SOIL CONSERVATION SERVICE

OF

NEW SOUTH WALES

WAGGA WAGGA

DISTRICT TECHNICAL MANUAL

September, 1973

CONTENTS.

1. INTRODUCTION

The Wagga District is situated in the eastern Riverina with headquarters located at the Riverina District Office at Wagga.

Its total area is approximately 3000 sq. miles comprising virtually all of the Mitchell and Kyeamba Shires; and approximately two thirds of each of the Coolamon and Illabo Shires.

The principal urban centre is the City of Wagga Wagga with a population of 29,000. It is a centre of tertiary education having a Teachers College, an Agricultural College and a College of Advanced Education. Rural research facilities in the area include the Agricultural Research Institute and the Soil Conservation Service Research Station. The city is the largest stock selling centre in New South Wales and is also a centre for light industries. It has regional abattoirs, flour milling and stock feed production units, milk and dairy factories, an egg marketing plant and small scale timber mills.

Junee with a population of approximately 4,000 is the only other municipality in the district. A number of smaller towns and villages are distributed throughout the area. Many of these are siutated approximately ten miles apart along the original rail links established to service the wheat industry.

The area was discovered by Sturt on his journey of exploration in 1829, and soon after, settlement commenced, with the area upon which Wagga is now situated, being taken up for settlement in 1832. By the early 1840's the whole area had been taken up by pastoralists. In this period cattle were more important than sheep, requiring less labour, lower handling costs and being easier to market.

Wheat was first grown in 1844 to meet local needs. A flour mill was established in Wagga in 1857. However, it was not until the coming of the Railway in 1879 and closer settlement in later periods that large scale wheat production developed.

Closer settlement was greatly stimulated by the development of the railway but much of the land was still unavailable for settlement, being locked up in large pastoral holdings which also enclosed the river frontages. Some pastoral companies controlling several holdings, shore up to 250,000 sheep per annum in the late 19th century.

With development of mechanization and further closer settlement after 1900 wheat growing was greatly expanded and former large pastoral holdings also commenced production. Production increased six-fold in the period from 1880 to 1920 and the Riverina became one of the principal wheat producing areas in Australia.

After 1900 commercial dairying was commenced on the fertile flats near Wagga. It ultimately expanded along these flats both north and south of Wagga and along the flats of the Kyeamba Creek and of the Tarcutta Creek about Tarcutta itself. In recent years there has been some expansion of the industry for fresh milk production and a marked decline in cream production. A change to beef production has occurred particuarly in outlying areas.

Cross-breeding for fat lamb production commenced after 1900. The wheat-sheep farm of later periods had its origin in this development. In the 1920's with production stimulated by further closer settlement the area became the most important wheat producing area in the State.

Farming was generally on a wheat-fallow rotation with stubble being burnt. Much of the accelerated erosion was initiated in this period.

High levels of wheat production continued into the 1930's. However early in this period the combined effects of skeleton weed, rabbits and the great depression asserted themselves and farming for many, particularly in marginal areas became unprofitable.

In an effort to maintain previous levels of income, farmers initially formed the land more intensively. Skeleton weed became even more widespread and erosion was greatly accelerated.

Towards the end of the 1930's the effect of the depression was receeding and the use of subterranean clover based pastures and wider rotations gave some control of Skeleton Weed.

During the immediate post-war decade the value of subterranean based pastures and annual applications of superphosphate became even more widely recognised. In this period the area of improved pasture in the Riverina increased by 600 percent.

The introduction of myxomatosis in 1951 aided by more recent and more effective poisons (e.g. 1080) have given more effective control of rabbits. Generally the rural industries prospered until the mid 1960's, when changes in the wheat marketing situation, and depression of wool prices again reduced prosperity.

Because of the generally favourable farming environment, diversity in production is possible and some changes, particularly away from wheat production, are taking place. Generally the object is to produce wheat up to the limit of the quota and to utilize additional arable capacity for the production of alternative crops. Choice has to be made between the traditional alternative crops, oats, barley or rye or the new crops being introduced such as rape, field peas and lupins.

Cattle are also replacing sheep in many areas, there being an increase in cattle numbers of approximately 24% over the 1969-70 period, and this trend is continuing.

In the grazing areas a marked reluctance to continue annual topdressing has been noted and less attention is being given generally to pasture improvement and management.

In conclusion, the accelerated erosion of the past occurred over a relatively short period. Measures to control it have been evolved. Changes in land use, however, demand that the position be kept constantly under review.

2. GEOLOGY

2.1 Introduction

In the district extensive areas of metamorphosed Ordovician sediments occur together with smaller areas of Silurian sediments.

Later intrusions of granites occupy large areas as represented by the Wantabadgery batholith N.E. of Wagga.

Small areas of Tertiary alluvium remain as remnants in the Forest Hill - Lake Albert area.

At lower levels the older sedimentary materials are overlain by extensive deposits of Quaternary (recent) alluvium.

2.2 Formations

2.2.1 Ordovician Metamorphosed Sediments

These deposits have a N.E. trend and occupy large areas east of Kyeamba Creek and between Wagga and Coolamon. Smaller interrupted deposits also occur south of Wagga, these being of the same general trend.

They are made up of quartzite, slate, graywacke, phyllites, schists and hornfels.

Common soil types found on them are red podzolics and red earths.

2.2.2 Silurian Sediments

These are found in the north east section of the district being contiguous with the much more extensive deposits to the east.

These are composed of sandstone, shales, slate, siltstones and conglomerate.

Red earths are the main soil types found on them.

2.2.3 Lower Devonian Granites

Lower Devonian granites run in a wide belt from N.E. of Wagga through Marrar and Junee and are contiguous with the Ardlethan granites to the North East. The Wantabadgery batholith is included in this section.

Smaller outcrops occur south of the Murrumbidgee River giving rise to areas of more rugged topography than the surrounding landscape.

The major soil types occurring on the old weathered granite landscapes are red podzolics and red earths, whilst solonetzics and red podsolics occur on the smaller outcrops.

2.2.4 Tertiary Alluvium

Small areas of these sediments are found in the Forest Hill and Lake Albert areas. At Forest Hill they occur as high level terrace remnants. Lake Albert (artificial) is the site of a former Tertiary lake. They are areas of generally level topography. The principal soil type occurring on them is a red earth.

2.2.5 Quaternary Alluviums

Extensive deposits of these occur in the west of the district, and along the major creek and river systems. They consist mainly of gravel, sand, silt and clay. Many different soil types are found on them but the principal ones are yellow solonetzic, chernozems and red brown earths. Yellow solonetzics are found along the creek systems, chernozems along the Murrumbidgee River and red-brown earths north and west of Coolamon.

2.3 Geology and Erosion

There appears to be no direct relationship between geology and erosion.

3. LANDFORMS

3.1 Introduction

The district comprises several physiographic regions. To the east and south east steep hill systems intrude into the area. Westward, the hill systems become progressively less pronounced and gradually change to sloping plains. Hence the Wagga district comprises elements of both the South West slopes and the associated riverine plains.

Altitude varies from 2300' on the S.E. corner to a little over 500' on the Murrumbidgee River flood plain.

The principal drainage system is the Murrumbidgee River which bisects the district in its westerly course.

To the east of Wagga secondary drainage lines generally run in a north to south direction before joining the Murrumbidgee. In the western portion of the district the Kindra and Boggy Creeks flow in a westerly direction.

3.2 Description of Landform Classes

The area has been classified and mapped into four general slope classes.

3.2.1 Land with Slopes Greater than 30%

These lands are not extensive but occur along the eastern and south eastern boundaries of the district. In many places they represent scarp faces or steep ridge crests. Owing to their steepness most of these lands still retain their native vegetation. Further clearing may produce only unproductive pasture and lead to severe erosion.

3.2.2 Land with Slopes between 10-30%

The remainder of the hill systems comprise these slope classes which are typified by lower ridges with generally shallow lithosolic soils. In many eareas the better country has been cleared but severe erosion can occur. This is typified by extensive sheeting or deep gullying and control of erosion on this country by structures is extremely difficult.

3.2.3 Land with Slopes between 3-10%

Land of this class is common throughout the district, occurring on the foot slopes of the hill systems and extending in a westerly direction. They are favoured lands for arable use and extensive areas exist north of the Murrumbidgee River.

With intensive arable use banks and waterways are recommended otherwise serious erosion will result.

3.2.4 Land with Slopes less than 3%

Most of this land occurs in the westerly portion of the district where it is typified by gentle slopes falling to the west. Extensive areas also occur along the valley floors of the Murrumbidgee River and the Houlaghans, Kyeamba and Tarcutta Creeks. Sheet erosion can occur on the gently sloping land in the western portion, but due to the better moisture relationships existing in the drainage systems, erosion is negligible.

4. CLIMATE

4.1 Rainfall

4.1.1 Average Annual Rainfall

The average annual rainfall for the district is shown in figure 4.1. It varies from less than 18 inches in the North West to more than 30 inches in the South East. Rainfall increases from west to east and from north to south.

Highest rainfalls are recorded at higher elevations in the south east corner.

4.1.2 Distribution

Mean monthly rainfall for Wagga Wagga, Junee, Ganmain, The Rock, Tarcutta and Junee Reefs are shown in figure 4.2. Distribution is generally winter dominant, with June the wettest month.

4.1.3 Variability

An estimate of rainfall variability for six stations is given by the quartile analysis as shown in table 4.1.1.

Rainfall is rarely distributed normally. Occasional high monthly totals greatly affect the monthly mean which is therefore a poor indicator of rainfall occurrence. Hence the monthly median rainfall is preferred.

Lower and upper quartilesare also presented. The first or lower quartile is the rainfall that has been exceeded in 75% of the years. The third or upper quartile is the rainfall that has been exceeded in 25% of the years.

As a measure of variability the median deviation has been calculated. For Wagga Research Station for January, the median is 118 points and the median deviation from this is 79 points. That means that in half of the years the departure from the median is 79 points or less. The deviations have also been expressed as percentages of the median to give a percent variability.

Generally the winter and early spring months have the most reliable rainfall.

Table 4.1.2 indicates the percentage of total rain per month that may be expected to fall within various intensity classes. Although June is the wettest month, the average rain per wet day is 17 points whilst during the period October to April the amount of rain received per wet day varies between 19.2 and 32.1 points. For this latter period a greater percentage of the total rain falls in higher intensity classes.

Table 4.1.1 Rainfall Distribution and Variability for selected stations in the Wagga District

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Wagga Soil Conservation Station (1948-1970)													
1st Quartile	70	32	36	69	95	107	102	146	115	151	115	66	1910
Median	118	85	148	132	172	165	222	190	187	210	168	139	2139
3rd Quartile	211	151	225	236	317	248	256	238	249	334	233	224	2512
Median Deviation	79	60	98	65	77	59	62	45	62	86	60	73	289
Percentage Deviation	67	70	66	49	45	36	28	24	33	41	36	53	12
Wagga Wagga P.O. (1872-1968)													
1st Quartile	43	27	40	60	81	133	109	117	116	120	53	43	1709
Median	116	92	111	136	152	226	174	195	173	193	162	126	2103
3rd Quartile	237	219	214	241	264	341	258	277	241	292	232	233	2551
Median Deviation	74	83	83	86	80	100	67	76	67	92	98	90	399
Percentage Deviation	64	90	75	63	53	44	39	39	39	48	60	71	19
The Rock (1894-1967)													
1st Quartile	40	24	38	67	75	132	111	112	97	117	39	51	1706
Median	100	101	105	125	152	237	211	226	164	186	119	129	2093
3rd Quartile	199	207	220	214	227	324	307	282	237	334	215	219	2525
Median Deviation	75	88	81	64	76	99	96	77	67	78	85	81	398
Percentage Deviation	75	87	77	51	50	42	45	34	41	42	71	63	19
Ganmain (1900-1968)													
1st Quartile	21	14	19	61	59	115	90	92	94	93	52	32	1494
Median	84	64	127	88	113	154	187	162	126	159	129	85	1773
3rd Quartile	238	171	222	206	245	250	241	222	209	257	227	212	2162
Median Deviation	74	62	99	57	69	64	74	68	59	79	83	70	344
Percentage Deviation	88	97	78	65	61	42	40	42	47	50	64	82	19

FIGURE 4:2

RAINFALL MONTHLY DISTRIBUTION

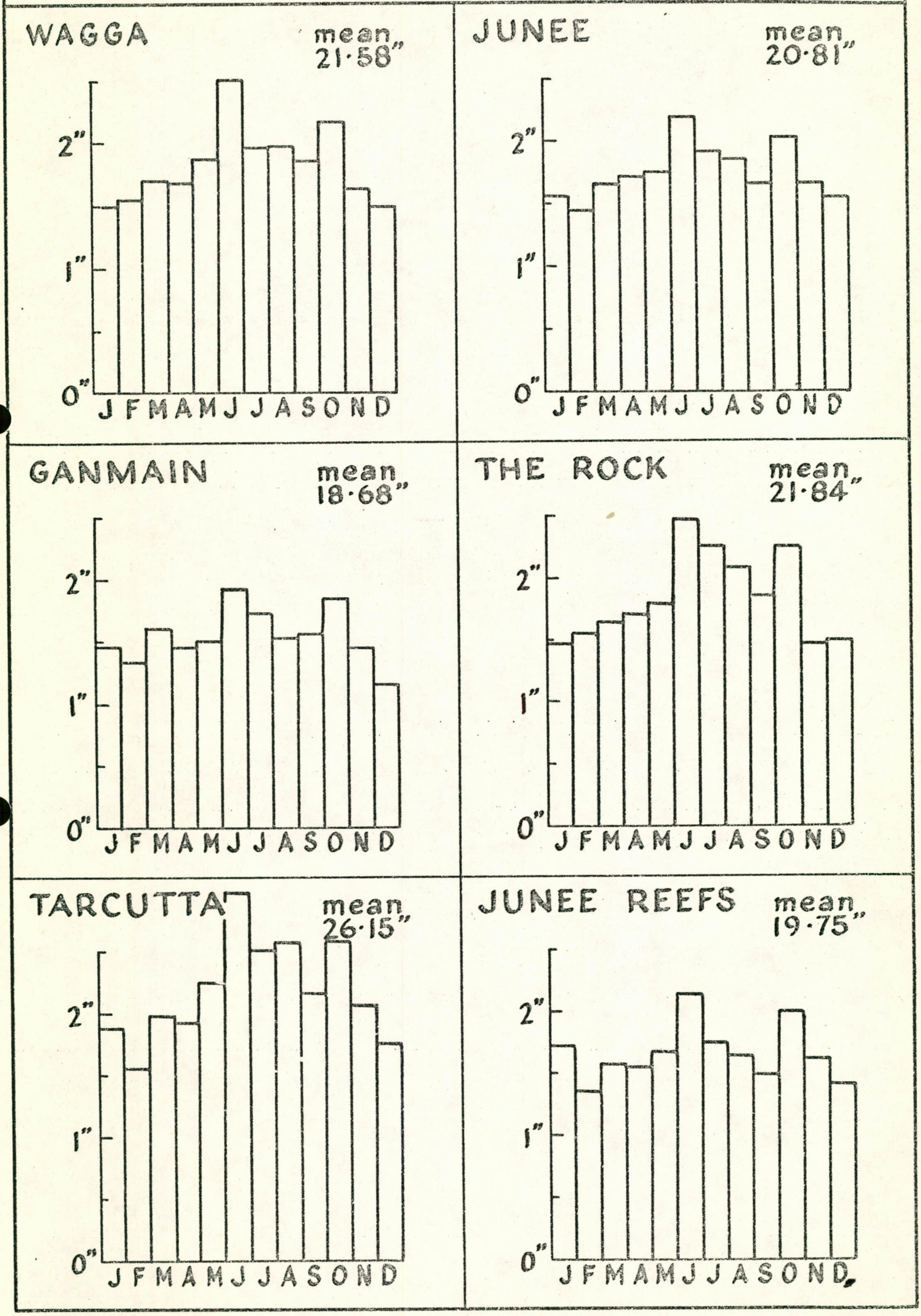


Table 4.1.1 (Contd)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Junee (1892-1968)													
1st Quartile	58	24	42	64	72	114	105	109	87	114	66	59	1702
Median	110	106	127	123	138	186	185	167	143	195	153	140	2017
3rd Qartile	213	221	225	256	265	299	244	264	225	255	230	232	2382
Median Deviation	75	84	88	87	83	80	76	74	84	64	83	81	336
Percentage Deviation	68	79	69	71	60	43	41	44	59	33	54	58	17
Tarcutta P.O. (1872-1968)													
1st Quartile	56	36	61	67	97	159	136	163	129	157	79	78	2084
Median	130	127	127	154	188	252	226	251	212	243	194	149	2545
3rd Quartile	268	228	266	279	302	384	346	323	276	345	303	263	3053
Median Quartile	93	91	80	104	96	102	108	81	78	87	110	83	461
Percentage Deviation	72	72	63	68	51	40	48	32	37	36	57	56	18

Wg. 4.3

Table 4.1.2 Wagga Research Station

Total Rain - Rainfall Intensities - 1948-60 (inches/hr)

% Between the following.

Points of Rain

Month	0-25	25-50	50-75	75-100	100-150	150-200	> 200	Rain per Wet Day (pts)
Jan	40.54	13.54	8.38	4.44	6.87	5.41	20.61	25.6
Feb	36.53	12.09	5.96	4.47	4.51	5.41	31.03	27.8
Mar	50.78	9.16	10.55	5.66	5.19	6.15	12.45	32.1
Apl	52.30	16.50	5.17	3.98	3.98	5.60	12.47	20.3
May	73.49	9.73	6.10	2.09	2.22	2.69	3.67	17.3
June	84.39	7.85	4.25	0.57	1.78	1.01	0.16	17.0
July	80.99	8.05	4.56	1.56	0.50	2.30	2.03	17.0
Aug	75.01	8.95	4.57	1.57	3.98	1.57	4.33	11.8
Sept	71.91	13.14	4.77	1.50	2.07	3.07	3.54	20.8
Oct	61.04	12.89	3.81	2.79	2.68	5.39	11.65	21.3
Nov	47.47	11.52	5.95	3.41	5.47	6.95	19.21	20.4
Dec	61.77	6.54	3.29	5.87	4.83	5.26	12.42	19.2

Wg. 4.4

4.1.4 Rain Days and Rainy Periods

A rain period is a period of rain not separated by a period of two or more rainless days (Slatyer 1960). The results of this analysis and the average number of rain days per month for Wagga Research Station are shown in Table 4.1.3.

Tables 4.1.4 and 4.1.5 show the percentage probability of receiving monthly rainfall in excess of specified amounts; and the number of days per month on which falls of specified amounts can be expected at Wagga Research Station.

4.2 Temperature

4.2.1 Monthly Averages

Table 4.2.1 lists the average monthly maximum, minimum and terrestrial minimum temperatures for Wagga Research Station.

Figure 4.3 illustrates the mean temperature variation over the year and includes the soil temperature at 6 ft. (Table 4.2.2 for Wagga Research Station). The temperature lag between the atmosphere and soil is due to the insulating properties of soil.

4.2.2 Daily Temperatures

Daily temperatures for the Wagga district can vary markedly on either side of the average, particularly in the summer months. Temperatures exceeding 37.8°C are common during December, January and February and temperatures exceeding 37.8°C can be expected in most years.

The average length of the frost free period at the Wagga Research Station 1948 - 1970 was 198 ± 60 days, which compares with Foley's 226 ± 43 days for a ten year period. The earliest recorded frost was on 22nd March, 1965 and the latest 21st November, 1968. The lowest terrestrial minimum temperature recorded at the Wagga Research Station was -9.5°C on 10th July, 1965. An average of 36 frosts per year between 1948 and 1970 were experienced in which the terrestrial minimum was less than -1.7°C and an average of 15 frosts having a terrestrial minimum temperature greater than -1.7°C.

The average number of days of frost at Wagga Research Station is given in table 4.2.3.

Table 4.2.3 - The average number of days of frost per month. Recorded at Wagga Research Station.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
0	0	0	1.0	6.2	9.9	11.6	10.4	4.7	1.5	0.3	0

4.3 Evaporation

Evaporation figures are limited to those recorded at the Research Station. Table 4.3.1 lists the mean monthly evaporation figures and their standard deviations.

Table 4.1.3 Number Rainy Periods per Month of Length Equal to or Exceeding the Number of Days Specified.

Month	1	2	3	4	5	6	8	10	15	Average No. Rain Days/Month
Jan	3.2	1.5	0.8	0.4	-	-	-	-	-	5
Feb	3.1	1.5	1.0	0.7	0.5	0.2	0.2	-	-	6
Mar	2.9	1.5	1.0	0.7	0.4	0.2	0.1	-	-	6
Apr	3.4	2.2	1.1	0.8	0.5	0.2	0.1	0.1	-	7
May	3.7	2.6	1.8	1.2	1.1	0.9	0.4	-	-	11
June	3.5	2.6	1.8	1.2	0.8	0.8	0.4	0.2	-	11
July	3.6	2.7	2.2	1.3	1.0	0.9	0.6	0.5	0.1	13
Aug	3.8	2.7	2.1	1.7	1.3	0.9	0.4	0.2	0.1	13
Sept	3.6	2.6	1.3	0.9	0.7	0.5	0.1	0.1	-	10
Oct	4.4	3.2	2.1	1.3	0.8	0.5	0.3	0.2	0.1	11
Nov	3.9	2.5	1.5	0.8	0.6	0.4	0.1	-	-	8
Dec	3.2	2.1	1.3	0.5	0.2	-	-	-	-	7

Table 4.1.4 Percentage Probability of Receiving Monthly Rainfall in Excess of Specified Amounts Wagga Research Station.

Month	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00
Jan	65	49	35	26	20	16	9	0
Feb	72	53	40	30	22	19	11	1
Mar	73	55	44	27	22	16	10	8
Apr	81	61	47	32	25	15	7	0
May	86	65	51	39	27	18	8	4
June	97	84	69	57	42	30	12	6
July	98	76	59	42	27	13	6	1
Aug	91	82	59	40	24	15	4	4
Sept	90	78	59	38	16	10	6	0
Oct	92	80	64	47	37	25	9	1
Nov	78	66	54	31	20	12	2	0
Dec	75	53	42	30	13	9	4	1

Table 4.1.5 No. Days/Month on which Falls of Specified Amount can be Expected. - Wagga Research Station.

Amount of Rainfall (ins).

Month	0.01-0.10	0.110-0.25	0.26-0.50	0.51-1.00	1.01-2.00	2.01-4.00
Jan	1.5	0.7	0.6	0.5	0.4	0.1
Feb	1.6	0.9	0.8	0.8	0.3	0.2
March	1.3	1.0	1.3	0.8	0.4	0.2
Apr	2.5	2.0	1.0	0.6	0.4	
May	3.5	2.3	1.9	1.1		
June	4.5	2.6	1.9	0.8	0.1	
July	6.1	2.6	1.4	1.3	0.2	
Aug	6.0	2.6	1.5	0.5		
Sept	2.9	2.2	1.8	0.7	0.3	
Oct	3.3	2.4	2.0	1.7	0.4	
Nov	2.7	1.8	1.4	0.8	0.2	
Dec	1.7	1.0	1.3	0.3	0.2	

Table 4.2.1 Average Monthly Maximum, Minimum and Terrestrial Minimum Temperatures of Wagga Research Station

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Maximum Temperature	31.1	30.3	27.3	22.3	16.5	13.9	12.3	14.4	17.5	21.1	24.9	28.7
Range	28.3 34.1	26.8 33.3	25.1 30.2	19.1 24.5	14.4 18.6	11.5 18.7	11.1 19.4	12.7 16.1	14.4 19.7	17.7 25.1	20.8 29.6	25.8 31.8
Minimum Temperature	16.2	16.4	14.1	10.1	6.2	4.3	3.1	4.1	5.7	8.5	10.8	12.5
Range	12.9 18.7	14.7 19.3	11.4 16.8	7.9 12.4	2.5 9.3	2.1 6.6	1.4 5.4	2.7 5.3	4.1 7.9	5.8 10.8	8.3 13.3	10.6 16.1
Terrestrial Minimum Temperature	11.9	11.7	9.7	5.7	2.9	1.1	0.2	0.9	2.3	5.3	7.2	9.8
Range	8.8 14.3	9.1 15.6	4.6 13.1	1.9 9.1	-0.2 6.7	-3.4 3.7	-2.7 2.1	-1.3 3.7	-0.3 3.8	3.1 7.7	4.7 10.7	5.9 13.8

Period of Observation at Wagga Research Station from 1948-1970.

(Temperatures in °C)

Table 4.2.2 Averages for Various Climatic Datum at Wagga Research Station to 1969.

Climatic Datum	Period of Records	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Rainfall (in)	98 years	1.46	1.49	1.71	1.65	1.87	2.43	1.91	1.96	1.77	2.12	1.60	1.42	21.39
Evaporation (in)	22 years	8.96	7.05	6.20	3.77	2.04	1.29	1.19	1.76	2.69	4.15	6.07	8.16	53.32
Max. Temp (°C)	22 years	31.2	30.2	27.4	22.4	16.6	13.9	12.3	14.4	17.7	21.2	24.9	28.7	21.7
Min. Temp (°C)	22 years	16.3	16.3	14.1	10.1	6.3	4.3	3.1	4.1	5.7	8.5	10.7	12.4	9.3
Terr. Min Temp	21 years	12.0	11.7	9.8	5.7	2.9	1.2	0.3	0.1	2.3	5.3	7.2	9.8	5.7
Dry Bulb Temp(°C)	21 years	24.4	23.3	20.7	15.5	10.3	7.6	6.4	8.4	11.5	15.7	19.2	22.6	16.2
Wet Bulb Temp(°C)	21 years	17.0	17.1	15.8	12.3	8.7	6.6	5.4	7.1	9.4	12.3	15.3	15.6	11.7
Dew Point	21 years	11.4	12.6	12.0	9.4	6.9	5.4	4.2	5.4	7.1	9.1	12.3	9.8	7.2
Anemometer (miles M.M.)	22 years	3305	2784	2701	2222	2241	1975	2109	2380	2415	2851	3096	3374	31425
Anemometer (miles D.M.)	22 years	108	99	88	76	73	64	69	76	82	92	104	110	87
Soil Temp @ 4" (°C)	5 years	22.7	22.9	20.8	16.4	12.7	9.7	8.5	9.7	11.8	15.8	18.3	20.8	15.8
Soil Temp @ 8" (°C)	5 years	23.7	24.1	22.2	18.2	14.3	11.1	9.7	10.6	12.7	16.5	19.2	21.5	17.0
Soil Temp @ 20" (°C)	5 years	23.7	24.2	22.5	19.0	15.1	11.9	10.3	11.1	13.1	16.5	19.3	21.6	17.4
Soil Temp @ 40" (°C)	5 years	22.1	23.1	22.4	20.1	17.1	13.9	12.1	11.9	13.2	15.7	18.0	20.2	17.4

Table 4.2.2 (Contd)

Climatic Datum	Period of Records	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Soil Temp @ 72" (°C)	12 years	20.0	21.2	21.4	20.6	18.3	16.3	14.5	13.6	13.9	15.1	16.7	18.3	17.5
No. of wet days	22 years	5.3	5.6	6.3	7.4	11.4	11.1	13.4	13.3	9.8	10.9	8.0	6.4	108.8
Days of Frost	21 years	0	0	0	1.0	6.2	9.9	11.6	10.4	4.7	1.5	0.3	0.0	47.5

M.M. = Monthly Mean
D.M. = Daily Mean.

W8. 4.11

FIG.4:3 MEAN TEMPERATURE VARIATIONS
WAGGA RESEARCH STATION

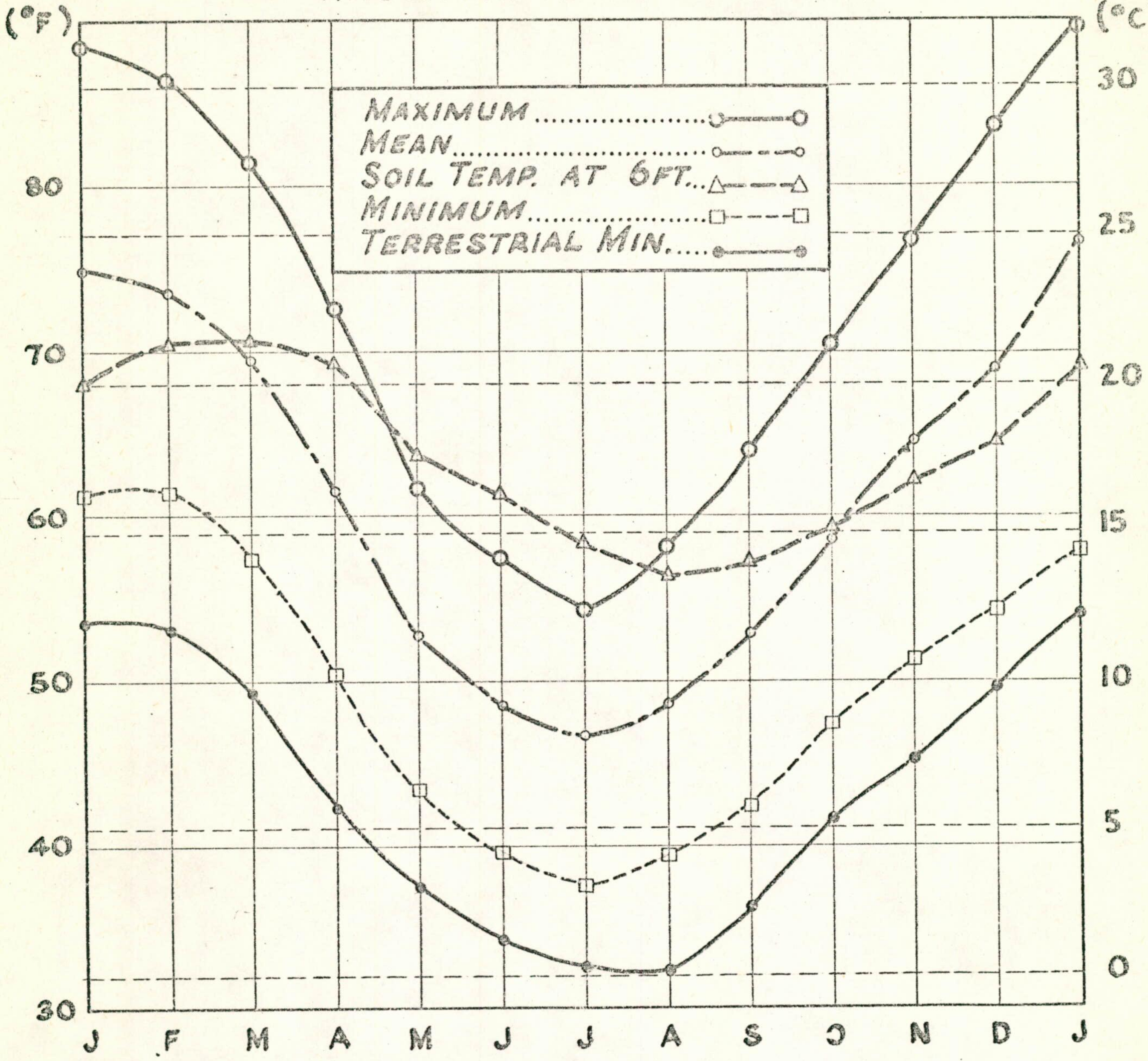
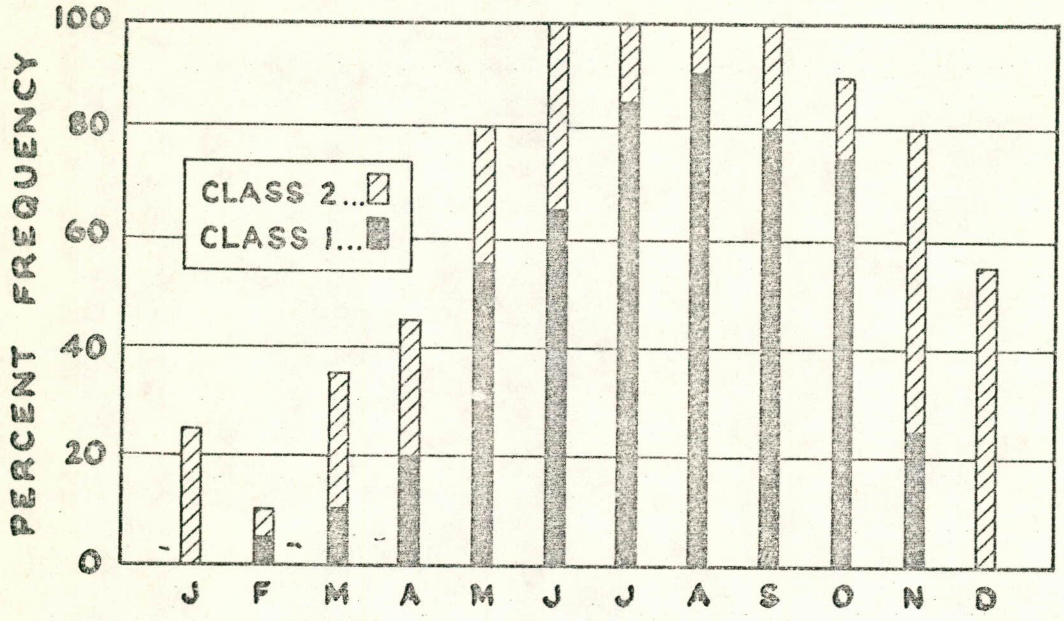


Table 4.3.1 Mean Monthly Evaporation

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	885	706	611	374	202	127	120	175	266	414	601	816
S.D.	121	106	106	45	35	13	21	23	38	69	91	102
Mean	5298	S.D.	421									

Fig. 4.12

FIG.4:4 CLASSIFICATION OF SEASONAL CONDITIONS
WAGGA RESEARCH STATION



5. SOILS

5.1 Notes on the Soils Map

The soils map (Fig. 5.1) is modified from the "Atlas of Australian Soils, Sheet 3", prepared by the C.S.I.R.O. Because of the complexity of soils it is difficult to map actual soil types therefore landscapes (land forms) are used as the mapping unit. The mapping units are, more precisely, associations of various soils rather than just one single soil group. In the following description of the major great soil groups other soils that occur in association with each group are listed.

Soils are identified according to "A Factural Key for the Recognition of Australian Soils" (Northcote, 1971). This Key codes soils according to profile features. Each Principle Profile Form is coded by a series of letters and numbers e.g. Dy 3.43. These codings have been correlated with great soil groups by various workers. The correlation of Charman (1971) has been used.

The great soil groups that have been used as mapping units are listed below with the Northcote codings of soils that occur within them.

Great Soil Group	Northcote Codings		Associated Soils
	Commonest	Others	
Red Podzolic	Dr 2.21	Dr 3.21	Dr 2.22, Dr 2.32 Dr 3.42
Yellow Solonetzic	Dy 3.42	Dy 3.43	Dr 2.21 Gn 2.12
Red Earths	Gn 2.12	Gn 2.13 Gn 2.15	Gn 2.25 Dr 2.21 Dr 2.33
Red Brown Earths	Dr 2.33	Dr 2.23	Dr 2.43 Gn 2.12 Ug 5.2 Ug 5.3
Chernozems	Um 6.11		
Siliceous Sands	Uc 1.22	Uc 1.23	

The first four great soil groups occur in major proportions in the district but the latter two are only of minor importance.

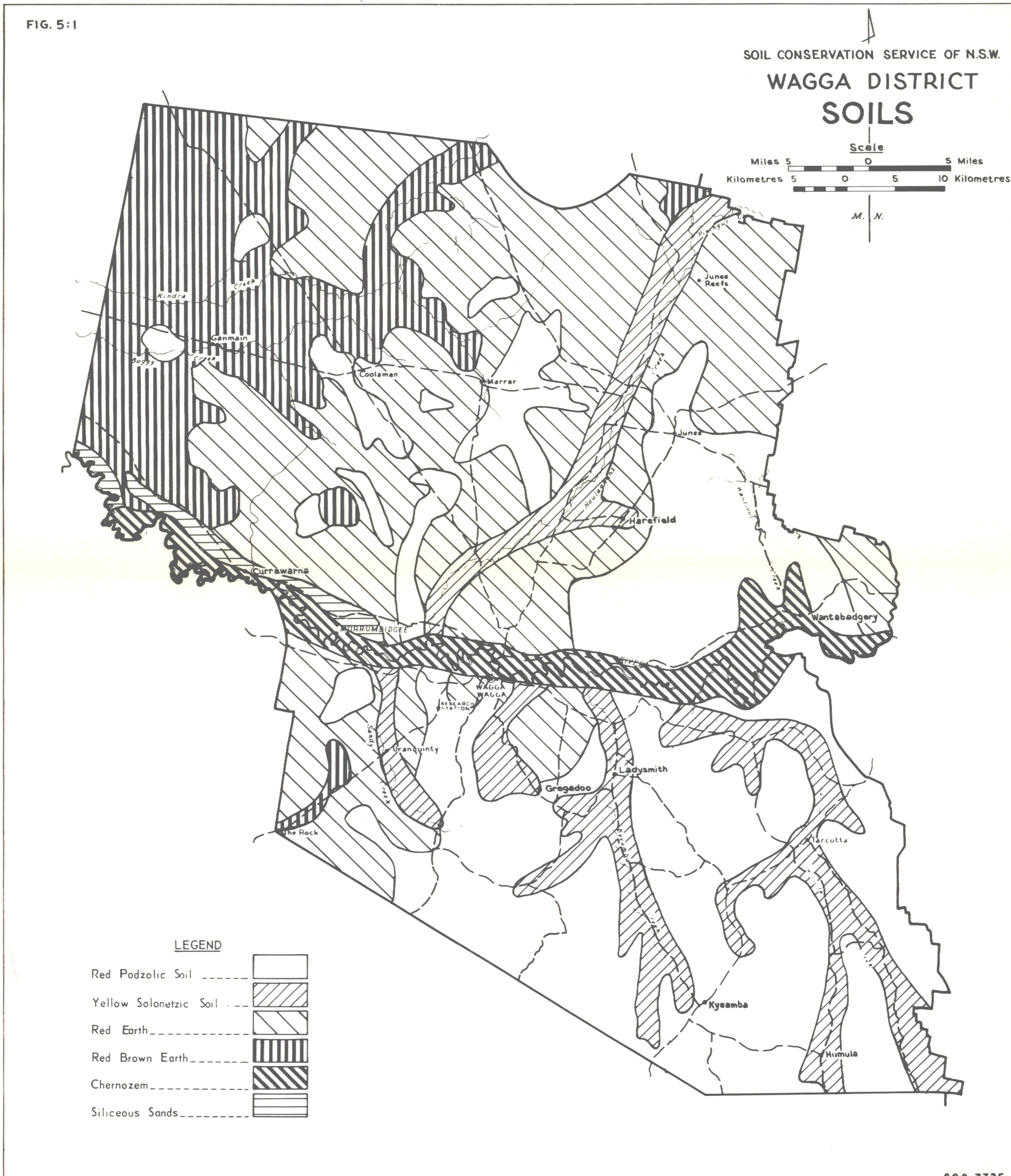
5.2 Great Soil Groups

5.2.1 Red Podzolic Soils

Red podzolics are found in large tracts throughout the district. The main areas are found east of Junee, between Junee and the Murrumbidgee, and south of the Murrumbidgee east of Wagga. They are found mainly on undulating to steep hilly country. These soils tend to form under a higher rainfall so are found predominately in the east of the district.

The red podzolics (Dr 2.21 and Dr 3.21) are the dominant soils. In close association are red solodics, yellow solonetzics, yellow podzolics and red earths.

FIG. 5:1


SOIL CONSERVATION SERVICE OF N.S.W.
WAGGA DISTRICT
SOILS
Scale
Miles 5 0 5 Miles
Kilometres 5 0 5 10 Kilometres
M. N.
Junee Reefs
Kindra Creek
Ganmain
Boggy Creek
Coolamon
Marrar
Junee
Harefield
Currawarna
MURRUMBIDGEE
Wantabadgery
WAGGA WAGGA
RESEARCH STATION
Uranquinty
Sandy Creek
Gregadoo
Ladysmith
The Rock
Tarcutta
Kyeamba
Humula
LEGEND
Red Podzolic Soil
Yellow Solonetzic Soil
Red Earth
Red Brown Earth
Chernozem
Siliceous Sands
S.C.S. 7725

For example red podzolics and yellow solonetzics occur in close association in the south east of the district around Tarcutta and Kyeamba. Yellow solonetzics occur on the creek terraces in Quaternary alluvium and the red podzolics occur on the slopes and hills which are Ordovician slates with a few scattered areas of granite (see Fig. 2.1).

These red podzolics are well developed on the middle slopes but on the upper slopes and crests of hills they are less developed. The podzolics on the upper slopes are often shallow and associated with lithosols (Um 4.1).

Morphology

The essential features of these soils are a pronounced texture contrast, medium to coarse-textured A horizons overlaying a predominately red B horizon of much higher clay content; a distinct pale A_2 horizon; and acid reaction throughout the solum. The boundary between the A and B horizon is characteristically clear to gradual rather than abrupt and it is a duplex soil.

A typical profile has the following features.

Ao-Shallow organic horizon.

A_1-Dark reddish brown (Munsell 5 YR 3/4) loam which has little structure. pH 5.5 to 6.5 Seasonally hard setting crust on surface.

A_2-Weak boundary differentiation between A_1 and A_2. Colour light reddish brown (Munsell 5 YR 6/4). Loamy texture with little structure, pH 5.5 to 6.5

B-Red (Munsell 10R 4/6) light clay with strong ped structure. Peds have distinct cutans, pH 5.5 to 6.5.

Identification

1. Loamy A horizon, clayey B Horizon with a clear to gradual boundary between A and B horizon. These soils are duplex.
2. An A_2 horizon is present but not bleached.
3. Red clayey B horizon usually with strong ped structure.

Northcote classification of these soils is Dr 2.21 or Dr 3.21.

Chemical and Physical Properties

Red podzolics are inherently infertile commonly with deficiencies of phosphorous, nitrogen and molybdenum. These soils are highly erodible and suffer from sheet erosion and moderate to severe gully erosion.

5.2.2 Yellow Solonetzic Soils

In the district these soils are found along flood plains and creek terraces. Common examples occur along several creek systems such as Sandy Creek, Kyeamba Creek, Tarcutta Creek and Houlaghans Creek.

Other soils that occur in close association with yellow solonetzic soils are red podzolics and red earths, with small areas of yellow podzolics and yellow earths and small areas of chernozems along creek banks.

Morphology

The important features of these soils are strong texture differentiation with a very abrupt boundary between A and B horizons. The A horizon is usually loamy and often has a well developed bleached A_2 horizon. The B horizon is clayey with strong coarse columnar blocky structure.

A typical profile has the following features.

Ao-Shallow organic horizon.

A_1-Dark reddish brown (Munsell 2.5 YR 3/4) loam which has little structure, pH slightly acid pH 5.5 to 6.5.

A_2-Weak boundary differentiation between A_1 and A_2. Colour dark red (Munsel 2.5 YR 3/6) and when dry the A_2 is often strongly bleached. Loamy texture with little structure. The pH is slightly less acid than A_1 being pH 6 to 7. Ferromanganiferous nodules are often found in the lower A_2 or upper B horizon.

B Yellowish brown (Munsell 10YR 5/4) and when dry mottled with red, brown and grey. Texture is generally medium clay and structure is moderate to strong, blocky. A special feature of these soils is the columnar structure of the B horizon characterized by a distinct vertical cracking pattern. Peds are strongly developed with distinct cutans, (shiny clay surfaces). The pH increases from neutral at the top of the B to strongly alkaline in the lower B horizon.

Identification

Features to look for in the field to identify these soils are:

1. Loamy A horizon, clayey B horizon with a sharp boundary between A and B horizon. These soils are duplex.
2. Yellow B horizon with red, brown and grey mottling.
3. Columnar structure of B horizon. Vertical cracks are strongly developed in a dry soil.
4. Strong ped structure in B horizon. The peds have shiny clay skins which are often grey in colour.

Northcote classification of these soils is Dy 3.43 or Dy 3.42.

Chemical and Physical Properties.

These soils are inherently infertile with severe deficiencies of nitrogen and phosphorous and may have deficiencies of calcium and a range of trace elements. Use of fertilizers and legumes are necessary to obtain satisfactory pasture and crop growth.

Moisture relationships can be a problem. The surface soil sets hard and the infiltration rate is low. The B horizon when wet expands filling the cracks and becomes very impermeable. These soils are highly erodable suffering from severe gully erosion.

5.2.3 Red Earths

The major areas of red earths occur in the northern portion of the district but there are also fairly large areas in the south west. These soils are found mainly on undulating, and undulating to rolling country. They are found north of the Murrumbidgee and west of Wagga and Junee extending west to about Ganmain. There is also a small area between The Rock and Murrumbidgee River. They are found mainly over granite.

Other soils that occur in close association with red earths are, yellow earths, red podzolics, red brown earths, and small areas of yellow solonetzics.

Morphology

Boundaries between horizons are indistinct with a gradual increase in clay from top soil to deeper portions of subsoil. The soil has an earthy fabric with no, or very little ped structure. These soils are red-brown to red in colour. The A horizon is usually loamy sand to sandy clay loam. The B horizon has slightly higher clay content and may be as clayey as a medium clay.

A typical profile has the following features.

Ao-Shallow organic horizon.

A_1-Dusky red (Munsell 10R 3/3) loam which has little structure. The pH is 6 to 6.5.

B-Clear to gradual boundary between A and B horizons. Colour red (Munsell 10R 4/6) clay loam, massive earthy soil which is highly porous, pH of subsoil between red earths varies greatly.

Identification

1. Loamy A horizon with a gradual increase in clay content with depth. Boundary between A and B gradual to clear. Textural differences between horizons only slight so profile is a gradational soil.
2. Very distinctive red B horizon.
3. B horizon earthy with few if any peds.
4. B horizon is very porous.

Northcote classification of these soils is Gn 2.12, Gn 2.13, Gn 2.15.

Chemical and Physical Properties

Generally their nutrient status is low and heavy fertilization with phosphorous and nitrogen and smaller applications of various trace elements are necessary for maximum yields.

Red earths have a high water permeability and also since they have a relatively low clay content they have a low water holding capacity.

5.2.4 Red Brown Earths

These soils are common in semi arid to sub humid areas. They are found mainly in the western parts of the district north of the Murrumbidgee River, west of Marrar. A small area also occurs north east of The Rock. They mainly occur on Cainozoic alluvium.

Other soils that occur in close association with red brown earths are red earths and grey and brown clays.

A typical profile has the following features.

Ao-Shallow organic layer.

A_1-Dark reddish brown (Munsell 2.5 YR 3/4) loam. Weak crumb to blocky structure with a reasonably hard setting crust on the surface. The pH varies greatly.

A_2-May have a weakly differentiated A_2 to a differentiated bleached A_2 loamy, strong brown (Munsell 7.5 YR 5/8). The pH varies but is alkaline to neutral.

B-Clear to abrupt boundary between A_2 and B horizons. Medium clay, red (Munsell 2.5 YR 4/8) strong ped structure with clay skins. Strong prismatic to blocky structure. The pH is strongly alkaline, pH 8 to 9.

Identification

1. Loamy A horizon with a clear to abrupt boundary to clayey B horizon, this soil is a duplex soil.
2. Brown to red B horizon.
3. B horizon has strong ped structure with shiny surfaces (cutans).
4. Alkaline B horizon (ph to 9) and may have carbonate nodules.

Northcote classification of these soils is Dr 2.33 or Dr 2.23.

Chemical and Physical Properties

For maximum production in these soils fertilizers are required, especially phosphorous. Because of their suitable physical status they are very good soils for wheat production. The clayey sub-soil has a high water holding capacity but is still easily penetrated by plant roots.

5.2.5 Chernozems

These soils are found along the flood plains and river terraces of the Murrumbidgee. Northcote classification is Um 6.11. They have a thick dark A horizon, dark grey brown, brown or black in colour and varying from loam to light clay in texture. Structure is moderate crumb, granular or fine blocky polyhedral. The B horizon is dark yellow-grey brown or yellow brown or reddish brown, with a slightly higher clay content and moderate medium blocky structure. The A horizon is moderately acid, and deeper in the B horizon the soil is mildly alkaline.

5.2.6 Siliceous Sands

These soils occur on sand hills and sand sheets. They are found close to the Murrumbidgee in the western portion of the district. Northcote classification is Uc 1.22 and Uc 1.23. They have a uniform sand to clayey sand texture, deep profiles and the general absence of horizon differentiation except for a darker A_1. Soil colour varies but brown colours predominate.

5.3 Soil Properties and Design Criteria

5.3.1 Introduction

The following three tables are presented in order to facilitate the adjustment of design for soil conservation works to the nature of the soil involved. The tables deal with the soil factor in the coefficient of run-off, critical velocities of flow in bank channels and adjustments to "K" values for bank spacing. Details of the design methods using these parameters are set out in Section 11 of this manual. The tables hereunder are intended as a guide to design on the particular soils found in the district.

5.3.2 Coefficient of Run-off and Soil Type

Table 5.3.1 enables the estimation of the "soil factors" in the co-efficient of run-off to be carried out. Soils are expressed as Northcote codings.

Table 5.3.1 Increasing hazard.

Low 0-5	Medium 5-10	High 10-15	Very High 15-20	Extreme 20-25
		Dr 2.3 Dr 2.4	Dr 3.4	Shallow lithosols or rock outcrop
Gn 2		Dr 3.2		Hard-setting soils in dry season.
	Dr 2.2	Dy 2.3	Dy 3.4	
Ucl		Dy 2.4		
Gn 4	Dr 2.6	Dy 3.2 Um		

Infiltration is of paramount importance in table 5.3.1 and allowance should be made if a particular soil is more or less permeable than the table indicates.

Surface sealing or "hard-setting" nature of the surface soil, textural and structural condition of both surface soil and profile are all factors which should be borne in mind. State of erosion and state of cultivation are also important.

If in doubt about the correct grouping, it is wise to err on the safe side and apply a higher weighting.

5.3.3 Critical Velocities

Table 5.3.2 indicates the critical velocities of flow to be used in bank design, based on soil type.

Table 5.3.2 Increasing Hazard

Low 2ft/sec	Medium 1.8ft/sec	High 1.5ft/sec	V. High 1.2ft/sec	Extreme 1.0ft/sec
uml (dense silty soils)	Gn 2	Dr 2.3 Dr 2.4 Dr 3.2 Dy 2.3 Dy 2.4 Dy 3.2 Dr 2.2	Dr 3.4 Dy 3.4	Dy soils known to be highly dispersible

The assumption has been made, in preparing table 5.3.2 that the normal excavation for banks in the Wagga district will extend at least to the top of the clayey B horizon. If this is not so (e.g. if a soil has a particularly deep A_2 horizon) then suitable adjustment must be made, allowing for the texture and structure of the material reached during excavation of the channel.

The soils have been placed according to the expected detachability of the B_1 horizon, and in some cases this would be increased by the dispersibility of the clay material.

Land use can also be an important factor in relation to subsequent farming operations. If the channel itself is to be cultivated, then scouring is much more likely to occur, and a lower velocity must be chosen. When the land is to be used for improved pasture, then a higher velocity will be more suitable. Bank channels that are properly vegetated and maintained will carry flows well in excess of two feet per second.

5.3.4 Adjustment of Stewart's 'K' for Soil Type

Table 5.3.3 provides a guide to the adjustments which can be made when calculating bank spacings. Soils are grouped according to their expected credibilities. Soils are listed in great soil groups, with typical Northcote codings in brackets.

Table 5.3.3 Adjustment of Stewart's "K" for Soil Type

Class I	No adjustment to "K". Uniform friable loams and sands (Um, Uc). Hard-setting solonetzic soils (Dr 2.32 Dy 3.43).
Class II	Add 0.1 "K". Red-brown earths (Dr 2.23). Hard-setting podsolic soils (Dy 2.2 Dr 3.21).
Class III	Add 0.2 "K". Red Earths (Gn 2).
Class IV	Add 0.3 "K". Black earths (ug 5.16).
Class V	Add 0.4 "K". Porous coarse sandy or gravelly soils.

5.4 Suitability of Soils for Use in Structures.

Red Podzolic

These soils are good constructional material because they have a fair clay content in the subsoil. Some of these soils are dispersible and caution should be taken where this is suspected.

Solodized Solonetz and Solonetzic Soils

These soils are often dispersible and structures often fail due to tunnelling. Care should be taken in compaction and the use of chemicals is advisable if soil tests show that the soils are dispersible.

Red Earths

These soils often do not have a high enough clay content and since they are porous soils, structures can leak. Dispersible red earths have not been found in the Riverina.

Red Brown Earths

These soils are good constructional material with a well graded clay subsoil. These soils are seldom dispersible.

6. VEGETATION

6.1 Introduction

Figure 6.1 shows the distribution of the major plant communities within the Wagga district. This map has been compiled from the survey by Moore (1953) who defined the communities in terms of associations and alliances. The general term community has been adopted for the purpose of this study and is analagous to Moore's term alliance.

Small areas of dry sclerophyll forest have been reserved for the establishment of State Forests in the Kyeamba, Pulletop, Humula regions.

Similarly in the Ganmain, Coolamon regions, areas have been reserved for *Pinus radiata* plantations and for Cypress Pine regeneration.

6.2 Vegetation Communities

Six major Communities have been recognised.

6.2.1 River Red Gum Community (*Eucalyptus camaldulensis*)

This community has the structural form of a savannah woodland. In the Wagga district its occurrence is generally restricted to the flood plain of the Murrumbidgee River and hence most commonly occurs on chernozem soils.

Other tree species found in the community are.

Eucalyptus woollsiana - grey box

E. albens - white box

E. melliodora - yellow box

Where soils are well drained in areas free from periodic flooding the following pasture species are found: *Danthonia* and *Stipa* spp are the usual perennials; whilst the most common annuals are *Bromus* spp., *Vulpia* spp., *Hordeum leporinum* (Barley grass), *Medicago polymorpha*, together with various naturalised *Trifolium* spp.

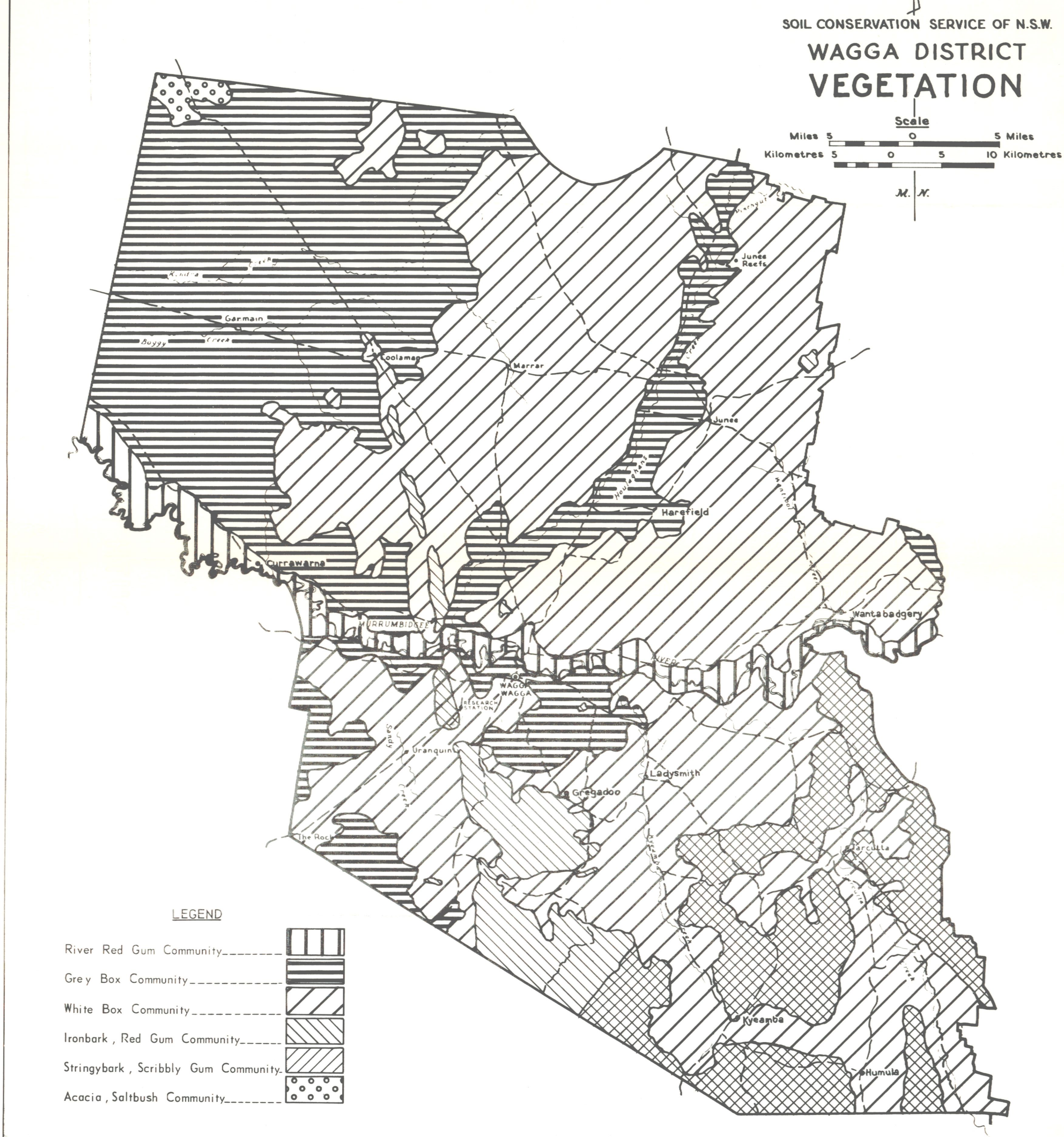
Generally pastures are of poor quality but in areas not subject to periodic flooding pasture improvement is possible using species recommended for the area. (See section 13).

Except for some gully erosion adjacent to the major streams this community is not a problem from a soil conservation viewpoint.

6.2.2 Grey Box Community (*Eucalyptus woollsiana*)

This community has the structural form of a tall woodland. It occurs predominately in the N.W. of the district westward of the 20" isohyet on red brown earths of heavy texture. It is also found along Houlaghans Creek in the centre of the district and south of the Murrumbidgee River between Wagga and Forest Hill on solonetzic soils.

FIG. 6:1


SOIL CONSERVATION SERVICE OF N.S.W.
WAGGA DISTRICT
VEGETATION
Scale
Miles 5 0 5 Miles
Kilometres 5 0 5 10 Kilometres
M. N.
Junee Reefs
Garmain
Coolamon
Marrar
Junee
Harefield
Currawarna
MURRUMBIDGEE
RIVER
Wantabadgery
WAGGA WAGGA
RESEARCH STATION
Uranquinty
Sandy Creek
Ladysmith
Gregadoo
The Rock
Tarcutta
Kyeamba
Humula
LEGEND
River Red Gum Community
Grey Box Community
White Box Community
Ironbark, Red Gum Community
Stringybark, Scribbly Gum Community
Acacia, Saltbush Community
S.C.S. 7726

There is little correlation between the distribution of this community and topography, the main factors affecting distribution being rainfall and soil type.

Other tree species found are white box, yellow box, and Callitris columellaris (white Cypress Pine), although the association with the latter species is usually west of the 20" isohyet.

On heavier soil the principal grass species are the perennials Danthonia spp and Stipa spp. Whilst in lighter soils annual grasses and legumes are similar to those found in the River Red Gum community.

Much of the area has been cleared for cereal production.

6.2.3 White Box Community (Eucalyptus albens)

This community occupies the major portion of the district between the 20"-24" isohyets. Its structural form is typically a tall woodland varying to a savannah woodland in the least favourable sites. It is commonly found on red podsolic soils but there appears to be little relationship between soil type and its general distribution.

Other tree species found include yellow box, grey box, Eucalyptus macrorhyncha (Red stringybark) and Eucalyptus blakelyi (Red Gum).

Evidence suggests that the dominant grasses were once Themeda australis (Kangaroo grass) along with Poa australis (Tussock grass) and Stipa aristiglumis (Plains grass). However under grazing the main species are Stipa falcata (Spear Grass) and Danthonia spp with Bothriochloa decipiens (pitted blue grass) becoming very common particularly on overgrazed country.

As with the Grey Box community much of the area has been cleared.

6.2.4 Red Gum - Red Iron bark Community (Eucalyptus dealbata - Eucalyptus sideroxylon)

This community has the general form of a dry sclerophyll forest, although it is very variable, the height of the dominant trees ranging from 20' to 60' or more depending on the situation. It is generally found below the 26" isohyet in the south of the district and running N.N.E. across the Murrumbidgee River along the Malebo range almost to Coolamon.

In the S.E. of the district above the 26" isohyet it occurs in conjunction with Red stringybark and Eucalyptus rossii (scribbly gum).

Its occurrence is restricted to ridge country consisting of upper ordovician quartzite, slates and phyllites which give rise to poor skeletal soils.

Eucalyptus dealbata is most commonly found on the poorest and least developed soils at or near the tops of the ridges often in association with Casurina stricta (Hill Oak) and white cypress pine.

The dominant grass species are Danthonia spp and Stipa spp.

6.2.5 Red Stringybark - Scribbly Gum Community (*Eucalyptus macrorryncha* - *Eucalyptus rossii*)

This community has the structural form of a dry sclerophyll forest occurring above the 24" isohyet on the higher ridge country in the S.E. corner of the district. It is frequently associated with Red Gum (*E. dealbata*) and red ironbark.

Slopes range from 10% to 30% or more, and except for rink barking and clearing, are little improved.

Following clearing the dominant grass species are *Danthonia* spp, *Stipa* spp and *Aristida* spp especially on the deep soils in higher rainfall areas. Following heavy grazing *Aristida ramosa* (wire grass) becomes dominant.

6.2.6 Shrub Woodland Community (*Acacia pendula*) (*Atriplex nummularia*)

This shrub woodland community is represented as a very small area in the N.W. corner of the district.

It seems likely that *Acacia pendula* (Myall) was once the dominant species with *Atriplex nummularia* (Salt bush) occurring as a shrub stratum.

7. LAND USE

7.1 Introduction

Land use in the district broadly conforms to land systems as defined by Christian and Stewart. However, topography exerts the greatest influence on land use.

Much of the area has been cleared and even the few remaining extensive timbered areas are utilized to some extent for grazing.

The three principal types of land use are.

(a) Arable - with wheat as the principal crop.

(b) Grazing.

(c) Dairying - with lucerne and intensive cropping.

In addition small areas in the district have been reserved for State forests.

7.2 Description of Land Use Divisions

7.2.1 Arable 'A' Eastern Zone (wheat, plus other cereals and grazing)

This division comprises the major portion of the district. It consists of undulating country with slopes ranging from 3-10 percent.

Rainfall varies from 19-22 inches increasing from N.W. to S.E. with reliability in the growing season increasing in the same direction.

Property size varies from 600 to 1500 acres with an average size of 700-800 acres, and there are few large holdings left in the area.

Wheat is the principal crop, but barley is grown and a large number of sheep and cattle are grazed in conjunction with crop production.

The main form of sheep enterprise is crossbred sheep for fat lamb production to meet the early market. The Coolamon-Rannock area caters particularly for this market.

The cattle industry is a well established one based on good quality stock. Numbers have increased significantly in recent years. (15% per annum in the 1969-1971 period).

There has been some increase in the growing of other cereals such as barley and cereal rye. Rape, lupins, field peas and sunflowers are also being introduced with the principal areas of production being around Wagga, The Rock and Harefield.

The production of subterranean clover seed has been an important sideline to some farmers at various times but there has been little activity in the industry during recent seasons.

7.2.2 Arable 'B' Western Zone (wheat, plus other cereals and grazing).

This division generally comprises the gently sloping lower rainfall lands to the west of the district.

Lower rainfall, with less probability of receiving effective rainfall in the growing season, results in slightly lower average yields than in the above division. This trend is accentuated westward. The growing season is generally one week shorter than at Wagga.

Slopes vary from 0-3% and generally there is no appreciable erosion. Soils are predominately red-brown earths in contrast to the red earths and red podzolics of the above division.

Property sizes are similar, the average being 700-800 acres.

Sheep are the most important grazing animal. In the eastern section fat lambs for the early lamb market are produced but towards the west merinos are carried.

The area is generally marginal for cattle. However, there has been a large increase in numbers in recent years, the increase being 30% in 1970-71. This may lead to difficulties in the future.

A feature of the area is that it is a traditional wheaten and oaten hay, and chaff growing area with a widely developed market. Hay is usually cut in early October. This offers and alternative to wheat growing for grain production.

7.2.3 Grazing 1st Class

This division comprises land generally too steep and too dissected for broad acre wheat production.

Rainfall is generally in excess of 22 inches per annum and is reliable with a growing season generally extending from mid-April to the end of November. Whilst this is ideal for pasture production with fodder crops it may be too high for quality grain production in most seasons.

Much of the division has been sown to improved pastures. Fodder crops in the form of oats and barley are grown together with dryland lucerne on the limited areas of river terrace. Lucerne is also included in the pasture mixtures to some extent.

This division carries both sheep and cattle but whilst sheep numbers have remained static in the recent years (1970-1971) cattle numbers have increased at the rate of 15-20% per annum. The area favours a stable cattle industry producing quality stock. Sheep are predominately cross-breds for fat lamb production.

7.2.4 Grazing 2nd Class

This represents the poorest class of land in the district. Relief varies from 1200-2000 ft., rising to 2000 ft., in the S.E. corner of the district. Topography is steep with the main ridges themselves frequently in excess of 30% slope.

Poor immature skeletal soils have been developed on metamorphosed sediments, whilst other areas consist of infertile degraded soils formed on steep granite ridges.

Climatically the area is favourable with rainfall increasing from 24" to 40" per annum towards the S.E. corner; and the growing season normally extends into early December.

The area is mainly utilized for grazing with merino sheep but cattle numbers are increasing also.

There is limited scope for cultivation and improvement has generally consisted of clearing, aerial sowing and fertilizing, and the control of noxious weeds and vermin.

Portions of the area have been reserved for forestry purposes. With the favourable moisture regime this form of land use could be extended.

7.2.5 Dairying with Lucerne and Intensive Cropping

Most of the dairying in the district occurs in this division with fresh milk producers being mainly located on the Murrumbidgee River near Wagga or downstream from there, and along the Kyeamba Creek in the Ladysmith area.

Although there are limits on the number of licences for fresh milk production, production has increased 15-20% in recent years (1970-71 incl.) in response to increasing demand. Cream production has declined sharply and this has particularly affected the industry in the Tarcutta Creek area where there has been a swing to beef production.

Property size varies from approximately 50-500 acres and carrying capacity is generally one cow to 4-5 acres.

Irrigation is both from the river and from bores.

In addition to lucerne growing under irrigation, sunflower and grain sorghum growing has also recently been introduced. Seed production mainly under dryland conditions is also practised. There is particular interest in the production of *Phalaris tuberosa* cv. sirocco at the present time.

Some dry land wheat crops are also sown along the river west of Wagga but the likelihood of floods discourages this form of production.

7.2.6 Forest Areas

Small areas of land have been reserved as State Forests. Approximately 20,000 acres have been reserved in the South East portion of the district for hardwood and *Pinus radiata* production, whilst approximately 2-3000 acres have been reserved in the drier North West portion for Cypress Pine regeneration.

The more moist South East corner would appear to have a good potential for extending this form of production.

8. EROSION

Three classes of erosion are recognised within the Wagga district and have been indicated on the accompanying map.

8.1 Erosion Classes

8.1.1 No Appreciable Erosion

This erosion class occurs in two main areas.

(a) In the far western portion of the district, west of Coolamon. The land is flat or only gently sloping with the average annual rainfall generally less than 20".

(b) In the central and eastern portions of the district e.g. the flood plain of the Murrimbidgee River, the Houlaghans Creek system, the small creek systems around Big Springs, between The Rock and Uranquinty and the area around Lake Albert. Some minor gullying does occur along drainage lines of large catchments extending into the surrounding hills.

8.1.2 Slight Sheet Erosion with Shallow Gullies

This class occurs on undulating to hilly lands in the central portion of the district north of Wagga. The soils are predominately red earths and erosion is a direct consequence of poor land management.

Roadside erosion is common in this area.

8.1.3 Gully Erosion with Sheet Erosion on Uplands

This class occurs over large areas of the eastern part of the district. Topography is hilly, but dissected by gently sloping creek valleys.

Sheet erosion is often associated with the Podsolic soils of the upland slopes.

Very extensive gully erosion can occur on the lower slopes between the creek flood plain and the surrounding steeper slopes, mainly associated with solonetzic soils.

Gully erosion is frequently found in the drainage lines of the steeper slopes.

8.2 Tunnel Erosion

Dispersible soils are found in all major soil types within the district except the red earths.

Tunnel erosion has only been encountered in small areas within the district associated with either solonetzics or red podsolics and less frequently on red brown earths. The main area of occurrence is east of Wagga, south of the Murrumbidgee River.

8.3 Soils and Erosion

The most severe erosion occurs on the yellow solonetzic soils. Bad sheet erosion and major gully erosion occurs.

Podsolic soils erode easily and sheet and gully erosion occur on them but with less severity than on the yellow solonetzics.

Red brown earths are affected by moderate sheet and gully erosion. They are usually found on flatter areas so the erosive action of water is not as severe.

Red earths suffer only mild erosion under normal agricultural practice.

8.4 Land Use and Erosion

The most severe erosion in the district is found on arable sloping country. The more intensive the cropping the more severe is the erosion.

In the past red earths suffered from severe erosion after continuous cropping but this has been halted by the use of rotations incorporating a subterranean clover-ley period.

Unimproved hilly grazing country south east of Wagga is very vulnerable to erosion but is stable under improved pasture.

Generally the introduction of rotations with a clover ley phase on arable areas and pasture improvement on grazing lands has reduced the erosion hazard.

9. GENERAL SOIL CONSERVATION PRACTICES

9.1 Soil Conservation Regions

The Wagga district can be roughly divided into three regions based on variations in general soil conservation practice, namely:

(a) The South Eastern Region.

(b) The Central Region.

(c) The Western Region.

9.1.1 The South Eastern Region

This region can again be roughly sub-divided into northern and southern zones on the basis of topography.

The southern zone comprises steep rugged hilly lands with slopes generally in excess of 20 percent. These lands are mainly located east of the Hume Highway and include the Kyeamba, Humula, Oberne and Westbrook areas. The zone is mainly second class grazing country with sheep the main grazing animal although cattle numbers have been increasing in recent years.

Pasture management is an important soil conservation practice, emphasis being placed mainly on stocking rates and stocking management to maintain pasture cover.

Pasture improvement is possible using species recommended for the area (Section 13). Aerial sowing and fertilizing with superphosphate is the usual method of pasture improvement.

Structural soil conservation works are usually limited to diversion banks and associated gully control structures. Trickle pipes are also frequently used.

The northern zone comprises lands with slopes usually ranging from 10-20 percent and includes the areas around Ladysmith, Borambola and Tarcutta.

Soil conservation practices include crop rotations, pasture establishment and management in accordance with recommendations (section 13) and stocking rates consistent with the degree of development. In addition some structural soil conservation works such as diversion banks and gully control structures may be required to support these practices. The latter are sometimes fitted with trickle pipes. Diversion banks must be further supported by contour guide lines where cultivation is undertaken.

9.1.2 The Central Region

This region comprises more than half the area of the district and includes The Rock, Wagga, Junee and Coolamon areas. Slopes range from 1-10 percent. Agricultural activities consist primarily of cereal growing in association with sheep and cattle grazing and some pig enterprises. Some oil seed crops are also grown.

Conservation practices rely more on structural works and include comprehensive graded bank systems diverting run-off into constructed waterways or stable watercourses, together with gully control structures.

Management practices include contour cultivation, crop rotation and pasture improvement. This is the best area in the district for growing subterranean clover and the recommended crop rotation is two years cropping followed by two years of clover ley. This is provided that other management inputs are applied at the same intensity.

9.1.3 The Western Region

This area comprises the mainly flat arable land with slopes under 3 percent. The main centres in this area are Ganmain, Matong, and Cowabbie.

There is no appreciable erosion.

Agricultural activities consist primarily of cereal cropping with some grazing, mainly sheep.

Soil conservation practices consist of land management with some structural works aimed at diverting run-off flows into gully control structures.

10. LAND CLASSIFICATION AND FARM PLANNING

10.1 Farm Planning

The farm plan is the basis for sound soil conservation management. It provides for the classification of the land into various land classes - it indicates the highest and best use of each acre of land on a property. The capability classes are used to indicate the various management requirements to achieve sound soil conservation at the different levels of land use.

Management requirements for arable lands include crop rotations, sound soil and crop residue treatments, well planned fencing and supporting soil conservation measures. These soil conservation measures include graded banks, diversion banks and gully control structures and contour cultivation. The intensity of these measures is governed by climate, topography, soil type and the level of land use.

For grazing lands, management includes use of the most suitable kinds of livestock, stocking rates consistent with the degree of development, grazing systems, sound soil management and forage treatment, fodder conservation and supporting soil conservation measures. In the Wagga district supporting soil conservation measures include diversion banks, gully control structures and contour guide lines. Gully control structures usually have a dual purpose. They provide additional watering points and control gully erosion.

10.2 Land Capability Classification

The following basic criteria are used for identifying capability classes in the Wagga district.

10.2.1 Climatic Zones

The whole of the district has a mediterranean type climate. However, there are variations in the climate within it. The main variations are rainfall and rainfall reliability. The climatic zones based on rainfall are:

Table 10.2.1 Climatic Zones

Zone	Rainfall (per annum)
C_1	Over 25"
C_2	20-25"
C_3	Less than 20"

Zone C_1 covers the south-eastern part of the district, C_2 the central and C_3 the western part.

10.2.2 Slope Classes

Slope is the only readily measurable factor for the identification of land classes. Factors such as physical limitations and soil characteristics modify the slope limits of the various land classes.

Table 10.2.2 Slope Classes

Symbol	Slope % (usual range)	Description	Remarks
S_1	0-1%	Flat	Class I.
S_2	1-3%	Gently sloping	Upper limit of Class II on Red Podzolic and Red brown earth soils.
S_3	2-4%	Gently sloping	Upper limit of Class II on Red earths.
S_4	4-12%	Moderately sloping to rolling.	Upper limit of Class III on all soil types.
S_5	0-10%	Moderately sloping	Upper limit of Class IV lands in 25-30" rainfall on Red Podzolic soils.
S_6	12-25%	Hilly	Upper limit Class V on all soil types.
S_7	25% +	Hilly and mountainous	Class VI.

10.2.3 Physical Limitations (excluding slope)

If slope is not a limiting factor for arable use, there must be no other physical limitations to cultural practices. Other physical limitations determine the grazing classes to be applied.

Table 10.2.3 Physical Limitations (excluding slope)

Symbol	Physical Limitation	Remarks
P_1	No physical limitations to arable use.	Slope and erodibility are the only limits to arable use. Also forestry and grazing use.
P_2	Very wet areas, isolated.	Grazing, forestry or unusable land.
P_3	Very stony or rocky.	
P_4	Very dissected.	
P_5	Very severe effects of past erosion.	
P_6	Very infertile soils.	

10.2.4 Soil Erodibility

Table 10.2.4 Soil Erodibility Gradings

Symbol	Degree of Hazard	Great Soil Group
1	Low	Red Earths
2	Moderate	Red Brown Earths
3	Moderately High	Red Podzolics
4	High	Solonetzics

10.2.5 Other Factors

Land may be classified as arable by all the above criteria but be utilized for some less intensive use such as grazing or forestry. Its development towards its potential capability would depend upon social, economic or technological circumstances.

10.3 Land Capability Classes and their Identification

Class I Definition: Arable lands requiring no special soil conservation practices.

Identification: Level to almost level slope class 0-1% with no physical limitations except occasional flooding. Usually very fertile and suitable for irrigation.

Extent: These lands are generally confined to the alluvial flats of the Murrumbidgee River and Tarcutta and Kyeamba Creeks. Soils are a prairie type of medium fine texture.

Class II Definition: Arable lands requiring simple soil conservation measures such as contour cultivation and crop rotation.

Identification: Slopes for this class never exceed 4%. Where slope lengths exceed 20 chains a class III classification may be applied. For example on red brown earth soils with heavy texture and slopes of 2-3% in excess of 20 chains are classified as Class III.

Extent: Found throughout the whole of the district but are extensive in the gently sloping lands of the central and western sections.

Class III Definition: Arable lands requiring intensive soil conservation practices such as diversion banks, graded banks and grassed waterways in addition to the practices for Class II.

Identification: Slopes range up to 12%. Above 12% slope cereal crops cannot be harvested by machinery when operating between contour banks. Slopes of 2-3% which would normally fall into class II are included in this class when slope lengths are in excess of 20 chains with no physical limitations but with climate and soil limitations.

Extent: Found in association with Class II lands principally in the central region.

Class IV Definition: Grazing lands requiring no special soil conservation measures, that is no structural works are required. Land in this class should be capable of sustaining a vigorous native or improved pasture sward to protect it from erosion.

Identification: Slopes range from 0-10% and Class IV lands are topographically suitable for cultivation but for reasons of stone, gravel, shallow soils or other features could not be classified as Class II or Class III lands.

Extent: The majority of Class IV lands in the district are located in the south eastern zone. These lands are usually very wet during the months April to October and the surface is unable to support cultivation implements.

They are usually associated with red podzolic and solonetzic soils.

In other parts of the district they are confined to small areas along creek flats on the effluent of drainage lines from steep country.

Some Class IV lands may be cropped occasionally. This practice entails the sowing of a pasture mixture with oats as a cover crop. It allows the nitrogen build up to be utilized and pastures to be renovated. The oats also provide valuable winter grazing.

Class V Definition: Grazing lands requiring intensive soil conservation measures.

Identification: Generally slopes range from 0-25%. The other physical factors that are used to identify Class V lands are shallow infertile soils, dissected landscape, and severe effects of past erosion.

Lands with 0-10% slope with solonetzic soils would be excluded from Class III and placed in Class V.

In other instances lands with slopes in excess of 25% may be classified as Class V. These lands have N.W. aspects and have been overgrazed. Structural works in the form of pasture furrows would be installed on them with crawler type equipment and the full range of recommended management practices would be applied to them.

Extent: These lands occur primarily in the south eastern region of the district.

Class VI Definition: Grazing lands that require very good management to remain stable. Management includes use of the right kind of livestock, restrictive stocking rates, provision of watering points, good fencing, prevention of fire and control of pests and weeds.

Extent: Limited occurrence in the south eastern region of the district.

Identification: Land that requires special protective measures. Usually steep grazing lands with slopes in excess of 25%. Topography so rugged that intensive soil conservation structural works cannot be carried out. Soils are usually of low fertility.

Salted land also is normally placed in Class VI. Special soil conservation measures and strick stocking control must be applied to salted areas if reclamation is to be successful.

Class VII Definition: Lands reserved for green timber because of erosion hazard, inaccessibility, steepness, shallowness, infertility or other factors.

Extent: These lands occur generally in the south eastern margins of the district.

Class VIII Definition: Land which is economically unproductive (cliffs, lakes, swamps etc.). These areas are often best suited to wild life preservation.

Extent: Instance of occurrence in the district is insignificant.

10.4 Land Management of the Various Capability Classes within the Wagga district.

10.4.1 Management of Arable Lands

The management requirements have been listed at the beginning of this section. No management input should be considered alone as each will effect the stability of the system as a whole. Each should be considered in relation to the whole management and the level of land use that must be sustained.

1. Crop Rotations

(a) Red Earth Soils: Observation indicates that the highest intensity of use that these soils could sustain would be 2 years cropping followed by 2 years clover ley.

(b) Red Brown Earths: The highest intensity of use for these soils is 2 years cropping, 3 years clover ley.

(c) Red Podzolic Soils: The highest intensity of use for these soils is 2 years cropping, 2 years clover ley.

2. Soil and Crop Residue Treatment

These treatments include length of fallow, type of implement used, direction of cultivation, moisture content of soil at working, establishment and maintenance of clover ley and stubble disposal or use.

Length of fallow on red earths and red podzolics can be of short duration. The initial workings are delayed until December - February period. Red brown earths require longer fallow and may be worked in September - October preceeding sowing.

Tyne implements should be used on all soil types, where possible, in preference to disc implements. Excess pasture or crop residue should be reduced by either heavy stocking or mowing prior to soil working. Further at all times, the initial and final cultivation should be on the contour.

The establishment and maintenance of good clover ley are essential for the maintenance and improvement of the chemical and physical properties of all arable lands in the district. In short rotations, clover must be undersown with the final crop of a rotation. Further, the rate of sowing must be sufficiently heavy to ensure maximum coverage in one year. On red earths and red podzolic rates in excess of 4 lbs/acre are strongly recommended. In longer rotations such as in a 3 year clover ley in a 6 year rotation, clover should be topdressed with superphosphate in the 1st and 2nd year of ley. That is fertilizer should be applied in the 4th and 5th year of the 6 year cycle.

Stubble incorporation has in many areas proved impractical because of the short term crop/clover ley rotations (2 x 2) common throughout most of the district. Cumulative nitrogen deficiencies develop and as nitrogenous fertilizers would then be essential, cereal production becomes uneconomic. In most cases stubble is burnt. Such practices necessitate the use of supporting structural soil conservation measures. However, on the red brown earths a clover ley rotation of longer duration is employed. On this soil type the last crop in the rotation is oats. This crop can, in most cases be successfully established when mulch is incorporated.

10.4.2 Provision of Adequate Water Disposal System

Excess run off from arable land is usually disposed of in either a constructed or natural waterway. In either case the following points should be noted:

(a) All waterways should be located to provide the least obstruction possible to farming operations. In some cases natural surfaces may have to be re-shaped to achieve this point.

(b) All water disposal surfaces must be compact and covered with vigorous mat of vegetation before being required to carry excess run off.

(c) All waterway areas should be fenced.

(d) Waterways must never be used as lanes, stock routes or fire breaks. They should be located and protected to prevent this type of use.

(e) Excess growth should be removed at periodic intervals by controlled grazing.

10.4.3 Fencing

Fencing on arable lands should always aim to encourage the longest working run across the slope. Paddock size, watering points and type of rotation and livestock enterprises are other points to be considered when determining farm layout. Further, the paddock layout must be considered in relation to the water disposal system of the whole farm.

10.4.4 Supporting Conservation Measures

Information on design of these measures is dealt with in other sections of the hand-book.

The intensity of structural earthworks may vary with different levels of land use. However, the location and design of these works must always be relative to the highest level of land use. An individual paddock approach should be avoided at all costs.

11. DESIGN OF STRUCTURES

11.1 Estimation of Runoff Rates

11.1.1 General

Soil conservation structures are used to control the erosive potential of runoff generated by rainstorms within the catchment. Within the Wagga district both short duration high intensity thunderstorms and long duration low intensity frontal storms are the main source of water erosion. For soil conservation structures peak rates of runoff have to be estimated for design purposes. The investment in the structure determines the return period frequency for the storm so more expensive structures are designed for higher intensities. The following rainfall return periods are used for soil conservation structures in the Wagga district.

Structure	Return period for design rainfall
Graded banks	5-10 years
Diversion banks	10-20 years
Waterways	10 years
Gully control structures	20-50 years

When land management practices that reduce runoff are used in association with structures, protection from rainstorms of longer return periods will be provided.

11.1.2 The Rational Formula

The Rational Method is used to estimate the peak discharge for the design of the structure and is applicable to areas up to 3200 acres.

It is expressed by the equation:

$$Q = CiA$$

Q = design peak runoff rate in cubic feet per second.

C = runoff coefficient - dimensionless.

i = rainfall intensity in inches per hour for the design return period and for a duration equal to the "time of concentration" of the catchment.

A = catchment area in acres.

11.1.3 Intensity Duration of Design Storm

The Rational Method assumes that the peak rate of discharge from a catchment area will be caused by a storm of duration just long enough for all parts of the catchment to contribute simultaneously to flow past the site of the structure to be designed. This duration is usually referred to as the "Time of concentration" and is the time required for water to flow from the most remote (in time of flow) point of the area to the outlet.

It is determined by the following formula:

$Tc = To + Tch$

Tc = Time of concentration (minutes)

To = Time of overland flow

Tch =Time of channelised flow.

Figures 11.1.1, 11.1.2 and 11.1.3 enable time of concentration to be calculated.

It is important to remember three main points when determining time of concentration:

(1) Overland flow occurs as a thin sheet of water spread more or less evenly over the surface and as such is restricted to very short distances usually less than 200 feet.

(2) Time of concentration of a catchment following introduction of intensive soil conservation works will differ from time of concentration of the untreated area. Design time of concentration to be used should be that of the treated catchment.

(3) In any system of design involving many different structures e.g. a system of banks feeding a waterway, several trial times of concentration should be calculated. The time of concentration with the longest duration should then be selected for the design as this allows for the whole area to be contributing at that instant.

Table providing times of concentration to be expected for various soil conservation structures are given in the relevant sections.

After the time of concentration has been estimated this is then used to determine the rainfall intensity that has a duration equal to the time of concentration for a particular return period.

Figures 11.1.4 and 11.1.5 enable rainfall intensities for the Wagga district to be determined. Figure 11.1.4 delineates isopleths for the 5 year return period and 20 minute intensities while figure 11.1.5 is an intensity duration frequency curve derived from data for the Wagga Research Station. Frequency, or return periods from 1 to 20 years are given for durations of 5 to 360 mins. (Table 11.1.1 gives the data from which the curves are derived).

To determine rainfall intensities outside the 2.7 to 2.8 inches/hour isopleths that bound the Research Station the following ratios are to be used. These can be applied to any return period and are given in table 11.1.2.

Table 11.1.2

Rainfall Intensity Inches/Hour	Multiplier
2.5 - 2.6	0.93
2.6 - 2.7	0.97
2.7 - 2.8	1.00
2.8 - 2.9	1.05
2.9 - 3.0	1.08
3.0 - 3.1	1.12
3.1 - 3.2	1.15

Table 11.1.1 Return Period/Duration Data for Rainfall - Wagga Research Station

Duration (minutes)	1 in 1 Year		1 in 5 Year		1 in 10 Year		1 in 20 Year	
	Points	In/hr	Points	In/hr	Points	In/hr	Points	In/hr
5	11	1.32	55	6.60	70	8.40	84	10.10
10	18	1.08	72	4.32	91	5.46	109	6.55
15	23	.90	83	3.42	104	4.16	124	4.95
20	25	.77	90	2.70	112	3.36	134	4.00
30	30	.60	100	2.00	125	2.50	148	2.95
60	37	.37	118	1.18	146	1.46	174	1.74
120	45	.22	135	.67	167	.84	198	.99
240	52	.13	153	.38	188	.47	222	.55
360	57	.09	163	.27	200	.33	238	.40

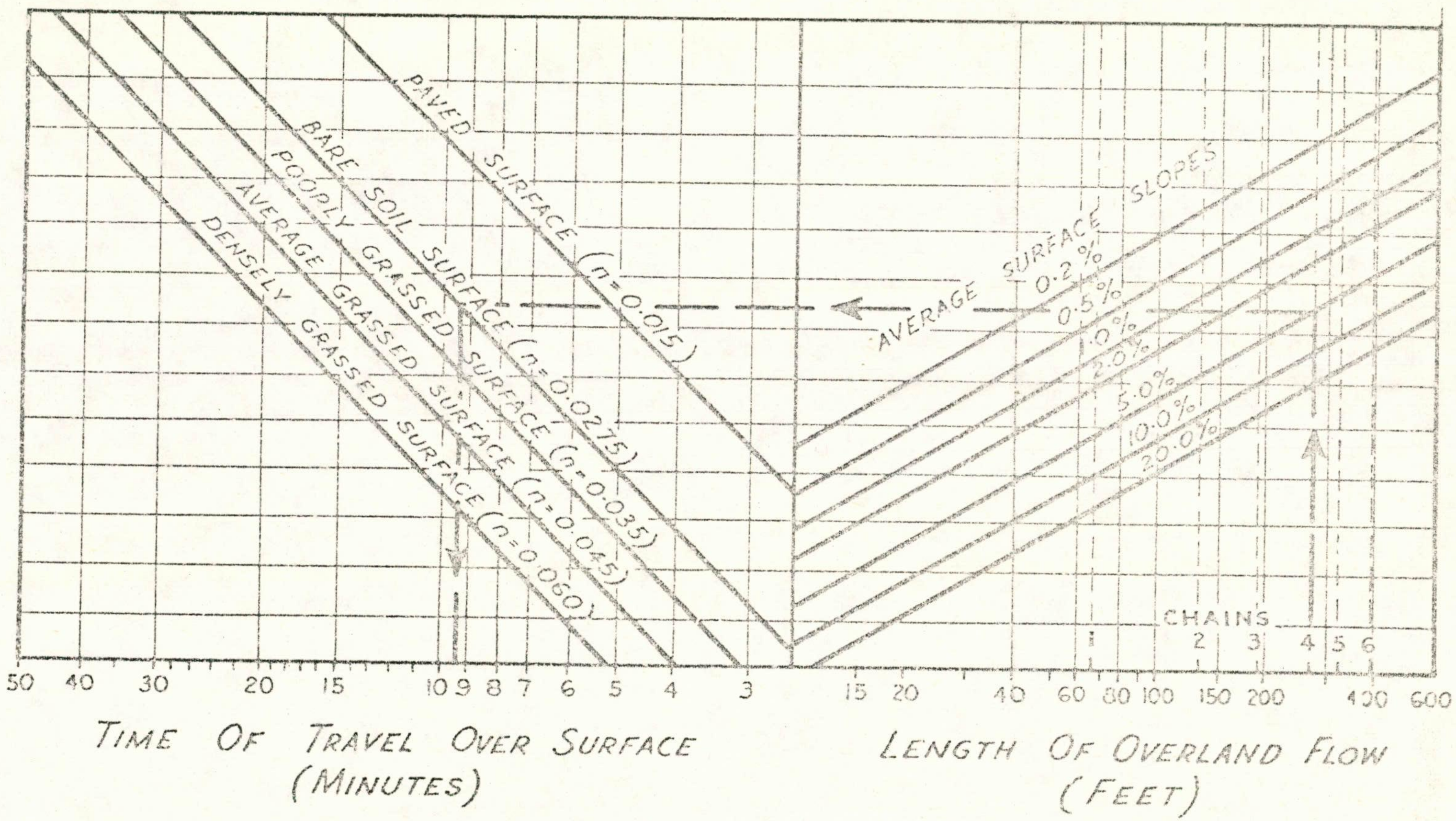


Figure II:I Time of Overland Flow

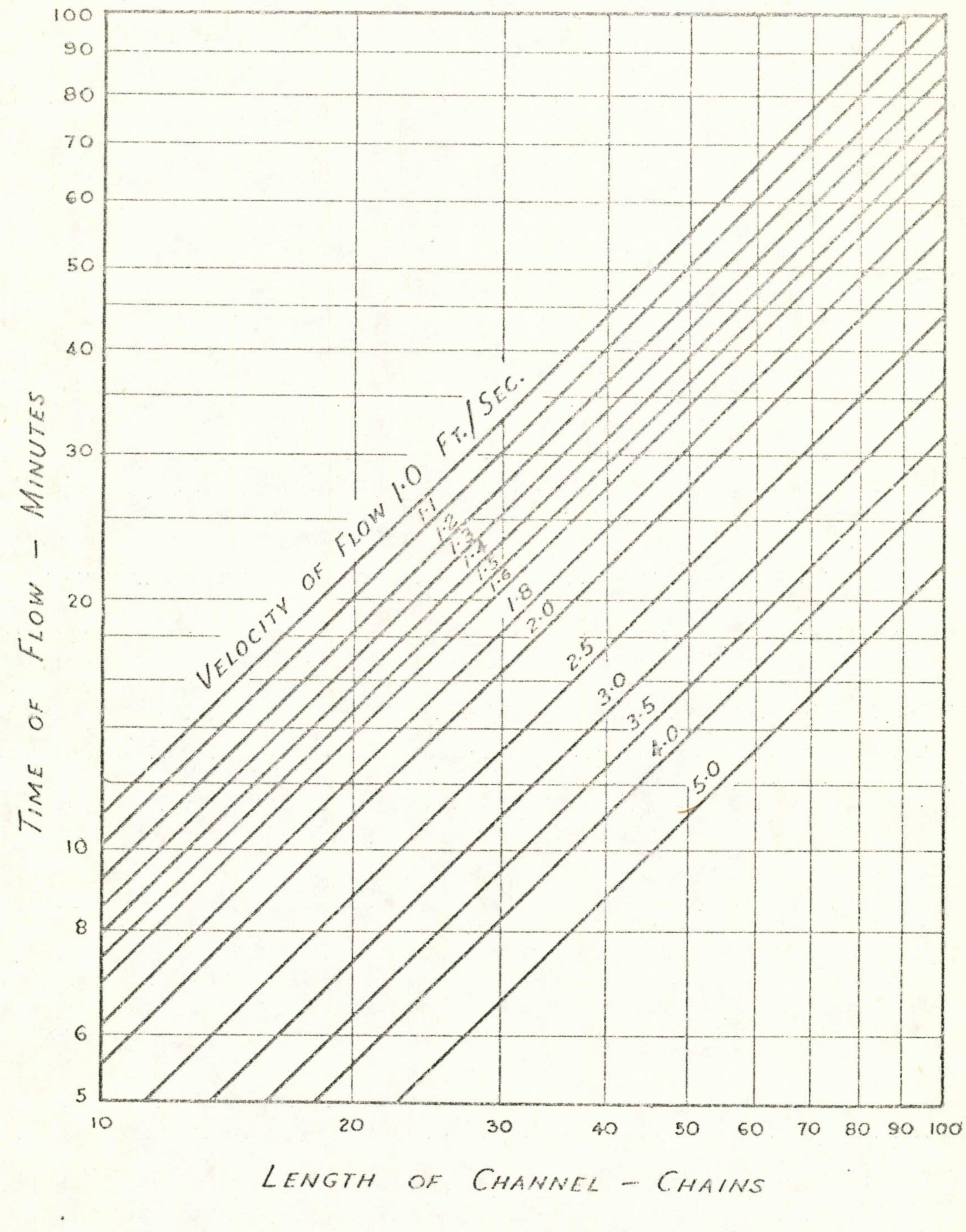
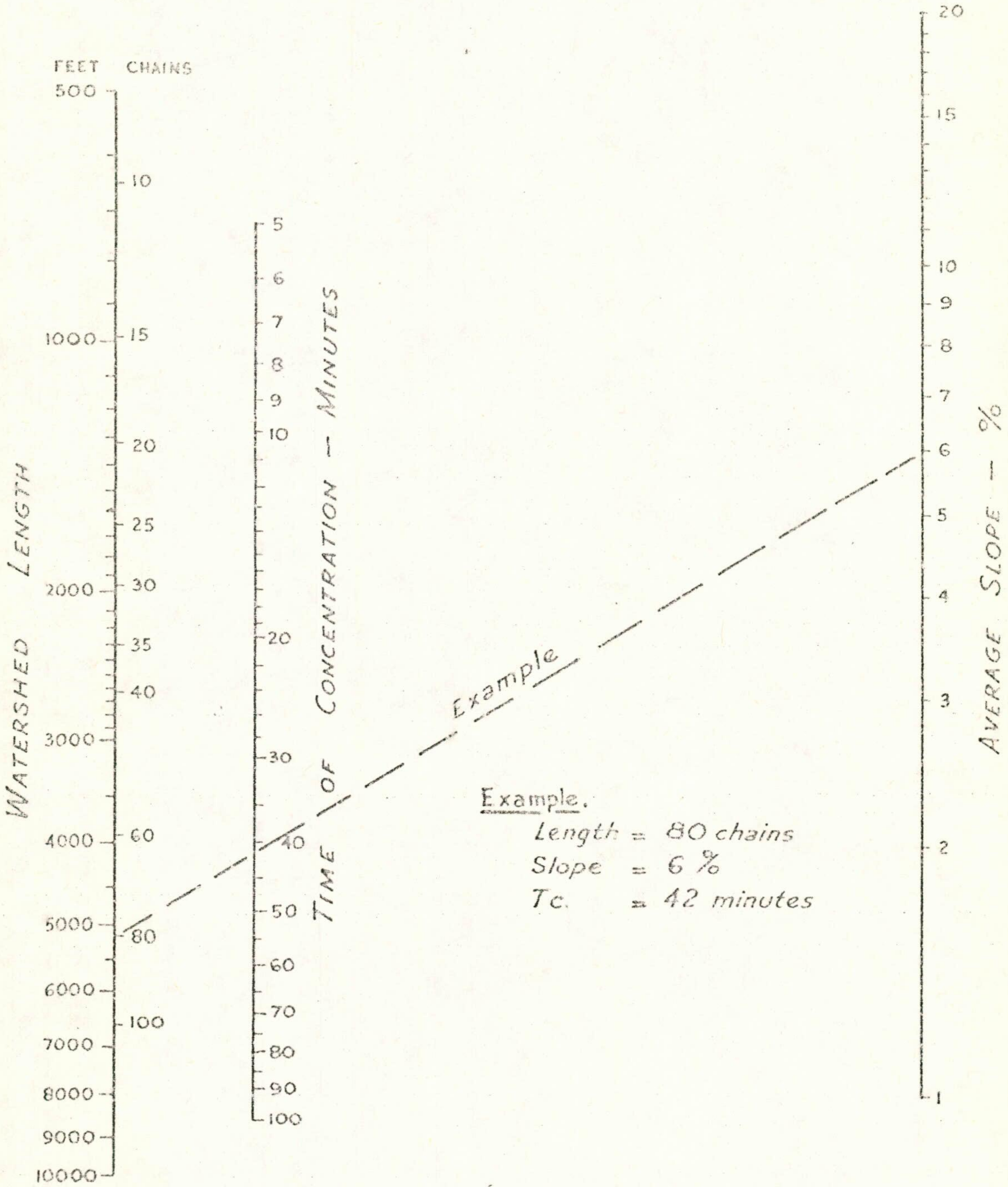


Figure II:1:2 Time of Channelised Flow

For average soil & fair pastures

Poor pastures .... x ·5 *Soil above average infil. .... x 1·5*

Good pastures .... x 2 *Soil below average infil. .... x ·75*

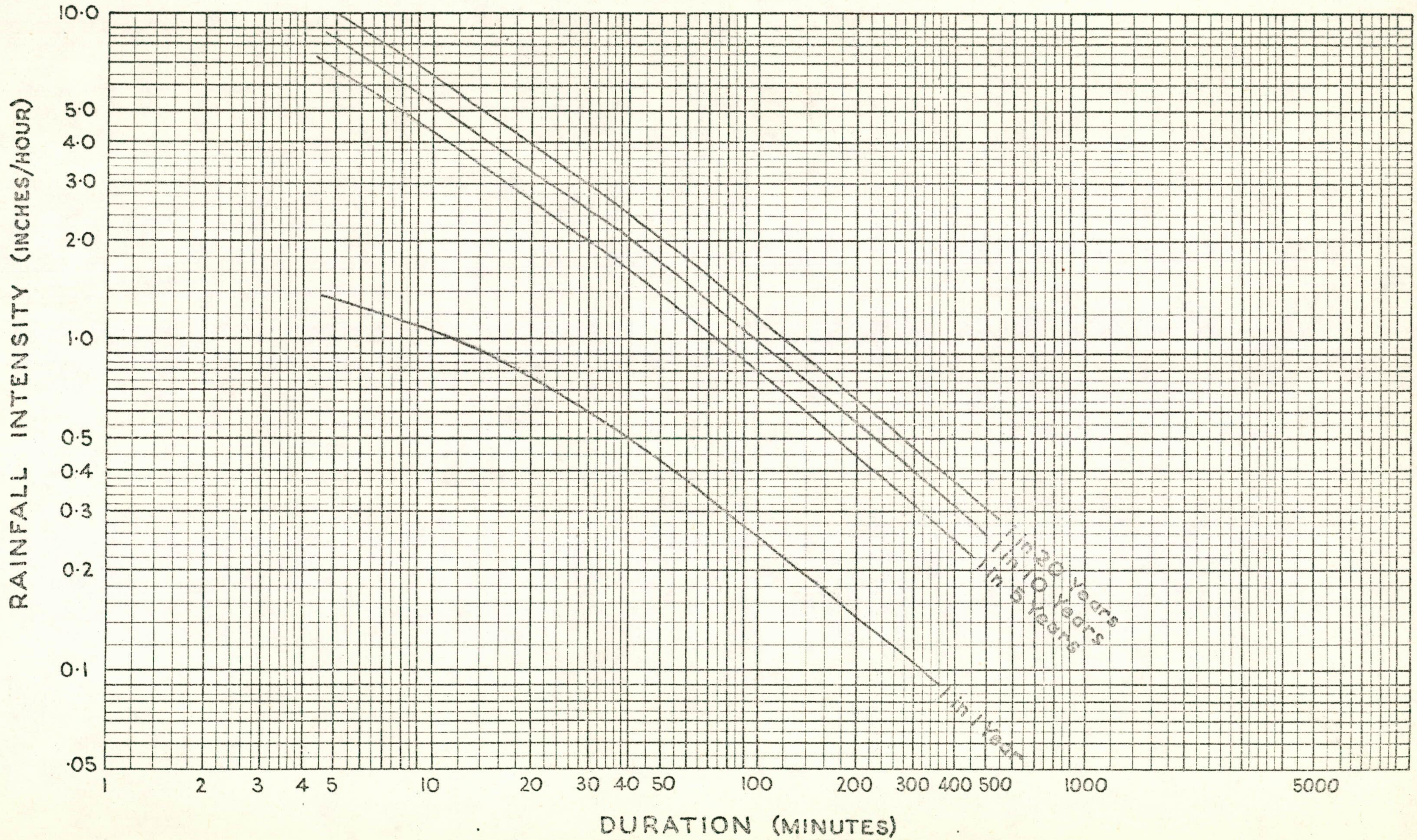


$$Tc = \frac{L(ft.)}{88\sqrt{S}}$$

Figure II:1:3 Time of Concentration for Catchments

FIGURE 11.1.5

RAINFALL INTENSITY FREQUENCY DURATION CURVES
WAGGA RESEARCH STATION



SOIL CONSERVATION SERVICE OF N.S.W.

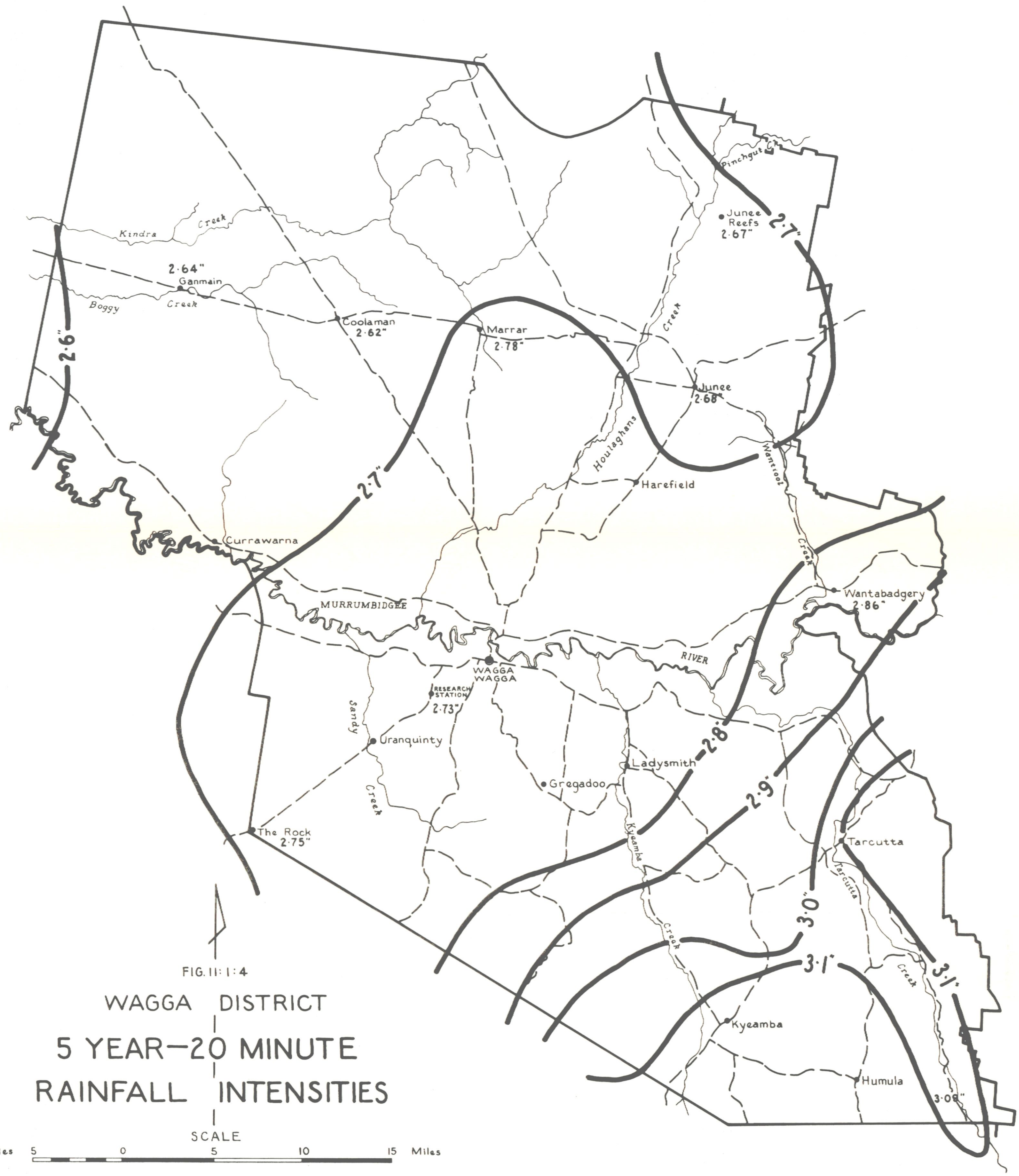


FIG. 11:1:4

WAGGA DISTRICT

5 YEAR—20 MINUTE RAINFALL INTENSITIES

S.C.S. 7730

e.g. to determine the rainfall intensity at Coolamon for a structure with a 10 year return period. (The time of concentration has already been determined as 40 minutes).

Procedure

1. Enter Fig. 11.1.5 with a duration of 40 minutes and move vertically to the 1 in 10 year return period line. Read off the rainfall intensity as being 2.0 inches/hour.

2. Coolamon lies between the 2.6 and 2.7 inch/hour isopleths and from table 11.1.2 this has to be multiplied by 0.97.

$$0.97 \times 2.0 = 1.95 \text{ inches/hour}$$

this is the intensity to be used for substitution into the Rational formula.

11.1.4 Coefficient of Run-off

The coefficient of run-off (C) represents the ratio of the rate of runoff to the rate of rainfall.

The value of C will be directly effected by rainfall intensity, infiltration capacity of the soil, cover, relief and by surface and stream detention and storage.

The coefficient of runoff can be estimated by addition of the values given in each sub-section (A to E) of Table 11.1.3).

Where differing C values apply for different areas within the catchment, the C value must be weighted according to the areal proportions of the various values. The simplest method is to take rainfall intensity for the whole area and use this to calculate the contribution from each area separately.

Example - If there are 90 acres with C of 0.3 and 60 acres with C of 0.6 and i for the whole 150 acres is 2.0 inches per hour.

$$q = (0.3 \times 2.0 \times 90) + (0.6 \times 2.0 \times 60)$$
$$= 54$$
$$= 126 \text{ cusecs.}$$

11.1.5 Adjustment for Large Areas

For areas greater than 200 acres, the calculation of runoff using the equation q = C.i.A. will give over-estimations. To overcome this, the quantities should be multiplied by the values given in table 11.1.4.

Table 11.1.3 Estimation of Coefficient of Run-off

A.	**Rainfall Intensity**		
	1 in per hr		0
	1 in to 2 in per hr		0.10
	2 in to 3 in per hr		0.20
	3 in to 4 in per hr		0.25
B.	**Relief**		
	Relatively flat average slopes	0-5%	0
	Rolling " "	5-10%	0
	Hilly " "	10-20%	0.05
	Steep " "	20%	0.10
C.	**Surface retention and stream and surface storage**		
	Poorly defined and meanering streams; large surface storage; water and soil conservation on 90 per cent.		0
	Considerable surface depressions; overland flow significant; some ponds and swamps; some banks and furrows		0.05
	Well defined system of small watercourses (not S.C.S. Banks)		0.05+
	Negligible; few surface depressions; watercourses steep, overland flow thin.		0.10
D.	**Infiltration**		
	Run-off low (Soils Gn4 and Uc1)		0.05
	Run-off medium (Soils Gn3, Ug5, Db2, Dr2.2)		0.10
	Run-off high (Soils Dr2.3, Dr2.4, Dr3.2 Dy2.3, Dy2.4, Dy3.2)		0.15
	Run-off very high (Soils Dr3.3, Dr3.4, Dy3.3, Dy3.4)		0.20
	Run-off extreme (Shallow lithosols or rock outcrops)		0.25
E.	**Cover**		
	About 90% of area with improved pasture or dense dry forest		0.05
	About 50% of area with improved cover, not more than 50 per cent cultivation, open woodland.		0.10
	Sheet-eroded native pastures; less than 10 per cent under good native or improved pasture; clean cultivated crops.		0.20
	No effective plant cover.		0.25

Table 11.1.4 Correction for Area

200 acres	0.92	1,000 acres	0.80
300 acres	0.90	1,500 acres	0.77
400 acres	0.88	2,000 acres	0.75
500 acres	0.86	2,500 acres	0.73
600 acres	0.85	3,000 acres	0.72
800 acres	0.82		

11.2 Banks on Arable Land

11.2.1 General

The chief purpose for banks on such land is to reduce sheet and rill erosion and prevent gully erosion.

The spacing and dimensions of banks on this type of country will depend on:

(a) the control of inter-bank erosion

(b) the ability of the bank to convey the runoff from the inter-bank areas.

In the Wagga district, systems of banks on arable land are common. Where they are required the following principles of design should be followed.

11.2.2 Graded Banks

11.2.2.1 Bank Spacing

On cultivated land, bank spacing will in almost all instances be governed by the distance downslope that the bank can be placed without inter-bank erosion becoming serious. Spacing will depend on:

Land use,

Degree of slope,

Frequency and nature of the rains that cause erosion,

Erodibility of the soil,

Degree of existing erosion,

Subsequent management and maintenance.

The basic formula for bank spacing is :

$$HI = \frac{K}{\sqrt{S}} \quad \text{or}$$

$$VI = \frac{K\sqrt{S}}{100}$$

where HI = Horizontal interval
VI = Vertical interval
S = Land slope percent
K = A constant.

The following values are applicable to this district. The values are based on a cropping rotation of two years crop and 2 years ley which is considered the maximum cropping frequency which can be sustained without adverse long term effects.

Basic K values are:

Podzolics, solodics and solonetzics

Dr 2.21	Dr 3.21 Dr 2.32	Dr 2.43 Dr 3.42	650

Red brown earths

Dr 2.22	Dr 2.23	Dr 2.33	750

Red and yellow earths

Gn 2.12	Gn 2.13	Gn 2.25	800

An addition of 10% K and 20% K is justifiable as a land use factor where a build up in fertility and improvement to structure has resulted from the continued use of sub clover in the ley period. These factors would not be applied in shorter rotations.

The following table for bank spacing has been adjusted in terms of the land use factor. Where land is regularly cropped for two years in four the values are shown under regular cultivation; where the cropping frequency is less than two years in four (e.g. 2 years in five) the values shown for occasional cultivation should be used.

<u>Table 11.2.1</u> Spacings of Banks - Horizontal Intervals (Chains)

Slopes	Podzolic & Solonetzic Soils K = 650		Red Brown Earths K = 750		Red Earths K = 800	
	Regular cultivation	Occasional cultivation	Regular cultivation	Occasional cultivation	Regular cultivation	Occasional cultivation
2%	7.6	8.4	9.0	9.8	9.5	10.1
3%	6.2	6.8	7.2	8.0	7.6	8.4
4%	5.4	5.9	6.3	6.8	6.6	7.2
5%	4.8	5.2	5.6	6.1	6.0	6.6
6%	4.4	4.7	5.1	5.6	5.4	6.0
7%	4.1	4.5	4.8	5.1	5.0	5.5
8%	3.8	4.2	4.4	4.8	4.6	5.1

11.2.2.2 <u>Bank Size</u>

The capacity of the channel must be sufficient to convey the runoff. The capacity formula is:

$$q = a.v.$$

where q = runoff in cusecs
a = cross sectional area of the channel
v = velocity of flow.

11.2.2.3 Maximum Permissible Velocity

The maximum permissible velocity will depend on the soil type (in the case of banks on arable land, cultivated channels must be assumed).

Table 11.2.2 gives maximum velocities for soils of the Wagga district. Where it is desirable to reduce the flow at the outlets, lower velocities may be used. However, it is recommended that they be not less than 1.0 ft. per sec.

Table 11.2.2 Maximum Permissible Velocities of Flow for Soils of the Wagga District

Yellow duplex soils known to be highly dispersible	1.0 ft. per sec.
Red and yellow duplex soils mottled clay subsoils (Dr 3.3, Dr 3.4, Dy 3.3, Dy 3.4)	1.2 ft. per sec.
Other duplex soils (Dr 2.3, Dr 2.4, Dr 3.2 Dy 2.3, Dy 2.4, Dy 3.2 Dr 2.2, Db 2.2)	1.5 ft. per sec.
Red and Yellow earths (Gn 2)	1.8 ft. per sec.
Dense silty loams (Uml)	2.0 ft. per sec.

11.2.2.4 Required Capacity

This is calculated by use of the rational formula, q = C.i.A.

Time of concentration will be the time of overland flow plus the time of channelised flow. Table 11.2.3 gives times of concentration for a variety of bank lengths. On a range of land slopes at various mean velocities, differences in times of overland flow between bank spacings on different soil types will be negligible and may be disregarded.

For the time of concentration, from table 11.2.3 determine the rainfall intensities from figures 11.1.4 and 11.1.5.

Using this rainfall intensity, determine the value of C from table 11.1.3.

From the values for i, C and area, calculate the discharge.

11.2.2.5 Bank Dimensions

From the discharge and the velocity, calculate the cross-sectional area.

a = q/v

The velocities given in table 11.2.2 are the maximum permissible velocities for conditions of bare soil. Under these conditions there is no vegetal resistance.

TABLE 11.2.3

TIME OF CONCENTRATION IN GRADED BANKS (MINUTES).

Slope per cent	Bank Length (chains) 10	15	20	25	30	40	50	60
Velocity = 1.0 feet per second								
2	25	29	35	40	46	57	69	80
3	23	27	33	38	44	55	67	78
4	22	26	32	37	43	54	66	77
5	21	25	31	36	42	53	65	76
6	20	24	30	35	41	52	64	75
7	19	23	29	34	40	51	63	74
8	19	23	29	34	40	51	63	74
Velocity = 1.2 feet per second								
2	22	27	31	35	40	50	59	69
3	20	25	29	33	38	48	57	67
4	19	24	28	32	37	47	56	66
5	18	23	27	31	36	46	55	65
6	17	22	26	30	35	45	54	64
7	16	21	25	29	34	44	53	63
8	16	21	25	29	34	44	53	63
Velocity = 1.5 feet per second								
2	21	24	27	31	35	42	49	57
3	19	22	25	29	33	40	47	55
4	18	21	24	28	32	39	46	54
5	17	20	23	27	31	38	45	53
6	16	19	22	26	30	37	44	52
7	15	18	21	25	29	36	43	51
8	15	18	21	25	29	36	43	51
Velocity = 1.8 feet per second								
2	19	22	25	28	31	38	44	50
3	17	20	23	26	29	36	42	48
4	16	19	22	25	28	35	41	47
5	15	18	21	24	27	34	40	46
6	14	17	20	23	26	33	39	45
7	13	16	19	22	25	32	38	44
8	13	16	19	22	25	32	38	44
Velocity = 2.0 feet per second								
2	19	21	24	27	31	35	41	46
3	17	19	22	25	29	33	39	44
4	16	18	21	24	28	32	38	43
5	15	17	20	23	27	31	37	42
6	14	16	19	22	26	30	36	41
7	13	15	18	21	25	29	35	40
8	13	15	18	21	25	29	35	40

If channels are vegetated, the velocities for a given grade will be less. For the type of vegetation that will be found in the channels in cultivated land, the resistance is low to moderate and this will reduce the velocity to approximately two thirds of that for bare soil. This means that the capacity as calculated from the maximum velocities must be increased by 50%.

To determine bank dimensions, select the type of cross-section required i.e. batter slopes, batter lengths, degree of freeboard, and depth of cut from the range given in tables 11.2.4. For the required cross-section and slope, read from the table the required dimensions.

11.2.2.6 Grade

The grade of the bank has direct bearing on both the velocity and capacity.

The grade to be used will depend on:

(a) the required velocity of low;

(b) the resistance in the channel;

(c) the depth of flow and the shape of the channel.

Velocity of flow is determined by use of Manning's formula.

$$V = \frac{1.5 R^{\frac{2}{3}} S^{\frac{1}{2}}}{n}$$

where V = velocity in feet per second
R = hydraulic radius
S = grade in feet per foot
n = coefficient of roughness.

See figure 11.2.1 for graphical solutions to this equation.

$$\text{Hydraulic radius} = \frac{a}{p} = \frac{\text{cross sectional area}}{\text{wetted perimeter}} \frac{\text{sq ft}}{\text{ft}} = \text{ft}$$

Hydraulic radius (and hence velocity) increase with with increase of depth of flow.

For parabolic and trapezoidal banks, R is approximately two-thirds of the depth.

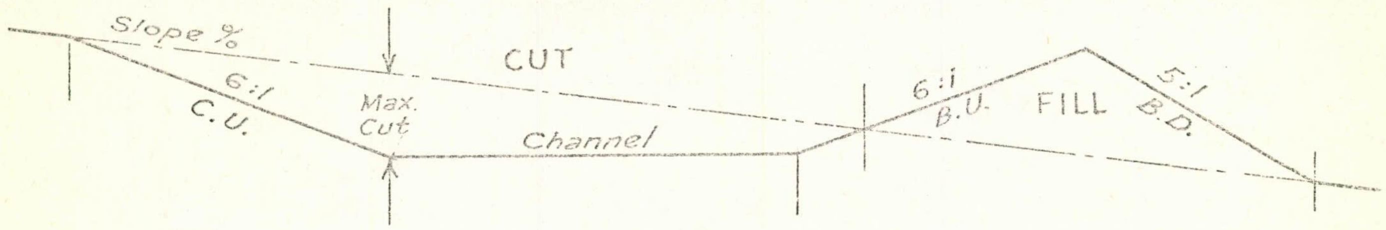
Roughness coefficient 'n' is influenced by:

the nature, density and height of any vegetation;
the nature of the channel;
the gradient;
the depth of flow.

For graded banks with bare channels, a value of 0.035 is commonly used. For vegetated channels, figure 11.2.4 gives direct solutions of Manning's formula.

To assist in the determination of grade, figures 11.2.2 and 11.2.3 give the approximate relationship between depth of flow, grade and velocity for bare channels and channels with low to moderate vegetal resistance.

Table 11.2.4(a) Dimensions of broad based banks with Trapezoidal Channels.

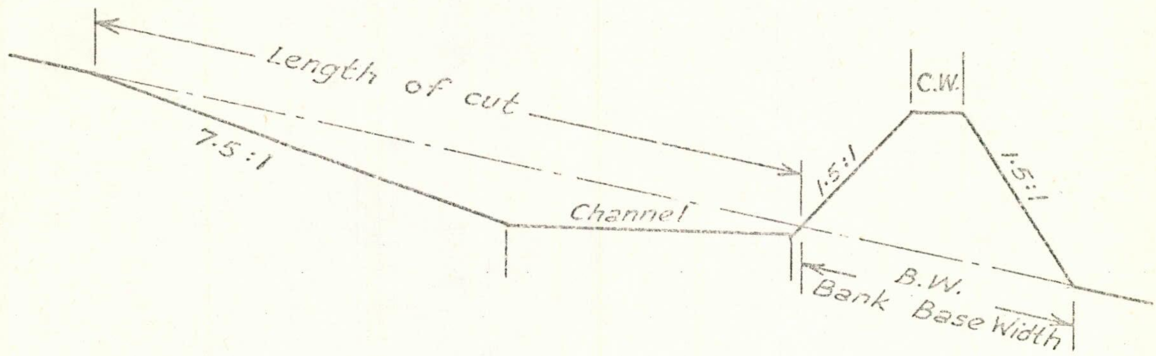


Cross Sectional Area (sq. ft.)	Channel Width	Depth of Flow (ft.)	Hyd. Radius R	Ht. of Bank above channel (ft.)	Bank Uphill (ft.)	Bank Downhill (ft.)	Cut Uphill (ft.)	Bank Base (ft.)	Max. Depth of Cut (ft.)	Slope %
15	8.5	1.02	0.71	1.50	8.5	5.7	4.5	14.0	0.7	2
						6.5	5.5	14.7	0.8	3
						7.5	7.0	15.7	0.9	4
						8.3	8.5	16.5	0.95	5
						9.4	10.0	17.6	1.05	6
20	10.0	1.17	0.82	1.62	10.0	7.0	5.0	17.0	0.8	2
						8.0	6.3	18.0	0.9	3
						9.2	7.8	19.0	1.0	4
						10.2	9.5	20.0	1.1	5
						11.8	11.5	21.5	1.2	6
25	11.0	1.32	0.91	1.80	11.0	7.8	5.8	18.5	0.9	2
						9.0	7.1	19.5	1.0	3
						10.0	8.7	20.5	1.1	4
						11.4	10.6	22.0	1.2	5
						12.9	12.7	23.5	1.3	6
30	12.0	1.45	1.00	2.00	12.0	8.3	6.2	20.5	1.0	2
						10.0	7.5	21.5	1.1	3
						11.3	9.5	23.0	1.2	4
						12.7	11.5	24.5	1.3	5
						14.3	13.5	26.0	1.4	6

Approximate length Cut and Fill from Peg Line (feet)

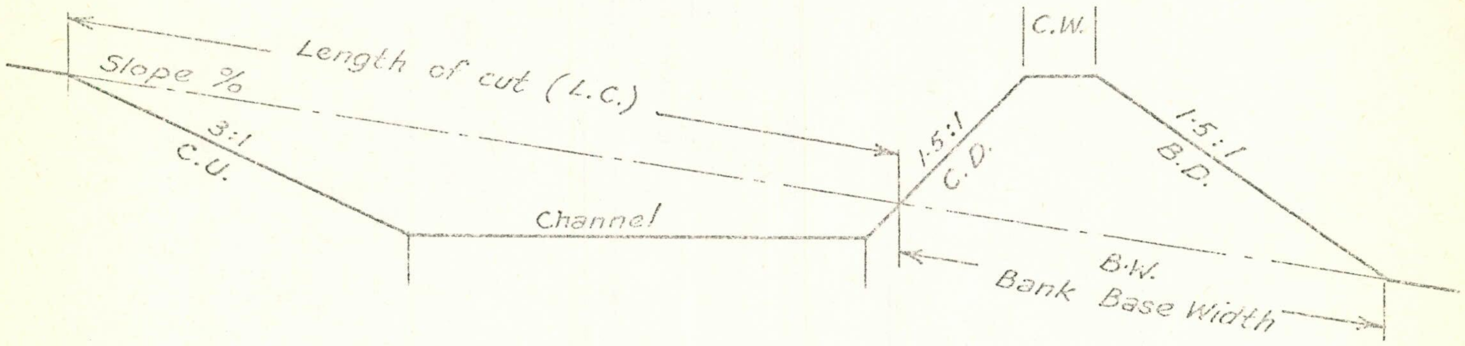
Slope %	15 sq. ft.		20 sq. ft.		25. sq. ft.		30 sq. ft.	
	Cut	Fill	Cut	Fill	Cut	Fill	Cut	Fill
2	15.5	11.5	18.0	14.0	20.0	15.5	21.5	17.0
3	16.5	12.5	19.0	15.0	21.0	16.5	22.5	18.5
4	17.5	13.5	20.5	16.5	22.5	18.0	24.0	20.0
5	19.0	14.5	22.0	17.5	24.0	19.5	26.0	21.5
6	20.5	15.5	23.5	19.0	26.0	21.0	28.5	23.0

Table 11.2.4(b) Dimensions of ridge type banks with Trapezoidal Channels



Cross Sect-ional Area (Sq. ft.)	Chan-nel Width (ft.)	Depth of Flow (ft.)	Hyd. Radius R	Settled Height Bank above channel (ft.)	Crest Width C. W. (ft.)	Length Fill (ft.)	Length Cut (ft.)	Slope %
20	10.0	1.27	0.9	1.72	0.9	5.8	15.0	3
						6.3	17.5	5
						6.7	21.5	7
25	11.0	1.43	1.0	1.93	1.0	6.5	17.0	3
						7.0	20.5	5
						7.5	25.0	7
30	12.0	1.59	1.10	2.09	1.0	7.0	19.0	3
						7.5	22.5	5
						8.0	29.0	7
40	14.0	1.81	1.27	2.46	1.1	8.0	22.0	3
						8.7	25.5	5
						9.3	31.5	7

Table 11.2.4(c) Dimensions of Diversion Banks



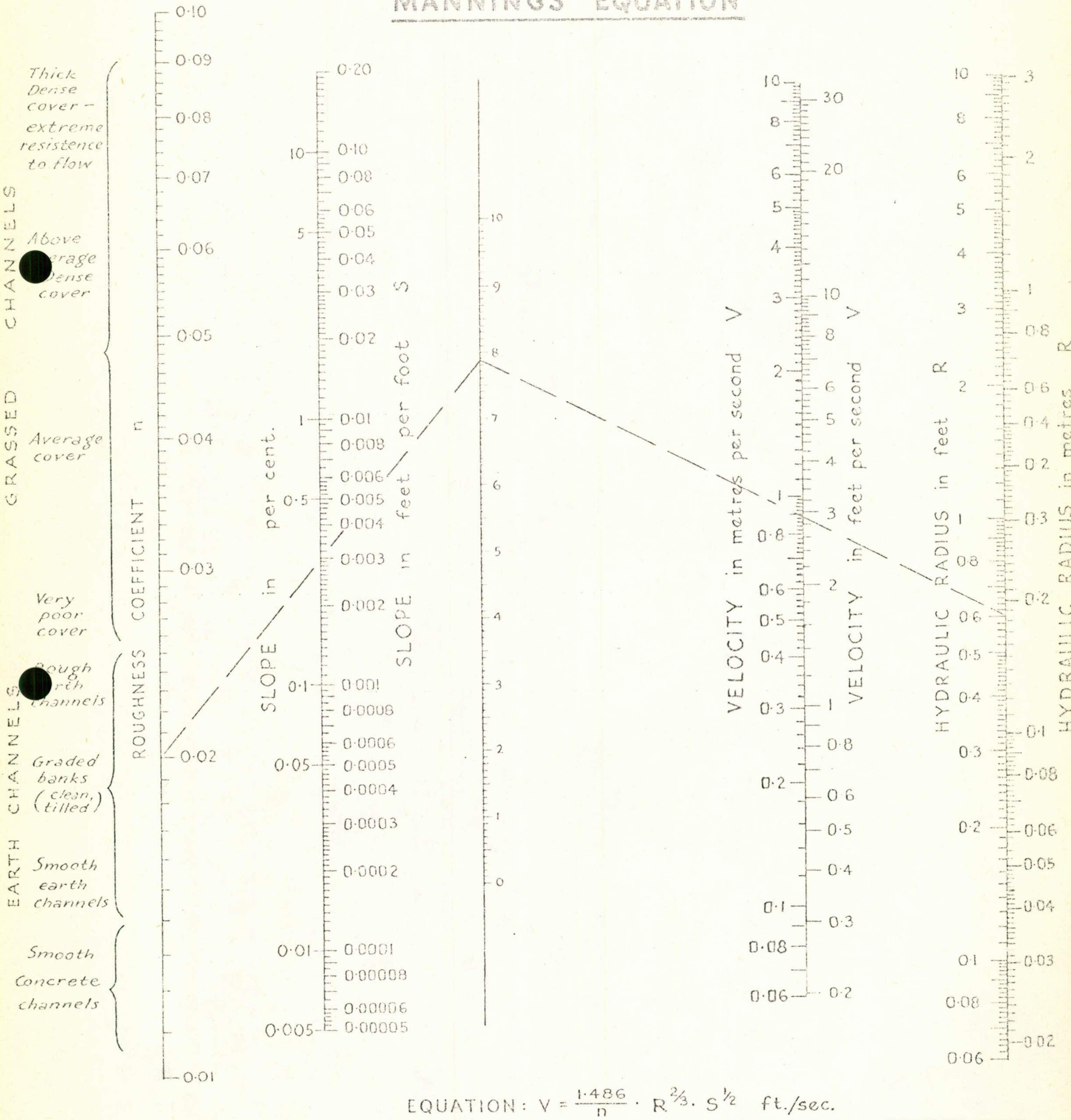
Cross Sect-ional Area (Sq. ft.)	Chan-nel Width (ft.)	Depth of Flow (ft.)	Hyd. Rad-ius R	Settled Height of bank above channel (ft.)	Crest Width C. W. (ft.)	Length of Fill (ft.)	Length of Cut LC (ft.)	Max. Depth of Cut (ft.)	Slope %
30	10	2.05	1.5	2.55	1.0	9.0	16.5	1.4	10
						9.5	18.0	1.5	12
						10.0	19.5	1.7	14
						10.5	21.5	1.9	16
40	10	2.54	1.7	3.04	1.0	10.0	18.0	1.6	10
						10.5	19.0	1.7	12
						11.5	21.0	1.9	14
						12.0	23.0	2.1	16
50	10	2.99	2.0	3.49	1.0	11.0	19.0	1.8	10
						11.5	20.5	1.9	12
						12.5	22.0	2.1	14
						13.0	24.0	2.3	16

Figure 11.2.1.

NOMOGRAM

for solution of

MANNING'S EQUATION



EQUATION: $V = \frac{1 \cdot 486}{n} \cdot R^{2/3} \cdot S^{1/2}$ ft./sec.

$V = \frac{1}{n} \cdot R^{2/3} \cdot S^{1/2}$ metres/sec.

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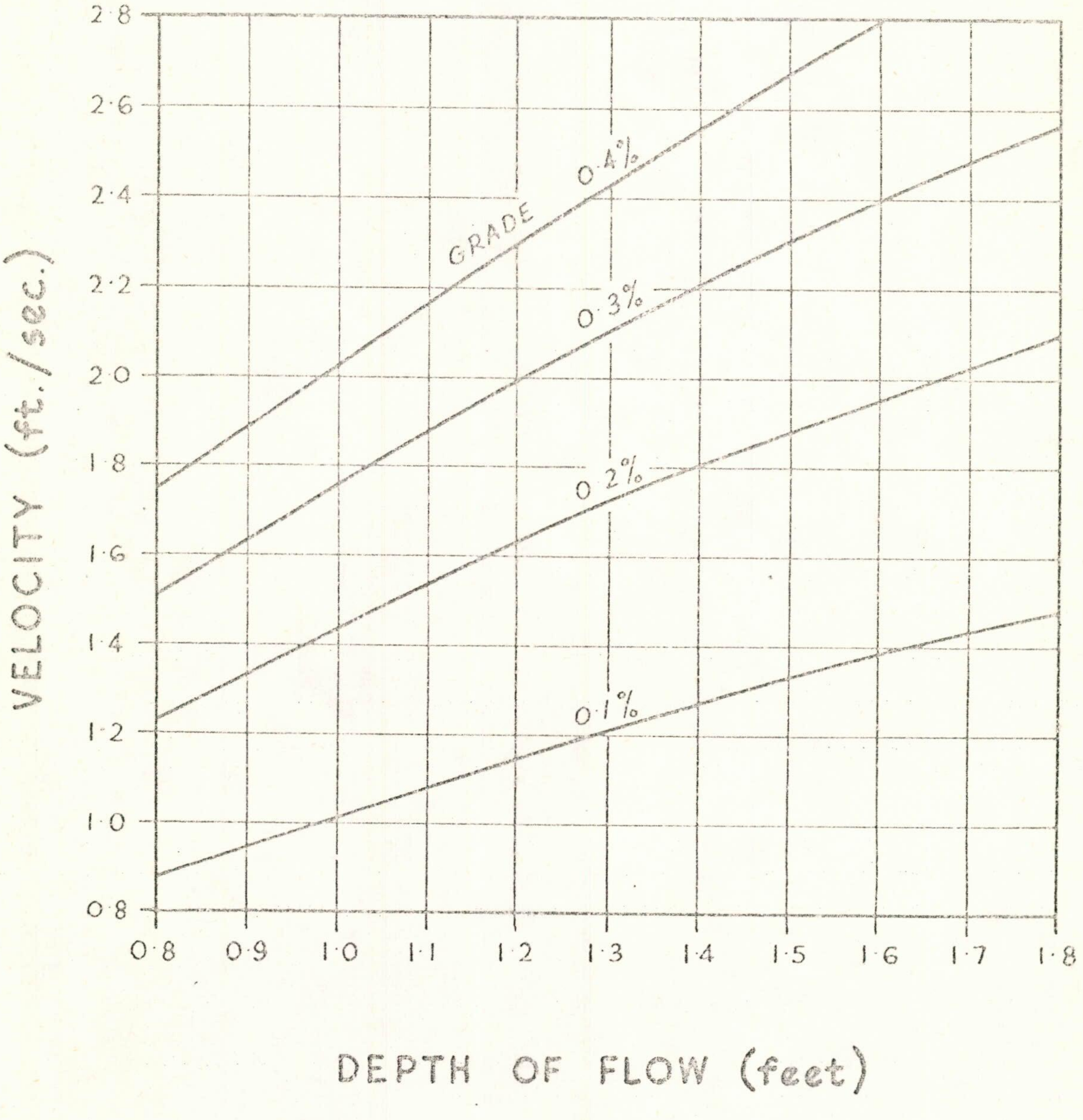


Figure II.2.2. Approximate relationship between depth of flow, grade of channel and velocity of flow in bare channels

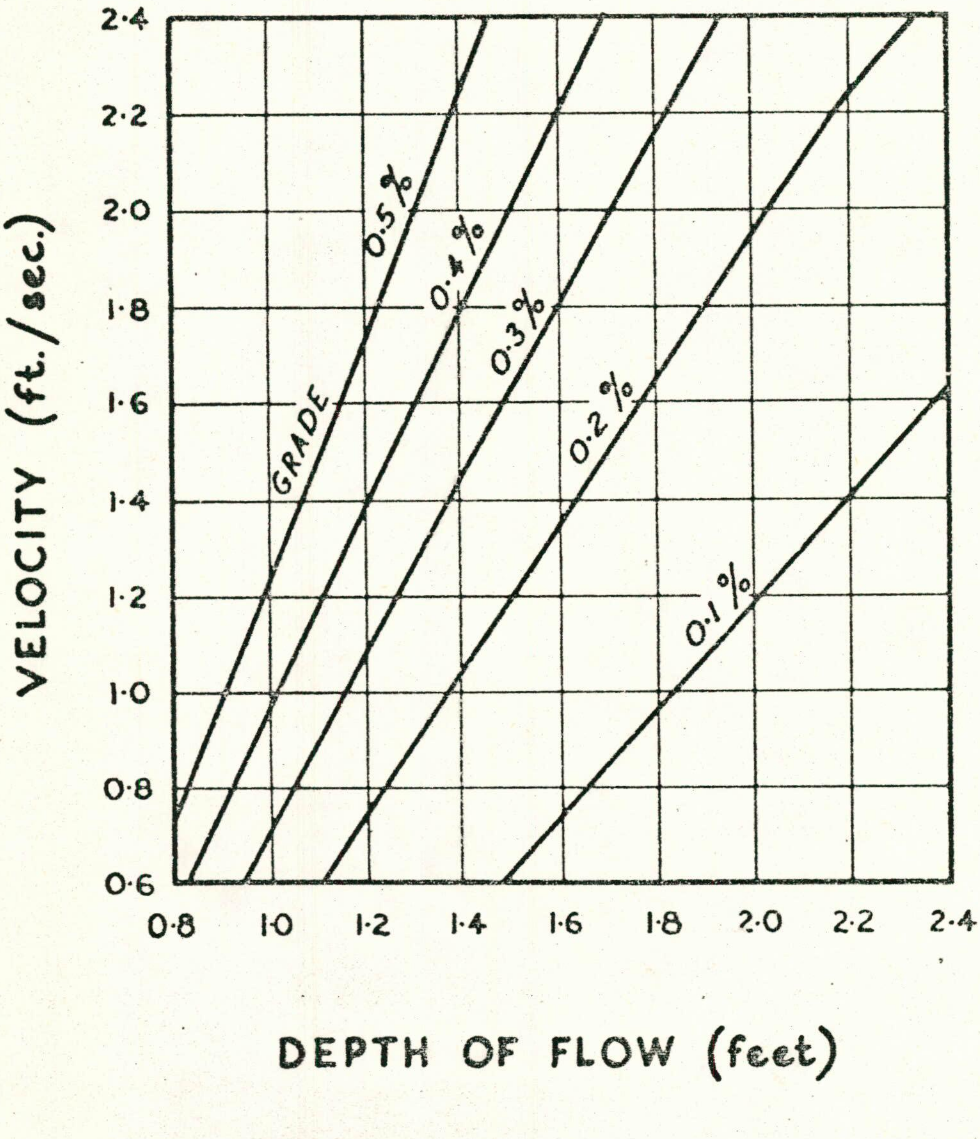


Figure II.2.3. Approximate relationship between depth of flow, grade of channel and velocity of flow in vegetated channels. (Good stands 2-6" high or Fair stands 2-10" high.)

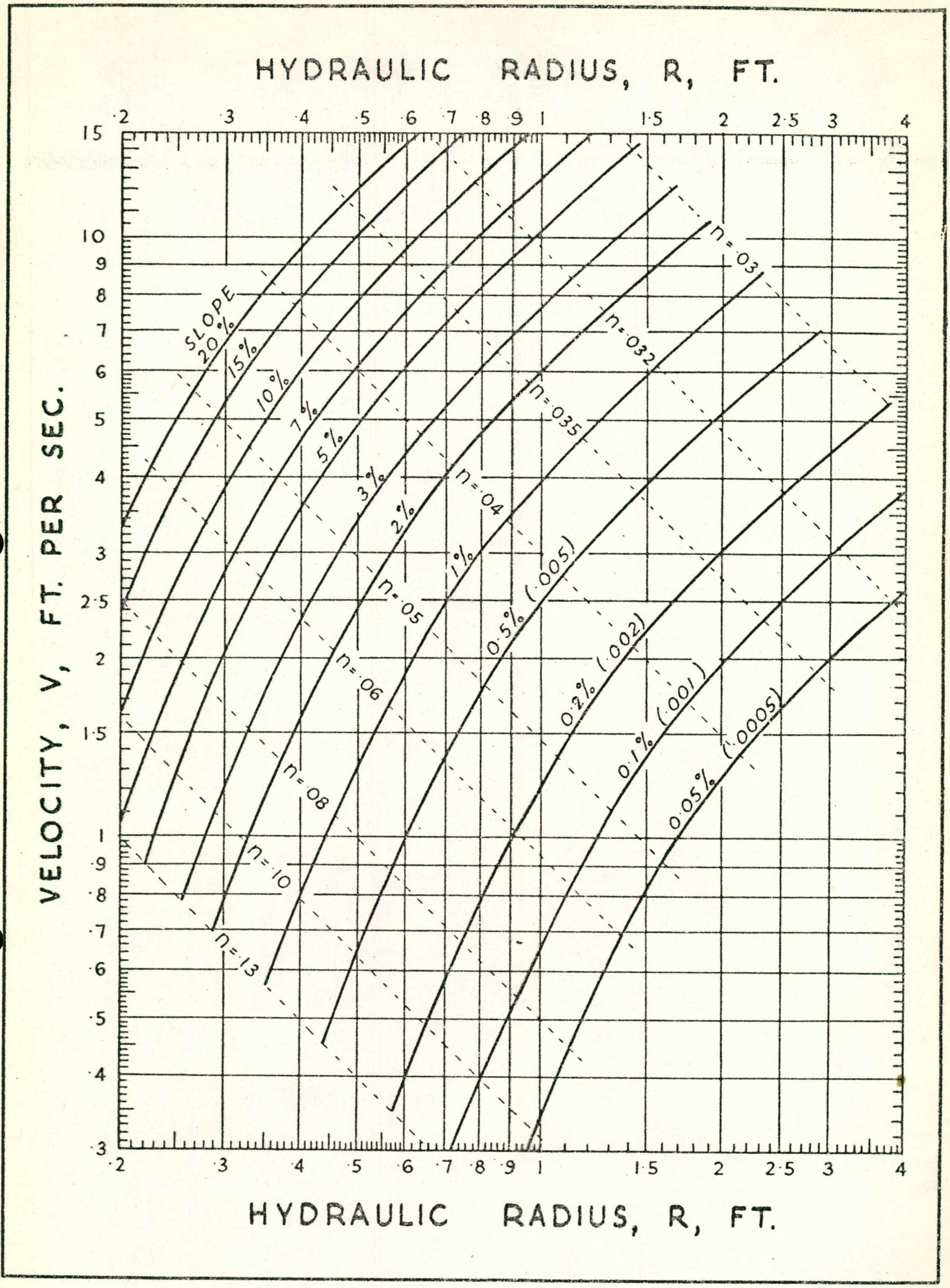


Figure II.2.4(a) Solution of Mannings Formula for vegetated channels of low vegetal retardance (Good stand 2 - 6 inches high or Fair stand 2-10 inches high.)

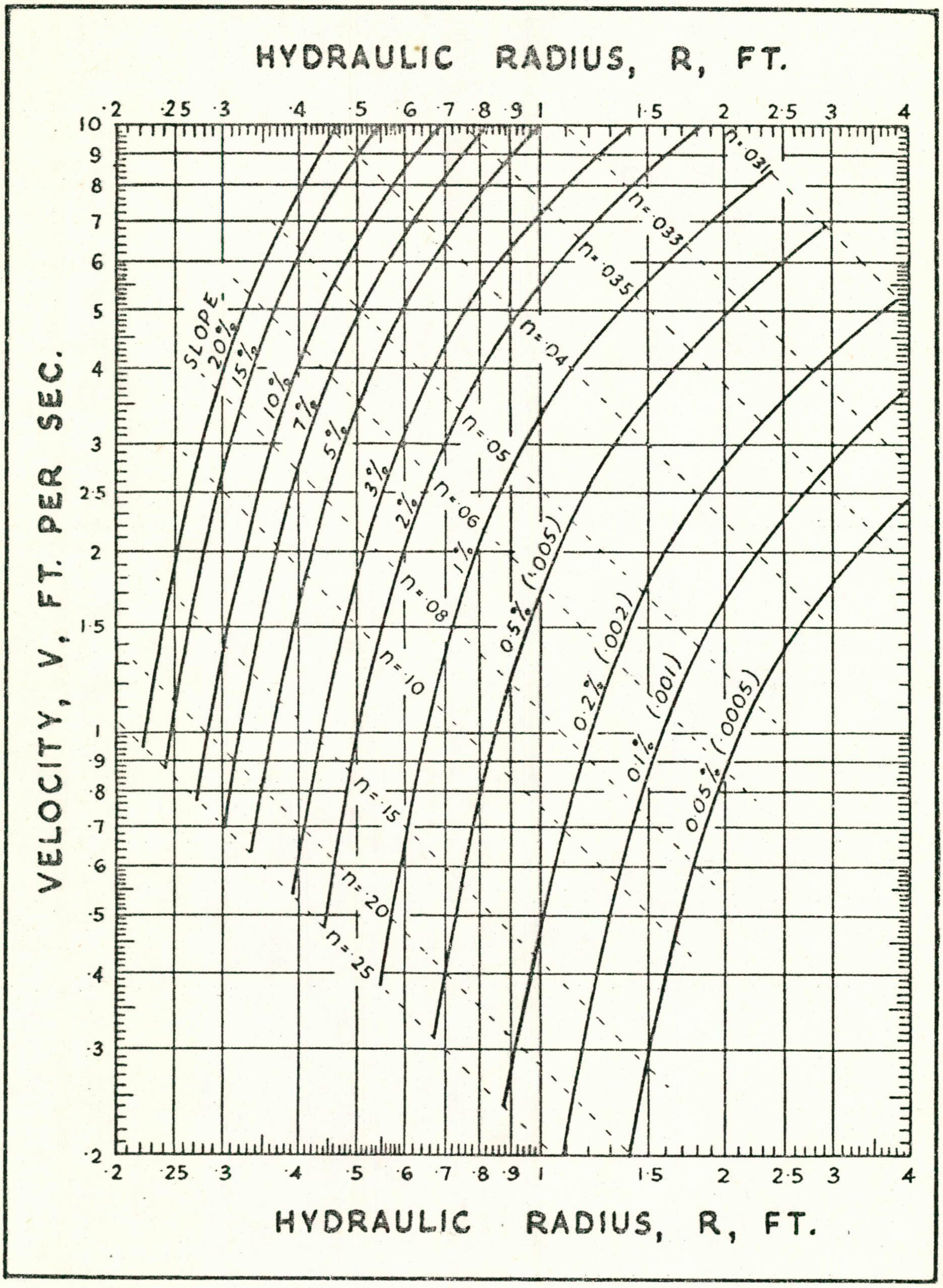


Figure 11.2.4 (b) Solution of Mannings Formula for vegetated channels of moderate vegetal retardance (Good stand 6-10 inches high or Fair stand 11-24 inches high.)

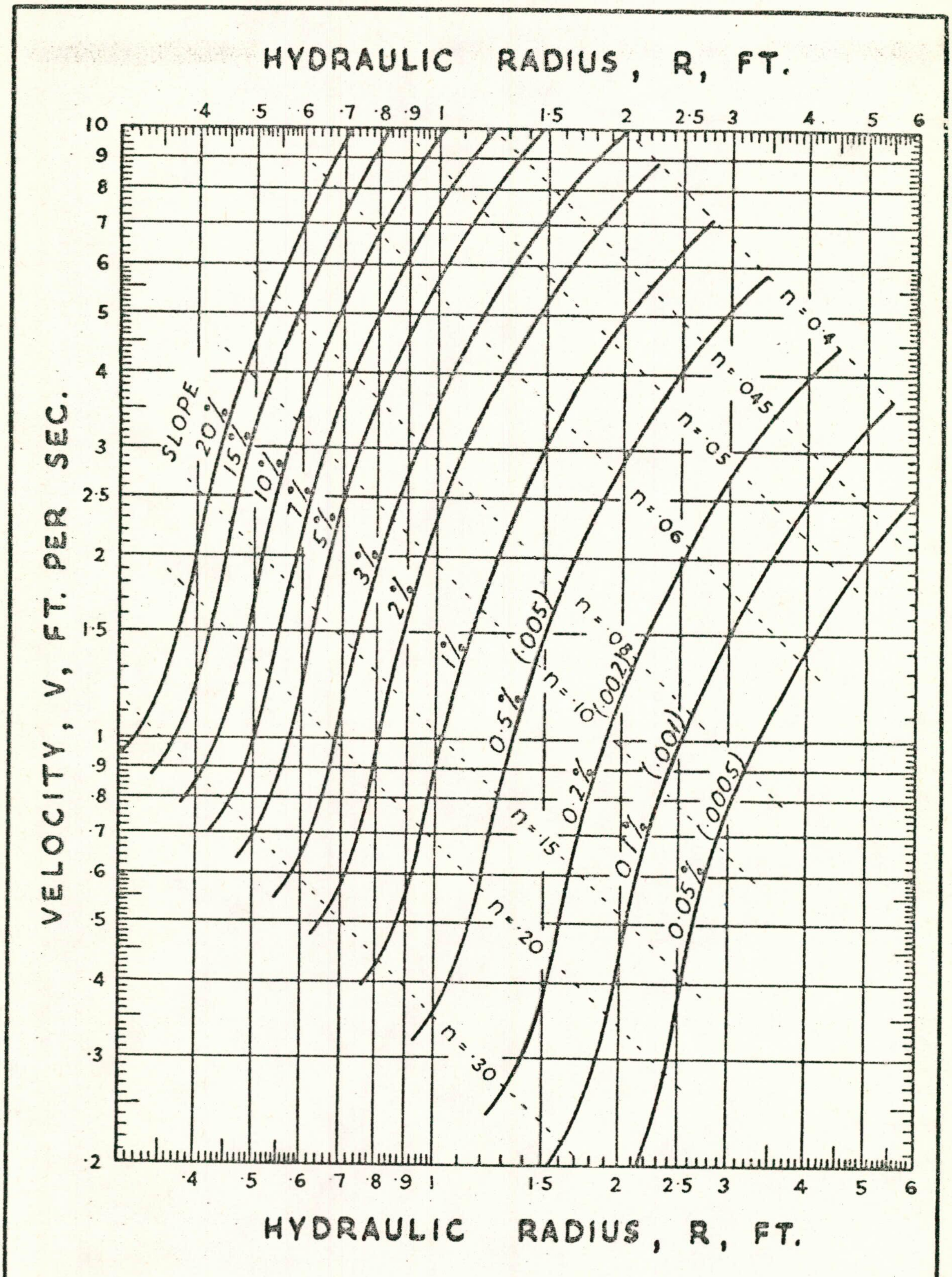


Figure 11.2.4(c) Solution of Mannings Formula for vegetated channels of high vegetal retardance.
(Good stand 11-12 inches high or
Fair stand greater than 24 inches high.)

If the calculation of cross-sectional area is based on bare soil conditions figure 11.2.2 is used for the determination of grade of the channel.

If the calculation of required area has allowed for vegetation by adding 50%, figure 11.2.3 should be used to determine grade, keeping in mind that velocity will be reduced by two-thirds.

Example

1. Calculated q = 30 cusecs.
2. Maximum velocity = 1.4 ft. per sec.
3. Cross-sectional area = $\frac{30}{1.4}$ = 22 sq. ft. (if vegetal resistance is anticipated, the required cross-section is 33 sq. ft.)
4. Land slope is 4%; channel is to be 12 ft. wide; batters are channel uphill 6:1, channel downhill 6:1, bank downhill 5:1, freeboard 0.5 ft.
5. From table 11.2.4, height of bank is 1.8 ft. (approx.)
6. Also from table 11.2.4, the depth of flow for a cross-sectional area of 22 s2. ft. (30 cusecs at 1.4 ft. per sec.) is 1.3 ft.
7. From figure 11.2.2 for depth of 1.3 ft. and velocity of 1.4 ft. per second grade is 0.15%.

Note If the calculation of grade is carried out for the 33 sq. ft. cross-section, the velocity is 0.95 ft. per sec. and the grade from figure 11.2.3 is 0.15%.

11.2.3 Level Banks

When used on arable land, these are left open at the ends so that they will empty after rain and be ready to receive run-off from following rains.

Because of the absence of a gradient in the channel, flow will depend on the level of water and there is a complex relationship between bank spacing, bank height and bank capacity.

11.2.3.1 Bank Spacing

The maximum spacing for such banks is that given for graded banks in 11.2.2.1 and table 11.2.1.

11.2.3.2 Bank Height

Table 11.2.5 gives suitable bank heights for a range of bank lengths and spacings.

These heights allow for 0.5 ft. freeboard and are sufficient to allow a discharge of 1 cusec per acre from the inter-bank areas. Coefficient of roughness is taken as 0.050 to allow for possible resistance to flow by vegetation. These figures are for a bank with a channel width of 10 ft., a channel uphill batter of 5:1 and bank uphill batter of 1.5:1.

While runoff rates of greater than 1 cusec per acre may be experienced, these are unlikely to persist for long durations and the storage capacity of the banks should be sufficient to compensate for this extra runoff. Amounts of runoff that can be temporarily stored in the banks are also given in table 11.2.5.

The relationship between bank spacing and cross-sectional area is given by:

$$HI = \frac{a}{5.5\ Q}$$

where HI = horizontal interval
a = cross-sectional area
Q = runoff in inches.

Runoff Q can be determined from -

$$Q = CI$$

where C = coefficient of runoff
I = rainfall in inches.

If it is desired to check the runoff, the 1 hour rainfalls give a suitable measure of the heavy rain that is likely to occur.

11.3 Drainage Banks on Grazing Land

11.3.1 General

Banks referred to in this section are either graded banks or open-ended level banks. Closed end level banks (pondage or absorption banks) which are also used on grassland are dealt with in Section 11.5.

11.3.2 Banks on Potentially Arable Land

This is Class III land that is potentially arable but is under pasture at the time of banking. Bank spacings should be such that it will be possible to adapt the system to provide adequate protection should the land-use be changed and the area enters regular cultivation. Spacings should be determined as outlined in 11.2 and then doubled or tripled according to the degree of erosion and the capacity of the banks to handle the runoff. The bank size that is required is, in the case of graded banks, determined from $a = q/v$ as outlined in 11.2.2.2. Rate of runoff q is calculated as described in 11.1 and values for v are given in table 11.2.2.

For open ended level banks, bank size is determined as described in 11.2.3.

11.3.3 Diversion Banks on Hilly Grazing Land

Location of the banks and spacing of the banks is frequently determined by the availability of outlets, rock outcrops, gully heads and patches of severe erosion. Natural outlets are normally used and the stability of these will often be the limiting factor in determining the acreage to be drained.

Table 11.2.5 Bank Heights and Storage Capacities - Level Banks

Bank spacing (chains)	Bank Length (Chains) 10 Ht. (ft)	10 Storage (in)	20 Ht. (ft)	20 Storage (in)	30 Ht. (ft)	30 Storage (in)	40 Ht. (ft)	40 Storage (in)	50 Ht. (ft)	50 Storage (in)
3	1.7	1.0	1.8	1.1	2.0	1.3	2.4	1.6	2.7	2.2
4	1.7	0.8	1.8	0.9	2.3	1.3	2.6	1.6	2.9	1.9
5	1.7	0.6	1.8	0.7	2.5	1.2	2.8	1.5	3.1	1.8
6	1.7	0.5	2.1	0.8	2.7	1.1	3.0	1.4	3.3	1.6
8	1.7	0.4	2.1	0.6	2.7	0.8	3.0	1.0	3.3	1.2

The capacity required in the banks is determined as previously outlined. Note however, that the channels will be vegetated and figure 11.2.3 should be used to determine grade.

Wherever possible, level sill outlets should be used. Figure 11.3.1 is used to determine suitable sill widths. For sills on natural pastures, the lower velocity of 3.5 ft. per second should be used.

11.3.4 Open-ended Level Banks

These are used on both potentially arable land (Class III land) and on hilly grazing land.

For the Class III land, table 11.2.5 indicates minimum heights for the banks. On hilly grazing land, the area drained by the bank is known rather than the bank spacing. Table 11.3.1 gives a series of minimum heights for banks of various lengths and catchment areas. These are for a bank with a 10 foot channel 5:1 upslope and 1½:1 downslope batters and allowing 0.5 feet for freeboard. Runoff is taken as 0.8 cusecs per acre.

Table 11.3.1 Bank Heights for Level Banks (ft)

Catchment Area	Bank Length (Chains)			
	10	20	30	40
10 acres	2.0 ft	2.0 ft	2.0 ft	2.0 ft
15 acres	2.1	2.1	2.4	2.5
20 acres	2.4	2.4	2.6	2.7
30 acres	2.8	2.8	2.9	3.1

11.4 Waterways

Where waterways are used the following criteria and method for determining the width should be used.

11.4.1 Required Capacity

The capacity that will be required will be the peak discharge in cusecs estimated as outlined in section 11.1. For exceptionally long waterways it may be desirable to estimate the flow at a number of points but generally the flow at the outlet is the one taken for design purposes.

11.4.2 Permissible Velocity of Flow

The maximum velocity of flow that can be permitted will depend on cover, slope and soil type.

Maximum velocities for vegetated waterways are given in table 11.4.1.

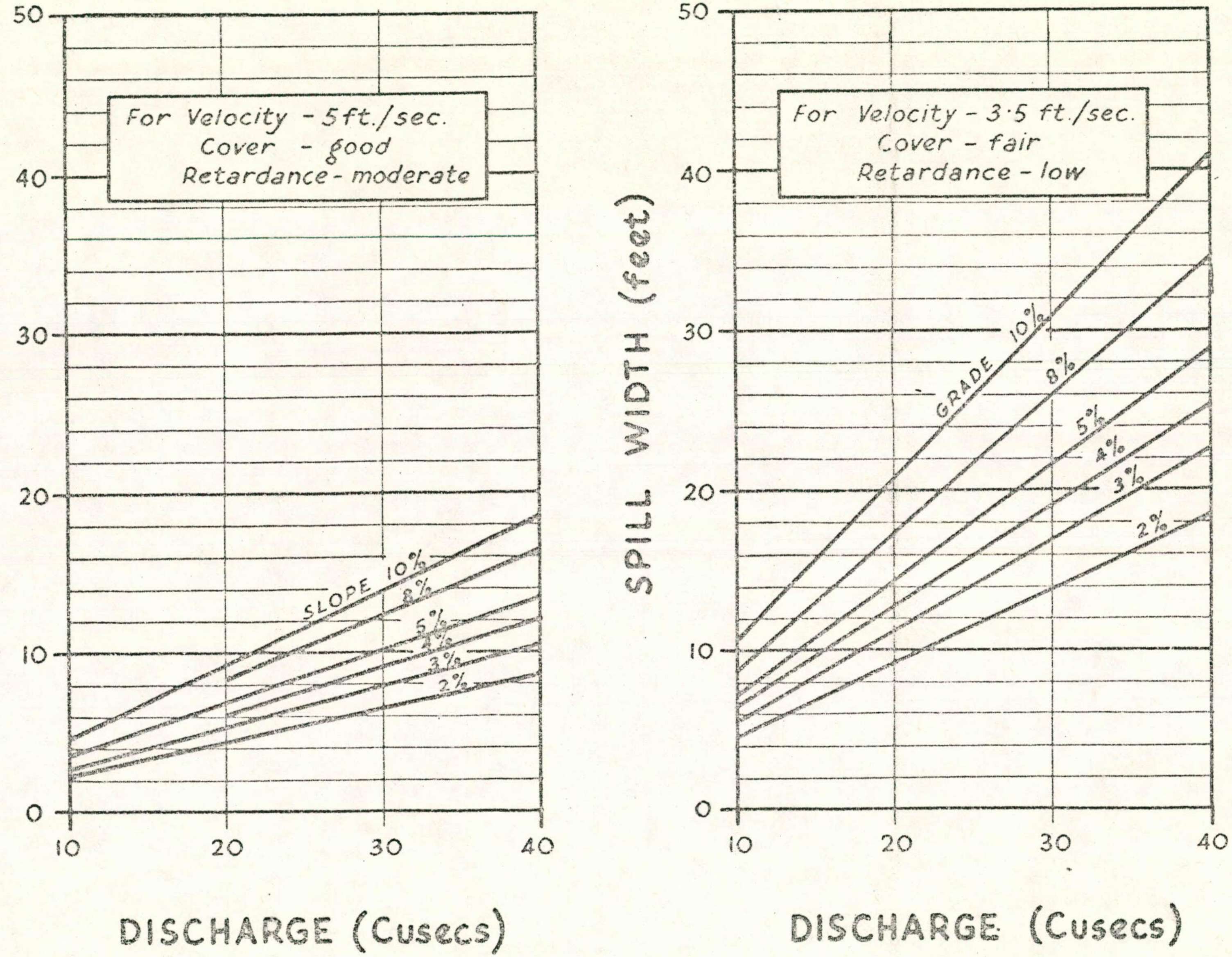


Figure 11:3:1 Sill lengths for outlets of banks

Table 11.4.1 Maximum Velocities of Flow for Vegetated Waterways

	Maximum velocity ft/sec		
	Group A Soils	Group B Soils	Group C Soils
Kikuya Grass	8	6	5
Couch grass, Phalaris	6	5	4
Improved pasture predominately clover	5	4	3.5
Native pasture	4	3.5	3

Group A soils	Red and Yellow Earths	Gn 2.12 Gn 2.13 Gn 2.25
Group B soils	Red Brown Earths	Dr 2.22 Dr 2.23 Dr 2.33
Group C soils	Podzolics, solodics and solonetzics	Dr 2.21 Dr 3.21 Dr 2.43 Dr 2.32 Dr 3.42 Dy 3.42 Dy 3.43

11.4.3 Depth of Flow

For waterways with a level cross-section, the hydraulic radius R may be taken as being equal to the depth of flow.

In vegetated channels, there is a complex relationship between depth and velocity of flow and the density and height of the vegetation. For such channels, the graphs of figure 11.2.4 provide a ready solution.

For the velocities given in table 11.4.1 and the range of slopes encountered in soil conservation work in the Wagga district, table 11.4.2 gives depths of flow for various degrees of vetetal resistance.

The low or moderate retardance figures as given should be used in calculation of waterway width and the high retardance figures indicate maximum flow height under dense vegetation.

11.4.4 Waterway Width

Waterway width is calculated as follows:

$$\text{Cross-sectional area} = \frac{\text{Capacity (cusecs)}}{\text{Velocity of flow (ft per sec)}}$$

$$\text{Width} = \frac{\text{Cross-sectional area (ft)}}{\text{depth of flow (ft)}}$$

To simplify determination of waterway widths, tables 11.4.3, 11.4.4, 11.4.5 and 11.46 give widths for a range of flow and slope conditions.

For cases outside the range of these tables, the widths per cusec of flow from Table 11.4.2 are used.

Table 11.4.2 Depths of Flow and required widths for Waterway Calculations

Grade	Depths (ft.) Retardance 3.5 ft. per sec. Low	High	Width per Cusec (ft.)	Depths (ft.) Retardance 4.0 ft. per sec. Low	High	Width per Cusec (ft.)	Depths (ft.) Retardance 5.0 ft. per sec. Low	High	Width per Cusec (ft.)
2%	0.63	1.20	0.453	0.70	1.30	0.357	0.85	1.50	0.235
3	0.50	1.00	0.571	0.56	1.10	0.446	0.67	1.20	0.299
4	0.45	0.88	0.635	0.49	0.94	0.510	0.57	1.00	0.351
5	0.40	0.78	0.714	0.43	0.82	0.582	0.50	0.92	0.400
6	0.37	0.72	0.771	0.40	0.77	0.625	0.45	0.85	0.445
7	0.35	0.68	0.816	0.37	0.72	0.676	0.42	0.80	0.476
8	0.33	0.70	0.865	0.35	0.67	0.714	0.39	0.76	0.513
10	0.28	0.55	1.020	0.31	0.62	0.806	0.35	0.70	0.572
	6.0 ft. per sec. Moderate	High		7.0 ft. per sec. Moderate	High		8.0 ft. per sec. Moderate	High	
2%	1.10	1.60	0.152	1.25	1.80	0.114	1.40	2.00	0.089
3	0.86	1.30	0.194	0.99	1.40	0.145	1.10	1.60	0.114
4	0.76	1.20	0.220	0.83	1.25	0.173	0.93	1.40	0.135
5	0.66	1.10	0.252	0.74	1.15	0.194	0.82	1.25	0.152
6	0.60	0.95	0.278	0.68	1.05	0.210	0.76	1.15	0.165
7	0.57	0.90	0.292	0.62	0.98	0.231	0.69	1.05	0.181
8	0.53	0.68	0.314	0.53	0.81	0.270	0.58	0.90	0.215
10	0.48	0.66	0.347	0.53	0.81	0.270	0.58	0.90	0.215

NOTE: For velocities of 3.5, 4.0 and 5.0 feet per second, widths are based on conditions of low vegetal retardance and for 6.0, 7.0 and 8.0 feet per second on conditions of moderate vegetal retardance.

Table 11.4.3 Waterway Width (Feet)

Slope %	Design depth of Flow (ft)	Capacity in Cusecs 20	40	60	80	100	125	150	175	Maximum depth of Flow (ft)
2	0.63	9	18	27	36	45	57	68	80	1.20
3	0.50	11	23	34	46	57	72	86	100	1.00
4	0.45	13	25	38	51	64	80	95	111	0.88
5	0.40	14	29	43	57	71	89	107	125	0.78
6	0.37	15	31	46	62	77	96	116	135	0.72
7	0.35	16	33	49	65	82	102	122	143	0.68
8	0.33	17	35	52	69	87	108	130	151	0.70

Velocity of Flow 3.5 ft. per second.
Low Vegetal retardance:
Add freeboard to figures in right hand column for minimum bank height

TABLE 11.4.4

WATERWAY WIDTH (FEET)

Slope %	Design Depth of Flow (ft.)	Capacity in cusecs											Maximum Depth of Flow (ft.)
		20	40	60	80	100	125	150	175	200	250	300	
2	0.70	7	14	21	29	36	45	54	63	71	89	107	1.30
3	0.56	9	18	27	36	45	56	67	78	90	112	134	1.10
4	0.49	10	20	31	41	51	64	77	90	102	128	153	0.94
5	0.43	12	23	35	47	58	73	88	102	116	145	175	0.82
6	0.40	13	25	38	50	63	78	94	110	125	157	188	0.77
7	0.37	14	27	41	54	68	85	102	118	136	170	-	0.72
8	0.35	15	29	43	57	71	89	107	125	143	178	-	0.67

- Velocity of flow 4 feet per second
- Low vegetal retardance
- Add required freeboard to figures in right hand column for minimum bank height.

TABLE 11.4.5

WATERWAY WIDTH (FEET)

Slope %	Design Depth of Flow (ft)	Capacity in cusecs											Maximum Depth of Flow (ft)
		20	40	60	80	100	125	150	175	200	250	300	
2	0.85	5	10	14	19	23	29	35	41	47	59	70	1.50
3	0.67	6	12	18	24	30	37	45	52	60	75	90	1.20
4	0.57	7	14	21	28	35	44	53	62	70	88	105	1.00
5	0.50	8	16	24	32	40	50	60	70	88	100	120	0.92
6	0.45	9	18	27	36	45	56	67	78	89	111	133	0.85
7	0.42	10	19	29	38	48	60	71	84	95	119	143	0.80
8	0.37	10	20	31	41	51	64	77	90	103	129	154	0.76

- Velocity of flow 5 feet per second
- Low vegetal retardance
- Add freeboard to figures in right hand column for minimum bank height.

TABLE 11:4.6

WATERWAY WIDTH (FEET)

Slope %	Design Depth of Flow (ft)	Capacity in cusecs											Maximum Depth of Flow (ft)
		20	40	60	80	100	125	150	175	200	250	300	
2	1.10	4	6	9	12	15	19	23	27	30	38	46	1.60
3	0.86	4	8	12	16	19	24	29	34	39	48	58	1.30
4	0.76	5	9	13	18	22	28	33	39	44	55	66	1.20
5	0.66	5	10	15	20	25	32	38	44	50	63	75	1.10
6	0.60	6	11	17	22	28	35	42	49	56	70	84	0.95
7	0.57	6	12	18	24	30	37	44	52	59	73	88	0.90
8	0.53	7	13	19	25	32	40	47	55	63	79	94	0.68

- Velocity of flow 6 feet per second
- Moderate vegetal retardance
- Add freeboard to figure in right hand column for minimum bank height.

11.5 Absorption Banks

11.5.1 General

These are level banks closed at each end so that runoff is retained. It is usual for one or both ends to be left lower than the bank so that, if excessive runoff occurs, the bank will spill before the bank is overtopped.

Where the soil is impervious, absorption banks tend to hold water for long periods and so become relatively ineffective. In wet seasons, useful plants may be drowned out and useless plants encouraged.

11.5.2 Size and Spacing

Spacing and size are related by:

$$HI = \frac{12a}{Q}$$

and

$$a = \frac{HI \times Q}{12}$$

where HI = horizontal interval in feet
a = cross-sectional area in feet
Q = quantity of runoff in inches.

Quantity of runoff Q is determined from long duration rains by Q = C x Rainfall. For short banks on soils that are not particularly impervious, the one day rain should be used, but for banks on impervious soil the 3 day rain.

For the Wagga district, the long duration rainfalls for the different return periods are given in Table 11.5.1.

Table 11.5.1 Wagga district Long Duration Rainfall

Period	Frequency of Occurrence		
	5 years	10 years	20 years
1 day	260 points	280 points	285 points
3 days	335 points	400 points	460 points

Values of C can be determined from table 11.1.3 using the less than inch per hour rainfall intensity figure.

11.5.3 Storage

It is sometimes advantageous to know the storage capacity of these structures so that they can be compared with the capacity of a gully control structure. These are given in table 11.5.2. If absorption-diversion banks are used, the cross-section areas below spillway level should be used in calculation of storage.

Table 11.5.2

Storage Cross-sectional Area (sq.ft.)	Capacity of Banks (cu yds) Length (Chains) 10	20	30	40	50	60
10	244	488	732	1220	1220	1464
15	366	732	1098	1830	1830	2196
20	488	976	1464	2440	2440	2928
25	610	1220	1830	3050	3050	3660
30	732	1464	2196	3660	3660	4392
35	854	1708	2562	4270	4270	5124

11.5.4 Pipe Outlets

Where pipe outlets are used to reduce the period during which water is stored in absorption banks, the following should be considered.

(1) Discharge from pipes larger than 2 inch diameter can cause rilling to bare areas, gully fill or highly erodible soils. Care should therefore be taken in the location of these larger pipes.

(2) As the discharge through any pipe size, (up to 6 inches) even with a 3 ft. head, is negligible in terms of cusecs (6" pipe - 3 ft. head - discharge 1 cusec) the discharge intake ratio should be disregarded in any calculations of runoff and storage. For this reason it is recommended that:

(a) the size and spacing of banks should be calculated as per section 11.5.2.

(b) Storage of banks should be as per 11.5.3.

(c) Total discharge of flows from banks through pipes should not be attempted.

(3) The size and number of pipes in any bank should have sufficient discharge to:

(a) Ensure drainage of the bank prior to expected return of follow-up rains.

(b) Ensure drainage prior to causing drowning out of useful plant species.

(c) Ensure that pipe flows from other sources (e.g. higher banks) into the bank will not cause over-topping.

Table 11.5.2 shows approximate discharges which may be expected from pipe outlets.

Table 11.5.2 Discharge from Dribble Pipe Outlets - Cu yds/hr

Pipe Size	2"	3"	4"	6"
Head in ft.				
3.3	9.0	24	50	145
3.0	8.5	23	49	135
2.75	8.0	22	47	130
2.5	7.75	21	45	125
2.0	7.0	20	40	115
1.5	5.9	17	35	100
1.0	4.7	14	28	80

Table 11.5.2 used in conjunction with table 11.2.5 and figure 11.5.1 (nomogram relating catchment runoff and storage) will give a reasonable assessment of pipe sizes and numbers to be used.

11.6 Gully Control Structures

11.6.1 Batters

The slope of the batters will depend on the type of material used. Recommended slopes are given in table 11.6.1.

Table 11.6.1 Minimum Batter Grades for Embankments of Gully Control Structures

	Material	Upstream Batter	Downstream Batter
A.	Gravels and sands with appreciable amounts of silt and clay	2½:1	2½:1
B.	Silty fine sands, silts of low plasticity. Gravelly clays sandy clays, clays of low to medium plasticity	3:1	2½:1
C.	Clays of high plasticity Silts of high plasticity	3½:1	3:1

Note: If the soils are susceptible to tunnelling the batter grades should be flattened by 1/2 unit e.g. 2½:1 becomes 3:1.

If no plasticity test is available soils with more than 65% clay should be considered as belonging to Group C. These soils are very sticky when wet and the dough can be rolled into long threads that can be formed into a ring.

11.6.2 Surcharge

This is the height of water above spillway level when the maximum outflow is taking place.

Surcharge heights can be read from table 11.6.3 when the velocity of discharge has been selected.

11.6.3 Freeboard

Freeboard is the vertical distance allowed in addition to surcharge. For farm structures, the following height should be used:

Up to 2,000 cub. yds. capacity - 2.0 ft.
2,000 to 4,000 cub. yds. capacity - 2.5 ft.
Above 4,000 cub. yds. capacity - 3.5 ft.

These heights are those after settling has taken place and should be considered the minimum.

11.6.4 Settlement

The amount of settlement of the wall will depend on the materials used, the amount of compaction achieved during construction and the height of the wall. For structures of the size used in soil conservation works, the embankment should be constructed 10% higher than the design height.

Up to 10 feet add 1.0 foot to design height
10 to 15 feet add 1.5 feet to design height
15 to 20 feet add 2.0 feet to design height

11.6.5 Top Width

Table 11.6.2 gives suitable top widths for the walls of gully control structures or earth embankments.

Table 11.6.2 Top Widths for Earth Embankments

Height (ft)	Top Width (ft)
4.0	6.0
6.0	7.0
8.0	7.5
10.0	8.5
12.0	9.0
14.0	9.5
16.0	10.0
18.0	10.5
20.0	11.0

11.6.6 Spillways

The capacity of the spillway can be determined from table 11.6.3.

Table 11.6.3 Spillway Depths and Capacities

Conditions	Maximum Velocity (ft/sec)	Maximum Depth (ft)	Surcharge (ft)	Width per cusec (ft)
Erodible soils and poor cover	3.0	0.4	0.5	0.95
	3.5	0.5	0.7	0.60
Intermediate	4.0	0.6	0.9	0.40
	4.5	0.8	1.2	0.30
Good cover and erosion resistant soils	5.0	1.0	1.5	0.20
	5.5	1.2	1.8	0.15
	6.0	1.4	2.1	0.10

To obtain the spillway width:

(a) Determine the critical runoff in cusecs (from Section 11.7).

(b) Determine the appropriate soil and cover conditions.

(c) From this, decide the velocity at the outlet.

(d) From table 11.6.3, read the width per cusec.

(e) Multiply the runoff in cusecs by width per cusec.

Example - If the soil is considered to be not highly erodible and with fair cover, the maximum velocity is 4.0 ft. per sec. and width per cusecs 0.4 ft. If the discharge is 60 cusecs then width is 0.4 x 60 = 24 ft.

11.6.7 Catchment Area - Runoff - Storage Relationship

One inch of runoff per acre is approximately 134 cubic yards. From this the capacity required to hold a certain runoff from a given catchment area can be calculated. e.g. $\frac{1}{2}$ inch runoff from 80 acres = 0.5 x 80 x 134 = 5,360 cubic yards.

A graphical solution is given in figure 11.5.1.

Figure 11.6.1 is a graph relating cubic yards to acre feet and to gallons.

11.7 Grass Flumes

These are used to conduct runoff safely to a lower level e.g. from a waterway to the floor of a gully, or the overshot spillway of a gully control structure.

11.7.1 Velocity of Flow

The maximum velocities of flow are given in table 11.7.1.

Table 11.7.1 Maximum Velocities of Flow for Vegetated Flumes

Cover	Maximum Velocity of Flow		
	Group A Soils ft/sec	Group B Soils ft/sec	Group C Soils ft/sec
Couch grass) In dense Phalaris) swards Kikuyu grass)	7	6	5
Improved pasture predominately clover	6	5	4
Native pasture	4	3.5	3

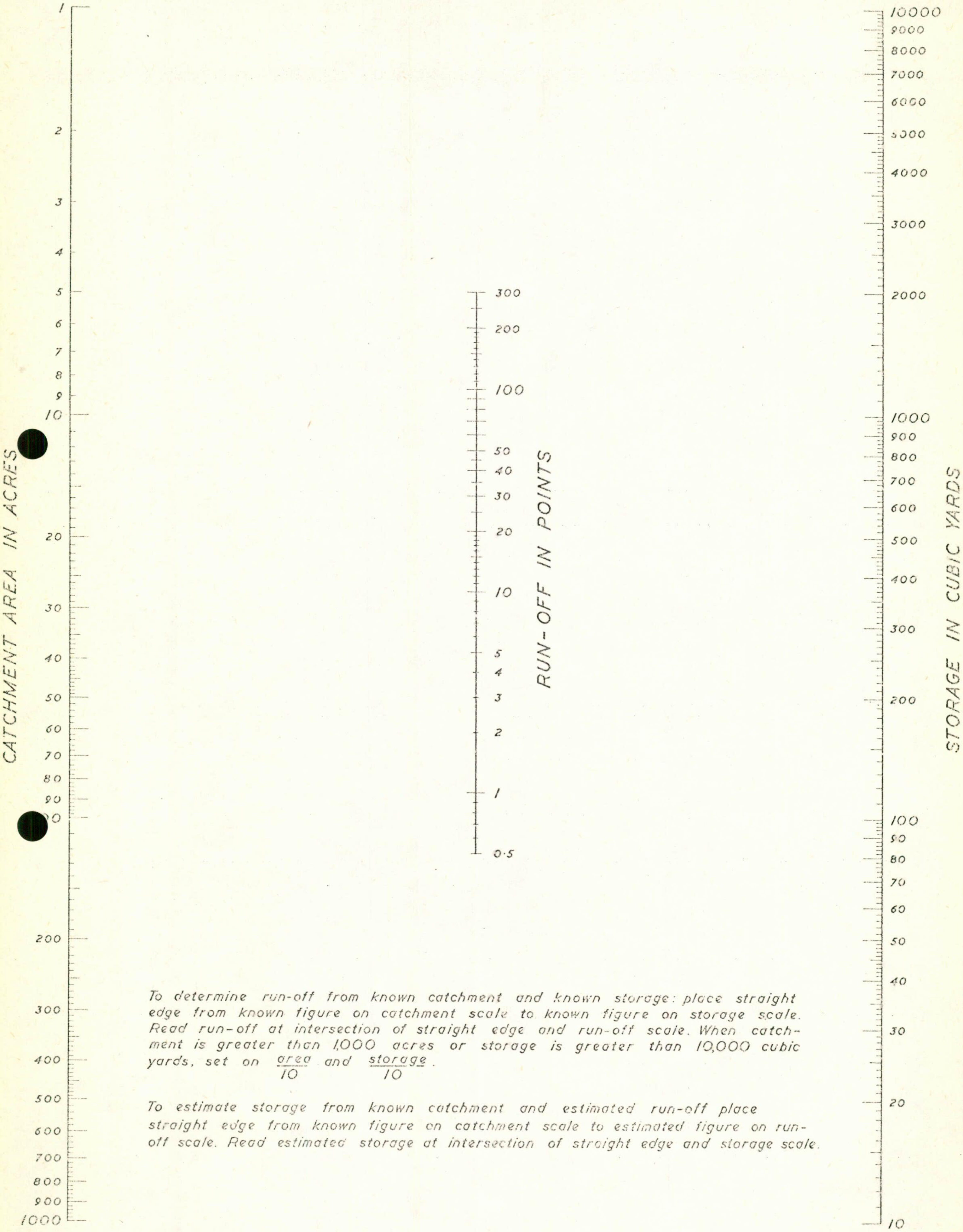
For other grasses, interpolate in the above table to obtain suitable velocities of flow.

Fig. 11·5·1

NOMOGRAM RELATING CATCHMENT, RUN-OFF AND STORAGE

FORMULA $S = 1{\cdot}344\ RA$

Where S = storage in cubic yards, R = run-off in points, A = catchment area in acres.



To determine run-off from known catchment and known storage: place straight edge from known figure on catchment scale to known figure on storage scale. Read run-off at intersection of straight edge and run-off scale. When catchment is greater than 1,000 acres or storage is greater than 10,000 cubic yards, set on $\frac{area}{10}$ and $\frac{storage}{10}$.

To estimate storage from known catchment and estimated run-off place straight edge from known figure on catchment scale to estimated figure on run-off scale. Read estimated storage at intersection of straight edge and storage scale.

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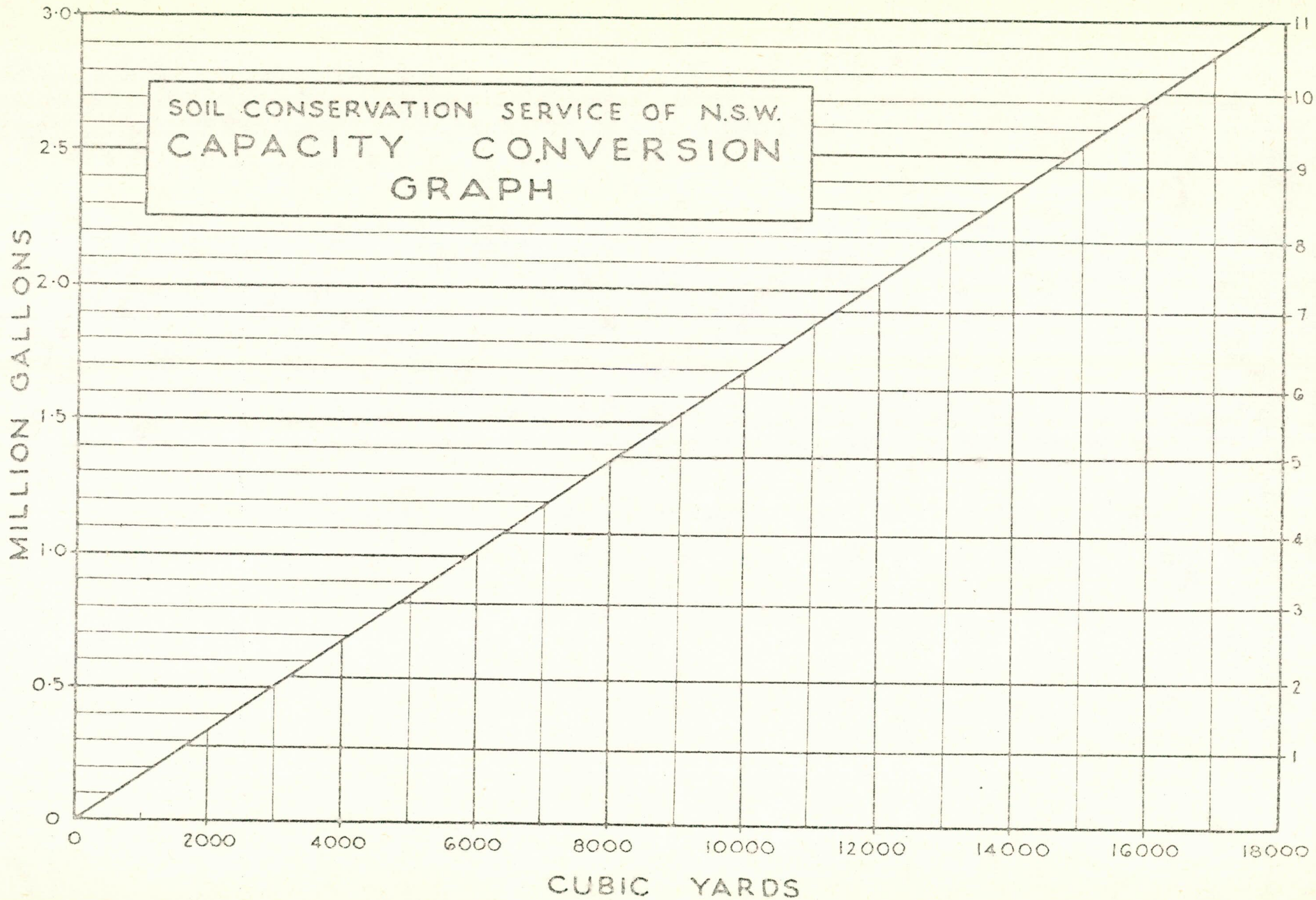
Figure 11:6:1



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11.7.2 Depth of Flow

Depth of flow with gradient and resistance to flow (roughness) are the factors governing velocity. The degree of resistance or retardance is chiefly governed by the amount and nature of the vegetation. Table 11.7.2 gives a guide to enable the degree of retardance to be selected for a particular case.

Table 11.7.2 Classification of Vegetation According to Retardance

Degree of Retardance	Stand	Height of Vegetation
High	Good	Greater than 11 inches
	Fair	Greater than 30 inches
Moderate	Good	6 to 10 inches
	Fair	11 to 24 inches
Low	Good	2 to 6 inches
	Fair	2 to 10 inches

Table 11.7.3 gives depths of flow for moderate and high retardance conditions for a number of gradients. If only low retardance is expected, grassed flumes should not be used.

Table 11.7.3 Depths of Flow (ft)

		Moderate Vegetal Resistance				High Vegetal Resistance			
		Velocity (ft/sec)				Velocity (ft/sec)			
		4	5	6	7	4	5	6	7
1 in 20	(5%)	.53	.60	.66	.74	.84	.94	1.06	1.15
1 in 14	(7%)	.46	.51	.56	.62	.73	.80	.89	.96
1 in 10	(10%)	.40	.43	.48	.52	.63	.69	.76	.81
1 in 7	(15%)	.34	.36	.40	.43	.54	.59	.64	.69
1 in 5	(20%)	.30	.32	.35	.38	.48	.52	.56	.60

For this table, depth of flow is considered to be equal to the hydraulic radius in Manning's formula. The calculations of depth bare based on figures 11.2.4 (a) and 11.2.4 (b).

11.7.3 Gradient and Width

From the calculated critical flow and the data of table 11.7.2, it is possible to determine the width for a particular gradient (or the gradient for a particular width).

e.g. Step 1: Calculate the discharge in cusecs (from Section 11).

Step 2: Determine the maximum velocity of flow from table 11.7.1.

Step 3: Classify the vegetation according to table 11.7.2.

Step 4: For the chosen velocity and gradient, determine depth of flow from the table 11.7.3.

Step 5: Divide discharge by the velocity obtained in step 2, to give the cross-sectional area.

Step 6: Divide the area obtained in step 5 by the depth obtained in step 4 to give the width in feet.

Example

Step 1: Discharge is calculated as 60 cusecs.

Step 2: Soil is group B and cover as a dense sward of Kikuyu so velocity is 6 ft/sec.

Step 3: The flume will be fenced so retardance will be moderate.

Step 4: Gradient will be 1 in 7 so, with moderate retardance and velocity of 6 ft per second depth will be 0.40 ft.

Step 5: Cross-sectional area =

$$\frac{\text{Discharge}}{\text{Velocity}} = \frac{60}{6} = 10 \text{ sq. ft.}$$

Step 6: Width $= \frac{\text{Area}}{\text{Depth}} = \frac{10}{.4} = 25$ ft.

If the width is fixed and the gradient is required:

(a) Divide discharge by velocity to obtain area.

(b) Divide area by width to obtain depth.

(c) In the appropriate velocity column, interpolate between the depths given to obtain the appropriate gradient.

e.g. If in the above example only 20 ft. is available for width -

(a) $\frac{\text{Discharge}}{\text{Velocity}} = \frac{60}{6} = 10$ sq. ft.

(b) $\frac{\text{Area}}{\text{Width}} = \frac{10}{20} = 0.50$ sq. ft.

(c) From table 11.7.3 gradient will be approximately 1 in 10.

It is emphasised that flumes should be fenced in order to maintain a good cover of vegetation to prevent erosion of the surface and undercutting of the vegetation.

12. SPECIAL TECHNIQUES

12.1 Interpretation of Soil Tests

The following chart has been prepared to assist in the interpretation of soil-testing results issued from Wagga Research Station. The chart gives an indication of the advisability (or otherwise) of building soil conservation structures with soil material of given analysis. It is based on the experience gained and a review of soils tested over the last four years.

D.I.	Clay Contents < 35%	Clay Contents > 35%	Clay Contents > 35% & V.E > 20%	Remarks
Greater than 6.0	safe	safe	safe (c)	Higher seepage rates* as D.I. rises above 6.0
3.0 - 6.0	safe	safe	safe (c)	Optimum D.I. is between 4.5 and 6.0
2.0 - 3.0	safe(c)	safe(c)	Unsafe	Critical D.I. is 3.0
1.5 - 2.0	safe(c)	safe*(c)	Unsafe	Optimum mechanical analysis desirable
Less than 1.5	safe*(c)	safe*(c)	Unsafe	Unwise to construct without ameloirants.

D.I. = Dispersal Index

V.E. = Volume expansion co-efficient

(c) = Good construction conditions desirable

* = Ameliorant required. Types and rates assessed by soil test. Specific recommendations will be given after soils are tested.

The optimum mechanical analysis would be:

Clay 25 - 35%
Silt 10 - 15%
Sand 50 - 65% (Fine and coarse sand combined).

This is essentially a clay-loam soil, and when properly compacted gives a dense impervious soil mass of great stability, particularly is the D.I. and V.E. levels are within safe limits. The more a soil diverges from this optimum, the greater the problems will be, with regard to seepage, dispersibility and cracking - and this must be borne in mind when using the above chart.

12.2 Control of Field Tunnel Erosion

Control techniques for small shallow field tunnelling have been devised from results of trials at Urangeline and Pleasant Hills.

The following measures should be applied.

(1) The area should be fenced and grazing controlled to maintain an effective vegetative cover.

(2) Existing tunnelling areas should be contour ripped.

(3) An improved pasture mixture containing both annual legumes and perennial grasses should be sown. For successful establishment fertilizer rates higher than normally applied may be necessary.

The pasture helps to achieve a more even infiltration of water; and prevents the accumulation which leads to tunnelling.

(4) A cereal crop should be grown occasionally as cultivation helps to improve even water infiltration, and breaks up cracks. All cultivation should be on the contour.

At Urangeline complete control of tunnelling was achieved where the area was cultivated to grow a wheat crop once very three years.

13. AGRONOMIC RECOMMENDATIONS

13.1 Introduction

There are two aspects of soil conservation agronomy, namely:

(a) Pasture improvement and management, usually associated with broad acre stabilisation or protection.

(b) Revegetation, which involves the re-establishment of growing plants over relatively small areas. The re-vegetation of waterways, flumes, gully control structures and other denuded areas liable to erosion are examples of this type of work.

13.2 Choice of Species

There are three alternatives available with regard to species selection namely:

(a) Improvement of native pasture swards.

(b) Utilisation of introduced species.

(c) The introduction of special purpose plants.

The most common selections are introduced species, particularly for revegetation work, and most frequently for broad acre sowing. The improvement of native pastures, using fertiliser or seed and fertiliser is usually carried out only on steeper lands. Special purpose plants are most frequently used as pioneer plants to provide rapid stabilisation on very adverse sites, which are later replaced by more permanent plants.

The initial objective of soil conservation agronomy is to obtain a protective sward as soon as possible. The ultimate objective being to establish a permanent perennial sward responsive to good management. Whilst the initial objective may be achieved using simply a single species, the final sward should include both grasses and legumes. For this reason, recommendations for initial sowings are usually mixtures.

As a result of previous experience in the Wagga district, emphasis has been placed on cool-season species in all sowing recommendations. This is a result of the Mediterranean type climate, characterised by wet cool winters and hot, dry summers (see section 4). However exceptions do occur, particularly on very small areas and where special techniques are used at sowing.

13.3 Establishment and Management Techniques

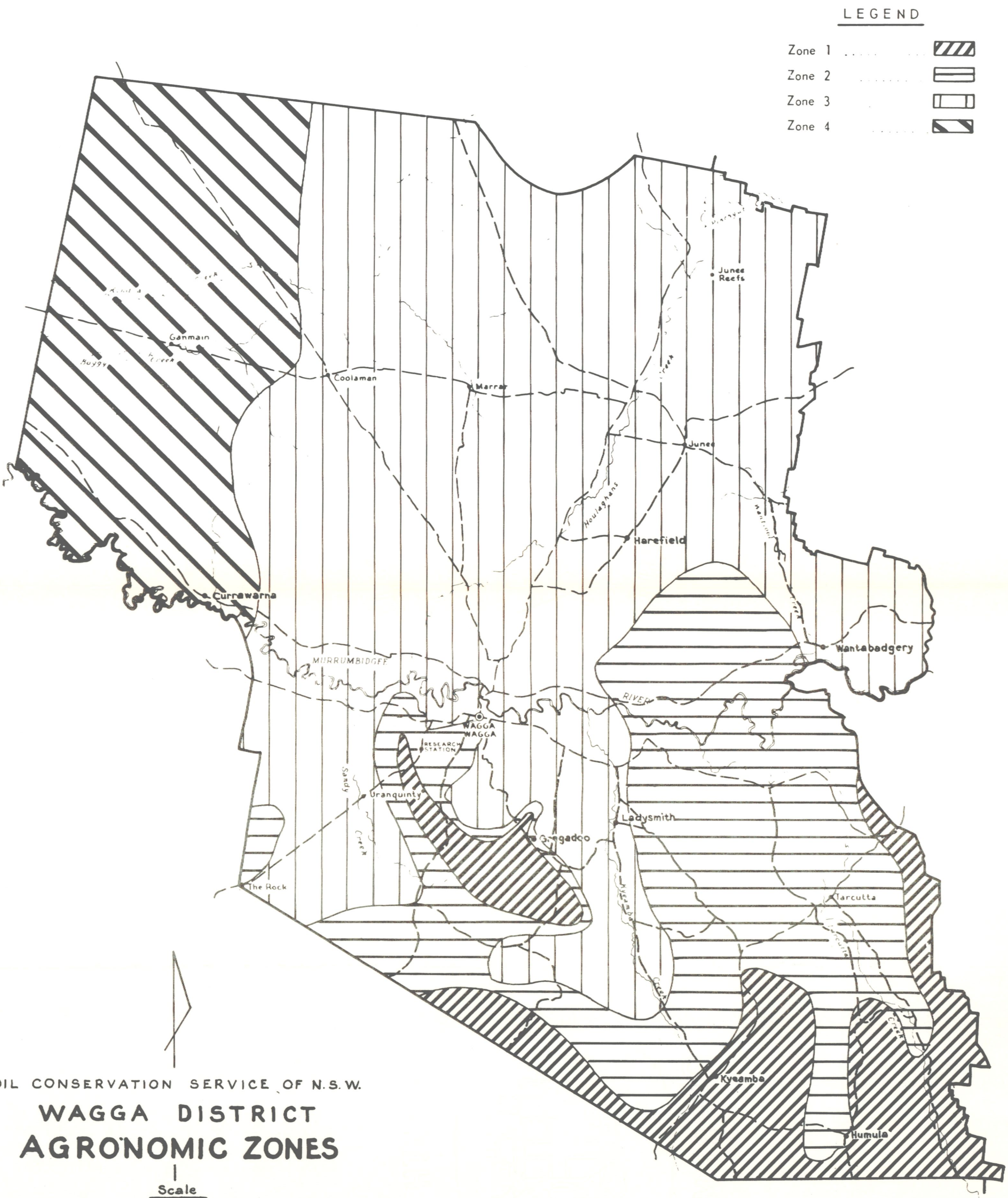
13.3.1 Batter Grades

As a general rule batter grades of structural works should not exceed $1\frac{1}{2}$:1, to allow for effective revegetation.

13.3.2 Replacement of Top-soil

Research conducted at Wagga Research Station has demonstrated that the spreading of only $\frac{1}{2}$" of top-soil over freshly exposed surfaces greatly assists revegetation by providing a more favourable environment for plant growth. It should also be possible to reduce both seed and fertilizer rates.

FIG. 13:1



SOIL CONSERVATION SERVICE OF N.S.W.

WAGGA DISTRICT
AGRONOMIC ZONES

Scale

Miles 5 0 5 10 Miles

Kilometres 5 0 5 10 15 Kilometres

M.N.

S.C.S. 7722

Consequently top-soil should be stock piled prior to the construction of earthworks and re-spread over the completed structure. On sheet eroded areas every attempt should be made to obtain an adequate supply of top-soil.

13.3.3 Sowing Rates

Sowing rates used in revegetation projects are generally considerably higher than those for normal pasture improvement. The greater the depth of soil removal, during earthwork construction or by erosion, the higher is the seeding rate.

In other words, with increasing depth of soil removal, the soil environment for plant growth becomes increasingly deleterious so that a higher initial sowing rate is required to achieve similar plant densities. For broad acre work every attempt should be made to assess soil loss and sowing rates adjusted accordingly.

13.3.4 Fertilizer Rates

Similar considerations to those mentioned above apply here.

13.3.5 Seed Bed Preparation and Sowing Procedures

Within the limitations of the particular site in question every attempt should be made to produce a fine seed bed.

For most revegetation work (i.e. relatively small areas) seed and fertiliser will usually be hand broadcast and then harrowed. For harrowing very small areas heavy duty garden rakes are ideal but for larger areas a small wheel tractor and diamond harrows could be used. For large scale revegetation and broad acre sowings conventional cultivation and sowing machinery will be used, so that wherever possible contour cultivation should be practised.

When revegetating structural works, sowing should be carried out as soon as possible after construction. Compaction following sowing generally significantly improves germination and is recommended where it can be safely undertaken. Under dry conditions, where only small areas are involved, watering is recommended until good establishment is achieved.

13.3.6 Legume Inoculation

For all revegetation work legume seed should be inoculated with the appropriate strain of inoculum and pelletted. Pelleting should be done as near to sowing time as possible.

13.3.7 Mulching

Mulching materials should be applied immediately following sowing.

13.3.8 Insect Control

The activity of insects frequently results in the failure of revegetation programmes particularly under certain climatic conditions.

In order to control insect damage seed should first be dusted with a suitable insecticide to prevent seed harvesting by ants and other insect damage. The area should then be sprayed at sowing to control lucerne flea and red legged earthmite particularly if consistent rain has fallen in the early autumn period.

13.3.9 Post Establishment Management

All revegetation projects irrespective of size can be divided into establishment and management phases. The establishment phase clearly involves initial preparation of the site, sowing, fertilising and, where necessary the installation of special protective measures, (e.g. straw or bitumen mulch) and is relatively straightforward.

The subsequent management of the sward is more complex. For example, it is generally not possible to replace the entire nutrient loss resulting from soil erosion with one fertiliser application. This is not because of the actual quantities of fertiliser required, although these could be immense, but because the fertiliser nutrients which are relatively readily available, would be far in excess of the requirements for one seasons growth, and would therefore be wasted and lost from the profile. The survival of a successfully established sward cannot be guaranteed after the first year if additional fertiliser is not applied. It is essential that a regular top-dressing programme be followed for at least 2-3 years after establishment.

The presence of grazing animals on the developing sward will seriously affect the final result. All waterway, flume, spillway and other water disposal areas should be specially fenced following sowing to exclude stock for at least two to three years.

Unrestricted growth resulting in a large bulk of topgrowth with a sparse ground cover is detrimental. A regular programme of slashing (where practicable) or stocking should be commenced. Stocking rates should be high (i.e. 10-15 sheep/ac.) for very short periods (i.e. 7-10 days). Both slashing and stocking should not be carried out more than twice each year and usually at the height of the growing season. This will permit control of bulk and will not markedly affect seed set in annual species.

In field practice it is frequently desirable to provide immediate protection for water disposal areas. This involves the use of complete sodding, straw mulch or bitumen. Some general notes on these techniques have been provided in section 13.5.

13.4 Zone Recommendations

Agronomic zones within the district are shown on the attached map. Generally they are similar to the land use zones shown on the land use map.

The agronomic recommendations vary between zones to account for variations in soil conservation practice. These recommendations are designed as basic guidelines only and are not meant to cover every situation likely to be encountered in the field. Research Station staff are readily available for discussion should any unusual circumstances be encountered.

To assist in the calculation of seeding and fertilizer rates for small areas conversion tables are included at the end of this section.

13.4.1 Zone 1

This zone comprises steep, sharply dissected second class grazing country at elevations of 1200-2000' with poor skeletal soil. Rainfall varies from 24-30 inches with the main growing period from mid-April to early December.

Soil conservation practices involve land management. Pasture improvement, topdressing and improvement of native pastures controlled stocking, control of noxious animals, tree planting and some re-afforestation. Some gully control structures and associated diversion works are also installed.

Trickle pipes are frequently used and this causes some problems with species selection. Water logging, and surface flows of brackish water have deleterious effects on plant growth in some situations.

Species and Sowing Rates for Zone 1 (all rates are lbs/ac.)

The following species are suited to the area, and sowings should be made at the rates indicated for either top-soil or sub-soil.

	Top Soil	Sub-soil
Phalaris tuberosa cv. Commercial (Commercial Phalaris)	3-4	6-8
Lolium perenne cv. Victorian (Victorian Perennial Rye)	3-4	6-8
Lolium rigidum (Wimmera Rye)	4	10
Ehrharta calycina (Perennial Veldt Grass)	4	8
Dactylis glomerata cv. Currie (Currie Cocksfoot)	3-4	6-8
Festuca arundinacea v. Demeter (Demeter Fescue)	3-4	6-8
Trifolium repens cv. Ladino (Ladino White Clover)	2	4
Trifolium repens cv. Irrigation (Irrigation White Clover)	2	4
Trifolium subterraneum cv. Woogenellup	4	10
T. subterraneum cv. Mt. Barker	4	10
Trifolium incarnatum cv. Dixie (Dixie Crimson Clover)	2	4

Mixtures can be prepared from this list. A suitable mixture for the zone would be:

Phalaris	-	4 lbs/acre
Victorian Perennial Rye	-	4
Woogenellup sub-clover	-	4
Mt. Barker sub-clover	-	4
Irrigation White Clover	-	2
Dixie Crimson Clover	-	2

Currie cocksfoot and Demeter Fescue can be considered as alternatives to phalaris, the latter species will grow well into the summer months. Perennial Veldt grass is particularly suited to lighter soils but will not stand continuous heavy grazing.

Considering the subterranean clovers, Woogenellup is more suited to the drier steeper lands, whilst Mt. Barker would be recommended for lower altitudes and seepage areas.

For adequate ground cover during the summer months native species must be relied upon, therefore stocking rates should be adjusted accordingly.

Fertiliser Rates for Zone 1 (All rates cwt/ac.)

	Initial Application		Subsequent Application	
	Top-soil	Sub-soil	Top-soil	Sub-soil
Fertiliser				
Superphosphate 22% Mo	2	2	-	-
Superphosphate 22%	-	2	1	1
Sulphate of Ammonia	-	1	-	-
Total Fertiliser per acre	2	5	1	1
P_2O_5 lbs/ac	44	88	22	22
N lbs/ac	-	20		

Note: With pure grass stands a mixed fertiliser such as 18:18:0 can be substituted.

13.4.2 Zone II

This zone comprises good undulating grazing lands with slopes of 10-20 per cent. Soils are mainly red podsolic with solonetzics occurring on the lower slopes and adjacent to watercourses. Rainfall varies from 22-24 inches per year.

Within the zone structural soil conservation works are more widely used.

Species and Sowing Rates for Zone II

The recommendations made for Zone 1 generally apply in this zone but with the following exceptions.

(a) Medicago sativa cv. Hunter River (Lucerne) should be substituted for white clover.

(b) Woogenellup should be the only cultivar of subterranean clover used.

(c) Limited field experience suggests that Lolium rigidum cv. Merredin (Merredin Wimmera Rye) should be substituted for standard commercial Wimmera Rye.

General sowing recommendations are similar but the following mixture is recommended for revegetating banks.

Merredin Wimmera Rye	10 lbs/ac
Woogenellup sub-clover	10 lbs/ac
Oats (as a cover crop)	20 lbs/ac (Cooba)

Again native species should be carefully managed to provide summer ground cover over broad acres.

Fertilizer Recommendations for Zone II

Again recommendations are similar to those for Zone 1. However, Superphosphate - Mo, is not required for top-soil sowings and ordinary superphosphate should be used. It should still be used for sub-soil sowings.

13.4.3 Zone III

This zone comprises undulating fertile arable land with slopes of 3-10 per cent. Rainfall varies from 19-22 inches per year. The soils are mainly red podzolic and red earths with solonetzics occurring along watercourses. Grazing is normally carried out in association with arable enterprises.

Soil conservation measures used in this zone rely even more heavily on structural works including contour banks, waterways, gully control structures and flumes.

Species and Sowing Rates for Zone III (all rates are in lbs/ac)

The following species are suited to the area, and sowings should be made at the rates indicated for either top-soil or sub-soil.

	Top-soil	Sub-soil
Phalaris tuberosa cv. Commercial (Commercial Phalaris)	3-4	6-8
Phalaris tuberosa cv. Sirocco (Sirocco Phalaris)	2	4
Lolium rigidum cv. Merredin (Merredin Wimmera Rye)	4	10
Ehrharta calycina (Perennial Veldt Grass)	4	8
Dactylis glomerata cv. Currie (Currie Cocksfoot)	3-4	6-8
Bromus uniloides cv. Priebes (Priebes Perennial Prairie)	4	8
Triofolium subterraneum cv. Woogenellup (Woogenellup sub-clover)	4	10

Contd.

	Top-soil	Sub-soil
T. subterraneum cv. Clare (Clare sub-clover)	4	10
Medicago sativa cv. Hunter River (Hunter River Lucerne)	6	10
Trifolium incarnatum cv. Dixie (Dixie Crimson Clover)	2	4
T. hirtum cv. Kondinin (Kondinin Rose Clover)	3	6
Vicia daisycarpa cv. Namoi (Namoi Woolly-pod vetch)	20	20
Cynodon dactylon (Couch Grass)	4	8
Secale cereale (Cereale Rye)	30	30
Avena sativa (oats) (Cooba)	20	20

From this list the following specific recommendations can be made.

(1) For Waterways

Phalaris	4 lbs/ac
Priebes Perennial Prairie	4
Couch Grass	4
Merredin Wimmera Rye	4
Woogenellup sub-clover	4
Hunter River Lucerne	6

(2) For Bank Revegetation

Merredin Wimmera Rye	10 lbs/ac
Woogenellup sub-clover	10
Oats (as a cover crop) Cooba	20

(3) For Badly Eroded Areas - Gravel Pits etc.

Merredin Wimmera Rye	10 lbs/ac
Woogenellup sub-clover	4
Clare sub-clover	4
Kondinin rose clover	4
Cereal rye (as a cover crop)	30

or

Phalaris	8 lbs/ac
Merredin Wimmera Rye	4
Clare sub-clover	4
Woogenellup sub-clover	4
Dixie Crimson Clover	2

(4) In very Coarse Parent-materials

Namoi wolly-pod vetch	20 lbs/ac
Perennial Veldt Grass	8
Kondinin Rose Clover	8

Fertiliser Recommendations for Zone III

Fertiliser recommendations are as for Zone II.

This zone comprises generally gently sloping lands of 0-3 per cent slope, with soils predominently red-brown earths. Rainfall is less than 19 inches per year which decreases even further westward, along with a decreasing probability of receiving effective rainfall during the growing season.

Structural conservation measures are generally limited to gully control structures and associated diversion banks.

Species and Sowing Rates for Zone IV

The species suited to the area, and the sowing rates are similar to those for Zone III. Although emphasis should be placed on those species suited to drier conditions, and particular use should be made of:

Trifolium subterraneum cv. Geraldton (Geraldton sub-clover), Medicago truncatala cv. Jemalong (Jemalong Barrel Medic).

The specific recommendations for the zone are:

(1) General Waterway sowings

Sirocco Phalaris	4 lbs/ac
Wimmera ryegrass	4
Woogenellup sub-clover	4
Geraldton sub-clover	4
Hunter River Lucerne	6

(2) Waterway Sowings in Self-mulching Soils - pH 7.0

Sirocco Phalaris	4 lbs/ac
Wimmera ryegrass	4
Jemalong barrel medic	4
Geraldton sub-clover	4

(3) General Bank and denuded area sowings

Merredin Wimmera ryegrass	10 lbs/ac
Clare sub-clover	10
Kondinin Rose Clover	4
Oats (Bundy)	20

(4) Bank and denuded Area Sowings in self-mulching Soils - pH 7.0

Jemalong Barrel medic should be substituted for Clare sub-clover at 4 lbs/ac.

(5) Alternative Mixtures - Denuded Areas, Gravel Pits etc.

Sirocco Phalaris	4 lbs/ac
Namoi Woolly-pod vetch	4
Clare sub-clover	20

or

Sirocco Phalaris	4
Merredin Wimmera ryegrass	4
Jemalong Barrel medic	4
Kondinin rose clover	4

Fertiliser Recommendations for Zone IV

Fertiliser recommendations are as for Zone II.

13.5 Special Techniques

13.5.1 Introduction

Special techniques of stabilization and revegetation are reserved for critical problem areas where normal establishment techniques are insufficient to ensure erosion control.

The stability of areas of water concentration is probably the most important factor in the success of any well designed programme of soil conservation structural works. A soil conservationist should make every effort during the initial design period to ensure that undisturbed soil surfaces are used as water disposal areas. Where disturbed sites have to be used these should be stabilized prior to carrying concentrated flows.

Occasionally immediate protection is required to both control erosion and promote the growth of vegetation. A number of techniques are available to this purpose.

13.5.2 Hydromulching

This process consists of mixing either wood pulp or hammer-milled hay and seed and fertilizer with water in a large tank and spraying this on the area to be treated. The hydromulcher is a machine specially designed for this purpose.

The method is particularly suited to sowing very steep and high road batters or inaccessible areas which cannot be traversed by conventional seeding equipment.

The wood pulp or hay acts as a vehicle to distribute the seed, and also adheres to the batter, thereby holding the seed in place until it germinates.

The method is very convenient, is quick and does not represent such a hazard to passing traffic as does bitumen being sprayed.

13.5.3 Hay and Bitumen

This is a well established technique in which the hay is blown mechanically, or spread by hand, on the area to be treated and is "tacked" to the surface at the same time by spraying with slow breaking anionic bitumen emulsion. The seed and fertilizer are sown by hand or with a mechanized blower in a separate operation prior to the placement of hay and bitumen.

The hay is spread at a rate of $\frac{1}{2}$-2 tons per acre depending on:

(a) the season, which affects soil temperature, and

(b) the degree of protection required in the particular circumstances.

It has been found that when the soil temperature is considerably lower than the air temperature a heavy mulch limits growth. Consequently a light mulch is applied in this situation and a heavy mulch is applied when soil temperature equals or exceeds air temperature.

The bitumen is used at a rate of 0.05-0.10 gallons per square yard.

It is used by the Service only in specialized situations where it is critical to obtain a quick vegetative cover, such as along the top edge of a road batter, in a drainage line or along the shoulder of a road.

The technique is more expensive than hydromulching.

13.5.4 Hay and Wire Netting

Hay, held in place with wire netting is a well-established technique used only in particular situations because it is a slow manual operation and is consequently expensive. Usually it is restricted to extreme situations where bitumen would not be sufficient to hold the hay in place. Extremely windy or steep areas are examples of such situations.

Wire netting is always used to hold hay in place on waterways or drainage lines which have to carry runoff before the vegetation is established.

The technique consists of spreading hay (usually pasture or oaten) by hand, at 1½-2 tons per acre, after sowing the area with seed and fertilizer. The hay is held in place with a special grade of black wire netting pinned down with galvanized wire pins or "rabbit bows" about 9 inches long.

The black netting is 19 gauge, 6 feet wide with only 2 twists instead of the usual 5 twists found in normal netting and has a 2 inch mesh.

This netting is very pliable and can be easily moulded to the shape of the land surface. It can be laid in any direction but is usually laid at right angles to any expected flow so that the upper layer overlaps and overlies the low layer in such a manner as to offer little resistance to the water flow.

The netting is overlapped and pinned along the edge at 3-4 feet centres and across the middle of the netting at 3-6 feet centres, depending upon the particular situation. For example, in a waterway, where concentrated flows might be expected, the netting would be pinned at 3 feet centres whereas on a slope where little flow occurs, 6 feet centres would be sufficient.

The success of the entire technique depends to a marked degree on the efficiency of the pinning.

13.5.5 Hay and Plastic Weave Fabric

Plastic weave fabric is employed in exactly the same manner as the wire netting described in the previous technique and is also held in place by galvanized wire pins.

The fabric costs twice as much as an equivalent quantity of wire netting, however wire netting weights seven times as much as plastic weave fabric. The latter material is used particularly in alpine reclamation work where transport of materials is by specialized vehicles with a limited carrying capacity.

Plastic fabric is an effective replacement for wire netting on areas which have to be closely mown after vegetation is established, as it breaks down much quicker than wire netting.

13.5.6 Bitumen and Other Liquid Stabilizers

The use of medium setting, slow breaking anionic bitumen has been described previously (Skurlow, 1964).

Where soil moisture conditions are good it is used to hold seed and fertilizer in place on a batter until germination has taken place.

On steep batters the technique consists of lightly spraying the batter with bitumen, and while it is still "tacky" the seed and fertilizer are applied. Another slightly heavier application of bitumen is then sprayed on to ensure complete adhesion of the seed and fertilizer. The total bitumen applied should be no more than 0.2 gallons per square yard.

The main disadvantages of the use of bitumen are (1) the drift of the bitumen spray onto passing vehicles, (2) it is unpleasant to handle and necessitates extreme care in keeping spray equipment clean to maintain efficient operation, (3) it peels off quickly once the surface seal is broken, (4) in the alpine and sub-alpine areas where frost heave constitutes a real problem, bitumen does not prevent frost action, (5) high temperatures created under the bitumen surface during the summer months can adversely effect germination and establishment.

Liquid stabilizers are available which are clean, relatively easy to handle and relatively clear would possibly be more suitable for summer sowings despite the greater expense involved.

13.5.7 Jute Mesh and Bitumen

Although this is a very expensive technique, it has proved extremely worthwhile in very particular situations where provision must be made for runoff to flow before vegetation is established.

The technique is used in table drains and catch drains, particularly where these are on a steep grade and need protection against erosion. It is also used to protect a shaped "dropdown" drain directing runoff down a batter from a catch drain to the table drain or from the shoulder of the road down a fill batter to a safe disposal area. The entrance or outlet of culverts can also be protected with this material before vegetation is established.

The area for treatment is prepared by shaping to remove obvious irregularities, raking and watering prior to sowing with seed and fertilizer. This is held in place by a light coating of bitumen emulsion applied at a rate of between 0.1-0.2 gallons per square yard.

The jute mesh is then laid on the wet bitumen and "pressed" into place. A heavier application of bitumen is then sprayed on to bring the total application to between 0.3 and 0.5 gallons per square yard.

Situations treated by this method are capable of taking flows for which they are designed, without damage, four hours after the jute mesh is laid in place.

13.5.8 Sundry Techniques

The techniques listed above constitute the main methods used in stabilization programmes. However, there are many variations and combinations not listed.

As examples, jute mesh is often used as a soil protection under the hay-wire netting treatment to give more stability to the soil surface, and plastic weave fabric is used in place of jute mesh in hay-netting or hay-plastic treatment mentioned above. The hydromulcher can be used to re-fertilize established areas using only water and fertilizer.

Finally, it is emphasized that, where practicable, accepted farm practices associated with the establishment of pastures are probably the most efficient method of stabilizing exposed surfaces. The specialized technqiues should only be used as additional measures where conditions for vegetation establishment are difficult.

13.6 Sowing Rate and Fertilizer Application Tables

These tables have been prepared to assist in the calculation of sowing rates and fertilizer applications for small areas for revegetation and for waterways and other water disposal areas.

Table 13.6.1 Fertilizer Application per Chain of Waterway for a Range of Fertilizer Rates (cwt/ac) and a Range of Waterway Widths

Fertilizer Rate	Width of Waterway (Feet)								
Cwt/ac	15	20	25	30	35	40	50	60	120
1	2½	3	4	5	6	7	9	10	20
2	5	6	8	10	12	14	18	20	40
3	7½	9	12	15	18	21	27	30	60
4	10	12	16	20	24	28	36	40	80
5	12½	15	20	25	30	35	45	50	100
6	15	18	24	30	36	42	54	60	120
7	17½	21	28	35	42	49	63	70	140
8	20	24	32	40	48	56	72	80	160
9	22½	27	36	45	54	63	81	90	180
10	25	30	40	50	60	70	90	100	200

Table 13.6.2 Fertilizer Application (lbs) for a Range of Fertilizer Rates (Cwt/ac) Over Small Areas

Fertilizer Rates	Area (Sq. Feet)					Area	
cwt/ac	100	200	400	800	1000	¼ acre	½ acre
1	¼	½	1	2	2½	28	56
2	½	1	2	4	5	556	112
3	¾	1½	3	6	7½	84	168
4	1	2	4	8	10	112	224
5	1¼	2½	5	10	12½	140	280
6	1½	3	6	12	15	168	336
7	1¾	3½	7	14	17½	196	392
8	2	4	8	16	20	224	448
9	2¼	4½	9	18	22½	252	504
10	2½	5	10	20	25	280	560

Table 13.6.3 Sowing Rates (oz/chn) of Waterway for a Range of Sowing Rates (lbs/ac) and a Range of Waterway Widths

Sowing Rate	Waterway Width (Feet)								
lbs/ac	15	20	25	30	35	40	50	60	120
6	2¼	3	3½	4½	5½	6¾	7½	9½	19
8	3	4	5	6	7	8	10	12	24
10	4	5	6½	8	9	10½	13	16	32
12	4¾	6	7¼	9¼	11	12½	15	19	38
14	5¼	7	8¾	10¾	12½	14	18	21	42
16	6	8	10	12	14	16	20	24	48
18	7	9	11½	14	16	18½	23	28	56
20	8	10	13	16	18	21	26	32	64
24	9½	12	14½	18½	22	25	30	38	76

Table 13.6.4 Sowing Rate (ozs) for a Range of Seeding Rates (lbs/ac)

Sowing Rate lbs/acre	Area (Sq. feet)					Area	
	100	200	400	800	1000	¼ acre	½ acre
6	¼	½	1	2	2	24	48
8						32	64
10						40	80
12	½	1	2	4	5	48	96
14						56	112
16						64	128
18	¾	1½	3	6	7½	72	144
20						80	160
24	1	2	4	8	10	96	192

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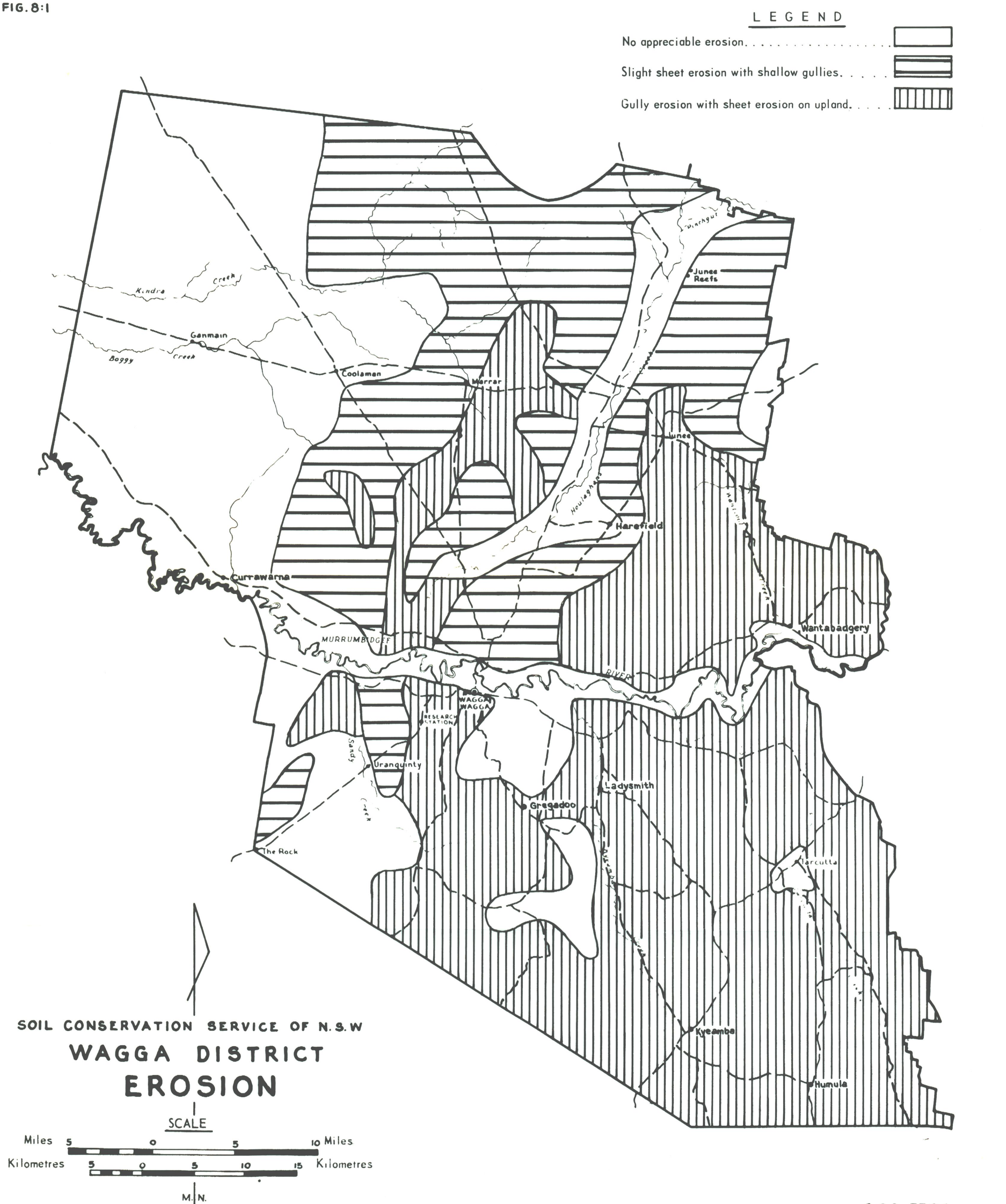
FIG. 8:1



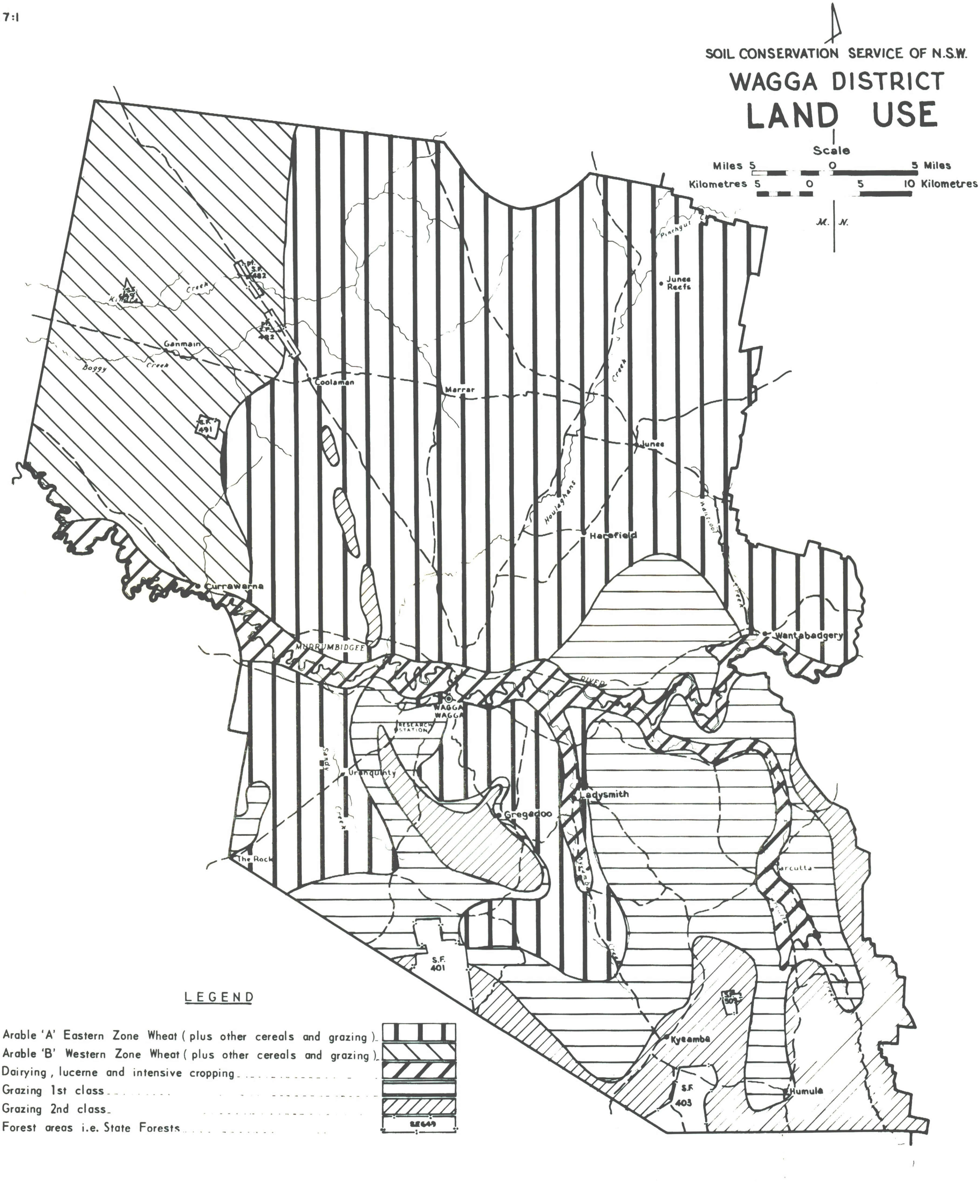
SOIL CONSERVATION SERVICE OF N.S.W

WAGGA DISTRICT

EROSION

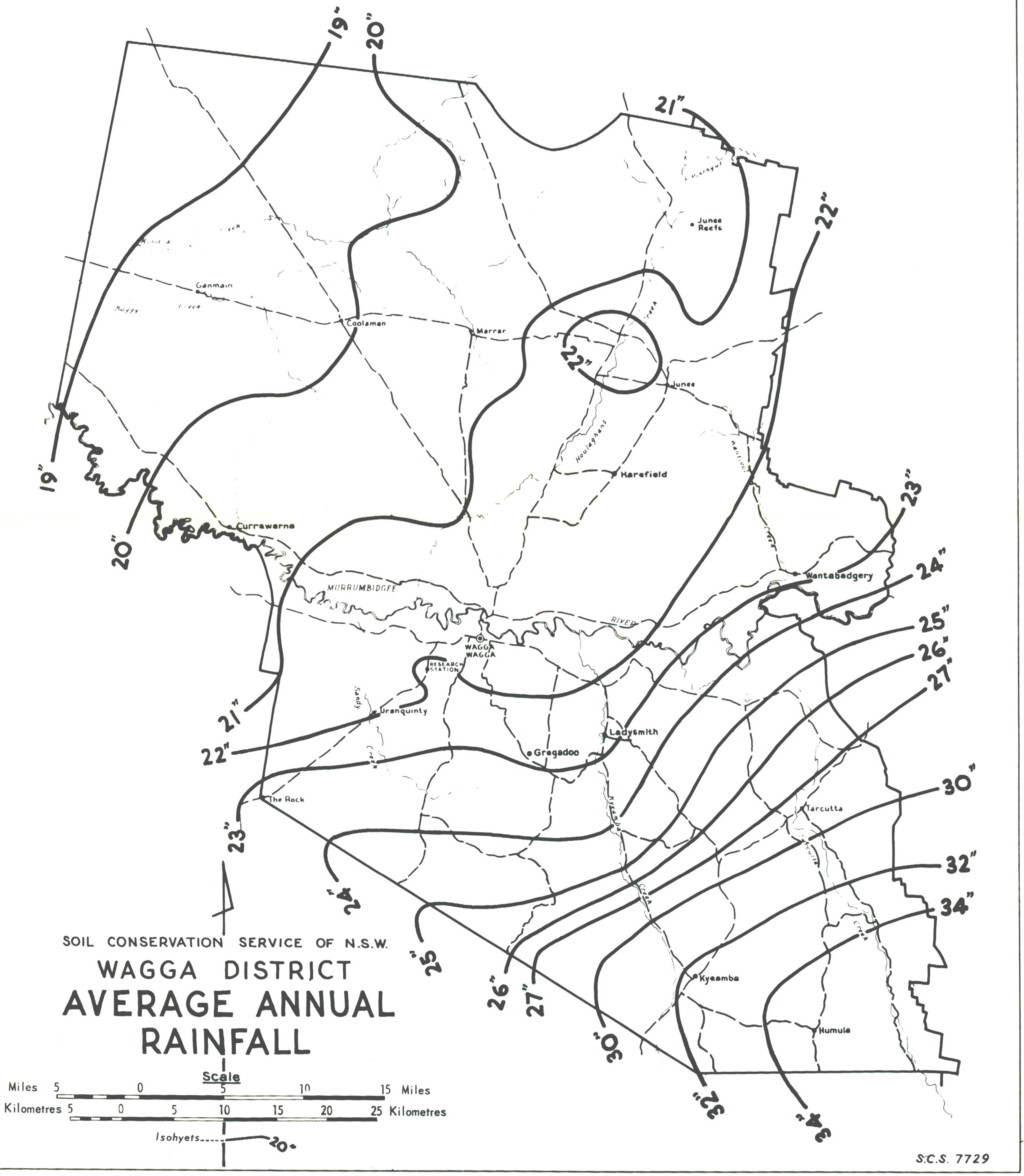
S.C.S. 7724

FIG. 7:1



S.C.S. 7727

FIG. 4:1


19"
20"
21"
22"
23"
24"
25"
26"
27"
30"
32"
34"
Junee Reefs
Ganmain
Boggy Creek
Coolamon
Marrar
Junee
Houlaghans Creek
Harefield
Currawarna
MURRUMBIDGEE
RIVER
Wantabadgery
WAGGA WAGGA
RESEARCH STATION
Sandy Creek
Uranquinty
Ladysmith
Gregadoo
The Rock
Kyeamba Creek
Tarcutta
Kyeamba
Humula
SOIL CONSERVATION SERVICE OF N.S.W.
WAGGA DISTRICT
AVERAGE ANNUAL
RAINFALL
Scale
Miles 5 0 5 10 15 Miles
Kilometres 5 0 5 10 15 20 25 Kilometres
Isohyets 20"
S.C.S. 7729

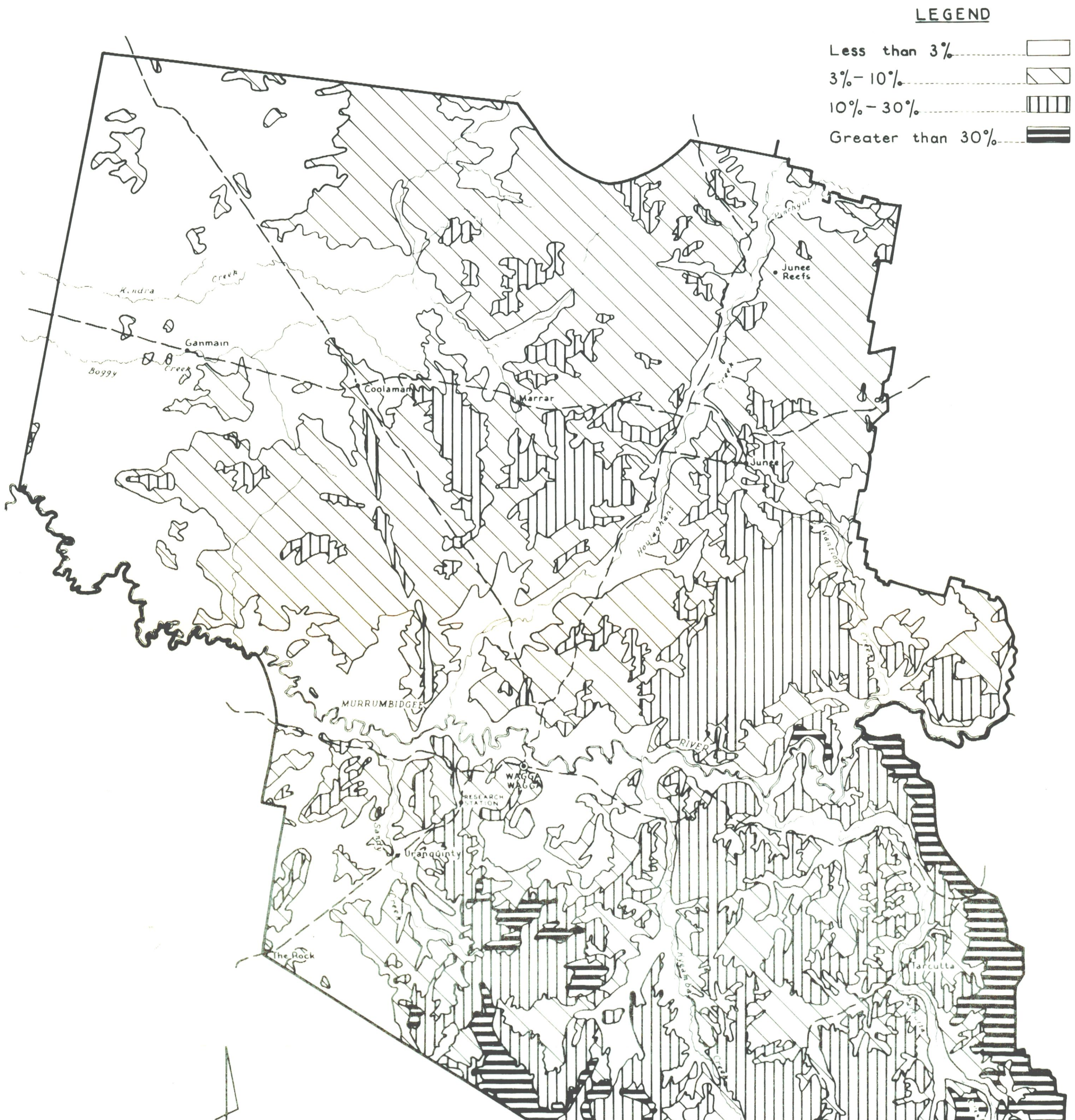


FIG. 3:1

SOIL CONSERVATION SERVICE OF N.S.W.

WAGGA DISTRICT LANDFORM CLASSES

SCALE

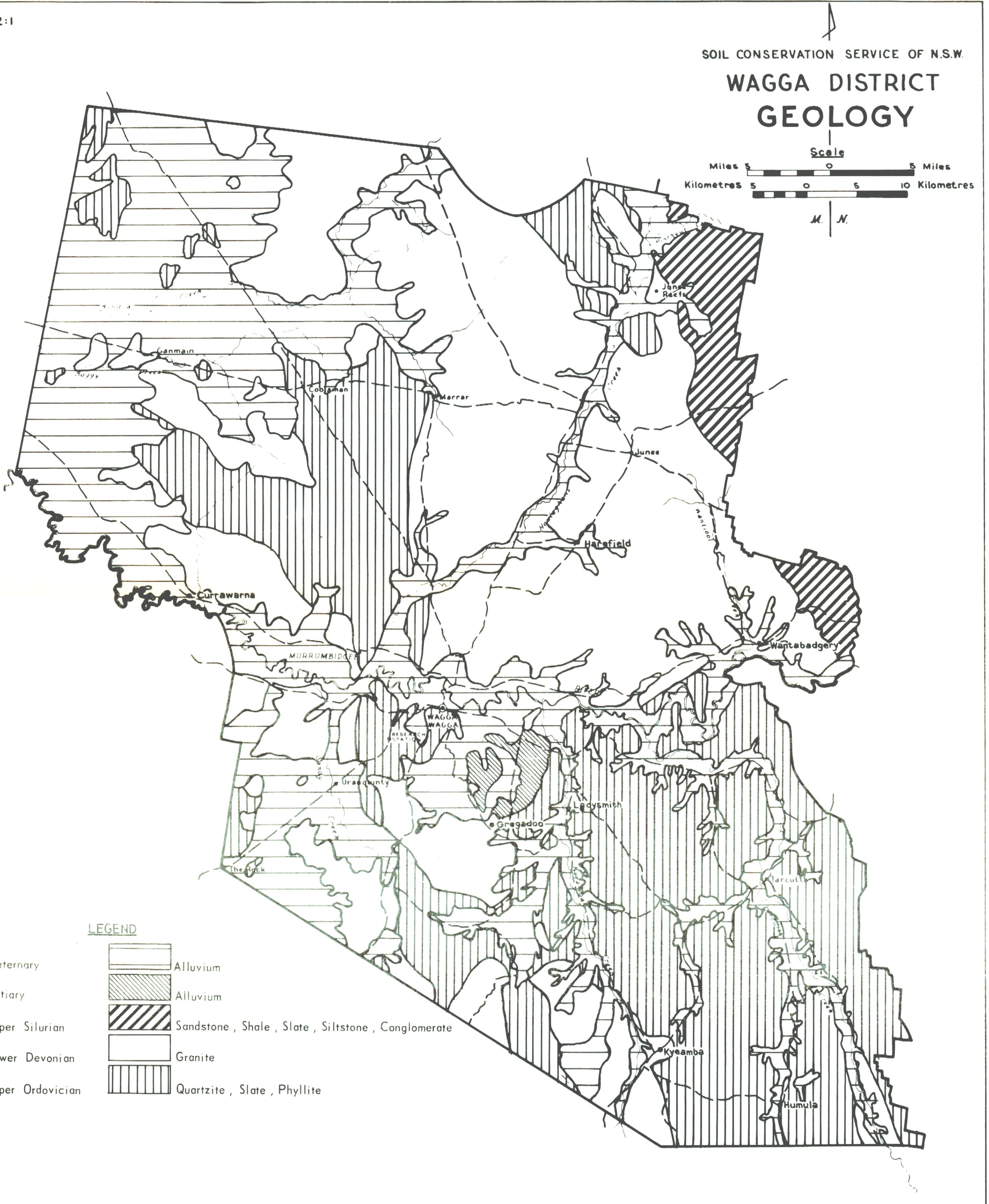
Miles 5 0 5 10 Miles

Kilometres 5 0 5 10 15 Kilometres

M. N.

S.C.S. 7728

FIG. 2:1



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