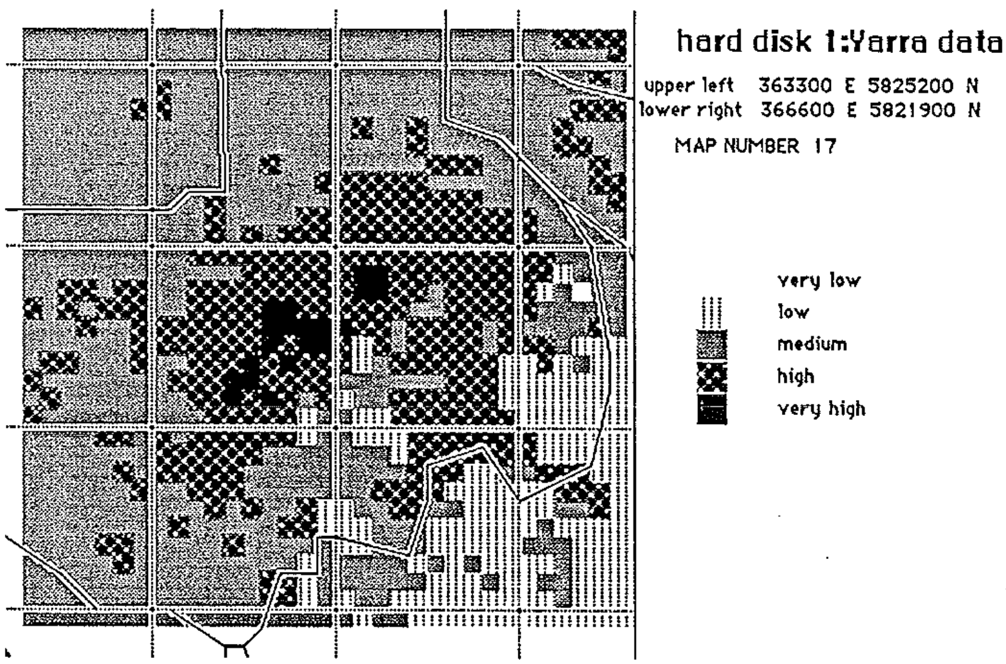
BISHOP

INFORMATION SYSTEM FOR LOCAL FIRE HAZARD MANAGEMENT



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This report describes the development and preliminary evaluation of the 'Information System for Local Fire Hazard Management' developed by the School of Environmental Planning, The University of Melbourne under a grant from the Department of Local Government and Administrative Services.

The first section summarizes the project brief and sets out the work program anticipated at commencement of the project. The following sections describe the work done to complete each of the identified tasks, and our evaluation of the system to this stage. Finally, some work outside the original brief and work program, but considered necessary to on-going system development, is described.

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In the Shire of Gisborne and the Upper Yarra Valley and Dandenong Ranges Authority, Geoff Lush and John Ginivan co-ordinated operations and provided valuable suggestions for software modification.

Professor Michael McCarthy shaped the project and kept a watchful eye over developments.

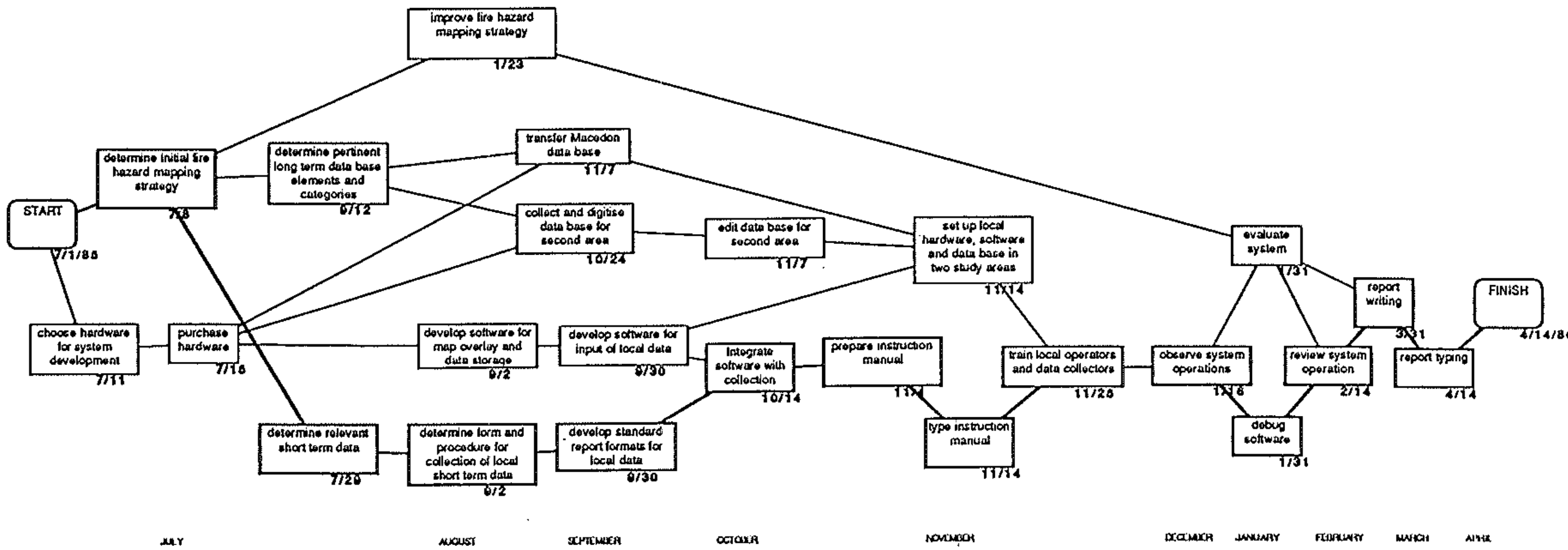


Figure 1. Project schedule showing major tasks with their completion dates (MM/DD/YY). The critical path is shown in bold.

1.0 THE PROJECT BRIEF

The brief for an 'Information System for Local Fire Hazard Managenment' called for:

- development of a suite of low cost micro-computer software
- collection of base data for two pilot areas, one being the Macedon Ranges
- determination of the most appopriate form and procedure for the collection of local short term data
- development of standard report formats for such data
- development of software for accepting that data and combining it with the longer term data-base
- the preparation of an instruction manual for all aspects of the operation.

Appendix 1 is a copy of the original research proposal which explains the rationale of the project and gives some additional detail of the work program. Figure 1 is the project schedule showing the major tasks, anticipated start and completion dates and the critical path for the project.

The project team was to be led by Dr. Ian Bishop and Professor Michael McCarthy of the School of Environmental Planning. Ms Margaret Cutler was research assistant.

The Management Committee for the project originally included representatives of:

- The School of Environmental Planning
- The Ministry of Local Government and Administrative Services
- The Victorian Local Government Department
- The Victorian Country Fire Authority
- The Macedon Ranges Redevelopment Advisory Committee.

Early in the project, when pilot areas had been selected, representatives from

- The Department of Conservation, Forests and Lands
- The Upper Yarra Valley and Dandenong Ranges Authority
- The Shire of Gisborne

were also invited to joint the Management Committee.

2.0 DETERMINATION OF FIRE HAZARD MAPPING STRATEGY

A literature review of the major parameters of fire hazard and existing fire hazard mapping techniques led to certain early decisions.

1. The separation of long and short term data bases. Components of fire hazard assessment were catagorized by their rate of change. Factors which would not change substantially over the study period were classified as long term, while those which would need updating during the fire season were considered short term. Slope, for example, is clearly a long term data item whereas fuel moisture is variable in the short term.

2. The Victorian Country Fire Authority (C.F.A.) and Ministry for Planning and Environment fire hazard mapping technique was used as the basis for mapping in the new system. All parameters included in that technique except frequency of fire season, length of fire season and fire history, were regarded as important for this system. Frequency and length of fire season were excluded because they would not vary across the small pilot areas being used in this study (see below). Fire history would be treated in a different way. The Department of Conservation, Forests and Lands (C.F.&L.) also have a mapping strategy which incorporates such things as the value of assests in danger. Consideration would be given at a later date to mechanisms for inclusion of these.

3. Long term fire hazard parameters would be mapped and computerised at the School of Environmental Planning.

4. Short term parameters would be monitored and input to the computer based system by operators in the local regions.

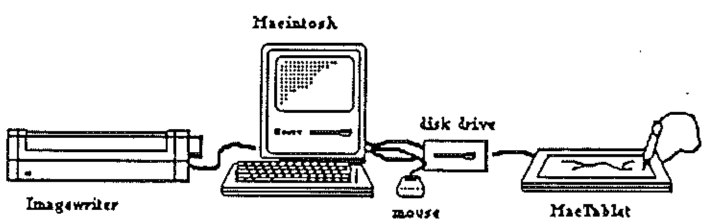
5. The possible means of collection of local short term data were seen to be:
(a) casual - observance of the condition of the pertinent parameters, while driving around the study area,
(b) formal - recording of measured data, gathered from set station points,
(c) remote - material gathered and interpreted from satellite monitoring.
Data collection by remote sensing was not seen to be a viable option for the 1985/86 fire season.

3.0 HARDWARE

The Apple Macintosh was selected as the most suitable computer for development of the mapping system. The advantages of the Macintosh were seen to be:
(a) low cost (field unit hardware for each location costing less than $5000)
(b) user-friendly and easy to learn (the Macintosh operating system and graphics capabilities minimize training requirements)
(c) there was existing software (a map-overlay program for the Macintosh was already well advanced)

The developed system would have to make possible:
- . simple, frequent and accurate input of mapped data
- . a flexible approach to data combination for hazard mapping
- . high quality output for use by personnel involved in fuel reduction.

After testing of potential system components, including camera and scanning map input devices, the following suit of equipment was used as the basic field unit:
- 1 Apple Macintosh with 512K RAM
- 1 Apple 400K external disk drive
- 1 Apple 9 inch imagewriter (printer)
- 1 Summagraphics MacTablet digitiser.



4.0 MAP OVERLAY SOFTWARE

The selected hardware imposed certain constaints on the way in which the software and the data bases could be configured. Using a two disk system (one for the operating system and software and one for the data base) allowed a maximum of 400K bytes for each area's data. Of this some 30-40K was needed for linear features and area identification files. The minimum possible storage required for each map cell on each map is one byte. The option then is to develop a system with more cells and fewer maps or vice-versa. It was felt that the mimimum number of maps required for a viable system was about 20. This implied a maximum of 18K bytes for each map.

The resolution of the Macintosh screen also played a part in chosing final map dimensions. Because the Macintosh has a black-and-white monitor map areas have to be distinquished by different shading patterns. It was felt that a minimum of 3 by 3 screen pixels would be required to adequately distinquish map cells of different character. With an available drawing area of roughly 500 by 330 pixels this set a map limit of about 165 by 110 cells. In view of the storage limit and need to work in dimesions divisible by 4 for efficient data entry (see below), a data area of 160 by 108 cells was chosen.

This decision meant that:
a. the full screen is required for mapping, explanatory and tabular information must be written into separate windows,
b. one data disk could accommodate 21 maps in addition to linear features and map legend related information, and
c. the process of drawing a composite map for the entire area might take over an hour.

The software as developed at August 1985 is described in a paper given by Dr Bishop at the 13th Conference of the Australasian Regional and Urban Planning Information Systems Association in Adelaide. A copy of this paper is included as Appendix 2.

During the trial period several suggestions for system improvement were made by the users. Some of these were too major to be considered under this project but others could be added quite readily. These were:
a. a quick map retrieval option which reduced the time for reproduction of a single data map to about 5 minutes;
b. the ability to retain a chosen window when going to the next mapping function, this allowed users to explore the reasons for mapped hazard levels; and
c. printing of AMG coordinate values of map corners in the legend for all output maps.

Choose the operation required:

- ○ Reproduce existing map
- ○ Weighted overlay
- ○ Search for specific characteristics
- ○ Quick map
- ○ Reallocate fuel conditions
- ○ Default fire hazard mapping

5.0 THE STUDY AREAS

The original project proposal had included the Macedon Ranges as one study area for the project. This decision flowed from the School's ongoing involvement with the Ranges since the 1983 bush fires. In particular an extensive data base covering approximately 21 km by 19 km at a resolution of 1 hectare was already held on one of the University's VAX 11/780 computers. The choices available were to cover just 16 by 10.8 km of the area with the fire hazard system at a resolution of 1 ha or to cover the whole area at 4 ha. The latter would have meant losing considerable detail and also not testing fully the capabilities of the system (since only 105 by 94 cells would have been required at this resolution). We chose to cover the smaller area and selected a portion of land mainly on the southern slopes of the ranges spanning the Shires of Gisborne and Romsey. This encompassed Riddell's Creek in the southeast, the peak of Mount Macedon in the north and part of Roslynne Reservoir in the southwest. The south-west corner was placed at AMG co-ordinates 284000E, 5849000N.

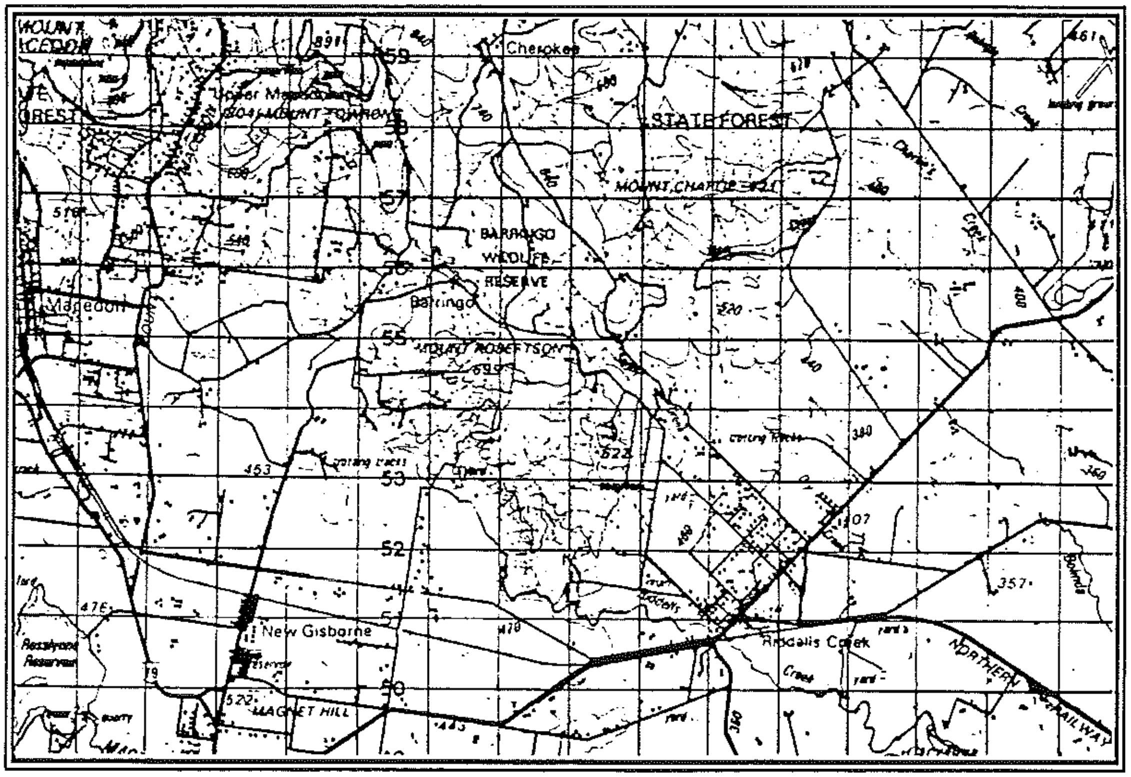


Figure 2. The Macedon Ranges study area.

The Management Committee identified a number of possible second areas of study:

a. Western District (Shire of Ararat) - broad scale pastures and cropping;

b. Maryborough area (North-Central Victoria) - mainly crops and grazing with pocket of bush and forest plantation; and

c. Upper Yarra Valley - combination of forest, intensive agriculture (market gardening, viticulture) and grazing on small holdings.

The Upper Yarra Valley was seen as the most suitable because of a demonstrated high level of community awareness and concern, the previous involvement of the Upper Yarra Valley and Dandenong Ranges Authority (UYVDRA) in fire related research and community programs and the existance of a digital data base for the area.

Through discussion with the UYVDRA it was felt that a 1ha grid was appropriate and that the possible 16 by 10.8 km area of coverage should include the northern part of Lilydale and southern Healesville. Placing the southwest corner at AMG 352000E, 5820000N would mean including Christmas Hills in the northwest, the outskirts of Healesville in the northeast, and the Warramate Hills and Gruyere in the southeast. The land is a mix of grassland, some cropping, vineyards and forest, and is an important recreational area. While similar to the Macedon area in being a cool-temperate mixture of forest and cleared lands this areas was also a contrast in that agriculture is more intensive, there is a substantial river and the area of remaining forest is much less.

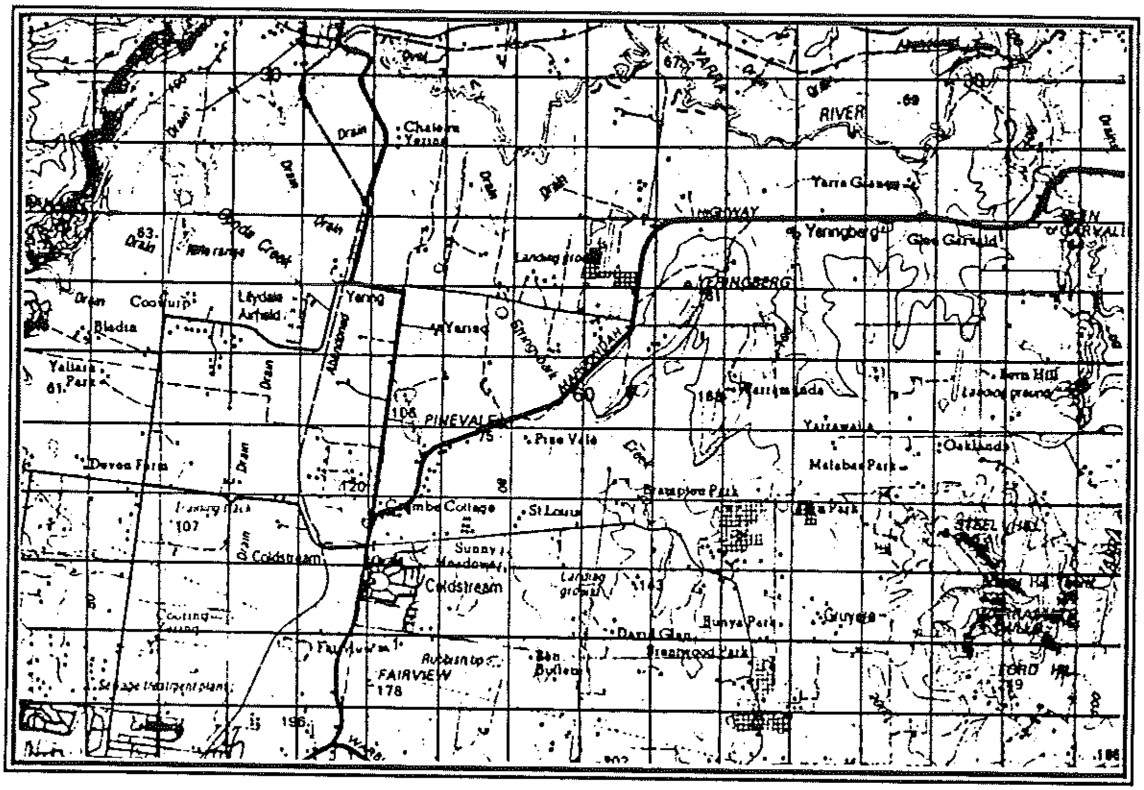


Figure 3. The Yarra Valley study area.

6.0 DETERMINATION OF LONG TERM DATA

Based on an initial decision to use the C.F.A. mapping system as a starting point for the system and further discussions with the Management Committee the following elements were determined to compose the long term data base.

Map Position	Data Element	Map Catagories
1	land ownership	private, various classes of public
2	elevation	50m(Yarra) or 100m(Macedon) intervals
3	slope	0-5%, 6-10%, 11-20%, 21-30% and over 30%
4	aspect	flat and 8 cardinal directions
5	land cover	grassland, woodland and forest types
6	development	4 levels of urban density
7	egress	5 levels of escape capability
8	fire services	5 levels of access to fire fighting services
9	wildlife	5 levels of conservation significance
10	water catchment	inside/outside (Macedon only)

Most of the Macedon data was transfered from our existing VAX data base. Although the UYVDRA has a digital data base this is stored with the commercial organisation ESRI in Perth and was not available to us because ESRI have recently changed software systems. We were however able to get digitised contour information from Associated Surveys, the ESRI affiliate in Melbourne. This was converted to 100 m grid using the GRIDDEM software from CSIRO. Other Yarra Valley data was digitised manually using the new data input software for the Macintosh.

The data categories were not always the same in the two study areas. Wildlife value, for example, was based on Ministry for Conservation mapping of Botanical and Zoological significance in the Yarra Valley but on a School of Environmental Planning overall rank for Macedon. Land cover categories were also different in the two locations.

Mapping of levels of development, egress and fire services required special methods because none of these had been previously mapped in a compatable form for either area.

Levels of development were mapped by counting, on recent aerial photographs, the number of dwelling within a specified area. In Macedon the area was a 25 ha grid (Figure 4). In the Yarra Valley a 100 ha grid was used over most of the site but 25 ha used in areas of rapid change around built-up areas. The number of dwellings was used to divide each area into approximately the same categories of development level as used in the CFA hazard mapping procedure (A 0-1 house/km^2, B 2-7 houses/km^2, C 8-80 houses/km^2, D over 80 house/km^2).

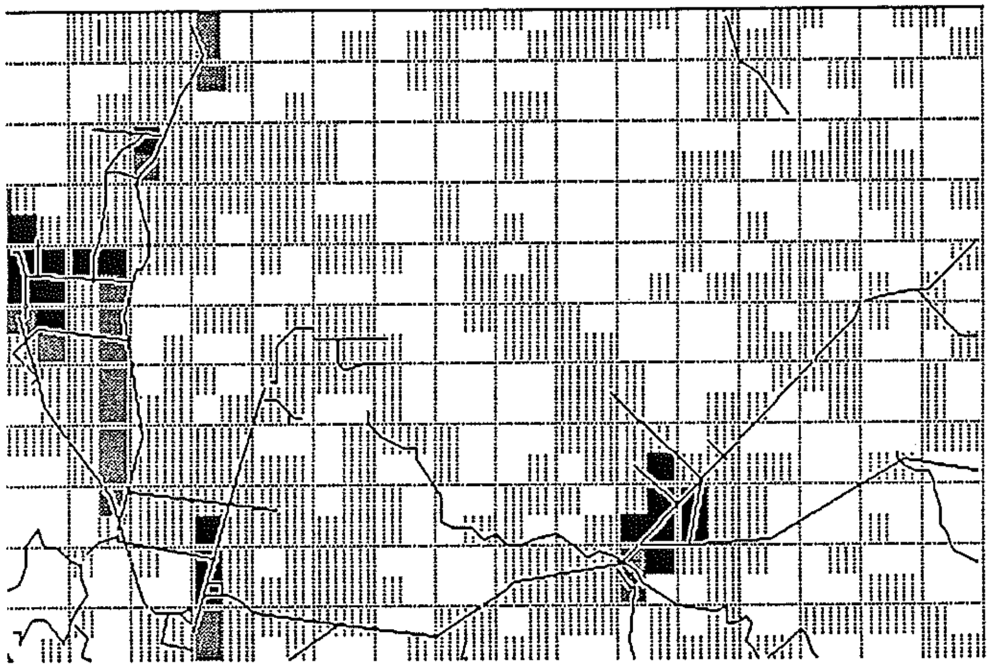


Figure 4. Four levels of development density in the Macedon study area. The grid shown is the 1 km AMG while density ratings are based on 25 ha grid cells.

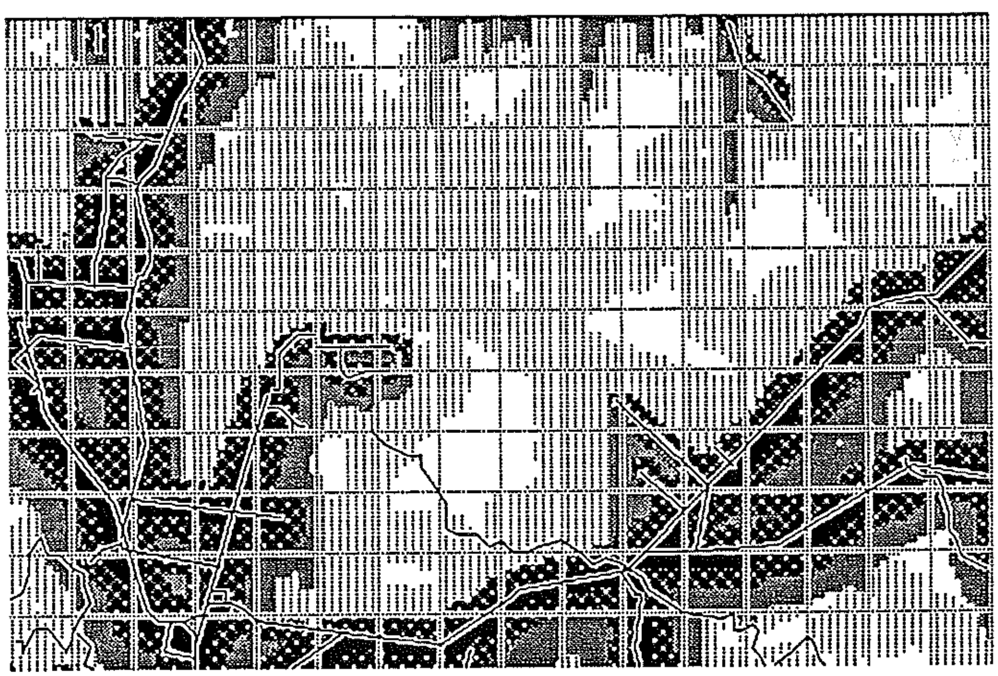


Figure 5. Egress capability for the Macedon study area mapped to five levels.

Egress was mapping using a facility in the Map Analysis Package (MAP) (Tomlin, unpub.) which permits proximity relations to be mapped. In the case of the Yarra Valley the roads had to first be transfered from Macintosh to the University's VAX computer on which MAP operates. The classification of egress levels was then based on road type and distance as follows:

	2 lane bitumen	1 lane bitumen	unsealed
less than 100m	very high	high	medium
100-400m	high	medium	low
400m-1 km	medium	low	very low
more than 1 km	very low	very low	very low

Recognizing that in areas of high slope lower distances would be appropriate, the classification was modified such that distance had twice the effect at slopes between 20% and 39% and three times the effect at slopes from 40-59% and four times at slopes of 60% or over. Figure 5 shows the result for Macedon.

Access to fire services was also mapped using the proximity function of MAP. In this case, CFA stations were located by grid co-ordinates and accessibilty was dependent on distance to the station where a distance on 1 lane bitumen roads was considered 50% more than the same distance on 2 lane bitumen roads. On dirt roads the apparent distance was doubled and off-road a factor of 4 was applied. This was done for each station in or near the study areas and the results added on the assumption that its better to be near two stations than one. As shown in Figure 6 accessibility patterns follow the road patterns under this method of calculation.

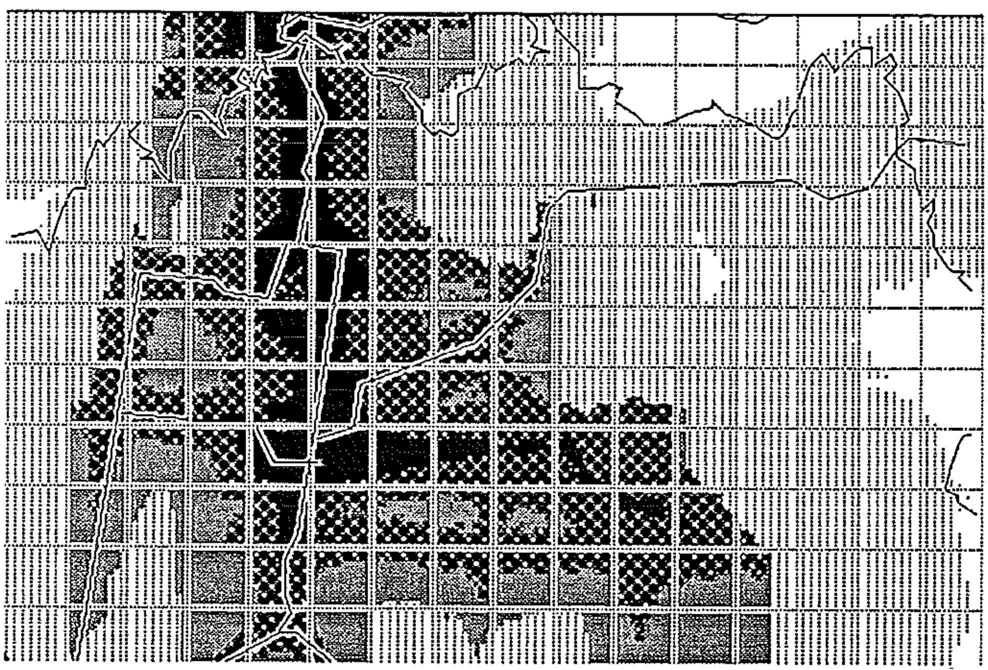


Figure 6. Access to fire services in the Yarra Valley area. CFA stations at Coldstream, Yarra Glen, Healesville and Gruyere were used as the basis for calulation.

7.0 DETERMINATION OF SHORT TERM DATA

7.1 IDENTIFICATION OF DATA NEEDS

The study regions encompassed both grasslands and forests. Relevant short term fire hazard parameters and their collection methods may differ in forests and grasslands. There is considerable ongoing research in Victoria and elsewhere to determine the key parameters.

A joint study of forest fuel levels conducted by Rusden State College/Monash University in the Christmas Hills found that:
1. litter loads show a seasonal and annual dependence. These levels are further affected by drought, severe wind and past fires (including fuel reduction burns).
2. The fuel moisture content of the litter experiences large variations due to diurnal effect.
3. It is difficult to judge the moisture content of fuels as litter observed as dry may actually contain >15% moisture (oven dry weight).
4. Fuel moisture content and fuel weight are related to the vegetation associations, slope and aspect.

The following fire danger prediction formulæ are in use at the CFA and by CF&L. These include
. McArthur's Forest Fire Danger Meter - temperature and humidity, days since rain, wind speed and Drought Index
. Soil Dryness Index - time since previous rain + accumulated daily rainfall + temperature (grassland only)
. McArthur Grassland Fire Danger Meter (Mark V) - used to assess rate of fire spread via - fuel weight (t/ha) + wind velocity + fuel moisture (estimated as a function of relative humidity) + air temperature + % curing of grass.
. Byramm-Keetch Drought Index - accumulated daily rainfall + temperature (grassland and forest)
. McArthur Forest Fuel Danger Index - litter distribution + humidity + drought index (forest only)
. Fine Fuel Flammability Index - previous day's maximium and minimum temperatures, maximum and minimum humidity and rainfall.

The quantity of fine fuel (<6 mm smallest dimension) and the dryness of the fuel are generally regarded as the key short term variables in forest fire danger.

Grassland conditions have a more predictable pattern following seasonal conditions more than short term weather conditions. The sequence is essentially one of growth in the spring, drying beginning in late spring and continuing into January (or later in a wet summer), and harvesting of crops or slashing of pasture late in the summer or in autumn. The sequence may be interrupted however by a fire which destroys the crop or pasture.

Thus, although the basic variable are still fuel quantity and fuel condition, it was felt that estimation of these values in grassland may prove easier.

7.2 POTENTIAL ESTIMATION METHODS

In consultation with the Management Committee as well as CF&L (Kallista Office), Municiple Fire Prevention Officers (Shire of Lilydale and Healesville) and the Gisborne Shire Planner, four potential mechanisms for generating mappable short term data were identified.

1. Field observation:
a. rated levels of: forest fuel moisture content/degree of grass curing
fine fuel litter levels/amount of grass
b. changes in field management by private land holders (e.g. crop harvesting).

2. Reporting by management agencies:
a. controlled or uncontrolled fires (size and type)

b. landuse /development changes.

3. Remote sensing/observation
Aerial and satellite based estimation of fuel moisture content. Potentially useful for grasslands but not for forests.

4. Prediction
a. litter accumulation predictions from dynamic fuel curves
b. daily forest fuel moisture content calculated from the Fine Fuel Flammability Index or other indices
c. crop and pasture cycle stage estimated from accumulated weather data.

There are difficulties with each of these methods.

Use of prediction formulæ requires the recording of vegetation associations, fire data and accumulated daily weather (rainfall, temperature, relative humidity, vapour pressure) for many station points within each study area. Setting the monitoring system to sustain a prediction based approach would be a major undertaking.

Satellite based monitoring of grassland conditions appears very promising. This also however requires an investment in time, money and equipment which was not available at the time of this study. It is hoped that this technology can be merged with the mapping system in the near future.

Reporting of all relevant management activities to a recording and processing centre should become a normal and essential part of an operational system. Again however establishment of the necessary communications channels is a major undertaking which is both beyond the scope of this work and also dependent on successful application of the pilot system to justify the admistrative costs.

For this study we were therefore left with field observation. This could be done by precise measurement or by casual observation and estimation. The time involved in taking fuel level measurements (particularly of moisture content) means that this more accurate method can only be used infrequently. Late in the study we conducted some tests in order to establish the degree of accuracy of field observers in estimating fuel conditions (see section 10). Unfortunately the early results were not encouraging. This research is being continued to better assess the capabilities of local observers.

Some improvement would probably flow from observer training using photographs taken at measured station points. More uniform perceptions of 'low', 'moderate' and 'high' fuel levels might then be achieved. C.F.&L. (and to a lesser extent the CFA) are currently looking into establishment of such training programs.

7.3 DETERMINATION OF HOMOGENOUS FUEL AREAS

To assist in mapping fuel variations the regions were divided into zones which would be treated as homogenous with respect to fuel type and condition (in the absence of any management or fire activity). Each zone take the form of multiple discontinuous irregular polygons (Figure 5). In grasslands the homogeneous areas were larger and more regular than in the forests. Within a representative area a sample site is located as the gauging point for observation, and less regularly for measurement of the fuel condition in each of these different vegetation regimes.

Nineteen polygons of homogeneous vegetation associations were defined for Macedon, 23 for the Upper Yarra. For the Macedon area, distinctions were made first on the basis of vegetation type (i.e. grasslands, open or closed forests) then within the grasslands on the basis of SCA land systems and in the forests by aspect and elevation.

For the Upper Yarra area, the forest mapping available was in terms of dry schlerophyll, wet schlerophyll, etc. rather than open or closed forests. Only aspect was taken into account in the Upper Yarra forests since the range of elevations was not so great as at Macedon. Again, grasslands were sub-divided according to the Soil Conservation Authority Land Systems.

The definition of the zones needs to be reviewed annually to account for changes following recent fires or due to forest plantation planting or growth. No subdivision of zones on the basis of fire history occurred in the 1985/86 mapping. In the Yarra Valley no documentation of recent fires in the study area could be found. At Macedon the effect of the 1983 fires had been largely taken into account in the original definition of land cover, and so implicitly in the definition of mapping zones.

Within each zone 'station points' were set. These were designed to provide field collectors with a site typical of the zone at which to assess fuel conditions. This combination of homogeneous zones and representative sample points was thought to be the most effective strategy for regularly recording fuel information within the 180 km^2 of each study area. It was envisaged that an estimate of fuel weight and dryness would be made at each station point every two or three weeks.

These points were reviewed by local C.F.A. brigades, Municiple Fire Prevention Officers and conservation groups, who indicated that there were difficulties with some of the selected points either in regard to accessibility or non-representativeness flowing from deficiencies in the original data. These were to be adjusted by the local groups.

7.4 SOFTWARE FOR INPUT OF LOCAL DATA

The use of zones and station points as the basis for local data collection considerably reduced the complexity of the input procedure for most of the short term data. Mapping and digitisation was then only required as an input mechanism for fuel reduction areas arising either from farm management, special fuel reduction activity or fire.

Local data input was therefore via either:

a. a digitising tablet which allows the input of mapped data relating to management activities or fire, or

b. allocation of fuel weight and dryness to permanently mapped 'homogeneous' fuel type zones.

The digitising tablet chosen for mapped input had only a small active area (roughly the size of the Macintosh screen). This meant that mapping at a scale of 1:25000 could only cover an area of about 5 by 3 km on one recording sheet. To cover 16 by 11 km it was necessary, at this scale, to divide the regions into 16 sectors. At 1:50000, 4 sectors were required and at 1:100000 the whole of either area fitted onto the tablet. The software was designed to accommodate the use of any of these three scales. Use of the digitising system is illustrated in the user instruction manual which forms Appendix 3. Fuel reduction information is stored in map position 11 on the data base.

A recent software enhancement permits the user to 'screen digitize' areas of fuel reduction. In this mode the system displays major roads, waterways and the AMG on the screen. The user selects the portion of the study area in which the activity has taken place. This is blown up to full screen size and the user can use the mouse to trace out the affected area.

The homogeneous fuel zones are in position 12 on the data base. When the operator enters new fuel weight or dryness estimates for certain station points the corresponding zone is selected and maps 13 and 14 which contain these parameters are updated to the new values. The procedure for data entry is explained in the instruction manual Appendix 3.

7.5 FORM AND PROCEDURE FOR COLLECTION OF LOCAL SHORT TERM DATA

Maps were prepared for each sector of the study areas, illustrating the fuel zones and their proposed sampling points. The sampling points were referenced to tracks or streams within forested areas and roads in grasslands. The sector maps were accompanied by pro-forma sheets on which the short term data for each zone could be recorded (Appendix 4).

The field observer rates each zone's sample point for fine fuel load and moisture content (for forest sites) or percentage curing (for grassland sites) by ticking the appropriate box. These sampling points are marked and numbered for consistent referencing.

Observer recording sheets for fuel reduction activity were prepared at the three scales (1:25,000, 1:50,000 and 1:100,000). The scale actually used will depend on the size and complexity of the area affected and the amount of detail required. This is at the discretion of the observer. The size of each map is identical in order to simplify the digitizing process (Figure 7). Appendix 5 is a full recording sheet for fuel reduction activity.

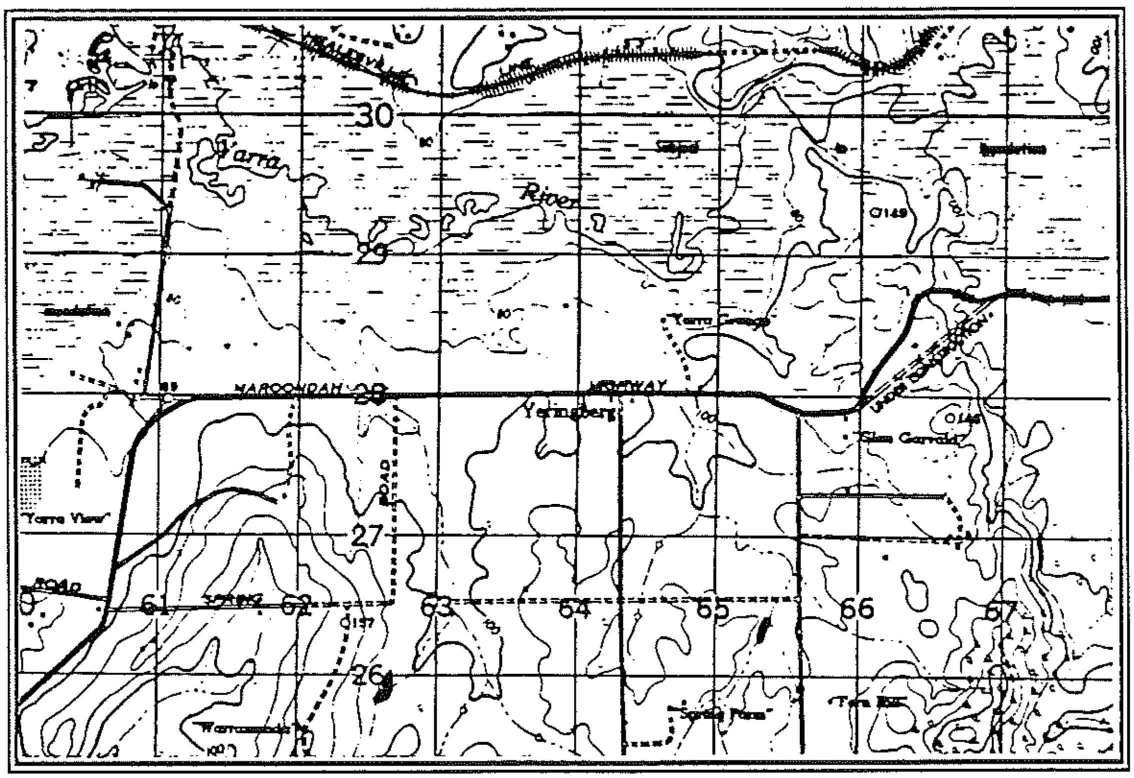


Figure 7. A portion of the Yarra Valley study area at 1:25,000 scale. This scale is sufficiently large for information to be recorded to at least the level of accuracy compatible with the data base.

8.0 FIELD INSTALLATION

8.1 COMPUTER LOCATION

It was agreed that the Macedon Ranges computer equipment be located in the the Gisborne Municiple Offices. The Upper Yarra equipment was located in the UYVDRA offices and accessible by both the Lilydale and Healesville Municiple Fire Prevention Officers. Both systems were installed during the week November 11-15, 1985.

The principle local users, Mr John Ginivan (UYVDRA) and Mr Geoff Lush (Gisborne Shire), were trained during the initial set-up period. Demonstrations were arranged for local data gatherers and other interested parties in the following week.

It was envisaged that field observation would be carried out on a weekly or fortnightly basis by Municiple Fire Prevention Officers and on an irregular basis by casual reporters. It was also hoped that C.F.A. regional officers would contribute to data collection.

8.2 INSTRUCTION MANUAL AND TRAINING

An instruction manual 'Using the Macintosh computer and Poligrid software in fire hazard mapping' was prepared (Appendix 3)

In addition an introduction to the use of the system was developed using the Slide Show Magician software. This enables local operators to graphically introduce the system to others. The Slide Show Magician could also be used for storage and reproduction of fire hazard maps. This option was not developed this summer as the system was new to the users.

8.3 USE OF THE SYSTEM

Once the fuel data has been input the user can generate a fire hazard map using either their own selection of data and their own prefered rating and weightings, or they may choose the default rating scheme. The data elements and their relative influences in the default scheme are set out below.

Element	Rating 0	25	50	Weighting 75	100	
slope	0-5%	6-10%	11-20%	21-30%	over 31%	2
aspect	E,SE	S	SW,flat	NE,W	NW,N	2
development		<4/km^2	4-20	20-200	>200/km^2	1
egress	v.high	high	med.	low	v.low	1
fire services	v.high	high	med.	low	v.low	1
fuel reduction*	0-20%	20-40%	40-70%	>70%		-5
fuel level	v.low	low	med.	high	v.high	5
fuel condition#	damp		med.	dry	very dry	5

* when fuel reduction occurs it is presumed to counteract the fuel level for the remainder of the fire season, i.e. no additional growth or accumulation will occur during one season. (This is of course a simplification of the reality that fuel reductions are effective for several seasons but that re-growth is continuous from the time of reduction.)
# there are five categories of fuel condition, if the fuel is described as 'wet' an exclusion rating applies and other variables become irrelevant.

The result is a map such as Figure 8 with darker shading indicating higher hazard. If some area is of particular interest to the user they may window on the selected portion (Figure 9). The table below shows the relationship between fire hazard and conservation significance in the windowed area. All the areas of highest fire hazard (E) are found to have regional conservation significance and fuel reduction programs should be designed accordingly.

	A	B	C	D	E	TOTAL
Regional botanical & zoological significance	0	66	53	95	9	223
Regional botanical sig.	0	0	0	37	11	48
Local zoological sig.	0	73	61	52	0	186
no mapped significance	0	0	514	117	0	631
TOTAL	0	139	628	301	20	1089

The user can choose any of the maps in the data base for crosstabulation.

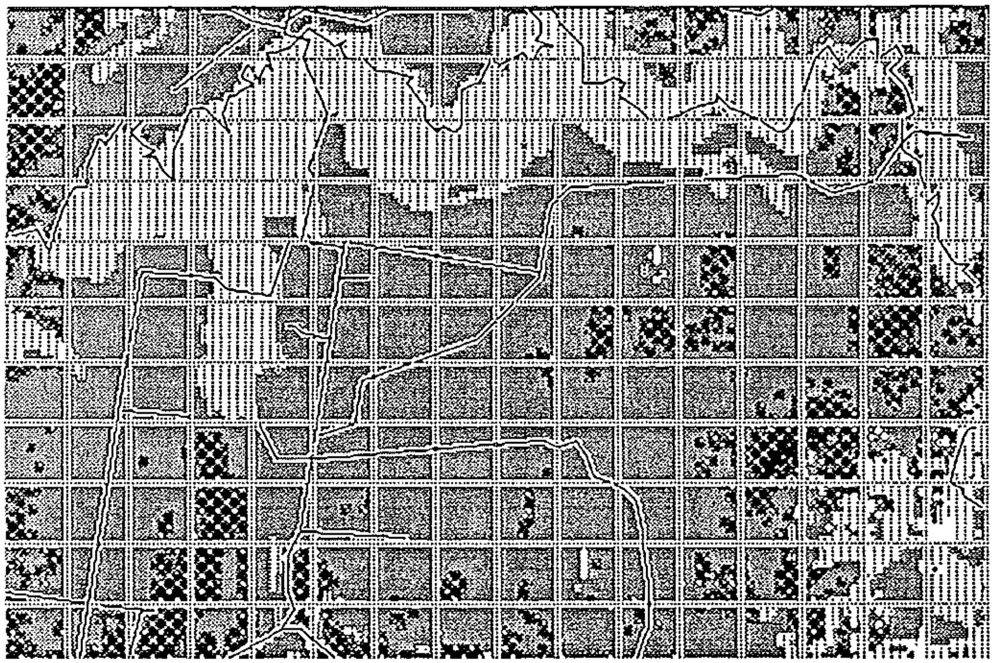


Figure 8. Fire hazard mapped for the whole Yarra Valley study area.

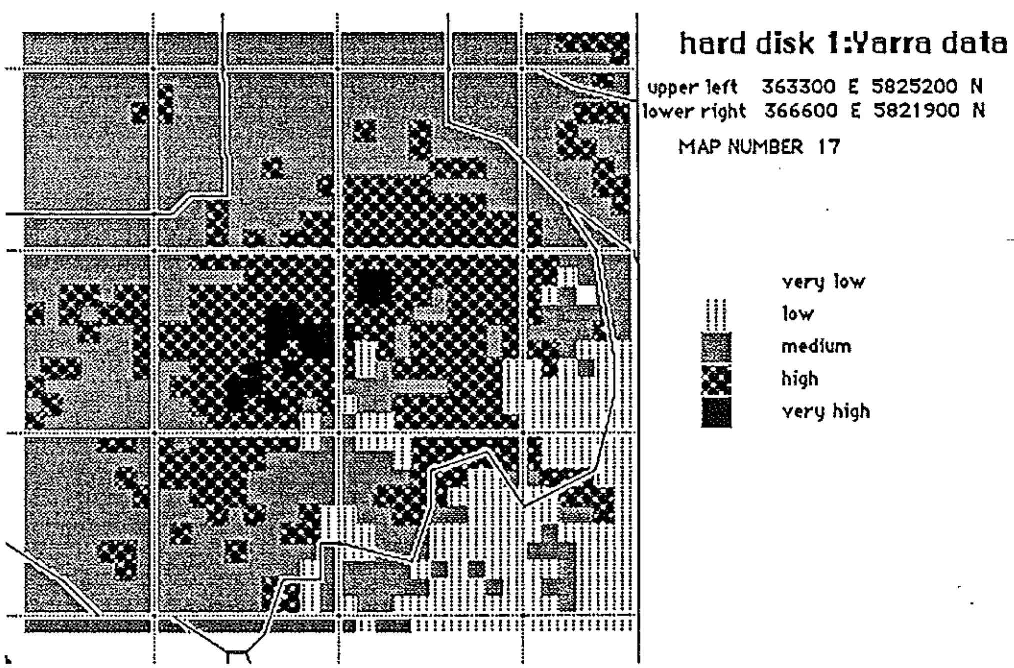


Figure 9. Window on sub-set of yarra Valley data area showing variation in fire hazard across the Warramate hills.

9.0 EVALUATION

Despite a wet start to the summer of 1985/86 which reduced the demands placed on the system by local users certain conclusions can be draw from the initial trials.

1. For successful operation the system requires a significant commitment of local staff time to inital set-up. In the beginning time is needed to (a) ensure that suggested station points are sufficiently accessible and representative to be used for fuel data collection, and (b) organise a collection system through Fire Prevention Officers, CFA brigades and local residents. Once this is done the time required for on-going system operation should be much less. The level of initial commitment will vary between municipalities (or regions) according to the nature of the landscape, current staff responsibilities and work loads, and existing potential for community involvement.

2. More than just a handful of people need to be involved in each area. These people must be regularly collecting and reporting data to the system operator. (They must however not see this as a substantial additional work burden. It should be possible in conjunction with their normal activities.)

3. Data collectors will require a substantial level of training before quick and accurate estimation of fuel conditions is possible (see 10.2 below).

4. Fire management personnel need to trust the system and to come to it regularly for information.

5. Any such system should be installed in the autumn, rather than late spring, so that it may be used for planning management activities which take place primarily in the early spring.

6. The area covered by a data base should be part of a single administrative unit unless further work in setting up new communications channels is anticipated. Ready access to staff from other agencies might help to overcome this constraint provided a strong sense that the system was a joint facility were created and that all parties had agreed on the siting of the system.

7. The speed of map production must be increased, especially to facilitate demonstration of the system to interested parties, potential new users or data collectors. Access to larger screen output would also help in this regard.

8. At least one study area should have been on a larger grid and covered a larger area in order to determine the operational implications of greater coverage.

9. Both hardware and software are sufficiently simple for personnel with little training in computers to use them confidently. Even so, to assist personnel with no previous experience two changes to the system were sought (a) an on-screen 'HELP' facility, and (b) greater use of default options.

In our original proposal we indicted that the success of the project could be judged on:
(i) the degree to which local authorities felt the system was a useful addition to their fire control capabilities, and
(ii) the degree to which local community support could be generated (althought it was recognised that this could take several years to develop).

In broad terms the developed system has impressed the local authorities and both parties were keen to be involved in further system development. As yet however the necessary community support to sustain system operation has not been generated. This is a problem in both communication and logistics. Obtaining time commitment from busy people for a still to be proven system is difficult, and yet proving the system depends on that input.

10.0 FURTHER RESEARCH

Three areas of further research outside the brief have been identified, some work done, and new funding sought through the Australian Research Grants Scheme (ARGS) - Appendix 6.

10.1 Interfacing of the system with satellite observation

The CFA intends to install equipment to permit frequent assessment of grassland fuel conditions using satellite data. This data would be particularly valuable to the mapping system if it could be disseminated quickly to field users of the mapping system.

This could be done via dial-up modem connection of each field system to a master data manager at the CFA. The School has done some preliminary work to identify suitable software and modems for the central facility.

10.2 Testing the accuracy of field observers

As indicated above, some work has already been done in this direction. Both completely untrained people and others with some experience in fuel estimation have been tested in forest conditions. The results are still being analysed but it appears that, without additional training, fuel condition estimation is not sufficiently reliable to justify the level of mapping detail provided by the system.

Many questions about preferred estimation techniques and hence about the best form of training remain. For example, it has not been resolved if the use of ratings (high-low) are of more benefit than the use of actual quantifiable estimations. It is hoped that if CF&L and CGA do develop training programs that these will be accessible to data collectors for the mapping system. Future tests will then, hopefully, tell a different story.

10.3 Development of an expert systems module.

The proposal to ARGS makes much of the role of local knowledge in assessing both the parameters relevant to fire hazard and the appropriate combination of these. The most promising technique for incorporation of the views of the local operators about fire hazard conditions, that does not require them to quantify every variable, is the use of expert systems.

Such systems make use of the programming languages developed in artificial intelligence research. We have begun experimentation with MacProlog and anticipate translating the expert system shell (GEOMYCIN) developed by CSIRO for fire behaviour modelling in the Kakadu National Park to the Macintosh for interfacing with the mapping system.

APPENDIX 1

The project brief

INFORMATION SYSTEM FOR LOCAL FIRE HAZARD MANAGEMENT

1. INTRODUCTION:

Fire hazard mapping in Australia at present gives an approximation of which areas in a local government region are more susceptible to fire. These systems are also useful for determining limited planning controls but contribute little to day-to-day or seasonal management of fire prone areas. Information systems and computer map manipulation techniques can produce more detailed fire hazard assessments and can generate updated hazard ratings whenever new information comes to hand.

Fire hazard depends on many factors. Some of these factors change rapidly, some can be controlled by man, and others are rather constant. Those factors which change slowly are often the same ones that are mapped by governments for other purposes e.g.: topography, slope, aspect, land use, transport routes, property lines. These are readily accessible (sometimes already in computer-readable form) and can be easily disseminated to local users.

The factors which change more rapidly, such as fuel levels, dryness or recent management techniques, etc., are seldom collected in a systematic way. Yet, at the local level there is a network of underutilized sources of information. Most farmers have a rain-gauge, they take note of pasture growth and dryness, and are aware of changes in other conditions which they observe may threaten their property. Local naturalists or walkers know the condition of the forest areas, the amount of forest litter or dryness. Country Fire Authority volunteers often see certain problem areas. This type of information could be accumulated by local governments, combined in computers with the more permanent data and regular updates of fire hazard levels could be mapped. The fators which contribute to high hazard values can be analysed and the degree to which management action might reduce the risk could also be plotted. Priorities for management action could then be quickly set. At the same time sensitive conservation zones may also be mapped and management adjusted accordingly.

2. PRODUCT:

The product of this research will be a suite of computer software, data and operating manuals which will be readily useable by local people and agencies (after appropriate training). At this stage, it is envisaged that local government and local fire control agencies (such as the CFA in Victoria) would be supplied with:

(i) software to run on existing computer facilities in the region (or requiring small additional hardware costs i.e. about $5,000);

(ii) base data for the region such as elevation, slope, aspect, transport routes, current land use, major property boundaries;

(iii) an instruction manual;

(iv) sample data acquisition sheets for local residents or officials to supply data on rainfall, pasture growth, forest conditions and other variables determined to be pertinent to fire hazard.

The users and suppliers of data would be given training sessions in application and assistance for an introductory period.

3. WORK PROGRAM:

Eight tasks have been identified:

(i) adaptation of existing map analysis software to low cost microcomputers (this would continue throughout the project);

(ii) collection of base data for two pilot areas. These areas would include the Macedon Ranges for which an extensive computerised data base already exists and in which strong ties to the community area already established, and one other area which could serve as a control and second application/testing site;

(iii) determination of the most appropriate form and procedure for collection of local short term data;

(iv) development of standard report formats for such data;

(v) development of software for accepting that data and combining it with the longer term data base;

(vi) preparation of an instruction manual for all aspects of the operation;

(vii) ensuring that the system would function on local computing equipment and training the operators and the data collectors in operation of the system. (N.B.: given the specialized graphic input and output anticipated it is likely that new equipment will be required in each locality - See # 1.)

(viii) evaluation of system, reporting. (See Section 5)

This would complete the first phase of the research.

A second phase (which would more extensively disseminate and test this prototype) would be the subject of a further research proposal after completion of this effort.

4. MANAGEMENT:

The project team will be led by Dr. Ian Bishop and Professor Michael McCarthy.

The management committee for the project will include representatives of:

- The School of Environmental Planning
- The Ministry of Territories and Local Government

- The Victorian Ministry of Local Government
- The Victorian Country Fire Authority
- The Macedon Ranges Redevelopment Advisory Committee

This committee will also consult regularly with the New South Wales National Parks and Wildlife Service.

5. PROJECT EVALUATION:

The success of the project will be measured by the degree to which the local authorities feel that the final project is a useful addition to their fire control capabilities given the expected cost of system installation. This will in turn depend upon the degree to which they are able to gain local support for an input into the trial period. It may be that the level of cooperation envisaged in this proposal will take several years to develop. If those using the system and the computers don't want us to take them away then we will have succeeded at the end of project period for the first phase.

6. TIMETABLE:

The project will commence on June 1, 1985. The latest completion date is June 30, 1986 but present plans suggest a final report by mid-April 1986. The key element in successful testing of the systems developed is having them in the field for the 1985/86 fire period. We are aiming for installation in Macedon and the second test area in November 1985.

APPENDIX 2

Paper to URPIS 13 describing software

A MICRO-COMPUTER BASED GIS FOR LOCAL APPLICATION

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ABSTRACT

There are a number of micro-computer based Geographic Information (or at least map overlay) Systems commercially available. None has been a noteworthy success because of such problems as poor graphics (e.g. non-square pixels), slow speeds (especially retrieval from disk) and unfriendly interfaces (often constrained by the operating system). In exploring options for a micro-computer based local area fire hazard mapping system it was important that these problems be overcome and yet a low hardware cost retained. The Apple Macintosh appeared to offer a solution because of its large memory, excellent graphics and fool proof operating system. In the beginning there were new problems, especially in map input. This paper describes how the Macintosh has been programmed in BASIC for local area GIS applications and how most of the problems have been overcome. Programming options such as pull-down menus, dialog buttons and multiple output windows allow very friendly programming. The PoliGrid software happily manipulates up to 21 maps on a 160 by 108 cell grid (without recourse to hard disk) and appears to have great potential for planning and land management at the local level.

INTRODUCTION

The stimulus for this system development work comes from a project to produce an 'Information System for Local Fire Hazard Management' supported by the Commonwealth Department of Local Government and Administrative Services. The system will allow a local operator, with no previous computer training, to input, manipulate and map data relevant to fire hazard management. Some of the data will be supplied with the system (e.g. land ownership, slope, aspect, land use) while the remainder will be input by the user (e.g. fuel levels as effected by short term management of forest, crop or pasture). Two systems will be installed in fire prone locations near Melbourne for the 1985/86 fire season. If successful the system will become available for wider distribution.

These intentions provide certain criteria that the system has to meet:

1. It must be simple to use for operators with only brief training.
2. It must be fool proof in that entering the wrong instruction will not crash the system
3. It should have sufficiently good graphics to encourage the user unused to interpreting computer maps.
4. It should be affordable.

The last point in particular made it necessary to base the system on a micro-computer. We were familiar with two micro-computer based map-overlay/GIS packages - Ap-Grid (from IRIS) and Grid-Apple (from ERSI). The capacity of the former was far too limited. The latter was more interesting, having wide ranging capabilities and provision for large data sets. It still, however, had substantial disadvantages, namely -

- .a requirement for a hard disk
- .a high price tag on the software
- .a need to understand the Pascal operating system
- .complex file creation procedures

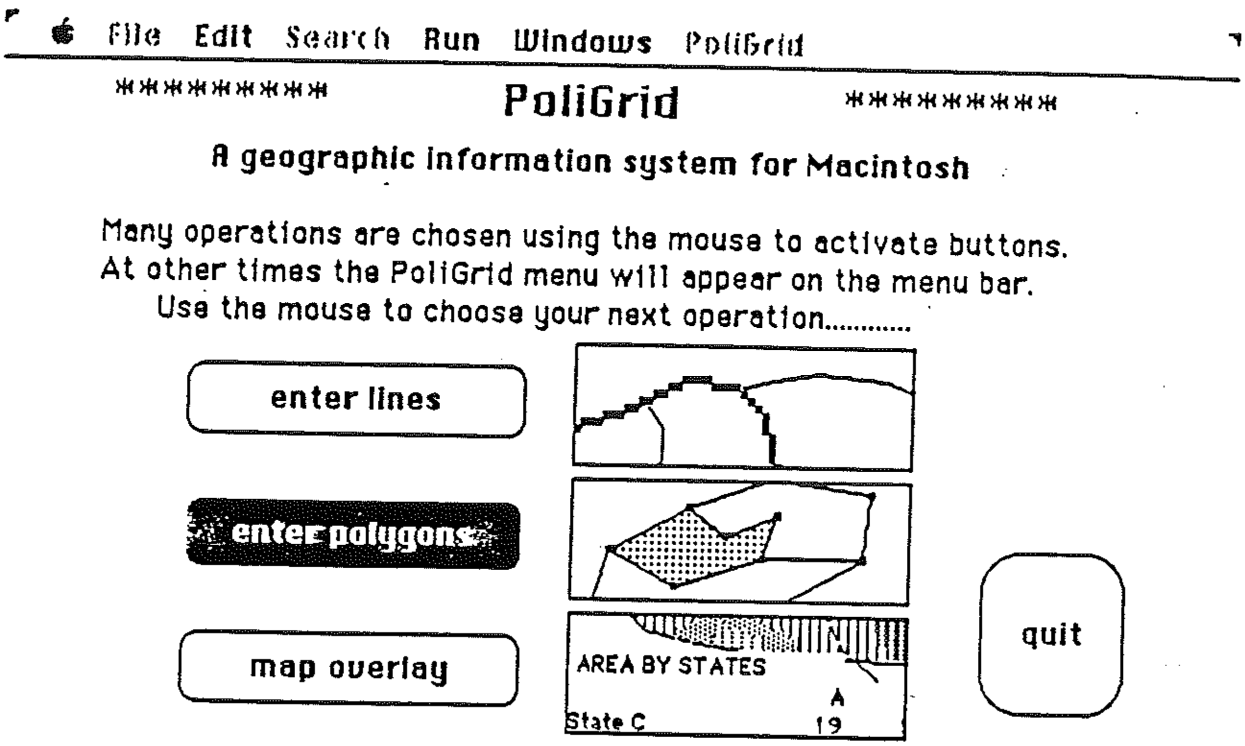

Figure 1. The PoliGrid main menu. The graphic symbols associated with each user option are stored in a file on the software disk. They are read into an array by the program and placed on the screen using the PUT command.

.low screen resolution and non-square pixels
.no direct screen dump procedure for hard copy
.it was very slow.

Other systems have been reported, e.g. *"Map Overlay, Micro-map, Themaps"* (see Bishop et al., 1984); but there was no way of directly evaluating these packages. However, most of these systems were CP/M based and it was reasonable to assume that the graphics would be restricted, access to new users would be difficult, floppy disk based storage limited and data retrieval and processing not very fast.

The Apple Macintosh had already made a good impression as a machine for computing beginners and for its graphics strengths. Disk storage was 400K without the expense of hard disk and 512K RAM was capable of handling the sort of large arrays that are common in GIS software. The current retail price for the hardware to be used (512K Macintosh, external disk drive, printer and graphics tablet) is about $5,800. The only obvious drawback is the purely black and white output. But as colour hard copy would add considerably to the price, this constraint was accepted.

Once the hardware choice had been made, there were more involved decisions regarding choice of programming language, data storage format, map dimensions and operational options.

INITIAL DECISIONS

At the time we began work on the software (late 1984), the only programming languages available were MacPascal and Microsoft BASIC 1.0. The latter was chosen because of some previous map-overlay programming experience in BASIC and much greater familiarity. Microsoft BASIC 1.0 was a rapidly introduced Macintosh compatible version of the long standing microcomputer standard. It

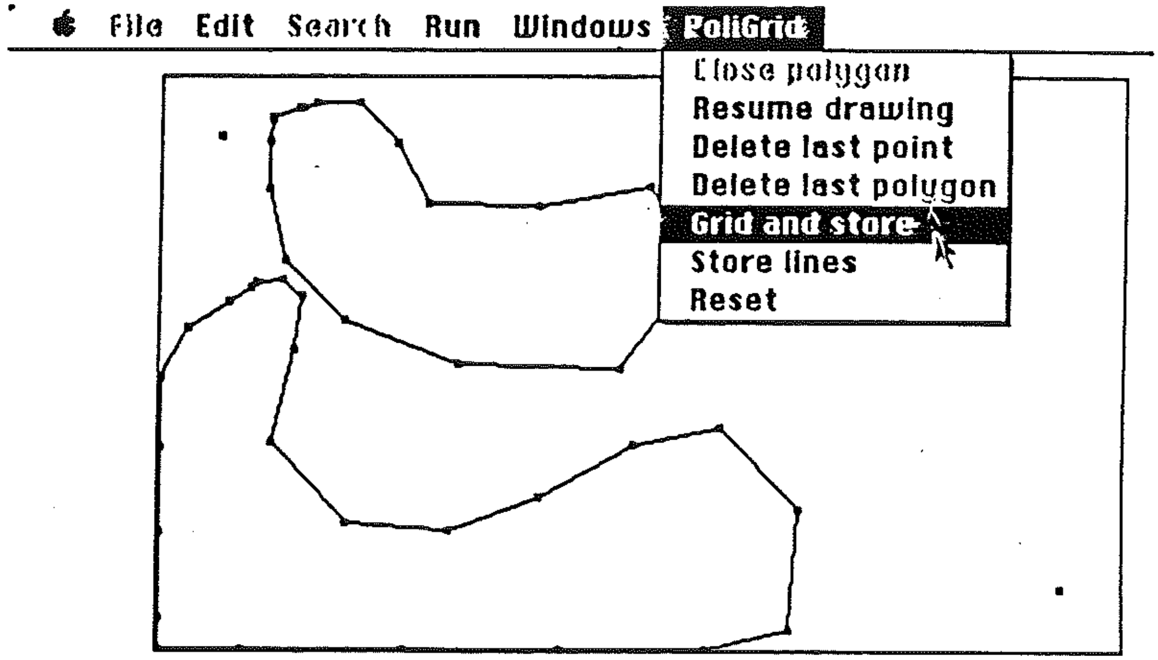

Figure 2. This shows the screen configuration during the polygon digitising process. The corner check marks are for map alignment on the Tablet. As the user moves around the polygon boundary 3 points are recorded per second. If the user goes over the edge of the map that edge becomes the polygon boundary. The **PoliGrid** menu shows the user options. Selection of 'Grid and store' initiates the inversion and sampling of the polygons.

had a 'MOUSE' command and gave access to the Macintosh toolbox and quick draw routines but few other Macintosh specific commands. A short while later Microsoft introduced BASIC 2.0 which gave programmer access to a range of Macintosh operating system features such as pull down menus, multiple drawing windows, time based event trapping, array storage of screen segments and dialog boxes. In addition, the new version did away with compulsory line numbering and introduced sub-programs permitting more structured programming than has been possible in BASIC in the past. These features are now also available in other lanuages for the Macintosh (FORTRAN, FORTH and C) and while it is possible that some advantage in operating speed may be available through one or more of these they are unlikely to provide any additional functions. The programs described here are all written in Microsoft BASIC 2.0.

It was necessary next to determine the size of the data area that might be effectively handled by a 512K Mac with two 400K disk drives and a screen resolution of 512 by 340 pixels. Given that data is stored on a grid cell basis, the minimum storage requirement for each cell on each map is one byte. To fit 20 thematic maps onto one disk meant limiting each map to 20,000 cells (some relaxation of this might be afforded by run-length or quadtree based encoding). Three by three screen pixels were felt to be the minimum necessary to portray a decent range of shading patterns (a colour screen would relax this constraint) and therefore to fit the whole data area on the screen at once a limit of 170 by 110 cells (i.e. 18,700 cells) for each map applied. After some experimentation it was decided to work with a data area of 160 by 108 map cells and up to 21 maps per disk. This left room on the disk for a few small files containing linear features, map titles and map labels.

The operations and facilities that were seen to be necessary were -

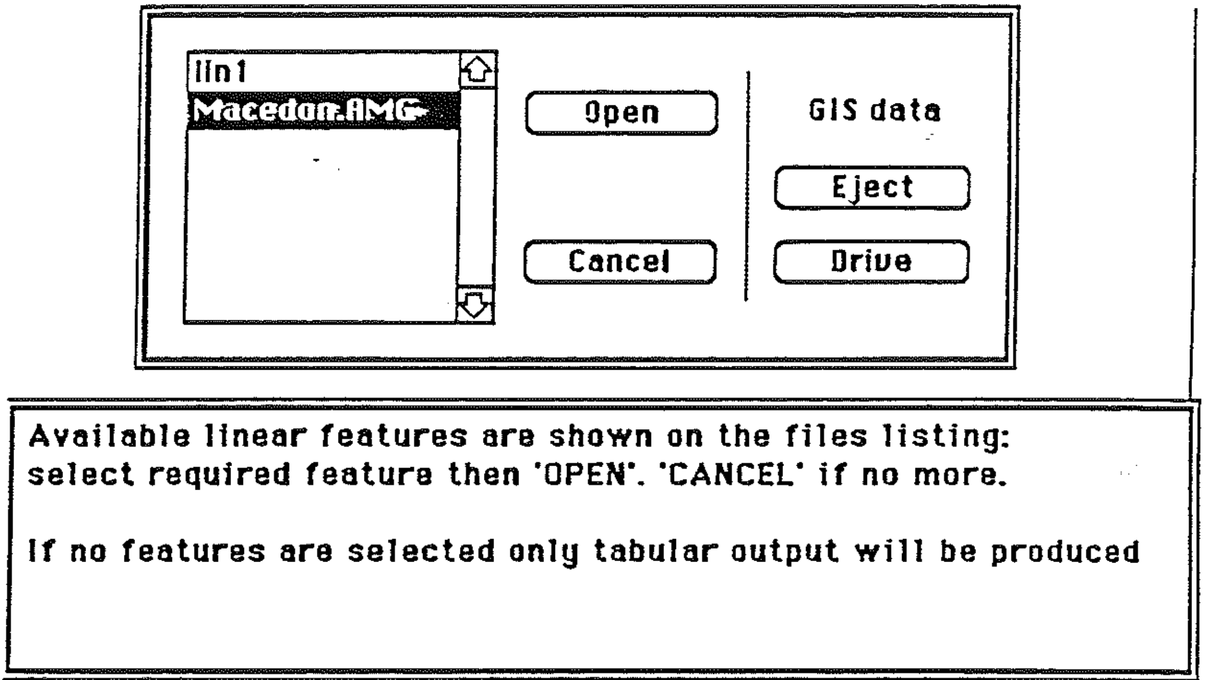

Figure 3. This shows how the BASIC command FILES can be used to bring up a system dialog box which lists the available linear features. The features to be included in the mapping can then be selected. Roads, rivers, administrative boundaries and so forth may all be stored and accessed independently.

. a selection of linear features files (including the AMG) from which to gain locational reference

. reproduction of maps from the supplied data base

. addition of new maps to the data base

. linear combination of maps based on user supplied ratings and weightings

. Boolean search for areas with particular combinations of characteristics on an .AND., .OR. or .XOR. basis

. tabular reporting of the class distribution of one map (either original or combination) against the categories of any other

. the ability to window into a subsection of the map.

The remainder of this paper describes the **PoliGrid** software developed for the project. It is divided into two sections dealing with (i) polygon and line data input and gridding, and (ii) grid based map overlay, tabulation and output. These are, in fact, the directions offered by the PoliGrid main menu as shown in Figure 1.

POLYGON AND LINE INPUT

Some of the data for one data area (the Macedon Ranges) was already stored in grid form on VAX through the Map Analysis Package (Tomlin, unpub.). This was transferred using **MacTerminal** and translated to byte form for the PoliGrid system. As indicted however, the field users will input their own polygonal and line data for gridding. In each case they may also wish to keep the line and boundary files for display as linear features.

When we began this project there was no graphic input device available for the Macintosh. There is now the choice of a small graphics tablet (MacTablet by Summagraphics), a scanning device which replaces the print head on the imagewriter

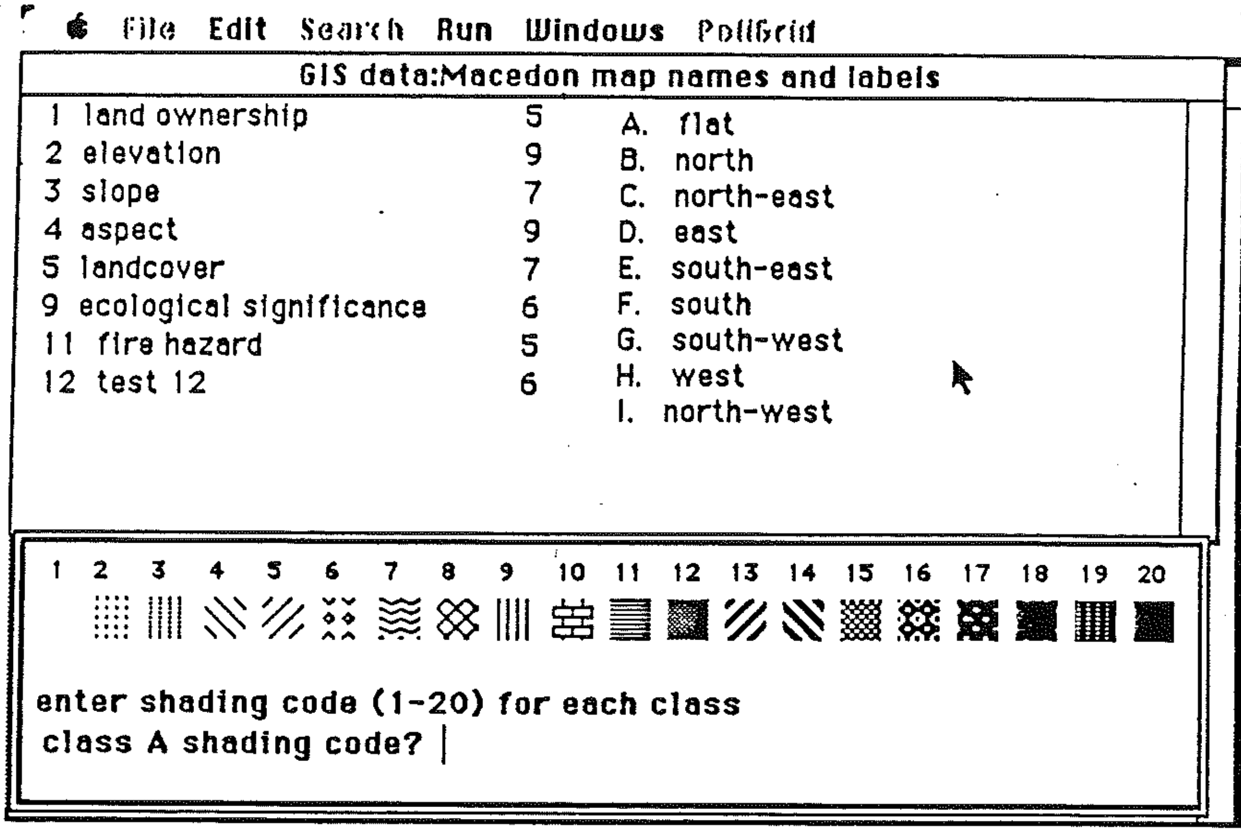

Figure 4. In setting the mapping required the user is shown, on the left, the maps available. As each map in the overlay is chosen the map categories are displayed on the right. If the user chooses non-standard shading the range of options is shown in the dialog window. This window scrolls while the map information is fixed.

(Thunderscan) and a number of camera based devices (MacVision, Micron-eye). By far the easiest of these to incororate into the software was the graphics tablet because it could be called in by the user as a replacement for the mouse (or used concurrently) with the same BASIC functions.

The size of the working area on the tablet is only 210mm by 110mm. This is something of a handicap, but as we envisaged field data collection taking place on A4 sheets it was acceptable. In fact, in order to divide each trial area into equal portions we reduced the size of the input area further. Working with 1 ha (100m by 100m) grid cells the area covered by each data base is 16 km by 10.8 km. At 1:100,000 the whole area fits onto the tablet; at 1:50,000 the area is divided into 4 sectors and at 1:25,000 into 16 sectors.

The system asks the user which scale is being used and then offers a map showing the sectors. Selection is made with the mouse (or tablet). Each sector is registered on the tablet by means of two or more registration points which appear on the screen and are also marked on the sector recording sheets. Once registered and fixed in place the user enters each polygon by tracing the boundary. The system uses time based event trapping to record a point every 3/10 of a second during the trace. Each polygon is closed by making a selection from the 'PoliGrid' pull down menu devised for this purpose (Figure 2).

When all the polygons (or lines) of interest have been draw they may be simply saved as linear features, or gridded for storage in the main cellular data base.

On selection of 'grid and store' from the PoliGrid menu the data points are written into a special array which permits use of the **INVERTPOLY** subroutine from the Macintosh tool box. With the inversion of each polygon the area is scanned using the **POINT** command which reports the

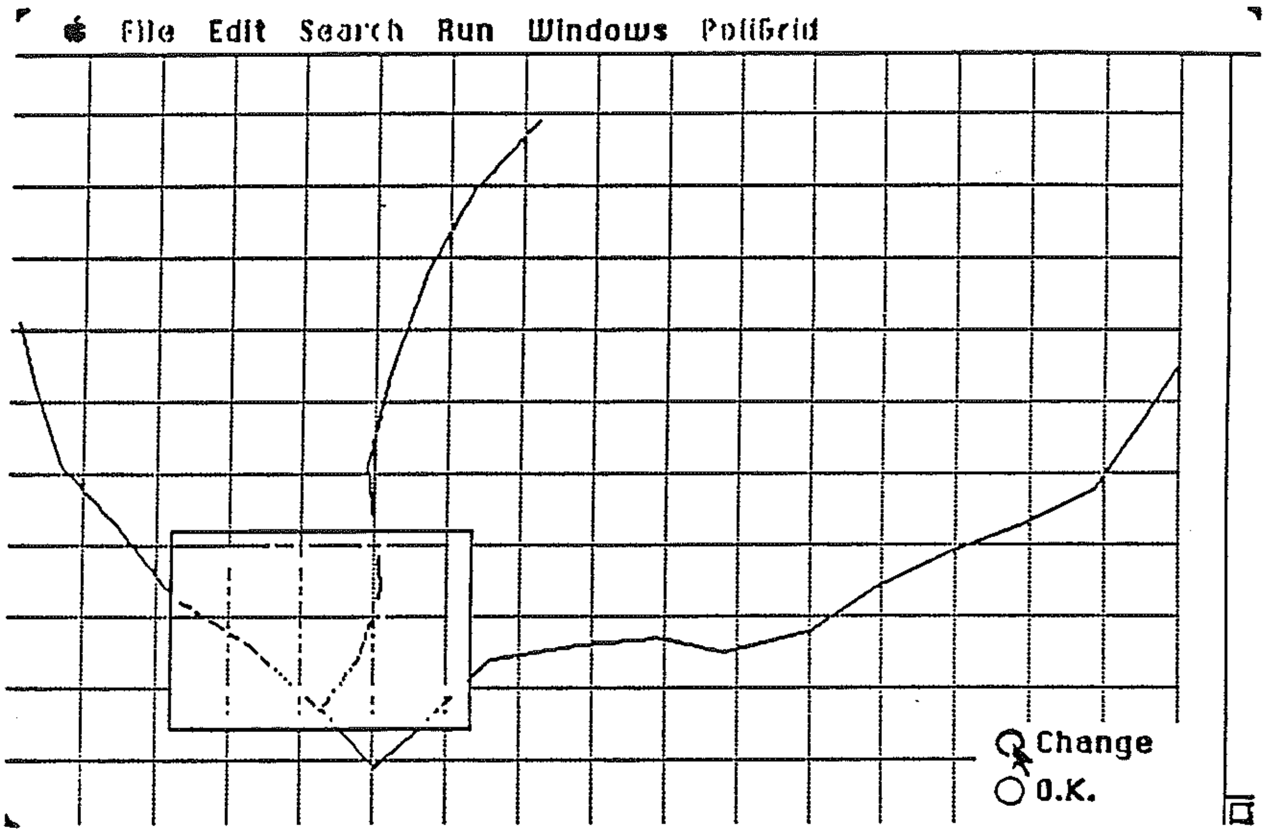

Figure 5. A subsection of the data area may be selected by dragging the mouse across the required portion. A box shows the selected window throughout the dragging process and the BUTTONs at the lower right permit a change of mind.

'colour' of the screen pixel addressed and points inside the polygon can be written to an array with a user supplied label. When all polygons from one sector have been gridded another sector can be chosen. If no more sectors are to be recorded the system dumps the stored array into a user specified position in the data base. This may be an addition to an existing map or a new map. The user also specifies a name for the map and tells the system how many differently coded polygons it contains.

The use of the **CALL INVERTPOLY** and **POINT** commands replaced an earlier gridding mechanism using a conventional point-in-polygon algorithm (Baxter 1976). For a 20 point polygon the old system took over 3 minutes, the special Macintosh graphics facilities allow this to be done in 7 seconds. When there are several polygons in each of several sectors to be entered the time difference is considerable.

In the case of line data the procedure is very similar although the gridding algorithm is quite different. In this case there were no suitable routines in the Macintosh toolbox and so a simple line following routine was devised which identifies the map cells falling between each pair of points on the line. A code can then be allocated to these points.

The promise of the scanning and camera based input systems to provide even more efficient input mechanisms is presently limited by the lack of BASIC commands to call up these devices. Control is via their own software systems and although transfer of images through the Macintosh clipboard is possible some mechanism for vectorizing the raster images would be necessary before further processing. Software developments from Microsoft (or another language supplier) may make them useable at another time. For now the tablet is quite satisfactory.

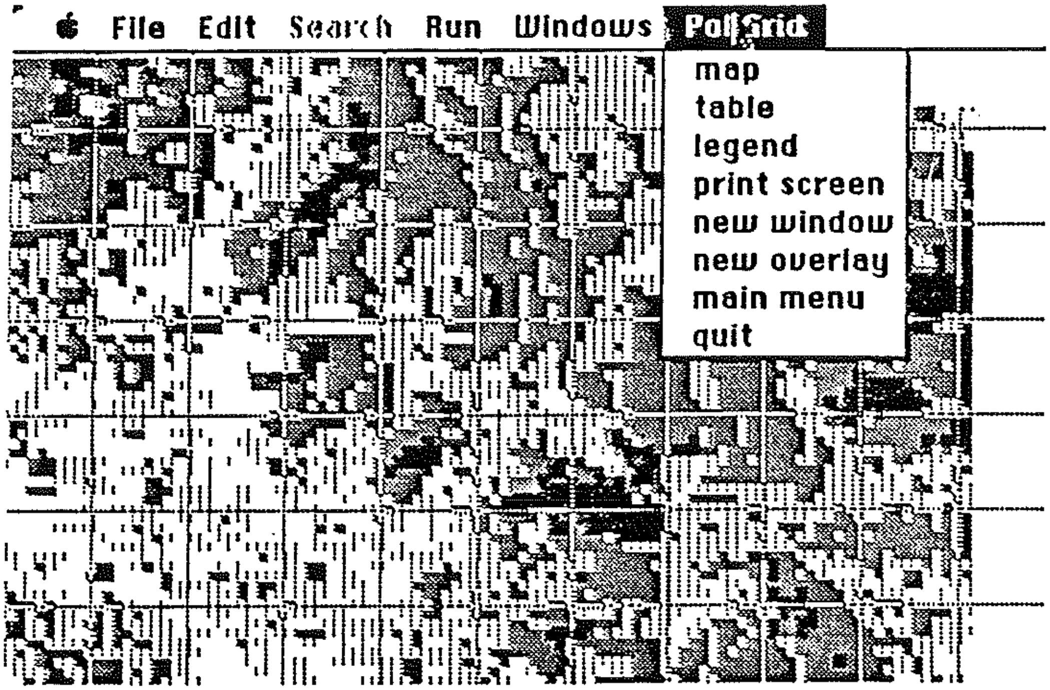

Figure 6. A section of the Macedon data area indicating the fire hazard based on slope, aspect and land cover. System development will permit more advanced hazard calculation algorithms to be applied on a day by day basis. The cell size is one hectare and the AMG grid is also shown.

MAP OVERLAY

The map overlay program makes use of the FILES command to indicate to the user the available linear features files (including the AMG grid) - see Figure 3. Having selected the backgound features the user opts to

. reproduce an existing map
. do a linear combination (weighted overlay)
. search for cells with a specified combination of values.

The system presents the user with map names and labels in one window while dialog takes place in a scrolling window below (figure 4).

Standard map shadings may be chosen, in which case the system adopts the number of shadings required from the twenty available, spacing them so as to get the greatest possible contrast. If users choose to select their own map shadings these are presented in the dialog box and can be assigned one by one to the map output categories.

When the map overlay requirements have been specified the selected linear features for the area are drawn up and the user may request a window from the data area (figure 5). This procedure uses two of the graphics commands built into Microsoft Basic. MOUSE detects the position of the cursor at any time while LINE draws a box incorporating the starting and current co-ordinate points defined using MOUSE. Either a black line or a white line can be specified for the box, so that while the mouse is still moving the past lines can be deleted.

Once a window has been selected the system requests confirmation that this is the required window and then redraws the linear features to the largest size, allowing the whole window to fit on the screen. The user may then select that whole area or window further. Having settled on a window for mapping purposes the system proceeds to process the data base cell by cell extracting the single byte code for each map from the 21 character string that stores the data for each cell. This process uses the BASIC string manipulation commands such as **LEFT$**, **MID$** and **RIGHT$**. The cell codes consist of upper case letters starting from 'A' and so numeric values are derived by converting to ASCII values and subtracting 64. The weighted overlay or search procedures are applied to the cell data and a result - either a yes/no or a combined category value for the cell - obtained. A pen size is determined according to the degree of enlargement of the window, a shading pattern is applied according to the previous selection and the cell is mapped on the screen. If it has been requested, the result is also written into an available location in the data base.

For the entire data area (17,280 cells) a combination map being written back into the data base can take two hours. This could be speeded considerably by adding a hard disk to the system (especially a device such as Hyperdrive which is installed inside the Macintosh with parallel interface).

On completion of the map the 'PoliGrid' pulldown menu (Figure 6) becomes active and the user may see the map legend or tabular information about the map. The menu also offers the options of printing the screen, another window on the same overlay, another overlay on the same data base, or return to the main menu.

Another advantage of the Macintosh is that the Imagewriter (or the Laserwriter) permits rapid screen dumps with full graphic detail. This removes the need for separate output routines for screen and hard-copy.

CONCLUSION

The **PoliGrid** system developed for the Macintosh is certainly not the most advanced GIS available. The storaghe of each data item in a single byte prohibits complex mathematical processing such as viewability analysis or fire behaviour modelling.

Sufficient data can be stored in this form however for **PoliGrid** to be useful to planners at any level. The Macintosh permits development of a very friendly user interface and a low initial hardware cost. Further developments, such as a hard disk version, would overcome the limitations of data storage and mapping speed but would add several thousand dollars to the cost.

The ability to transfer graphic information from the screen into word-processing programs permits easy incorporation of results into a report. This paper, for example, was prepared using Microsoft WORD. All the illustrations were taken from the screen and interpolated with the text. The final copy was printed using the Apple Laserwriter.

ACKNOWLEDGEMENTS

Paul Goodison wrote the polygon input software. Hemayet Hossain assisted with the transfer of data from the VAX. The Department of Local Government provided the funding. Steve Paynter and Stephen Withers of University Computing Services provided my first use of the Laserwriter.

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APPENDIX 3

PoliGrid User Manual

School of Environmental Planning
The University of Melbourne

Using the Macintosh computer and PoliGrid software in fire hazard mapping

Instructions

Prepared by
Ian Bishop
November 1985
Revised, June 1986

This booklet illustrates use of the procedures available through **PoliGrid** to assist fire hazard mapping.

On the left side of the page are images taken direct from the screen during the operation of **PoliGrid.** Use of the system at the corresponding stage is shown on the right.

The instructions are broken into four sections:

1. Allocation of fuel data to existing polygons - here the user is shown how to take information from the recording sheets and transfer fuel level and condition readings to the land areas which correspond to each sample site.(p3)

2. Entering new data - in this section the user is shown how to enter new polygonal data into the grid data base. This will be done to record fire management practise as it affects fuel levels and conditions.(p7)

3. Default fire harard mapping - the system contains a default algorithm for computing fire hazard from a combination of the fuels data, slope, aspect, development level, potential access/egress and proximity to fire fighting services: the user is shown how to produce such maps, how to window portions of them and print required sections.(p17)

4. Some of the steps relating to other options within **PoliGrid** are illustrated but not in the full step-by-step manner of the other sections. The user is left to explore in other areas.

The only general instructions which apply are:

- begin operations by switching on the Macintosh (left-rear)
- insert the **PoliGrid** disk in the internal drive (label up and towards you)
- insert the data disk for your area in the external drive (same orientation)
- if leaving the Macintosh on but unattended for an extended period, turn down the brightness level (left-front)
- don't forget to switch off when finished
- don't leave **MacTablet** plugged in.

PoliGrid was written primarily on a 512K Macintosh. It will not function on a 128K machine. On the Macintosh Plus the system will run as indicated here if versions of the System and Finder which do not employ the Heirarchical File System are used. A hard disk version compatible with HFS is now also available.

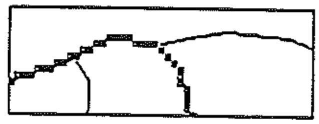
File Edit Search Run Windows PoliGrid

PoliGrid 2.0H

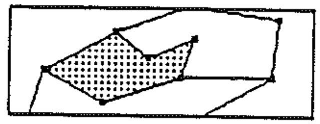
A geographic information system for Macintosh

Many operations are chosen using the mouse to activate buttons.
At other times the PoliGrid menu will appear on the menu bar.
Use the mouse to choose your next operation............

enter lines



enter polygons



map overlay

quit

File Edit Search Run Windows PoliGrid

Choose the operation required:

- ○ Reproduce existing map
- ○ Weighted overlay
- ○ Search for specific characteristics
- ○ Quick map
- ○ Land suitability mapping:
- ○ Default fire hazard mapping
- ○ Reallocate fuel conditions

1. Allocation of fuel conditions

When you insert you program disk this screen will appear (gradually). This is the **PoliGrid** main menu. You use it to select the next major function you wish to perform.

To select a function position the tip of the cursor in the box required and click (once) the mouse button.

Choose 'map overlay' to proceed with reallocation of fuel conditions.

Select 'reallocate fuel conditions' from the operations menu.

File Edit Search Run Windows PolIGrid

1	land ownership	3
2	elevation	9
3	slope	7
4	aspect	9
5	vegetation	7
6	development	4
7	egress	5
8	fire service	5
9	wildlife	6
11	fuel reduction	5
12	polygons	20
13	fuel level	5
14	fuel condition	5
15	haz 19/11/85	5
16	haz 4/2/86	5
17	haz 3/6/86	5
18	clearing	3

do not use this option unless polygon numbers are in map position 12 and you want fuel levels in position 13 and/or fuel condition in position 14

Is this true? [Yes] [No]

File Edit Search Run Windows PolIGrid

1	land ownership	3
2	elevation	9
3	slope	7
4	aspect	9
5	vegetation	7
6	development	4
7	egress	5
8	fire service	5
9	wildlife	6
11	fuel reduction	5
12	polygons	20
13	fuel level	5
14	fuel condition	5
15	haz 19/11/85	5
16	haz 4/2/86	5
17	haz 3/6/86	5
18	clearing	3

do you want to change fuel levels or fuel conditions or both

○ levels

○ conditions

○ both

This option assumes that the homogenous fuel polygons are in map position 12 and that fuel levels will be written into position 13 and dryness to position 14.

If there are different maps in any of these positions do not continue.

You may choose to change just the fuel levels in the polygons or the fuel conditions or both. Select the corresponding button.

File Edit Search Run Windows PoliGrid

1	land ownership	3
2	elevation	9
3	slope	7
4	aspect	9
5	vegetation	7
6	development	4
7	egress	5
8	fire service	5
9	wildlife	6
11	fuel reduction	5
12	polygons	20
13	fuel level	5
14	fuel condition	5
15	haz 19/11/85	5
16	haz 4/2/86	5
17	haz 3/6/86	5
18	clearing	3

Select scale of input sector

☐ 1 TO 25000 ☐ 1 TO 50000 ☐ 1 TO 100000

File Edit Search Run Windows PoliGrid

enter polygon numbers
separate individuals by spaces, or use '-' to indicate a range
? 3-11

5

You can change data in just one of the sectors or across the whole area. As the polygons are spread across the data area it is normal to reallocate fuel conditions over the whole area. This in effect means working at 1:100000.

If you are just doing a quick demonstration, or if you felt that changes in conditions were confined to one sector a smaller portion of the map could be altered.

Enter the polygon numbers you wish to change. Leave a space between each number or indicate a range e.g. 2-8.

File Edit Search Run Windows PollGrid

```
enter level for polygon 3
? 9
```

File Edit Search Run Windows PollGrid

```
enter polygon numbers
separate individuals by spaces, or use '-' to indicate a range
?
another sector? N

this will take some time (up to 1 hour for a full map)
```

6

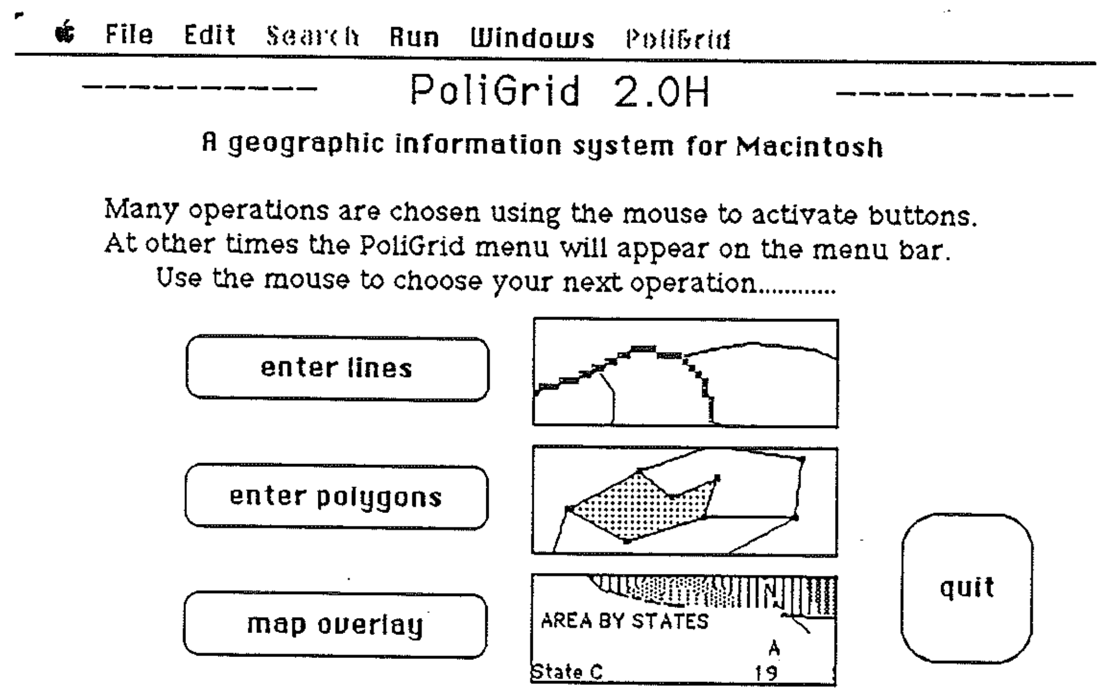
You are asked to enter a code letter for each polygon to indicate the new fuel level or fuel condition or both.

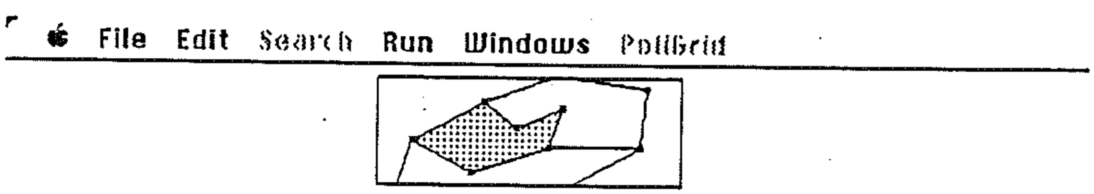
These codes are:

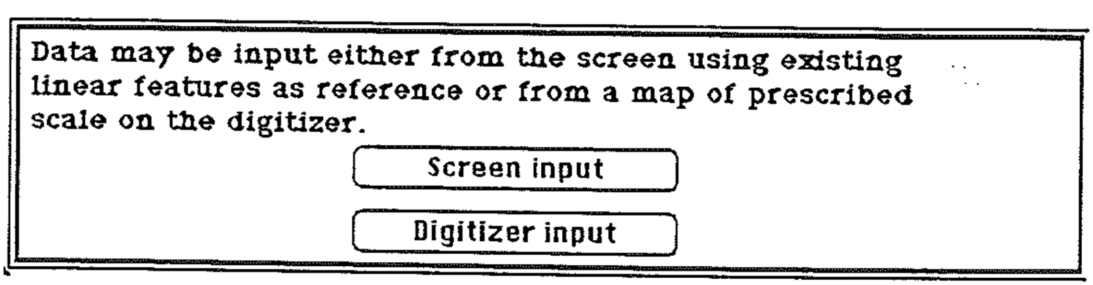
Fuel level - very low(A), low(B), moderate(C), high(D) and very high(E)
Fuel condition - wet(A), damp(B), moderate(C), dry(D) and very dry(E)

When all the specified polygons have been entered you are invited to enter another sector. If there are no more sectors (indictaed by entering a '0' or simply a carriage return) the revised fuel condition data is stored on the data file. After this is finished (up to 1 hour) the system returns to the operations menu.

You may then proceed to map fire hazard levels (or any other operation).


File Edit Search Run Windows PoliGrid
----------- PoliGrid 2.0H -----------
A geographic information system for Macintosh
Many operations are chosen using the mouse to activate buttons.
At other times the PoliGrid menu will appear on the menu bar.
Use the mouse to choose your next operation...........
enter lines
enter polygons
map overlay
AREA BY STATES
A
State C
19
quit


File Edit Search Run Windows PoliGrid

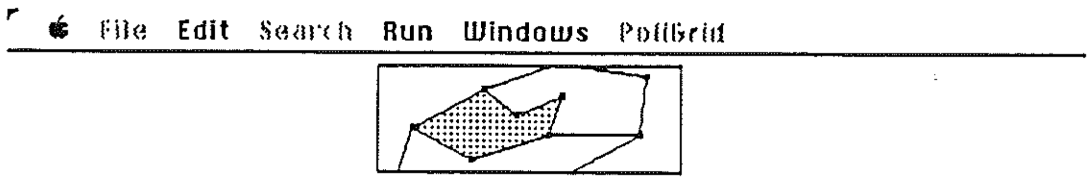

Data may be input either from the screen using existing
linear features as reference or from a map of prescribed
scale on the digitizer.
Screen input
Digitizer input

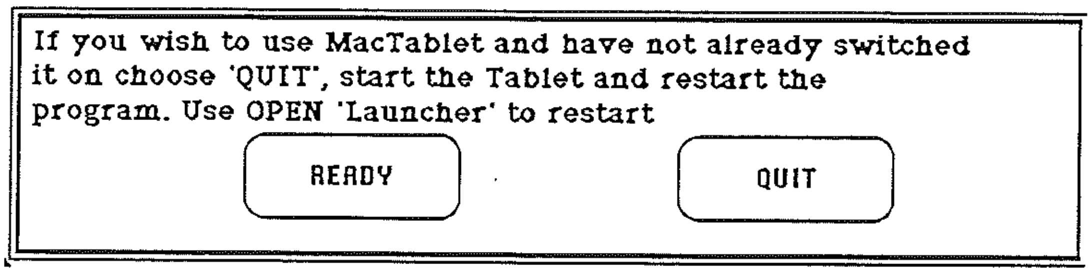
Entering new data

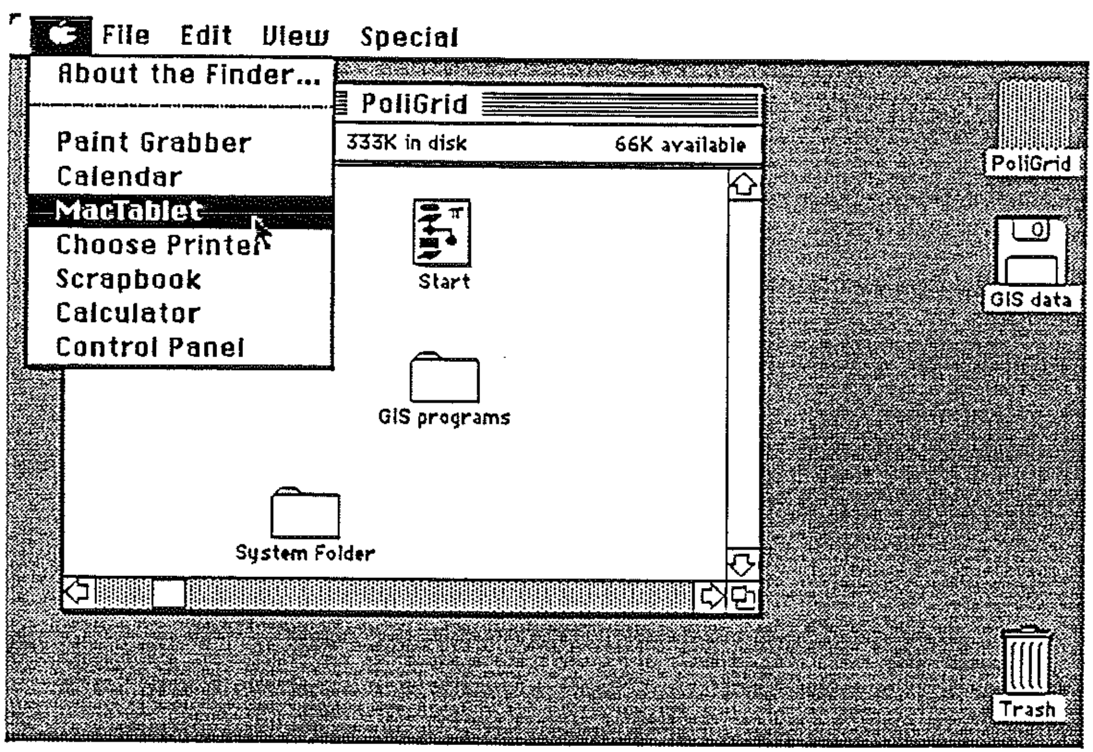
To enter new fuel reduction (or other) data select 'polygon entry' from the main menu.

You have the choice of entering data from a map fixed to the digitising tablet or directly onto the screen using the linear features already resident in the system as a guide.

For instructions on screen entry proceed to page 13.


File Edit Search Run Windows PoliGrid


If you wish to use MacTablet and have not already switched it on choose 'QUIT', start the Tablet and restart the program. Use OPEN 'Launcher' to restart
READY
QUIT


File Edit View Special
About the Finder...
Paint Grabber
Calendar
MacTablet
Choose Printer
Scrapbook
Calculator
Control Panel
PoliGrid
333K in disk
66K available
Start
GIS programs
System Folder
PoliGrid
GIS data
Trash

Digitiser entry

This screen will appear next to remind you that if entering new data using the digitising tablet (**MacTablet**) it is necessary to first activate the tablet. To do this it is necessary to leave **PoliGrid.** Chose 'QUIT'.

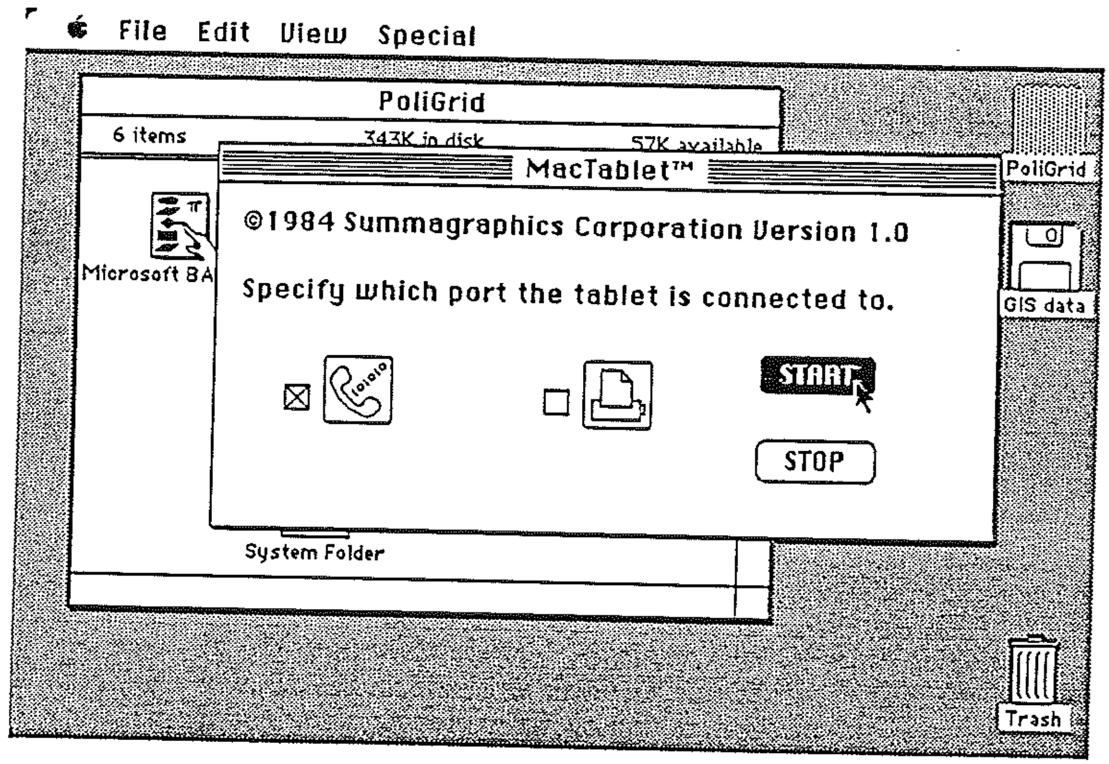
You will be returned to the 'desk-top'. Here the computer is under the control of its Operating System and not **PoliGrid.**

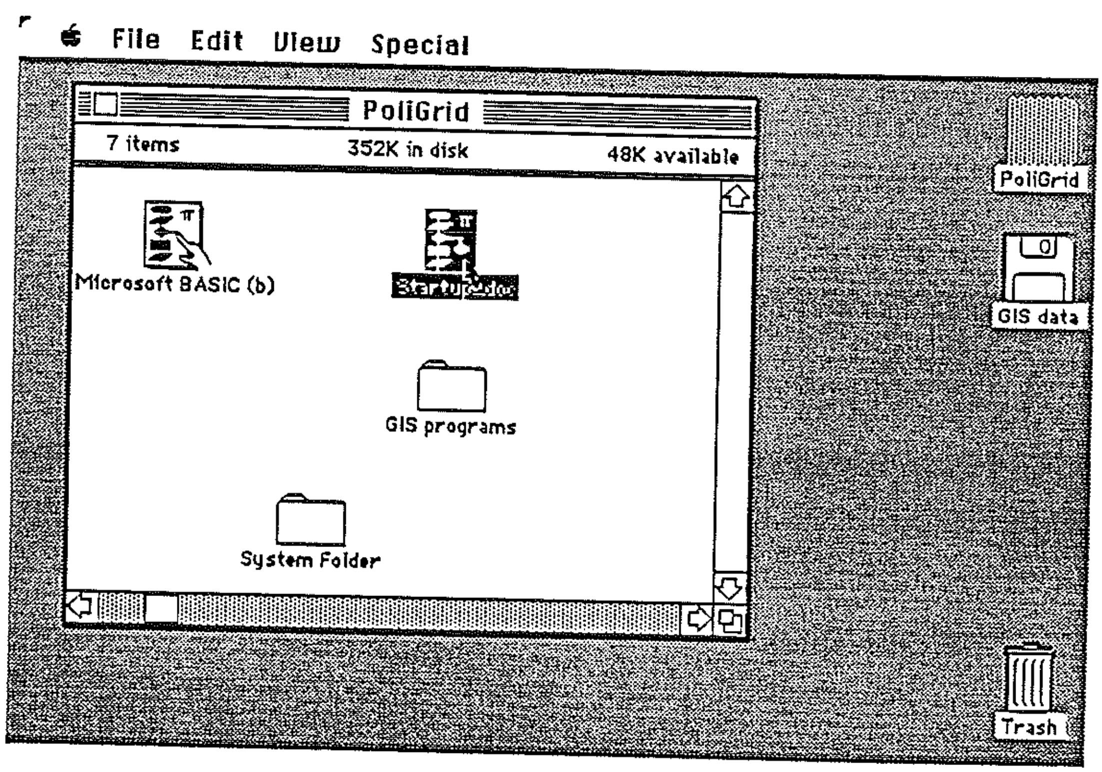
Make sure that the tablet is plugged in and connected to the Macintosh via the left most socket at the rear (with the telephone symbol).

Along the top of the screen are the names of various 'pull-down menus'. These are activated by positioning the cursor over a menu name and holding down the button. Selections are made from the menu by moving the cursor down to the required item (with the button still depressed) and then releasing the button.

The menu under the apple symbol is called the accessories menu. Select 'MacTablet' from this menu in the manner described.

(If you want to examine the other accessories you can do so. To get rid of any accessory click the small box in the upper left corner of the accessory window.)


File Edit View Special
PoliGrid
6 items
MacTablet™
©1984 Summagraphics Corporation Version 1.0
Specify which port the tablet is connected to.
START
STOP
System Folder
PoliGrid
GIS data
Trash

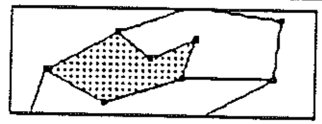

File Edit View Special
PoliGrid
7 items
352K in disk
48K available
Microsoft BASIC (b)
GIS programs
System Folder
PoliGrid
GIS data
Trash

When the tablet is selected from the accessories menu the window shown appears.

To activate the tablet click the 'START' box.

The desk top is restored and you restart **PoliGrid** by clicking the mouse button twice in quick succession while pointing at the icon labeled 'Startup_doc'. If nothing happens try altering the space between your clicks.

File Edit Search Run Windows PolIGrid



If you wish to use MacTablet and have not already switched it on choose 'QUIT', start the Tablet and restart the program. Use OPEN 'Launcher' to restart

READY QUIT

File Edit Search Run Windows PolIGrid

Select map scale for polygon entry

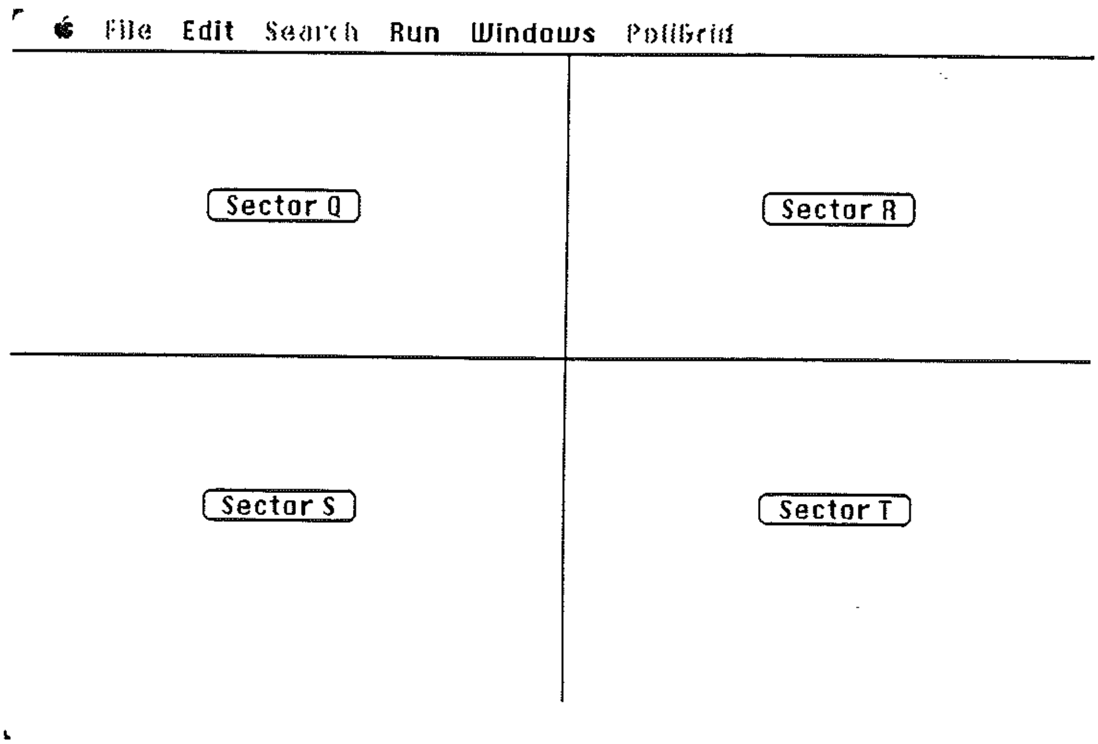
☐ 1 TO 25000 ☐ 1 TO 50000 ☐ 1 TO 100000

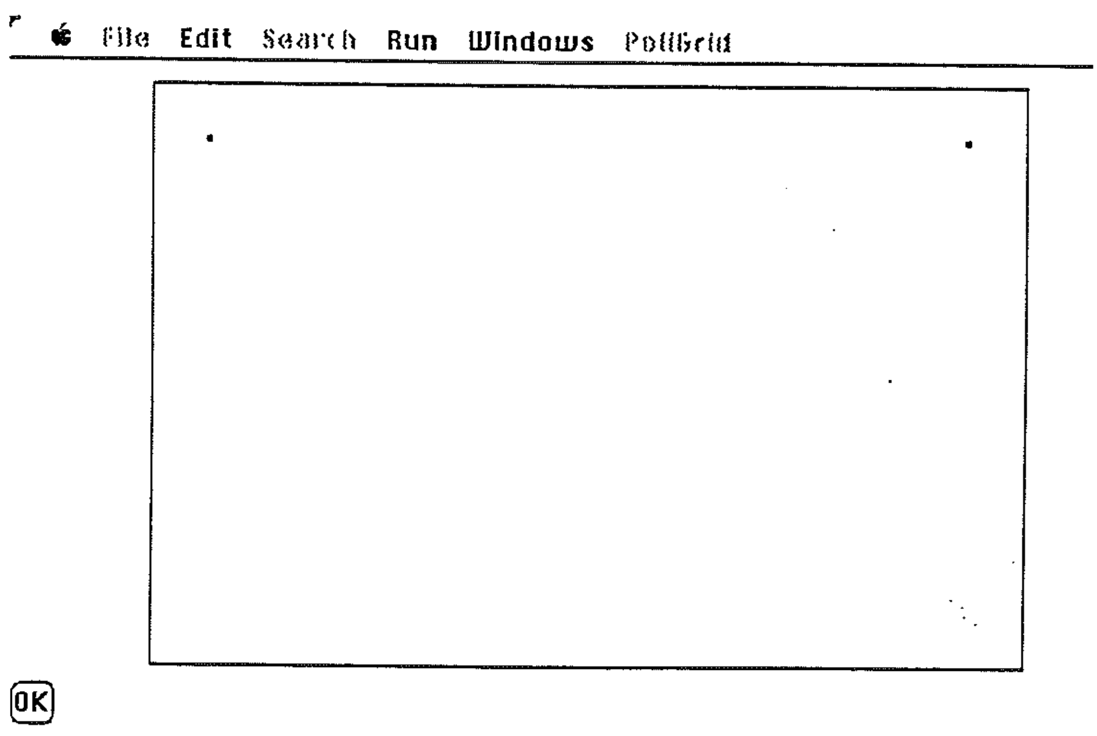
You can now click 'READY' when the tablet check appears.

The buttons of the digitiser cursor or puck are the equivalent of the button on the mouse. All the buttons are the same. You can press anyone to get the effect of the mouse button.

While the mouse affects the position of the screen cursor by its relative motion, puck position is an absolute determinant of screen cursor position. Therefore, if the puck is left on the tablet the mouse becomes unuseable. If you wish to use the mouse while the tablet is activated put the pen on the table away from the tablet.

The system allows you to input data at any one the the scales shown. You should have data sheets which correspond to each of these scales and which cover the whole of the area in your data base (16 km by 10.8 km). At 1:100000 only one map is required. At 1:50000 the area is divided into four equal sectors (each 8 km by 5.4 km) while at 1:25000 16 sectors are required each 4 km by 2.7 km.


File Edit Search Run Windows PollGrid
Sector Q
Sector R
Sector S
Sector T


File Edit Search Run Windows PollGrid
OK

Unless your are working at 1:100000 the system must be told which sector to expect data from. Indicate by clicking the corresponding button.

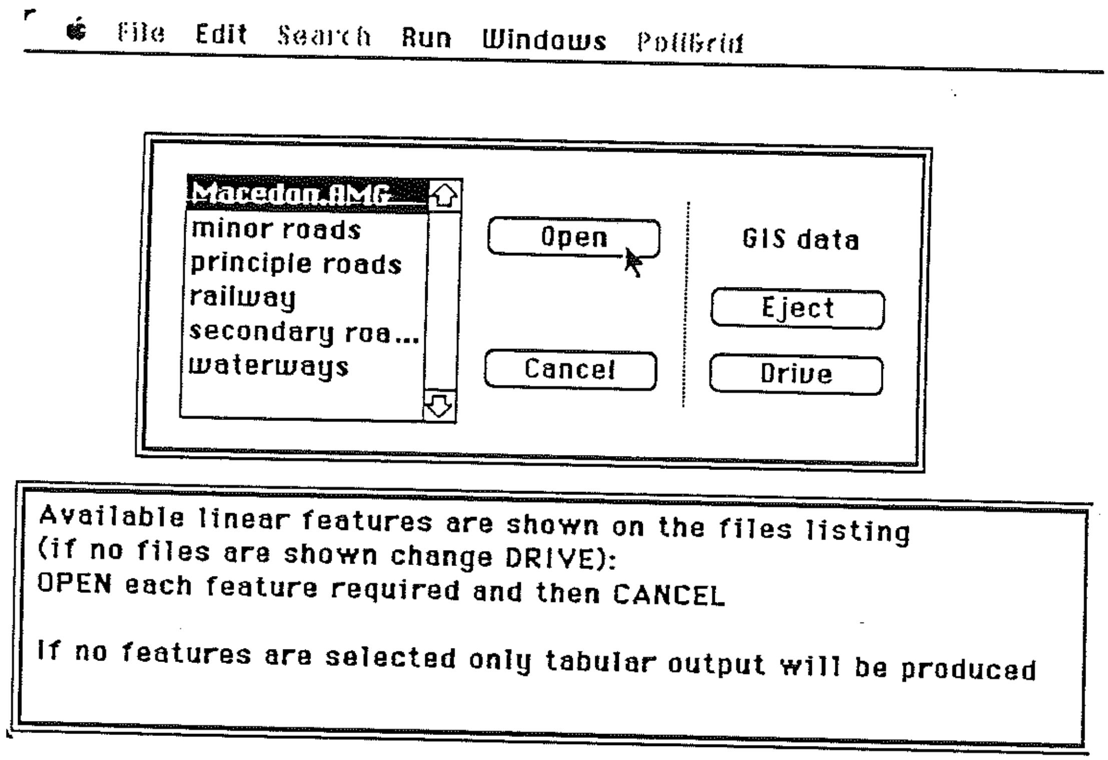
This outline will appear with an 'OK' button in the lower left corner.

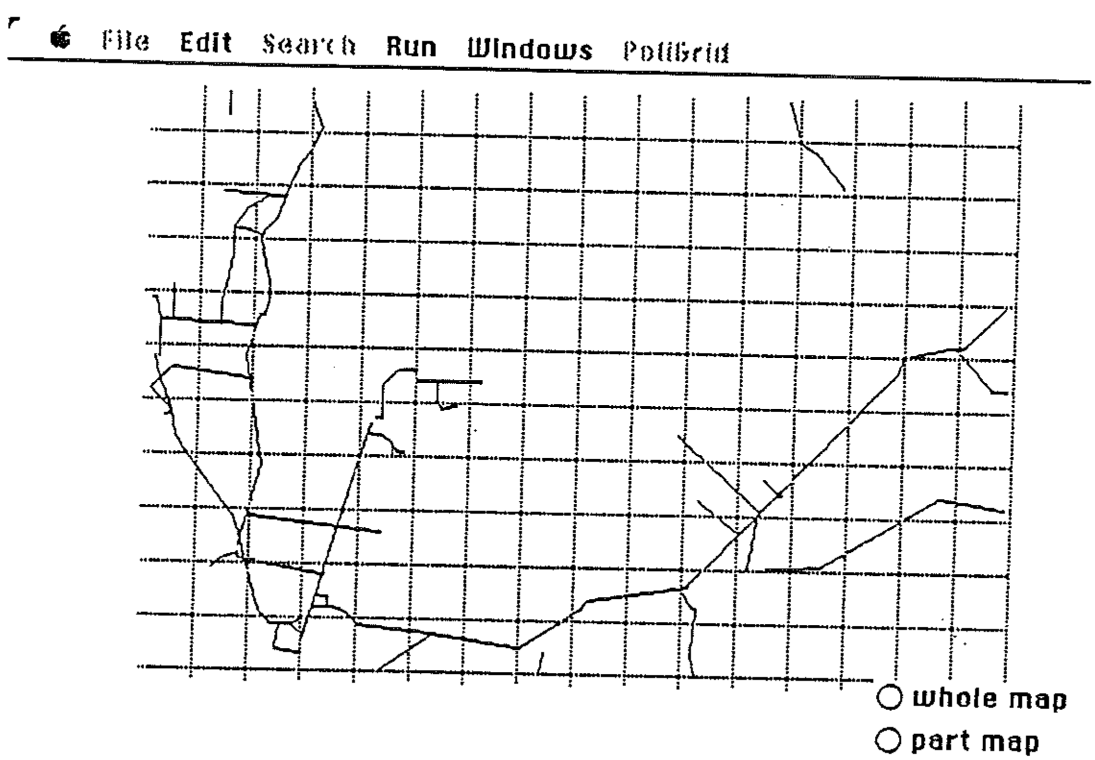
Hold the cursor such that the cross hairs are over one of the corners of the map. Move pen and paper until the point of the screen cursor is over the corresponding screen corner. Hold this portion of the paper is position and repeat the operation with another corner.

When you have two corners correctly in position fix the map firmly to the tablet. Check that all the corners are now in the right place.

Click the 'OK' button when the map is fixed in its correct position.

Now proceed to page 14.


File Edit Search Run Windows PoliGrid
Macedon.AMG
minor roads
principle roads
railway
secondary roa...
waterways
Open
Cancel
GIS data
Eject
Drive
Available linear features are shown on the files listing
(if no files are shown change DRIVE):
OPEN each feature required and then CANCEL
If no features are selected only tabular output will be produced


File Edit Search Run Windows PoliGrid
whole map
part map

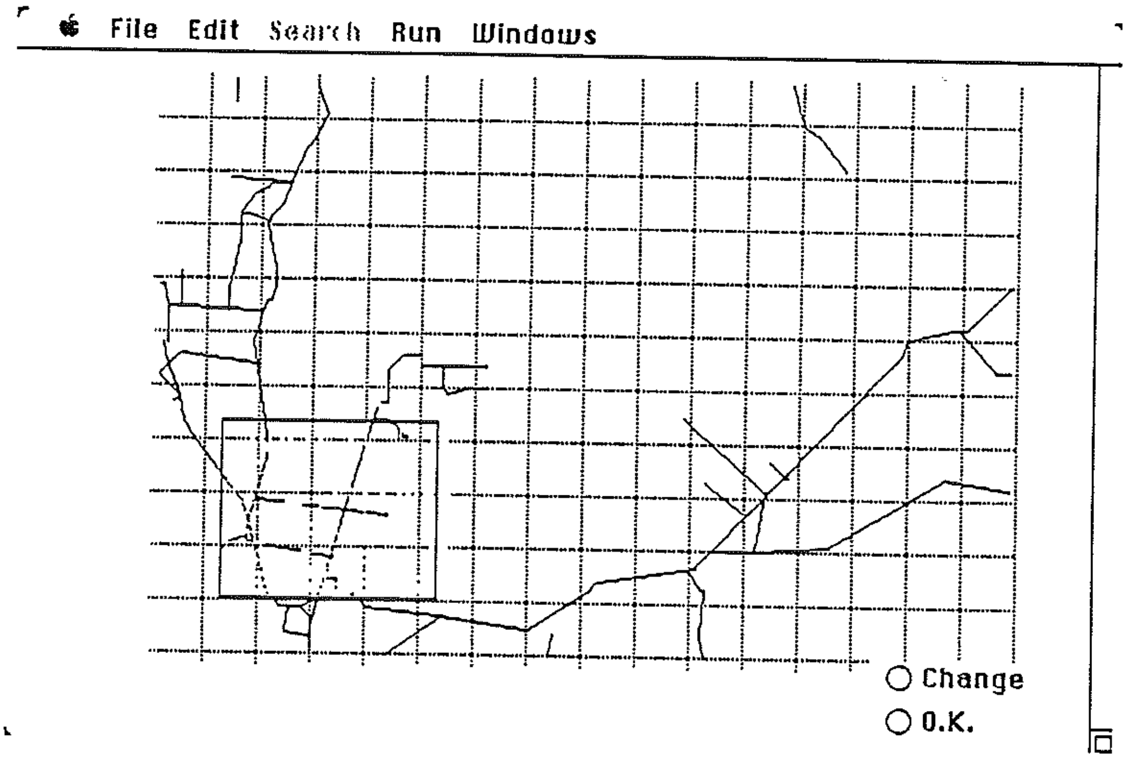
Screen digitising

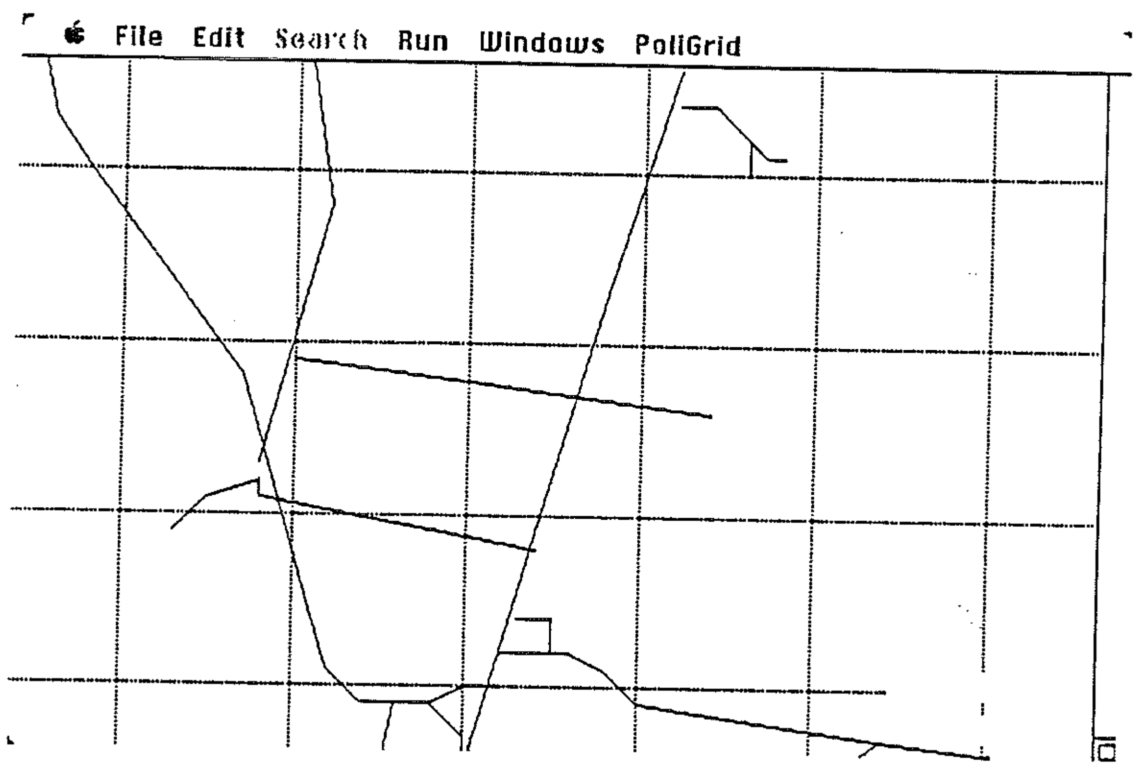
If you choose to digitise directly onto the screen you are shown a list of linear features from which you can select. Choose as many as you need to guide your data entry. If no names appear click the box marked 'Drive' to access the other disk drive.

Select those linear features that you wish to include in the mapping by double-clicking on the name of each feature. The panel will disappear briefly after each selection and reappear ready for the next selection.

When you have selected all the features you require click the box marked 'Cancel'.

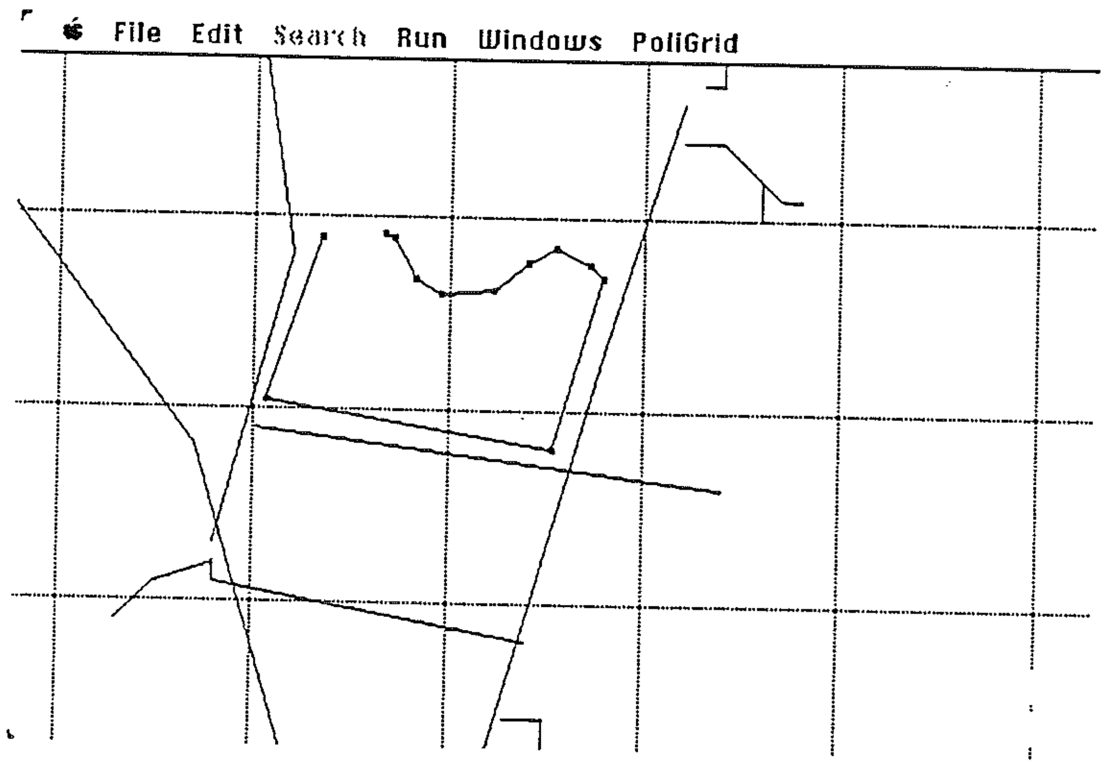
The system draws up the selected linear features and permits the user to select the rectangular portion of the data area within which the new data falls.If the area is quite large you can work on the full map by indicating 'whole map'.

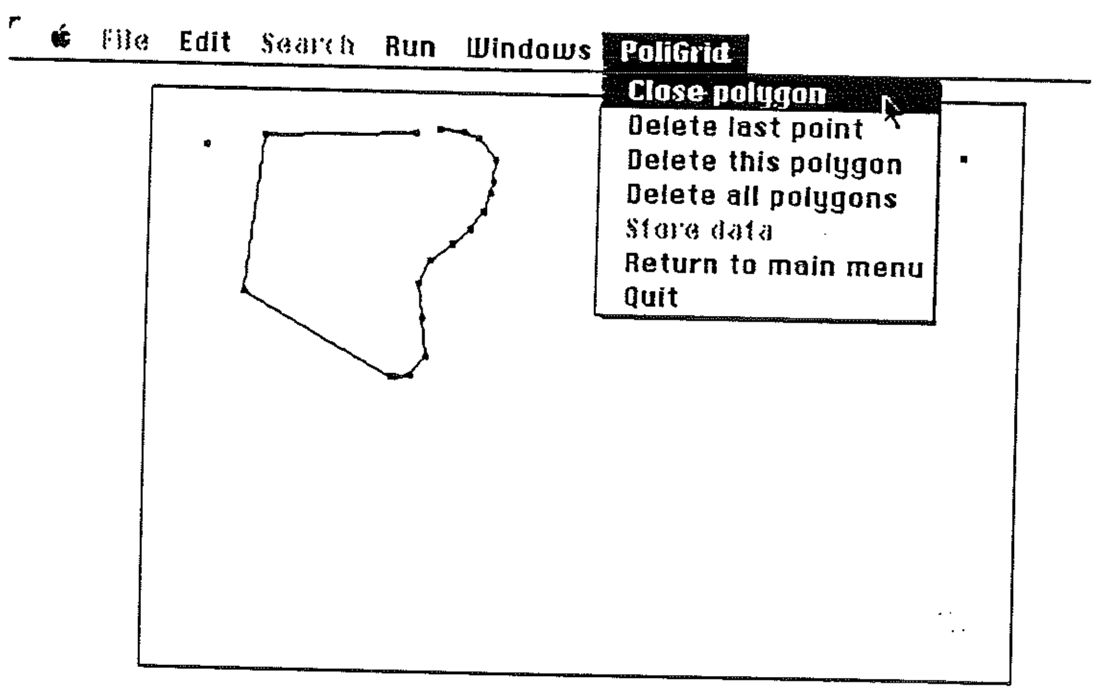

File
Edit
Search
Run
Windows
Change
O.K.


File
Edit
Search
Run
Windows
PoliGrid

If you have only a small area to digitise select 'part map' and then indicate the portion of the map where you intend digitising by
(i) placing the cursor at the upper left corner,
(ii) pressing and holding down the mouse button,
(iii) moving the cursor to the lower right corner of the area required, and
(iv) releasing the mouse button.

If you change your mind or have somehow selected the wrong area choose 'Change'. Otherwise click 'O.K.'


File Edit Search Run Windows PoliGrid


File Edit Search Run Windows PoliGrid
Close polygon
Delete last point
Delete this polygon
Delete all polygons
Store data
Return to main menu
Quit

Tablet digitisers re-enter here

You are now ready to start digitising.

Within **PoliGrid** a polygon is stored as a series of points on the boundary. These points can be entered in two ways:

(i) by locating the mouse/puck at particular points and pressing the button, or

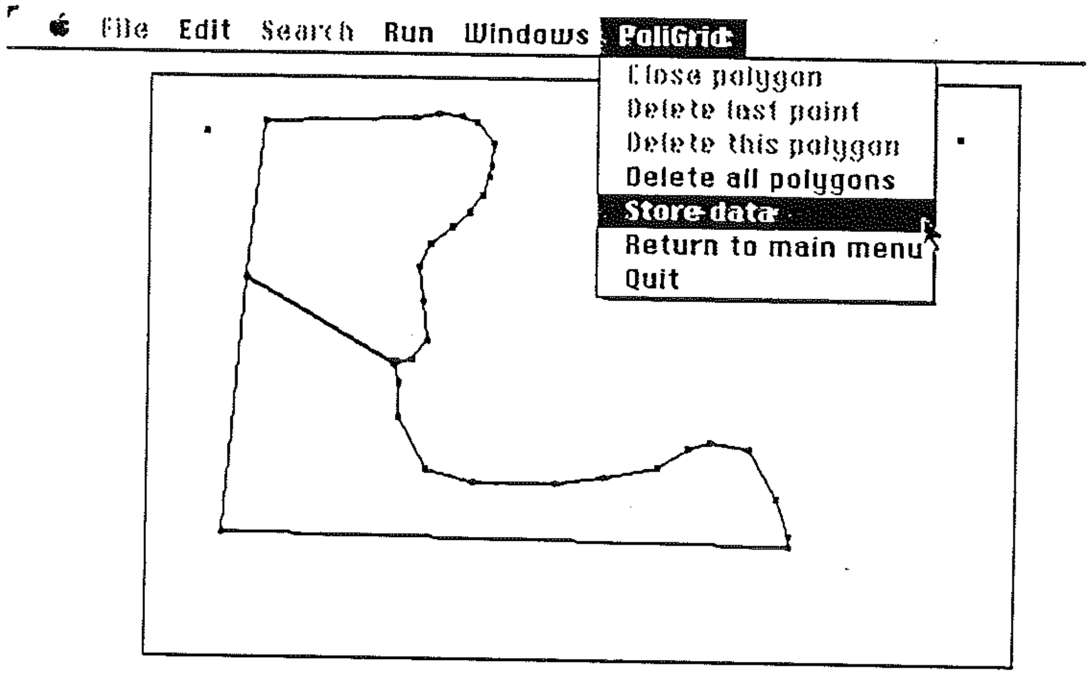
(ii) by holding the button down and moving the mouse/puck continuously along the boundary. The former method is preferable for straightline boundaries while the latter is better for sinuous curves. You can switch back-and-forth between the two techniques within the one polygon.

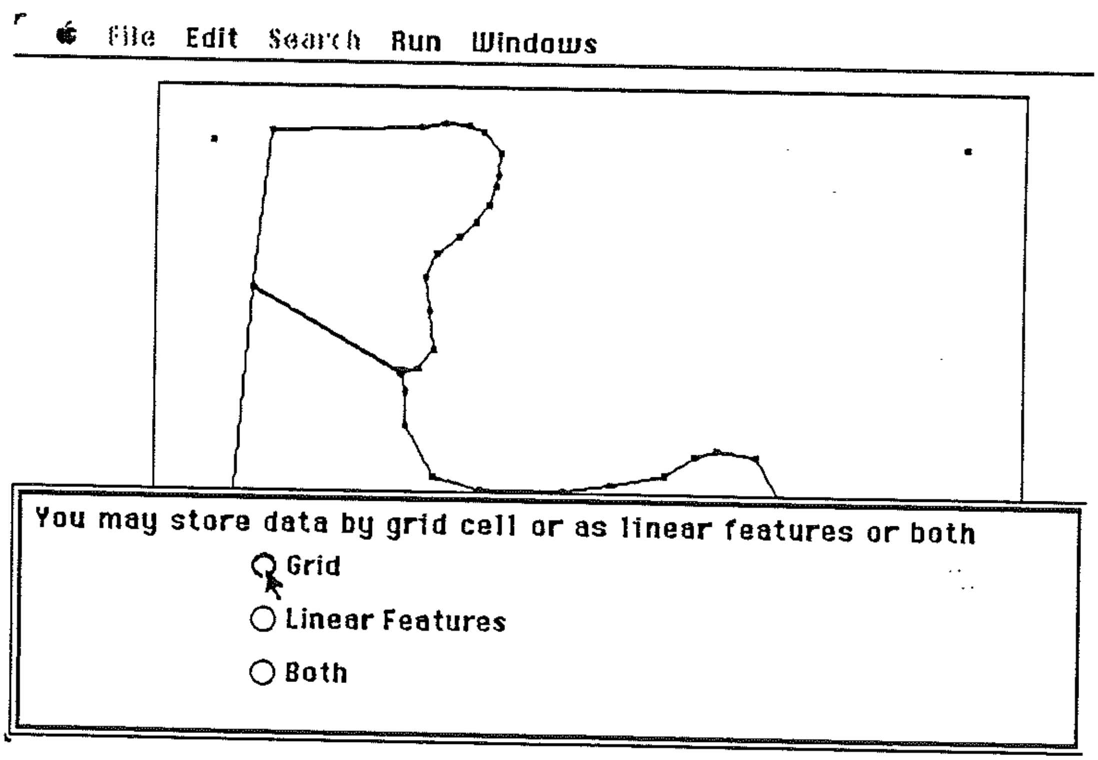
When you are close to rejoining the polygon start point you can stop digitising. Use the mouse/puck to select 'Close polygon' from the 'PoliGrid' pull down menu.

This will automatically join your last point to your first and leave the system ready to accept another polygon.

If you have not yet closed a polygon you can delete either the last point or the whole of the polygon by choosing the corresponding command from the 'PoliGrid' menu.

At any time you can delete all the digitising entered so far by using the 'Delete all polygons' command. You will not need to reposition the map but must click 'OK' to begin digitising again.


File Edit Search Run Windows PoliGrid
Close polygon
Delete last point
Delete this polygon
Delete all polygons
Store data
Return to main menu
Quit


File Edit Search Run Windows
You may store data by grid cell or as linear features or both
Grid
Linear Features
Both

All polygons must be complete. If they adjoin an already existing polygon the boundary must be retraced. Be careful not to leave a gap between the polygons, or to overlap greatly. If you do overlap the data base will gain the values of the polygon entered last.

When you have no more polygons to enter on this sector choose 'Store data' from the pull-down menu.

New information can be added to the system either in the grid data base or as a linear features file (which can be used as a position locator in later mapping). Polygonal data will usually be stored in the grid base for later overlay with other maps.

If, for example, you have digitised an area in which a fuel reduction burn has just been carried out you will want this information to be incorporated in future fire hazard mapping. It needs to be in the grid data base for this to occur.

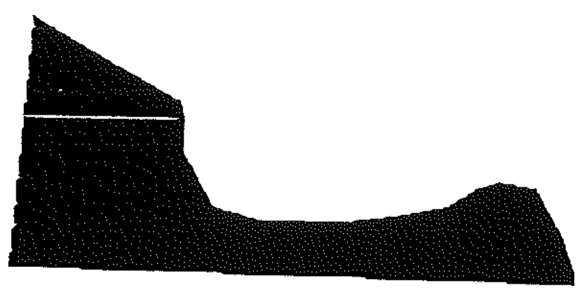
The system has been set so that fuel reduction areas are stored in map location 11.

File Edit Search Run Windows

Enter code letter for this polygon? D

File Edit Search Run Windows

Enter code letter for this polygon? E



The system calculates which points in the grid are inside each polygon and then requests a code letter for the polygon shown.

If entering fuel reduction areas this should be coded as -

A - 70-100% fuel reduction
B - 40-70% fuel reduction
C - 20-40% fuel reduction
D - 0-20% fuel reduction

E is the default data value which means no burning or other fuel reduction measure has been carried out.

Each entered polygon will appear in turn and a code letter entered. If you have entered a polygon which you no longer wish added to the data base just press 'return' when this polygon appears.

File Edit Search Run Windows

enter map position for storing this data? 11

File Edit Search Run Windows

You can add this new information to existing data in this map position or remove the existing data and zero the remainder of the map.

☐ add to existing data

☐ remove existing data

When codes for all the polygons have been entered the system will request the map position for storage of the new data.

Fuel reduction areas, for example, go in position 11.

Positions 1 to 14 are allocated to particular data maps. Positions 15-21 are available to the user.

The new data may add new an existing data map (i.e. only change existing values is areas covered by the new polygons), or remove an existing map (i.e. all areas no allocated values in the new data input become '0' or effectively blank cells).

Thus, if you are adding new fuel reduction information you would 'add to existing data'.

File Edit Search Run Windows

```
present map title is fuel reduction          with  5  classes
do you want to change these ?  N
```

File Edit Search Run Windows

```
Please wait - this can take some time
14   63 ACAAACC0AAC0D00000000
```

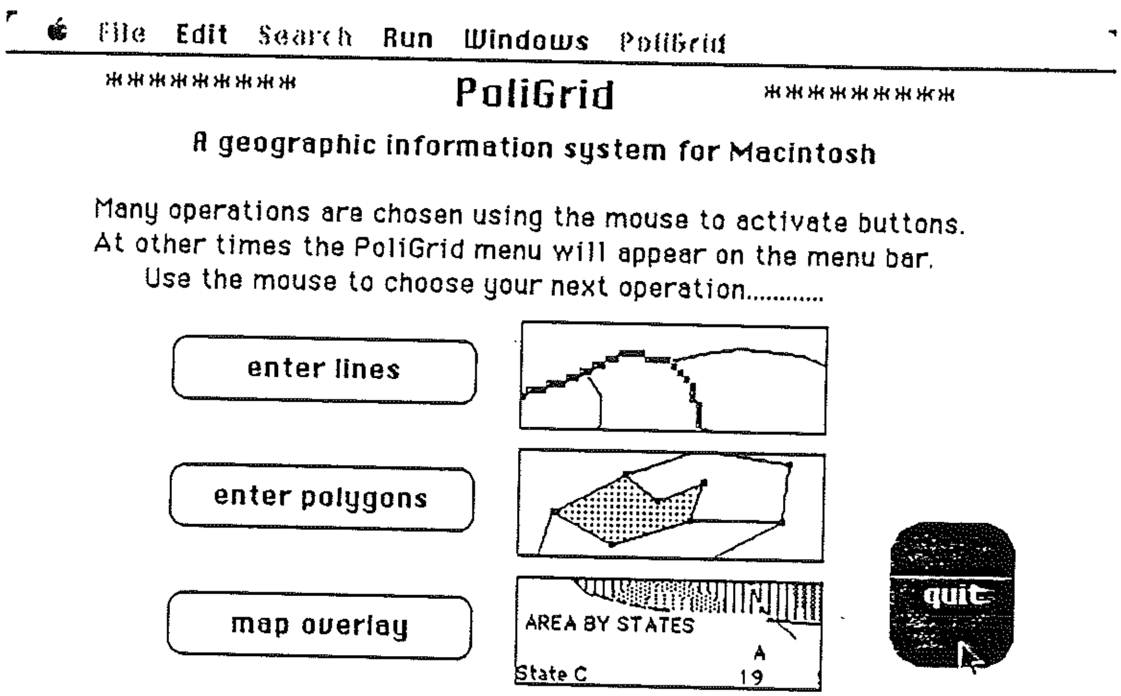
If you have chose to remove existing data then you are automatically asked for details of the new map, i.e. its name, the number of data categories and then the names of the catergories.

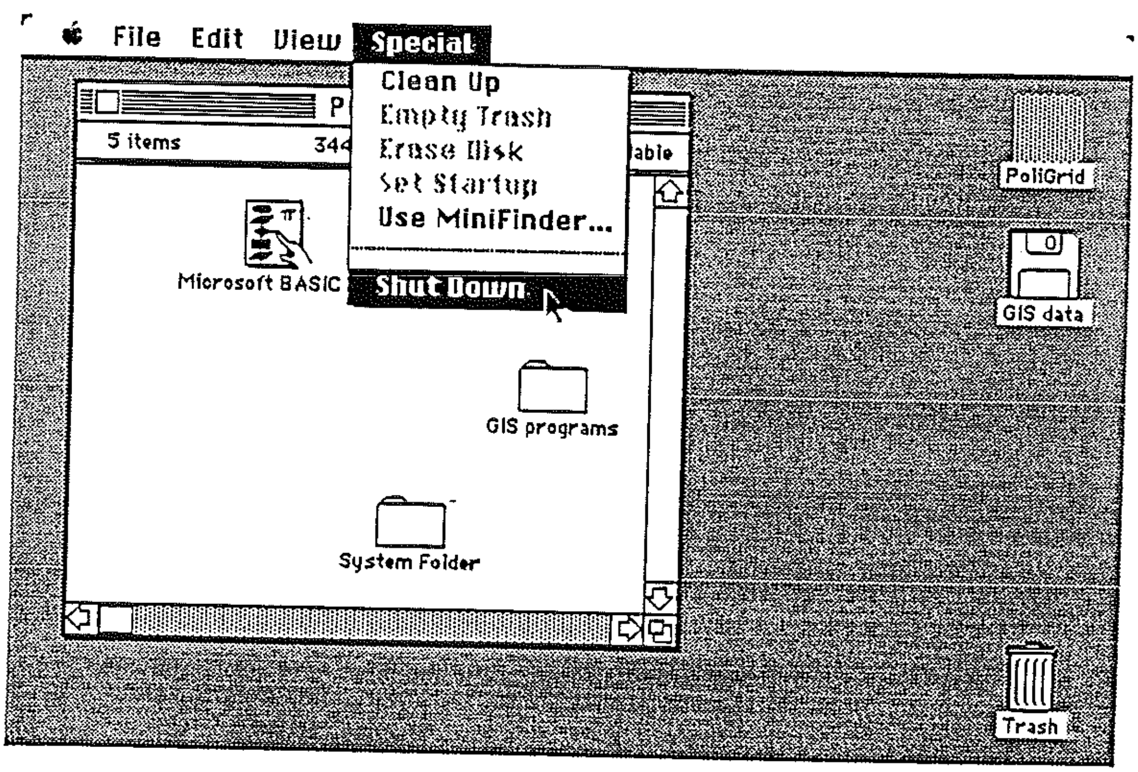
If you are adding to existing data the existing name and number of classes are shown and you are given the option of changing these.

When adding new fuel reduction areas there would be no need to change these details.

Addition to existing data is quite quick if only a small part of the data area is involved (e.g. a single 1:25000 sector). For larger areas or if removing the existing data the process can take up to 1 hour.

The code below the message shows the X and Y positions of the cell being entered and the map codes for that cell.


File Edit Search Run Windows PoliGrid
PoliGrid
A geographic information system for Macintosh
Many operations are chosen using the mouse to activate buttons.
At other times the PoliGrid menu will appear on the menu bar.
Use the mouse to choose your next operation...........
enter lines
enter polygons
map overlay
AREA BY STATES
A
State C
19
quit


File Edit View Special
Clean Up
Empty Trash
Erase Disk
Set Startup
Use MiniFinder...
Shut Down
5 items
Microsoft BASIC
GIS programs
System Folder
PoliGrid
GIS data
Trash

When dumping is complete you are automatically returned to the main menu.

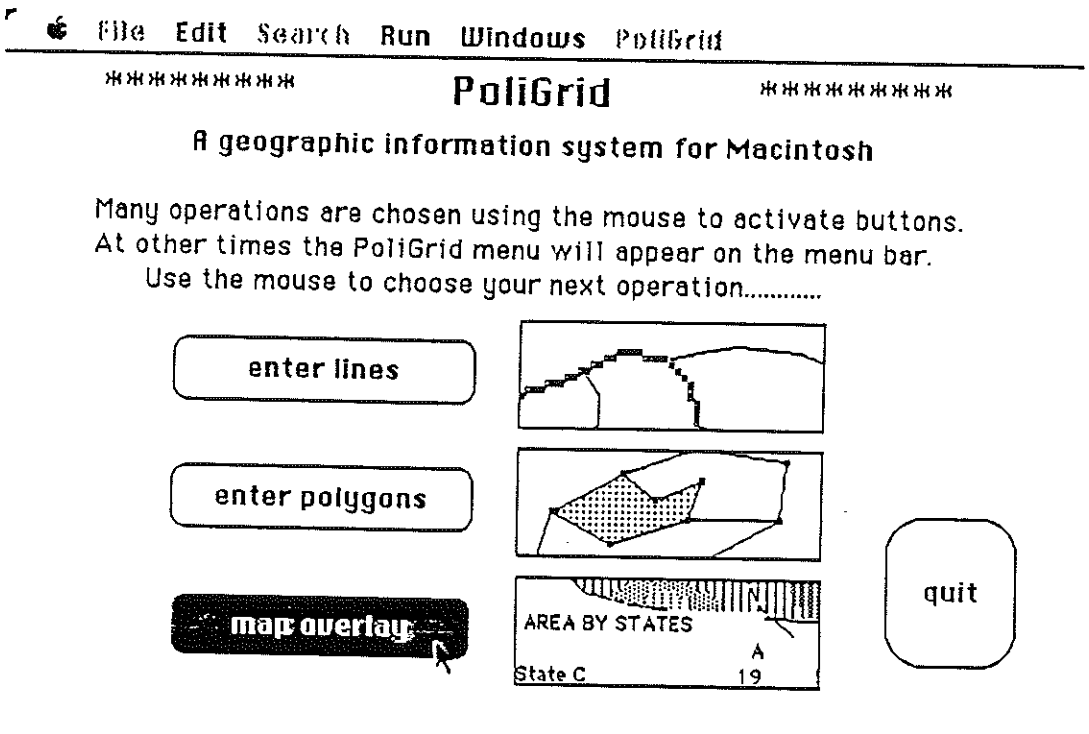
If you want to proceed to mapping choose 'map overlay'.

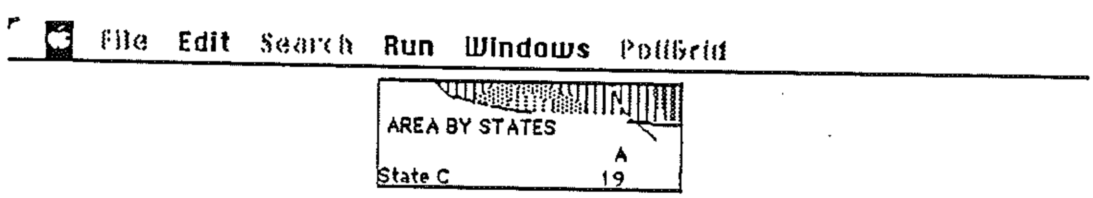
If you have had enough then 'quit'.

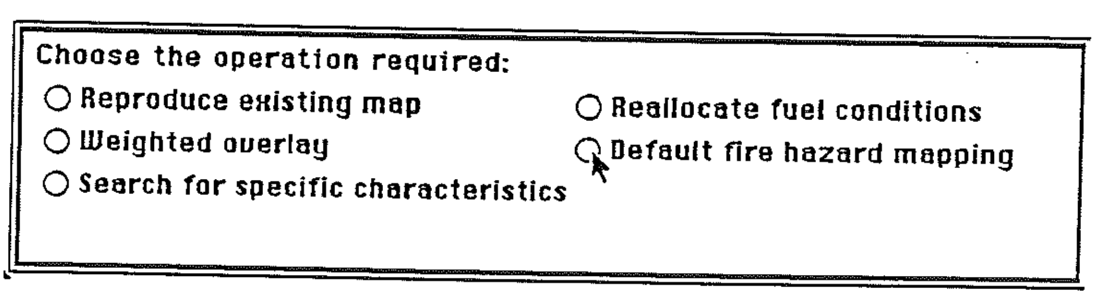
You are returned to the desk-top.

To halt operations choose 'Shut down' from the 'Special' menu. Both disks will be ejected.

Switch off the Macintosh and unplug the tablet.


File Edit Search Run Windows PoliGrid
********** PoliGrid **********
A geographic information system for Macintosh
Many operations are chosen using the mouse to activate buttons.
At other times the PoliGrid menu will appear on the menu bar.
Use the mouse to choose your next operation...........
enter lines
enter polygons
map overlay
AREA BY STATES
A
State C
19
quit

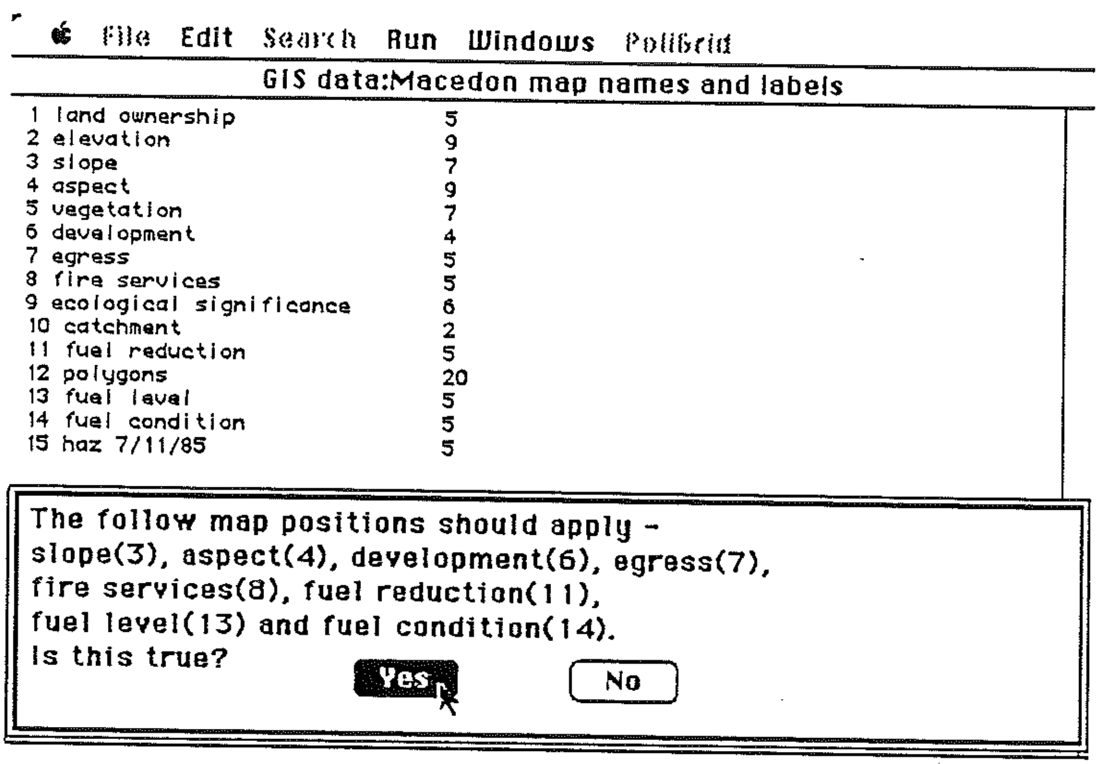

File Edit Search Run Windows PoliGrid
AREA BY STATES
A
State C
19


Choose the operation required:
Reproduce existing map
Weighted overlay
Search for specific characteristics
Reallocate fuel conditions
Default fire hazard mapping

Fire hazard mapping

Choose map overlay.

Choose default fire hazard mapping.

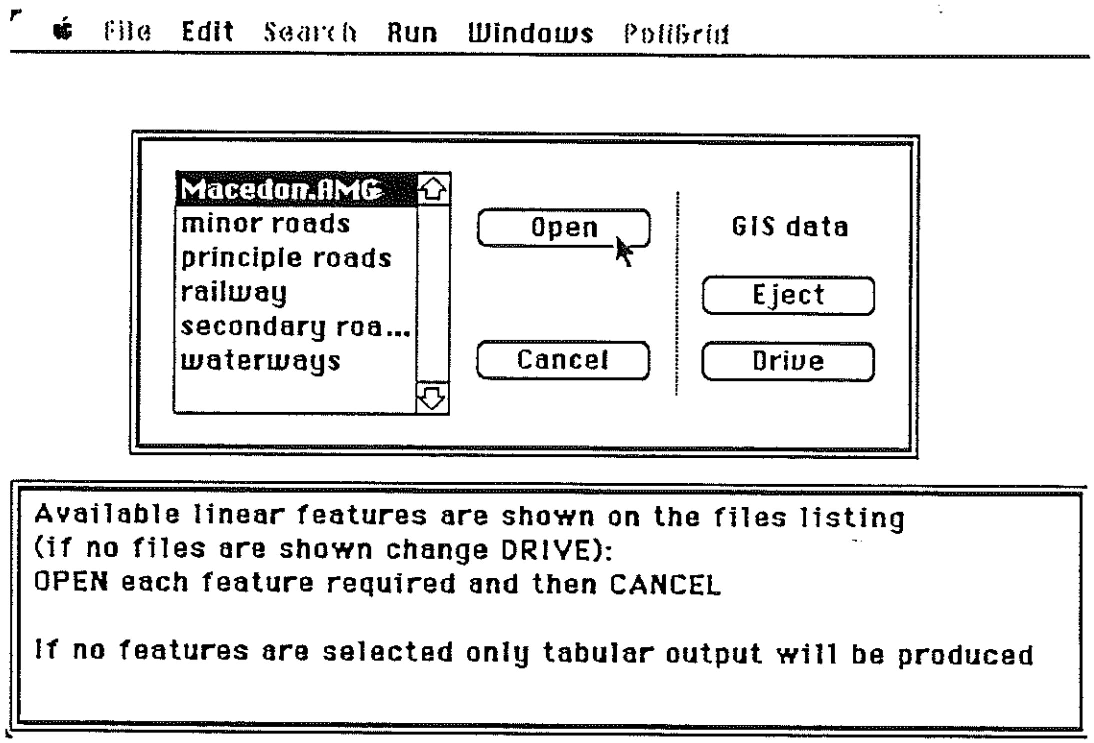

File Edit Search Run Windows PoliGrid
GIS data:Macedon map names and labels
1 land ownership 5
2 elevation 9
3 slope 7
4 aspect 9
5 vegetation 7
6 development 4
7 egress 5
8 fire services 5
9 ecological significance 6
10 catchment 2
11 fuel reduction 5
12 polygons 20
13 fuel level 5
14 fuel condition 5
15 haz 7/11/85 5
The follow map positions should apply -
slope(3), aspect(4), development(6), egress(7),
fire services(8), fuel reduction(11),
fuel level(13) and fuel condition(14).
Is this true?
Yes
No

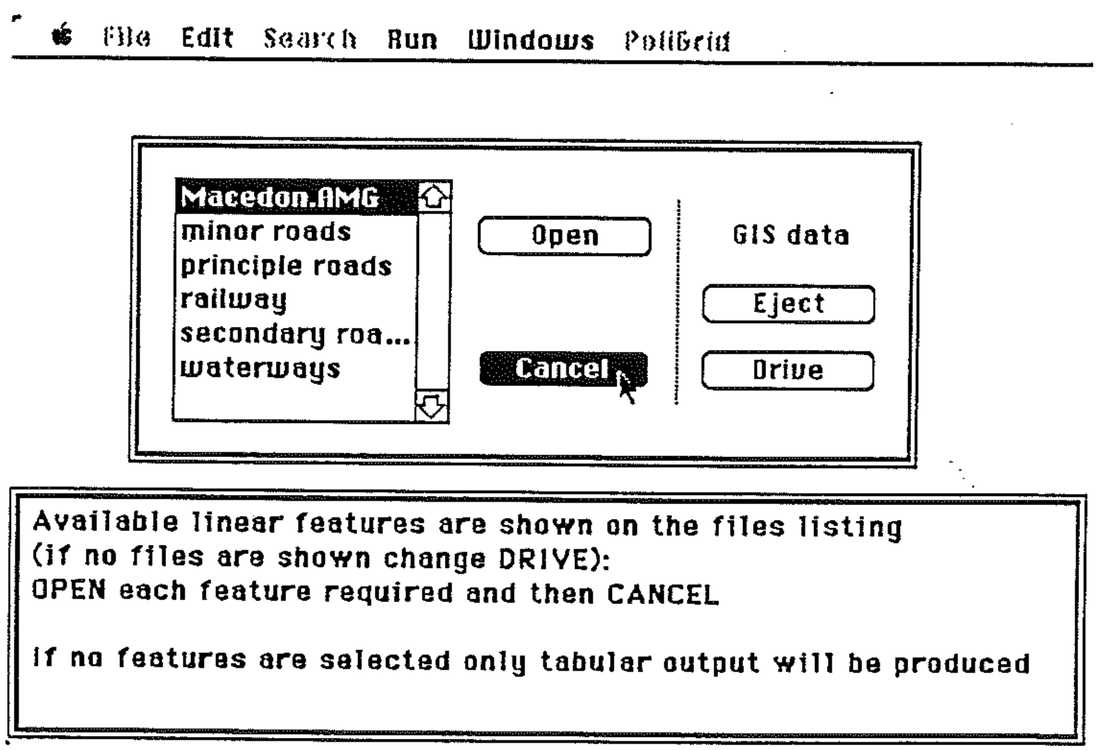
Default fire hazard mapping is not possible unless all the pertinent data elements are in their normal map positions. Default mapping is based on the ratings and weighting for the various data elements set out below.

Element	Rating					Weighting
	0	25	50	75	100	
slope	0-5%	6-10%	11-20%	21-30%	over 31%	2
aspect	E,SE	S	SW,flat	NE,W	NW,N	2
development		$<4/km^2$	4-20	20-200	$>200/km^2$	1
egress	v.high	high	med.	low	v.low	1
fire services	v.high	high	med.	low	v.low	1
fuel reduction*	0-20%	20-40%	40-70%	>70%	-	-5
fuel level	v.low	low	med.	high	v.high	5
fuel condition#	damp		med.	dry	very dry	5

* when fuel reduction occurs it is presumed to counteract the fuel level for the remainder of the fire season, i.e. no additional growth or accumulation will occur during one season.
# there are five categories of fuel condition, if the fuel is described as 'wet' an exclusion rating applies and other variables become irrelevant.

If you answer no at this stage, you will be returned to the operations menu.


File Edit Search Run Windows PoliGrid
Macedon.AMG
minor roads
principle roads
railway
secondary roa...
waterways
Open
Cancel
GIS data
Eject
Drive
Available linear features are shown on the files listing
(if no files are shown change DRIVE):
OPEN each feature required and then CANCEL
If no features are selected only tabular output will be produced


File Edit Search Run Windows PoliGrid
Macedon.AMG
minor roads
principle roads
railway
secondary roa...
waterways
Open
Cancel
GIS data
Eject
Drive
Available linear features are shown on the files listing
(if no files are shown change DRIVE):
OPEN each feature required and then CANCEL
If no features are selected only tabular output will be produced

The available linear features should appear in the panel in the centre of the screen. If no names appear click the box marked 'Drive' to access the other disk drive.

Select those linear features that you wish to include in the mapping by double-clicking on the name of each feature. The panel will disappear briefly after each selection and reappear ready for the next selection.

When you have selected all the features you require click the box marked 'Cancel'.

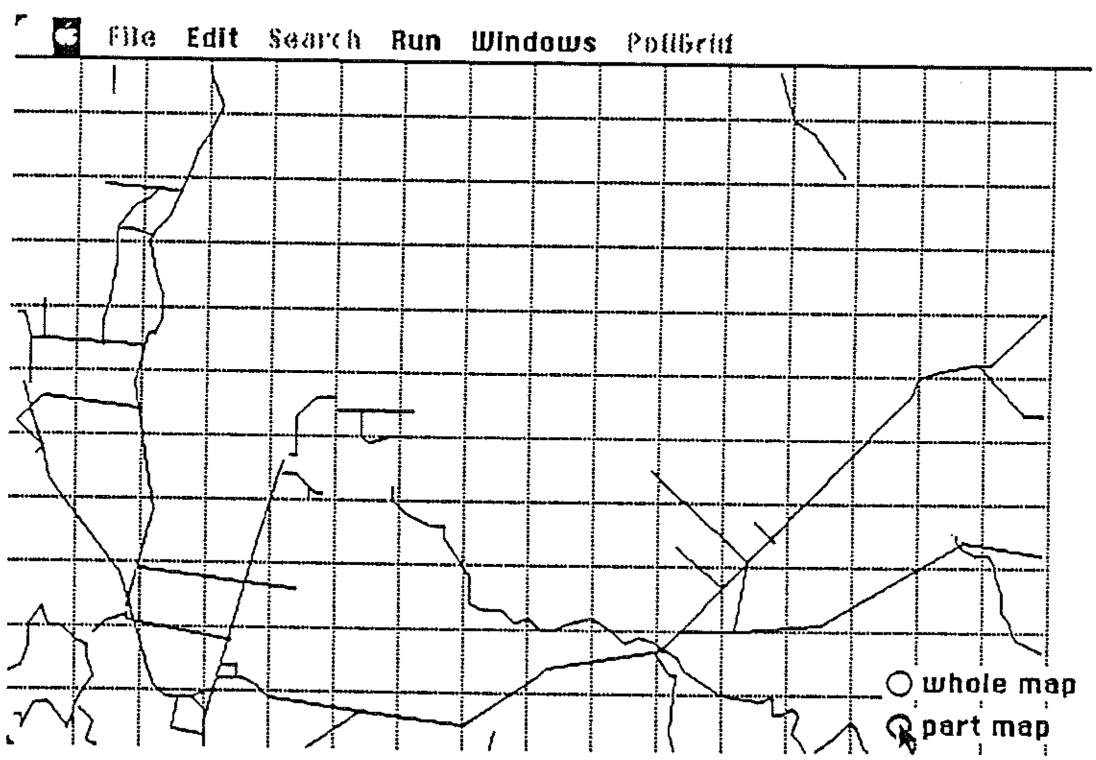
File Edit Search Run Windows PollGrid

GIS data:Macedon map names and labels

1 land ownership	5		A.	Very high
2 elevation	9		B.	high
3 slope	7		C.	medium
4 aspect	9		D.	low
5 vegetation	7		E.	very low
6 development	4			
7 egress	5			
8 fire services	5			
9 ecological significance	6			
10 catchment	2			
11 fuel reduction	5			
12 polygons	20			
13 fuel level	5			
14 fuel condition	5			
15 haz 7/11/85	5			
16 test	3			

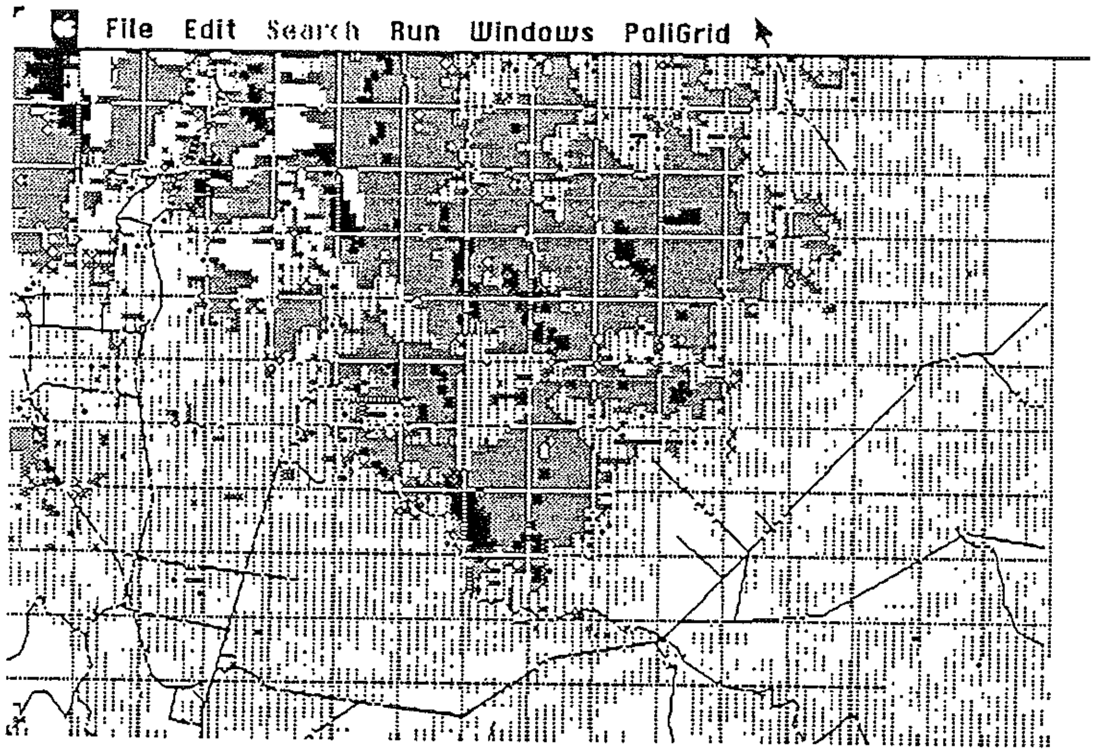
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

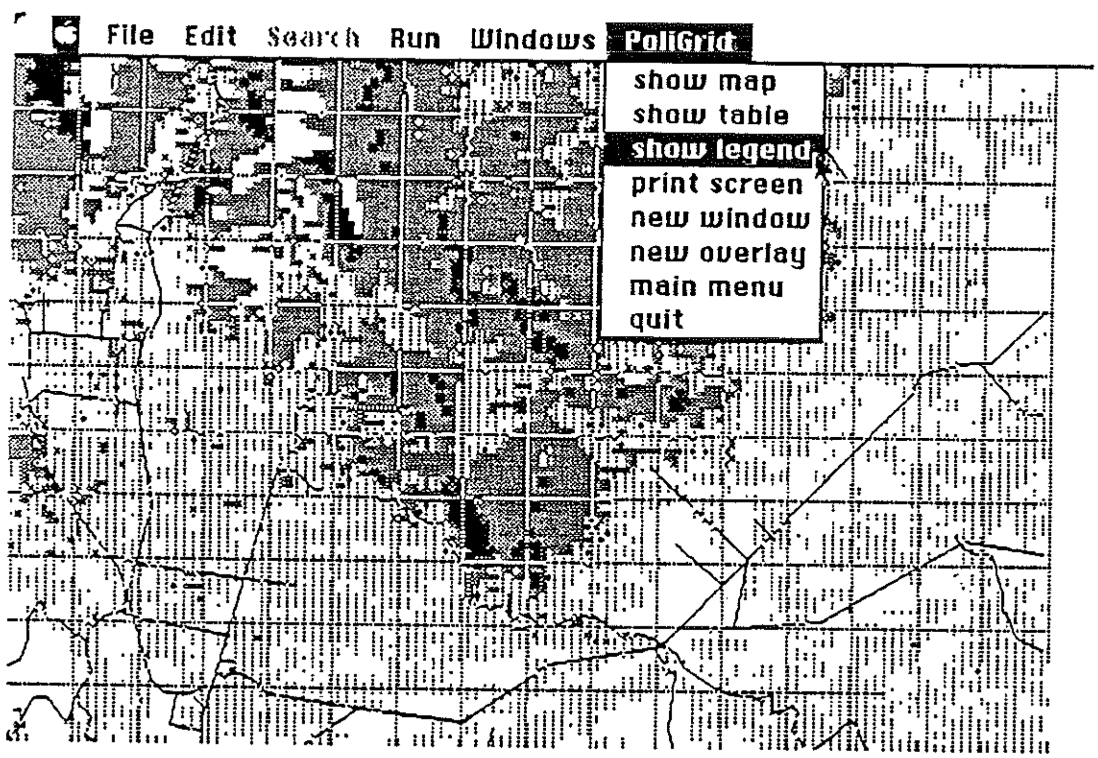
enter shading code (1-20) for each class
class E shading code? 20
Enter map number for cross-tabulation? 1



Default map shades for five levels of fire hazard are 2,6,11,15 and 20. If you want to select a different combination of shades enter the number of the shade required as each map level is requested. The lowest fire hazard will be 'class A' and the highest possible is 'class E'.

The system draws up the selected linear features and permits the user to select the portion of the data area to be mapped. If you require the whole data area indicate 'whole map'.


File Edit Search Run Windows PoliGrid


File Edit Search Run Windows PoliGrid
show map
show table
show legend
print screen
new window
new overlay
main menu
quit

Drawing up a new fire hazard map for the whole area and storing that map on the data base will take over two hours. However, the system will continue quite happily by itself without your attendance so you can get on with other work or even leave the mapping to happen overnight.

If you are leaving the machine for any length of time turn down the screen brightness.

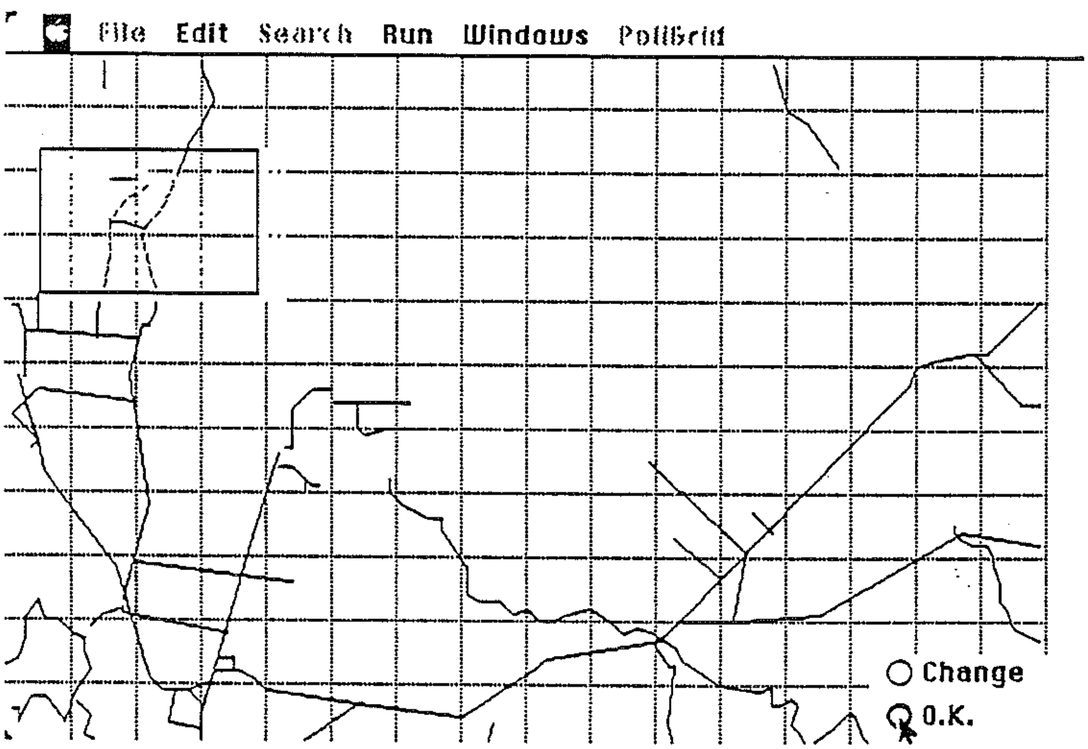
When the system has finished mapping, the 'PoliGrid' pull-down menu becomes available. Options are:

Show map - returns to the map after show table or show legend have been used.
Show table - displays a cross-tabulation of the mapped result with another map which you specified earlier.
Show legend - display a legend on the right side of the map.
Print screen - causes the entire screen to be printed (provided the printer is switched on).
New window - returns you to the linear features display and allows a different area to be mapped under the same overlay conditions.
New overlay- returns you to the operations menu, you have the option of retaining the current window.
Main menu - returns you to the main PoliGrid menu
Quit - drops you out of PoliGrid and back to the desk-top.

File Edit Search Run Windows PoliGrid

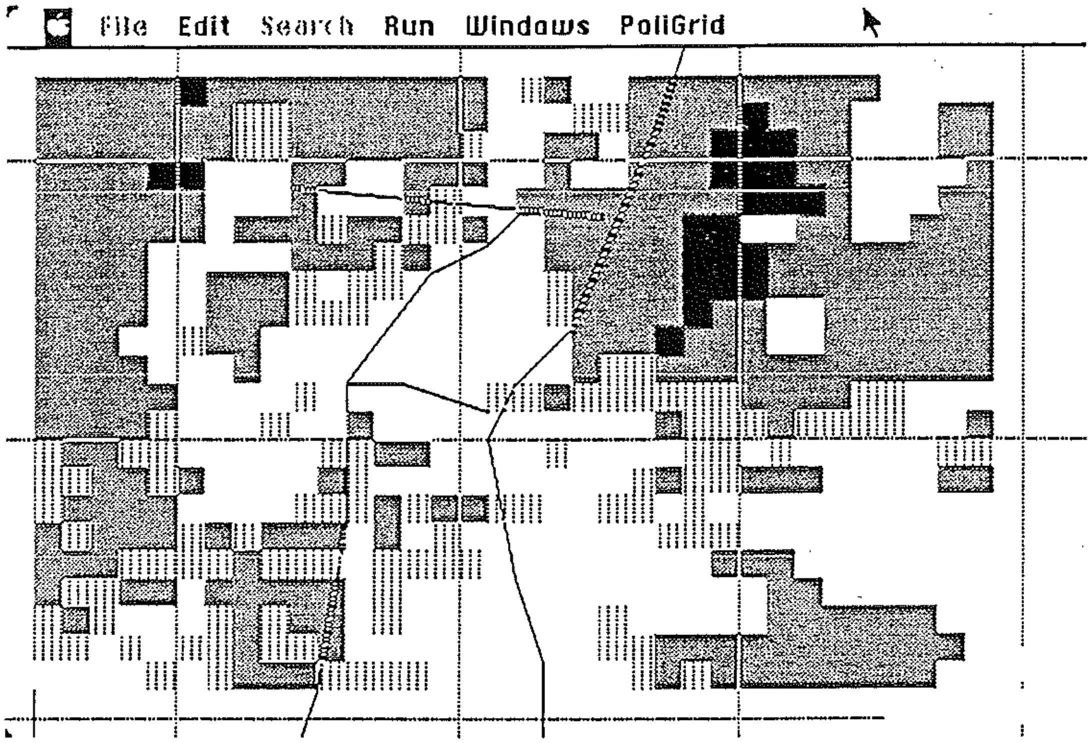
CROSS-TABULATION AREA TABLE

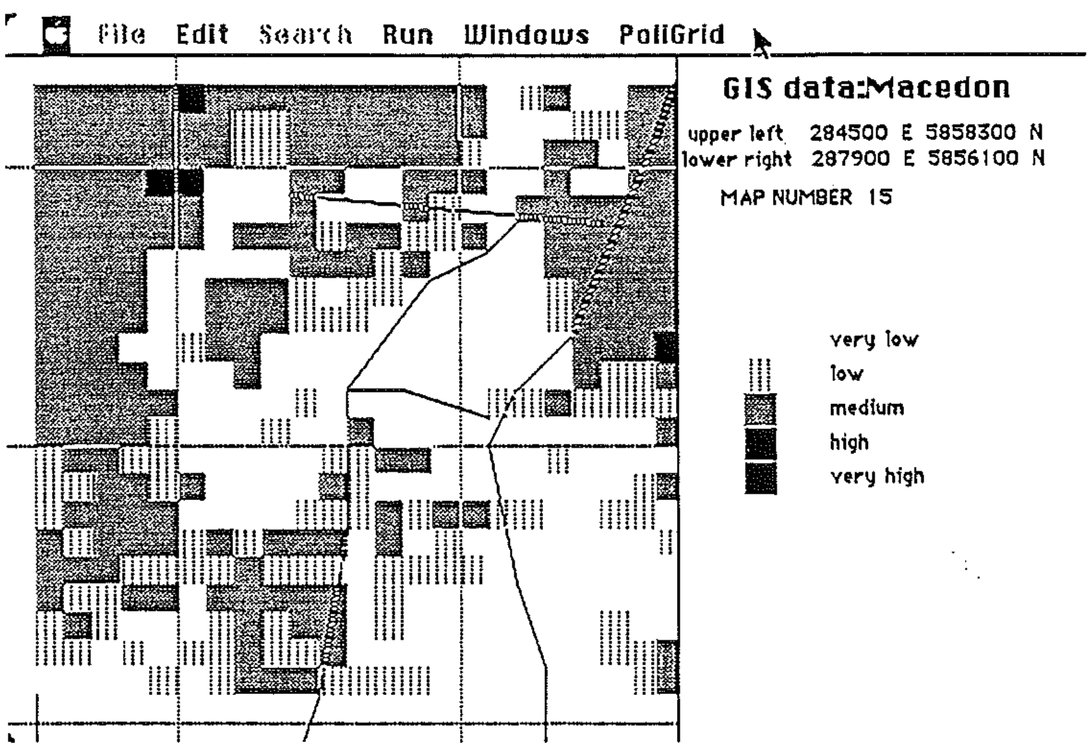
	A	B	C	D	E	TOTAL
private land	4527	7176	3607	218	0	15528
forestry land	203	111	849	132	0	1295
other public lan	100	66	16	0	0	182
Rosslyn Reservoi	146	19	1	0	0	166
Army land	109	0	0	0	0	109
TOTAL	5085	7372	4473	350	0	17280



This is a tabulation of fire hazard levels, as mapped, with land ownership. 'A' corresponds to very low hazard and 'E' to very high.

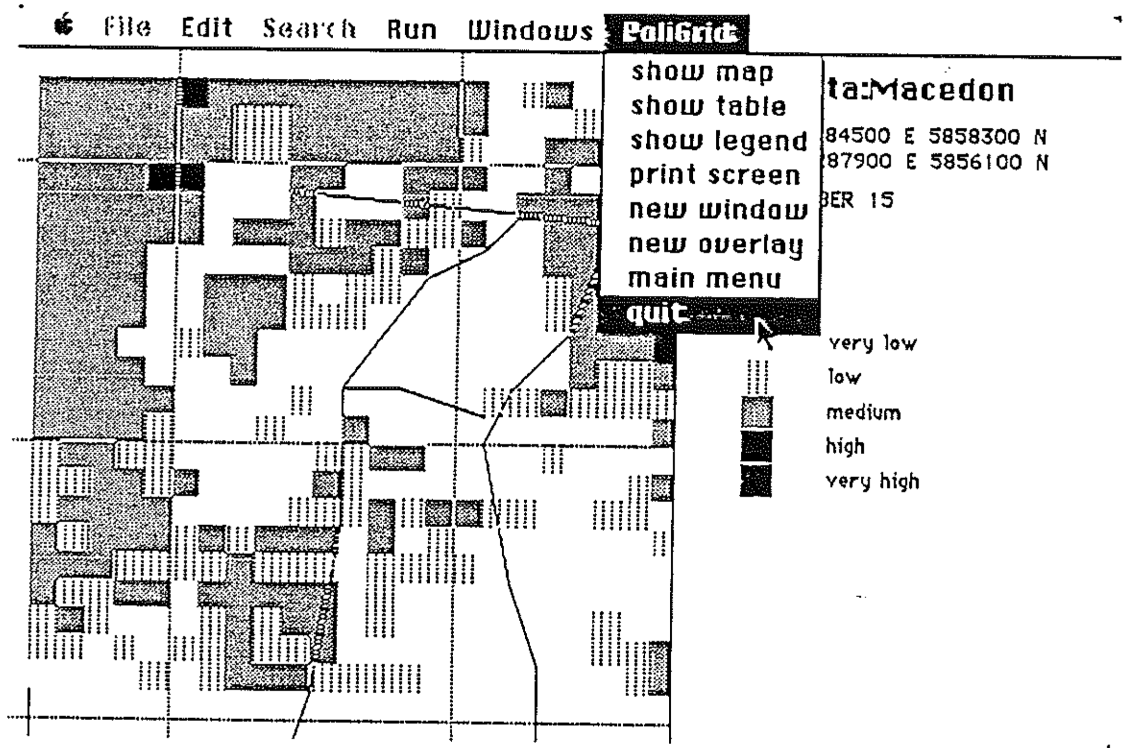
Mapping window are selected by dragging the mouse across the required area from upper left to lower right. Do not drag the other way!

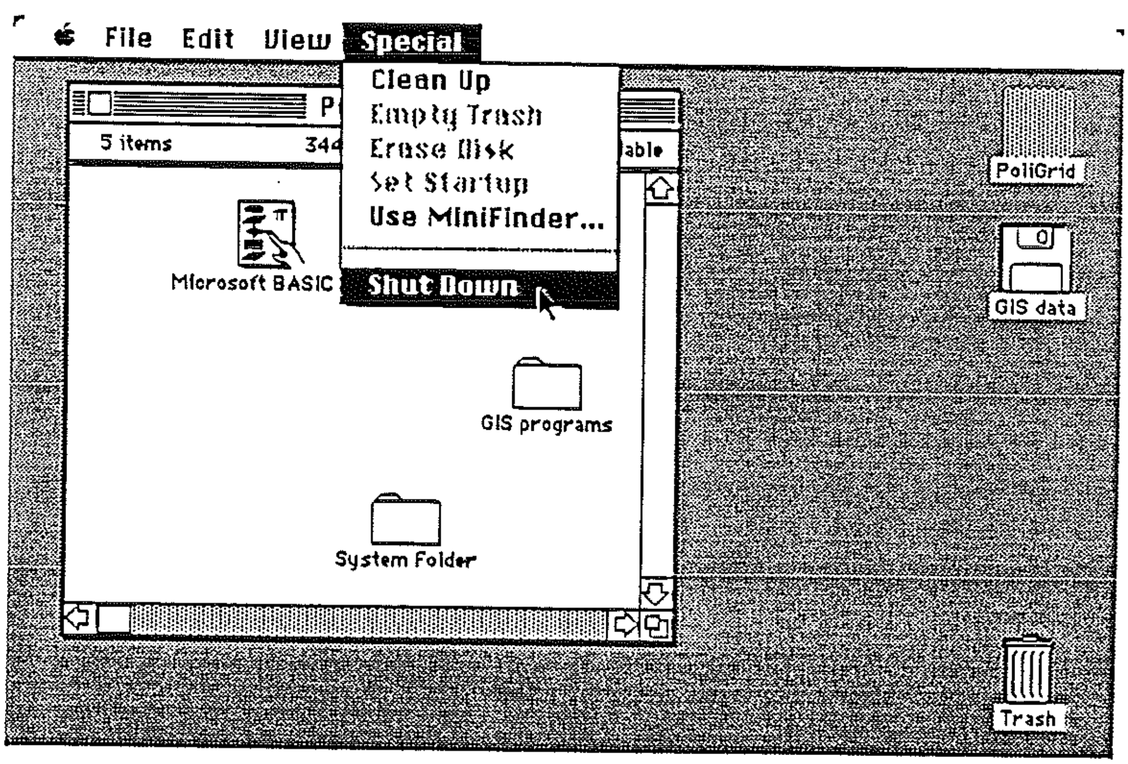

File Edit Search Run Windows PoliGrid


File Edit Search Run Windows PoliGrid
GIS data:Macedon
upper left 284500 E 5858300 N
lower right 287900 E 5856100 N
MAP NUMBER 15
very low
low
medium
high
very high

The smaller the area being mapped the larger the cells appear on the screen. In every case the shading blocks represent 1 ha.

When 'show legend' is selected, the AMG co-ordinates of two corners are shown. These are the corners of the shaded area, not the corners of the screen!


File Edit Search Run Windows PoliGrid
show map
show table
show legend
print screen
new window
new overlay
main menu
quit
ta:Macedon
84500 E 5858300 N
87900 E 5856100 N
ER 15
very low
low
medium
high
very high


File Edit View Special
Clean Up
Empty Trash
Erase Disk
Set Startup
Use MiniFinder...
Shut Down
5 items
Microsoft BASIC
GIS programs
System Folder
PoliGrid
GIS data
Trash

When you have no more operations to do select 'quit' from the 'PoliGrid' menu and return to the desk-top.

Shut down and switch-off.

APPENDIX 4

Fuel condition recording sheet

MACEDON
GRASSLANDS STATION POINT RECORDING SHEETS

RECORDER'S NAME/OFFICE:
DATE:

INSTRUCTIONS:

1. TICK THE BOX APPROPRIATE TO THE CONDITIONS IN THE SAMPLE SITE BEING OBSERVED (FUEL WEIGHT AND % CURING).

2. FUEL WEIGHT SHOULD BE RATED AS THE WEIGHT OF THE GRASSES IN RELATION TO THEIR POTENTIAL FIRE DANGER.

3. THE % CURING OF GRASSES SHOULD BE RATED ACCORDING TO THIS ADAPTATION OF MCARTHUR'S GRASSLAND CURING INDICATORS:

% CURED	PHYSIOLOGICAL CHANGES	COLOUR
0-10%	SEED HEADS FLOWERING - MATURING..............	GREEN
20-40%	MOST SEED HEADS MATURING-MATURED......... SEEDS ARE BEGINNING TO DROP	GREENISH-YELLOW TO YELLOWISH-GREEN
60-80%	SEEDS DROPPED, SOME STALKS SHOW SOME... GREENESS BUT AT LEAST HALF FULLY CURED	STRAW - ODD PATCH OF YELLOWISH-GREEN
90%	ODD STALKS MAY SHOW SOME GREENNESS.......	STRAW - ODD GREEN GULLY
100%	SEED HEADS AND STALKS BREAK EASILY...........	BLEACHED

KEY TO STATION POINTS

STATION POINT	CLASSIFICATION
2 - 10	GRASSLANDS BASED ON LAND SYSTEMS

MACEDON
GRASSLANDS STATION POINT RECORDING SHEETS

STATION POINT 2

FUEL WEIGHT	*% CURING*
☐ LOW	☐ 0-10
☐ MODERATE	☐ 20-40
☐ HIGH	☐ 60-80
☐ VERY HIGH	☐ 90
☐ EXTREME	☐ 100

STATION POINT 3

FUEL WEIGHT	*% CURING*
☐ LOW	☐ 0-10
☐ MODERATE	☐ 20-40
☐ HIGH	☐ 60-80
☐ VERY HIGH	☐ 90
☐ EXTREME	☐ 100

STATION POINT 4

FUEL WEIGHT	*% CURING*
☐ LOW	☐ 0-10
☐ MODERATE	☐ 20-40
☐ HIGH	☐ 60-80
☐ VERY HIGH	☐ 90
☐ EXTREME	☐ 100

STATION POINT 5

FUEL WEIGHT	*% CURING*
☐ LOW	☐ 0-10
☐ MODERATE	☐ 20-40
☐ HIGH	☐ 60-80
☐ VERY HIGH	☐ 90
☐ EXTREME	☐ 100

STATION POINT 6

FUEL WEIGHT	*% CURING*
☐ LOW	☐ 0-10
☐ MODERATE	☐ 20-40
☐ HIGH	☐ 60-80
☐ VERY HIGH	☐ 90
☐ EXTREME	☐ 100

STATION POINT 7

FUEL WEIGHT	*% CURING*
☐ LOW	☐ 0-10
☐ MODERATE	☐ 20-40
☐ HIGH	☐ 60-80
☐ VERY HIGH	☐ 90
☐ EXTREME	☐ 100

MACEDON
FOREST SAMPLE SITES RECORDING SHEETS

RECORDER'S NAME/OFFICE:
DATE:

INSTRUCTIONS:

1. TICK THE BOX APPROPRIATE TO THE CONDITIONS IN THE SAMPLE SITE BEING OBSERVED (FUEL WEIGHT AND MOISTURE CONTENT).

2. FUEL WEIGHT (FINE FUELS <6MM) SHOULD BE RATED AS THE WEIGHT OF THE VEGETATION TYPE IN RELATION TO ITS POTENTIAL FIRE DANGER.

3. THE MOISTURE CONTENT OF FINE FUELS SHOULD BE RATED ACCORDING TO THE SURFACE AND PROFILE EXAMINATION OF LITTER:

WET = BOTH SURFACE AND PROFILE FUELS MOISTURE CONTENT VERY HIGH
DAMP = BOTH SURFACE AND PROFILE FUELS MOISTURE CONTENT MODERATELY HIGH
DRYING = SURFACE FUELS DRYING, PROFILE FUELS MOISTURE CONTENT MODERATE
DRY = SURFACE FUELS DRY, PROFILE FUELS MOISTURE CONTENT DRYING
VERY DRY = BOTH SURFACE AND PROFILE FUELS MOISTURE CONTENT LOW

KEY TO STATION POINTS

STATION POINT	ASPECT	FOREST TYPE	ELEVATION
11		PINE	
12	S.E.	OPEN FOREST	<700m
13	S.E.	OPEN FOREST	>700m
14	N.W.	CLOSED FOREST	<500m
15	S.E.	CLOSED FOREST	<500m
16	N.W.	CLOSED FOREST	500-700m
17	S.E.	CLOSED FOREST	500-700m
18	N.W.	CLOSED FOREST	700+m
19	S.E.	CLOSED FOREST	700+m

MACEDON
FOREST STATION POINT RECORDING SHEETS

STATION POINT 11

FUEL WEIGHT	*MOISTURE (%)*
☐ LOW	☐ WET
☐ MODERATE	☐ DAMP
☐ HIGH	☐ DRYING
☐ VERY HIGH	☐ DRY
☐ EXTREME	☐ VERY DRY

STATION POINT 12

FUEL WEIGHT	*MOISTURE(%)*
☐ LOW	☐ WET
☐ MODERATE	☐ DAMP
☐ HIGH	☐ DRYING
☐ VERY HIGH	☐ DRY
☐ EXTREME	☐ VERY DRY

STATION POINT 13

FUEL WEIGHT	*MOISTURE (%)*
☐ LOW	☐ WET
☐ MODERATE	☐ DAMP
☐ HIGH	☐ DRYING
☐ VERY HIGH	☐ DRY
☐ EXTREME	☐ VERY DRY

STATION POINT 14

FUEL WEIGHT	*MOISTURE(%)*
☐ LOW	☐ WET
☐ MODERATE	☐ DAMP
☐ HIGH	☐ DRYING
☐ VERY HIGH	☐ DRY
☐ EXTREME	☐ VERY DRY

STATION POINT 15

FUEL WEIGHT	*MOISTURE (%)*
☐ LOW	☐ WET
☐ MODERATE	☐ DAMP
☐ HIGH	☐ DRYING
☐ VERY HIGH	☐ DRY
☐ EXTREME	☐ VERY DRY

STATION POINT 16

FUEL WEIGHT	*MOISTURE(%)*
☐ LOW	☐ WET
☐ MODERATE	☐ DAMP
☐ HIGH	☐ DRYING
☐ VERY HIGH	☐ DRY
☐ EXTREME	☐ VERY DRY

STATION POINT 17

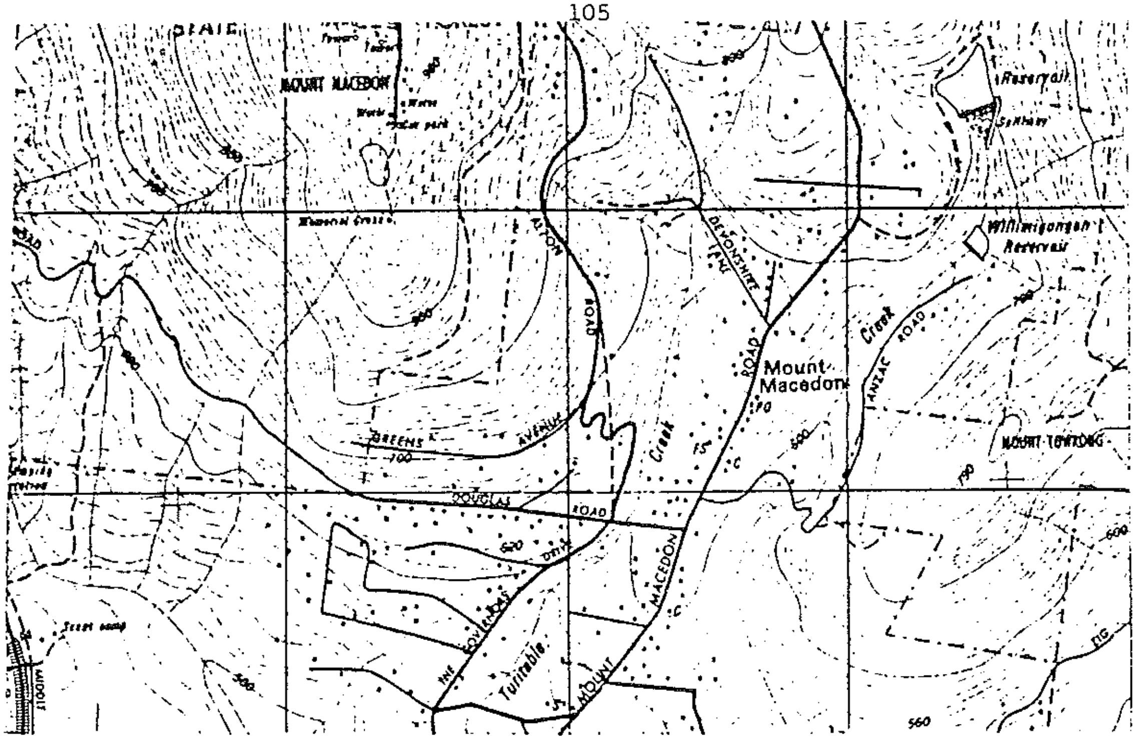
FUEL WEIGHT	*MOISTURE (%)*
☐ LOW	☐ WET
☐ MODERATE	☐ DAMP
☐ HIGH	☐ DRYING
☐ VERY HIGH	☐ DRY
☐ EXTREME	☐ VERY DRY

STATION POINT 18

FUEL WEIGHT	*MOISTURE(%)*
☐ LOW	☐ WET
☐ MODERATE	☐ DAMP
☐ HIGH	☐ DRYING
☐ VERY HIGH	☐ DRY
☐ EXTREME	☐ VERY DRY

APPENDIX 5

Fuel reduction recording sheet



MAP SECTION : **A**

SCALE: 1:25,000 **N**

RECORDERS NAME/OFFICE

DATE:

INSTRUCTIONS:

1. TO RECORD SITES OF ALTERED FUEL CONDITIONS, SUCH AS AREAS WHERE CROPS HAVE BEEN HARVESTED, OR CONTROL BURNING HAS OCCURED, ETC. DRAW AROUND THE AREA BOUNDARIES ON THE ABOVE MAP.
2. THESE AREAS (POLYGONS) MAY BE NUMBERED FOR REFERENCE IN THE SPACE BELOW AND WRITTEN INFORMATION ON THE AREA'S ALTERED CONDITION RECORDED AGAINST THESE.

POLYGON **DESCRIPTION**

3. INDICATE SUCCESS OF F.R.B.

PERCENT FUEL BURNT	REFERENCE CODE
70-100%	A
40-70%	B
20-40%	C
<20%	D
INEFFECTIVE BURN	E

APPENDIX 6

Proposal for further funding

AIMS AND SIGNIFICANCE

Fire is an inevitable and important component of the ecology of southern Australia. Areas prone to fire are also prone to habitation. The statistics of human tragedy, property destruction and economic loss that repeat every dry hot summer in southern Australia are well documented in Healy et al. (1985).

This is one example of the imperfect relationship between man and the environment. The problems that arise from the interaction of man and nature requires examination of processes, development of models and estimation of the effects of perturbations to the natural system. Once the system is properly understood measures can be taken which mimimize the adverse influences of man's presence on the environment, or the damage done to human society by the forces of nature.

This project is based on the supposition that better information can generate better management of fire hazard and hence less damage to both society and nature. We believe that improved fire hazard management will arise from an appropriate combination of scientific investigation, applied technology and a drawing out of the accumulated experience and empirical knowledge of those who work with and fight fire.

Fire hazard is typically a local problem currently addressed at the local level through Municipal Fire Prevention Officers and local Country Fire Authority Brigades. Local knowledge is an extremely important component of effective fire hazard management. All this implies a locally based (and low cost) system.

We anticipate development of a fire hazard management system that draws together the threads of technology and experience using an affordable micro-computer. We envisage a suite of computer hardware and software which will be used by local and regional agencies to select, organize and record their fire management activities. Current conditons will be mapped, the most cost-effective management option which reduces potential fire damage will be determined and, when the job has been done (e.g. a controlled fuel reduction burn), the results will be added to the data base and new hazard levels mapped. Figure 1 shows the various steps we see as necessary to achievement of this goal.

Three stages are identified in system development. The initial mapping system is complete and undergoing evaluation in the field. Based on this evaluation we have identified three necessary areas of research. The Stage 2 mapping system which will result will then be similarly tested. Research towards stage 3 will involve adaptations flowing from this second testing phase in addition to development of a hazard analysis module to assist in resource allocation to effectively, and efficiently, counter the hazards identified by the mapping system.

On-going consultation and trial application gives this project both research and implementation components. These must be carried forward simultaneously for the success of both. Existing and anticipated research developments will be incorporated into our developing fire hazard management system in collaboration with the Country Fire Authority (CFA), the Department of Conservation, Forests and Lands (CF&L), and both the State and Commonwealth Departments of Local Government. As indicated above, the first stage of the work ('An information system for local fire hazard management') is nearing completion. This was funded by the Commonwealth Department of Local Government and Administrative Services and early developments are described in Bishop(1985). Trial systems have been set up in the offices of the Shire of Gisborne (Macedon Ranges) and the Upper Yarra Valley and Dandenong Ranges Authority. We already had considerable knowledge of the fire problem in the Macedon area (Green et al.,1985) and had developed a substantial digital data base (Bishop et al.,1985). We selected the more extensively cleared Yarra Valley as a contrast. A wet summer in southern Victoria has hindered evaluation of the application of the system but both groups have appreciated its ease of use and indicated a keenness to continue to participate in the research project (see attachments).

In framing this proposal we have made clear the proportion of the work (about 25% in the second and third years) we regard as field application and testing and have assumed that the necessary level of financial support for that aspect of the project will be found from other sources.

The fire damage potential of a particular location is a combination of (a) the potential level of damage and (b) the likelihood of damage occurring. In this proposal we use the term fire hazard to mean, according to context, either these two factors in combination or, as is more common (e.g. Luke and McArthur, 1978), just the latter. Reducing the damage done by fire involves reduction in either the assets at risk or the risk itself. This requires (a) reduced habitation in fire prone areas, and (b) reduced fire incidence in inhabited areas.

Both strategies are already employed in Australia. The former is primarily the province of planning authorities who can refuse permits to build in the most fire prone areas and to a lesser extent insurance companies who can increase premiums for vulnerable homes. The second strategy has two components (i) fire hazard management through fuel reduction, strategic fire breaks, appropriate building practice and other measures which increase the controlability of fires that do occur and (ii) provision of fire suppression facilities.

One capability which can contribute to the increased effectiveness of all these mechanisms is improved mapping of fire damage potential. This is no simple matter as Hatch and Jarrett (1985) make clear:

> Bushfires are heterogeneous in all respects. Their origins are diverse, being the result of both natural and human causes. Their timing and location are similarly largely unpredictable. In addition their damage potential varies enormously according to their location and timing.
>
> In addition bushfires are a spreading or infection phenomenon. The 'untreated' spread of a fire depends upon weather, even micro-climate, topography, vegetation, land use, human structure *etc*. Some of these factors are subject to continuous and unpredictable change, for example weather; others are highly complex and largely unquantifiable for example, vegetation and topography. As a result the potential pattern of a particular fire cannot be predicted accurately and therefore its damage potential is unpredictable. This is compounded by the fact that damageable assets and their values are similarly difficult to measure. (p95)

Hatch and Jarret sought to find measures of potential damage as a guide to distribution of fire suppression resources. Although the problem is slightly different for the planning and management strategies which may preceed fire suppression many of the difficulties they identify remain relevant and support our contention that local knowledge and experience must be drawn upon. Some of their doubts are however misplaced. For example, quantification of vegetation and topography which may be daunting to economists is routine in landscape analysis.

The most promising existing mechanism for drawing together elements of scientific knowledge and experienced judgment is the computer based expert system (Hayes-Roth et al.,1983). A sub-set of developments in artificial intelligence, expert (or knowledge-based) systems have found application in many fields. Davis and Nanninga (1985) list these as medicine, organic chemistry, mineral exploration, computer configuring, weather forecasting, remote sensing interpretation, hydrological modelling, archeology and crop management. The use of such systems for land management, however, is still extremely limited.

We anticipate making a substantial contribution in this area. Already their is substantial Australian activity in mapping of fire hazard and fire behaviour. Gradient Modelling Pty. Ltd. are marketing an equation based hazard and behaviour modelling system called FIREPLAN based on relatively low cost ($40,000) hardware (Kessel,1985). The CSIRO Division of Water and Land resources have taken an expert systems approach to fire behaviour and damage in the Kakadu National Park (Davis and Nanninga,1985). This research will add to this developing expertise through its concentration on the local user of the systems prior to fire activity. This concentration will be expressed through still cheaper hardware ($6000), local data recording and input and expert systems based incorporation of local knowledge. We also expect improved mapping of fire related parameter through a combination of remote sensing, better observer training and, again, expert systems. Our choice of the complex outer suburban environment as one site for system testing will force development of a new interface between detailed mapping programs and expert systems. At all times the research is aimed at exploiting the strengths of both modern technology and expert knowledge and exploring the interface between them.

RESEARCH PLAN, METHODS AND TECHNIQUES

The essential components of an effective fire hazard management system are
(a) accurate and timely mapping of relevant parameters
(b) an appropriate procedure for combining mapped parameter to determine fire hazard levels, and
(c) the ability to determining proper management activities from the mapping.
This project anticipates advances in all three areas.

MAPPING OF FIRE HAZARD PARAMETERS.

Ground conditions which have a bearing on fire hazard can be categorized according to the time period over which they vary. Slope and aspect can be considered constant and can be reliably mapped with little difficulty. Accessibility for fire fighting services changes as new roads are developed or as road conditions change. Fuel conditions can change radically in just a few days.

It is generally agreed that fuel quantity and moisture content are the most important contributors to fire hazard (e.g. Vines,1983). A major part of this research involves improving our ability to estimate these variables and quickly incorporate the information into a fire hazard management system.

Use of remote sensing satellites as a source of such information is very appealing because of their frequent coverage and relatively low cost. NOAA satellites are used for this purpose in the USA (McKinley et al, 1985), their applicability in Australia has also been established (Barber,1979) and calibration of band ratios to southern Australia's grasslands is near completion (Barber, pers.comm.).

The high cost of image processing equipment to determine fuel conditions from NOAA satellite data means that a central receiving and processing station is necessary. If fire hazard mapping is to be carried on at a local level then some mechanism for rapid transmission of the centrally derived fuel information to the local mapping facilities is necessary. This proposal envisages direct transfer of the results of image analysis to a microcomputer with a high level of disk storage at CFA headquarters Melbourne. The analysis itself would also be done at CFA using a processing system to be installed in 1986. The interpreted data would be broken up by local mapping district. The central computer would be available on a dial-up basis to the local agencies (e.g. local government fire prevention offices, forest managers etc). Fuel condition data would be transfered down line to the local computer and automatically added to the local data base containing the less changeable parameters using our software. Newly derived fire hazard maps could then also be returned down the line to headquarters and re-integrated with neighbouring areas. These would permit the CFA to maintain a broad perspective and also assist in monitoring and evaluation of the system. The established network could also be used for other types of data between, for example, CFA headquarters and regional offices. The CFA is keen for this work to proceed and will co-operate with system development (see attachment).

Unfortunately, use of satellites as estimators of fuel condition is at present limited to cleared land. Estimation of ground level and understory fuel levels in Australian native forests, suburban woodlands or pine plantations is not yet possible because of the dense canopy. While in the long term remote sensing of forest fuel conditions may be possible we recognise that such a result is several years away. For the time being an entirely different approach to fuel condition mapping is required. Several procedures are used at present: estimation based on experience and observation, fuel indices derived from weather condition formulæ (Cohen and Deeming,1985), and calculation from litter accumulation formulæ based on mapped vegetation associations (Birk and Simpson,1980). If precise data is required, samples must be collected and taken to a laboratory for analysis.

Our initial research (Cutler,1985) has indicated that while experienced observers are as good at estimation as several of the formulæ, neither are particularly accurate. The Victorian Ministry of Conservation, Forests and Lands wishes to develop a training program for its forest officers to improve their ability to judge fuel quantities and conditions. The CFA also runs training programs for Municipal Fire Prevention Officers. We anticipate a high level of contact with CF&L and CFA to monitor the progress of their training programs. We will then test those who make the estimates in a variety of environments and moisture conditions. These tests involve selection of suitable sites, pegging out of an area of $100m^2$, random selection of 5 $1m^2$ sample plots within the site, estimation by observers of fuel weight and moisture content for both the site as a whole and the individual plots, collection and analysis of all the fine fuel (<6mm minimum dimension) from the plots, and application of conventional estimation tools such as the speedy grinder and the fine fuels flammability index (FFFI). It may be revealed that some circumstances suggest the use of a formula while at other times, or in other conditions, the trained observer can do better (e.g. where local micro-climate makes weather station data unrepresentative, or when vegetation has not been mapped in sufficient detail). We will program the system to accept observations if they are available and thought to be superior to a formula. The system will otherwise calculate fuel conditions from vegetation and climatic data.

Although fuel weight and condition have been identified as the major contributors to fire hazard. A number of other mappable parameters also affect the potential for fire or the potential damage arising. These include aspect (as it relates to prevailing winds), accessibility for fire fighters and equipment, probable time lag between fire outbreak, reporting, and arrival of fire fighters, access to water, vulnerable assets and so forth. In the system at present we have included some of these parameters but have not been in a position either to test our algorithms. Local knowledge is likely to be of great importance to assessment of such parameters and an expert systems approach combined with the geographic data base may well provide the best results.

COMBINING MAPPED PARAMETERS

The preceeding developments will supply personnel in the field (e.g. municipal fire prevention officers, CFA regional officers) with accurate data on all major parameters relating to fire hazard.

The question then arises, how can these parameter best be combined to:
(i) indicate the appropriateness of development proposals,
(ii) determine where fuel reduction or other management activity is most needed, and
(iii) suggest appropriate distributions of fire suppression facilities.

The fire hazard mapping system field tested in 1985/86 contained a default hazard assessment formula based on the parameters identified above (see also Morris and Barber,1981). This was a linear mathematical formula based on the subjective estimates of CFA and CF&L personnel and the recognized dominance of fuel weight and condition as expressed in the literature.

Reliance on subjective judgments is not sufficient. But, as the quote from Hatch and Jarrett(1985) above indicated the complexity of the problem makes any mathematical formulation appear presumptuous. In addition, the field officer, who trusts his own experience more than a black box full of numbers and formulæ, is clearly more likely to take advantage of the opportunities the system presents if he is able to contribute that experience to the mapping process.

Expert systems appear to provide the ideal compromise. Such formulæ as are known, or can be hypothesised, may be included in the system. The user is however invited to contribute their own opinion on the way in which parameters should be combined in their own domain. Where specific functional relationships are well accepted by researchers these can be fixed in the system or the user not permitted to diverge by more than recognized limits of possible error (or local deviation) in the formulæ.

With our existing mapping system developed on Apple Macintosh we intend to add the expert systems capabilities on the same computer. The languages of artificial intelligence (LISP, Prolog) are available for Macintosh and have the ability to access the graphics and communications firmware in the Macintosh toolbox that provide the ideal operating environment for the inexperienced user. We have acquired 'MacProlog' and anticipate using this for system development. Expert systems shells exist that have been partially adapted to work from geographic data bases and used in the related fields of fire behaviour and fire damage to vegetation (Davis et.al, 1985). To date, however, they have not been combined with mapping programs (Davis, pers.comm.). The GEOMYCIN shell (Nanninga et al.,1985) is available to us and would provide a starting point for addition of an expert system mode of hazard mapping to our existing mapping procedure and software.

In the areas of high fire hazard near major urban centres (such as our Macedon Ranges and Yarra Valley study areas) a high level of spatial disaggregation will be necessary. Among the problems to be faced in implementing the system will be the hitherto slow speeds and high demands on the user that such detailed breakdown brings (Davis and Nanninga,1985). New techniques will have to be developed to permit interfacing with the Stage 1 mapping system.

Such an expert system shell would also be available to assist in estimation of the hazard parameters themselves.

RESOURCE ALLOCATION TO HAZARD REDUCTION

Having established a viable data base and procedure for fire hazard mapping the system may be regarded as complete to stage 2. The system will be installed in the field (as was Stage 1) and evaluated by the end users. In using the system to assist with fire hazard management they will inevitably bring forward suggestions for either further development which would assist in delineating the best management path, or procedures which they have adopted as routine which could be incorporated in the system.

Defining proper management responses to particular fire hazard patterns becomes the next significant issue. Management is faced with strategic decisions such as

- best locations for strategic fire breaks
- best locations for equipment or water supplies
- allocation of resources between new breaks, new equipment etc

Such decisions will be much enhanced by the addition to our fire hazard management system of a fire behaviour module. Software already exists and have been calibrated for several parts of Australia (Kessel and Good,1985). Depending on developments to that time in the project (April 1988) it may be preferable to acquire source code from a third party or develop it ourselves based on equations in the literature (e.g. McArthur 1966,1967; Rothermel, 1972). This decision will depend on cost estimates, and the degree to which the existing process based models developed in procedural languages (FORTRAN, BASIC) are compatible with our logic based developments in PROLOG.

These modules will require additional data, particularly in relation to vegetation associations and their behaviour, and calibration for the area in question. At this stage results from the School's research into the fire behaviour implications of roadside verges (ARGS funded project 'The socio-environmental impact of roadsides') will feed into the project.

Having incorporated fire behaviour into the system, we would again seek to combine local experience with statistical methods to explore the implications of fires coming from a range of starting points under a range of wind conditions to potential distributions of strategic fire breaks (including existing roads etc), water supply points and fire stations.

Probable losses could be computed for each distribution of resources. While the least probable loss configuration would not necessarily give the least loss for the next fire, it should give the least loss over a period of years and (inevitably) fires.

The system would also be available to assist with planning of fuel-reduction burns in identifying those areas where a burn would be most useful, in plotting the best start point for such a burn, and in ensuring that a suitable day was chosen for the burn (i.e. suitable wind direction etc.). We would not, however, be designing for short term deployment of resources during the period of a fire (cf. Kessel,1985).

JUSTIFICATION OF BUDGET

The timing of the various phases of the project would be as set out in Figure 1. The dates are based on the first presented budget which includes a research associate for 3 years wholly funded under this project and largely by ARGS. The task durations shown on the chart are not identical to those given below because of overlap.

In 1987 the the project will require support in three areas:

A. Development of communications link between central remote sensing facility and local mapping systems.

	Cost	Priority
Research Associate for 3 months (salary $23473)	$6866	A
1 Macintosh Plus computer*	$2740	B1
Hard disk unit for Macintosh*	$1950	B1
Cabling, modems, software etc.*	$2000	B1

*This equipment is for system development and later installation at CFA headquarters. It will revert to the University at completion of this project (or any successor). The prices are much lower than retail because of the University's participation in the Apple consortium. Two modems are required for system development: one will be used at CFA the other at the University in emulation of the trial systems in the field. The trial systems themselves will belong to the participating authorities.

B. Development of expert systems module and improvement of both individual parameter and hazard mapping using expert system (to be completed March 1988).

Research Associate for 9 months (salary $23473)	$20597	A
Travel to local system installations	$ 2000	B3

C. Testing of trained personnel in estimation of forest fuel levels and conditions and determination of preferred estimation methods.

Research assistant for 4 months 2/5 time (salary $17970)	$ 2802	B2
A small proportion of the Research Associate's time	-	n/a

The total sought in 1987 is therefore	$38955

The second year of the project (1988) will see completion of the expert systems work and integration of all new developments into an operational fire hazard mapping system by May. At that time Dr Bishop will be going on Study Leave (under separate funding) and will not return until late in the year. During that time he will be meeting with American and European colleagues researching artificial intelligence and natural hazards. The remainder of the year will be devoted to setting up of the fire behaviour modelling for the study areas in question and beginning to use the entire model to explore the strategic implications of resource allocation. The research associate may also be called upon to sort out out problems that develop with the operational systems. To support this latter role we will be seeking support from involved agencies at State or Federal Government level or else from the involved Municipalities themselves who will find other benefits from having a flexible geographic information system available to planning staff. (The Shire of Gisborne and the Upper Yarra Valley and Dandenong Ranges Authority who operated Stage 1 of the system in 1985/86 found significant levels of use for non-fire related purposes.)

In 1988 we would therefore seek

Research Associate 4 months full time	$10360
& 8 months 3/5 time	$12440
Travel	$ 2200
Maintenance of Macintosh equipment	$ 600
	$25600

Finally, 1989 will see further research into strategic analysis and integration of this and the lesson learned from Stage 2 in the field into the Stage 3 system. The research fellow would return to full time support from this project for the final 4 months of the year for this integration period and for reporting.

Research Associate 8 months 3/5 time	$14070
4 months full time	$11720
Travel	$ 2400
Maintenance of Macintosh equipment	$ 600
	$28790

The Research Associate would need an aptitude for innovative development of computer systems. Ideally they would have some previous knowledge of expert systems, PROLOG, networking and process modelling. They would have to be sufficiently senior to work with limited direction in the second half of 1988. For project continuity we would want to make a 3 year appointment. This may not be possible if we have not secured support for the remaining salary component by the end of this year. Potential participating municipalities (and their State and Federal umbrella departments) will be asked to contribute if we receive this grant. The shortfall is about $17,000 and we will seek to have 5 or 6 authorities involved in Stage 2 testing and Stage 3 development over 2 years.

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Note: Between 1979 and 1983 Dr Bishop was employed as a Research Fellow in the Centre for Environmental Studies, The University of Melbourne. During that time most of his research work was contract based. He also edited the subscription newsletter - 'Land Use Modelling Quarterly'.