 1957 that the town of Bonny gained importance. A tide station was established at Bonny by Shell/ B.P and tide analysis was subsequently made from one-year tidal observation at this station. Bonny town has since then served as the only internationally recognised standard port in Nigeria. All subsequent tide observations east of the Niger delta and up to Bahai-de-Cabinda in Angola were therefore referred to Bonny. Further tide observations and analysis at Bonny however continued for decades with few interruptions. In the absence of a concerted effort by Nigeria to establish more standard ports, it does appear that Bonny will continue to serve as the only available standard port in the nation.

It therefore apparently implies that the distribution of standard ports and their secondary ports on the African coastline is based more on operational convenience than on any scientific considerations. This further explains why there are no defined geographical boundaries between the secondary ports covered by Bonny and those covered by Takoradi.

Choice of Standard Port for Nigeria

The above discussions clearly show the need to adopt a reference standard port that can serve all the secondary ports in Nigeria, or, in the alternative, establish more standard ports in Nigeria for a more effective tidal study in the country. Since the later option is a policy issue and is likely to be a long-term programme, an immediate approach is to adopt the first option.

We therefore need to verify the following:

- Since Forcados and Akassa form the limits of the secondary ports referred to Takoradi and Bonny respectively, it is necessary to verify which of the standard ports should be used as reference for hydrographic operations between Forcados and Akassa.
- The suitability of adopting Bonny as the reference standard port for all locations in Nigeria. This will

have an advantage by virtue of its location within the country.

To achieve this, the following investigations were carried out:

1. Short-period analysis for Lagos wharf, which is the tidal station in the extreme west of Nigeria, using Takoradi as a reference standard port and then Bonny as a reference standard port. The short-period analysis was chosen since this is the only condition for which reference is made to standard ports in the computation of tidal constants.
2. Repeat (i) above for Forcados, which is the extreme east location in Nigeria referenced to Takoradi. No analysis was made for Akassa due to unavailability of data. This does not however create any problem as Akassa is already referred to Bonny in Nigeria.
3. Each of the two sets of tidal constants (g and H) (i.e those with reference to Bonny and those with reference to Takoradi) is then used to predict tides for Lagos and Forcados.
4. The differences between the observed hourly water levels and the levels predicted with the two sets of constants were then computed separately.
5. The mean levels and root mean square were computed from iii and iv respectively. These values were employed to verify which set of the predictions gave a better representation of the observed data. The result from the above investigations will help to determine whether Bonny or Takoradi is more reliable as a reference standard port for the locations considered.

For the purpose of the above investigations, an in-house computer program was developed as none was locally available and available foreign software were relatively expensive. The least squares method was adopted in solving the equation for the harmonic analysis and the computer program was designed to incorporate the theory of Regional Relationship. The result from the program was first tested with real data and found reliable before being employed for further investigations.

Tidal Analysis and Predictions for Forcados Terminal and Lagos wharf

Among the Nigerian secondary ports referred to Ta-

koradi, Lagos is located in the extreme west while Forcados is located in the extreme east. Fortunately, observed tidal data are available for these locations. Observations available for this study dates back to 1980 and 1990 for Lagos and Forcados respectively. This does not however create any problem since we are interested in a comparative study which simply requires that data should be used for the same epoch.

The tide analysis and prediction program was utilized for the following operations:

1. Short period analysis for Forcados terminal and Lagos-Apapa using Bonny as reference standard port.
2. Repeat the above analysis using Takoradi as reference standard port.

The results of the above operations are discussed below.

Tidal Analysis and Prediction for Forcados Terminal

Available tide observations for January 1st to 15th 1990 were used to carry out short period analysis for Forcados with reference to Bonny and Takoradi separately. Table 1 shows the results of the analyses while table 2 shows the

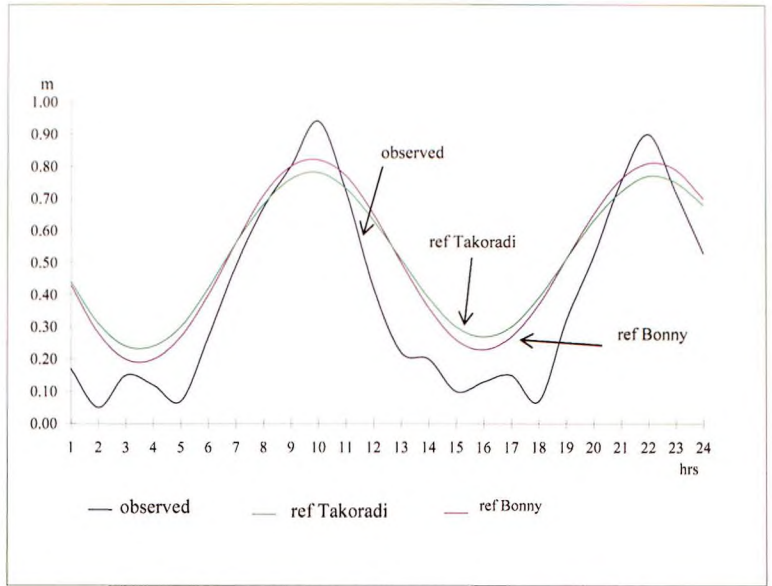


Figure 3: Observed and predicted tides for Forcados with ref. to Bonny.

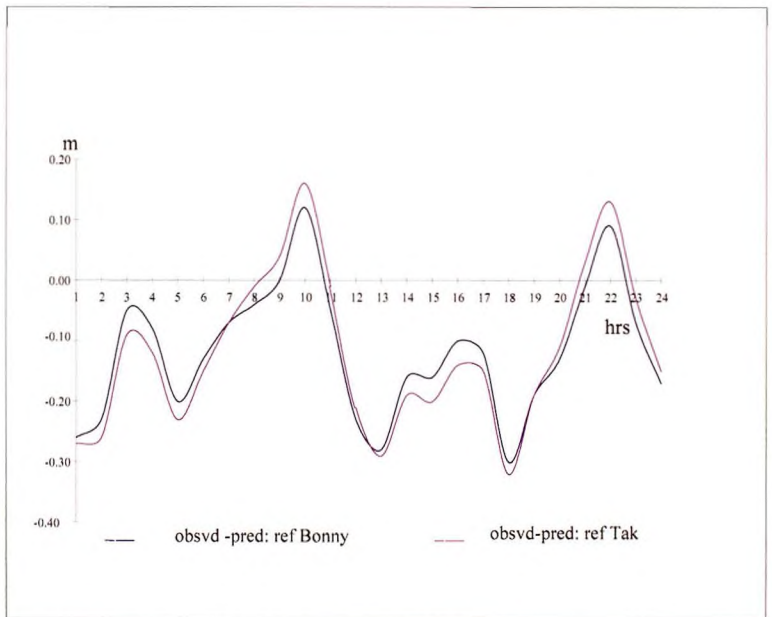


Figure 4: Observed -predicted values for Forcados ref. to Bonny.

| Stn | ref | M_2 | | S_2 | | K_1 | | O_1 | | z m | Period |
|----------|-----|-----------|------|-----------|------|-----------|------|-----------|------|------|---------|
| | | g° | H m | g° | H m | g° | H m | g° | H m | | |
| Forcados | Bon | 142 | 0.37 | 179 | 0.12 | 290 | 0.01 | 253 | 0.00 | 0.45 | 15 days |
| | Tak | 144 | 0.35 | 171 | 0.13 | 290 | 0.01 | 257 | 0.00 | 0.45 | |

Table 1: Computed Tidal Constants for Forcados Terminal.

Table 2

I_o = observed water levels
 P_B = predicted with constants obtained by ref. to Bonny
 P_T = predicted with constants obtained by reference to Takoradi
 $D_{IB} = I_o - P_B$, $D_{IT} = I_o - P_T$, date = 10/1/80

| time hrs | obsvd I_o (m) | predicted (m) | | differences (m) | |
|-------------|--------------------|---------------|-------|-----------------|----------|
| | | P_B | P_T | D_{IB} | D_{IT} |
| 0 | 0.17 | 0.43 | 0.44 | -0.26 | -0.27 |
| 1 | 0.05 | 0.28 | 0.31 | -0.23 | -0.26 |
| 2 | 0.15 | 0.20 | 0.24 | -0.05 | -0.09 |
| 3 | 0.12 | 0.20 | 0.24 | -0.08 | -0.12 |
| 4 | 0.07 | 0.27 | 0.30 | -0.20 | -0.23 |
| 5 | 0.27 | 0.40 | 0.42 | -0.13 | -0.15 |
| 6 | 0.49 | 0.56 | 0.56 | -0.07 | -0.07 |
| 7 | 0.67 | 0.71 | 0.68 | -0.04 | -0.01 |
| 8 | 0.80 | 0.80 | 0.76 | 0.00 | 0.04 |
| 9 | 0.94 | 0.82 | 0.78 | 0.12 | 0.16 |
| 10 | 0.72 | 0.77 | 0.73 | -0.05 | -0.01 |
| 11 | 0.42 | 0.65 | 0.63 | -0.23 | -0.21 |
| 12 | 0.22 | 0.50 | 0.51 | -0.28 | -0.29 |
| 13 | 0.20 | 0.36 | 0.39 | -0.16 | -0.19 |
| 14 | 0.10 | 0.26 | 0.30 | -0.16 | -0.20 |
| 15 | 0.13 | 0.23 | 0.27 | -0.10 | -0.14 |
| 16 | 0.15 | 0.27 | 0.30 | -0.12 | -0.15 |
| 17 | 0.07 | 0.37 | 0.39 | -0.30 | -0.32 |
| 18 | 0.32 | 0.51 | 0.51 | -0.19 | -0.19 |
| 19 | 0.52 | 0.65 | 0.63 | -0.13 | -0.11 |
| 20 | 0.75 | 0.76 | 0.72 | -0.01 | 0.03 |
| 21 | 0.90 | 0.81 | 0.77 | 0.09 | 0.13 |
| 22 | 0.72 | 0.79 | 0.75 | -0.07 | -0.03 |
| 23 | 0.53 | 0.70 | 0.68 | -0.17 | -0.15 |
| mean | 0.40 | 0.51 | 0.51 | -0.12 | -0.12 |
| Std dev | | | | 0.11 | 0.13 |

Table 2: Observed and predicted tides for Forcados Terminal.

observed and predicted values for a chosen date.

Table 1 shows that the tidal constants obtained, for Forcados Terminal, by reference to Bonny and Takoradi are almost equal. In table 2, the mean value of differences (DIB) between observed and predicted water levels for Bonny is the same as the mean value of the differences (DIT) obtained for Takoradi. This apparently suggests that the same result is obtained by using either Bonny or Takoradi as reference port for Forcados. However the marginal lower

value of standard deviation for Bonny shows that this station stands out as the logical choice when there is option to chose between the two.

Figures 3 and 4 show the plots of the observations and their differences respectively. Figure 4 gives a clearer picture of the errors from both locations. It is observed that the Bonny-related errors are almost always smaller than those of Takoradi. This apparently confirms that, under ideal situations, Bonny should be preferred to Takoradi

| Stn | ref | M_2 | | S_2 | | K_1 | | O_1 | | z m | Period |
|-------------|-----|-------|------|-------|------|-------|------|-------|------|------|---------|
| | | g° | H m | g° | H m | g° | H m | g° | H m | | |
| Apapa-Lagos | Bon | 134 | 0.34 | 171 | 0.11 | 15 | 0.06 | 338 | 0.01 | 0.95 | 15 days |
| | Tak | 136 | 0.36 | 163 | 0.12 | 15 | 0.06 | 342 | 0.01 | 0.95 | |

Table 3. Computed Tidal Constants for Apapa-Lagos.

as the standard reference port for tidal work at Forcados.

Tidal Analysis and Prediction for Apapa-Lagos referred to Bonny and Takordi

Similar analysis and prediction carried out for Forcados were repeated for Apapa-Lagos. Observed water level was available for November 1st to 30th 1989. Table 3 shows the result of the analysis while table 4 shows the predictions for a chosen date. Figures 5 shows the plots of the observed and predicted tidal curves while figure 6 shows the differences between predicted and observed for the two sets of tidal constants. In table 4, the mean difference of 0.05m is equal for both sets of tidal constants. Figure 6 actually shows that the differences in the errors from the two sets of constants are random and appear equal. This is further confirmed by the equal values of standard deviation which is 0.08m for the two sets of tidal constants. This apparently suggests that Bonny can be used as the reference standard port for Apapa-Lagos, in place of Takoradi, without introducing any relative error.

From the above discussions, it follows that, pending

the establishment of more standard ports in Nigeria, the Bonny standard port can be employed as the reference port for all tidal work in Nigeria.

Conclusion

The secondary ports on the Nigerian Coastline are referred to the standard ports at Bonny and Takoradi. Earlier publications of the Admiralty Tide Tables (ATT) show that the secondary ports between Lagos and Forcados are referred to Takoradi and until that date there has been no published report to the contrary. It is also observed that the division of the Nigerian secondary ports between two standard ports is based more on operational convenience than on any mathematical consideration. Consequently, there are no defined geographic boundaries between the two groups of secondary ports. It has however been shown in this study that, pending the establishment of more standard ports in Nigeria, the standard port located at Bonny can be employed, for all practical purposes, as the reference port for all tidal work along the Nigerian coastline. It is therefore suggested that efforts should be made to determine the time and height differences between these secondary ports and the Bonny standard port, with the ulti-

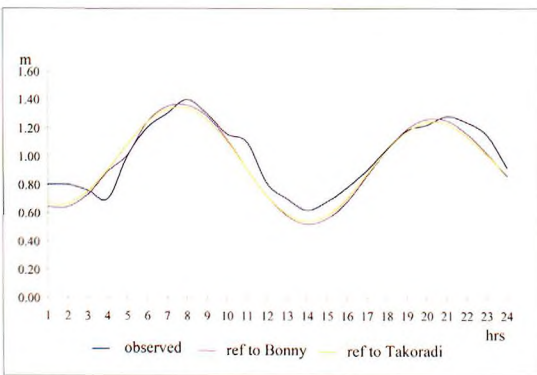


Figure 5: Observed and predicted tide for Lagos ref to Bonny and Takoradi.

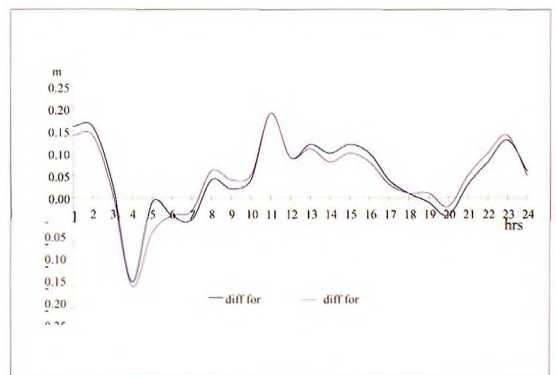


Figure 6: Observed -predicted for Lagos ref. to Bonny and Takoradi.

Table 4

I_o = observed water levels
 P_B = predicted with constants obtained by ref. to Bonny
 P_T = predicted with constants obtained by reference to Takoradi
 $D_{IB} = I_o - P_B$, $D = I_o - P_T$, date = 10/1/80

| time | obsvd | predicted (m) | | differences (m) | |
|---------|-----------|---------------|-------|-----------------|----------|
| hrs | I_o (m) | P_B | P_T | D_{IB} | D_{IT} |
| 0 | 0.80 | 0.64 | 0.66 | 0.16 | 0.14 |
| 1 | 0.80 | 0.64 | 0.66 | 0.16 | 0.14 |
| 2 | 0.76 | 0.73 | 0.75 | 0.03 | 0.01 |
| 3 | 0.70 | 0.89 | 0.90 | -0.19 | -0.20 |
| 4 | 1.00 | 1.01 | 1.08 | -0.01 | -0.08 |
| 5 | 1.20 | 1.24 | 1.24 | -0.04 | -0.04 |
| 6 | 1.30 | 1.35 | 1.33 | -0.05 | -0.03 |
| 7 | 1.40 | 1.36 | 1.34 | 0.04 | 0.06 |
| 8 | 1.30 | 1.28 | 1.26 | 0.02 | 0.04 |
| 9 | 1.16 | 1.12 | 1.11 | 0.04 | 0.05 |
| 10 | 1.10 | 0.91 | 0.91 | 0.19 | 0.10 |
| 11 | 0.81 | 0.72 | 0.72 | 0.09 | 0.09 |
| 12 | 0.70 | 0.58 | 0.59 | 0.12 | 0.11 |
| 13 | 0.62 | 0.52 | 0.54 | 0.10 | 0.08 |
| 14 | 0.68 | 0.56 | 0.58 | 0.12 | 0.10 |
| 15 | 0.78 | 0.68 | 0.70 | 0.10 | 0.08 |
| 16 | 0.90 | 0.86 | 0.87 | 0.04 | 0.03 |
| 17 | 1.05 | 1.04 | 1.04 | 0.01 | 0.01 |
| 18 | 1.18 | 1.19 | 1.17 | -0.01 | 0.01 |
| 19 | 1.22 | 1.26 | 1.24 | -0.04 | -0.02 |
| 20 | 1.28 | 1.25 | 1.23 | 0.03 | 0.05 |
| 21 | 1.24 | 1.16 | 1.14 | 0.08 | 0.10 |
| 22 | 1.15 | 1.02 | 1.01 | 0.13 | 0.14 |
| 23 | 0.92 | 0.86 | 0.87 | 0.06 | 0.05 |
| mean | 1.00 | 0.95 | 0.96 | 0.05 | 0.05 |
| Std dev | | | | 0.08 | 0.08 |

Table 4: Observed and predicted tides for Apapa-Lagos.

mate goal of finally adopting Bonny as the reference port for all tidal stations in Nigeria.

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About the Authors

Dr. O. C. Ojinnaka is a lecturer in hydrographic surveying at the University of Nigeria. He served as consultant on tides to the Nigerian Hydrographer of Navy

from 2000 to 2005 and has developed a number of software on tidal analysis. He has served as consultant in hydrographic surveying to companies and also as an examiner in Hydrographic Surveying for the Surveyors Council of Nigeria (SURCON). He is the author of *Principles of Hydrographic Surveying-From Sextant to Satellite*.

E-mail: oliverojinnaka@yahoo.co.uk

Prof. N.K. Ndukwe obtained his Ph.D in Photogrammetry and Remote Sensing in 1980 and is currently a lecturer at the Department of Geoinformatics and Surveying, University of Nigeria. He is the Dean of the Faculty of Environmental Studies and has researched and published widely in Geodesy, Engineering Surveying, Photogrammetry and Remote Sensing. He has to his credit several journal articles and mainline textbooks including *"Principles of Environmental Remote Sensing and Photo Interpretation"* and *"Digital Technology in Surveying and Mapping"*. He has also served as a consultant to UNDP on land degradation studies.