# CHAPTER 3

# DATA ANALYSES AND RAINFALL STATISTICS

The data for this research have been sourced from the Bureau of Meteorology (BOM) Australia, The Department of Natural Resources and Water (DNRW), Queensland and the Gregory field trial site. The following sections discuss these three data sources and the rainfall statistics that have been used in the research.

## 3.1 Data

### 3.1.1 The Bureau of Meteorology (BOM) Data

The data analyses started with the 6-minute data supplied by the Bureau of Meteorology (BOM) for the regions 35, 39 and 40 of Central and South-Eastern Queensland. Figure 3.1 shows the Australian Rainfall Districts defined by BOM.

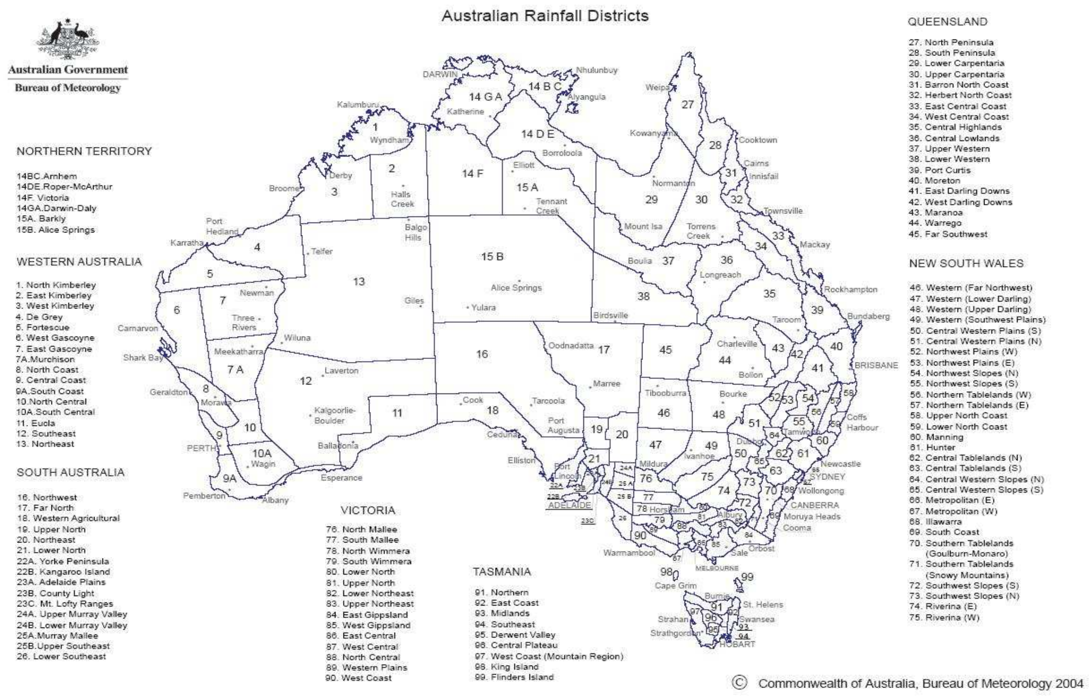


**Figure 3.1 Australian Rainfall Districts**

The intention is to identify regional parameters and check whether these parameters remain constant or vary across regions. The primary reason for selecting the regions 35, 39 and 40 is that they are the adjacent regions around Rockhampton in Queensland from where our analyses will be controlled. Since Rockhampton is one of the climatic stations used to develop the Australian Rainfall Database SILO Data Drill facility, the synthetic data are expected to be very close to reality. Table 3.1 shows the initial pluvio-stations having at least 10 years of 6-minute observed rainfall data for all months of the year that were used.

**Table 3.1 Pluvio-Station ID with minimum 10 years of 6 Minutes Rainfall Data for all months**

| Station ID | Site name | Latitude | Longitude | Data Length, yr | Station ID | Site name | Latitude | Longitude | Data Length, yr |
|---|---|---|---|---|---|---|---|---|---|
| 35000 | ALPHA POST OFFICE | -23.6497 | 146.6411 | 17.8 | 40112 | KINGAROY PRINCE STREET | -26.5544 | 151.8456 | 36.9 |
| 35025 | DINGO POST OFFICE | -23.6456 | 149.3308 | 21.7 | 40126 | MARYBOROUGH | -25.5181 | 152.7111 | 26.9 |
| 35029 | GILIGULGUL | -26.3564 | 150.0464 | 33.1 | 40135 | MOOGERAH DAM | -28.0303 | 152.5531 | 38.9 |
| 35059 | ROLLESTON METEOR ST | -24.4619 | 148.6261 | 18.3 | 40152 | MURGON POST OFFICE | -26.2425 | 151.9425 | 33.6 |
| 35065 | SPRINGSURE DAME ST | -24.1222 | 148.0867 | 35.4 | 40160 | NERANG GILSTON RD | -28.0092 | 153.3175 | 19.4 |
| 35069 | TAMBO POST OFFICE | -24.8819 | 146.2564 | 40.6 | 40178 | RATHDOWNEY POST OFFICE | -28.215 | 152.8639 | 37.7 |
| 35070 | TAROOM POST OFFICE | -25.6408 | 149.7958 | 32.4 | 40180 | MARGATE COLLINS ST | -27.2517 | 153.1008 | 16.6 |
| 35090 | REWAN STATION | -24.9606 | 148.3761 | 28.3 | 40189 | SOMERSET DAM | -27.1169 | 152.555 | 23.7 |
| 35104 | KILMACOLM | -22.4 | 147.5333 | 18.8 | 40192 | SPRINGBROOK FORESTRY | -28.2264 | 153.2786 | 37.1 |
| 35147 | EMERALD DPI FIELD STATION | -23.4669 | 148.1519 | 22.8 | 40197 | MT TAMBORINE FERN ST | -27.9694 | 153.1953 | 33.1 |
| 35267 | COOVIN | -22.4269 | 147.5478 | 21.5 | 40214 | BRISBANE REGIONAL OFFICE | -27.4778 | 153.0306 | 84.4 |
| 39006 | BILOELA DPI | -24.3789 | 150.5164 | 55.3 | 40222 | KALINGA BOWLS CLUB | -27.4117 | 153.0456 | 33.3 |
| 39069 | WALTERHALL | -23.6292 | 150.3869 | 32 | 40223 | BRISBANE AERO | -27.4178 | 153.1142 | 50.7 |
| 39070 | MT PERRY THE PINES | -25.1694 | 151.6375 | 26.5 | 40241 | SAMFORD CSIRO | -27.3617 | 152.8861 | 36.6 |
| 39083 | ROCKHAMPTON AERO | -23.3753 | 150.4775 | 66.1 | 40265 | REDLANDS HRS | -27.5278 | 153.25 | 38.3 |
| 39090 | THEODORE DPI | -24.9503 | 150.0725 | 38.1 | 40282 | NAMBOUR DPI | -26.6431 | 152.9392 | 51.1 |
| 39123 | GLADSTONE RADAR | -23.8553 | 151.2628 | 36.5 | 40308 | MT GLORIOUS FAHEY RD | -27.3342 | 152.7717 | 30.6 |
| 39128 | BUNDABERG AERO | -24.8885 | 152.3235 | 24.7 | 40312 | NEW BEITH | -27.7356 | 152.9442 | 31.6 |
| 39140 | BUILYAN FORESTRY | -24.5333 | 151.3833 | 16.9 | 40406 | BEENLEIGH BOWLS CLUB | -27.7094 | 153.2014 | 35.7 |
| 39297 | BUILYAN GUM STREET | -24.5272 | 151.3814 | 21.8 | 40458 | CAPALABA WATER TREAT | -27.5314 | 153.1825 | 34.3 |
| 39303 | CHILDERS SOUTH | -25.2558 | 152.2819 | 26.6 | 40459 | CARINA BCC DONALDSON RD | -27.5 | 153.1 | 17.3 |
| 39314 | TOWN OF 1770 | -24.1542 | 151.8875 | 16.3 | 40460 | MOUNT COTTON UNI FARM | -27.6081 | 153.2381 | 33.1 |
| 40004 | AMBERLEY AMO | -27.6297 | 152.7111 | 43.8 | 40461 | FERNY HILLS AUST WOOLSHED | -27.3947 | 152.9308 | 32.3 |
| 40014 | BEAUDESERT | -28.0206 | 153.0131 | 36.8 | 40469 | MARODIAN HOMESTEAD | -25.8694 | 152.3172 | 33.7 |
| 40019 | BENARKIN FOREST STATION | -26.9 | 152.15 | 19.4 | 40496 | CALOUNDRA WATER TREAT | -26.7928 | 153.1286 | 32.8 |
| 40059 | COOROY COMPOSITE | -26.4181 | 152.9128 | 32.9 | 40537 | DUNWICH | -27.4969 | 153.4078 | 20.2 |

| Station ID | Site name | Latitude | Longitude | Data Length, yr | Station ID | Site name | Latitude | Longitude | Data Length, yr |
|---|---|---|---|---|---|---|---|---|---|
| 40062 | CROHAMHURST | -26.8094 | 152.87 | 28.3 | 40584 | HINZE DAM | -28.0481 | 153.2875 | 31.5 |
| 40063 | DAYBORO POST OFFICE | -27.1967 | 152.8247 | 28.9 | 40606 | UPPER MUDGEERABA WATER | -28.1056 | 153.3289 | 30.7 |
| 40082 | UNIVERSITY OF QUEENSLAND GATTON | -27.5436 | 152.3375 | 46.2 | 40609 | ELANORA WATER TREAT | -28.1181 | 153.4456 | 30.4 |
| 40093 | GYMPIE | -26.1831 | 152.6414 | 22.8 | 40659 | GREENBANK THOMPSON ROAD | -27.6958 | 152.9408 | 28.7 |
| 40094 | HARRISVILLE POST OFFICE | -27.8117 | 152.6675 | 34.8 | 40677 | MAROON DAM | -28.1753 | 152.6553 | 27.8 |
| 40106 | KENILWORTH TOWNSHIP | -26.595 | 152.7236 | 19.6 | 40715 | SHAILER PARK OREGON DRVE | -27.6511 | 153.1933 | 17.1 |
| 40111 | KILKIVAN POST OFFICE | -26.0861 | 152.2381 | 33.9 | | | | | |

### 3.1.2 The Department of Natural Resources and Water (DNRW) Data

Fine timescale data are not available for all stations throughout Australia. Also, the data lengths vary quite substantially among the stations where fine timescale data are available. Synthetically produced data can provide uniform data lengths throughout the stations in a region. A source of such synthetic rainfall data is the SILO Data Drill maintained by the Department of Natural Resources and Water (DNRW), Queensland (http://www.nrw.qld.gov.au/silo/datadrill/index.html). The SILO Data Drill is a database that generates long term (1889 to date) synthetic daily rainfall data at any location within the Australian continent.

Three BOM rainfall stations from Table 3.1 have been selected for the synthetic data analyses. These were Rockhampton, Dingo and Brisbane in Queensland with BOM Station ID 39083, 35025 and 40214 respectively. This research used the synthetic daily data for these three stations from 1889 to 2006.

### 3.1.3 The Gregory Field Data

As part of erosion control studies on a railway embankment, under the banner of HEFRAIL Project (Gyasi-Agyei, 2005), rainfall data at 1-minute timescale were collected at the Gregory field trial site (Gyasi-Agyei, 2003, 2004; Gyasi-Agyei et al., 2001). The Gregory field trial site is situated between 8.450 and 8.750 km marks on the Gregory railway line, Central Queensland. The coordinates of the site are latitude 23.55 S and longitude 148.70 E. Tipping bucket pluviometers of a resolution of 0.18 mm were used. The data length of the Gregory site for this research is 9 years (from January 1998 to December 2006). These 9 years data were aggregated to 6-minute timescale to conform to the BOM data.

### 3.2 Rainfall Statistics

The first and second order properties from the observed 6-minute rainfall data (mean, variance, Lag-1, 2 and 3 autocorrelation, dry probabilities, duration, Lag-1, 2 and 3 auto covariance) are calculated for 12 aggregation levels (0.1, 0.2, 0.3, 0.5, 1, 2, 4, 6, 8, 12, 18 and 24 hour) and for each month of the year. The time series of all aggregation levels are generated sequentially for each month.

A brief description of each of these rainfall statistics and how they are calculated is given in the following sections.

#### 3.2.1 Mean

The Mean is defined as the sample average of the corresponding time series for the specified month at a specified aggregation level. For the rainfall time series, the mean is defined as:

$$\text{Mean, } \bar{X} = \frac{\sum X_t}{N} \tag{3.1}$$

where $X_t$ is the rainfall depth of the time series for the specified month at a specified aggregation level and $N$ is the number of sample data of the corresponding month and aggregation level.

### 3.2.2 Variance

The Variance is defined as the sum of the squared deviations for the corresponding aggregation values from their mean divided by $N$ -1. The variance of the rainfall series is defined as:

$$\text{Variance,} \quad \sigma^2 = \frac{\sum (X_t - \bar{X})^2}{N-1} \tag{3.2}$$

This is the variance of the specified month which the time series corresponds to.

### 3.2.3 Autocovariance

Autocovariance is defined as the serial covariance function at a time lag of the same time series.

$$\text{Autocovariance at Lag } \tau,\ C_\tau = \frac{1}{N-1} \sum (X_t - \bar{X})(X_{t+\tau} - \bar{X}) \tag{3.3}$$

For example, in the 6-minute Lag-2 Autocovariance equation, $X_t$ is the rainfall data of the first interval and $X_{t+2}$ is the rainfall data lagging every two intervals from the first one.

### 3.2.4 Autocorrelation

Autocorrelation is defined as the serial correlation function at a time lag of the same time series.

$$\text{Autocorrelation at Lag } \tau, \rho_\tau = \frac{\text{Covariance of } X_t, X_{t+\tau}}{(\text{Standard Deviation of } X_t)(\text{Standard Deviation of } X_{t+\tau})} \tag{3.4}$$

When the size of the sample becomes very large (>>100), the standard deviation would be the same for both $X_t$ and $X_{t+\tau}$ for any time series. In that case, the Autocorrelation equation reduces to:

$$\text{Autocorrelation at Lag } \tau = \frac{\text{Covariance of } X_t, X_{t+\tau}}{(\text{Variance of } X_t)}$$

$$= \frac{C\tau}{\sigma^2} \tag{3.5}$$

In the 6-minute Lag-2 Autocorrelation equation, $X_t$ is the rainfall data of the first interval and $X_{t+2}$ is the rainfall data lagging every two intervals from the first one.

### 3.2.5 Dry Probability

The Dry Probability is defined as the frequency of occurrence of the dry intervals in a specified aggregation level time series. For example, the 6-minute Dry Probability can be defined as:

$$\text{6- minute Dry Probability, } P(h) = \frac{\text{Number of 6-minute dry intervals}}{\text{Total number of intervals in the 6-minute time series}} \tag{3.6}$$

where $h$ is aggregation timescale in hours, e.g., 6-minute Dry Probability is written as $P(0.1)$. The Dry Intervals denote the intervals with "Zero" rainfall or no rain.

### 3.2.6 Duration

The Duration is defined as the average duration of storm events for a specified aggregation level time series. The average duration of the 6-minute rainfall event can be defined as:

$$\text{6-minute average Rainfall Duration} = \frac{\text{Sum of the durations of 6-minute events}}{\text{Number of 6-minute events}} \tag{3.7}$$

Table 3.2 shows the first and second order rainfall properties for the first station of Table 3.1 with station ID 35000 for the month of January for all aggregation levels.

**Table 3.2 Properties of Historical 6-minute Rainfall Data for station 35000 for January**

| Aggregation Level, hr | Mean, mm | Variance, mm$^2$ | Autocorrelation | | | Dry Probability (-) | Duration (hr) | Autocovariance | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lag-1 | Lag-2 | Lag-3 | | | Lag-1 | Lag-2 | Lag-3 |
| 0.1 | 0.009031 | 0.03239 | 0.7954 | 0.5828 | 0.4702 | 0.9766 | 1.978 | 0.02577 | 0.01888 | 0.01523 |
| 0.2 | 0.006547 | 0.01241 | 0.759 | 0.5425 | 0.446 | 0.9767 | 2.572 | 0.00942 | 0.006733 | 0.005535 |
| 0.3 | 0.005172 | 0.007808 | 0.7457 | 0.5079 | 0.3609 | 0.9846 | 1.252 | 0.005823 | 0.003966 | 0.002818 |
| 0.5 | 0.000976 | 0.001222 | 0.607 | 0.3403 | 0.1909 | 0.9951 | 1.057 | 0.000742 | 0.000416 | 0.000233 |
| 1 | 0.00371 | 0.006666 | 0.8069 | 0.562 | 0.4445 | 0.9875 | 1.324 | 0.005379 | 0.003746 | 0.002963 |
| 2 | 0.002234 | 0.00199 | 0.6753 | 0.4251 | 0.3176 | 0.9883 | 3.348 | 0.001344 | 0.000846 | 0.000632 |
| 4 | 0.001672 | 0.002365 | 0.5049 | 0.3322 | 0.2546 | 0.9934 | 1.199 | 0.001194 | 0.000786 | 0.000602 |
| 6 | 0.001794 | 0.001639 | 0.666 | 0.3682 | 0.2435 | 0.9894 | 2.067 | 0.001092 | 0.000604 | 0.000399 |
| 8 | 0.001895 | 0.003405 | 0.7228 | 0.4589 | 0.3623 | 0.9937 | 1.146 | 0.002461 | 0.001562 | 0.001234 |
| 12 | 0.005362 | 0.01328 | 0.7282 | 0.4399 | 0.3235 | 0.9828 | 1.626 | 0.009667 | 0.00584 | 0.004294 |
| 18 | 0.006113 | 0.01322 | 0.685 | 0.4361 | 0.3075 | 0.9829 | 1.58 | 0.009058 | 0.005767 | 0.004067 |
| 24 | 0.009156 | 0.02797 | 0.77 | 0.5403 | 0.3826 | 0.9804 | 1.118 | 0.02154 | 0.01511 | 0.0107 |

The next chapter presents the details of the stochastic model used in this research.