INSTITUTE OF HYDROLOGY

A CONVERSION FACTOR FOR STREAM FREQUENCY DERIVED FROM SECOND SERIES 1:25,000 SCALE MAPS

by

S E WILTSHIRE and A D HEWSON

Abstract

Second Series 1;25,000 scale maps are generally found to show more streams than their First Series counterparts. A brief account of the history of this map series is given, and a single conversion factor for Second Series junction counts is recommended that is applicable to maps of all regions.

REPORT NO 84

March 1983

CONTENTS

1 INTRODUCTION

Stream frequency (STMFRQ) is an index that attempts to quantify the density of natural drainage in a catchment, and is derived by counting the number of stream junctions within a catchment and dividing by the catchment area in square kilometres.

The use of STMFRQ in the Flood Studies Report (NERC, 1975) was prompted by the feeling that catchments having higher STMFRQ values would have larger floods, and this is borne out by the success of the STMFRQ variable in flood prediction equations. An example of these is the national equation for the estimation of the Mean Annual Flood (MAF) from catchment characteristics:

$$MAF = 0.0207\ AREA^{0.94}\ STMFRQ^{0.27}\ S1085^{0.16}\ SOIL^{1.12}\ RSMD^{1.03}\ (1 + LAKE)^{-0.85} \quad (1)$$

For further information on the other catchment characteristics see the Flood Studies Report or IH Report No 49 (Sutcliffe, 1978).

STMFRQ is also of use when estimating the Base Flow Index (BFI) of carboniferous limestone catchments (Low Flow Studies, 1980). The following equation can be used to estimate BFI for such catchments (Gustard, *personal communication*)

$$\sqrt{BFI} = 0.80 - 0.15\sqrt{STMFRQ} \quad (2)$$

STMFRQ values used in the Flood Studies Report and the Low Flow Studies are based mainly on measurements taken from the First (Provisional) edition of the 1:25,000 topographic map series. In Ireland STMFRQ values were derived from one inch maps and converted to a 1:25,000 equivalent (see Sprevak and Cochrane, 1980). These First Series maps are under active revision by the Ordnance Survey (OS) and the new Second Series maps have been found generally to show more streams than the corresponding First Series maps. The background to 1:25,000 scale mapping, the procedure for comparison of the two map editions and recommendations for adjusting Second Series junction counts are given in the following sections.

2 HISTORY OF THE 1:25,000 MAP SERIES

The First Series 1:25,000 scale OS maps are based on the nineteenth century 1: 10,560 scale County Series (revised in places according to more recent data). This Series is in turn based on various large scale surveys, typically at 1:2,500 in rural areas, but 1:10,560 in mountain and moorland areas. About 60% of the Second Series 1:25,000 OS maps are based on 1:12,500 and 1:2,500 mapping in urban and rural areas, much of which is derived from post-war surveys, but some of which is based on revisions of the old 1:2,500 series. The remaining 40% of the Second Series has been surveyed by aerial photography at a base scale of 1:10,000.

The Ordnance Survey now lays down stringent specifications for the mapping of streams at various scales and for the reduction of blue line information from one scale to another. While these specifications apply to the recently surveyed components of the Second Series, those controlling the mapping of the nineteenth century County Series are unknown.

Thus to summarise, there are three main points to note when comparing the First and Second Series:

(1) Blue line information of those Second Series maps produced by revision of County Series maps should compare well with corresponding First Series maps, but unfortunately it is not possible to identify that subset of maps.

(2) The Second Series maps based on post-war large scale surveys are likely to represent rivers in a more consistent manner than First Series equivalents.

(3) The stream network on Second Series maps derived from aerial photography may differ to a greater or lesser extent from the corresponding County Series (and so the First Series) and from the other Second Series maps, but again it is not practical to identify this subset of maps.

3 COMPARISON OF FIRST AND SECOND SERIES MAPS

3.1 Method

168 maps from the Second Series were available for comparison with First Series maps and their distribution in Britain is shown in Figure 1. Stream junctions were

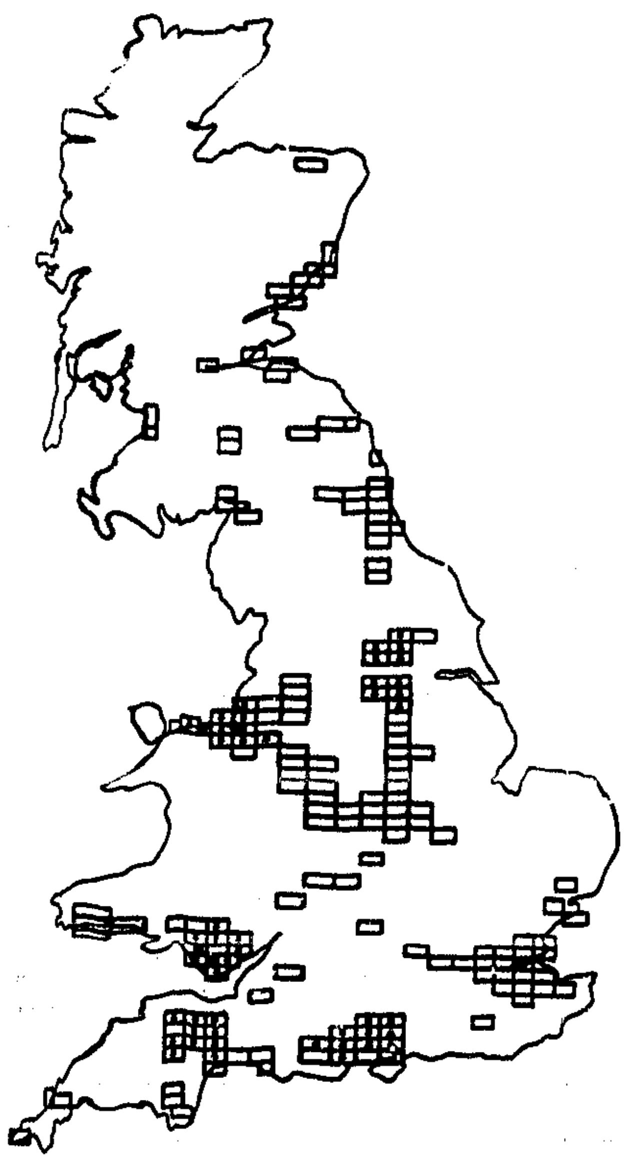

FIGURE 1

Distribution of 1:25,000 map pairs. *A star indicates use in the regional comparison.*

counted on each map in a 20 cm x 20 cm square (equivalent to 25 km^2 on the ground) positioned wherever possible in the north-west corner of each pair of maps. The FSR definitions of natural streams was used, i.e. artificial channels and canals were ignored, underground channels or those obscured by urban detail were sketched in and tributaries to lakes and reservoirs were treated as having one junction each with the notional main channel.

3.2 A national comparison

The data extracted in the manner detailed above are listed in Appendix 1 and Figure 2 shows a scatter diagram of First Series against Second Series junction counts. The figure shows that junction counts on the Second Series are generally higher than those on First Series maps and there is considerable scatter in the relationship when the number of counts is high.

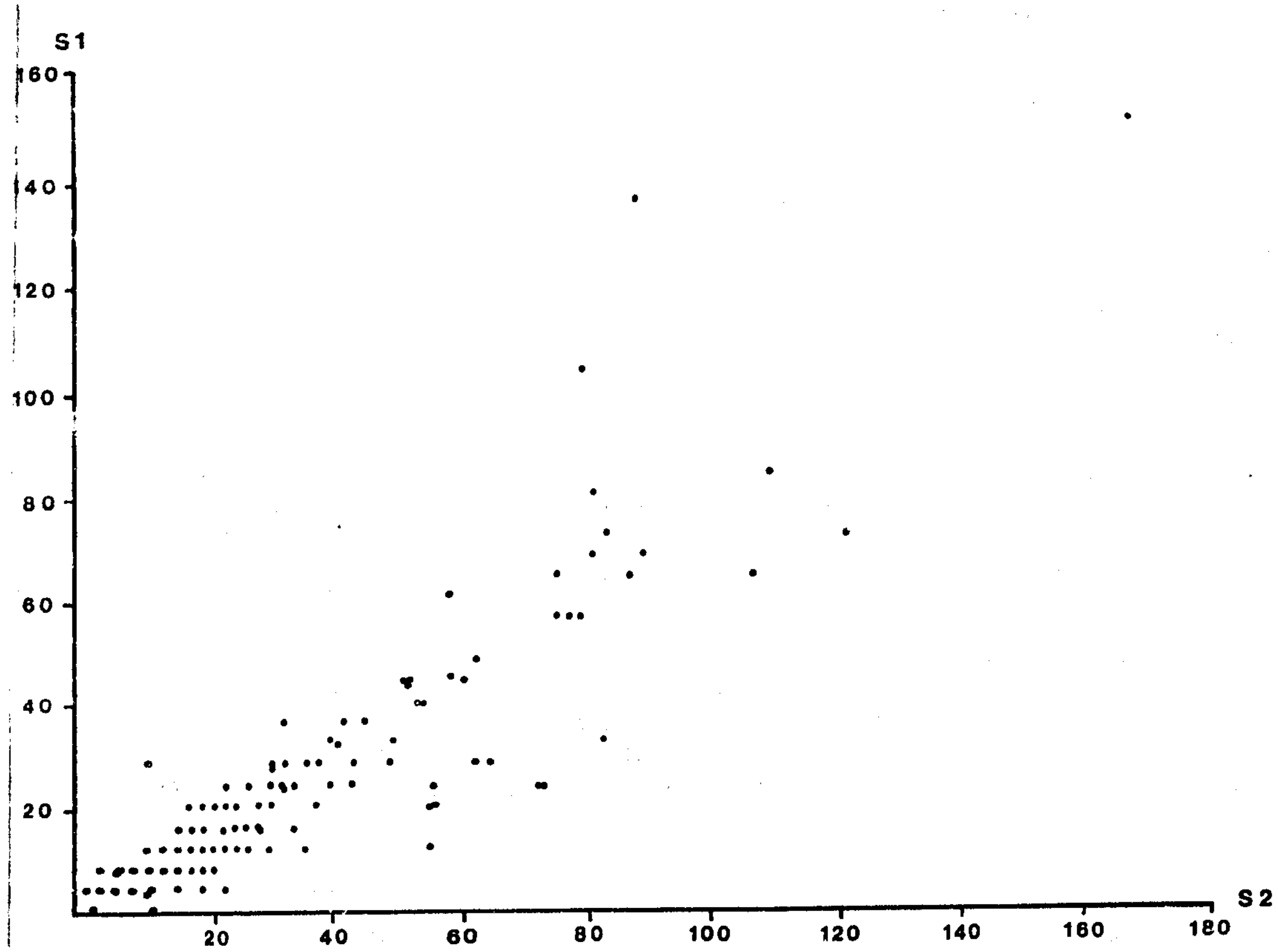

FIGURE 2 Scatter diagram showing relation between sampled First and Second Series junction counts

A tendency for more stream junctions to appear on the more recent Series means that MAF estimates would be biased when based on Second Series maps. Hence a correction factor is necessary but it is not immediately clear whether a single national correction factor or local, map-specific or perhaps regional correction factors would be preferable. A national factor has the merit of being simple to derive and apply but it risks obscuring significant detail, while regional or local factors can introduce boundary anomalies.

A simple linear regression of First Series Count (S1) on Second Series Count (S2) gives

$$S1 = 0.098 + 0.757 S2 \qquad r^2 = 0.79; \quad se = 10.41 \tag{3}$$

while a regression of S2 on S1 gives

$$S2 = 5.92 + 1.049 S1 \qquad r^2 = 0.79; \quad se = 12.25 \tag{4}$$

The difference in the two regression lines suggests there are substantial errors in the estimation of both S1 and S2, which have the effect of underestimating the true slope of the regression line. In this situation it is appropriate to fit a Structural Relation (Kendall and Stuart) to the data, which in this case is a regression line derived by minimising the orthogonal sum of squares rather than the sum of squares in the x- or y-direction. The pattern of residuals of the simple least-squares regression further suggests that a transformation of the data may be appropriate.

The performance of regressions on natural and on log-transformed data are compared in Table 1 for five cases of differing restrictions on the data set.

TABLE 1 REGRESSIONS ON NATURAL AND TRANSFORMED DATA

	Parameters of the structural relations					
Restrictions	Natural data $S1 = a + bS2$			Log transformed data $S1 = aS2^b$		
	a	b	r^2	a	b	r^2
1 None	-2.12	0.83	0.79	1.02	0.91	0.86
2 Two outliers excluded	0.05	0.74	0.80	1.06	0.90	0.86
3 24 points excluded for which S1 < 5	-2.57	0.84	0.77	1.05	0.91	0.78
4 Restrictions 2 + 3	0.35	0.73	0.77	1.16	0.88	0.77
5 None, forced through origin	(0)	0.74		(1)	0.92	

The regressions based on log-transformed data explain more variance than those based on non-transformed data, but such equations should strictly be applied to junction counts of areas comparable to that used in calibrating the equations (25 km^2). It is noted that

(1) Summing junction counts over larger areas and then converting to a First Series value via an exponential equation will lead to an underestimation of Second Series counts ($(a+b)^x < a^x + b^x$).

(2) If "Second Series areas" are partitioned into units of 25 km^2 and an exponential transform applied to each, the result tends towards that obtained by applying a relationship based on natural data to the total junction count.

(3) The intercept of the equation based on natural data and excluding two outliers is close to zero, so for practical purposes it is appropriate to use the slope-only structural relation

$$S1 = 0.74\, S2 \tag{5}$$

3.3 A regional comparison

A subset of 50 maps, ten from each of five areas, was selected in which to investigate regional effects. These maps are indicated by an asterisk in Figure 1. The five areas were selected to be locally homogeneous and to span a range of catchments consistent with the maps available.

A regression of S1 on S2 allowing a different slope for each region gives

$$S1 = 2.74 + cS2 \quad ; \qquad s.e. = 6.68 \tag{6}$$

where c takes the following values

Region	c
Devon	0.44
Hampshire	0.79
South Wales	0.76
North Wales	0.63
Pennines	0.60

The decrease in the sum of squares obtained by the fitting of this more complex model is not significant, suggesting local correction factors would not yield more accurate STMFRQ values. This means that the large local variation in the relationship between S1 and S2 overwhelms any regional variation. While more Second Series maps would help to improve the confidence of these results, it is likely that when the series is complete the MAF equations will be recalibrated using Second Series STMFRQ values.

3.4 The effect of altitude

It was felt that the policy of the OS to use aerial surveys to supplement or replace ground surveys in more remote areas might be reflected in the mapping of streams. It is not known which parts of which maps have been aerially surveyed but it is reasonable to assume that aerial surveys predominate in more mountainous or remote areas. Hence an eye-estimate was made from a 1:625,000 topographic map of the average altitude in the relevant 5 km square as an index of the likelihood of an aerial survey having been used in the construction of the map. These estimates varied from 80 to 1000 feet with a mean of 340 feet.

When tested in a regression equation it was found that the inclusion of an altitude term did not improve the estimation of First Series junction counts from Second Series junction counts in either the national or the regional comparison. In both cases the inclusion of an altitude term actually increased the mean residual sum of squares of the model indicating that the altitude term contained no additional information whatsoever.

As a cross check the number of juction counts in areas lying exclusively above 1000 feet was noted for five areas for which First and Second Series maps were available, and an estimated First Series Count was made from equation (5).

The results are shown in Table 2. In four of the five cases the agreement is good. An inspection of the First Series version of the fifth map (SH77) shows a very large number of streams mapped in a fairly small area suggesting an aberration of surveying in the original survey. Hence it is concluded that equation (5) is acceptable even at high altitude.

TABLE 2 JUNCTION COUNTS FOR AREAS LYING ABOVE 1000 ft MEASURED ON FIRST AND SECOND SERIES MAPS.
The estimated First Series value calculated using equation (5) is shown for comparison.

Map	Second Series	First Series	Estimated First Series
SO10	104	76	72
SO00	73	53	52
SH77	60	124	43
NT01	259	217	166
NT12	417	250	257

4 CONCLUSIONS

There are significantly more stream junctions on Second Series 1:25,000 OS maps than on those of the First Series. Regional variations in mapping practice are not large enough to justify regional correction factors. Hence the recommended equation for adjusting a count of stream junctions on a Second Series map to a First Series value is

First Series No. Junctions = 0.74 Second Series No. Junctions

5 AN EXAMPLE OF THE CALCULATION OF STMFRQ

The revised recommendations for the calculation of STMFRQ are as follows:

(1) Obtain 1:25,000 map(s) of the catchment. Larger catchments will usually straddle more than one map. When both First and Second Series maps can be obtained, it is preferable to use the First Series.

(2) Count the stream junctions within the catchment in accordance with the rules of the Flood Studies Report. Keep a separate note of the total number appearing on Second Series map(s).

(3) Scale the total obtained from Second Series map(s) by multiplying by 0.74 and add it to the total from First Series maps.

(4) Divide by the catchment area.

For example, suppose that the catchment of the Megget at Henderland (in south-east Scotland) is covered by two First Series maps (NT11 and NT12) and one Second Series map (NT22). The calculation of STMFRQ is as follows:

Number of junctions within the catchment on NT11	= 35
Number of junctions within the catchment on NT12	= 113
Total number of junctions on First Series maps	= 148
Number of junctions within the catchment on NT22	= 69
Total number of junctions on Second Series maps	= 69
Adjusted Second Series total (0.74 x 69)	= 51
Catchment area	= 56.7 km^2

$$\text{STMFRQ} = \frac{148 + 51}{56.7} = 3.51$$

6 REFERENCES

Natural Environment Research Council. 1975. Flood Studies Report, 5 vols.

Institute of Hydrology. 1980. Low Flow Studies.

Kendall, M. G., and Stewart, A. 1973. *The Advanced Theory of Statistics.* Griffin, London.

Sprevak, D., and Cochrane, S. R. 1980. A calibration line to relate stream frequencies on the 1:25,000 map for flood estimation in Ireland. *Proc. Instn. Civ. Engrs. Pt 1, 68*, 261-263.

Sutcliffe, J. V. 1978. Methods of flood estimation: A guide to the Flood Studies Report. Institute of Hydrology Report No. 49.

APPENDIX 1

DATA USED IN MAP STUDY

MAP NO.	NUMBER OF JUNCTIONS 1ST SERIES	2ND SERIES
NJ 65/75	12	17
NO 44/54	16	26
NO 53/63	9	15
NO 65/75	45	60
NO 76/86	7	12
NO 87/88	6	14
NS 22/23	10	12
NS 34	7	10
NS 28/98	11	13
NT 01/11	45	52
NT 02/12	64	107
NT 39/39	13	10
NT 47/57	10	12
NT 48/58/68	11	17
NT 62/72	7	13
NT 83/93	21	18
NU 03	21	15
NU 20	15	15
NY 6/16	23	56
NY 7/17	12	10
NY 25/35	25	44
NY 87/97	67	88
NZ 06/16	6	6
NZ 07/17	22	38
NZ 20/30	10	11
NZ 21/31	17	14
NZ 24/34	45	53
NZ 25/35	25	22
NZ 27/37	13	19
NZ 28/38	25	30
NZ 44	10	12
SK 00/10	43	52
SK 20/30	14	17
SK 21/31	58	74
SK 40/50	4	22
SK 42/52	26	34
SK 43/53	22	29
SK 44/54	27	32
SK 45/55	33	49
SK 46/56	15	24
SK 47/57	7	9
SK 48/58	19	17

MAP NO.	NUMBER OF JUNCTIONS 1ST SERIES	2ND SERIES
SD 60/70	22	24
SD 61/71	65	73
SE 20/30	51	81
SE 21/31	29	36
SE 23/33	29	43
SE 24/34	25	41
SE 40/50	30	29
SE 41/51	27	35
SE 43/52	13	24
SE 44/54	2	9
SE 45/55	12	29
SE 65/75	32	42
SH 67	104	78
SH 77/87	135	85
SH 78/88	30	61
SH 97	55	76
SJ 06/16	27	32
SJ 07/17	19	21
SJ 08/18	12	11
SJ 25/35	45	58
SJ 26/36	23	25
SJ 27/37	27	38
SJ 28/38	6	3
SJ 29/39	12	8
SJ 46/56	3	3
SJ 48/58	2	1
SJ 49/59	4	9
SJ 62/72	7	9
SJ 63/73	12	12
SJ 64/74	9	12
SJ 65/75	11	14
SJ 68/78	10	18
SJ 69/79	22	24
SJ 80/90	24	73
SJ 81/91	22	30
SJ 82/92	19	17
SJ 84/94	14	18
ST 00/10	41	55
ST 01/11	21	55
ST 02/12	17	35
ST 06/16	28	33
ST 07	49	61
ST 09/19	63	35
ST 17/27	17	[illegible]
ST 28/38	86	108
ST 21/39	70	80
ST 44/54	4	7
ST 66/76	18	22

MAP NO.	NUMBER OF JUNCTIONS 1ST SERIES	2ND SERIES
SK 49/59	16	28
SK 60/70	10	15
SK 67/75	0	0
SN 00/10	31	82
SN 01/11	14	56
SN 20/30	11	23
SN 60/70	74	119
SN 80/90	151	164
SO 00/10	71	83
SO 62/72	15	21
SO 84/94	37	46
SO 89/99	24	26
SP 04/14	19	20
SP 20/30	3	2
SP 26/36	6	5
SP 29/39	37	41
SP 48/58	9	12
SP 49/59	1	1
SP 88/98	15	16
SS 60/70	19	29
SS 62/72	22	55
SS 80/90	29	64
SS 81/91	24	73
SS 82/92	[illegible]	50
SS 87/96/97	14	21
TL 92	1	1
TM 02	7	7
TM 04/14	1	1
TM 11/21	8	8
TQ 7/17	29	10
TQ 22/32	31	40
TQ 26/36	7	4
TQ 27/37	1	1
TQ 28/38	5	2
TQ 45/55	12	12
TQ 46/56	7	13
TQ 47/57	3	3
TQ 48/58	10	6
TQ 64/74	12	11
TQ 65/75	13	17
TQ 66/76	0	0
TQ 67/77	1	1
TQ 68/78	10	11
TQ 69/79	18	16
TQ 85/95	7	20
TQ 86/96	0	0
TQ 88/98	18	15
TQ 89/99	4	10
TR 05/15	7	10

MAP NO.	NUMBER OF JUNCTIONS 1ST SERIES	2ND SERIES
ST 80/90	5	22
SU 00/10	18	14
SU 01/11	9	6
SU 20/30	24	39
SU 21/31	20	17
SU 22/32	4	18
SU 40/50	60	58
SU 41/51	23	31
SU 42/52	2	3
SU 68/78	10	9
SU 87/97	12	18
SW 32/42	16	18
SW 74/84	6	8
SW 75	13	25
SX 65/75	81	80
SX 66/76	27	29
SX 69/79	13	36
SX 74/84	23	32
SY 08/18	29	36
SY 09/19	37	31
SY 29/39	17	28
SY 49/59	27	50
SY 58	9	16
SY 89/99	5	6