IDF curves in the parts of United States and obtained these curves at ungauged sites using the newly developed rainfall frequency analysis techniques.

Projections from climate models suggest that the probability of occurrence of intense rainfall in future will increase due to the increase in green-house gas emission (Chow, 1988). Although, researches related to the analysis of extreme precipitation indices have projected an increase in the annual total precipitation during the second half of the past century; the number of days with precipitation is also expected to increase, with no consistent pattern for extreme wet events (David, 1961). Such changes in extreme events according to (Kothyari, 1992), can have enormous ecological, societal and economic impacts in the form of floods, droughts, heat waves, summer and ice storms, which may have great implications for municipalities: a small shift in the climate normals can have large consequences on the existing infrastructure; climate change will affect any municipalities (big or small, rural or urban) by damaging existing municipal infrastructure (bridges/roads), natural systems (watersheds, wetlands and forests) and human system (health and education).

The design standards at present are based on the historic climate information and required level of protection from natural phenomena as well as climatic change scenario. Under a changing climate, it has become a priority for municipalities to search for appropriate procedures, planning and management to deal with and adapt to changing climatic conditions. Present study aims to provide an insight into the future changes in the intensity of extreme rainfall events associated with model and scenario uncertainties and suggest methods for quantifying these uncertainties (Solaiman and Simonovic, 2011). The result is presented in the form of probability based intensity duration- frequency (IDF) curves appropriate for the future climatic conditions. Okonkwo and Mbajiorgu (2010) developed IDF curves for south eastern Nigeria using two methods, graphical and statistical and the results were compared. IDF data developed from the graphical and statistical methods were very close for the lower return periods of 2 to 10 years, but differ for higher return periods of 50 to 100 years. However, the difference was not significant at 5% level. Much work has been done by Eman, (2011) using ARCGIS to construct IDF curves, Isopluvial maps and proposed regional IDF formula parameters for Sinai Peninsula in the north eastern part of Egypt. In this study, rainfall intensity for various return period and rainfall duration of some gauged sites are estimated, using ArcView GIS model, in order to generate a regional rainfall intensity map an make related prediction for ungauged catchments located in the eastern part of Nigeria.

## Materials and Methods

The Maximum Annual Precipitation series is obtained at each station for different durations and fitted to one of the statistical distributions; General Extreme value (GEV). The distribution selected based on fitting comparison criteria of RRI map. Then, this distribution is used to find 24 hr intensity-duration-frequency values at 2, 5, 10, 25, 50 and 100 years.

These 24-hr IDF values are spatially interpolated using ArcView GIS model to obtain RRI maps for all durations and return periods and hence the ploting of IDF curves of selected catchments in Eastern Nigeria.

Accordingly the IDF curves are constructed for ungauged sites to estimate rainfall intensity for various return periods and rainfall durations. The regionalization of the parameters of

rainfall intensity-duration-frequency equations was generated for ungauged using gauged stations to estimate rainfall intensity for various return period and rainfall duration.

## Data collection and analysis

The hydrological data available for Imo State was obtained from the Anambra-Imo River Basin Development Authority (AIRBDA), a Federal Government Agency that collects and keeps rainfall and runoff data in the south-eastern part of Nigeria for hydrological analysis and other uses. The available rainfall record is from 1976 – 2001. In addition, rainfall data from the neighbouring States of Cross River, Anambra and Edo States, collected from the Calabar Airport Rainfall Station, Onitsha Meteorological Station and Benin city Station respectively, were obtained. To account for the extreme climatic variability in the future due to climate change, 20% increase in rainfall was assumed to occur using the historical dataset of 26 years as the base period. The daily maximum annual rainfall was selected i.e extreme values for excedence probability followed by analysis of the data as shown in Tables 1-2 from which Figures 1-8 were drawn.

The intensity generating sheet is prepared using the following formulae:

$$\text{Rainfall Intensity, } I = \frac{\text{Daily Rainfall (mm)}}{24\ (\text{hrs})} \quad (\text{mm/hr}) \qquad (1)$$

$$\text{Mean, } \bar{X} = \frac{\sum(I)}{n} \qquad (2)$$

where I = Rainfall intensity

n = number of occurrence

$$\text{Standard deviation, } S.D = \sqrt{\frac{\sum(\bar{X} - I)^2}{n-1}} \qquad (3)$$

$$\text{Skewness} = \frac{\sum(X_i - \bar{X})^3}{(n-1)(S.D)^3} \qquad (4)$$

$$\text{Alpha, } \alpha = \frac{4}{(\text{Skewness})^2} \qquad (5)$$

$$\text{Beta, } \beta = \frac{S.D}{\sqrt{\alpha}} \qquad (6)$$

$$\text{Gamma, } \gamma = \bar{X} - \alpha\beta \qquad (7)$$

$$\text{Excedence probability, } P = 1 - \text{Gammadist}\,[(I - \gamma), \alpha, \beta, \text{True}] \qquad (8)$$

Return period is genarated by the formula,

$$\text{Return period, } T = \frac{1}{P} \qquad (9)$$

Table 1: Analysis Sheet

| Month | Mean | Max. | Min. | Mean+(Standard Deviation) | Mean-(Standard Deviation) | Mean+3Std | Mean-3Std |
|---|---|---|---|---|---|---|---|
| Jan | 24.98 | 105.3 | 0 | 60.23155614 | -10.27155614 | 130.7346684 | -80.77466843 |
| Feb | 34.51 | 212 | 0 | 85.47538454 | -16.45538454 | 187.4061536 | -118.3861536 |
| Mar | 100.335 | 259.7 | 0 | 159.8593716 | 40.81062839 | 278.9081148 | -78.23811484 |
| Apr | 148.515 | 225.6 | 0 | 216.1852242 | 80.84477585 | 351.5256725 | -54.49567246 |
| May | 255.3245 | 361.5 | 89.39 | 327.2154247 | 183.4335753 | 470.9972742 | 39.65172583 |
| Jun | 339.715 | 498.3 | 185.9 | 435.6192136 | 243.8107864 | 627.4276408 | 52.00235923 |
| Jul | 366.318 | 650.1 | 222 | 478.0232688 | 254.6127312 | 701.4338064 | 31.20219357 |
| Aug | 340.6675 | 641 | 151.95 | 470.5635822 | 210.7714178 | 730.3557467 | -49.02074668 |
| Sep | 364.283 | 622.2 | 142.9 | 511.7889235 | 216.7770765 | 806.8007706 | -78.23477057 |
| Oct | 223.623 | 399.4 | 0 | 345.4398861 | 101.8061139 | 589.0736583 | -141.8276583 |
| Nov | 59.535 | 167.8 | 19.9 | 99.74008314 | 19.32991686 | 180.1502494 | -61.08024943 |
| Dec | 12.245 | 52.4 | 0 | 28.65098334 | -4.160983344 | 61.46295003 | -36.97295003 |

Table 2: Analysis Sheet

| Month | Mean | Max. | Min. | Mean+(Standard Deviation) | Mean-(Standard Deviation) | Mean+3Std | Mean-3Std |
|---|---|---|---|---|---|---|---|
| Jan | 22.24263158 | 68.6 | 0 | 45.38965871 | -0.90439555 | 91.68371297 | -47.19844981 |
| Feb | 50.19842105 | 176.7 | 0 | 104.0762452 | -3.679403108 | 211.8318935 | -111.4350514 |
| Mar | 139.9105263 | 291 | 4.6 | 215.9183687 | 63.90268392 | 367.9340535 | -88.11300086 |
| Apr | 192.3194737 | 300.3 | 9.97 | 268.3312753 | 116.3076721 | 420.3548785 | -35.71593113 |
| May | 264.5626316 | 442.4 | 8.79 | 354.9402036 | 174.1850595 | 535.6953478 | -6.570084603 |
| Jun | 371.4642105 | 619.9 | 15.72 | 537.0903146 | 205.8381065 | 868.3425226 | -125.4141016 |
| Jul | 407.0315789 | 661.4 | 196.9 | 538.4330928 | 275.6300651 | 801.2361204 | 12.82703746 |
| Aug | 381.0894737 | 728.7 | 120.4 | 525.194863 | 236.9840844 | 813.4056415 | -51.22669412 |
| Sep | 409.3868421 | 621.3 | 235.33 | 518.4555294 | 300.3181548 | 736.5929041 | 82.18078011 |
| Oct | 319.2473684 | 489.1 | 141.2 | 400.2678279 | 238.2269089 | 562.3087469 | 76.18598999 |
| Nov | 148.7263158 | 416.8 | 58.1 | 244.7327151 | 52.71991645 | 436.7455138 | -139.2928822 |
| Dec | 28.60526316 | 94.8 | 0 | 60.14351989 | -2.93299357 | 123.2200333 | -66.00950703 |

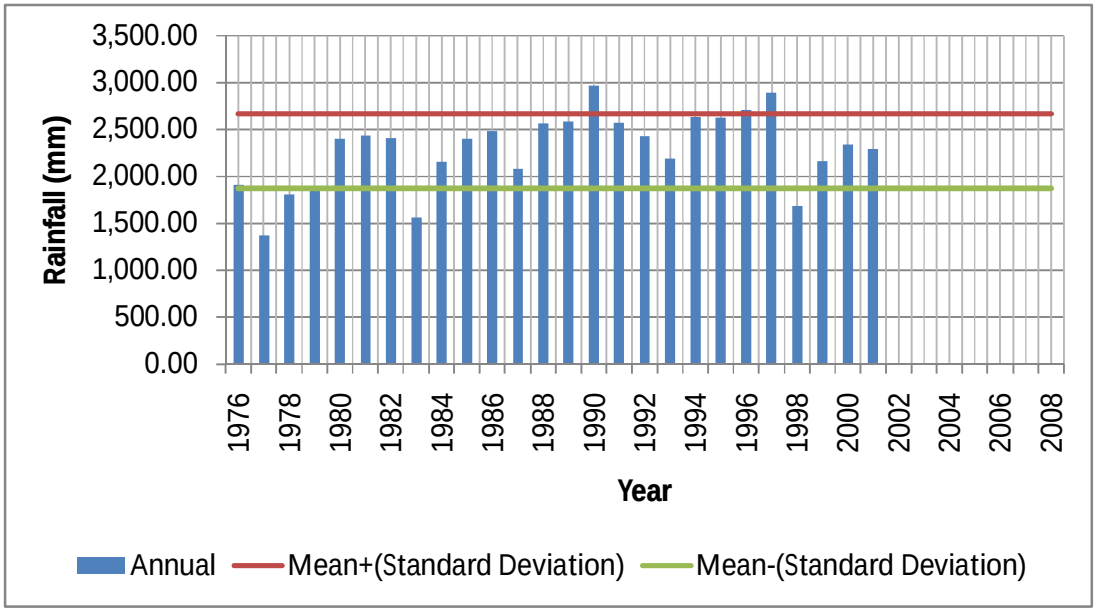


Figure 1: Annual Rainfall Amounts

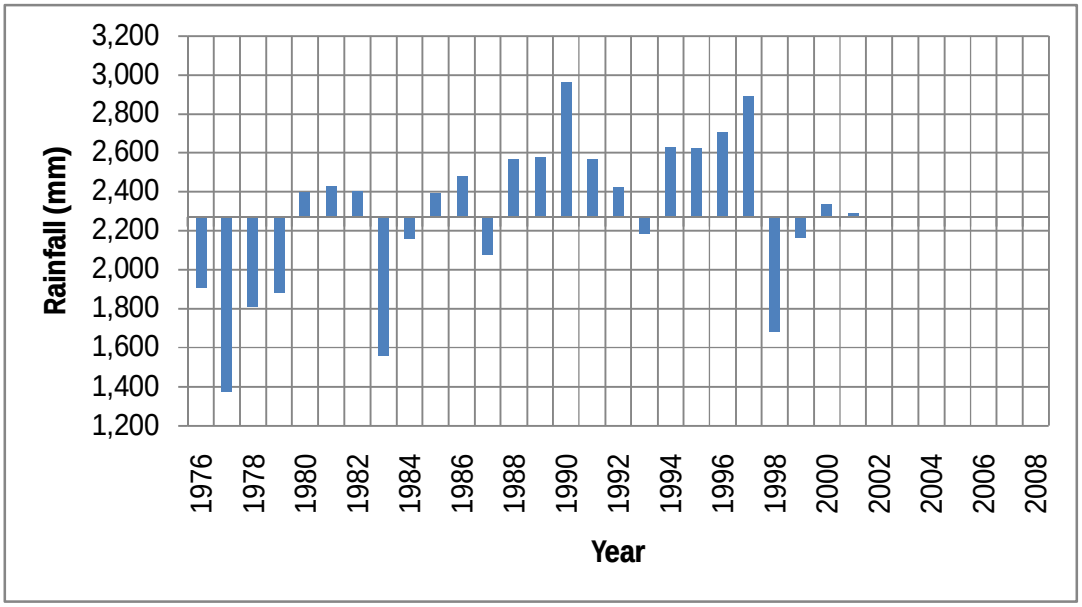


Figure 2: Annual Rainfall Amounts over Long-Term Mean

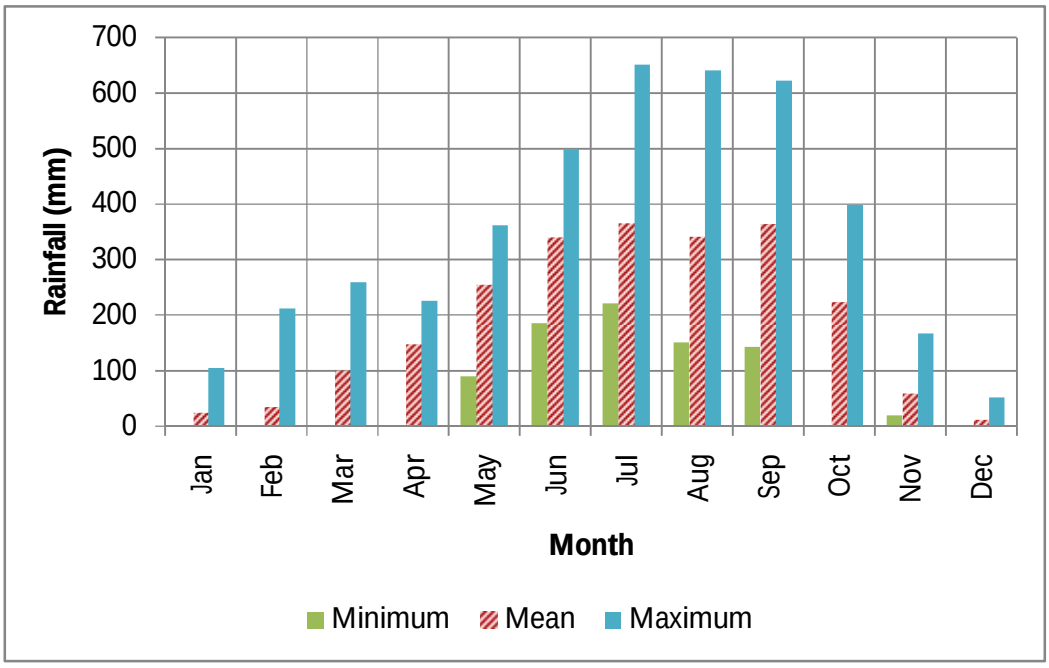


Figure 3: Monthly Rainfall Pattern

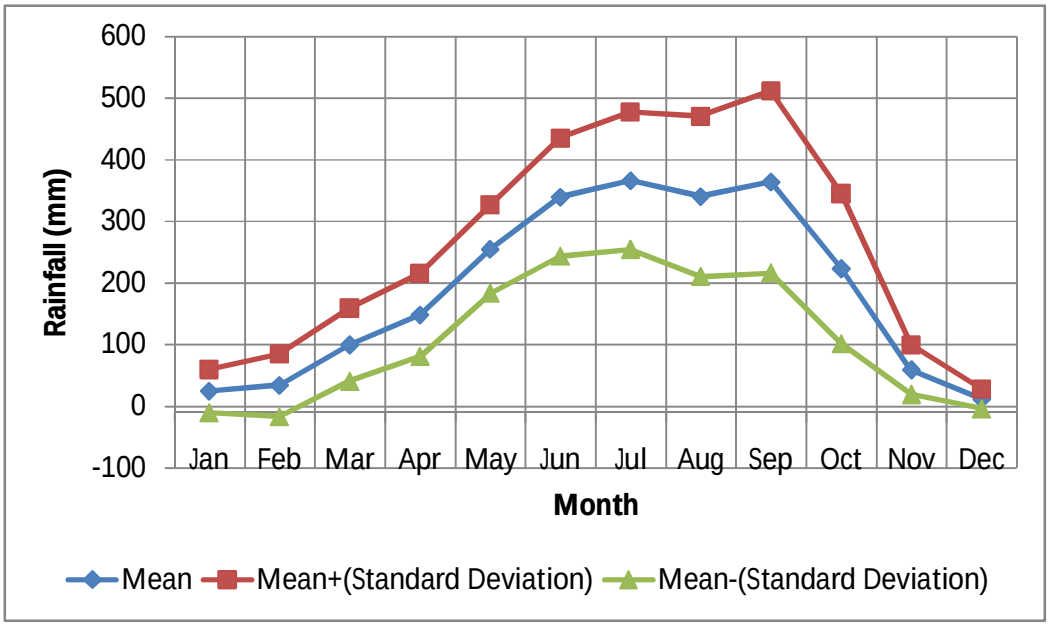


Figure 4: Seasonal Rainfall Pattern

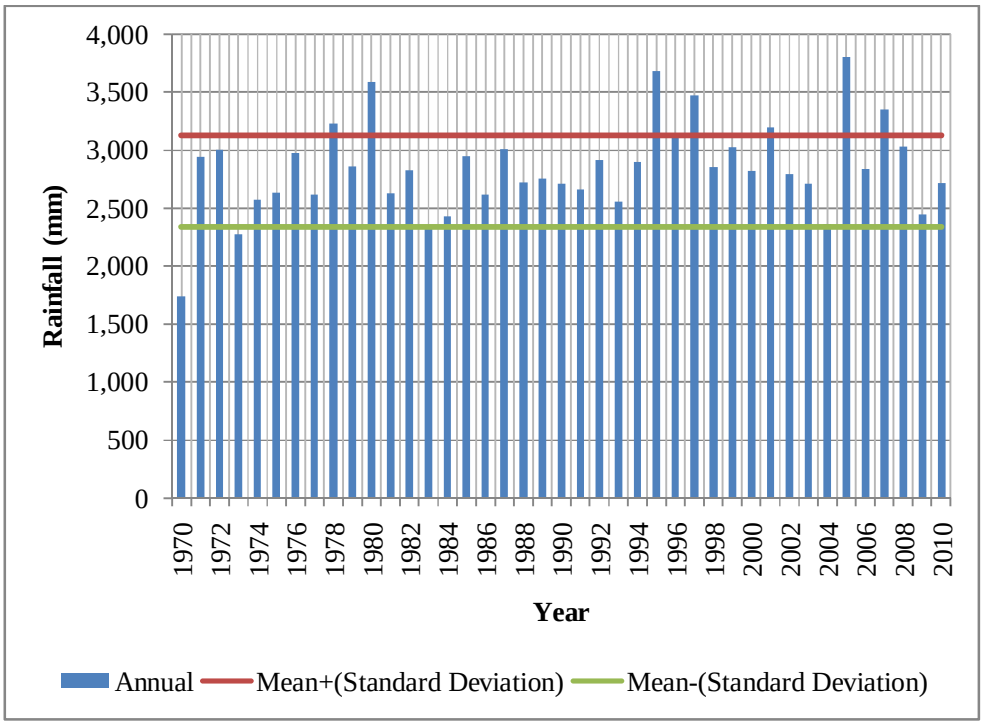


Figure 5: Annual Rainfall Amounts

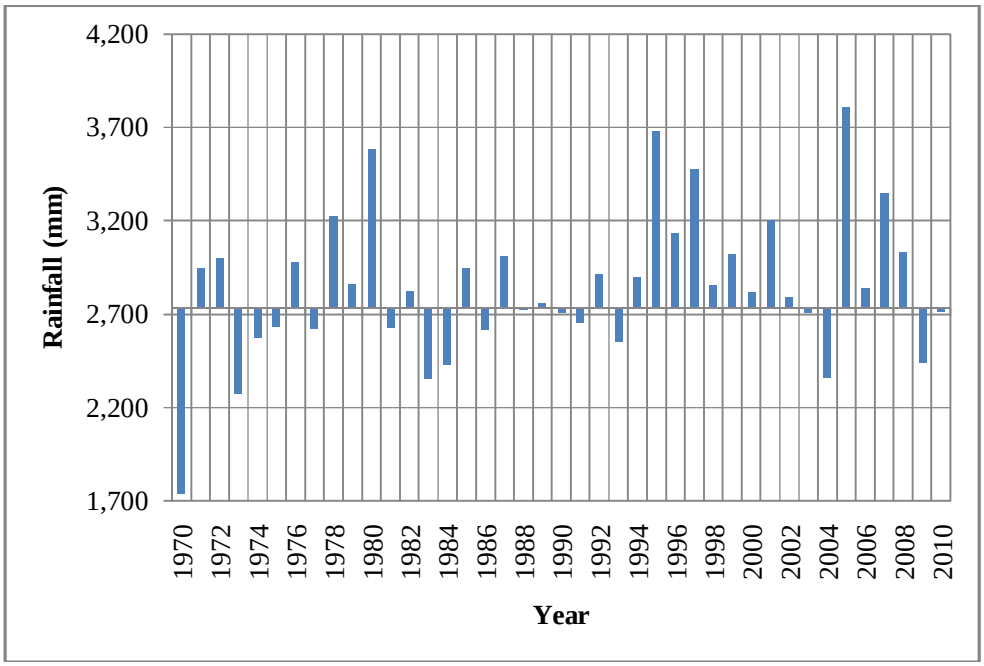


Figure 6: Annual Rainfall Amounts over Long-Term Mean (2,735 mm)

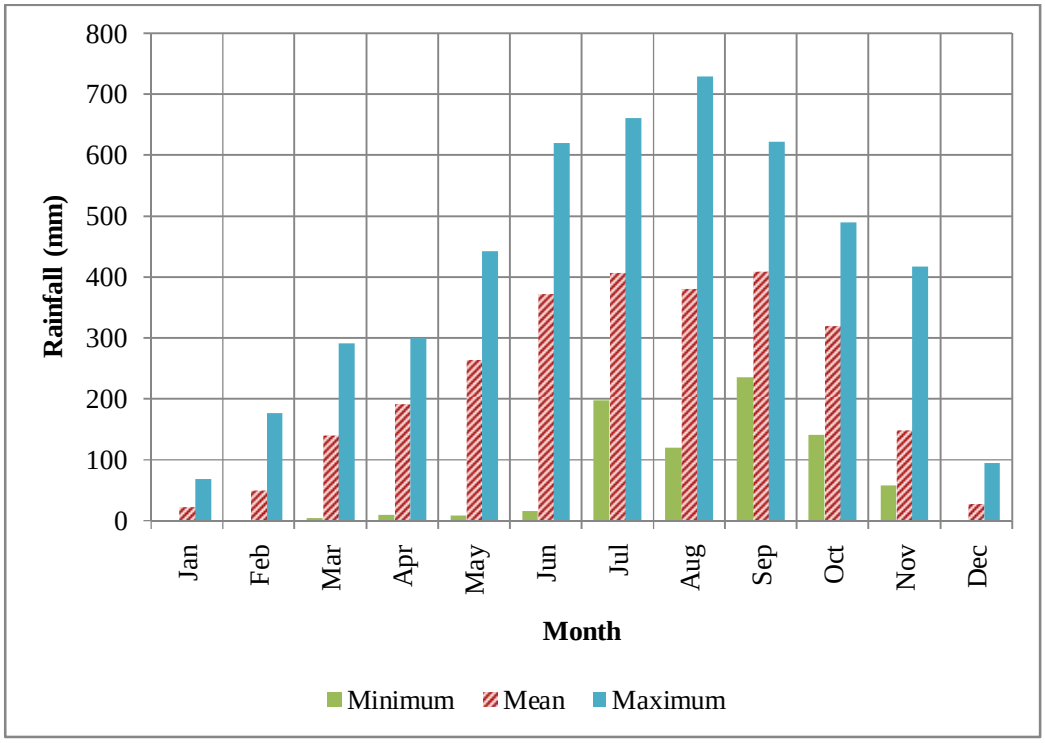


Figure 7: Monthly Rainfall Pattern (1970 - 2010)

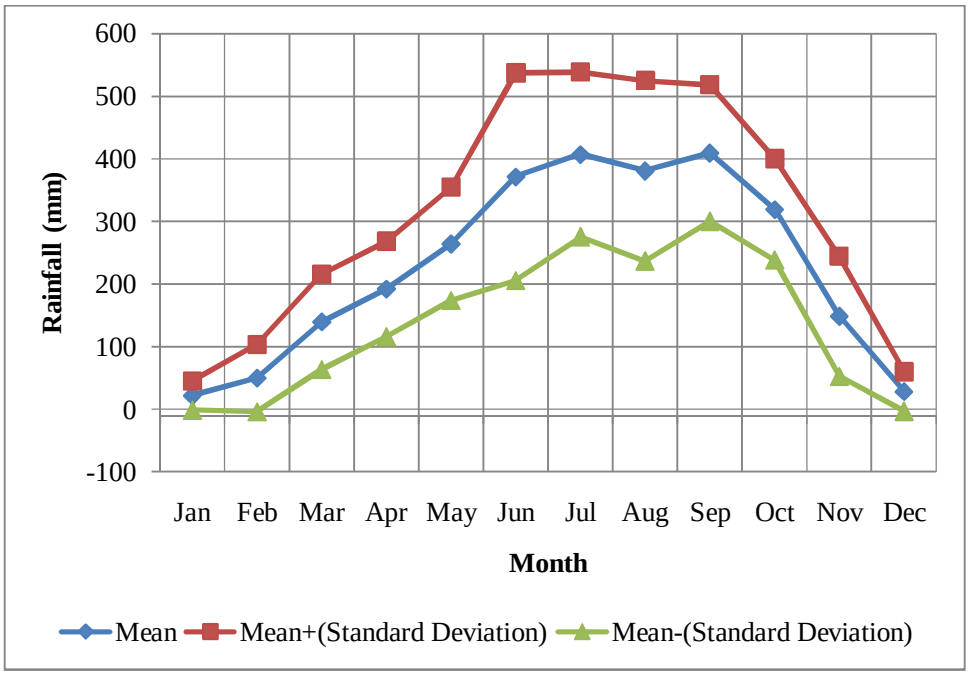


Figure 8: Seasonal Rainfall Pattern (1970 - 2010)

## Definition of Concept

For many hydrologic analyses, planning or design problems, reliable rainfall intensity estimates are necessary. Rainfall intensity duration frequency relationship comprises the estimates of rainfall intensities of different durations and recurrence intervals.

## Methods

The typical technique for establishing rainfall IDF curves is conducted via three steps.

**Step I:** Statistical analysis of the available rainfall records from the different rainfall stations which include statistical analysis to check the pattern of flow of the data, as shown in Figures 1-8.

**Step II** Determination of rainfall intensities, I (mm/hr): This is computed for 12-hr and 24-hr durations for that of Calabar rainfall data and 24-hr duration for Imo, Anambra and Benin city rainfall data following the nature of the rainfall data available for extreme values.

**Step III:** Extraction of annual extremes from the records and fitting of a probability distribution (Tables 3 - 5) was used to generate the 12-hr and 24-hr duration rainfall intensity curve as shown in Figures 9-12.

**Step IV:** Creation of Regional Rainfall Intensity (RRI) map (Figures 14 - 21) from the rainfall intensity frequency curve, for each return period shown in (Tables 6-7). An ArcView GIS model was used to generate a map applying the "inverse distance weighting method" for the interpolation of the stations' value.

**Step V:** Determination of IDF curves; for the case of only 24-hr duration records available, an empirical template developed for the Nigeria Erosion Watershed Management Project (NEWMAP) model (Table 8) was used to plot the IDF curve shown in Figures 13(a and b).

Table 3: Intensity generation sheet

| Rank | Daily Rainfall (mm) | Rainfall Intensity (mm/hour) | Exceedance Probability | Return Period | 24-Hour Duration Rainfall Intensity |
|---|---|---|---|---|---|
| 1 | 196.0644583 | 8.16935243 | 0.006821788 | 146.5891249 | 8.16935243 |
| 2 | 159.3903108 | 6.64126295 | 0.112042428 | 8.925190356 | 6.64126295 |
| 3 | 156.4032706 | 6.516802941 | 0.133247851 | 7.504811446 | 6.516802941 |
| 4 | 153.5481405 | 6.397839188 | 0.156051538 | 6.408139349 | 6.397839188 |
| 5 | 148.1828054 | 6.174283557 | 0.205773624 | 4.859709335 | 6.174283557 |
| 6 | 145.2895752 | 6.0537323 | 0.236279422 | 4.232277162 | 6.0537323 |
| 7 | 145.0391007 | 6.043295864 | 0.239038709 | 4.183422853 | 6.043295864 |
| 8 | 141.7108636 | 5.904619315 | 0.277419523 | 3.604648981 | 5.904619315 |
| 9 | 136.7976658 | 5.699902741 | 0.339430503 | 2.946111177 | 5.699902741 |
| 10 | 132.5958544 | 5.524827267 | 0.396628075 | 2.521253698 | 5.524827267 |
| 11 | 132.0146961 | 5.500612338 | 0.404778186 | 2.470488863 | 5.500612338 |
| 12 | 130.0350558 | 5.418127326 | 0.432883469 | 2.310090523 | 5.418127326 |
| 13 | 129.4396572 | 5.393319051 | 0.441426117 | 2.265384763 | 5.393319051 |
| 14 | 122.182386 | 5.090932751 | 0.547148308 | 1.827658032 | 5.090932751 |
| 15 | 120.7109101 | 5.029621252 | 0.568557253 | 1.75883782 | 5.029621252 |
| 16 | 120.1 | 5.004166667 | 0.577404 | 1.731889631 | 5.004166667 |
| 17 | 117.9946348 | 4.916443117 | 0.607628164 | 1.645743332 | 4.916443117 |
| 18 | 115.7976767 | 4.824903197 | 0.638584466 | 1.565963553 | 4.824903197 |
| 19 | 112.8 | 4.7 | 0.679522448 | 1.471621729 | 4.7 |
| 20 | 109.8 | 4.575 | 0.71858513 | 1.391623565 | 4.575 |
| 21 | 107.2182236 | 4.467425984 | 0.750378469 | 1.332660839 | 4.467425984 |
| 22 | 106.6578418 | 4.444076743 | 0.757034176 | 1.320944326 | 4.444076743 |
| 23 | 102.7732574 | 4.282219058 | 0.800567553 | 1.249113827 | 4.282219058 |
| 24 | 88.95255192 | 3.70635633 | 0.915188419 | 1.09267117 | 3.70635633 |
| 25 | 72.05244197 | 3.002185082 | 0.979195861 | 1.021246147 | 3.002185082 |
| 26 | 71.2 | 2.966666667 | 0.980839415 | 1.019534885 | 2.966666667 |
| | **Mean** | 5.247999004 | | | |
| | **Standard Deviation** | 1.137720301 | | | |
| | **Skewness** | 0.119763005 | | | |
| | **Alpha** | 278.8782356 | | | |
| | **Beta** | 0.068128401 | | | |
| | **Gamma** | -13.75152929 | | | |

Table 4: Intensity generation sheet

| Rank | Daily Rainfall (mm) | Rainfall Intensity (mm/hour) | Exceedance Probability | Return Period | 12-Hour Duration Rainfall Intensity |
|---|---|---|---|---|---|
| | | Extrapolate | 0.005 | 200 | 20.5 |
| 1 | 216 | 18 | 0.016247463 | 61.54807164 | 18 |
| 2 | 192.5 | 16.04166667 | 0.038466686 | 25.99652079 | 16.04166667 |
| 3 | 181 | 15.08333333 | 0.057640016 | 17.34905828 | 15.08333333 |
| 4 | 171.2 | 14.26666667 | 0.08050437 | 12.42168596 | 14.26666667 |
| 5 | 168.9 | 14.075 | 0.08693705 | 11.50257573 | 14.075 |
| 6 | 156.1 | 13.00833333 | 0.131789415 | 7.587862788 | 13.00833333 |
| 7 | 153.8 | 12.81666667 | 0.141695781 | 7.057373152 | 12.81666667 |
| 8 | 144.6 | 12.05 | 0.187898178 | 5.322031369 | 12.05 |
| 9 | 140.7 | 11.725 | 0.210937194 | 4.740747626 | 11.725 |
| 10 | 136 | 11.33333333 | 0.241661443 | 4.138020473 | 11.33333333 |
| 11 | 133.5 | 11.125 | 0.259373293 | 3.855447062 | 11.125 |
| 12 | 117.6 | 9.8 | 0.395070075 | 2.531196522 | 9.8 |
| 13 | 117 | 9.75 | 0.400960643 | 2.494010369 | 9.75 |
| 14 | 115.6 | 9.633333333 | 0.414910852 | 2.410156292 | 9.633333333 |
| 15 | 108.6 | 9.05 | 0.488694377 | 2.046268683 | 9.05 |
| 16 | 105.4 | 8.783333333 | 0.524393172 | 1.906966098 | 8.783333333 |
| 17 | 104 | 8.666666667 | 0.540331856 | 1.8507145 | 8.666666667 |
| 18 | 101 | 8.416666667 | 0.575027455 | 1.739047399 | 8.416666667 |
| 19 | 100.8 | 8.4 | 0.57736295 | 1.732012767 | 8.4 |
| 20 | 98 | 8.166666667 | 0.610283147 | 1.638583672 | 8.166666667 |
| 21 | 95.8 | 7.983333333 | 0.636351986 | 1.571457341 | 7.983333333 |
| 22 | 95.6 | 7.966666667 | 0.638726598 | 1.56561509 | 7.966666667 |
| 23 | 93.3 | 7.775 | 0.666042791 | 1.501405034 | 7.775 |
| 24 | 93.2 | 7.766666667 | 0.667229625 | 1.498734412 | 7.766666667 |
| 25 | 91.6 | 7.633333333 | 0.686188493 | 1.457325515 | 7.633333333 |
| 26 | 88.6 | 7.383333333 | 0.721448834 | 1.386099684 | 7.383333333 |
| 27 | 85.5 | 7.125 | 0.757176018 | 1.320696873 | 7.125 |
| 28 | 85.1 | 7.091666667 | 0.761712942 | 1.312830523 | 7.091666667 |
| 29 | 83.5 | 6.958333333 | 0.779655424 | 1.282617897 | 6.958333333 |
| 30 | 83.3 | 6.941666667 | 0.781873256 | 1.278979671 | 6.941666667 |
| 31 | 81.7 | 6.808333333 | 0.799392514 | 1.250949918 | 6.808333333 |
| 32 | 80 | 6.666666667 | 0.817523893 | 1.223205839 | 6.666666667 |
| 33 | 74.3 | 6.191666667 | 0.873769974 | 1.144465969 | 6.191666667 |
| 34 | 73.9 | 6.158333333 | 0.877409138 | 1.139719153 | 6.158333333 |
| 35 | 67.4 | 5.616666667 | 0.929681443 | 1.07563726 | 5.616666667 |
| 36 | 64.7 | 5.391666667 | 0.947187652 | 1.055757006 | 5.391666667 |
| | **Mean** | 9.490277778 | | | |
| | **Standard Deviation** | 3.156654913 | | | |
| | **Skewness** | 1.016092796 | | | |
| | **Alpha** | 3.874300004 | | | |
| | **Beta** | 1.603727158 | | | |
| | **Gamma** | 3.276957644 | | | |

Table 5: Intensity generation sheet

| Rank | Daily Rainfall (mm) | Rainfall Intensity (mm/hour) | Exceedance Probability | Return Period | 24-Hour Duration Rainfall Intensity |
|---|---|---|---|---|---|
| | | Extrapolate | 0.005 | 200 | 10.1 |
| 1 | 216 | 9 | 0.020521841 | 48.7285708 | 9 |
| 2 | 192.5 | 8.020833333 | 0.05496662 | 18.19285966 | 8.020833333 |
| 3 | 181 | 7.541666667 | 0.085853324 | 11.64777262 | 7.541666667 |
| 4 | 180.6 | 7.525 | 0.087153931 | 11.47395182 | 7.525 |
| 5 | 179.8 | 7.491666667 | 0.089805626 | 11.13515986 | 7.491666667 |
| 6 | 175.5 | 7.3125 | 0.105260423 | 9.500246852 | 7.3125 |
| 7 | 173.8 | 7.241666667 | 0.111957454 | 8.931964479 | 7.241666667 |
| 8 | 171.3 | 7.1375 | 0.122445892 | 8.166872614 | 7.1375 |
| 9 | 168.9 | 7.0375 | 0.133261663 | 7.504033644 | 7.0375 |
| 10 | 162.5 | 6.770833333 | 0.16591514 | 6.027177501 | 6.770833333 |
| 11 | 143.5 | 5.979166667 | 0.299123557 | 3.343100127 | 5.979166667 |
| 12 | 137.3 | 5.720833333 | 0.354731456 | 2.819033904 | 5.720833333 |
| 13 | 126.6 | 5.275 | 0.462942459 | 2.160095666 | 5.275 |
| 14 | 126.1 | 5.254166667 | 0.468311851 | 2.135329264 | 5.254166667 |
| 15 | 123.2 | 5.133333333 | 0.499874973 | 2.000500231 | 5.133333333 |
| 16 | 122 | 5.083333333 | 0.513119914 | 1.94886219 | 5.083333333 |
| 17 | 120.5 | 5.020833333 | 0.529800526 | 1.887502846 | 5.020833333 |
| 18 | 118.8 | 4.95 | 0.548841477 | 1.822019731 | 4.95 |
| 19 | 117.7 | 4.904166667 | 0.561221329 | 1.781828216 | 4.904166667 |
| 20 | 117 | 4.875 | 0.56911745 | 1.75710655 | 4.875 |
| 21 | 112.2 | 4.675 | 0.62338105 | 1.604155274 | 4.675 |
| 22 | 111.1 | 4.629166667 | 0.635779135 | 1.57287326 | 4.629166667 |
| 23 | 108.8 | 4.533333333 | 0.661553761 | 1.511592947 | 4.533333333 |
| 24 | 104.1 | 4.3375 | 0.713150888 | 1.402227799 | 4.3375 |
| 25 | 101 | 4.208333333 | 0.745980179 | 1.34051819 | 4.208333333 |
| 26 | 98 | 4.083333333 | 0.776509041 | 1.287815013 | 4.083333333 |
| 27 | 97.5 | 4.0625 | 0.781459783 | 1.279656384 | 4.0625 |
| 28 | 97.5 | 4.0625 | 0.781459783 | 1.279656384 | 4.0625 |
| 29 | 95.8 | 3.991666667 | 0.797968572 | 1.253182187 | 3.991666667 |
| 30 | 95.4 | 3.975 | 0.801777037 | 1.247229534 | 3.975 |
| 31 | 94.8 | 3.95 | 0.807433137 | 1.238492643 | 3.95 |
| 32 | 89.5 | 3.729166667 | 0.854184437 | 1.170707352 | 3.729166667 |
| 33 | 85.1 | 3.545833333 | 0.888116687 | 1.125978168 | 3.545833333 |
| 34 | 83.3 | 3.470833333 | 0.900609622 | 1.110359001 | 3.470833333 |
| 35 | 81.1 | 3.379166667 | 0.914743698 | 1.093202393 | 3.379166667 |
| 36 | 77.2 | 3.216666667 | 0.936690945 | 1.067587986 | 3.216666667 |
| | **Mean** | 5.309027778 | | | |
| | **Standard Deviation** | 1.547360945 | | | |
| | **Skewness** | 0.688142291 | | | |
| | **Alpha** | 8.447019423 | | | |
| | **Beta** | 0.532402253 | | | |
| | **Gamma** | 0.811815606 | | | |

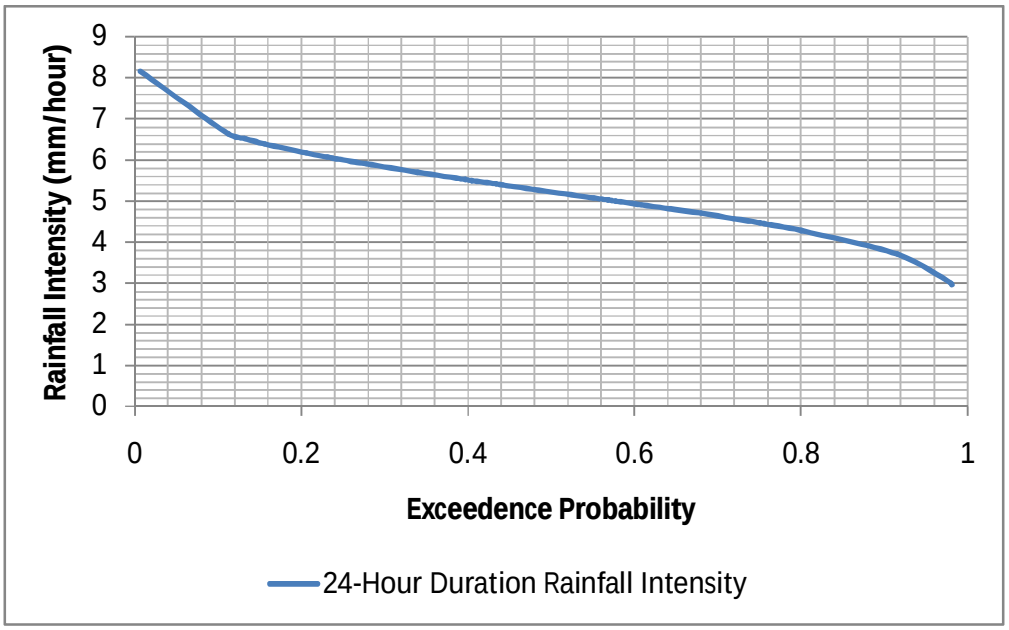


Figure 9: Rainfall Intensity Frequency Curve using Table 3

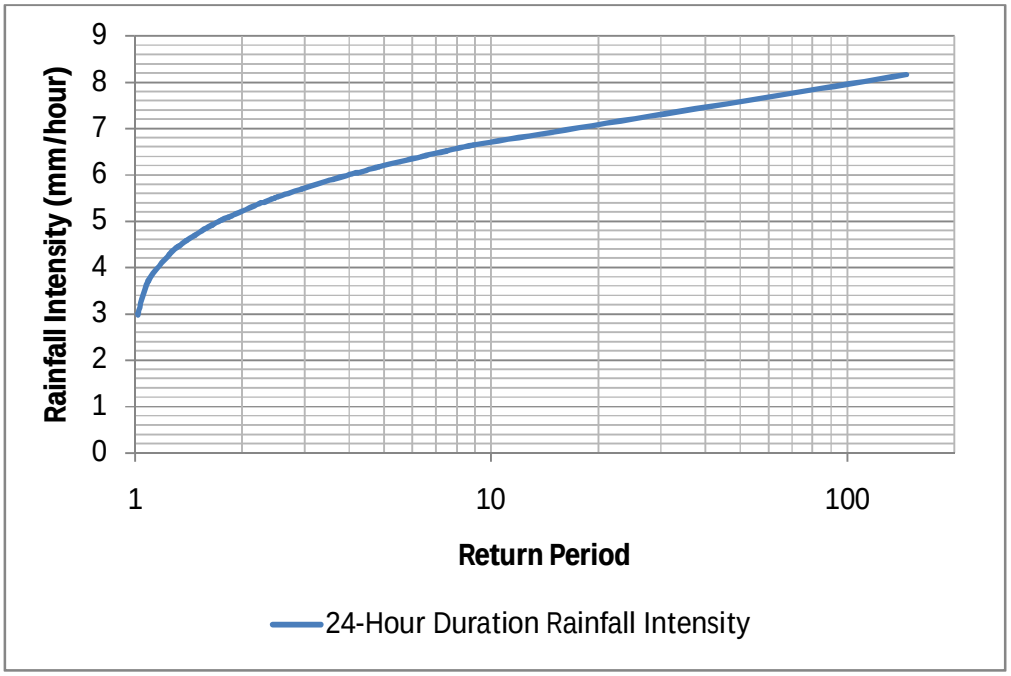


Figure 10: Rainfall Intensity-Return Period Curve using Table 3

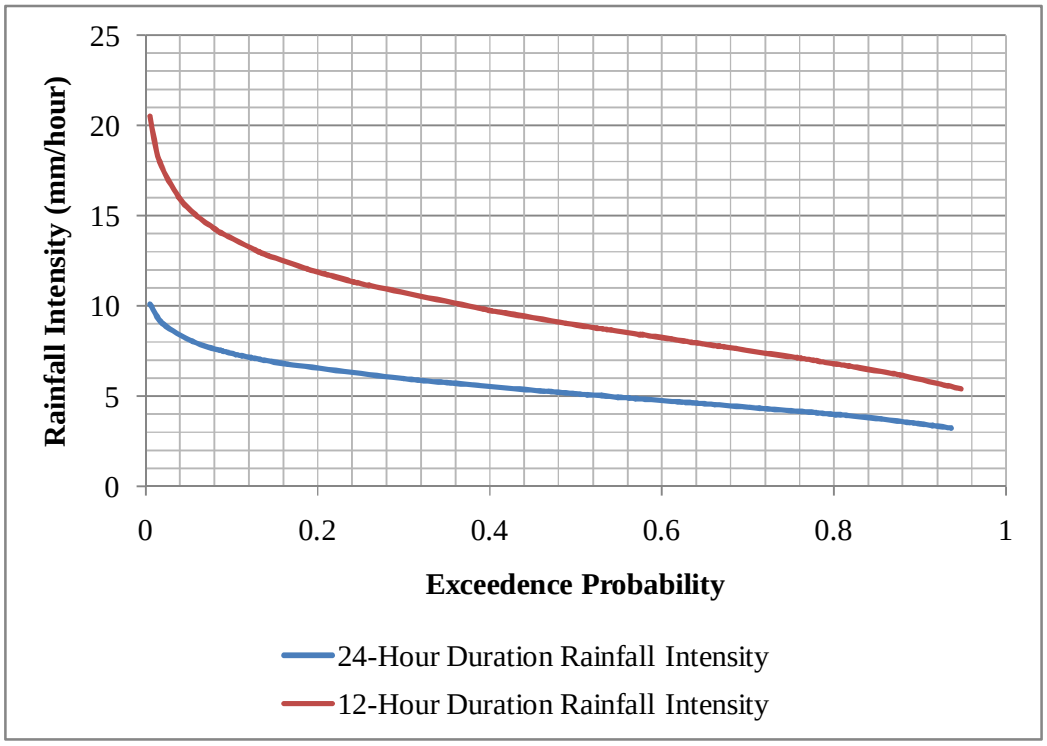


Figure 11: Rainfall Intensity-Frequency Curve (1970 - 2005) using Tables 4-5

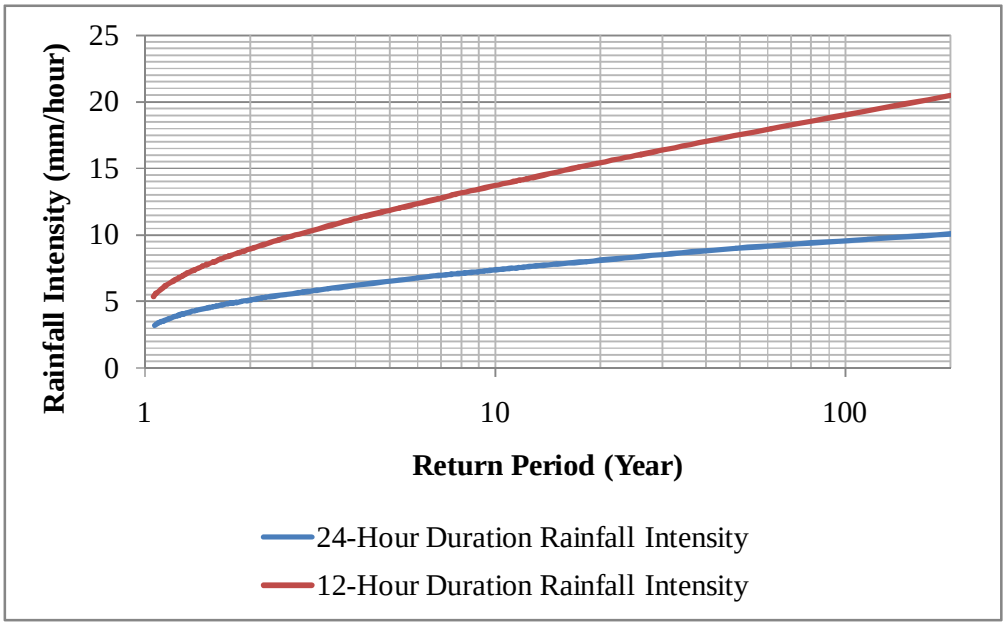


Figure 12: Rainfall Intensity-Return Period Curve (1970 - 2005) using Tables 4-5

Table 6: Gauged rainfall stations- historic data set

| Station | x-long | y-lat | 2-Year | 5-Year | 10-Year | 25-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|---|---|
| Benin | 5.68 | 6.34 | 4.4 | 5.4 | 6.1 | 6.9 | 7.5 | 8.1 |
| Onitsha | 6.78 | 6.15 | 4.4 | 5.5 | 6.2 | 6.9 | 7.5 | 8 |
| AIRBDA-Owerri | 7.19 | 5.66 | 5.2 | 6.2 | 6.7 | 7.1 | 7.6 | 8 |
| Calabar | 8.35 | 4.95 | 5.1 | 6.5 | 7.5 | 8.5 | 9 | 9.6 |

Table 7: Gauged rainfall stations- climate change scenario

| Station | x-long | y-lat | 2-Year | 5-Year | 10-Year | 25-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|---|---|
| Benin | 5.68 | 6.34 | 5.3 | 6.2 | 6.7 | 7.4 | 7.8 | 8.2 |
| Onitsha | 6.78 | 6.15 | 5.2 | 6.3 | 7 | 7.8 | 8.3 | 8.9 |
| AIRBDA-Owerri | 7.19 | 5.66 | 6.2 | 7.4 | 8 | 8.6 | 9.1 | 9.6 |
| Calabar | 8.35 | 4.95 | 6 | 7.5 | 8.5 | 9.5 | 10.3 | 11 |

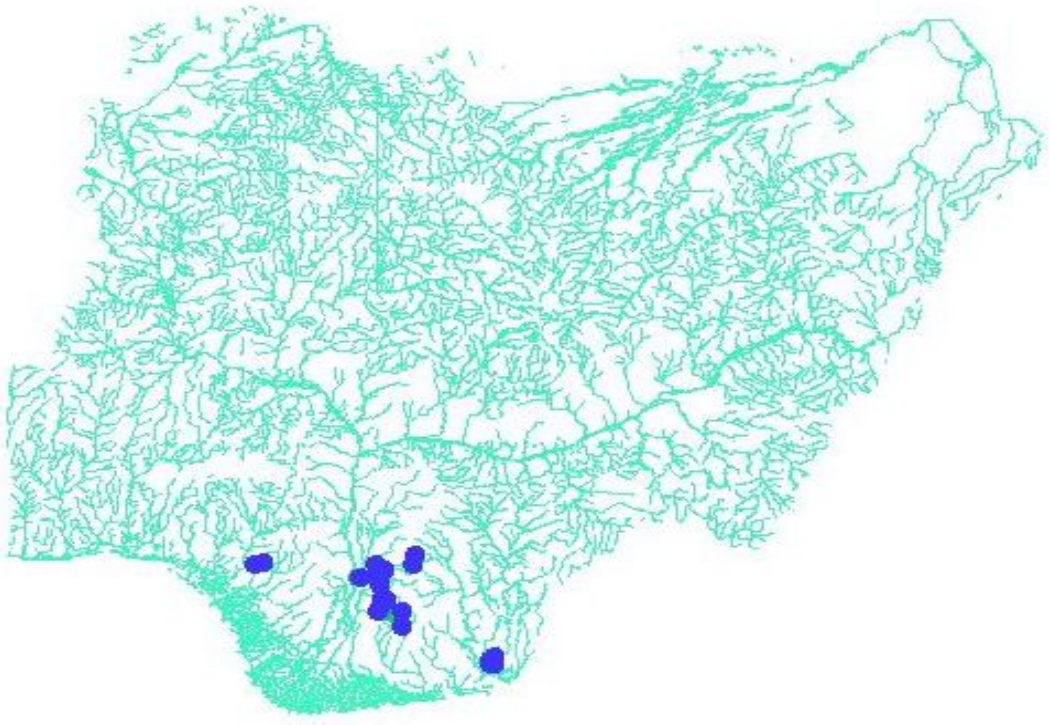

Figure 14: Map of Nigeria showing some selected erosion sites

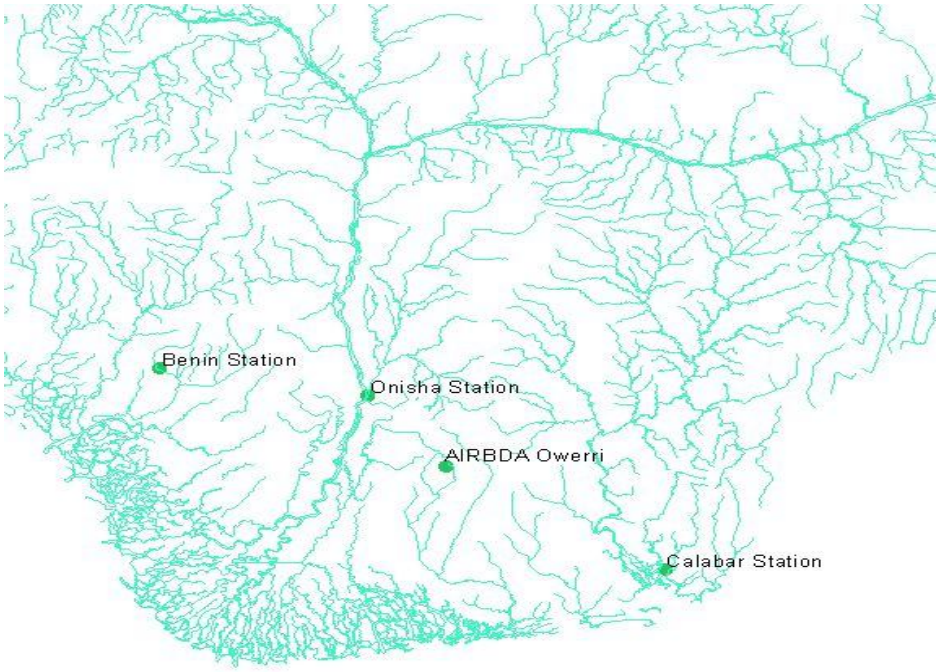


Figure 15: Map of Nigeria showing the rainfall guage stations

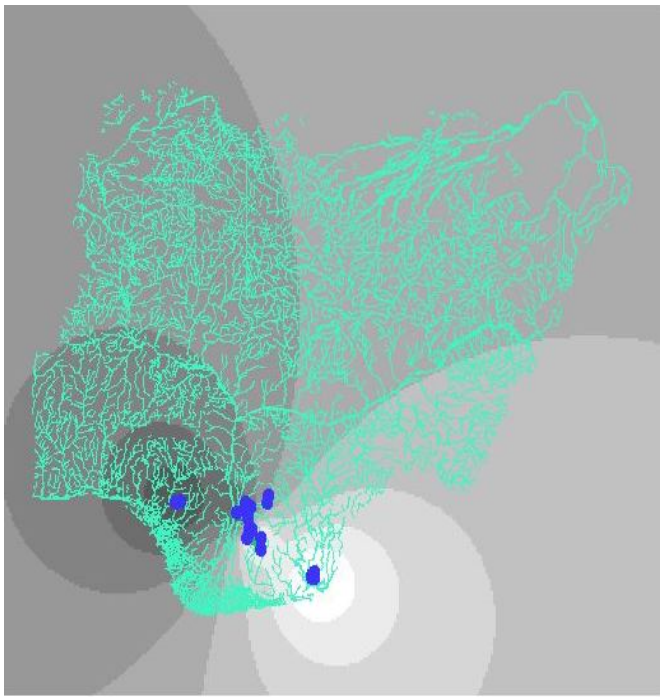

Figure 16: 2 years return period

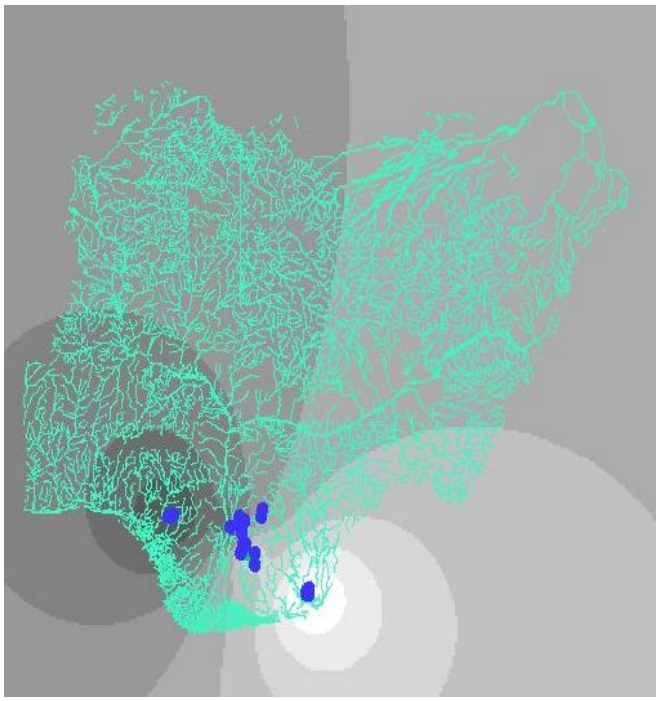

Figure 17: 5 years return period

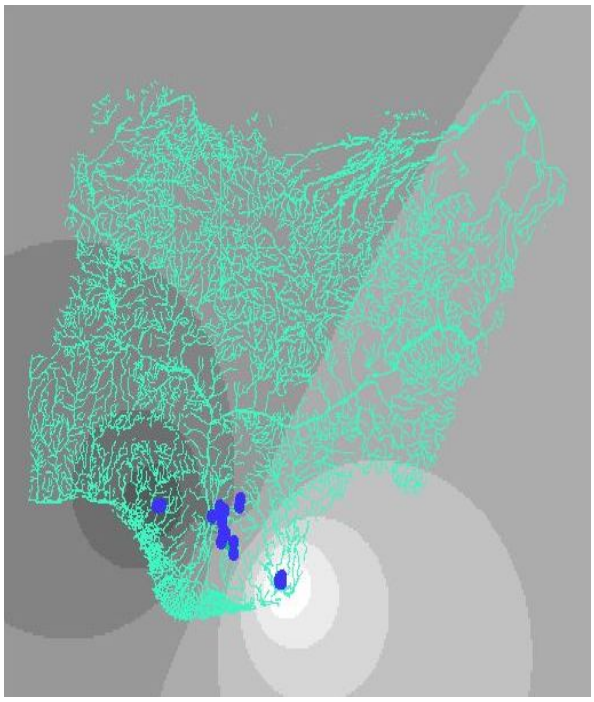

Figure 20: 10 years return period

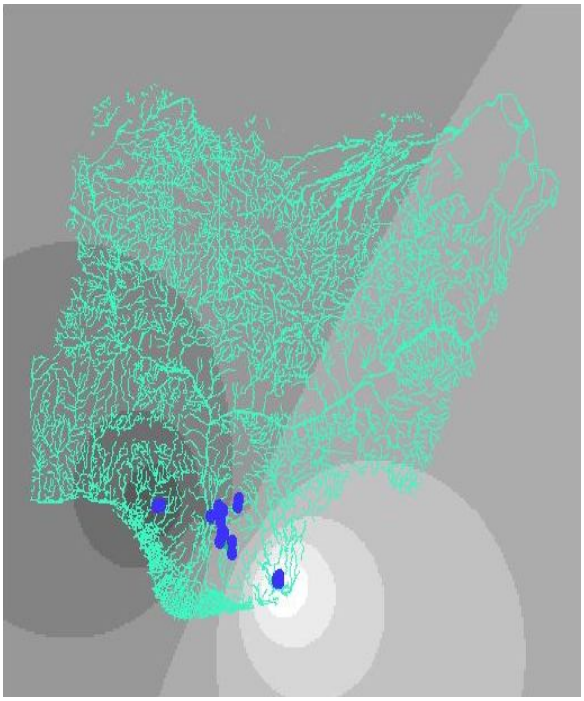

Figure 20: 25 years return period

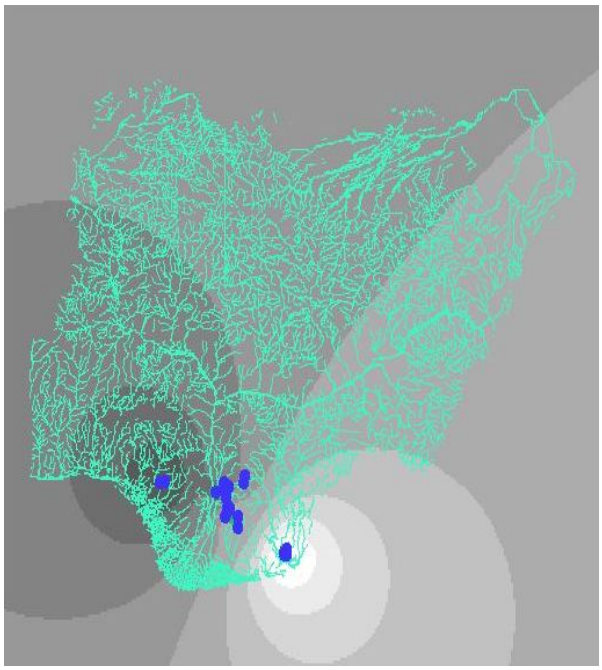

Figure 20: 50 years return period

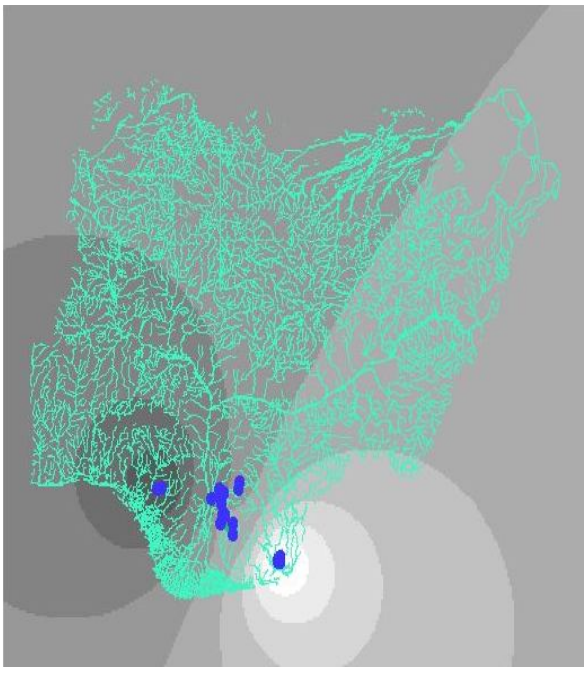

Figure 21: 100 years return period

Table 8: NEWMAP Empirical Template

| Duration | 100-Year | 50-Year | 25-Year | 10-Year | 5-Year | 2-Year | 100-Year | 50-Year | 25-Year | 10-Year | 5-Year | 2-Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1440 | 1 | 1 | 1 | 1 | 1 | 1 | 9.4175 | 8.8906 | 8.3876 | 7.728 | 7.0978 | 5.9242 |
| 720 | 1.979167 | 1.944444 | 1.882353 | 1.833333 | 1.815385 | 1.764706 | 18.6388 | 17.28728 | 15.78842 | 14.168 | 12.88524 | 10.45447 |
| 360 | 3.917101 | 3.780864 | 3.543253 | 3.288178 | 3.295621 | 3.114187 | 36.8893 | 33.61415 | 29.71939 | 25.41104 | 23.39166 | 18.44907 |
| 180 | 7.752595 | 7.35168 | 6.669652 | 5.962562 | 5.98282 | 5.495624 | 73.01006 | 65.36085 | 55.94237 | 46.07868 | 42.46486 | 32.55717 |
| 180 | 1 | 1 | 1 | 1 | 1 | 1 | 73.01006 | 65.36085 | 55.94237 | 46.07868 | 42.46486 | 32.55717 |
| 120 | 1.315385 | 1.304348 | 1.4 | 1.277778 | 1.428571 | 1.090909 | 96.03632 | 85.25328 | 78.31932 | 58.87832 | 60.66409 | 35.51692 |
| 100 | 1.181287 | 1.166667 | 1.071429 | 1.130435 | 1.15 | 1.25 | 113.4464 | 99.46216 | 83.91356 | 66.5581 | 69.7637 | 44.39615 |
| 80 | 1.138614 | 1.142857 | 1.2 | 1.153846 | 1.217391 | 1.2 | 129.1717 | 113.671 | 100.6963 | 76.7978 | 84.92972 | 53.27538 |
| 60 | 1.173913 | 1.2 | 1.222222 | 1.266667 | 1.142857 | 1.333333 | 151.6363 | 136.4053 | 123.0732 | 97.27722 | 97.06254 | 71.03384 |
| 40 | 1.362963 | 1.333333 | 1.272727 | 1.263158 | 1.28125 | 1.25 | 206.6746 | 181.8737 | 156.6386 | 122.8765 | 124.3614 | 88.7923 |
| 20 | 1.326087 | 1.375 | 1.464286 | 1.5 | 1.487805 | 1.466667 | 274.0686 | 250.0763 | 229.3637 | 184.3147 | 185.0255 | 130.2287 |
| 10 | 1.483607 | 1.454545 | 1.414634 | 1.388889 | 1.442623 | 1.5 | 406.6099 | 363.7473 | 324.4658 | 255.9927 | 266.922 | 195.343 |

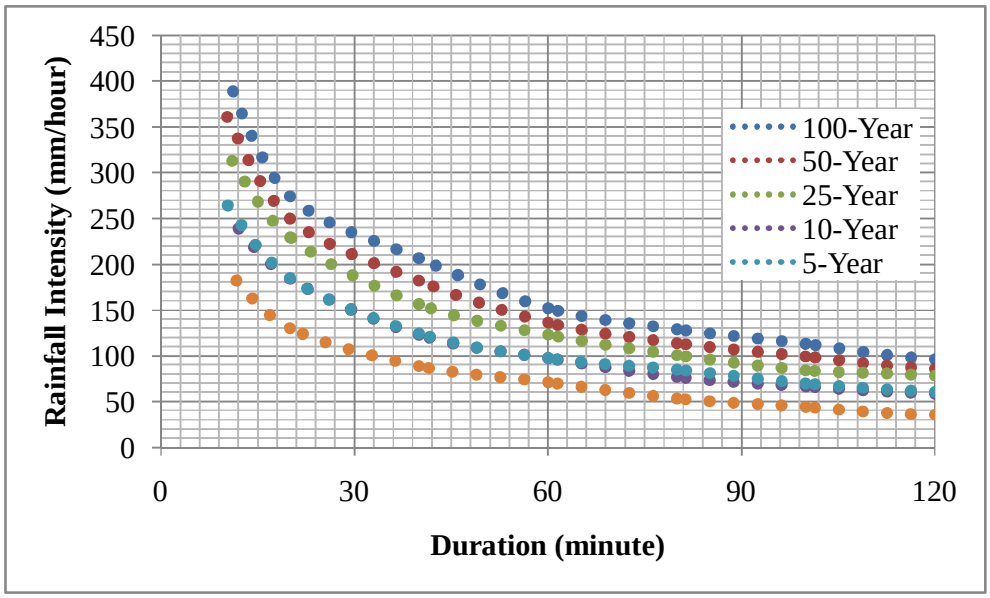


Figure 13(a): Developed Rainfall Intensity-Duration-Frequency Curve (duration ranging from 0-120 minutes)

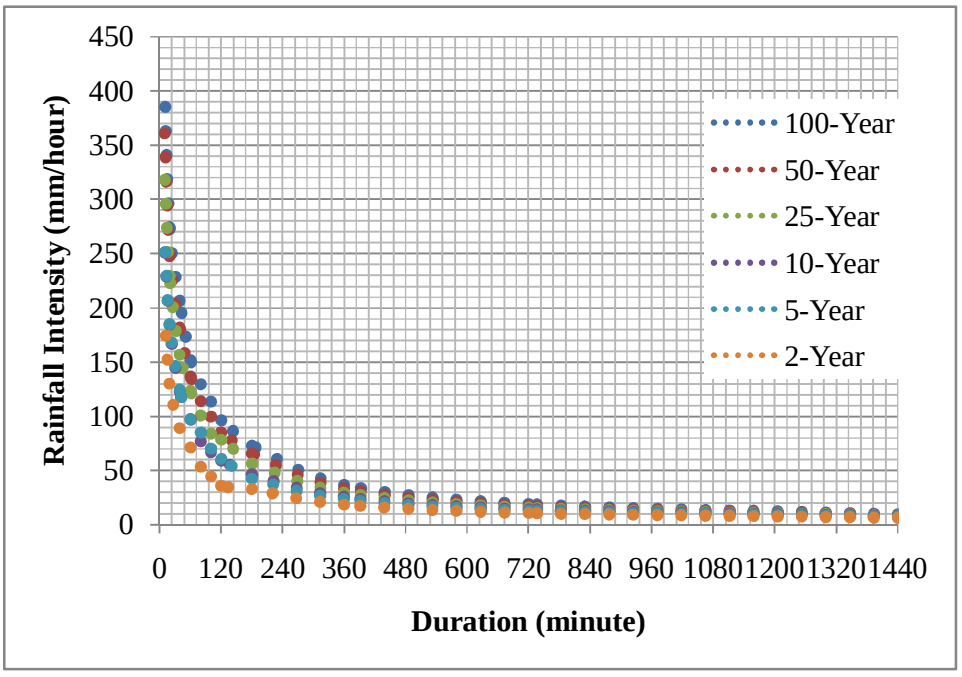


Figure 13(b): Developed Rainfall Intensity-Duration-Frequency Curve (duration ranging from 0-1440 minutes)

## Conclusion

Historical rainfall records are needed to obtain design estimates for both small and large projects. This study is an attempt to provide much needed, useful design data and guidance for water resources development in Eastern catchment of Nigeria.

The Maximum Annual Precipitation series as obtained at each station for different durations remained an acceptable tool for generating a-24 hr intensity-duration-frequency values at 2, 5, 10, 25, 50 and 100 years.

The regionalization of the parameters of rainfall intensity-duration-frequency equations generated for ungauged stations estimate rainfall intensity for various return period and rainfall duration. These 24-hr IDF values spatially interpolated using ArcView GIS model to obtain RRI maps for all durations and return periods should apply to catchments in eastern Nigeria.

## Reference

Bell F. C., 1969, *"Generalized rainfall-duration-frequency relationship"*, ASCE J. Hydraulic Eng., 95, 311–327.

Chen C. L., 1983, *"Rainfall intensity-duration-frequency formulas"*, ASCE J. Hydraulic Eng., 109, 1603–1621.

Chow, V.T., Maidment, D.R. & Mays, L.W. (1988). *Applied Hydrology*, McGraw-Hill.

David M. Hershfied (1961). Estimating the Probable Maximum Precipitation, *Journal of the Hydraulic Division, Proceeding of the ASCE,* HY5, 99-116.

Eman, A. H. El-Sayed (2011), *Nile Basin Water Science & Engineering Journal, Vol.4, Issue 1, 2011, pp 112.*

Kothyari, U.C. and Grade, R.J. (1992). Rainfall intensity duration frequency formula for India,

Koutsoyiannis, D., Kozonis, D., and Manetas, A., 1998, *"A mathematical framework for studying rainfall intensity-duration-frequency relationships"*, Journal of Hydrology, 206(1-2), 118-135.

Nhat L., Y. Tachikawa and K. Takara, 2006, *"Establishment of Intensity-Duration- Frequency Curves for Preceipitation in the Monsoon Area of Vietnam"*, Annuals of Disas. Prev.Res.Inst., Kyoto Univ., No. 49 B.

Okonkwo G.I. and C.C. Mbajiorgu, 2010, *"Rainfall Intensity-Duration-Frequency Analyses for South Eastern Nigeria"*, Agricultural Engineering International: the CIGR Ejournal. Manuscript 1304. Vol. XII.

Raiford J.P., N.M. Aziz, A.A. Khan and D.N. Powell, 2007, *"Rainfall Depth-Duration-Frequency Relationships for South Carolina, North Carolina, and Georgia*", American Journal of Environmental Science 3(2): 78-84.

Solaiman T. A. and Slobodan P. S. (2011). Quantifying Uncertainties in the Modelled Estimates of Extreme Precipitation Events at the Upper Thames River Basin. Water Resources Research Report no. 070, Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada, 167 pages. ISBN: (print) 978-0-7714-2878-4; (online) 978-0-7714-2880-7.

Solaiman T.A. and Slobodan P. S. (2011). Assessment of Global and Regional Reanalyses Data for Hydro-Climatic Impact Studies in the Upper Thames River Basin. Water Resources Research Report no. 071, Facility for Intelligent Decision Support,

Department of Civil and Environmental Engineering, London, Ontario, Canada, 74 pages. ISBN: (print) 978- 0-7714-2892-0; (online) 978-0-7714-2899-9.