DEPARTMENT OF CIVIL ENGINEERING

Water Resources Research Group

Software Profile

A User Manual for RADGAP

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RADGAP
(Radar Gauge Adjustment Program)

A program for adjusting distributed radar rainfall data estimates by raingauge rainfall data, incorporating two-dimensional surface fitting and interpolation procedures.

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Acknowledgements

RADGAP was developed exclusively as part of a three-year (1988-1990) research and development project (Anglian Radar Information Project, 'ARIP') with the Anglian Region of the National Rivers Authority. The author expresses his gratitude to the all involved with the project and especially the hydrologists in the Region who provided data for the study.

1. Introduction

This manual is a report in a series of Technical Reports produced by the Water Resources Research Group at the Department of Civil Engineering, University of Salford.

The manual is a reference to the software package known as RADGAP (Radar Gauge Adjustment Program), a program for adjusting distributed radar rainfall data by raingauge data which incorporates two-dimensional surface fitting and interpolation algorithms. The report begins by stating the software specification and goes on to discuss the input files required. After a brief conceptual introduction to the adjustment procedure, the structure of RADGAP is described and illustrated with a flowchart and an example run-time session described. Annotated samples of the input datafiles are included. Whilst the report concentrates on a single example (National Rivers Authority, Anglian Region, Northern Area), RADGAP has been designed and structured so that customisation and implementation in other areas is straightforward and a chapter is dedicated to this.

The Appendices provide a source listing of the program together with a hard copy listing of example input datafiles. The datafiles accompany the program on the distribution disk and may be used to replicate the run-time example in the report main body. User input datafiles should exactly replicate the format of the example datafiles.

This manual is not a definitive guide to the interpolation and surface fitting routines used. Further information can be found in the references listed in the bibliography.

The Water Resources Research Group would welcome any comments on this Software Profile. Please contact Professor Ian Cluckie at the address on the front of the report.

2. Typography and Flow Chart Symbols

The body of this manual is printed in a normal (Times font) typeface; other typefaces have special meanings.

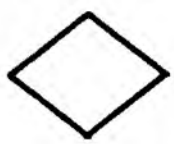
`courier` is used for the listings of the program, datafiles and screen output. **`Bolded courier`** represents interactive user keyboard input whilst annotated comments of source code and datafile listings are made in **bolded times**.

The program structure is illustrated by a flowchart and described (summarised) textually. Algorithms are described in terms of steps such as input, output and computations. Decisions are made by testing Boolean expressions that are evaluated to be true or false. The flowchart symbols for these processes, along with a symbol to indicate beginning and end are:

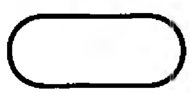
Assignments or computations

Input or output

Boolean expressions



Start or stop



3. Software Specification and System Requirements

RADGAP is an interactive, graphically based FORTRAN program. The software is coded in ANSI FORTRAN 77 and has been developed on a Digital Electronic Company (DEC) MicroVAX II minicomputer using VMS v5.4 and VAX FORTRAN 77 v5.5. The code utilises some VAX FORTRAN 77 implementations (extensions) and this should be considered before attempting to port the code to a different environment.

The two-dimensional interpolation and surface fitting algorithms are part of the Numerical Algorithms Group (Mark 14) Fortran Library[1].

Graphics play an integral role in the presentation of results in RADGAP and are facilitated by UNIRAS Graphics Software[2] package (Version 6.0). UNIRAS graphics modules are upwardly compatible with subsequent releases of UNIRAS. UNIRAS graphics modules are machine independent and can be implemented on a wide range of machines. A menu of devices for which the graphics elements of the software have already been implemented prompt the user to indicate the device on which the software is running enabling the correct device driver to be software selected. Implementation for new devices is straightforward if a UNIRAS driver for the device is available. It is envisaged that incorporation of an alternative graphics package (capable of producing two-dimensional colour surface plots) into RADGAP would be straightforward.

[1] Numerical Algorithms Group Ltd, Wilkinson House, Jordan Hill Road, Oxford, OX2 8DR, UNITED KINGDOM
NAG Inc, 1400 Opus Place, Suite 200, Downers Grove, IL 60515-5702, USA.

[2] UNIRAS A.S.,376 Gladsaxevej, DK-2860 Søborg, DENMARK
UNIRAS Ltd, Ambassador House, 181 Farnham Road, Slough, SL1 4XP, UNITED KINGDOM.

4. Adjustment of Distributed Radar Rainfall Estimates by Raingauge Data

Increasing attention has focussed on the incorporation of sophisticated (and usually complex) two-dimensional interpolation and surface fitting algorithms into procedures designed to improve the reliability and accuracy of radar rainfall estimates. The philosophy underlying such schemes is that the point accuracy of raingauges can be combined with the high spatial resolution of the radar data to derive an adjusted rainfall field which portrays the actual spatial rainfall field with higher accuracy than either of the rainfall fields in isolation. This chapter describes a routine which adjusts radar rainfall images for a particular predefined area, using raingauge data. The report is not judgmental and does not state the accuracy, reliability, shortcomings or advantages of this technique over other methods, and neither vindicates nor criticises the validity of this form of radar adjustment.

4.1. Radar Rainfall Adjustment Using Raingauge Data

The raingauge-based radar rainfall adjustment procedure is conceptually simple and can be considered as a three phase process. The phases can be summarised as:

- computation of assessment factors at each of the raingauge locations.
- two dimensional surface fitting of the scattered assessment factors. This results in a regularly distributed assessment factor field on a grid coincident with the cartesian grid used by the radar (5 km grid).
- node by node multiplication of the unadjusted radar data by the 'mapped' assessment factors to produce an adjusted rainfall field.

Each phase in the process is shown schematically in figure 1.

The approach is essentially stochastic because no attempt is made to relate or modify the assessment factors by physically related factors e.g. synoptic type, altitude, distance from sea, or prevailing wind direction / strength, although it would be possible to incorporate explanatory variables into the surface fitting algorithm. Consequently the technique differs from the raingauge-based adjustment approach used by the Meteorological Office which uses a system of physiographically defined adjustment domains and storm type identification algorithms. Where the raingauge network is reasonably dense, a considerable amount of information regarding rainfall at particular points (i.e. the raingauge locations) is available and can therefore be implicitly incorporated into the adjusted radar rainfall field.

4.1.1. Assessment Factors

Assessment factors are derived at each of the raingauge locations. The most basic form of the assessment factor is the simple ratio of radar rainfall value to raingauge rainfall value shown in eq 4.1:

$$AF = \frac{G}{R} \qquad \text{eq. 4.1}$$

where AF = assessment factor, G is the raingauge rainfall value and R the radar rainfall value.

In order to overcome discontinuities in this form when $R=0$, an amended form shown in eq 4.2. is used. Selection of the constants ρ and λ is not straightforward and is important since the constants have a direct influence on the value of the assessment factors. In the interests of generality this report assigns values of unity to both parameters (parameter optimisation would improve the assignment, and this should be carried out on the data on which the adjustment is to be based). It is worth noting that many other definitions of assessment factors can be derived (e.g. see Moore, *et al.*, 1989) though the benefits of alternative forms are difficult to assess. The representativeness of different forms of assessment factors remains unresolved and is still the subject of ongoing investigation. Incorporation of a different form of assessment factor in RADGAP would be straightforward.

$$AF_i = \frac{G_i + \lambda}{R_i + \rho} \quad \text{for } i=1,\ldots,n \qquad \text{eq. 4.2}$$

where there are n raingauges.

It should be noted that tipping bucket raingauges inherently have a quantisation error, the magnitude of which is a function of the bucket size. The two most common bucket capacities are 0.2 mm and 0.5 mm (equivalent rainfall depth), the maximum quantisation error associated with these being 0.8 mm/hr and 2.0 mm/hr respectively. No form of quantisation correction component has been included in the assessment factor definition.

Although the assessment factors can be formed over any time (limited only by the temporal resolution of the rainfall data), preliminary studies indicate that a cumulation period of one hour produces reasonable results and cumulation over this duration reduces the number of occasions where there is no or minimal rainfall (thereby reducing error in the assessment factor).

4.1.2. Two-Dimensional Interpolation and Surface Fitting

This section introduces three two-dimensional algorithms, one for surface fitting and the two for interpolation, all of which are supported by RADGAP. All the algorithms work with irregularly distributed data (although many solutions to related problems in two-dimensional interpolation have been in long use, interpolation functions making an exact fit for irregularly spaced data are rare [when the data points are on a regular grid, many solutions are possible]). The interpolation algorithm (the user selects at run-time which of the two algorithms is to be used for interpolation) is not explicitly used for radar adjustment but to derive a representation of the spatial rainfall field from the point raingauge data facilitating a visual comparison of the radar and raingauge rainfall fields. The surface fitting routine is used to map the irregularly distributed assessment factors to a regular grid coincident with the cartesian grid of the radar data.

The fundamental problem that any interpolation or surface fitting procedure for two-dimensional data scattered in the plane addresses is the following (after Renka and Cline, 1984):

> '...given a set of nodes (abscissae) $(x_i, y_i,)$ arbitrarily distributed in the x-y plane, with corresponding ordinates z_i, $i=1,2,...,M$, construct a bivariate function $F(x,y)$ which interpolates/fits a surface to, the data values, i.e., $F(x_i, y_i,)=z_i$, $i=1,2,...,M$...'.

The problem arises in the case of raingauge rainfall estimates where the information usually derives from points whose locations are determined logistically rather than as a result of network optimisation considerations. Thus, in practice most existing operational raingauge networks can be considered as randomly distributed as regards the observed rainfall process.

Regardless of the algorithm used, a satisfactory fit cannot be expected if the number and arrangement of the data points do not adequately represent the character of the underlying relationship. Ideally data points should extend over the whole domain of interest of the independent variable and extrapolation outside the data ranges is most unwise. It is advantageous to have additional points near the boundaries of the estimation domains, and also in special interest, high priority regions.

4.1.2.1. Surface Interpolation

A smooth interpolatory surface is often desired when a visual impression of the surface is required. The main requirements for an interpolation scheme are (Shepherd, 1968):

- the two dimensional interpolation function is to be 'smooth'.
- the interpolated surface must pass exactly through the specified data points.
- the interpolated surface should meet the user's intuitive expectations (about the phenomenon under investigation).

Two interpolation procedures are described and either can be used in RADGAP. The description will aid any choice in the routine used, though personal preference established from trial and error will inevitably also play a role in algorithm selection. Interpolation methods may be either local or global. In a global method the interpolant is dependent on all the data points regardless of their distance from the interpolation point, whereas in a local method, the interpolant does not depend on data points more than a certain distance from the interpolation point. Often a local method is used to avoid prohibitive computation time, although for rainfall, especially localised convective storms, a global method would not be appropriate.

Renka and Cline Method

This routine constructs an interpolating surface $F(x,y)$ through a set of M scattered data points (x_r, y_r, f_r), for $r=1,2,...M$, using a method due to Renka and Cline. In the (x,y) plane, the data points must be distinct. The constructed surface is continuous and has continuous first order derivatives.

The method involves firstly creating a triangulation with all the (x,y) data points as nodes, the triangulation being as nearly equi-angular as possible (Cline and Renka, 1984). Then gradients in the x- and y-directions are estimated at node r, for $r=1,2,....M$, as the partial derivatives of a quadratic function of x and y which interpolates the data value f_r, and which fits the data values at nearby nodes (those within a certain distance chosen by the algorithm) in a weighted least square sense. The weights are chosen such that closer nodes have more influence than more distant nodes on derivative estimates at node r. The computed partial derivatives, with the f_r values, at the three nodes of each triangle define a piecewise polynomial surface of certain form which is the interpolant on that triangle. More detailed information on the algorithm is provided in Renka and Cline (1984), Lawson (1977), and Renka (1984).

The interpolant $F(x,y)$ can be subsequently evaluated at any point (x,y) inside or outside the domain of the data in the second stage routine (see below). Points outside the domain of the data are determined by extrapolation.

The second stage routine computes the interpolant for a specified grid. The routine takes as input the parameters defining the interpolant $F(x,y)$ of a set of scattered data points (x_r, y_r, f_r), for $r=1,2,...M$, and evaluates the interpolant at the point (px,py). If (px,py) is equal to (x_r, y_r) for some value of r, the returned value will be equal to fr. If (px,py) is not equal to (x_r, y_r) for any r, the derivatives passed to the routine are used to compute the becomes approximately proportional to M^2.

The radii R_w and R_q are computed as:

$$\frac{D}{2}\sqrt{\frac{N_w}{M}} \text{ and } \frac{D}{2}\sqrt{\frac{N_q}{M}} \qquad \text{(eq. 4.4)}$$

where D is the maximum distance between any pairs of data points.

Default values N_w=9 and N_q=18 work quite well when the data points are fairly uniformly distributed. However, for data having some regions with relatively few points or for small data sets (M<25), a larger value of N_w may be needed. This is to ensure a reasonable number of data points within a distance R_w of each node, and to avoid some regions in the data area being left outside all the discs of radius R_w on which the weights $w_r(x,y)$ are non-zero. Maintaining N_q approximately equal to $2.N_w$ is usually an advantage. Increasing N_w and N_q does not improve the quality of the interpolant in all cases: it does increase the computational time and makes the method less local.

The interpolant $F(x,y)$ can be subsequently evaluated at any point (x,y) inside or outside the domain of the data in the second stage routine (see below).

The second stage routine computes the interpolant for a specified grid. The routine takes as input the parameters defining the interpolant $F(x,y)$ of a set of scattered data points (x_r,y_r,f_r) for $r=1,2,...,M$, and evaluates the interpolant at the point(px,py). If (px,py) is equal to (x_r,y_r) for some value of r, the returned value will be equal to f_r. If (px,py) is not equal to (x_r,y_r) for any r, all points that are within a prescribed distance of(px,py), along with the corresponding nodal functions will be used to compute a value of the interpolant.

4.1.2.2. Surface Fitting

The main constraint applied to the interpolation schemes described in section 4.1.2.1. is that the interpolating function passes exactly through each of the data points. Though an exact rendition of the rainfall field at the sampled points is ensured, it can in the case of rainfall result in a contorted surface. This is because the rainfall process is spatially dynamic (i.e. may be highly localised) and discontinuous. If this constraint is relaxed such that the interpolation function need not fit the given values exactly, trend surface fitting (Krumbein, 1959) may be appropriate. An advantage of this approach is that distortion of the rainfall field arising from possible random error in the data (measurement / observation error) may be reduced. Many surface fitting procedures, including the one described, provide user control of the smoothness of fit / closeness of fit balance by way of a smoothness parameter.

Bicubic Spline Surface Fitting

The knots of the spline are located automatically, but a single parameter must be specified to control the trade-off between closeness of fit and smoothness of fit.

The routines determine a smooth bicubic spline approximation $s(x,y)$ to the set of data points (x_r, y_r, f_r) with weights w_r for $r=1,2,...,m$ (scattered data only). The approximation domain is considered to be the rectangle $[x_{min}, x_{max}]*[y_{min}, y_{max}]$, where $x_{min}(y_{min})$ and $x_{max}(y_{max})$ denote the lowest and highest data values of $x(y)$, though the domain can be extended by augmenting the data with two artificial data points $(a,c,0)$ and $(b,d,0)$ with zero weight, where $[a,b]*[c,d]$ denotes the enlarged approximation rectangle.

The spline is given by the B-spline representation:

$$s(x,y) = \sum_{i=1}^{n_x-4} \sum_{j=1}^{n_y-4} c_{ij} M_i(x) N_j(y)$$

(eq. 4.5)

where $M_i(x)$ and $N_j(y)$ denote normalised B-splines, the former defined on the knots l_i to l_{i+4} and the latter on the knots m_i to m_{i+4}. The total numbers n_x and n_y of these knots and there values $l_1,...,l_{n(x)}$ and $m_1,...,m_{n(y)}$, are chosen automatically by the routine. The knots $l_5,...,l_{n(x)-4}$ are the interior knots; they divide the approximation domain $[x_{min}, x_{max}]*[y_{min}, y_{max}]$, into $(n_{x-7})*(n_{y-7})$ subpanels $[l_i, l_{i+1}]*[m_i, m_{i+1}]$, for $i=4,5,...,n_{x-4}$; $j=4,5,...,n_{y-4}$. Then, the coefficients c_{ij} are determined as the solution of the following minimisation problem:

minimise

η, subject to the constraint:

$$\theta = \sum_{r=1}^{m} \varepsilon_r^2 \leq S$$

(eq. 4.6)

where:

η is a measure of the (lack of) smoothness of $s(x,y)$. Its value depends on the discontinuity jumps in $s(x,y)$

across the boundaries of the subpanels. It is zero only where there are no discontinuities and is positive otherwise, increasing with the size of the jumps.

ε_r denotes the weighted residual $w_r(f_r - s(x_r, y_r))$.

S is a non-negative number specified by the user.

By means of the parameter S, the 'smoothing factor', the balance between smoothness and closeness and of fit, as measured by the sum of the squares of the residual in eq. 4.6. can be controlled. If S is too large, the spline will be too smooth (underfit) and if S is too small the spline will pick up too much noise (overfit) In the extreme cases the method returns an interpolating spine $(\theta=0)$ i.e. if S is set very small, and returns the least squares bicubic polynomial $(\eta=0)$ if S is set very large. Determination of the best value of S involves an adaptive search for locating the knots of the bicubic spline (depending on the function underlying the data and on the value S), and an iterative method for solving the constrained minimisation problem once the knots have been determined.

First suitable knot sets are built up in stages (starting with no interior knots). At each stage a bicubic spline is fitted to the data by least-squares and θ, the sum of the squares of the residuals is computed. If $\theta > S$, a new knot is added to one knot set or the other so as to reduce θ at the next stage. The new knot is located in an interval where the fit is particularly poor. When $\theta \leq S$ the knot sets are accepted. The routine goes on to compute a spline which has these knot sets and which satisfies the full fitting criterion specified by the minimisation requirement. The theoretical solution has $\theta=S$. The routine computes the spline by an iterative scheme which is ended when $\theta=S$ within a relative tolerance (of 0.001). The main part of each iteration consists of a linear least-squares computation of the special form. If the routine finds that even with no interior knots $(N=8)$, the least squares spline already has its sum of squares of residuals $\leq S$. In this case, since this spline (simply a bicubic polynomial) also has an optimal value for the smoothness measure η, namely zero, it is returned at once as the trivial solution (usually meaning S has been chosen too large). The timing of the routine depends on the complexity of the shape of the data, the value of the smoothing factor S, and the number of data points. Choosing S to be very small significantly increases the computation time.

Values of the computed spline are subsequently computed using a second phase evaluation routine (as with the routines described in section 4.2.1.1.).

4.1.3. Adjustment of the Radar Rainfall Estimates

Adjustment of the radar rainfall estimates takes place on a cell by cell basis for all cells within the predefined adjustment domain. For each cell, the unadjusted radar cell is multiplied by the assessment factor for that particular cell, resulting in an adjusted cell value (eq. 4.7):

$$(R_{adj})_i = (R_{unadj}) AF_i \quad \text{for } i=1,\ldots,n \qquad \text{(eq. 4.7)}$$

where:

R_{adj} value of adjusted radar cell i

R_{unadj} value of unadjusted radar cell i

AF_i assessment factor for cell i (as defined in equation 4.2),

and there are n cells in the adjustment domain.

The form of assessment factor utilised (eq. 4.2. and eq. 4.7) implicitly assumes that at each raingauge location, the raingauge rainfall amount is correct and differences between the raingauge value and value of the overlying radar grid square are attributed to radar estimation error.

Simplified examples for four different adjustment cases are shown in figure 2. Each of the examples show a rainfall cell passing through an area where there are three raingauges.

Case 1: The cell is located between all three raingauges which consequently register no rainfall. The radar cells overlying each raingauge also do not detect any rain. The assessment factor at each of these locations is therefore unity, the assessment factor field also has the spatially constant value of unity, and the adjusted radar field is identical to the unadjusted radar field in this region.

Case 2: The cell falls on one of the raingauges (G_3) which measures 10 units of rainfall. The radar cell overlying this raingauge also detects 10 units of rain. At the other two raingauge locations, no rain is detected either by raingauge or radar. The assessment factor at each of these locations is unity, the assessment factor field once again has the spatially constant value of unity, and the adjusted radar field is identical to the unadjusted radar field in this region.

Case 3: The cell falls on one of the raingauges (G_3) which measures 5 units of rainfall whilst the radar cell overlying this raingauge detects 10 units of rain. At the other two raingauge locations, no rain is detected either by raingauge or radar. The assessment factor at the first location is 0.55, and at the other two locations, unity. The assessment factor field therefore slopes from a value of unity to a value of 0.55 in the vicinity of the first raingauge. The adjusted radar field differs from the unadjusted radar field, the radar cell overlying G_3 having a value of 5.5 (reduced from 10 units).

Case 4: The cell falls on one of the raingauges (G_3) which measures 10 units of rainfall whilst the radar cell overlying this raingauge detects 5 units of rain. At the other two raingauge locations, no rain is detected either by raingauge or radar. The assessment factor at the first location is 1.83 and at the other two locations, unity. The assessment factor field therefore slopes from a value of unity to a value of 1.83 in the vicinity of the first raingauge. The adjusted radar field differs from the unadjusted radar field, the radar cell overlying G_3 having a value of 9.15 (increased from 5 units).

4.2. Other Information

Figure 3 shows the adjustment domain used for the National Rivers Authority, Northern Area.

The boundaries of the adjustment domain should be set-up so that adjustment takes place over the entire area of interest. Since regions are invariably not rectilinear but tend to follow political or natural boundaries, this invariably entails domain extension so that the adjustment domain covers the entire region. The surface fitting algorithm described in section 4.2.1.2 makes provision for the addition of additional data points with zero weight which can be used to extend the fitting domain. However in this case, the use of the mask around the area boundary (see following paragraph) effectively extends the domain (see figure 3) and additional points are not required. Ensuring that the domain extends (encloses) beyond the area boundary at all points means that the domain remains constant even though the number and locations of raingauge data available may vary.

Radar cells outside of the adjustment domain are not adjusted, since extrapolation of the assessment factor surface beyond the limits of the adjustment domain (and hence area of raingauge coverage) could result in large errors.

A problem frequently encountered when fitting polynomials is their tendency to develop fluctuations. In order to counteract this when fitting a surface to the assessment factor data, a mask is applied around the boundary of the adjustment domain (see figure 3), all cells falling within the mask are assigned an assessment factor value of unity (equivalent in adjustment terms to no change). Though not perfect (false gradients may be introduced in the surface, e.g. if all assessment factors inside the domain are, say, 0.2, the values of the field near to the boundary will be larger due to the field attempting to fit the larger value [of 1.0] in the mask, resulting in a dish-like surface), this simple technique does promote stability in the surface. In the future a more sophisticated technique may be incorporated. With polynomial fitting functions fluctuations become less likely as the number of terms in the polynomial function is reduced, although the fitting accuracy falls as a consequence. Another technique which is commonly applied to help avoid unwanted fluctuations in the fitted surface (e.g. if there are few sampled points), is data transformation (e.g. logarithmic). However preliminary trials suggest that instabilities which may arise are not severe enough to warrant such an approach.

The assessment factor defined in eq. 4.7. is unbounded and may therefore have extreme values (especially in the case of raingauge failure). This is unsatisfactory, and for reasons of stability, the assessment factor is constrained between 0.1 and 10 (corresponding to a ten-fold reduction in radar rainfall and a ten-fold increase in radar rainfall). Limiting the irregularly distributed assessment factors to this range is no guarantee that the assessment factor surface will be similarly bounded and the limit is subsequently applied to the surface. Similarly, it is possible for the interpolation function of the raingauge rainfall data to produce negative values. Since this is physically unreasonable, such values are reset to zero before graphical output (i.e. no rainfall).

5. Program Structure and Data Requirements

This chapter describes the structure of RADGAP, and the input datafiles it uses.

5.1. Structure

The program consists of small main segment, with most data handling, interaction and graph drawing being handled by subroutines. A full source code listing of RADGAP is provided in Appendix 1. The program flowchart in figure 4 illustrates the program structure which is also outlined below:

- Character and array initialisation
- Welcome message
- Runtime Options
- Establishment of date and time period for adjustment, and (implicitly) datafile names.
- Read and process raingauge rainfall data
- Data processing and adjustment domain set-up
- Main loop
    - Raingauge rainfall data processing
    - Read radar rainfall data
    - Compute assessment factors at raingauge location
    - Fit surface to assessment factor points
    - Node-by-node adjustment of radar rainfall data
    - Interpolation of raingauge rainfall data
    - Graphical presentation
- End of main loop
- Graphical display of cumulated rainfall data and mean assessment factor fields.

5.2. Input Datafiles

The program utilises raingauge and radar rainfall inputfiles, and files holding coastline and political boundary data.

The format of the raingauge rainfall input datafile is shown in figure 5, and an example file is listed in Appendix 2. Essentially the file comprises of 15 minute rainfall depths for a 24 hour period, for all available raingauges in the region. The file has a ten line header block which records the nature of the data, the date, number of stations, data time period, and data interval. Rainfall data for each raingauge follows sequentially, raingauge after raingauge. Each raingauge has a two line sub-header which shows the raingauge reference code, and the gauge location in national grid coordinates.

In contrast to the single raingauge input file, a number of radar rainfall input datafiles are used. This is because the radar data have to be pre-cumulated before RADGAP, so, for example, hourly adjustment over a 24-hour period necessitates 24 radar input files. Each hourly cumulation is stored as an unformatted file and can therefore be read as an unformatted (84*84) two-dimensional array. The filenames are time stamped so that RADGAP can recognise the appropriate files. It should be noted that RADGAP automatically checks whether the radar datafiles exist. If some are absent, for example due to radar failure, they are not listed on the duration selection screen.

It should be ensured that corresponding raingauge and radar rainfall data are processed, and that the files are appropriately structured and named.

The interpolation algorithms sends warning messages to an output file (for010.dat) when interpolation is taking place for points more than a certain distance from raingauge locations (extrapolation). The messages can be safely ignored (as long as the user is aware of the consequences of extrapolating raingauge data by an interpolating surface) and is advised to delete this file regularly, since it can reach sizeable proportions.

5.3. Include File

In order to simplify the program structure, introduce generality, and make application to different areas as straightforward as possible, all the major program parameters are held in a subsidiary include file 'radgap.inc' (see Appendix 2 for an example). When RADGAP is being used for the Northern Area referred to throughout this report, the user need only ensure that the correct value of *nstat* is used (this value can be changed by editing the include file) and should always be checked before running RADGAP. Further information on the parameters held in the include file and application of RADGAP to other areas can be found in Chapter 7.

5.4. Presentation of Results

Four fields are optionally presented by RADGAP in the form of two-dimensional colour or black-and-white filled contour plots. These are:

- unadjusted radar rainfall image (mm depth units)
- adjusted radar rainfall image (mm depth units)
- assessment factor surface (dimensionless)

- interpolated raingauge rainfall surface (mm depth units).

All the rainfall fields use the same slicing scale for ease of comparison.

Presentation of these fields can take place each hour, at the end of the adjustment period (or both), the choice being made by the user at run-time. If hourly graphical output is required, two operational modes are accommodated. In the first the user is required to press the return key at the end of each hour before RADGAP adjusts and displays data for the next hour, or alternatively an auto-refresh option is available, whereby the program continues automatically until the end of the adjustment period is reached.

6. Running the Program

This chapter describes run-time execution of RADGAP. A run-time listing of the program user-interface during run-time is provided in Appendix 4. RADGAP is straightforward to use and the information required of the user at run-time is limited to selection of certain run-time options, and the adjustment date and time period. Referral to the program flow chart (figure 4) may aid the reader.

6.1. Device Type

At present five devices are supported by RADGAP for graphical output (i.e. the device names appear in a program menu). However the machine independency of UNIRAS coupled with the large number of device drivers available means that RADGAP will run on many different device types. If you wish to run RADGAP on a device not displayed on the program menu contact the Water Resources Research Group indicating the UNIRAS (GROUTE) driver name for the device. This will then be incorporated in the code for a subsequent release version. See Appendix 5 for a list of the devices currently supported.

6.2. Option Menu

There is limited flexibility in graphical output produced by RADGAP. Graphs can be displayed for each adjustment hour, or just at the end of the adjustment period. If both are required, the user can specify auto refresh whereby the graphical output is automatically updated as data are adjusted. Alternatively, the user is required to press the return key at the end of each hour for the program to continue to the next adjustment hour. The user can select at run-time whether the graphical output is colour or black-and-white. The choice of interpolation algorithm is also made through the options module.

6.3. Adjustment Date

The user enters the date for which adjustment is required (in the form YYMMDD). From this information RADGAP constructs a total of 24 filenames (one per hourly cumulation, i.e. 00:00-01:00, 01:00-02:00, . . ., 23:00-24:00) and checks to see whether they exist or not. From this check, a radar datafile selection screen is produced which lists those time for which a corresponding radar datafile exists. From this the user selects the time period for which adjustment is required. It should be recognised that it is the responsibility of the user to ensure that the adjustment period selected does not span missing data. RADGAP does not perform any additional checks, and if some data are missing, RADGAP will stop. As long as this precaution is taken, the adjustment selection period can have any start and end time within the 24 hour data duration.

6.4. Rainfall Scale Slicing

The user interactively controls the rainfall scale used for the graphical presentation of the radar and raingauge rainfall fields. If the hourly graphics option is selected, RADGAP prompts the user to enter a value for the maximum hourly rainfall depth, and likewise for the final cumulation images at the end of the adjustment period. This value corresponds to the top of the rainfall depth scale. From this, RADGAP computes the scale slice range and sets up the slicing array. A linear rainfall slicing scheme used with a total of seven rainfall levels. Thus the slice range is computed as the maximum value divided by seven. For example, if the user enters a value of 70 (mm) the rainfall scale will have the values 0-7, 7-14, 14-21,...,63-70. RADGAP also provides a final 'catch-all' class of >maximum value. When drawing final cumulated/average fields at the end of the adjustment period a loop option exists whereby the fields can be replotted, enabling the user to select a different maximum value (and therefore different slice range).

6.5. Compiling and Linking RADGAP

When RADGAP is compiled, the include file is automatically compiled at the same time. It should be ensured that both the main module (radgap.for) and the include file (radgap.inc) are in the same directory. In addition, the two-dimensional surface fitting and interpolation subroutines are held in an object module (alg.obj) which must be linked with the compiled version of RADGAP.

6.6. Running RADGAP

The program is invoked by entering `Run RADGAP`. After each response the return (enter) key is pressed, the display scrolls and the next prompt is displayed. The reader is referred to Appendix 3 for the runtime listing.

6.7. Example Run-Time Session

The session shown in the example run-time listing in Appendix 3 is described below.

RUN RADGAP

Laserwriter output device selected.

Graphics options settings changed so that graphics are not produced every hour, only at end of adjustment.

Auto-refresh selected so that the programs continues adjustment until the end of the adjustment period.

Default interpolation algorithm used (Renka and Cline).

Black-and-white graphical output.

The date selected for adjustment is 7th July 1989.

The adjustment period selected is from 01:00-05:00 (note that no data are available from 14:00 - 19:00).

Maximum rainfall depth selected for graphics scale is 35 (mm). (This will result in the rainfall scale having the values 0-5. 5-10,10-15,...,30-35, greater than 35).

STOP

7. Customised Implementation of RADGAP

RADGAP has been designed and structured so that application to other areas is straightforward. As mentioned in section 5.3, this has been achieved largely through the use of a FORTRAN include module ('radgap.inc'). This subsidiary piece of code contains all the major program parameters and enables customisation to be made without altering the code of RADGAP. The reader should refer to figures 6 and 7 for an explanation of the terms and parameters used in this section.

The include file contains a total of 24 parameters and two arrays. An explanatory list of these follows:

rax,ray:	radar array dimensions
cell:	pixelsize of radar data (km)
ngr_lef_id:	ngr coordinates left-side of sub-region
ngr_rig_id:	ngr coordinates right-side of sub-region
ngr_top_id:	ngr coordinates of top of sub-region
ngr_bot_id:	ngr coordinates of bottom of sub-region
ngrx_or_rad:	ngr coordinates of x-origin of radar grid
ngry_or_rad:	ngr coordinates of y-origin of radar_grid
nx:	dimension of sub-region (x-axis)
ny:	dimension of sub-region (y-axis)
blcell_x_id:	radar cell for origin of sub-region (x-axis)
blcell_y_id:	radar cell for origin of sub-region (y-axis)
trcell_x_id:	radar cell for top-right of sub-region (x-axis)
trcell_y_id:	radar cell for top-right of sub-region (y-axis)
xlo:	lower bound of sub-region (x-axis)
xhi:	upper bound of sub-region (x-axis)
ylo:	lower bound of sub-region (y-axis)
yhi:	upper bound of sub-region (y-axis)
radx,rady:	ngr coordinates of radar site
idom:	number of points outside adjustment domain (ie in mask)
start,stop:	start and end cells of adjustment domain
nstat:	number of raingauge stations
mmax:	total number of data points (=nstat+idom)

The majority of these parameters are self-determining (i.e. they are computed from other parameters entered by the user), and RADGAP customisation requires only the first eleven parameters on the parameter listing shown above to be amended.

The first consideration to be made when applying RADGAP is the radar data to be utilised. In the U.K. this entails a choice between single-site data (2 km or 5 km), network (always 5 km but either regionalised [128 * 128 grid] or national [256 *256 grid]), or Frontiers Actuals (5 km on a 128 *128 grid). Once the choice has been made, the radar array dimension parameters *rax* and *ray*, the radar data pixelsize (in km) *cell*, and the radar grid origin parameters (i.e. 8-figure NGR for the south-west corner) *ngrx_or_rad* and *ngry_or_rad* are set accordingly.

The second phase entails setting up a rectangular sub-region of the radar coverage. The sub-region should be chosen so that there is adequate space for a mask having a depth of not less than least two-cells all the way around the adjustment domain, i.e. the area in which radar adjustment will take place. When the sub-region has been defined the following parameters: *ngr_lef_id, ngr_rig_id, ngr_top_id,* and *ngr_bot_id* (i.e. the 8-figure NGR coordinates of the left and right sides, top and bottom of the sub-region), and the sub-region sizing parameters *nx* and *ny* are set (see figure 7).

The third phase sets up the actual adjustment domain, i.e. the area inside of the sub-region for which radar cells will be adjusted. The variables determining the domain are held in the two arrays *start* and *stop*. Before these values can be set, it is recommended that a figure similar to figure 2 or figure 7 be produced. Once a similar figure is available it is straightforward to customise the *start* and *stop* values. In the example shown in figure 7, *nx=16*, *ny=18*, and the *start* and *stop* values in the include file would be set as follows:

```
data start /  1,  1,  3,  2,  2,  2,  2,  2,  2,  3,  3,  4,  4,  4,  4,  5,  1,  1, 1 /
data stop  /  1,  1,  8,  9, 11, 12, 13, 14, 15, 15, 15, 14, 14, 14, 14, 11,  1,  1, 1 /
```

It should be noted that the first and two and last three values of start and stop arrays are set to 1. Values of unity indicate to RADGAP that the adjustment domain does not extend into the sub-region at these points.

Finally, the number of cells falling outside of the adjustment domain (i.e. inside the mask), parameter *idom* is determined. In simple cases where there are not many cells, this can be achieved simply by counting the cells manually, however in more complex cases, it is advisable to use the utility program 'radgap_set_idom'. The program is listed in Appendix 6. Before running the user needs to set values *nx* and *ny*, and change the *start* and *stop* values held in the data statement (as described above for the include file). The program simply counts the cells inside the adjustment domain and when completed writes the required value of *idom* to the screen. Once *idom* has been determined, it should be set in the include file.

If all these stages has been carried out correctly, RADGAP has been successfully customised.

Postscript to Customisation:

In addition to the above changes, the names of the raingauge and radar data input files will need to be changed. In addition, the subroutines for drawing the coastline and political boundaries will also require some additional work. As a short-term solution, the subroutines ANGLIAN2 and COAST2 can be omitted, and reinstated when the required boundaries have been digitised.

8. Conclusions

This report is a users guide to the FORTRAN software package RADGAP, a program for adjustment radar rainfall data with rainfall data from a network of ground-based raingauges. The report contains listings of full source code and input datafiles; all of which are contained on the software distribution disk.

RADGAP is an interactive, user-friendly program featuring user selected options and graphical results presentation. The structure of the program has been described and illustrated using flowchart representation. Data requirements and input file formats are explicitly described. In addition, full details on customised implementation of RADGAP to different areas are provided.

A runtime listing is provided and described in the text, and the user options are described.

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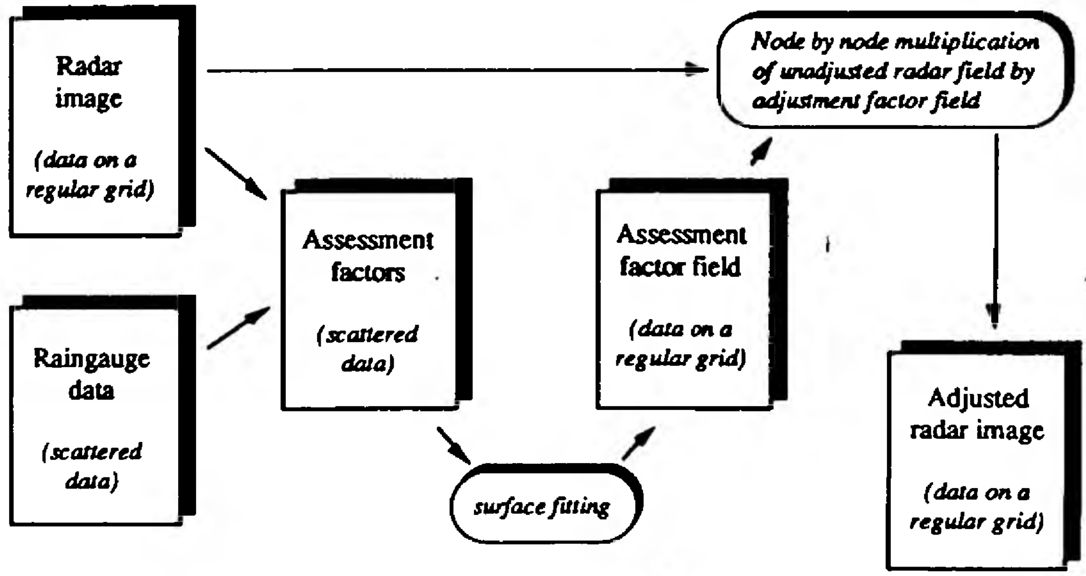

Figure 1: Schematic representation of radar rainfall data adjustment incorporating two-dimensional surface fitting of assessment factors

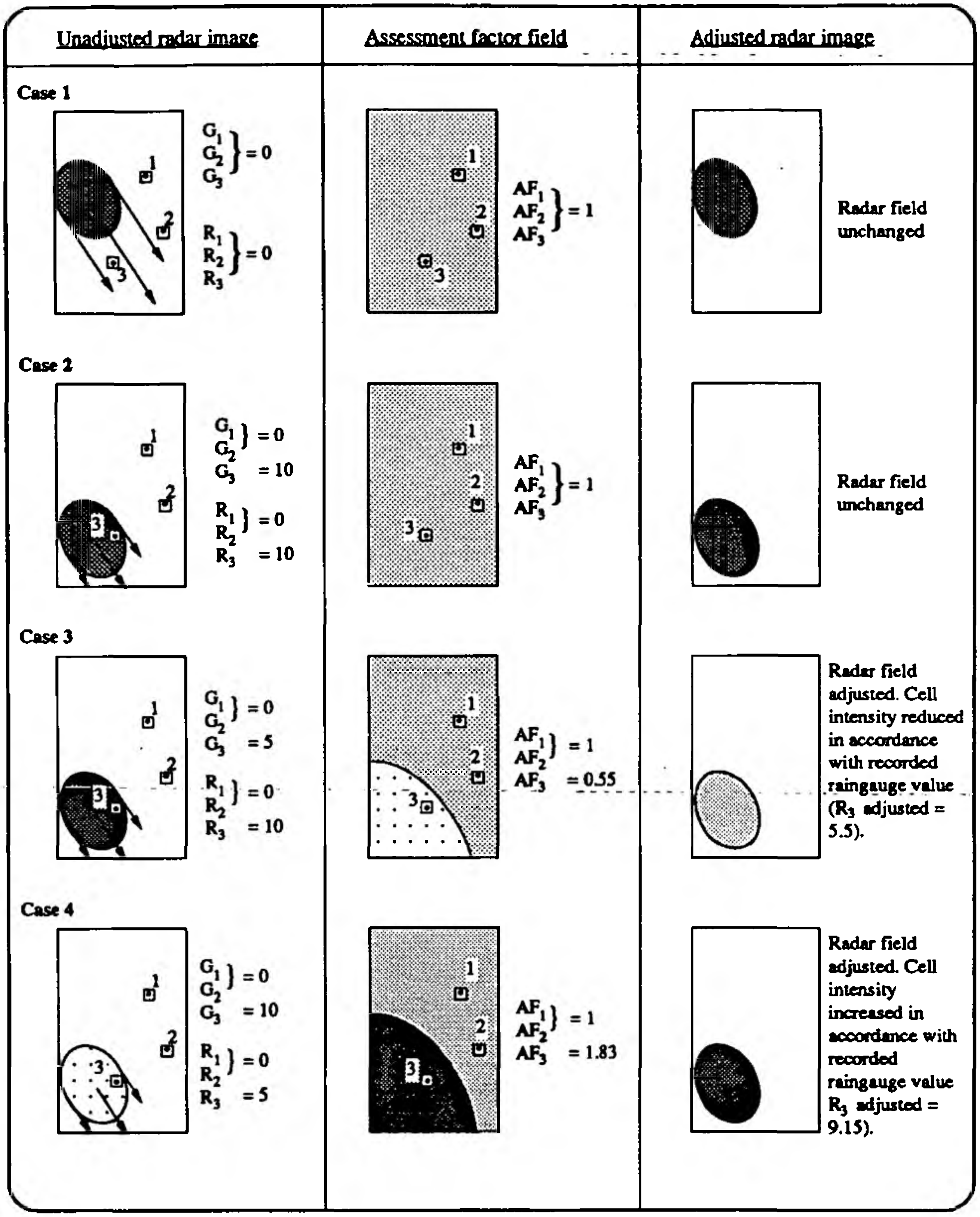

Figure 2: Adjustment Examples (Simplified)

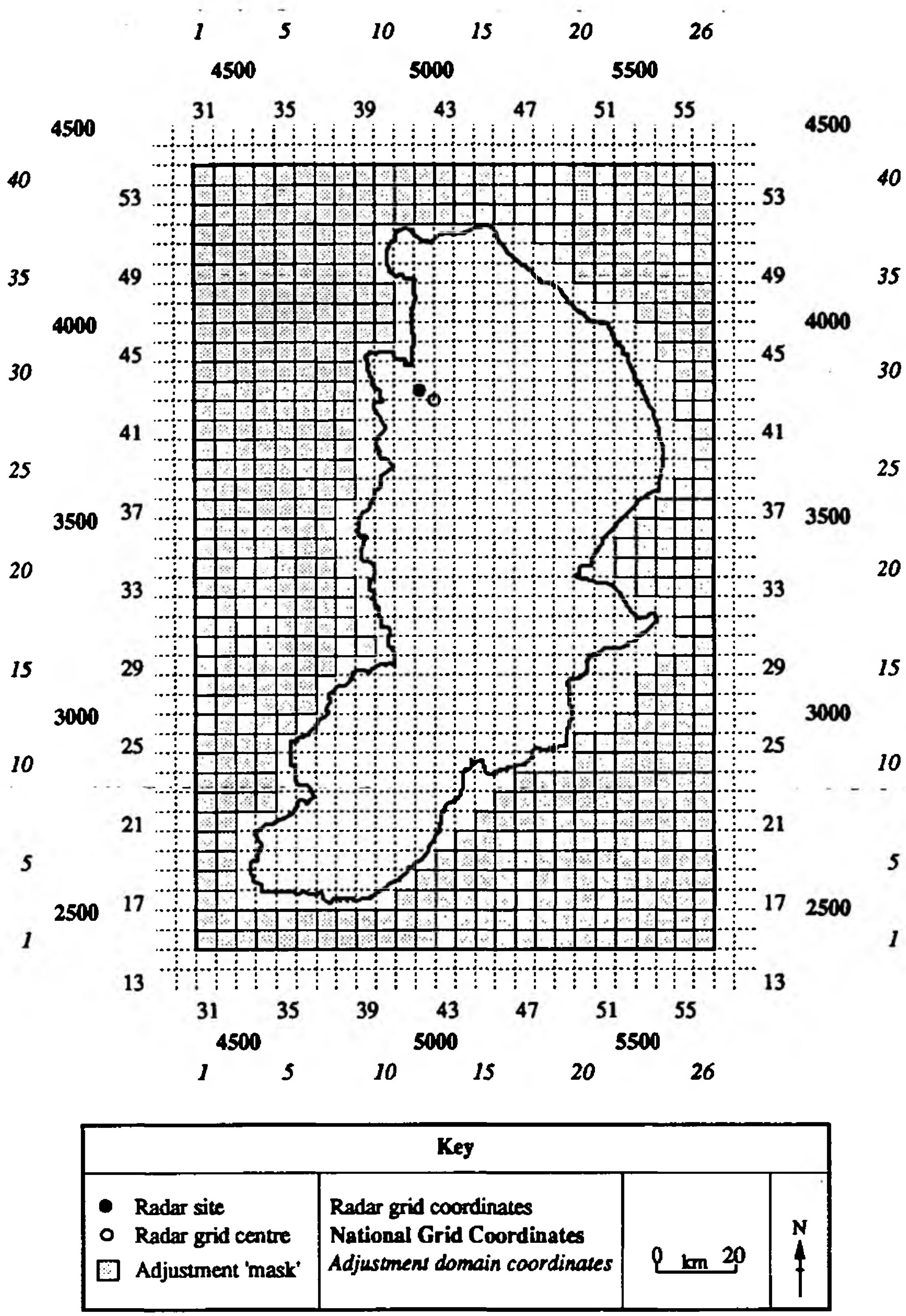

Figure 3: <u>Adjustment Domain (Northern Area, National Rivers Authority, Anglian Region)</u>

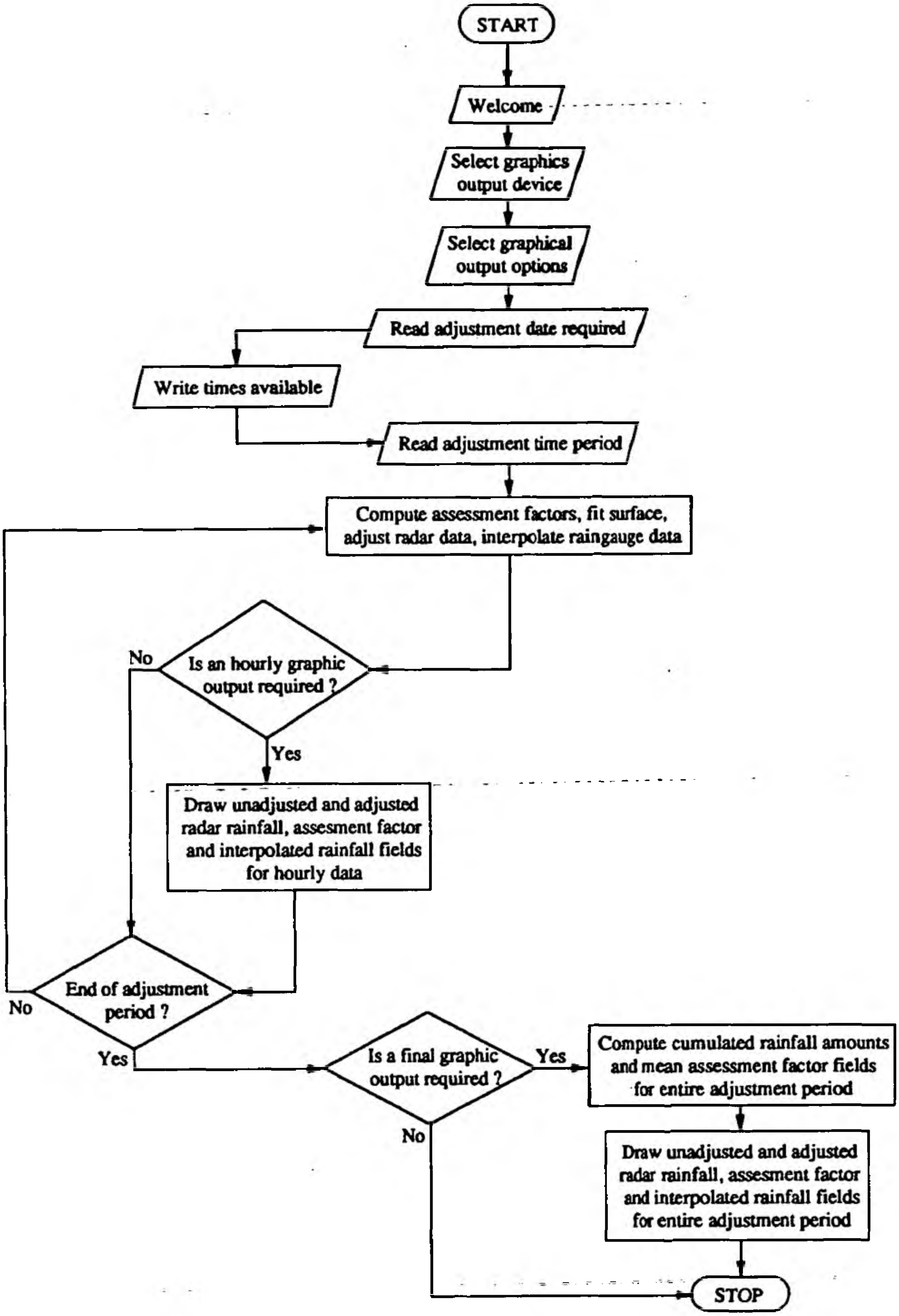

Figure 4 Flow Chart for RADGAP

Header block

Read as 25x, i2

```
------------------------------------------------------------------
Raingauge rainfall datafile
14 december   1989
Number of stations  66
Data from 00:00 (first datum) to 23:45 (last datum)
15 minute data interval

------------------------------------------------------------------
```

Sub-header block

Read as 21x, a3

Read as 20x, f6.1, 1x, f6.1

Data block

Read as 3x, 12f5.1

```
Gauge reference 802
Gauge location  5552.0 3586.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  1.0  0.5  0.5  0.0
  0.5  0.5  0.5  0.5  0.5  0.0  0.5  0.0  0.0  0.5  0.5  0.0
  0.5  0.0  0.5  0.0  0.0  0.0  1.5  2.5  2.5  1.5  1.0  0.5
  0.0  0.5  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.5  0.0  0.0
  0.0  0.0  0.0  1.0  0.5  0.5  1.0  0.5  0.0  0.0  0.0  0.5
  0.5  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference 803
Gauge location  5106.0 3698.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.5  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.5  0.5
  0.5  0.5  0.5  0.0  0.5  0.5  1.0  0.0  0.5  0.5  0.5  0.5
  1.0  0.0  0.5  0.0  0.5  0.0  0.0  0.0  1.0  0.0  0.0  0.5
  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0
  0.0  0.0  0.5  0.5  1.0  0.5  0.5  0.5  1.0  0.5  0.5  0.5
  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
```

96 15 minute rainfall totals per raingauge

Figure 5: Example rainfall datafile (items read by RADGAP in bold)

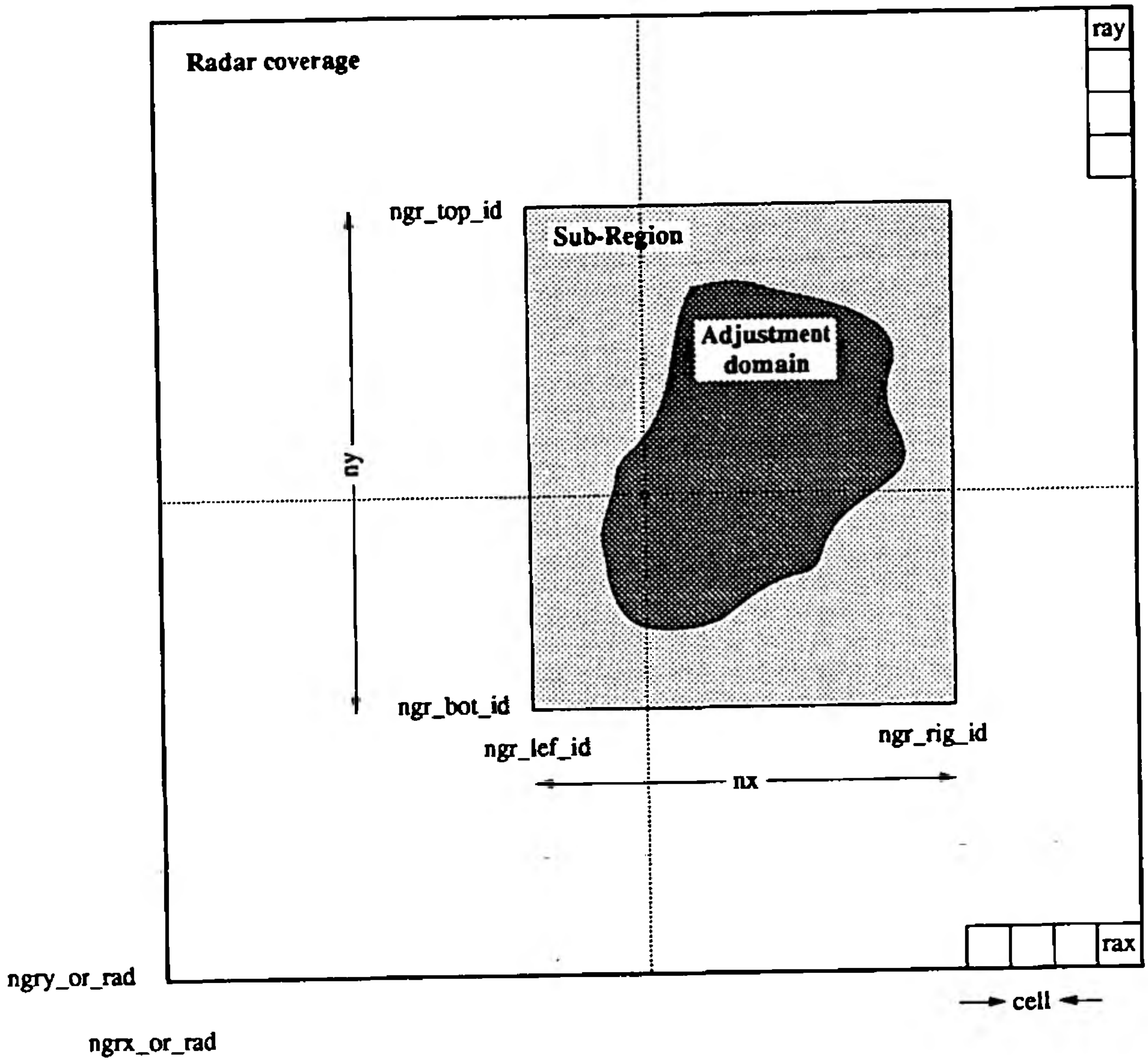

Figure 6: Explanation of terms used in Chapter 7

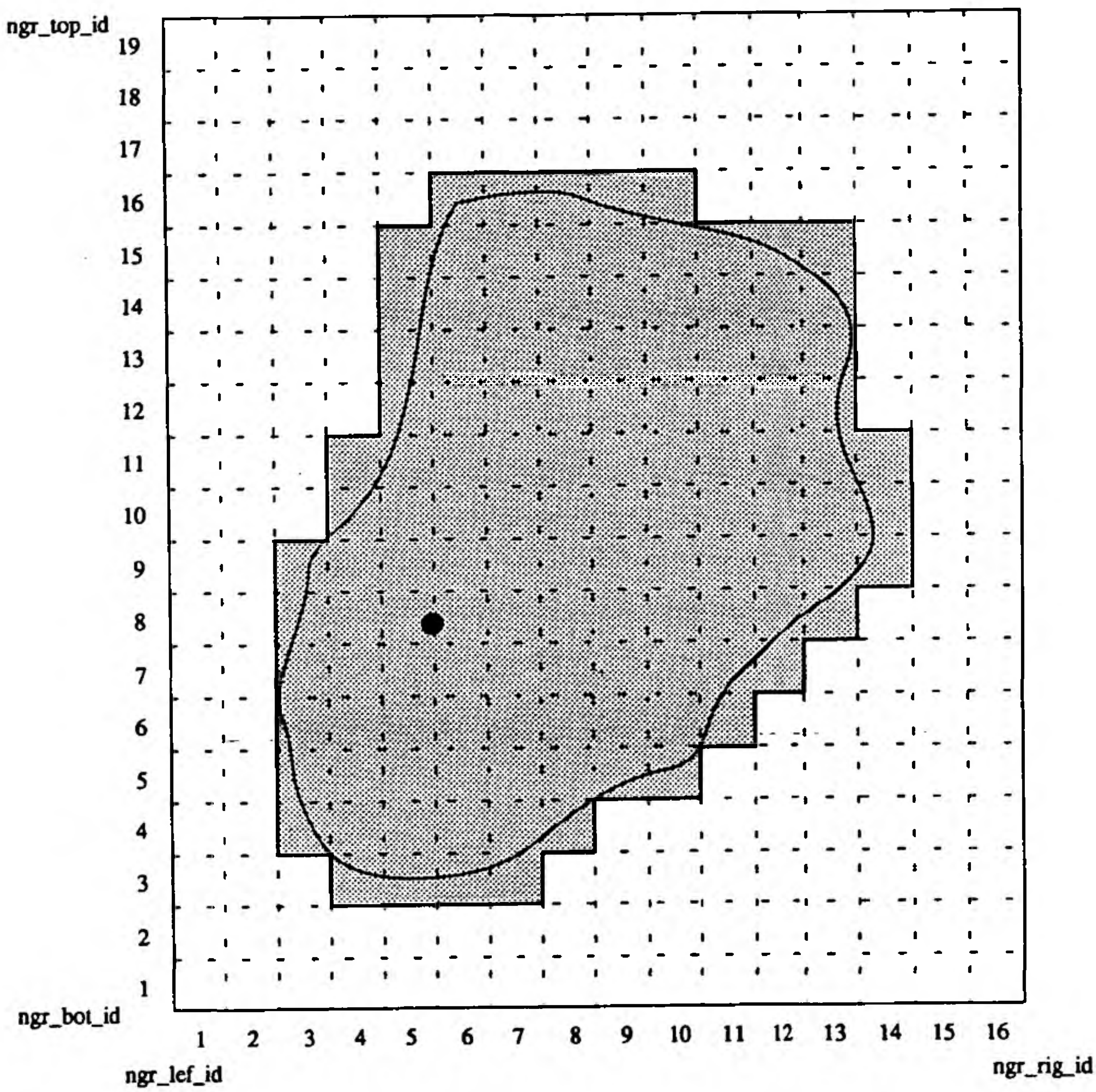

Figure 7: Sub-Region and Adjustment Domain

Appendices

Appendix 1	Source Code Listing
Appendix 2	Example Include File
Appendix 2	Example Raingauge Rainfall Inputfile
Appendix 4	Runtime Listing
Appendix 5	Devices Supported
Appendix 6	Utility Program Source Listing (radgap_set_idom)

Appendix 1: Source Code Listing

```
c
c
c
c     -----------------------------------------------------------------------
c
c                                  PROGRAM RADGAP
c
c     A program for adjusting distributed radar rainfall estimates by
c     raingauge rainfall data, incorporating two-dimensional surface
c     fitting and interpolation algorithms.
c
c         Water Resources Research Group
c         Department of Civil Engineering
c         University of Salford
c         SALFORD
c         M5 4WT
c
c         For further information contact:
c                 Prof. Ian Cluckie
c
c     -----------------------------------------------------------------------
c
c
c
       program radgap
c
c
       include 'radgap.inc'
       real data(rax,ray),radar(nx,ny),adj_radar(nx,ny)
       real cum_radar(nx,ny),cum_adj_radar(nx,ny)
       real rg_interp(nx,ny),cum_rg_interp(nx,ny)
       real newarray(nx*ny),newarray2(nx*ny),mean_af(nx*ny)
       real ax(nx*ny),ay(nx*ny)
       real add_x(idom),add_y(idom)
c
       real out(nx,ny)
       real array2(nx*ny),array3(nx,ny)
c
       real cum_rg(nstat)
       real value(nstat,96)
       character*3 gr(nstat)
       real w(mmax),x(mmax),y(mmax),af(mmax),f(mmax)
       real px(nx),py(ny),px_surf(nx),py_surf(ny)
c
c     arrays for raingauge interpolation
       real fnodes(5*nstat),wrk_rg(6*nstat)
       integer triang(7*nstat)
       real grads(2,nstat)
c
c     arrays for assessment factor surface fitting
       real fg(nx*ny),s
c
       character*1 opt1,opt2,opt3,opt4,replot
       character*6 day
       integer kh,istart_hour,iend_hour,idev,icount,icol
c
c     overlying arrays
c      real oversquare(nstat,24)
```

```
c     integer ixover1(nstat),iyover1(nstat)
c     integer ixover2(nstat),iyover2(nstat)
c     character grover2(nstat)
c
      icount=1
c
c
c  ---------------------------------------------------------------------
c
c  type welcome message
c
      call welcome
c
c  ---------------------------------------------------------------------
c
c  get graphics device and other options
c
      call options(idev,opt1,opt2,opt3,opt4,icol,s)
c
c  ---------------------------------------------------------------------
c
c  determine cumulation/adjustment period
c
      call run_period(istart_hour,iend_hour,day)
c
c  ---------------------------------------------------------------------
c
c  call routine to read and process raingauge data
c
      call rg_read(day,x,y,value,gr,cum_rg)
c
c
c  ---------------------------------------------------------------------
c
c
c  set arrays to zero
c
      do i=1,nx
         do j=1,ny
            cum_radar(i,j)=0.0
            cum_adj_radar(i,j)=0.0
         end do
      end do
c
c  ---------------------------------------------------------------------
c
c  assign AF=1 to data outside adjustment domain
c
      call outside_boundary1(add_x,add_y)
      do i=nstat+1,mmax
         af(i)=1.0
         x(i)=add_x(i-nstat)
         y(i)=add_y(i-nstat)
      end do
c
c  ---------------------------------------------------------------------
c
c  call routine to determine adjustment domain
c
      call setup_domain(px,py,px_surf,py_surf)
c
c  ---------------------------------------------------------------------
```

not used

not used - [illegible] need to set 's' = smoothness par

needs amending [illegible]

[illegible]

```
c
c
c   main loop
c
c ======================================================================
      do kh=istart_hour,iend_hour
c ======================================================================
c
c
c   --------------------------------------------------------------------
c
c   set 'f' array to have rainfall data for correct hour inside
c
         do kk=1,nstat
            f(kk)=0.0
         end do
         jj=((kh-1)*4)+1
         do kk=1,nstat
            do i=jj,jj+3
               f(kk)=f(kk)+value(kk,i)
            end do
         end do
c
c
c
c   --------------------------------------------------------------------
c
c   call routine to read and process radar data
c
         call rad_read(kh,radar,data,day)
c
c   --------------------------------------------------------------------
c
c   call routine to compute assessment factors at each gauge location
c
         call compute_af(af,f,radar,x,y)
c
c   --------------------------------------------------------------------
c
         if (kh.eq.istart_hour) then
            write(*,*)
            write(*,*)' ---------------------------------------------
     #-----------------------'
            write(*,*)
            write(*,*)'                  Computation segment'
            write(*,*)
            write(*,*)' ---------------------------------------------
     #-----------------------'
            write(*,*)
         end if
         write(*,*)
         write(*,*)' Computing for hour ',kh
         write(*,*)' -------------------------------------'
c
c   --------------------------------------------------------------------
c
c   call routine to compute af surface
c
         call surface_af(x,y,af,s,ax,ay,px_surf,py_surf,newarray)
c
c   --------------------------------------------------------------------
c
```

- Calculates hourly data from 15 min data
- [illegible] – [illegible] be done in [illegible] program

```
c   values of newarray outside boundary are set to -999.999 and are therefore
c   undefined in terms of UNIRAS and not drawn.
c
          call outside_boundary2(newarray,ax,ay)
c
c ------------------------------------------------------------------
c
c   adjust raw radar data by node by node multiplication
c
          do i=1,nx*ny
             if (newarray(i).lt.-900.0) then
                  newarray2(i)=1.0
                else
                  newarray2(i)=newarray(i)
             end if
             adj_radar(int(ax(i)),int(ay(i)))=
     #          radar(int(ax(i)),int(ay(i)))*newarray2(i)
          end do
c
c ------------------------------------------------------------------
c
c   write values for adjusted radar squares that overly raingauges
c   into a storage array
c
c         call overlying1(adj_radar,oversquare,kh)
c
c ------------------------------------------------------------------
c
c   update arrays for cumulating unadjusted and adjusted radar arrays
c
          do i=1,nx
             do j=1,ny
                cum_radar(i,j)=cum_radar(i,j)+radar(i,j)
                cum_adj_radar(i,j)=cum_adj_radar(i,j)+adj_radar(i,j)
             end-do
          end do
c
c ------------------------------------------------------------------
c
c   two algorithms are available to interpolate raingauge data to a
c   regular grid.
c
          if (opt4.eq.'A') call
     #       rg_interpolate1(x,y,f,px,py,rg_interp)
          if (opt4.eq.'B') call
     #       rg_interpolate2(x,y,f,px,py,rg_interp)
c
c ------------------------------------------------------------------
c
c   update arrays for cumulating interpolated raingauge arrays
c
          do i=1,nx
             do j=1,ny
                cum_rg_interp(i,j)=cum_rg_interp(i,j)+rg_interp(i,j)
             end do
          end do
c
c ------------------------------------------------------------------
c
c   rg_interp and af cells outside adjustment domain are assigned
c   a value of -999.999 so that they are not plotted
c
```

```
             call outside_boundary3(rg_interp)
             call outside_boundary3(newarray)
      c
      c  ---------------------------------------------------------------
      c
      c  if required call graphics routines to plot hourly adjustment
      c
             if (opt1.eq.'Y') call graphics(icount,idev,icol,kh,
         #        istart_hour,x,y,radar,adj_radar,newarray,rg_interp)
      c
      c  ---------------------------------------------------------------
      c
      c
             if (opt1.eq.'Y'.and.opt3.eq.'N') then
                write(*,*)' Press return to continue...'
                read(*,*)
                write(*,*)' '
             end if
             do i=1,nx*ny
                mean_af(i)=mean_af(i)+newarray2(i)
                newarray(i)=0.0
                newarray2(i)=0.0
             end do
      c
      c
      c =================================================================
          end do ! end of main loop
      c =================================================================
      c
      c
      c
      c ------------------------------------------------------------------
      c
      c
      c  if required process data and call graphics routines to plot final
      c  adjustment fields
      c
          call outside_boundary3(cum_rg_interp)
          do i=1,nx*ny
             mean_af(i)=mean_af(i)/float(iend_hour+1-istart_hour)
          end do
          call outside_boundary3(mean_af)
          write(*,*)
          write(*,*)' Please wait, preparing final graphics...'
          if (opt2.eq.'Y') then
       36    call graphics(icount,idev,icol,99,istart_hour,x,y,
         #                 cum_radar,cum_adj_radar,mean_af,cum_rg_interp)
             write(*,*)' '
       13    write(*,*)' Do you wish to replot the fields shown (Y/N) ?'
             read(*,12,err=13)replot
             if (replot.ne.'y'.and.replot.ne.'Y'.and.
         #       replot.ne.'n'.and.replot.ne.'N') goto 13
             if (replot.eq.'y'.or.replot.eq.'Y') goto 36
             write(*,*)' '
          end if
       12 format(a1)
      c
      c  ---------------------------------------------------------------
      c
      c
          write(*,*)
          write(*,*)
```

```
      write(*,*)' ----------------------------- RADGAP STOP
     & -----------------------------'
      write(*,*)
      write(*,*)
      read(*,*)
      call gclose
      end
```

```
c
c
c    ----------------------------------------------------------------
c
c
c
c
c
c    Subroutines follow.......
c
c
c
c
c
c    ----------------------------------------------------------------
        subroutine welcome
c    ----------------------------------------------------------------
c
        write(*,*)
        write(*,*)
        write(*,*)'  ---------------------------------------------
     #------------------------'
        write(*,*)
        write(*,*)'                                     RADGAP'
        write(*,*)
        write(*,*)'  A program to adjust distributed radar rainfall.
     # data by raingauge'
        write(*,*)'  rainfall data, incorporating two-dimensional
     # surface fitting and'
        write(*,*)'  interpolation algorithms'
        write(*,*)
        write(*,*)'  Written by:'
        write(*,*)'     Water Resources Research Group'
        write(*,*)'     University of Salford'
        write(*,*)'     Salford, M5 4WT'
        write(*,*)'     England, U.K.'
        write(*,*)
        write(*,*)'  ---------------------------------------------
     #------------------------'
        write(*,*)
c
        write(*,*)'  IMPORTANT: Before continuing...'
        write(*,*)'     Are you sure that the parameter settings in the
     # file "radgap.inc"'
        write(*,*)'     are correct? If not, abort program and change
     # settings by editing'
        write(*,*)'     the file. If OK...'
        write(*,*)
        write(*,*)'  Hit return to continue...'
        read(*,*)
c
        return
        end
```

```
c
c
c
c
c
c  -----------------------------------------------------------------
      subroutine options(idev,set1,set2,set3,set4,icol,s)
c  -----------------------------------------------------------------
c
      character*1 set1,set2,set3,set4,set5
      integer opt,icol
      real s
c
 35   format(i1)
 45   format(a1)
c
      write(*,*)
      write(*,*)
      write(*,*)'  ------------------------------------------
     #-----------------------'
      write(*,*)'  The UNIRAS graphics routines in this program are
     # device independent.'
      write(*,*)'  ------------------------------------------
     #-----------------------'
      write(*,*)
 696   write(*,*)'  Please type in the integer corresponding to the
     # device required'
      write(*,*)'    (1) VAXstation      (GPX driver)'
      write(*,*)'    (2) VAXstation      (X11 driver)'
      write(*,*)'    (3) VT Emulator     (ReGIS driver)'
      write(*,*)'    (4) IBM PC          (VGA driver)'
      write(*,*)'    (5) Inkjet Printer'
      write(*,*)'    (6) Laserwriter     (Postscript)'
      write(*,*)
 31    write(*,*)'  Please type integer [1,2,3,4,5 or 6]...'
      read(*,*,err=31)idev
      if (idev.gt.6.or.idev.eq.0) goto 31
      write(*,*)
c
      set1='Y'
      set2='Y'
      set3='Y'
      set4='A'
      icol=1
      s=5.0
      write(*,*)
      write(*,*)
      write(*,*)
      write(*,*)'  ------------------------------------------
     #-----------------------'
      write(*,*)'  Option Menu'
      write(*,*)'  ------------------------------------------
     #-----------------------'
      write(*,*)
      write(*,*)'  Options (default in UPPER CASE)'
      write(*,*)
      write(*,*)'  1. Graphics every hour                    (Y/n)'
      write(*,*)'  2. Graphics at end of adjustment period (Y/n)'
      write(*,*)'  3. Auto refresh                           (Y/n)'
      write(*,*)'  4. Interpolation algorithm (enter a or b):'
      write(*,*)'     (a) Renka and Cline              (default)'
      write(*,*)'     (b) Modified Shepherd'
```

```
      write(*,*)'  5. Colour or black/white graphics       (C/b):'
      write(*,*)'  6. Smoothness parameter (for surface)    (5.0):'
5     write(*,*)
      write(*,*)'  To change a default setting enter integer
     # corresponding to the setting'
      write(*,*)'  to be changed, press return key and enter y or n
     # as appropriate'
25    write(*,*)'  [Enter 0 <rtn> to continue]...'
26    write(*,*)
        read(*,35,err=25)opt
      if (opt.ne.1.and.opt.ne.2.and.opt.ne.3.and.opt.ne.4.
     #            and.opt.ne.5.and.opt.ne.6.and.opt.ne.0) then
          write(*,*)'  Enter integer (1,2,3,4,5,6 or 0)...'
          goto 25
      end if
        if (opt.eq.0) then
           goto 15
          else if (opt.eq.1) then
             read(*,45)set1
             if (set1.eq.'y') set1='Y'
             if (set1.eq.'n') set1='N'
          else if (opt.eq.2) then
             read(*,45)set2
             if (set2.eq.'y') set2='Y'
             if (set2.eq.'n') set2='N'
          else if (opt.eq.3) then
             read(*,45)set3
             if (set3.eq.'y') set3='Y'
             if (set3.eq.'n') set3='N'
          else if (opt.eq.4) then
             read(*,45)set4
             if (set4.eq.'a') set4='A'
             if (set4.eq.'b') set4='B'
          else if (opt.eq.5) then
             read(*,45)set5
             if (set5.eq.'c'.or.set5.eq.'C') icol=1
             if (set5.eq.'b'.or.set5.eq.'B') icol=3
          else if (opt.eq.6) then
             read(*,45)s
             if (s.lt.0.1) s=0.1
          else
             write(*,*)' Error in options module'
      end if
      goto 26
15    continue
c
      return
      end
```

```
c
c
c
c
c
c     ------------------------------------------------------------------
      subroutine run_period(istart_hour,iend_hour,day)
c     ------------------------------------------------------------------
c
      integer flag(24)
      character fname(24)*34,root*44,ifile*78
      character day*6,date*8,time(24)*13
      logical exist1
c
      time(1)='00:00 - 01:00'
      time(2)='01:00 - 02:00'
      time(3)='02:00 - 03:00'
      time(4)='03:00 - 04:00'
      time(5)='04:00 - 05:00'
      time(6)='05:00 - 06:00'
      time(7)='06:00 - 07:00'
      time(8)='07:00 - 08:00'
      time(9)='08:00 - 09:00'
      time(10)='09:00 - 10:00'
      time(11)='10:00 - 11:00'
      time(12)='11:00 - 12:00'
      time(13)='12:00 - 13:00'
      time(14)='13:00 - 14:00'
      time(15)='14:00 - 15:00'
      time(16)='15:00 - 16:00'
      time(17)='16:00 - 17:00'
      time(18)='17:00 - 18:00'
      time(19)='18:00 - 19:00'
      time(20)='19:00 - 20:00'
      time(21)='20:00 - 21:00'
      time(22)='21:00 - 22:00'
      time(23)='22:00 - 23:00'
      time(24)='23:00 - 24:00'
c
      root='[cluckie.tilford.radar_data.ingham.cumulate]'
      fname(1)='_5KM_b0_DEC_60CUM_HH01.DAT'
      fname(2)='_5KM_b0_DEC_60CUM_HH02.DAT'
      fname(3)='_5KM_b0_DEC_60CUM_HH03.DAT'
      fname(4)='_5KM_b0_DEC_60CUM_HH04.DAT'
      fname(5)='_5KM_b0_DEC_60CUM_HH05.DAT'
      fname(6)='_5KM_b0_DEC_60CUM_HH06.DAT'
      fname(7)='_5KM_b0_DEC_60CUM_HH07.DAT'
      fname(8)='_5KM_b0_DEC_60CUM_HH08.DAT'
      fname(9)='_5KM_b0_DEC_60CUM_HH09.DAT'
      fname(10)='_5KM_b0_DEC_60CUM_HH10.DAT'
      fname(11)='_5KM_b0_DEC_60CUM_HH11.DAT'
      fname(12)='_5KM_b0_DEC_60CUM_HH12.DAT'
      fname(13)='_5KM_b0_DEC_60CUM_HH13.DAT'
      fname(14)='_5KM_b0_DEC_60CUM_HH14.DAT'
      fname(15)='_5KM_b0_DEC_60CUM_HH15.DAT'
      fname(16)='_5KM_b0_DEC_60CUM_HH16.DAT'
      fname(17)='_5KM_b0_DEC_60CUM_HH17.DAT'
      fname(18)='_5KM_b0_DEC_60CUM_HH18.DAT'
      fname(19)='_5KM_b0_DEC_60CUM_HH19.DAT'
      fname(20)='_5KM_b0_DEC_60CUM_HH20.DAT'
      fname(21)='_5KM_b0_DEC_60CUM_HH21.DAT'
      fname(22)='_5KM_b0_DEC_60CUM_HH22.DAT'
```

```
      fname(23)='_5KM_b0_DEC_60CUM_HH23.DAT'
      fname(24)='_5KM_b0_DEC_60CUM_HH24.DAT'
c
      write(*,*)
      write(*,*)
      write(*,*)' ----------------------------------------------
     #------------------------'
      write(*,*)
      write(*,*)'                          Data selection routine'
      write(*,*)
      write(*,*)' ----------------------------------------------
     #------------------------'
      write(*,*)
      write(*,*)' Enter adjustment date in the form YYMMDD...'
      write(*,*)' e.g. for 7th July 1989 enter:'
      write(*,*)' 890707  <rtn>'
      read(*,11)day
 11   format(a6)
      date='i_'//day
      do i=1,24
         flag(i)=1
      end do
      do i=1,24
         ifile=root//date//fname(i)
         inquire(file=ifile,exist=exist1)
         if (.not.exist1) flag(i)=0
      end do
      write(*,*)
      write(*,*)' Radar datafiles (hourly rainfall depth cumulations with
     # rainfall in mm units)'
      write(*,*)' exist for the following periods...'
      do i=1,24
         if (flag(i).eq.1) write(*,10)i,time(i)
      end do
 10   format(2x,i2,')    ',a13)
c
      write(*,*)
      write(*,*)' To select adjustment/cumulation period enter start and
     # end hours required'
      write(*,*)' (note, only select periods where the radar datafiles are
     # contiguous)'
      write(*,*)' e.g. to adjust from 03:00 to 07:00 enter:'
      write(*,*)' 4  <rtn>'
      write(*,*)' 8  <rtn>'
      read(*,*)istart_hour,iend_hour
c
      return
      end
```

```
c
c
c
c
c
c
c   ---------------------------------------------------------------
      subroutine rg_read(day,x,y,value,gr,cum_rg)
c   ---------------------------------------------------------------
c
      include 'radgap.inc'
      real value(nstat,96),cum_rg(nstat)
      real x(mmax),y(mmax)
      character*3 gr(nstat)
      character*6 day
      character ifile*80
c
c
c   raingauge data set-up procedure
c
      ifile='[cluckie.tilford.raingauge_data.raw_data]'//day//'_rg.dat'
      open(unit=33,name=ifile,status='old',readonly)
      do i=1,4
         read(33,*)
      end do
c     read(33,34)nstat
      read(33,34)
 34   format(t25,i2)
      do i=1,5
         read(33,*)
      end do
      do i=1,nstat
         x(i)=0.0
         y(i)=0.0
         do j=1,96
            value(i,j)=0.0
         end do
      end do
c
      do kk=1,nstat
         read(33,30)gr(kk)
 30      format(t21,a3)
         read(33,31)xpos,ypos
 31      format(t20,f6.1,1x,f6.1)
         x(kk)=(xpos-ngr_lef_id)/50.0
         y(kk)=(ypos-ngr_bot_id)/50.0
         k=1
         do i=1,96/12
            read(33,16)(value(kk,j),j=k,k+11)
            k=k+12
         end do
 16      format(3x,12f5.1)
      end do
      do kk=1,nstat
         do i=1,96
            cum_rg(kk)=cum_rg(kk)+value(kk,i)
         end do
```

```
c
c
c
c
c
c     ----------------------------------------------------------------------
      subroutine outside_boundary1(add_x,add_y)
c     ----------------------------------------------------------------------
c
      include 'radgap.inc'
      real out(nx,ny)
      real add_x(idom),add_y(idom)
c
      do i=3,37
         do j=1,start(i)
            out(j,i)=10.0
         end do
         do j=stop(i),nx
            out(j,i)=10.0
         end do
      end do
      do i=1,2
         do j=1,nx
            out(j,i)=10.0
         end do
      end do
      do i=38,ny
         do j=1,nx
            out(j,i)=10.0
         end do
      end do
c
      k=1
      do i=1,nx
         do j=1,ny
            if (out(i,j).eq.10.0) then
              add_x(k)=i-1
              add_y(k)=j-1
              k=k+1
            end if
         end do
      end do
c
      return
      end
```

```
c
c
c
c
c
c ---------------------------------------------------------------
      subroutine rad_read(inumber,radar,data,day)
c ---------------------------------------------------------------
c
      include 'radgap.inc'
      real radar(nx,ny),data(rax,ray)
      character fname(24)*34,root*44,ifile*78
      character date*8,day*6
      integer inumber
c
      date='i_'//day
      root='[cluckie.tilford.radar_data.ingham.cumulate]'
      fname(1)=date//'_5KM_b0_DEC_60CUM_HH01.DAT'
      fname(2)=date//'_5KM_b0_DEC_60CUM_HH02.DAT'
      fname(3)=date//'_5KM_b0_DEC_60CUM_HH03.DAT'
      fname(4)=date//'_5KM_b0_DEC_60CUM_HH04.DAT'
      fname(5)=date//'_5KM_b0_DEC_60CUM_HH05.DAT'
      fname(6)=date//'_5KM_b0_DEC_60CUM_HH06.DAT'
      fname(7)=date//'_5KM_b0_DEC_60CUM_HH07.DAT'
      fname(8)=date//'_5KM_b0_DEC_60CUM_HH08.DAT'
      fname(9)=date//'_5KM_b0_DEC_60CUM_HH09.DAT'
      fname(10)=date//'_5KM_b0_DEC_60CUM_HH10.DAT'
      fname(11)=date//'_5KM_b0_DEC_60CUM_HH11.DAT'
      fname(12)=date//'_5KM_b0_DEC_60CUM_HH12.DAT'
      fname(13)=date//'_5KM_b0_DEC_60CUM_HH13.DAT'
      fname(14)=date//'_5KM_b0_DEC_60CUM_HH14.DAT'
      fname(15)=date//'_5KM_b0_DEC_60CUM_HH15.DAT'
      fname(16)=date//'_5KM_b0_DEC_60CUM_HH16.DAT'
      fname(17)=date//'_5KM_b0_DEC_60CUM_HH17.DAT'
      fname(18)=date//'_5KM_b0_DEC_60CUM_HH18.DAT'
      fname(19)=date//'_5KM_b0_DEC_60CUM_HH19.DAT'
      fname(20)=date//'_5KM_b0_DEC_60CUM_HH20.DAT'
      fname(21)=date//'_5KM_b0_DEC_60CUM_HH21.DAT'
      fname(22)=date//'_5KM_b0_DEC_60CUM_HH22.DAT'
      fname(23)=date//'_5KM_b0_DEC_60CUM_HH23.DAT'
      fname(24)=date//'_5KM_b0_DEC_60CUM_HH24.DAT'
c
      ifile=root//fname(inumber)
      open(unit=27,name=ifile,status='old',form='unformatted',readonly)
      read(27)data
      close(unit=27)
      do i=blcell_x_id,trcell_x_id
         do j=blcell_y_id,trcell_y_id
            radar(i-(blcell_x_id-1),j-(blcell_y_id-1))=data(i,j)
         end do
      end do
c
      return
      end
```

```
c
c
c
c
c     ----------------------------------------------------------------
      subroutine outside_boundary2(array2,ax,ay)
c     ----------------------------------------------------------------
c
      include 'radgap.inc'
      real out(nx,ny),ax(nx*ny),ay(nx*ny),array2(nx*ny)
c
      do i=3,37
         do j=1,start(i)
            out(j,i)=10.0
         end do
         do j=stop(i),nx
            out(j,i)=10.0
         end do
      end do
      do i=1,2
         do j=1,nx
            out(j,i)=10.0
         end do
      end do
      do i=38,ny
         do j=1,nx
            out(j,i)=10.0
         end do
      end do
c
      do j=1,ny
         do i=1,nx
            if (out(i,j).eq.10.0) then
               do jk=1,nx*ny
                  if (int(ax(jk)).eq.i-1.and.int(ay(jk)).eq.j-1) then
                     array2(jk)=-999.999
                     goto 666
                  end if
               end do
 666        end if
            continue
         end do
      end do
c
      return
      end
```

```
c
c
c
c
c
c     -----------------------------------------------------------------
        subroutine outside_boundary3(array3)
c     -----------------------------------------------------------------
c
        include 'radgap.inc'
        real out(nx,ny),array3(nx,ny)
c
        do i=3,37
           do j=1,start(i)
              out(j,i)=10.0
           end do
           do j=stop(i),nx
              out(j,i)=10.0
           end do
        end do
        do i=1,2
           do j=1,nx
              out(j,i)=10.0
           end do
        end do
        do i=38,ny
           do j=1,nx
              out(j,i)=10.0
           end do
        end do
c
        k=1
        do i=1,nx
           do j=1,ny
              if (out(i,j).eq.10.0) array3(i,j)=-999.999
           end do
        end do
c
        return
        end
```

```
c
c
c
c
c
c -----------------------------------------------------------------------
      subroutine compute_af(af,f,radar,x,y)
c -----------------------------------------------------------------------
c
      include 'radgap.inc'
      real x(mmax),y(mmax),af(mmax),f(mmax),radar(nx,ny)
c
c
      do i=1,nstat
         af(i)=(f(i)+1.0)/(radar(int(x(i)+1.0),int(y(i)+1.0))+1.0)
         if (af(i).gt.10.0) af(i)=10.0
         if (af(i).lt.0.1) af(i)=0.1
      end do
c
      return
      end
```

```
c
c
c
c
c
c
c     ------------------------------------------------------------------
      subroutine setup_domain(px,py,px_surf,py_surf)
c     ------------------------------------------------------------------
c
      include 'radgap.inc'
      real px(nx),py(ny),px_surf(nx),py_surf(ny)
c
c     evaluate the spline on a rectangular grid at nx*ny points over
c     the domain (xlo to xhi) * (ylo to yhi)
c
      delta=(xhi-xlo)/(nx-1)                        ! = 1
      do i=1,nx
         px(i)=min(xlo+(i-1)*delta,xhi)
         px_surf(i)=px(i)-1.0
c        px_surf(i)=px(i)
      end do
      do i=1,ny
         py(i)=min(ylo+(i-1)*delta,yhi)
         py_surf(i)=py(i)-1.0
c        py_surf(i)=py(i)
      end do
c
      return
      end
```

```
c
c
c
c
c
c
c -----------------------------------------------------------------
      subroutine rg_interpolate1(x,y,z,px,py,rg_interp)
c -----------------------------------------------------------------
c
c this routine interpolates raingauge data after a modified
c Renka and Cline routine
c
      include 'radgap.inc'
      integer triang(7*nstat),ifail
      real grads(2,nstat),px(nx),py(ny),rg_interp(nx,ny)
      real x(mmax),y(mmax),z(mmax)
c
c
c interpolation of raingauge data to a regular grid
c generate triangulation and gradients
c
      ifail=0
      write(*,*)' Please wait, computing interpolating function...'
      call e01sae(nstat,x,y,z,triang,grads,ifail)
      call x04aae(1,10)
      write(*,*)' Please wait, evaluating interpolant...'
      write(*,*)' '
      do j=ny,1,-1
         do i=1,nx
            ifail=-1
            call e01sbe
     #      (nstat,x,y,z,triang,grads,px(i),py(j),rg_interp(i,j),ifail)
         end do
      end do
c
      do i=1,nx
         do j=1,ny
            if (rg_interp(i,j).lt.0.0) rg_interp(i,j)=0.0
         end do
      end do
c
      return
      end
```

```
c
c
c
c
c
c     ------------------------------------------------------------------------
      subroutine rg_interpolate2(x,y,z,px,py,rg_interp)
c     ------------------------------------------------------------------------
c
c     this routine interpolates raingauge data using a modified
c     Shepard routine
c
      include 'radgap.inc'
      integer ifail,minnq,nq,nw
      real rnq,rnw
      real x(mmax),y(mmax),z(mmax)
      real px(nx),py(ny),rg_interp(nx,ny)
      real fnodes(5*nstat),wrk_rg(6*nstat)
c
c     compute nodal function coefficients
c
      rnq=0.0
      nq=0
      write(*,*)' Please wait, computing nodal function...'
      ifail=0
      call e01see(nstat,x,y,z,rnw,rnq,nw,nq,fnodes,minnq,wrk_rg,ifail)
c
c     evaluate interpolant
c
      write(*,*)' Please wait, evaluating interpolant...'
      write(*,*)' '
      call x04aae(1,10)
      do i=ny,1,-1
         do j=1,nx
            ifail=-1
            call e01sfe(nstat,x,y,z,rnw,fnodes,
     #                  px(j),py(i),rg_interp(j,i),ifail)
         end do
      end do
c
      do i=1,ny
         do j=1,nx
            if (rg_interp(j,i).lt.0.0) rg_interp(j,i)=0.0
         end do
      end do
c
      return
      end
```

```
c
c
c
c
c
c     -----------------------------------------------------------------
      subroutine surface_af(x,y,af,s,ax,ay,px,py,newarray)
c     -----------------------------------------------------------------
c
      include 'radgap.inc'
      integer lwrk,liwrk
      integer nxknot,nyknot,rank,ifail
      real fp,s
      character*1 starte
c
      parameter (lwrk=(7*(nxest-4)*(nyest-4)+25*(nxest-4))
     #           *(nxest-3)+2*((nxest-4)+(nyest-4)+4*mmax)
     #           +23*(nxest-4)+56
     #           +4*(nxest-4)*(nyest-4)*(nxest-4)
     #           +2*(nxest-4)*(nyest-4)+4*(nxest-4),
     #           liwrk=mmax+3*(nxest-7)*(nyest-7))
c
      real c((nxest-4)*(nyest-4))
      real lamda(nxest),mu(nyest),px(nx),py(ny),wrk(lwrk)
      real w(mmax),x(mmax),y(mmax),af(mmax),fg(nx*ny)
      integer iwrk(liwrk)
      real ax(nx*ny),ay(nx*ny),newarray(nx*ny)
c
      starte='C'
c
      do i=1,mmax
         w(i)=1.0
      end do
c
      write(*,*)
      write(*,*)' Please wait, computing surface knots...'
      ifail=0
      call e02dde(starte,mmax,x,y,af,w,s,nxest,nyest,nxknot,lamda,nyknot,
     #            mu,c,fp,rank,wrk,lwrk,iwrk,liwrk,ifail)
c     write(*,*)
c     write(*,*)' -----------------------------'
c     write(*,*)' ASSESSMENT FACTOR SURFACE'
c     write(*,*)' -----------------------------'
c     write(*,*)' smoothness factor S = ',s
c     write(*,*)' nx knots            = ',nxknot
c     write(*,*)' ny knots            = ',nyknot
c     write(*,*)' rank                = ',rank
c     write(*,*)' rank deficiency     = ',(nx-4)*(ny-4)-rank
c     write(*,*)' nxest               = ',nxest
c     write(*,*)' nyest               = ',nyest
c     write(*,*)' fp                  = ',fp
c
      write(*,*)' Please wait, evaluating surface...'
      write(*,*)
      ifail=0
      call e02dfe(nx,ny,nxknot,nyknot,px,py,lamda,mu,c,
     #            fg,wrk,lwrk,iwrk,liwrk,ifail)
c
      do i=1,nx*ny
         if (fg(i).gt.10.0) fg(i)=10.0
         if (fg(i).lt.0.1) fg(i)=0.1
      end do
```

```
c
c     put surface data into a new array 'new array'. The coordinates of this
c     are contained in the arrays ax, and ay.
c
      k=0
      do i=1,ny
         do j=1,nx
           k=k+1
           newarray(k)=fg(ny*(j-1)+i)
           ax(k)=j-1
           ay(k)=i-1
         end do
      end do
      do i=1,nx*ny
         fg(i)=0.0
      end do
c
      return
      end
```

```
c
c
c
c
c
c     -----------------------------------------------------------------
      subroutine graphics(icount,idev,icol,kh,istart_hour,x,y,
     #                    radar,adj_radar,aff,rg_interp)
c     -----------------------------------------------------------------
c
      include 'radgap.inc'
      integer idev,kh,istart_hour,icount,icol
      real radar(nx,ny),adj_radar(nx,ny),aff(nx,ny),rg_interp(nx,ny)
      real x(mmax),y(mmax)
      real zcl(2),zclm(8),xoff(4),yoff(4),xoffk(4)
c
      data zclm / 0.25, 0.5, 0.75, 1.0, 2.5, 5.0, 7.5, 10.0 /
c
      if (icount.eq.1) then
         if (idev.eq.1) call groute('select mgpx;exit')
         if (idev.eq.2) call groute('select mx11;exit')
         if (idev.eq.3) call groute('select mregis;exit')
         if (idev.eq.4) call groute('select mvga;exit')
         if (idev.eq.5) call groute('select glj250;exit')
         if (idev.eq.6) call groute('select hposta4;exit')
         call gopen
         call rorien(2)
         call grpsiz(xsi,ysi)
         xsize=0.22*xsi
         ysize=(2.0/1.3)*xsize
         height=0.03*min(xsize,ysize)
         xmax=26.0
         xmin=0.0
         ymax=40.0
         ymin=0.0
         xoff(1)=0.15*xsi
         xoff(3)=xoff(1)
         xoff(2)=0.55*xsi
         xoff(4)=xoff(2)
         yoff(3)=0.35*ysi
         yoff(4)=yoff(3)
         yoff(1)=0.7*ysi
         yoff(2)=yoff(1)
         xoffk(1)=0.15*xsi
         xoffk(2)=0.32*xsi
         xoffk(3)=0.49*xsi
         xoffk(4)=0.66*xsi
         call rshade(icol,0)
         call rundef(-999.999,0)
         call glimit(xmin,xmax,ymin,ymax,0.0,0.0)
      end if
      icount=icount+1
c
      if (kh.eq.istart_hour) then
         write(*,*)
         write(*,*)' Hourly graphics presentation display:'
         write(*,*)'   Please enter a value for the top of the rainfall
     # slicing scale. This'
         write(*,*)'  will be used to determine an appropriate slice
     # range.'
         read(*,*)ztop
         zcl(2)=ztop/7.0
```

```
             zcl(1)=0.0
          end if
c
          if (kh.eq.99) then
             write(*,*)
             write(*,*)' Final graphics presentation display:'
             write(*,*)'   Please enter a value for the top of the rainfall
     # slicing scale. This'
             write(*,*)'   will be used to determine an appropriate slice
     # range.'
             read(*,*)ztop
             zcl(2)=ztop/7.0
             zcl(1)=0.0
          end if
c
          do i=1,4
             call gvport(xoff(i),yoff(i),xsize,ysize)
             if (i.eq.1) then
                call rclass(zcl,8,5)
                call gcnr2s(radar,nx,ny)            ! raw radar image
             end if
             if (i.eq.2) then
                call rclass(zcl,8,5)
                call gcnr2s(adj_radar,nx,ny)  ! adj radar image
             end if
             if (i.eq.3) then
                call rclass(zclm,8,0)
                call gcnr2s(aff,nx,ny)        ! adjustment factors
             end if
             if (i.eq.4) then
                call rclass(zcl,8,5)
                call gcnr2s(rg_interp,nx,ny)  ! interpolated raingauge
             end if
             call gscale
             call draw_axes(height)
             call dradar
             call raingauge(x,y,nstat)
             call coast2
             call anglian2
             if (kh.eq.istart_hour.or.kh.eq.99)
     #              call key(height,0.14*ysi,xoffk(i))
          end do
          call gempty
c
          return
          end
```

```
c
c
c
c
c
c -----------------------------------------------------------------
      subroutine draw_axes(height)
c -----------------------------------------------------------------
c
      include 'radgap.inc'
      parameter (gundef=999.999,iundef=9999,undef=0.0)
      integer lenarl(4)
      character*14 texarl(4)
c
      data lenarl / 0,13,0,14 /
      data texarl / ' ','Easting (NGR)',' ','Northing (NGR)' /
      data dbl,ntick / 1000.0,4 /
c
      call glimit(ngr_lef_id,ngr_rig_id,ngr_bot_id,ngr_top_id,0.0,0.0)
      call raxtef(6,'SWIM',1)
      call raxlfo(0,0,iundef,iundef)
      call raxbti(6,gundef,gundef,dbl)
      call raxsti(ntick)
      call raxdis(4,1,iundef)
      call raxdis(3,1,iundef)
      call raxdis(6,1,iundef)
      call raxis2(ngr_bot_id,ngr_lef_id,height,lenarl,texarl)
      call raxis(1,ngr_top_id,height,2)
      call raxdis(4,0,iundef)
      call raxis(2,ngr_rig_id,height,2)
c
      return
      end
```

```
c
c
c
c
c
c  ---------------------------------------------------------------------
       subroutine coast2
c  ---------------------------------------------------------------------
c
      include 'radgap.inc'
      character*80 fname
c
      xshift=-ngr_lef_id
      yshift=-ngr_bot_id
      xdiff=ngr_rig_id-ngr_lef_id
      ydiff=ngr_top_id-ngr_bot_id
c
      fname='[cluckie.tilford.radar_data.programs]coastline.dat'
      open (unit=3,file=fname,status='old',readonly)
      call glimit(0.0,xdiff,0.0,ydiff,0.0,0.0)
      call gwicol(0.7,32)
      call gvect(xor,yor,0)
      iflag=0
      do i=1,6000
         read(3,*,end=98)ix,iy
         if ((ix.ge.ngr_lef_id.and.ix.le.ngr_rig_id).and.
     #         (iy.ge.ngr_bot_id.and.iy.le.ngr_top_id)) then
            id=1-iflag
         else if (ix.eq.32767.and.iy.eq.32767) then
            iflag=1
            goto 97
         else
            id=0
         end if
         call gvect(float(ix)+xshift,float(iy)+yshift,id)
         iflag=0
 97      continue
      end do
 98   close(unit=3)
c
 999  return
      end
```

```
c
c
c
c
c
c ------------------------------------------------------------------
      subroutine anglian2
c ------------------------------------------------------------------
c
      include 'radgap.inc'
      integer ix(6000),iy(6000),icolour(6000)
      real ngr_x(6000),ngr_y(6000)
      real ang_ngr_xmax(6), ang_ngr_xmin(6)
      real ang_ngr_ymax(6), ang_ngr_ymin(6)
      character*80 fname(6)
c
      xshift=-ngr_lef_id
      yshift=-ngr_bot_id
      xdiff=ngr_rig_id-ngr_lef_id
      ydiff=ngr_top_id-ngr_bot_id
c
      fname(1)='[cluckie.tilford.dig]anglian_inland_boundary.map'
      fname(2)='[cluckie.tilford.dig]lobound.map'
      fname(3)='[cluckie.tilford.dig]ocbound.map'
      fname(4)='[cluckie.tilford.dig]ncbound.map'
      fname(5)='[cluckie.tilford.dig]nor_only_bound.map'
c
      do k=1,5
         open (unit=3,file=fname(k),status='old',readonly)
         num_data=0
         ixmax=0
         iymax=0
         ixmin=10000
         iymin=10000
         do i=1,6000
            read(3,*,end=98)ix(i),iy(i),icolour(i)
            if (ix(i).gt.ixmax) ixmax=ix(i)
            if (iy(i).gt.iymax) iymax=iy(i)
            if (ix(i).lt.ixmin) ixmin=ix(i)
            if (iy(i).lt.iymin) iymin=iy(i)
            num_data=num_data+1
         end do
   98    ang_ymax=float(iymax)
         ang_ymin=float(iymin)
         ang_ngr_ymax(1)=4250.0
         ang_ngr_ymin(1)=1750.0
         ang_ngr_ymax(2)=3390.0
         ang_ngr_ymin(2)=3170.0
         ang_ngr_ymax(3)=3270.0
         ang_ngr_ymin(3)=2520.0
         ang_ngr_ymax(4)=3420.0
         ang_ngr_ymin(4)=2290.0
         ang_ngr_ymax(5)=2580.0
         ang_ngr_ymin(5)=2340.0
         ang_xmax=float(ixmax)
         ang_xmin=float(ixmin)
         ang_ngr_xmax(1)=5700.0
         ang_ngr_xmin(1)=4505.0
         ang_ngr_xmax(2)=5340.0
         ang_ngr_xmin(2)=4890.0
         ang_ngr_xmax(3)=5563.0
         ang_ngr_xmin(3)=4570.0
```

```
            ang_ngr_xmax(4)=6106.0
            ang_ngr_xmin(4)=5570.0
            ang_ngr_xmax(5)=6250.0
            ang_ngr_xmin(5)=5920.0
c
            dy=ang_ngr_ymax(k)-ang_ngr_ymin(k)
            dx=ang_ymax-ang_ymin
            ay=dy/dx
            by=ang_ngr_ymax(k)-(ay*ang_ymax)
            dy=ang_ngr_xmax(k)-ang_ngr_xmin(k)
            dx=ang_xmax-ang_xmin
            ax=dy/dx
            bx=ang_ngr_xmax(k)-(ax*ang_xmax)
            do i=1,num_data
               ngr_x(i)=(ax*float(ix(i)))+bx
               ngr_y(i)=(ay*float(iy(i)))+by
            end do
            call glimit(0.0,xdiff,0.0,ydiff,0.0,0.0)
            call gwicol(0.2,32)
            do i=1,num_data
             if ((ngr_x(i).ge.ngr_lef_id.and.ngr_x(i).le.ngr_rig_id).and.
     #          (ngr_y(i).ge.ngr_bot_id.and.ngr_y(i).le.ngr_top_id)) then
                 if (icolour(i).eq.0) ipen=0
                 if (icolour(i).gt.0) ipen=1
               else
                 ipen=0
             end if
            call gvect(ngr_x(i)+xshift,ngr_y(i)+yshift,ipen)
            end do
            close(unit=3)
         end do
c
  999    return
         end
```

```
c
c
c
c
c
c     -----------------------------------------------------------------
      subroutine key(height,y_off,x_off)
c     -----------------------------------------------------------------
c
      integer lenar3(3)
      character*9 texar3(3)
      data lenar3 / 5,5,9 /
      data texar3 / 'Below','Above','Undefined' /
      call rtxfon('SWIM',1)
      call gscamm
      call gclopt(lenar3,texar3,1.6*height,2,0.0,1)
      call gcoscl(x_off,y_off)
      return
      end
```

```
c
c
c
c
c
c --------------------------------------------------------------------------------
      subroutine dradar
c --------------------------------------------------------------------------------
c
      include 'radgap.inc'
c
      call glimit(ngr_lef_id,ngr_rig_id,ngr_bot_id,ngr_top_id,0.0,0.0)
      call gwells(3,radx,rady,3.0,0.05,32)
      return
      end
```

```
c
c
c
c
c
c     -----------------------------------------------------------------------
      subroutine raingauge(x,y)
c     -----------------------------------------------------------------------
c
      include 'radgap.inc'
      real x(nstat),y(nstat)
c
      anx=real(nx)
      any=real(ny)
      call glimit(0.0,anx,0.0,any,0.0,0.0)
      do i=1,nstat
         call gwells(3,x(i),y(i),1.5,0.02,33)
      end do
      return
      end
```

Appendix 2: <u>Example Include File</u>

Note, that in this example, the *nstat* parameter for 7th August 1989 will be used.

```
c
c
c    radgap.inc:  an include file used by radgap
c
c
c
c    PARAMETER NOTES
c
c    rax,ray      = radar array dimensions
c    cell         = pixelsize of radar data (km)
c    ngr_lef_id   = ngr coordinates left-side adjustment domain
c    ngr_rig_id   = ngr coordinates right-side adjustment domain
c    ngr_top_id   = ngr coordinates of top of adjustment domain
c    ngr_bot_id   = ngr coordinates of bottom of adjustment domain
c    ngrx_or_rad  = ngr coordinates of radar grid origin (x-axis)
c    ngry_or_rad  = ngr coordinates of radar grid origin (y-axis)
c    radx,rady    = ngr coordinates of radar site
c    nx           = dimension of adjustment domain (x-axis)
c    ny           = dimension of adjustment domain (y-axis)
c    blcell_x_id  = radar cell for origin of adj domain (x-axis)
c    blcell_y_id  = radar cell for origin of adj domain (y-axis)
c    trcell_x_id  = radar cell for top-right of adj domain (x-axis)
c    trcell_y_id  = radar cell for top-right of adj domain (y-axis)
c    xlo          = lower bound of adjustment domain (x-axis)
c    xhi          = upper bound of adjustment domain (x-axis)
c    ylo          = lower bound of adjustment domain (y-axis)
c    yhi          = upper bound of adjustment domain (y-axis)
c    idom         = number of points outside adjustment domain (ie in mask)
c    start,stop   = start and end cells of adjustment domain
c    nstat        = number of raingauge stations
c    mmax         = total number of data points (=nstat+idom)
c
c
c
c    PARAMETER DATA TYPES
c
       integer nx,ny,rax,ray,nstat,idom,nxest,nyest
       integer blcell_x_id,blcell_y_id,trcell_x_id,trcell_y_id
       real xlo,xhi,ylo,yhi,delta
       real ngr_lef_id,ngr_rig_id,ngr_top_id,ngr_bot_id
       real ngrx_or_rad,ngry_or_rad
       real radx,rady,cell
c
c
c    PARAMETER STATEMENTS
c
       parameter (rax=84,ray=84,cell=5.0)
       parameter (ngr_lef_id=4400.0,ngr_rig_id=5700.0)
       parameter (ngr_bot_id=2400.0,ngr_top_id=4400.0)
       parameter (ngrx_or_rad=2900.0,ngry_or_rad=1700.0)
       parameter (radx=5000.0,rady=3800.0)
c
       parameter (nx=(ngr_rig_id-ngr_lef_id)/(cell*10.0) )
       parameter (ny=(ngr_top_id-ngr_bot_id)/(cell*10.0) )
       parameter (blcell_x_id=((ngr_lef_id-ngrx_or_rad)/(cell*10.0))+1.0)
       parameter (trcell_x_id=(ngr_rig_id-ngrx_or_rad)/(cell*10.0))
       parameter (blcell_y_id=((ngr_bot_id-ngry_or_rad)/(cell*10.0))+1.0)
```

```
      parameter (trcell_y_id=(ngr_top_id-ngry_or_rad)/(cell*10.0))
c
      parameter (xlo=1.0,xhi=real(nx),ylo=1.0,yhi=real(ny))
      parameter (nxest=21,nyest=21)
c
      parameter (idom=522)
      integer start(ny),stop(ny)
c
      data start /  1, 1, 2, 2, 2, 2, 2, 2, 3, 3,
     #               3, 4, 5, 6, 7, 7, 7, 7, 7, 7,
     #               7, 7, 7, 7, 7, 7, 7, 7, 7, 7,
     #               7, 7, 7, 7, 7, 7, 7, 1, 1, 1 /
      data stop /   1, 1,11,12,13,14,15,16,16,17,
     #              20,22,23,23,24,25,25,25,25,25,
     #              25,25,25,25,25,25,25,25,25,25,
     #              24,24,23,21,20,19,18, 1, 1, 1 /
c
c   NOTE: use correct value of nstat for data (if necessary uncomment
c         appropriate line, and comment out others)
c
c   use these settings for 891218
      parameter (nstat=68)
c   use these settings for 891214
c     parameter (nstat=66)
c   use these settings for 890729
c     parameter (nstat=63)
c   use these settings for 890707
c     parameter (nstat=58)
c   use these settings for 890627
c     parameter (nstat=66)
c   use these settings for 890320
c     parameter (nstat=49)
c   use these settings for 881129
c     parameter (nstat=64)
c
      parameter (mmax=nstat+idom)
c
c
```

no of raingauges (for given date)

Appendix 3: Example Raingauge Rainfall Inputfile

```
-------------------------------------------------------------------

Raingauge rainfall datafile
27 June       1989
Number of stations  66
Data from 00:00 (first datum) to 23:45 (last datum)
15 minute data interval

-------------------------------------------------------------------

Gauge reference S02
Gauge location   5552.0 3586.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.5  0.0  0.0  0.5
 0.0  0.5  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  1.0  0.0
 1.0  0.5  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0  1.0
 0.0  0.5  0.5  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference S03
Gauge location   5106.0 3698.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.5  0.0  0.0  0.5
 0.0  0.5  0.5  0.0  0.0  2.5  2.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0
 1.0  0.0  1.0  1.0  0.0  0.0  2.0  1.0  0.5  0.0  0.0  0.0
 0.5  0.0  0.0  0.0  1.0  0.5  0.0  1.0  1.0  0.5  1.0  0.5
 0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  1.5  0.5  0.0  0.0
 0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference S04
Gauge location   5241.0 3611.0
 0.0  0.0  0.0  0.0  1.0  0.5  0.5  0.5  0.5  0.0  0.5  0.0
 0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  1.0  0.0  0.0  0.0  0.5  0.0  0.5  1.5  1.0  0.0  0.5
 0.0  2.0  1.0  0.0  0.0  0.0  0.0  1.5  1.5  0.0  0.5  0.5
 0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0
 0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference S05
Gauge location   5222.0 3740.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.5  0.0  0.0  0.5
 0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.5  0.0  1.0  0.5  0.5  2.5  0.0  1.0  0.5  0.0
 0.5  0.0  0.0  0.0  0.0  0.0  0.5  0.5  1.0  0.5  1.0  1.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference S06
Gauge location   5203.0 3826.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.5  0.5  0.5  0.0  0.0
 0.0  0.0  0.5  0.5  0.5  0.0  0.5  1.5  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  1.5  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0
 0.0  0.5  0.0  0.5  0.5  2.0  5.0  0.5  1.5  0.5  0.0  0.0
```

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	2.0	2.0	0.5
0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference S07
Gauge location 5296.0 3754.0

0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.5	0.0	0.5	0.0	0.0
0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	0.5	0.0	0.5
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference S11
Gauge location 5319.0 3859.0

0.0	0.0	0.0	0.0	0.5	1.0	0.5	0.5	0.0	0.5	0.5	0.0
0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.5	1.5	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference S13
Gauge location 4985.0 3756.0

0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0
1.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	0.5
1.0	3.5	1.0	0.0	0.0	1.0	1.5	1.0	0.5	0.0	0.0	0.0
0.0	0.5	0.5	0.5	0.5	0.0	1.0	0.5	0.0	0.0	0.5	0.5
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference S14
Gauge location 5405.0 3730.0

0.0	0.0	0.0	0.0	0.5	0.5	0.5	1.0	0.5	0.5	0.0	0.5
0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	3.0	0.5
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.5
1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference S16
Gauge location 4996.0 4053.0

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
0.0	0.0	0.5	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference S17
Gauge location 5174.0 3356.0

0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.0	0.5	0.5	0.5	0.0
0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5	0.5	0.5	1.0	0.5	1.0	1.0	0.5	0.5	0.0	0.0	0.0
0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
Gauge reference S18
Gauge location 5324.0 3445.0
0.0 0.0 0.0 0.0 0.5 0.5 0.5 0.5 0.0 0.5 0.5 0.0
0.0 0.0 0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 1.0
0.0 0.5 0.0 0.0 0.0 0.0 0.0 0.5 0.0 1.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
Gauge reference T01
Gauge location 4861.0 2831.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 1.5 1.5 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 3.5 1.0 0.5 0.5 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
Gauge reference T02
Gauge location 4838.0 3065.0
0.0 0.0 0.0 0.0 0.5 0.5 0.0 0.0 0.5 0.5 0.5 0.5
0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
Gauge reference T03
Gauge location 5124.0 2982.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.0 1.0
0.5 0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 2.5 0.5 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.5 0.5
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
Gauge reference T05
Gauge location 4627.0 2607.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.5 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.5 0.0 0.0 0.0 0.0 0.5 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
Gauge reference T07
Gauge location 5013.0 2975.0
0.0 0.0 0.0 0.0 0.0 0.5 0.0 0.0 0.0 0.0 1.0 1.5
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.5 1.5 0.5 0.0 0.5 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
Gauge reference T10

```
Gauge location  4867.0 2574.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U01
Gauge location  5109.0 3202.0
 0.0  0.0  0.0  0.0  0.5  0.5  0.5  0.5  0.0  0.0  0.0  0.0
 1.5  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0
 0.0  0.0  0.0  1.5  1.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5
 0.0  0.0  0.0  0.0  0.0  1.5  1.0  0.5  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U04
Gauge location  4992.0 3247.0
 0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.5  0.5  0.0  0.0  0.0
 0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  1.0  1.5  0.5  0.0  0.0  0.5  0.5  0.5  0.5  1.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U05
Gauge location  5246.0 3091.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.5  1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0 -0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  2.5  0.5  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.5
 0.0  0.0  0.0  0.5  0.0  0.0  2.0  1.0  0.5  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U06
Gauge location  5272.0 3993.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5
 0.0  0.0  0.5  0.0  0.0  0.0  0.0  2.0  1.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U07
Gauge location  5143.0 3051.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.5  1.5
 0.0  0.5  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.5  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0
 0.5  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U08
Gauge location  5177.0 3008.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.5
```

```
 1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  6.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0
 0.0  0.5  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U10
Gauge location  5358.0 3258.0
 0.0  0.0  0.0  0.0  0.5  0.5  0.5  0.0  0.0  0.0  0.5  0.0
 0.0  0.5  0.5  0.5  0.5  0.5  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.5  0.5  0.0  0.0  0.0  0.5  0.5  1.0  0.5  0.0  0.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U11
Gauge location  5067.0 3164.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.0  0.5  0.5  0.5  0.0
 0.0  0.0  0.0  2.0  0.5  0.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.5  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U13
Gauge location  5201.0 2984.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0
 0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0
 0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U14
Gauge location  5201.0 3003.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5
 0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  3.5  3.5  0.0  0.0  0.5  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5
 0.0  0.5  0.5  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U15
Gauge location  5193.0 2986.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0
 0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  1.5  1.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5
 0.0  0.5  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U17
Gauge location  5001.0 3336.0
 0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.5  0.0  0.5  0.0  0.0
 0.5  0.5  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
```

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 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.5  0.5  0.5  1.0  0.0
 0.5  0.0  0.0  0.0  4.0  2.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U18
Gauge location  4946.0 3081.0
 0.0  0.0  0.0  0.0  0.5  0.5  0.5  0.0  0.5  0.0  0.5  0.5
 0.5  0.0  1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  1.5  1.0  0.5  0.0  0.0  0.5  0.5  0.5  1.0  0.0
 0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U19
Gauge location  5262.0 3251.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.5  0.0  0.5  0.0  0.0
 0.5  1.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0
 0.0  0.5  0.0  1.5  1.0  0.5  0.5  1.0  0.5  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U21
Gauge location  5476.0 3201.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.0  0.5  0.0  0.0  0.0
 0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.5  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.5
 0.0  0.5  0.0  0.0  0.5  0.0  0.0  0.5  0.0  0.5  0.5  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U22
Gauge location  5183.0 3029.0
 0.0  0.0  0.0  0.0  1.0  0.0  0.5  0.0  0.5  0.0  0.0  0.0
 0.0  0.0  0.5  1.5  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.5  1.5  0.5  0.0  0.0  0.5
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U23
Gauge location  5460.0 3140.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.0  0.5  0.0  0.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.0  0.0  0.0  0.5
 0.0  0.0  0.5  1.0  0.0  0.0  0.0  1.0  1.5  1.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference U25
Gauge location  5274.0 3962.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.5
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0
```

```
 0.0  0.0  1.5  0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V01
Gauge location  4760.0 2647.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  2.5  0.5  0.5  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  1.0  1.0  1.5  1.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V02
Gauge location  4902.0 2593.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  2.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  2.0  1.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V03
Gauge location  4948.0 2847.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.5  1.0  1.5
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  4.5  1.5  2.5  0.5  0.0  0.5  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V04
Gauge location  5000.0 3024.0
 0.0  0.0  0.0  0.0  0.0  1.0  0.0  0.0  0.0  0.5  2.0  0.5
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.5  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.5  1.0  0.0  0.5
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V05
Gauge location  4861.0 2888.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.5
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V06
Gauge location  5148.0 2946.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5
 0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  1.0  0.0  0.0  0.0  0.5  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  1.0  1.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
```

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 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V07
Gauge location  4584.0 2619.0
 0.0  0.0  0.0  1.0  0.0  0.0  2.5  1.5  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V08
Gauge location  4774.0 2867.0
 0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  1.5  3.5  0.5  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.5  4.5  1.0  0.5  0.5  0.0  0.5  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V09
Gauge location  4754.0 2768.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  2.5  0.5  0.5  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.5  0.5  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V10
Gauge location  4729.0 2596.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.5  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.5  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V11
Gauge location  4882.0 2619.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.5  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.5  2.0  0.0  0.0  0.5  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V12
Gauge location  4879.0 2642.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.5
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.5  0.5  1.5  0.5  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
Gauge reference V13
```

Gauge location 4854.0 2962.0

0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V14
Gauge location 4795.0 2959.0

0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	1.0	0.5	0.0	0.5
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.5	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V16
Gauge location 4645.0 2847.0

0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	1.5	1.0	0.5	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	1.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V18
Gauge location 4691.0 2936.0

0.0	0.0	0.0	0.0	0.5	0.0	0.0	1.5	0.5	0.5	0.5	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.5	0.5	2.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V19
Gauge location 4624.0 2551.0

0.0	0.0	0.0	0.0	0.0	0.0	4.5	4.5	1.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	2.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V20
Gauge location 4727.0 2869.0

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	0.0	0.0	0.5
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	8.0	0.0	0.5	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V21
Gauge location 5042.0 2883.0

0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	1.5	0.0

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
0.0	0.0	0.0	0.0	0.5	1.5	0.5	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V22

Gauge location 5038.0 2897.0

0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	1.0
0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	1.0	0.5	0.0	0.5	0.0	0.5	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V23

Gauge location 4757.0 2688.0

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.5	2.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V24

Gauge location 4567.0 2545.0

0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.5	0.5	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	3.0	0.5	0.0	0.5	0.0	0.5	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V25

Gauge location 4826.0 2807.0

0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5	1.5	1.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.5	1.0	0.5	0.5	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V26

Gauge location 4946.0 2675.0

0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	1.0	0.0	0.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V27

Gauge location 4691.0 2823.0

0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.5	0.5	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

0.0	0.0	0.0	4.5	1.5	1.0	0.5	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V28
Gauge location 5090.0 2962.0

0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	1.5
0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	1.5
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V29
Gauge location 4768.0 2616.0

0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V30
Gauge location 4760.0 3005.0

0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.5	0.0	0.5	0.0	0.0
1.5	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	1.0	2.0	0.0	0.5	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V31
Gauge location 4877.0 2994.0

0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.5	1.0	0.5
0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gauge reference V32
Gauge location 4908.0 2674.0

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	1.5	0.0	0.5	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 4: <u>Runtime Listing</u>

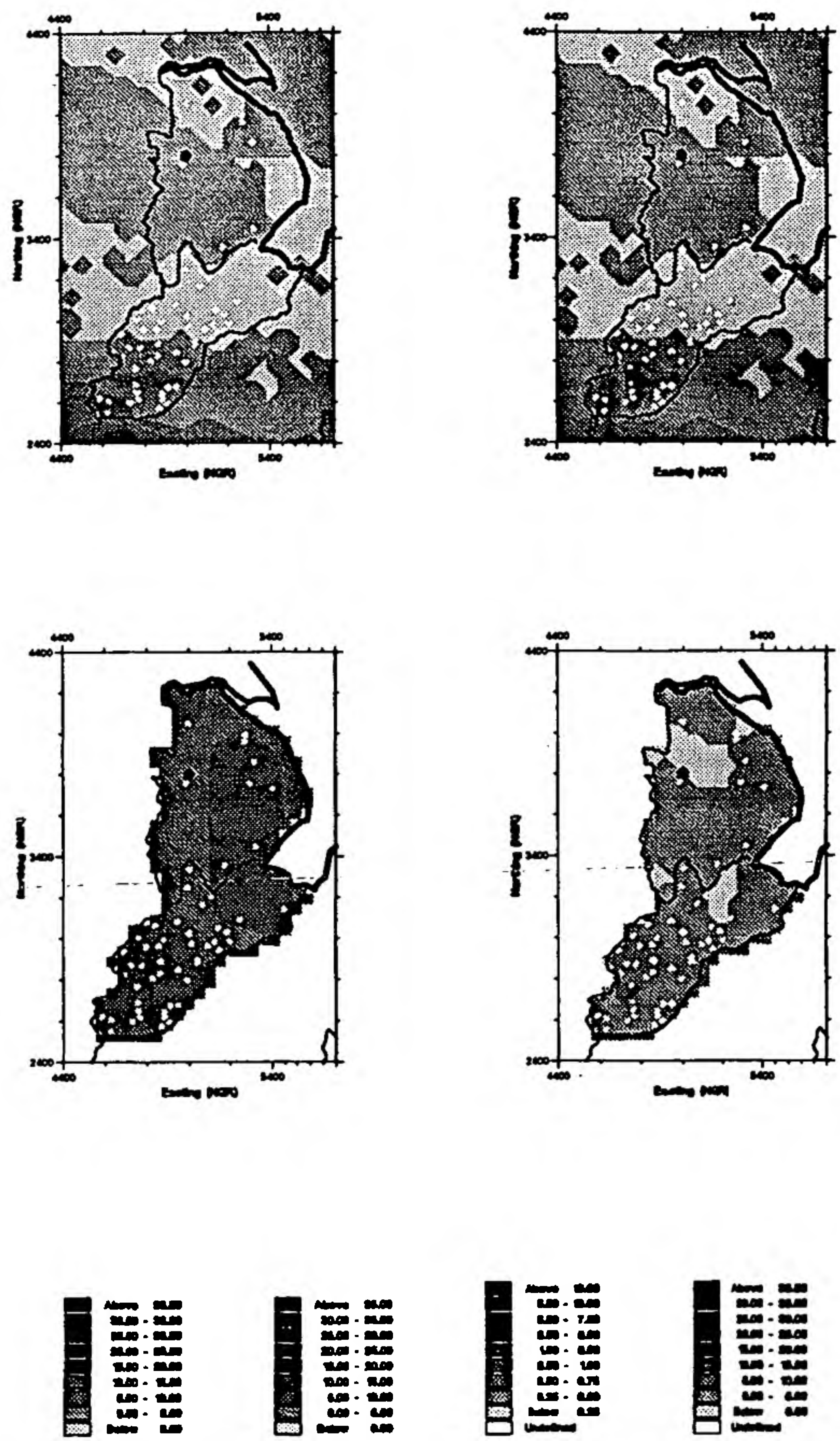
The following is a runtime listing of RADGAP as described in chapter 6 of the main report.

Bolded text indicates user input.

```
$run radgap

  ----------------------------------------------------------------

                              RADGAP

  A program to adjust distributed radar rainfall data by raingauge
  rainfall data, incorporating two-dimensional surface fitting and
  interpolation algorithms

  Written by:
     Water Resources Research Group
     University of Salford
     Salford, M5 4WT
     England, U.K.

  ----------------------------------------------------------------

  IMPORTANT: Before continuing...
     Are you sure that the parameter settings in the file "radgap.inc"
     are correct? If not, abort program and change settings by editing
     the file. If OK...

  Hit return to continue...


  ----------------------------------------------------------------
  The UNIRAS graphics routines in this program are device independent.
  ----------------------------------------------------------------

  Please type in the integer corresponding to the device required
    (1) VAXstation      (GPX driver)
    (2) VAXstation      (X11 driver)
    (3) VT Emulator     (ReGIS driver)
    (4) IBM PC          (VGA driver)
    (5) Inkjet Printer
    (6) Laserwriter     (Postscript)

  Please type integer [1,2,3,4,5 or 6]...
6


  ----------------------------------------------------------------
  Option Menu
  ----------------------------------------------------------------

  Options (default in UPPER CASE)

  1. Graphics every hour                  (Y/n)
```

```
  2. Graphics at end of adjustment period (Y/n)
  3. Auto refresh                         (Y/n)
  4. Interpolation algorithm (enter a or b):
     (a) Renka and Cline              (default)
     (b) Modified Shepherd
  5. Colour or black/white graphics       (C/b):

  To change a default setting enter integer corresponding to the setting
  to be changed, press return key and enter y or n as appropriate
  [Enter 0 <rtn> to continue]...

1
0

5
b

0

  --------------------------------------------------------------

                       Data selection routine

  --------------------------------------------------------------

 Enter adjustment date in the form YYMMDD...
 e.g. for 7th July 1989 enter:
 890707  <rtn>
890707

 Radar datafiles (hourly rainfall depth cumulations with rainfall in mm units)
 exist for the following periods...
  1)  00:00 - 01:00
  2)  01:00 - 02:00
  3)  02:00 - 03:00
  4)  03:00 - 04:00
  5)  04:00 - 05:00
  6)  05:00 - 06:00
  7)  06:00 - 07:00
  8)  07:00 - 08:00
  9)  08:00 - 09:00
 10)  09:00 - 10:00
 11)  10:00 - 11:00
 12)  11:00 - 12:00
 13)  12:00 - 13:00
 14)  13:00 - 14:00
 20)  19:00 - 20:00
 21)  20:00 - 21:00
 22)  21:00 - 22:00
 23)  22:00 - 23:00
 24)  23:00 - 24:00

 To select adjustment/cumulation period enter start and end hours required
 (note, only select periods where the radar datafiles are contiguous)
 e.g. to adjust from 03:00 to 07:00 enter:
 4  <rtn>
 8  <rtn>
2
5

  --------------------------------------------------------------
```

```
                    Computation segment

 --------------------------------------------------------------------

Computing for hour            2
---------------------------------------

Please wait, computing surface knots...
Please wait, evaluating surface...

Please wait, computing interpolating function...
Please wait, evaluating interpolant...


Computing for hour            3
---------------------------------------


Please wait, computing surface knots...
Please wait, evaluating surface...

Please wait, computing interpolating function...
Please wait, evaluating interpolant...


Computing for hour            4
---------------------------------------


Please wait, computing surface knots...
Please wait, evaluating surface...

Please wait, computing interpolating function...
Pleaso wait, evaluating interpolant...


Computing for hour            5
---------------------------------------


Please wait, computing surface knots...
Please wait, evaluating surface...

Please wait, computing interpolating function...
Please wait, evaluating interpolant...


Please wait, preparing final graphics...

Final graphics presentation display:
  Please enter a value for the top of the rainfall slicing scale. This will
  be used to determine an appropriate slice interval.
35

Do you wish to replot the fields shown (Y/N) ?
N


 ----------------------------- RADGAP STOP ---------------------------

$
```



4400
5400
2400
3400
Northing (NGR)
Easting (NGR)
Above
Below
Undefined

Appendix 5: Devices Supported

The following devices are explicitly supported by RADGAP.

DEC VAXstations (GPX driver)
DEC VAXstations (X11 driver)
VAX Terminal Emulators (ReGIS driver)
DEC Ink Jet Printer
Laserwriter (Postscript Driver)

Appendix 6: Utility Program Source Listing (radgap_set_idom)

```
c
      program radgap_set_idom
c
c  this routine determines the correct setting for the parameter
c  idom (i.e. the number of cells falling outside of the adjustment
c  boundary. Use this if the boundary has been changed or if a new
c  adjustment boundary is being defined.
c
c  before running enter correct values for the adjustment domain
c  dimensions (i.e. nx and ny)
c
      integer nx,ny
      parameter (nx=26,ny=40)
      integer start(ny),stop(ny)
c
c
c  'straight-edge' anglian region, northern area boundary
c
      data start /  1, 1, 2, 2, 2, 2, 2, 2, 3, 3,
     #              3, 4, 5, 6, 7, 7, 7, 7, 7, 7,
     #              7, 7, 7, 7, 7, 7, 7, 7, 7, 7,
     #              7, 7, 7, 7, 7, 7, 7, 1, 1, 1 /
      data stop /   1, 1,11,12,13,14,15,16,16,17,
     #             20,22,23,23,24,25,25,25,25,25,
     #             25,25,25,25,25,25,25,25,25,25,
     #             24,24,23,21,20,19,18, 1, 1, 1 /
c
c
      ic=0
      do i=3,37
        do j=start(i)+1,stop(i)-1
        ic=ic+1
        end do
      end do
      ic=(nx*ny)-ic
      write(*,*)
      write(*,*)'  Parameter idom should be set to the following value
',ic
c
      end
```