TRANSPORT RESEARCH LABORATORY

Traffic calming in villages on major roads: Final report

Prepared for Charging and Local Transport Division, Department of the Environment, Transport and the Regions

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Executive Summary

In 1994 the Village Speed Control (VISP) Working Group reported on its initiative which examined ways of reducing the speed of traffic passing through villages. A range of techniques was considered but the success of many of the schemes in reducing speeds was limited, especially those schemes lacking physical measures or any measures in the village itself.

Changes to legislation and special authorisation procedures now enable local authorities to install a wider range of measures in villages on busy roads. This Report describes research to assess the effectiveness of more comprehensive schemes, especially those with physical measures, which have been applied to roads carrying high levels of traffic, particularly of heavy vehicles. These schemes aim to reduce 85th percentile speeds at least to the village speed limit, and thereby to improve safety and the quality of life for local residents.

All but one of the schemes assessed were developed by the Highways Agency and its agents, then the relevant Local Highway Authorities. The research to monitor scheme effectiveness was undertaken by TRL under contract to the Charging and Local Transport Division of the Department of the Environment, Transport and the Regions.

Schemes on the main roads through nine villages across England were assessed. All but one scheme was on a trunk road and several had two-way daily flows of more than around 10,000 vehicles; the weekday percentage of heavy vehicles ranged from 10-20%. The scheme at Costessey is on minor roads but was included since those roads carry lorries accessing local gravel pits. The villages varied widely in size and population. Four villages already had a 30mph speed limit in force but at two, the national (60mph) speed limit applied. After scheme installation, no speed limit exceeded 40mph. The schemes were installed between 1995 and 1997.

All of the schemes involved village gateways. These mainly comprised prominent signing and marking measures, together with an area of coloured surfacing. Measures involving physical narrowing were introduced at some gateways. The most common features employed within the villages themselves were repeated patches of coloured surfacing and coloured areas along the centre of the road with centre lining/hatching superimposed. Extensive physical measures were introduced in Costessey (speed cushions, one-way working narrowings, flat-top hump); Craven Arms (speed cushions, mini-roundabouts); and Thorney (chicanes, mini-roundabout).

Before and After monitoring was undertaken to establish the effect of the schemes on traffic speeds and flow. At the three schemes with extensive physical measures, surveys of vehicle and traffic noise and of public opinions were also undertaken. Additionally, noise was measured at Hayton, and vehicle journey times and ground-borne vibration were recorded at Craven Arms and Thorney. The results were as follows:

i As was expected, neither traffic flows nor the proportion of heavy vehicles was affected by the introduction of the schemes. In Costessey, however, the use of speed cushions and carriageway narrowings appeared to stem an expected increase in flow levels.

ii Vehicle speeds have been reduced almost everywhere. 85th percentile speeds decreased by between 3mph and 15mph, both inbound at gateways, and in the villages themselves. However, they remained above the new/retained speed limit, albeit generally by only a few mph within the village. Mean speed reductions were generally up to about 2mph less then reductions in 85th percentile speeds.

iii The use of a range of different measures in combination makes it difficult to compare their effect, especially as some schemes were accompanied by a reduction in the speed limit. Large speed reductions at the gateways occurred with physical measures but reductions of the order of 10mph also occurred where there was signing and marking at the gateway with a strong visual impact. Additional approach signing was beneficial, as was speed camera signing.

iv Within the villages, physical measures resulted in mean and 85th percentile speed reductions of 7-12mph. Without such measures, reductions were more modest and large proportions of vehicles still exceeded the speed limit at some locations. The addition of speed cameras had a small effect. At Costessey, the speed cushions reduced speeds and maintained them at a constant level, through optimum spacing.

v Outbound speeds at gateways were also reduced (but to a lesser extent than inbound speeds) and speeds were often reduced most at night and at weekends. This reflects the fact that the speeds of the faster vehicles tended to be affected the most. Only a small erosion in speed reductions was observed after one year, suggesting that the measures studied are likely to have long term impact. Where monitored, journey times increased with the introduction of the measures. This has resulted, at Craven Arms, in concern by the fire and ambulance services over increased response times.

vi The speed reductions resulted directly in decreased noise levels where noise was measured. Maximum vehicle noise levels, for light and for heavy vehicles, reduced by up to about 10dB(A), and traffic noise levels reduced typically by up to about 5dB(A). However, many village residents believed that noise levels had in fact increased. This was thought to be due to: an increase in the number of short-duration, high noise events, resulting for example from heavy vehicles ‘clipping’ speed cushions; changes in driver behaviour or the use of different surface materials causing a change in the characteristics of noise

emitted; and variability of low frequency noise from heavy vehicles. These properties may be perceived as annoying, especially at night.

vii Heavy vehicles at Craven Arms produced ‘worst case’ vibration levels in a house near the speed cushions no greater than those generated by normal household activities, and below the threshold for human perception. However, the soil conditions in Thorney resulted in peak levels of ground-borne vibration in a house adjacent to the imprinted surface at the gateway which marginally exceeded the threshold for human perception. The level was nowhere near that which would result in structural damage.

viii Reactions from residents in the villages with schemes comprising extensive physical measures were less encouraging than the measured speed reductions would have suggested. Even quite large speed reductions seemed not to be widely recognised. In Costessey, villagers were disappointed that speeds had not been brought down below the new 20mph speed limit; in Thorney, plans for a long-awaited bypass had recently been scrapped and this probably influenced views.

ix Despite residents’ limited enthusiasm for the schemes, some of the component measures were regarded favourably, but the preferred measures varied from scheme to scheme. In all three villages with extensive physical measures, about 40% of residents expressed concern about the appearance of the scheme.

x The results indicate a small overall reduction (not statistically significant) in injury accident frequency in the periods immediately following scheme installation (between 1 and 3 years). The reduction for the three schemes with extensive physical measures is greater (about 25%). However, there is a much stronger indication of a reduction in accident severity, with only one serious accident occurring since scheme installation, across all 9 schemes.

Conclusions and recommendations

i The size of the speed reductions following the installation of a traffic calming scheme at a village on a main road is likely to be affected by the pre-existing speed limit, the magnitude of the Before speeds, the new speed limit and the traffic calming measures used.

ii Signing and marking measures can bring about large speed reductions at entries to villages on trunk roads, when used in combination to give high visual impact. Repeated use through the village can also reduce speeds there but is unlikely to achieve 85th percentile speeds below the posted speed limit.

iii Speed cushions, mini-roundabouts and chicanes can be used in trunk road villages to bring about greater speed reductions than signing and marking measures alone. However, care is needed, particularly with the design and siting of vertical deflections, where there are high flows of heavy vehicles or emergency service vehicles, or where the soil type is especially prone to transmit vibration. It is important that measures are appropriately spaced, so as to induce constant speeds.

iv Narrow cushions, 1.5m wide, allow heavy vehicles and emergency vehicles to straddle them. They can be effective in bringing mean speeds down to below 30mph but the results presented here support other work which suggests that they are unsuitable for reducing speeds to 20mph.

v Residents are unlikely to be satisfied with schemes that do not achieve their expectations of reducing speeds below the new/retained speed limit and it is important not to raise their hopes unrealistically. They often do not perceive even quite large reductions in vehicle speeds and noise levels, with changes in the characteristics of the noise generated apparently nullifying reductions in overall noise levels in terms of the annoyance created.

vi It is possible that, if the improvement in accident severity that is apparent to date is sustained, this may help to influence residents’ views for the better.

vii As far as the design of new traffic calming schemes in villages is concerned, the study has highlighted the importance of involving residents in the development of schemes and providing them with an understanding of what can be achieved. Inevitably there will usually be a trade-off between scheme effectiveness (in terms of vehicle speed and accident reduction) and potential unwanted effects (such as visual intrusion). The optimum solution will vary widely according to the situation.

1 Introduction

In 1994 the Village Speed Control (VISP) Working Group reported on its initiative which examined ways of reducing the speed of traffic passing through villages (County Surveyors' Society/Department of Transport, 1994; Wheeler *et al*, 1994; Wheeler and Taylor, 1995). A range of techniques was considered, from signing alone at the entrance (or 'gateway') to the village, through measures at the gateway and in the village (mainly signing and/or contrasting road surface treatments), to physical measures, such as road narrowings. The success of many of these schemes in reducing speeds was limited, especially those schemes lacking physical measures or any measures in the village itself.

Changes to legislation and special authorisation procedures now enable local authorities to install a wider range of measures at locations within a 30mph speed limit which include, for example, villages on trunk and other major roads which carry high traffic flows. This Report describes research to assess the effectiveness of more comprehensive schemes, especially those with physical measures, which have been applied on main roads through villages carrying high levels of traffic, particularly of heavy vehicles. These schemes aim to reduce 85th percentile speeds at least to the village speed limit, and thereby to improve safety and the quality of life for local residents.

All but one of the schemes assessed were developed by the Highways Agency and its agents, then the relevant Local Highway Authorities (LHAs); the Highways Agency has also funded scheme installation. The research described here, to monitor the schemes, was commissioned by the Charging and Local Transport Division of the Department of the Environment, Transport and the Regions (DETR). The monitoring included the impact of the schemes on traffic speeds, traffic flows and accidents, and, particularly for schemes involving physical measures, on noise, ground-borne vibration and public opinions. The results were outlined briefly in Taylor and Wheeler (1998).

2 The schemes

Nine village schemes were selected for assessment. The main criteria were:

- a two-way daily flow of through traffic of at least 8,000 vehicles per day;
- at least 10% of the flow comprising heavy vehicles;
- the inclusion of more extensive and/or substantial measures than the schemes typical of the VISP study.

Table 1 lists the villages with their key characteristics.

The schemes were installed between 1995 and 1997 and were located widely across England, albeit with three (related) schemes in Shropshire. All but one scheme were on trunk roads. Several had two-way 24 hour flows exceeding 10,000 vehicles, with the weekday proportion of heavy vehicles ranging from 10-20%. The scheme at Costessey, on minor roads with much lower flows, was included since those roads carry lorries accessing local gravel pits. The villages varied widely in size and population. All schemes were on single-carriageway roads (of width typically 7.0-7.5m), though Hayton had one dual-carriageway approach. Four villages already had a 30mph speed limit but at two, the national (60mph) speed limit for rural single-carriageway roads applied. After scheme installation, no speed limit exceeded 40mph. The schemes at Craven Arms, Thorney and Costessey, and their effects, have been reported fully elsewhere (Wheeler *et al*, 1996; 1997; 1998).

A summary of the measures installed at each village, and the date and approximate cost of scheme implementation, are given in Table 2. A number of measures required special authorisation from DETR, as indicated in Table 2. Most of the schemes extended for 1.0-1.5 km. The characteristics of each village and the features employed in each scheme are described below; outline plans and accompanying photographs of the schemes are contained in Appendices A to I.

2.1 Copster Green, Lancashire (Appendix A)

This scheme was implemented on the A59 trunk road by Lancashire County Council in October 1995 and extends through the adjoining villages of Copster Green and Clayton-le-Dale, near Blackburn. This section of the A59, which is a cross-Pennine route between Preston and Harrogate, has a gently curved alignment through the villages and straight sections on the approaches. The speed limit, previously 60mph right through the villages, was reduced to 40mph through the built-up area as part of the

Table 1 Characteristics of the villages

Village and local highway authority	*Main road*	*Traffic flow (2-way 24 hours)*	*% heavy vehicles (>1.5t unladen, weekday)*	*Approximate population of village*	*Original speed limit (mph)*
Copster Green (Lancashire)	A59(T)	11,500	18%	400	60
Costessey (Norfolk)	C162/C171	5,500	10%	5,400	30
Craven Arms (Shropshire)	A49(T)	9,000	15%	1,900	40
Dorrington (Shropshire)	A49(T)	9,000	16%	350	30
Great Glen (Leicestershire)	A6(T)	17,000	10%	3,900	30
Hayton (East Yorkshire)	A1079(T)	17,000	15%	150	60
Pant (Shropshire)	A483(T)	8,000	16%	1,200	40
Thorney (Cambridgeshire)	A47(T)	13,000	20%	2,200	30
West Wellow (Hampshire)	A36(T)	16,500	18%	3,370	50

Table 2 Summary of measures installed in each village, with implementation date and scheme costs

Village	*Copster Green*	*Costessey*	*Craven Arms*	*Dorrington*	*Great Glen*	*Hayton*	*Pant*	*Thorney*	*West Wellow*
Date	10/95	7/97	5/95	9/96	4/96; 8/97	9/95	2/97	5/95	10/96
New speed limit (mph)	40	20	30	30 (n/c)	30 (n/c)	40	30	30 (n/c)	40
Cost £ (thousands)	45	72	80	25	75	256	27	486	100
Ahead of gateways									
Countdown signing†			✔	✔					
Coloured bars	✔								
Coloured patches						✔			
Vehicle actuated 30mph sign†		✔							
Speed camera signing								✔	
Other signing	✔					✔		✔	
At gateways									
Dragon teeth†			✔	✔	✔		✔		
Signing/textured surfacing								✔	
Signing/marking/coloured surfacing	✔		✔	✔	✔	✔	✔		✔
Narrowing	✔							✔	
Narrowing + speed cushion		✔							
In village									
Centre hatching	✔		✔+	✔+		✔+			
Coloured patches			✔	✔			✔		✔
Speed limit roundels †			✔				✔		✔
Speed limit repeaters				✔					✔
Pedestrian refuges	✔		✔			✔		✔	
Island/enlarged island(s)						✔			✔
Speed camera(s)				✔*	✔		✔*	✔	
Part-time 20mph speed limit†								✔	
Pedestrian crossing								✔	
Mini-roundabout(s)		✔	✔					✔	
Two-way chicanes								✔	
Narrowings		✔							
Speed cushions‡		✔	✔						
Flat-top hump		✔							

† *Required special authorisation from DETR (‡ at Craven Arms only)*
* *Part-time (portable) speed cameras*
+ *On coloured background*
n/c no change

scheme. A signalled four-way junction with the B6245 lies near the western end of the 40mph limit. A total of 18 injury accidents, 3 fatal, were reported within the built-up area over the 5 years before scheme installation.

On each main road approach, a set of 10 red bar markings about 5mm thick preceded by 'Uneven Road Surface' (referring to the bar markings), 'Reduce Speed Now' and 'Road Narrows' signing were installed in advance of gateway features. The latter comprise 40mph speed limit signing on a grey background, integral with the village name and a 'drive slowly' message, together with a narrow build-out (0.3m) on each side of the carriageway. Within the 40mph speed limit, 5 pedestrian refuges linked by centre hatching were installed.

2.2 Costessey (Appendix B)

Costessey, west of Norwich, is situated on two adjoining minor roads (West End and Longwater Lane) which carry a good deal of commuter traffic flowing between neighbouring radial routes (e.g. the A1067 and A1074) to the city. The roads (width mainly 6.0-6.5m) also serve as access to local gravel pits and thus HGVs can make up over 20% of the traffic flow early on weekday mornings. Prior to scheme installation in July 1997, there was a 30mph speed limit throughout the village. Fifteen injury accidents were reported in the previous 5 years. The scheme was aimed at reducing mean speeds to 20mph and stemming further increases in traffic flows through the village.

The scheme was designed and funded by Norfolk County Council and comprises a 20mph zone in the village core, entered from the south and northwest via a single-lane working carriageway narrowing to 3.5m with a 1.5m wide speed cushion, and from the east via a new mini-roundabout. The zone is entered from the south and east from a 30mph speed limit, but the northwest access (through one of the narrowings) is from a 60mph limit (though speeds are constrained by the road alignment). On the 30mph approach from the south, a fibre-optic speed limit reminder sign (triggered by vehicles exceeding 35 mph) was installed about 600m in advance of the 20mph zone on a downhill section just inside the 30mph limit. This radar detection sign, introduced before a bend where speed-related accidents had occurred, has been used successfully at several other villages in Norfolk, e.g. Scole on the A140 (Barker, 1997; Farmer *et al*, 1998).

Within the 20mph zone, pairs of speed cushions 1.5m wide, 3.5m long and 60mm high and spaced at 60-80m were installed, interspersed with single-lane working carriageway narrowings (to 3.5m) at three locations. A ‘bus-friendly’ 75mm high flat-top hump (of block paving and rounded at the top of the ramps) was also provided outside a school access. The cushions, except those at the entries, were surfaced in a buff-coloured calcined bauxite aggregate, which has high skidding resistance and low visual intrusion. The buff surfacing extended beyond the edges of the cushion to make them appear larger. More details are given in Wheeler *et al* (1998).

2.3 Craven Arms, Shropshire (Appendix C)

As a result of an accident study carried out by Shropshire County Council, Craven Arms was found to have the highest accident frequency in Shropshire of any village on the A49 south of Shrewsbury (it is the largest settlement on this stretch of road); 23 injury accidents were reported within the 40mph village speed limit during the 5 years prior to scheme installation. The first move was to reduce the speed limit through the village to 30mph, though it was realised that this would be ineffective without other speed reducing measures. A bypass had been proposed as long ago as 1937, and in the Highways Agency’s Roads Review of 1992, Craven Arms was included as a long term candidate for a bypass There are difficulties, however, associated with this, as there is a railway on one side of the village and attractive countryside on the other. A traffic calming scheme was thus introduced as an interim solution, in May 1995.

The scheme features a variety of measures on the approaches and within the village. Each main road approach is fairly straight and ‘countdown’ signs were installed in advance of gateway features. These included ‘dragon teeth’ markings, self-authorised by LHAs, and first used on the A952 at Crimond, Aberdeenshire (Wheeler *et al*, 1994). The other measures at the gateways comprise 30mph speed limit signing mounted above large village nameplates each side of the carriageway, together with an area of bright red road surfacing with white edge markings and a painted ‘30’ roundel.

In the village, the red patches and associated markings at the gateways were repeated at intervals in the outskirts of the village, and mini-roundabouts (with flat painted islands) were installed at four junctions (one serving a supermarket) around the village centre. A number of speed cushions, 1.5m wide, 3.5m long and 60mm high, and also coloured red, were installed between the mini-roundabouts. These narrow cushions were the first application of vertical deflections on a trunk road and were designed to allow large vehicles to straddle them (to minimise noise and vibration). A pair of ‘false’ cushions (of the same appearance, but flat) was installed on the approach to one of the mini-roundabouts. Centre hatching on a red background and new pedestrian refuges completed the scheme, which had a high visual impact overall. Full details are given in Wheeler *et al* (1996).

2.4 Dorrington, Shropshire (Appendix D)

Dorrington, on the A49 in Shropshire, lies between Craven Arms and Shrewsbury. The main road in the vicinity of the village has a gently curved alignment and the immediate northern approach is uphill. The speed limits of 30mph in the village and 60mph on the approaches were unchanged. Two injury accidents were reported during the 5 years prior to scheme installation in September 1996.

The calming measures installed by Shropshire County Council are similar to those at Craven Arms except that no physical measures were installed. On each main road approach to the village, ‘countdown’ signs to the 30mph speed limit and ‘dragon teeth’ markings were installed in advance of gateway treatment. The ‘dragon teeth’ markings extend for nearly twice the distance as those at Craven Arms, for greater visual impact. The gateway itself features red road surface treatment and prominent signing on both sides of the carriageway; this signing incorporates a speed camera sign in addition to a 30mph roundel (on a yellow background) and village nameplates. The gateway surface treatment was laid at intervals through the village, each with upright 30mph repeaters (instead of painted roundels) on each side of the carriageway. Centre hatching on a red background was installed between these features. Portable speed cameras (connected to permanent piezo-electric sensors) have occasionally been employed at two locations within the village. As at Craven Arms, the scheme has a high visual impact.

2.5 Great Glen, Leicestershire (Appendix E)

Great Glen, on the A6 just southeast of Leicester, has a speed limit of 30mph in the village and 60mph on the approaches. The village centre lies just off the main road, which has a curved alignment with a straight section on the southern approach to the village. Twenty-four injury accidents, 1 fatal, were reported within the 30mph speed limit over the 5 years before scheme installation.

The scheme, designed by Leicestershire County Council, did not feature any measures involving physical deflection. Gateway features were installed in April 1996, followed by a speed camera and associated signing during 1997. The gateways consist of surface treatment in the inbound lane approaching the 30mph speed limit, with prominent signing and marking, and have high visual impact. The surface treatment comprises two consecutive red patches each with a SLOW marking; between these are two parallel white-edged red strips, widening towards the village, with yellow tooth markings on their inside edges. The strips and tooth markings impart a channelling effect. The signing comprises yellow village nameplates plus safety message and 30mph speed limit roundel at the start and finish of the surface treatment respectively.

Within the village, a speed camera (for traffic in the southbound lane) was installed instead of previously proposed mini-roundabouts, and a warning sign was added at each gateway. The camera uses digital technology and still awaits Home Office Type Approval at the time of writing; it therefore has not been used for enforcement.

2.6 Hayton, East Riding of Yorkshire (Appendix F)

This scheme, on the A1079 in the East Riding of Yorkshire, was designed by (the then) Humberside County Council. The main road in the vicinity of Hayton is straight with a dual-carriageway approach on the southeastern side of the village; consequently approach speeds were high before scheme installation. The speed limit within the village was reduced from 60mph to 40mph as part of the scheme. A total of 10 injury accidents, 1 fatal, were reported within the built-up area over the 5 years before the scheme was installed in September 1995.

On each main road approach to the village, a set of 24 red patches (of about 5mm thickness and reducing length and spacing), preceded by 'Reduce speed now' and 'Road narrows' signing were installed in advance of gateway features. Side hatching narrowing the lane width was superimposed on the red patches on the dual-carriageway approach. At each gateway, signs comprising a 40mph speed limit roundel, the village name and a 'Reduce speed now' on a yellow background were erected on each side of the carriageway. Within the village, 2 pedestrian refuges and an island linked by centre hatching on a red background were installed. These involved local widening of the road and provide some horizontal deflection.

2.7 Pant, Shropshire (Appendix G)

This scheme, on the A483 south of Oswestry in Shropshire, and installed by Shropshire County Council, shares some features with the Craven Arms and Dorrington schemes; no physical measures were installed. Prior to scheme installation in February 1997, the main road had a 40mph speed limit on the approaches to, and within, the village of Pant. This speed limit extended from Llanymynech, the next village to the south, to a point several hundred metres to the north of the main built-up area of Pant. The road is partly hedge- and tree-lined, imparting a less urban character than many villages. Nine injury accidents, 1 fatal, were reported in the 5 years prior to scheme installation.

On scheme installation, the speed limit was lowered to 30mph in the village, but because of the 40mph limit on the approaches, 'countdown' signs, as featured at Craven Arms and Dorrington, were considered unnecessary. 'Dragon teeth' markings were installed in advance of the gateways, which comprise red surface treatment with painted speed limit roundels and prominent signing on both sides of the carriageway. The signing and the 'dragon teeth' markings are identical to those at Dorrington (see section 2.4). The gateway surface treatment is repeated at intervals through the village, each with painted 30mph roundels in both directions. Between these features, much of the centre-lining was relaid on a red median strip. As at Dorrington, part-time speed cameras have been used at two locations within the village.

2.8 Thorney, Cambridgeshire (Appendix H)

Thorney lies on the A47 east of Peterborough and Eye. Prior to scheme installation in May 1995, there were 26 reported injury accidents (1 fatal) in 5 years. A variety of measures were installed on the approaches and within the village but the speed limit within, and outside, the village was unchanged at 30mph and 60mph respectively. The designation of the A47 as a wide load route had to be considered in the design of some of the calming features.

The scheme was designed by Cambridgeshire County Council. On each main road approach, prominent signing warning of the traffic calming scheme was installed in advance of the gateways. Speed camera signing was later added in advance of the traffic calming warning signs. The gateways each comprise a raised (by 20mm using ramps 2m long) imprinted brick-patterned contrasting surface within a slight narrowing. The 6m wide narrowing (the minimum width requirement for wide loads) was formed by Trief-kerbed build-outs, on which were erected 30mph speed limit signs, on each side of the carriageway. The speed limit signs were mounted on a black background of black plastic strips similar to those used in chevron signs on bends. A two-way chicane, comprising a Trief-kerbed elongated central island, slightly angled, was installed about 100m inside each gateway. Hatching on a red background was laid around the island, and on the nearside edge of the carriageway for outbound traffic. It is necessary for wide loads entering the village to negotiate the chicanes by passing their islands on the 'wrong' side, where the required 6m width is available. The western chicane allows passage, but the eastern chicane has removable black bollards on the outbound side, so that the footway, strengthened to carriageway standards, can be overridden.

In the village, two mini-roundabouts, with domed islands, were installed, one within a part-time 20mph speed limit. One of the mini-roundabouts was later removed following complaints from nearby residents of noise, probably generated by HGVs overrunning the island. The part-time 20mph speed limit uses variable message signing displaying the lower speed limit when children go to and from a nearby school. Near the school entrance, a zebra crossing was installed, again on a raised imprinted surface. This surface was subsequently removed due to complaints of noise. Near the village centre, some junction remodelling was carried out involving some kerb realignment, providing mild horizontal deflection. Speed cameras (one for each direction) were introduced several months after the implementation of the main scheme, with the addition of warning signing outside the village. Full details are given in Wheeler *et al* (1997).

2.9 West Wellow, Hampshire (Appendix I)

West Wellow lies on the section of the A36 between the M27 and Salisbury. The speed limit prior to scheme installation was 50mph on the approaches to, and within, the village. The hedge- and tree-lined road runs along the edge of the built-up area, imparting a less urban character than many villages. Before scheme installation in October 1996, 25 injury accidents (2 fatal) were reported in 5 years.

As part of the Hampshire County Council designed scheme, the speed limit within the village was lowered to 40mph. On each main road approach, gateways were installed with red and buff surface treatment, painted speed limit roundels and prominent signing on both sides of the carriageway. The red and buff treatment was designed to give the illusion of a flat-top hump. The gateway surface treatment and markings were repeated at intervals through the village, each reinforced with 40mph low-level repeater signs on each side of the carriageway. The footways were converted to shared pedestrian/cyclist use.

3 Scheme monitoring

3.1 Scope

Monitoring was undertaken to establish the effectiveness of the schemes at meeting their objectives of reducing speed and improving quality of life. The monitoring at each village was dependent on the scale of the scheme, and is summarised in Table 3. Measurements were made for all schemes of vehicle speeds and flows (no flows at Copster Green) before scheme installation, about one month afterwards, and about one year afterwards. The latter 'long-term' measurements were made to establish whether any changes achieved in the short term were sustained. Journey times between gateways were measured before and after scheme installation at Craven Arms and Thorney.

Traffic calming measures have been found to influence the noise climate in a number of ways (Abbott *et al*, 1997). Generally speaking, lower speeds result directly in lower noise levels, but vehicle acceleration/deceleration patterns and body rattle can also affect noise levels. Monitoring of noise levels was undertaken at the schemes with the most extensive physical measures. Maximum vehicle noise and traffic noise were measured at Costessey, Craven Arms, Thorney and Hayton, before and after scheme installation, to establish whether there had been any change in noise levels caused either by individual vehicles negotiating particular measures, or by the traffic overall. Additionally, at Craven Arms and Thorney, ground-borne vibration was measured, since it is known that vehicles traversing undulations in the road surface can, in some circumstances, generate perceptible vibrations (Watts, 1990; Watts *et al*, 1997).

At Costessey, Craven Arms and Thorney, surveys of residents' opinions were also undertaken after scheme installation (before and after at Costessey). The aim was to establish people's perceptions of the measures and their effectiveness, or otherwise, in reducing any of the traffic problems resulting from the main road.

3.2 Monitoring techniques

3.2.1 Vehicle speed and flow measurements

Speed measurements in each direction were made, mainly using automatic traffic classifier (ATC) equipment connected to tube or loop detectors; the measurements were carried out continuously for a whole week in each monitoring period. Data were collected at a number of points - typically just inside the gateways and at one or more locations within the village, often close to traffic calming features. Monitoring positions are shown on each of the scheme diagrams in the Appendices.

Some speed measurements were made using radar guns; all readings were taken during daytime periods of free-flowing light and heavy vehicles (vehicles over 1.5 tonne unladen and buses). Radar guns were used for all speed measurements at Copster Green, and within the villages of Craven Arms and Thorney. At Hayton, radar speed readings supplemented automatic measurements at the gateways, and were used exclusively within the village. Within Costessey, where automatic measurements were taken at 7 positions, radar measurements were carried out at and between two pairs of speed cushions principally to assist in the analysis of the noise monitoring. Some of the radar data collected in Craven Arms, Thorney and Hayton were also used for this purpose.

Unclassified hourly and daily traffic flows were recorded as a by-product of automatic speed monitoring. The equipment/software used at Costessey, Great Glen and Hayton enabled flow counts classified by vehicle type to be obtained. At other sites manual vehicle composition counts were carried out, usually over a 12 hour period between 0700 and 1900. At Craven Arms, for example, with speed cushions included in the scheme, the classification enabled the number of vehicles for which road humps in general have been a sensitive issue (for example emergency vehicles, buses and two-wheelers) to be identified.

Table 3 Summary of monitoring in each village

Village	*Automatic speed and flow*	*Radar speed readings*	*Manual classified flow count*	*Journey times*	*Traffic and vehicle noise*[2]	*Ground-borne vibration*	*Public opinion survey*
Copster Green		✔ (3)					
Costessey	✔ (7)	✔ (2)			✔		✔
Craven Arms	✔ (2)	✔ (4)	✔	✔	✔	✔	✔
Dorrington	✔ (3)		✔ [1]				
Great Glen	✔ (3)						
Hayton	✔ (2)	✔ (4)			✔		
Pant	✔ (3)		✔ [1]				
Thorney	✔ (2)	✔ (7)	✔	✔	✔	✔	✔
West Wellow	✔ (3)						

(3) Number of monitoring positions (see Appendices for locations)
[1]*Before only*
[2]*For details see Table 4*

3.2.2 Journey time measurements

An overall effect of the measures on traffic can be assessed by calculating vehicle journey times through the length of the village. This was carried out for the most comprehensive trunk road schemes, i.e. in Craven Arms and Thorney. At each end of the village speed limit, the number plates and times of vehicles travelling in each direction were recorded on video, before and after scheme installation, using cameras positioned as discreetly as possible. Video recording was carried out for 8 hours, and the direction of travel that was recorded was switched each hour.

Registration numbers of those vehicles which passed both ends of the speed limit were matched and their journey times calculated. To avoid the inclusion of vehicles which might have parked or stopped in circumstances other than being within the traffic stream, those taking more than 5 minutes to pass through the village were excluded.

3.2.3 Vehicle noise

The internationally accepted Statistical Pass-by (SPB) method (Franklin *et al*, 1979) was used to measure maximum vehicle noise levels, for light and heavy vehicles separately, alongside key traffic calming features. The method involves determining the relationship between noise level and speed using observations for individual vehicles; a fuller description is given elsewhere (Wheeler *et al*, 1996, 1997, 1998). This allows any change in noise level resulting from the introduction of traffic calming measures to be separated into that resulting from any change in vehicle speed and that resulting from the measure itself.

A microphone was placed 1.2m above the road surface and several metres from the carriageway, connected to a noise analyser configured to record the maximum A-weighted sound level (L_{Amax}) during individual vehicle pass-bys. Vehicles chosen for measurement were judged to be sufficiently separated in the traffic stream so that their noise characteristics were not influenced by other vehicles. Speeds were measured concurrently using a radar gun.

In Craven Arms, low frequency vehicle noise (in the range 50 to 125 Hz) was studied, extracted from the vehicle noise measurements obtained. At Hayton, profiles of the noise from individual vehicles were also measured as they traversed the textured patches. At Thorney, a second After survey was undertaken to examine noise frequency spectra of vehicles crossing the imprinted surfacing at the eastern gateway.

The locations of vehicle noise measurements are shown in Table 4.

3.2.4 Traffic noise

Overall noise levels were monitored immediately outside selected residential properties for a minimum of 24 hours during each monitoring period, using an environmental sound level meter. The $L_{A10,18h}$ index, derived from the noise level exceeded for 10% of the time in each hour from 0600 to 2400, has been found to correlate well with levels of annoyance (Baughan and Huddart, 1993) and was used here as the main measure of daytime traffic noise. Night-time noise level was measured as $L_{A10,6h}$, the equivalent index for the period 0000-0600. The corresponding $L_{A90,18h}$ and $L_{A90,6h}$ indices, based on the noise level exceeded for 90% of the time in each one-hour period, were used as measures of background noise levels in some cases. At Costessey, some C-weighted measurements were additionally made since the dB(C) scale is more sensitive to low frequency noise.

At Craven Arms and Costessey, the noise instrumentation was also configured to record the

Table 4 Locations of traffic and vehicle noise monitoring

Village/location	*Vehicle noise*	*Traffic (A-weighted)*	*Max. noise (A-weighted)*	*Events*
Costessey				
- at speed cushion	✔	✔ [3]	✔ [3]	✔
- between cushions	✔			
- at road narrowing		✔	✔	✔
Craven Arms				
- between cushions	✔ [1]			
- at cushion/mini-roundabout	✔ [1]	✔		
- at mini-roundabout exit			✔	
- away from measures		✔	✔	
Hayton				
- at east gateway	✔ [2]	✔		
Thorney				
- at east gateway	✔ [4]			
- at zebra crossing		✔		
- at mini-roundabout	✔			
- away from measures	✔			

[1] *low frequency vehicle noise also extracted*
[2] *vehicle noise profiles also measured*
[3] *C-weighted noise also monitored*
[4] *also a second After survey of more detailed vehicle noise properties*

maximum noise level in each hour, $L_{Amax,1h}$ (also $L_{Cmax,1h}$ at Costessey). This was to give some indication of the effect of the traffic calming measures on the generation of short duration noisy events. The number of events exceeding a certain noise threshold was also recorded at Costessey.

The locations of traffic noise measurements are also shown in Table 4.

3.2.5 Vibration

Measurements of ground-borne vibration were made at the foundation of a house in Thorney and in Craven Arms with the schemes in place. At Thorney, the house was 50m from the east gateway, with its raised, imprinted surface. At Craven Arms, the house was immediately adjacent to a pair of speed cushions. These were considered to be ‘worst case’ scenarios. A triaxial geophone array was attached to the external facade of the property near ground level. The geophones produce signals directly proportional to particle velocity; peak particle velocity has been found to correlate well with damage occurrence in buildings (New, 1986). Continuous sample vibrations were recorded during 15 minute periods in each hour between 0900 and 1600. Measurements were taken in the presence of passing traffic, and for comparison, during household events such as closing doors, in the absence of traffic.

3.2.6 Public opinion surveys

Two hundred people resident in Craven Arms and Thorney were interviewed in their homes in the Autumn of 1995, respectively 3 and 6 months after the installation of the schemes; this allowed time for residents to get accustomed to the measures. The aim was to establish people’s perceptions of the measures and their effectiveness, or otherwise, in reducing any traffic problems resulting from the main road. Only those respondents who had lived in the villages prior to 1995 were eligible for interview. As many homes as possible along the main road were visited, followed by homes elsewhere until the required number of interviews had been conducted.

A similar survey, of 100 residents living on the main roads in Costessey, was carried out before and after the traffic calming scheme was introduced (in February and September 1997 respectively). Only those respondents living in the village at least 6 months prior to the Before survey were eligible for interview. In the After survey, interviewers were instructed to re-interview as many of the original respondents as possible, and over two-thirds of those interviewed in the Before survey were re-interviewed. When a respondent was unavailable for re-interview or refused, a close neighbour of the same sex was taken as a substitute.

The interviewers covered the following issues:

- Problems before the changes;
- Effect of the scheme on different groups of people;
- Effect of the scheme on, for example, safety, speeds and traffic noise;
- Necessity of changes, preference for other changes;
- Overall satisfaction with the scheme;
- Usefulness of the measures;
- Concerns about the measures;
- Appearance of the scheme.

The full questionnaires used in the surveys are reproduced in Wheeler *et al* (1996, 1997, 1998).

4 Results

4.1 Traffic flows

In the trunk road villages, no changes in overall traffic flow levels, or in the proportion of heavy vehicles, were apparent after the schemes were introduced. The general absence of suitable alternative routes for through traffic is likely to have influenced this result.

At Costessey, where alternative routes are available and where traffic growth was expected to occur between the monitoring periods, there was some indication that the effect of this growth had been stemmed along the road where the speed cushions had been installed. It could be that some drivers may be deliberately avoiding these measures, but the scheme did not affect the proportion of HGVs: it was not expected that HGV traffic would reduce, as its only practicable access to the gravel pits was through Costessey.

In Craven Arms and Thorney, buses and two-wheelers each comprised less than about 1% of the daytime traffic flow. In Craven Arms an average of 14 ambulances were observed in each of the 12 hours of manual flow counts.

4.2 Vehicle speeds

Results of mean and 85th percentile speeds measured by ATC are shown in Tables 5 and 6. Speeds measured by radar are shown in italics. Where measurements were taken at specific features in the village, these are indicated. Comparison of the changes for different measures is confounded by the range of different Before speeds and the fact that in several villages the speed limit was itself reduced. 85th percentile speed reductions were generally slightly larger than the mean speed reductions, but the differences, with one exception, were no more than 2mph.

4.2.1 Inbound changes at the gateways

Before scheme installation, inbound mean speeds ranged from below 35mph at Costessey to about 50mph at Hayton. 85th percentile speeds were about 40mph at Costessey and mainly over 45mph elsewhere, reaching about 60mph at Hayton.

Following scheme installation, there were reductions (statistically significant at at least the 1% level) at all but one gateway (at Great Glen), ranging from 3 to 13mph in mean speeds, and up to 15mph in 85th percentile speeds. The largest consistent reductions in mean and 85th percentile speeds (10-12mph) occurred at the narrowed, speed-cushioned entries to the 20mph zone at Costessey.

Mean and 85th percentile speeds were reduced by at least 8-10mph at the Craven Arms and Dorrington gateways, which included ‘dragon teeth’, and ‘countdown’ signs on

Table 5 Mean speeds (changes from Before speeds in brackets; radar speeds in italics)

Village (+ speed limit changes, mph)	*N/W gateway (inbound)*	*In village (mean of both directions)*					*S/E gateway (inbound)*
Copster Green (60-40)	B *43* A1 *40 (-3)* Bar markings, signing, slight narrowing (S1)	B A1		40 38 (-2) Refuge + centre hatching (S2)			B *46* A1 *42 (-4)* Bar markings, signing, slight narrowing (S3)
Costessey (30-20)	B1/2 33 A1 23 (-10) A2 25 (-8) Narrowing + speed cushion (S7)	B1/2 A1 A2	33 23 (-10) 25 (-8) Between speed cushions (S6)	33 24 (-9) 25 (-8) At speed cushions (S5)	26 18 (-8) 18 (-8) Flat-top hump (S3)	27 20 (-7) 20 (-7) Mini- roundabout (S4)	B1/2 36 A1 24 (-12) A2 25 (-11) Narrowing + speed cushion (S2)
Craven Arms (40-30)	B 41 A1 33 (-8) A2 33 (-8) Countdown signs, dragon teeth, red surfacing, '30' roundels, markings (S6)	*B* *A1* *A2*	*36* *32 (-4)* *31 (-5)* Between repeated red patches with '30' roundels (S5)	*28* *19 (-9)* *19 (-9)* Between mini- roundabout & speed cushions (S4)	*34* *26 (-8)* *25 (-9)* Between mini- roundabout & speed cushions (S3)	*39* *33 (-6)* *31 (-8)* Between repeated red patches with '30' roundels (S2)	B 42 A1 33 (-9) A2 33 (-9) Countdown signs, dragon teeth, red surfacing, '30' roundels, markings (S1)
Dorrington (30-30)	B 41 A1 28 (-13) A2 33 (-8) Countdown signs, dragon teeth, red surfacing, markings (S1)	B A1 A2		31 29 (-2) 28 (-3) Between repeated red patches with '30' repeaters (S2)			B 39 A1 31 (-8) A2 32 (-7) Countdown signs, dragon teeth, red surfacing, markings (S3)
Great Glen (30-30)	B 39 A1 39 (0) A2 37 (-2) A3 35 (-4) Coloured surfacing, dragon teeth, markings, signing (S1)	B A1 A2 A3		35 36 (+1) 34 (-1) 31 (-4) Speed camera by stage A2 (S2)			B 43 A1 39 (-4) A2 37 (-6) A3 35 (-8) Coloured surfacing, dragon teeth, markings, signing (S3)

Hayton	B	48	B		*52*	*50*			B	53
(60-40)	A1	42 (-6)	A1		*40 (-12)*	*42 (-8)*			A1	48 (-5)
	A2	40 (-8)	A2		*40 (-12)*	*42 (-8)*			A2	50 (-3)
	Red patches, signing (S1)				Refuge (S2)	Refuge (S3)			Red patches, signing (S4)	
					+ centre hatching	+ centre hatching				
					on red background	on red background				
					(through village)	(through village)				
Pant	B	38	B		39				B	37
(40-30)	A1	31 (-7)	A1		33 (-6)				A1	34 (-3)
	A2	31 (-7)	A2		34 (-5)				A2	32 (-5)
	Dragon teeth,				Between repeated				Dragon teeth,	
	red surfacing,				red patches with				red surfacing,	
	‘30’ roundels,				‘30’ roundels (S2)				‘30’ roundels,	
	markings (S1)								markings (S3)	
Thorney	B	46	B	*45*	*38*	*35*	*36*		B	42
(30-30)	A1	37 (-9)	A1	*33 (-12)*	*32 (-6)*	*32 (-3)*	*32 (-4)*		A1	33 (-9)
	A2	36 (-10)	A2	-	-	*31 (-4)*	-		A2	31 (-11)
	A3	38 (-8)	A3	*33 (-12)*	*32 (-6)*	*30 (-5)*	*29 (-7)*		A3	34 (-8)
	Advance signing,			Chicane (S2)	Refuge (S3)	Camera (S4)	20mph limit		Advance signing,	
	speed camera signing (later),						signs OFF (S5)		speed camera	
	surface treatment,								signing (later),	
	slight narrowing (S1)		B	*36*	*35*	*35*	*40*	*43*	surface treatment,	
			A1	*27 (-9)*	*28 (-7)*	*24 (-11)*	*32 (-8)*	*35 (-8)*	slight narrowing (S9)	
			A2	-	-	-	-	-		
			A3	*26 (-10)*	*28 (-7)*	*25 (-10)*	*32 (-8)*	*34 (-9)*		
				20mph limit	20mph limit	20mph limit	Near	Chicane (S8)		
				signs ON (S5)	signs OFF (S6)	signs ON (S6)	chicane (S7)			
West Wellow	B	42	B			41			B	46
(50-40)	A1	37 (-5)	A1			38 (-3)			A1	40 (-6)
	A2	38 (-4)	A2			39 (-2)			A2	38 (-8)
	Red/buff surfacing,					Between repeated red/			Red/buff surfacing,	
	‘30’ roundels,					buff patches with both			‘30’ roundels,	
	signing (S1)					‘40’ roundels and			signing (S3)	
						‘40’ repeaters (S2)				

B = Before; A1 = typically 1 month after; A2 = typically 1 year after (long-term).
Great Glen and Thorney: A2 = after addition of speed camera in village (see text); A3 = long-term.
S1 = speed monitoring position reference (see Appendices)

Table 6 85th percentile speeds (changes from Before speeds in brackets; radar speeds in italics)

Village (+ speed limit changes, mph)	*N/W gateway (inbound)*	*In village (mean of both directions)*					*S/E gateway (inbound)*
Copster Green (60-40)	B *48* A1 *44 (-4)* Bar markings, signing, slight narrowing (S1)	B A1		*45* *42 (-3)* Refuge + centre hatching (S2)			B *52* A1 *47 (-5)* Bar markings, signing, slight narrowing (S3)
Costessey (30-20)	B1/2 39 A1 29 (-10) A2 30 (-9) Narrowing + speed cushion (S7)	B1/2 A1 A2	39 29 (-10) 31 (-8) Between speed cushions (S6)	39 30 (-9) 31 (-8) At speed cushions (S5)	33 24 (-9) 24 (-9) Flat-top hump (S3)	33 26 (-7) 27 (-6) Mini-roundabout (S4)	B1/2 43 A1 32 (-11) A2 31 (-12) Narrowing + speed cushion (S2)
Craven Arms (40-30)	B 49 A1 39 (-10) A2 40 (-9) Countdown signs, dragon teeth, red surfacing, ‘30’ roundels, markings (S6)	B A1 A2	*40* *36 (-4)* *35 (-5)* Between repeated red patches with ‘30’ roundels (S5)	*33* *22 (-11)* *22 (-11)* Between mini-roundabout & speed cushions (S4)	*39* *30 (-9)* *29 (-10)* Between mini-roundabout & speed cushions (S3)	*43* *38 (-5)* *35 (-8)* Between repeated red patches with ‘30’ roundels (S2)	B 49 A1 40 (-9) A2 41 (-8) Countdown signs, dragon teeth, red surfacing, ‘30’ roundels, markings (S1)
Dorrington (30-30)	B 48 A1 33 (-15) A2 39 (-9) Countdown signs, dragon teeth, red surfacing, markings (S1)	B A1 A2		36 32 (-4) 31 (-5) Between repeated red patches with ‘30’ repeaters (S2)			B 46 A1 36 (-10) A2 37 (-9) Countdown signs, dragon teeth, red surfacing, markings (S3)
Great Glen (30-30)	B 45 A1 49 (+4) A2 44 (-1) A3 42 (-3) Coloured surfacing, dragon teeth, markings, signing (S1)	B A1 A2 A3		41 41 (0) 39 (-2) 37 (-4) Speed camera by stage A2 (S2)			B 49 A1 45 (-4) A2 44 (-5) A3 42 (-7) Coloured surfacing, dragon teeth, markings, signing (S3)

Hayton (60-40)	B 56 A1 49 (-7) A2 50 (-6) Red patches, signing (S1)	B A1 A2		*59* *45 (-14)* *46 (-13)* Refuge (S2) + centre hatching on red background (through village)	*57* *48 (-9)* *48 (-9)* Refuge (S3) + centre hatching on red background (through village)			B 63 A1 53 (-10) A2 55 (-8) Red patches, signing (S4)
Pant (40-30)	B 43 A1 37 (-6) A2 35 (-8) Dragon teeth, red surfacing, '30' roundels, markings (S1)	B A1 A2		44 37 (-7) 39 (-5) Between repeated red patches with '30' roundels (S2) markings (S3)				B 42 A1 40 (-2) A2 37 (-5) Dragon teeth, red surfacing, '30' roundels,
Thorney (30-30)	B 53 A1 44 (-9) A2 41 (-12) A3 45 (-8) Advance signing, speed camera signing (later), surface treatment, slight narrowing (S1)	B A1 A2 A3	*51* *39 (-12)* - *38 (-13)* Chicane (S2)	*43* *36 (-7)* - *36 (-7)* Refuge (S3)	*39* *36 (-3)* *34 (-5)* *33 (-6)* Camera (S4)	*41* *36 (-5)* - *33 (-8)* 20mph limit signs OFF (S5)		B 42 A1 33 (-9) A2 31 (-11) A3 40.8 (-8) Advance signing, speed camera signing (later), surface treatment, slight narrowing (S9)
		B A1 A2 A3	*41* *32 (-9)* - *30 (-11)* 20mph limit signs ON (S5)	*39* *32 (-7)* - *32 (-7)* 20mph limit signs OFF (S6)	*39* *29 (-10)* - *29 (-10)* 20mph limit signs ON (S6)	*47* *37 (-10)* - *37 (-10)* Near chicane (S7)	49 40 (-9) - 39 (-10) Chicane (S8)	
West Wellow (50-40)	B 48 A1 41 (-7) A2 43 (-5) Red/buff surfacing, '30' roundels, signing (S1)	B A1 A2		46 43 (-3) 44 (-2) Between repeated red/ buff patches with both '40' roundels and '40' repeaters (S2)				B 52 A1 45 (-7) A2 43 (-9) Red/buff surfacing, '30' roundels, signing (S3)

B = Before; A1 = typically 1 month after; A2 = typically 1 year after (long-term).
Great Glen and Thorney: A2 = after addition of speed camera in village (see text); A3 = long-term.
S1 = speed monitoring position reference (see Appendices)

their approaches. At Dorrington's south gateway, the speed reduction was similar to that found at Craven Arms, but at the north gateway the reduction was much greater, even though the speed monitoring position was the same relative to each gateway. The reason for the greater reduction at the north gateway could be that the monitoring position in the Before period was outside the original 30mph speed limit prior to its extension northwards. This means that the change in speed was probably affected by the change in speed limit at the monitoring point as well as the introduction of the gateway.

The absence, compared with Craven Arms, of painted 30mph roundels on the coloured surfacing at the Dorrington gateways had little effect, though this was probably compensated for by the inclusion of speed camera signing. The similar gateways at Pant (with painted speed limit roundels) yielded smaller reductions of no more than 7mph. This could be attributed to the absence of countdown signs and the fact that inbound approach speeds to the gateways at Pant before scheme installation were lower: drivers were already constrained by the 40mph speed limit, whereas the limit is 60mph on the approaches to Craven Arms and Dorrington. Despite these encouraging reductions, 85th percentile speeds at the village gateways were still up to 10 mph above the 30mph speed limit at Craven Arms and Pant, and 6mph at Dorrington.

At Great Glen (yellow 'dragon teeth' and other coloured surfacing plus signing), speeds were only affected initially at the south gateway, where mean and 85th percentile speeds fell by 4mph. Speeds at the north gateway were already constrained by a nearby bend. The addition of speed camera signing, coinciding with the installation of a camera in the village more than a year after the introduction of the gateways, yielded a further 1-2mph reduction in mean and 85th percentile speeds at the south gateway but they were still little changed at the north gateway. After 85th percentile speeds at the gateways were initially at least 15mph above the 30mph speed limit.

Similar reductions to those at Craven Arms and Dorrington occurred at Thorney, where there were higher Before speeds than at the majority of other villages. Advance signing warning of the traffic calming scheme may have contributed towards the 9mph decrease in mean and 85th percentile speeds; arguably the signing had more visual impact than the gateways themselves, where the dull-coloured imprinted surfacing was inconspicuous until it was encountered.

At West Wellow, the use of buff/red coloured surface treatment and painted speed limit roundels yielded a 5-7mph reduction in mean and 85th percentile speeds, but gateway signing was less prominent than at the Shropshire villages and there was no advance signing. A similar reduction in mean speeds occurred on the high speed approaches to Hayton with the extensive use of red patches and advance warning signing; the 85th percentile speed fell by 10mph on the higher speed eastern approach. In contrast with the speeds measured automatically, the 85th percentile radar speeds (of free-flowing light vehicles) on this approach fell by as much as 20mph (not shown in Table 6). These two results imply that faster, particularly free-flowing, vehicles were affected the most. This is consistent with previous findings (Wheeler *et al*, 1994) that the largest speed reductions are often associated with the highest Before speeds. Also, the visual narrowing used on the eastern approach at Hayton may have been particularly effective.

The measures introduced in Copster Green (where only radar speed readings were taken) had similarities to those used at Hayton, but at the former, lower Before speeds were accompanied by smaller speed reductions of 3-5mph. These reductions were also somewhat less than those found at Craven Arms and Dorrington with its greater number of signing/marking measures at the gateways. Other factors probably contributing to the modest speed reductions at Copster Green were: (a) the red bars, immediately ahead of the gateways, extended for a much shorter distance than the red patches at Hayton, and (b) there were no superimposed hatch markings imparting a visual narrowing. Overall these measures had less visual impact than at the Shropshire villages, and approach speeds, although comparatively high at around 50mph, were also probably constrained by a bend inside each gateway.

At the 30mph fibre-optic reminder sign at Costessey, inbound mean and 85th percentile speeds (not shown in Tables 5 and 6) fell by 5mph, though 85th percentile speeds still remained about 7mph above the speed limit. This was probably due to this section of road being downhill towards the village, and its open aspect.

As at Great Glen, the addition of speed camera signing on the gateway approach at Thorney, several months after the introduction of the main scheme, yielded a further 2mph reduction in mean speeds. The effect of the speed camera signing at the Pant and Dorrington gateways is unknown as it was included with other gateway features at the outset.

4.2.2 Changes within the village

Before scheme installation, mean speeds within the village ranged from 35mph or below in Costessey, Dorrington and Great Glen (all with pre-existing 30mph speed limits) to more than 50mph at Hayton, where the pre-existing speed limit was 60mph. Elsewhere, mean speeds were mainly between 35 and 40mph. 85th percentile speeds were typically 35-40mph in Costessey, Dorrington, and in parts of Thorney and Craven Arms, and over 40mph elsewhere, reaching nearly 60mph at Hayton. The results for Copster Green, Craven Arms, Hayton and Thorney are based only on radar speed readings of free-flowing light vehicles, as indicated in Tables 5 and 6. These will tend to give higher speeds than ATC measurement of all vehicles.

Except for Great Glen (initially), two-way average reductions in mean speeds in the village ranged from 2 to 12mph, with 85th percentile reductions of up to 14mph. All changes were statistically significant at at least the 0.1% level. The largest reductions occurred in Costessey, Craven Arms and Thorney, where extensive physical measures were introduced, and in Hayton with its high Before speeds prior to the reduction in the speed limit from 60 to 40mph.

The physical measures yielded mean and 85th percentile speed reductions of 7-12mph. In the 20mph zone at

Costessey, mean speeds fell on average by 9mph at and between the speed cushions and near the flat-top hump, and by 7mph at the zone entry near the mini-roundabout. The fact that the same reductions occurred at and between the speed cushions indicated that these particular cushions were optimally spaced (at about 60-80m) to induce constant speeds and minimise acceleration and deceleration. A requirement of a 20mph zone is that average speeds of 20mph should be maintained within it. This was only achieved along the section near the school; elsewhere, mean speeds measured automatically were nearer 25mph, with mean speeds of free-flowing light vehicles measured by radar (not shown in Table 5) reaching 27mph. The speed reductions at the cushions are broadly consistent with those obtained at cushions of the same width on the A49 trunk road at Craven Arms, where 85th percentile speeds were reduced to the 30mph speed limit or below. As in Costessey, the close spacing of the speed cushions and mini-roundabouts afforded little opportunity for drivers to increase speed between these features.

In Thorney, mean and 85th percentile speeds fell by 8-12mph at the chicanes inside each gateway, the larger reductions occurring at the chicane with the higher Before speeds. Near the school, reductions of about 10mph were achieved during the operation of the part-time 20mph speed limit along this section, but 85th percentile speeds here still approached 30mph, rising by a further 3-4mph when the 20mph speed limit signs were off. The target 85th percentile speed of 30mph was only achieved near the chicanes, mainly by HGVs (not shown in Table 6).

At Hayton, where the emphasis was on coloured surfacing with superimposed carriageway markings in the village (in part linking two islands), speed reductions of 8-14mph were achieved; these changes were larger than would be expected for such measures probably because of the high Before speeds and the reduction in the speed limit from 60 to 40mph. Although these reductions are encouraging, the 85th percentile speed of light vehicles in the village was still on average 7mph above the new speed limit, with over half of these vehicles still exceeding this limit.

In Craven Arms, Dorrington, Pant and West Wellow, the gateway surface treatment repeated at intervals through the village yielded average speed reductions of 4-5mph, though reductions in Dorrington and West Wellow averaged only 3mph. The larger reductions in Pant than in Dorrington (which most closely resembles the Pant scheme) may be attributed to (a) the closer spacing of the repeated red patches; (b) the inclusion of painted speed limit roundels rather than repeater signing, and (c) comparatively low Before speeds in Dorrington, probably constrained by a bend close to the monitoring position. (Note, however, that repeated roundels in lit 30mph-limited areas are not normally permitted by DETR.) In West Wellow, speeds were probably constrained downstream of the roundabout. 85th percentile speeds still exceeded the speed limit by 2-3mph in Dorrington and West Wellow (with at least one third breaking the limit), and by an average of 7mph in Pant and Craven Arms (away from the mini-roundabouts and speed cushions). In Pant, over three-quarters of vehicles exceeded the new speed limit.

At Copster Green, the series of refuges linked by centre hatching (no coloured background) had only a small effect, the reduction of 2-3mph in mean and 85th percentile speeds probably not enough to be subjectively noticeable in the village. The 85th percentile speed was still about 2mph above the new 40mph speed limit, which was exceeded by one quarter of vehicles.

In both cases where a speed camera was separately introduced, reductions increased, but only by 1-2mph. 85th percentile speeds, however, still remained above the village speed limit, particularly at Great Glen. It is not known what effect the use of part-time (portable) speed cameras had in Pant and Dorrington, as they were not deployed during After monitoring periods.

Until the installation of the speed camera in Great Glen one year after the implementation of the gateways, there were no calming measures within the village. Initial monitoring following gateway installation showed no speed reduction within the village, but the addition of the camera and associated signing at the gateways reduced mean and 85th percentile speeds by 2mph. Drivers were unaware of the fact that the camera, using digital technology, could not be used for enforcement as it was still awaiting Home Office type approval. As such, its flash unit was disabled. Despite the installation of the camera, the proportion of drivers exceeding 30mph in the village was 80%, only slightly less than before, and just after, gateway installation. Relatively few drivers, however, exceeded 40mph.

4.2.3 Outbound speed reductions at the gateways

Outbound mean and 85th percentile speed reductions at the gateways were mostly 2-4mph smaller than inbound reductions with a few exceptions: at Craven Arms, Hayton (west gateway, mean speed only), and Thorney after speed camera installation, reductions were similar in each direction. At the gateways with speed cushions in Costessey, outbound reductions were about 2mph greater than inbound reductions.

4.2.4 Daytime/night-time and weekday/weekend changes

Where speeds were measured automatically, speed changes for different periods of the day and week could be computed. Night-time and weekend mean and 85th percentile speeds were generally higher than the corresponding daytime and weekday speeds by typically 2-4mph both before and after scheme installation. Night-time reductions at the gateways, and where measured in the village, were generally similar to, or slightly greater than, daytime reductions, showing that measures were equally effective at night. This may be due to the reflectivity of the signing and markings at night maintaining visual impact. Weekend reductions were also similar to, or slightly greater than, weekday reductions. Both results reflect the fact that speeds of the faster vehicles tended to be reduced more than speeds of the slower vehicles.

4.2.5 Long term changes

In the longer term, most speed reductions were largely maintained, any erosion being generally no more than

2mph (Tables 5 and 6). Reductions seemed more likely to be better maintained within the village, where the physical measures prevailed, than at the gateways. Otherwise, there was no indication that some measures resulted in better-sustained speed reductions than others.

4.3 Journey times

The mean journey time between gateways (distance 1.6 km) through Thorney was 2min 20sec in each direction before scheme installation, rising after scheme installation to 2min 38sec westbound but only to 2min 24sec eastbound. The reason for the very small increase eastbound is unclear, since most observed speed changes were similar in both directions.

In Craven Arms, the Before mean journey time between gateways (1.2 km) was 1min 25sec in each direction, rising after scheme installation to 1min 56sec northbound and 1 min 49sec southbound, an increase of about one third. The changes were statistically significant at the 0.1% level.

4.4 Noise

This is a complex subject, but some indication of the meaning of the results which follow is that a reduction in noise level of 3dB(A) represents a reduction of about a quarter in subjective loudness while a reduction of 10dB(A) corresponds to a halving of subjective loudness.

4.4.1 Vehicle noise

Table 7 shows the changes in the level of maximum vehicle noise measured at each of the monitoring locations, as described in section 3.2.3. It can be seen that in all cases a reduction was observed for both light and heavy vehicles, which ranged from about 1 dB(A) away from any calming measures in Thorney to more than 10 dB(A) for light vehicles at one gateway at Hayton (where a sequence of coloured, textured patches were installed). In most cases these noise reductions could be attributed almost entirely to the speed reduction resulting from the measures employed. At Hayton, however, the new surface appeared also to contribute to the reduction in noise level, while at the mini-roundabout in Thorney, the reduction observed for heavy vehicles was less than would have been expected from the speed reduction that occurred. This latter result suggested that increased braking/gear changing activity by the heavy vehicles influenced the noise level generated.

At the cushion site close to a mini-roundabout in Craven Arms, the reductions in noise given in Table 7 are for vehicles which did not ‘clip’ a cushion; for light vehicles a similar reduction was observed for those which did clip, but for heavy vehicles, the reduction was more than halved (heavy vehicle noise for vehicles clipping a cushion was 5 dB(A) higher than for those not clipping). Low frequency noise at Craven Arms was found to be less influenced by speed than the A-weighted noise levels, resulting in rather smaller reductions in low frequency noise. It also appeared that low frequency noise from heavy vehicles was more variable than that from light vehicles as they travelled through the scheme; it is possible that such variability could have contributed to residents believing that levels of vibration had increased (see section 4.6) as low frequency noise has previously been shown to be related to floor vibrations inside a property (Martin *et al*, 1978; Martin, 1978).

Table 7 Vehicle noise results

	Change in noise level dB(A)		*Change in low frequency noise dB*	
Village/location	*Light vehicles*	*Heavy vehicles*	*Light vehicles*	*Heavy vehicles*
Costessey				
- at speed cushion	-3.8	-2.7		
- between cushions	-4.1	-1.6		
Craven Arms				
- at cushion/mini-roundabout	-9.5	-8.3	-3.0	-6.5
- between speed cushions	-7.1	-5.4	-3.2	-2.4
Hayton				
- at east gateway	-10.5	-7.1		
Thorney				
- at east gateway	-4.0[1]	-3.2[1]		
- at mini-roundabout	-4.4	-2.2		
- away from measures	-1.9	-1.2		

[1]*Second After survey result*

At Hayton, a nearby resident had complained of a ‘pulsing’ sound as vehicles crossed the textured patches and the measurement of vehicle noise profiles as they traversed a sequence of patches showed that this phenomenon was indeed measurable, but only for a minority of light vehicles. The effect is possibly linked to tyre type. Generally the fluctuation in noise levels was less than 1 dB(A).

At Thorney, residents close to a gateway had complained of the noise as vehicles traversed the imprinted surfacing. The subsequent detailed measurement of noise characteristics there indicated that frequency spectra of typical vehicle pass-by noise showed distinct peaks at certain frequencies, which were related to the vehicle speed and the regular pattern of the imprinted surfacing.

4.4.2 Traffic noise

Table 8 shows the changes in overall traffic noise levels measured at each of the monitoring locations as described in section 3.2.4. It can be seen that in all cases other than at the Craven Arms sites at night, a reduction in traffic noise was observed. Again these reductions are largely attributable to reductions in traffic speed. A particularly large reduction in L_{10} was observed at night in Hayton; however, the background noise level (L_{90}) was reduced far less because at night, when traffic flows are low, vehicles are not present for sufficiently long to influence background noise.

At Costessey, where it was speculated that low frequency body noise may be caused by commercial vehicles traversing the cushions, all of the C-weighted traffic noise levels measured were reduced. Thus there was no evidence of increased low frequency noise resulting from the scheme.

The monitoring of individual noisy events at Costessey

Table 8 Traffic noise results

	Change in noise level (dB(A))			
Village/location	*Day time* $L_{A10,18h}$	*Night time* $L_{A10,6h}$	*Day time* $L_{A90,18h}$	*Night time* $L_{A90,6h}$
Costessey				
- at speed cushion	-3.7 (-1.4)[1]	-2.6 (-3.3)[1]	-1.9 (-0.6)[1]	-2.5 (-4.3)[1]
- at road narrowing	-4.7	-1.9		
Craven Arms				
- at cushion/mini-roundabout	-3.6	-0.1		
- away from measures	-2.1	+0.9		
Hayton				
- at east gateway	-8.6	-12.9	-9.4	-2.3
Thorney				
- at east gateway	-5[2]			
- at zebra crossing	-3.5	-3.4		
- away from measures	0[2]			

[1] *Changes in brackets are the equivalent for C-weighted noise (dB(C))*
[2] *Predicted from changes in vehicle noise*

(at cushions and at a road narrowing) showed that there was no increase in the maximum level from short, noisy events (for example, body rattle or excessive braking/ acceleration) and that the number of such events reduced at both sites during the 24-hour periods monitored. At Craven Arms, however, there was some indication of an increase in the number of noisier events, particularly at the cushion site; it is likely that these events relate to heavy vehicles clipping a cushion (see section 4.4.1).

4.5 Vibration

Thorney is located on soft soil containing peat, a situation particularly prone to generate vibration. Peak levels of ground-borne vibration measured in the structure of the house near the east gateway were found to exceed the threshold for human perception of 0.3 mm/s in every 15-minute observation period and were in the range 0.31 to 0.46 mm/s. This level is an order of magnitude below the level at which structural damage would be likely to result (Watts, 1990), but some disturbance might be experienced upstairs, where amplification may occur. For light vehicles, vibration was similar when crossing the gateway and when travelling on the smooth road surface immediately outside the house; for heavy vehicles, the gateway typically caused the level recorded from the smooth surface to double.

The soil type at Craven Arms is less likely to generate vibration. Here the peak levels of ground-borne vibration measured in the structure of the house near the speed cushion were much lower than the perception threshold level, at 0.04 to 0.10 mm/s. Heavy vehicles ‘clipping’ a cushion produced vibration levels about 50% higher than those which did not. Vibration levels generated by normal use of the building and from other non-vehicle sources were similar to those produced by the worst case conditions when a heavy vehicle ‘clipped’ a cushion.

4.6 Public opinions

All three surveys showed that the speed of traffic was widely considered to be a problem before scheme installation (Table 9[i]). Together with the level of traffic, this made it difficult to cross the road and made it dangerous for children. In Costessey, ‘rat-running’ and HGVs were also key problems. Attitudes to the schemes after installation are also summarised in Table 9: in Craven Arms and Thorney, respondents’ overall level of satisfaction with the schemes and their level of agreement with various statements were measured on a scale 1-5; the mean responses are shown. A score of 5 represents ‘very good/agree a lot’; 4 is ‘quite good/agree a little’; 3 is ‘no opinion either way’; 2 is ‘quite bad/disagree a little’; 1 is ‘very bad/disagree a lot’. In Costessey, a different questionnaire format was used.

Full results from all three surveys are given in Wheeler *et al* (1996, 1997, 1998).

4.6.1 Craven Arms and Thorney

Of those interviewed in Craven Arms and Thorney, more than half were female and nearly three-quarters were at least 40 years old. Half of the respondents lived on the main road in Thorney and just over a quarter did so in Craven Arms.

Over two-thirds of respondents in Craven Arms and 90% in Thorney knew beforehand that measures were to be installed; two-thirds in Craven Arms but less than 60% in Thorney thought that changes were necessary.

In spite of the generally encouraging speed reductions measured, half of the respondents in Craven Arms and three-quarters in Thorney thought speeds had not been reduced enough after scheme implementation. In both villages, over half of the respondents thought that the scheme made it safer for pedestrians, but somewhat less safe for drivers. All of these responses resulted in mean scores of about 3 or less (Table 9[ii, iii]).

Just over half of the residents in Craven Arms and over two-thirds in Thorney were dissatisfied overall with the scheme, reflected in mean scores of 2.7 and 2.1 respectively (Table 9[iv]). Under 40% of respondents were satisfied with the scheme in Craven Arms and only a quarter were in Thorney, the remainder having no opinion either way. The reactions were similar whether the residents lived on, or away from, the main road.

When asked about specific measures, about two-thirds of respondents in Craven Arms thought that the countdown signs, gateway features, repeated red patches and pedestrian refuges were all useful (Table 9[v]), although one in five expressed concern about the refuges, the main criticism being that they were too narrow, with preferences for a zebra or pelican crossing outside the supermarket.

The mini-roundabouts in Craven Arms came in for particular criticism, with two-thirds of respondents expressing concern about them (Table 9[vi]). Problems mentioned were related to who had priority, that they were difficult to see and that there were too many of them. Although little concern was expressed about the speed cushions, the centre hatching on a red background and the

Table 9 Key results from the public opinion surveys

	Costessey	Craven Arms	Thorney
[i] Problems before changes	Percentage of respondents thinking a problem		
Speed of traffic	85%	82%	74%
Heavy traffic	86%	59%	69%
Number of lorries	76%	56%	70%
Crossing road	72%	76%	80%
Danger to children	89%	79%	84%
Too much noise	43%	35%	48%
Rat-running	90%	-	-
[ii] Effect on		(1: very bad - 5: very good)	
Pedestrians	-	3.00	3.06
Cyclists	-	2.39	3.11
Drivers	-	2.47	2.63
Main road residents	-	2.34	1.89
		(1: disagree a lot - 5: agree a lot)	
[iii] The changes were necessary	-	3.60	3.08
It is safer now*	-	2.77	2.84
Speeds have reduced	28%	3.69	3.18
Speeds have reduced enough	-	3.05	2.22
Noise has increased	[*Less* noise 1%]	3.51	4.21
Prefer other changes	-	4.44	3.25
	(1: very dissatisfied - 5: very satisfied)		
[iv] Level of satisfaction with changes	2.13	2.66	2.13
[v] Measure is useful (measures with >50% in favour)	Flat-top hump (93%) Mini-roundabout (74%) N'wing+cushion (72%) Narrowings (69%) 30mph reminder sign (65%) 20mph zone signs (59%)	Countdown signs (68%) G'way red surface (66%) Refuges (65%) Repeated red patches (62%)	Cameras (81%) Zebra crossing (61%) Part-time 20mph speed limit (59%) Blue/yellow gateway signs (53%)
[vi] Measure causes concern/problems	Speed cushions (74%)	Mini-r'bouts (67%)	Mini-r'bout (59%)
[vii] Concerned about look of scheme (measures with >50% concerned)	39%	41%	39%

* *average of the effect on different groups of people*

'dragon teeth' markings at the gateways, about 40% of respondents thought that these features were of little use.

In Thorney, over 80% of respondents thought that the speed cameras were useful, and over half thought the same about the blue and yellow signing in advance of the gateways, the part-time 20mph speed limit and the zebra crossing (Table 9[v]). On the other hand, about 40% of respondents thought that the blue and yellow signing, the imprinted surfacing at the zebra crossing, and the kerb realignment in the centre of the village were of little use. As in Craven Arms, the mini-roundabout caused the most concern of any of the measures, with nearly 60% of respondents concerned. Comments were mixed, the main ones implying that it was ignored by drivers and difficult for HGVs to negotiate because of the restricted space to manoeuvre. Nearly a tenth of these respondents mentioned noise nuisance generated by the mini-roundabout and being kept awake at night.

Although the chicanes in Thorney were effective in reducing speeds, nearly 40% of respondents were concerned about them. The main criticisms were that the road was too narrow, HGVs could not get through, and there were claims implying they do not reduce speed. A third of respondents were also concerned about the kerb realignment in the centre of the village, again in connection with the available lane or carriageway width, with an equal concern about not being able to park outside the shops and the consequent loss in trade.

Although only one resident thought that the speed cushions in Craven Arms generated extra noise, there was mild agreement generally that the measures overall had increased traffic noise, and vibration from passing HGVs. There was fairly strong agreement that other changes or a bypass would have been better than the measures installed (Table 9[iii]).

In Thorney there was fairly strong agreement that the measures had increased traffic noise (Table 9[iii]) and that there was perceptible vibration in houses from HGVs. The lack of satisfaction with the scheme overall was reflected in respondents' strong agreement that a bypass, for which there had recently been an active campaign, would have been better. This appeared to be preferred to the option of other changes, as residents were fairly non-committal about the latter, but this is likely to be because the bypass issue was uppermost in their minds.

In both villages about 40% of respondents were concerned about the look of the scheme (Table 9[vii]). At Craven Arms, nearly all of these respondents thought that the measures had a garish appearance (referring to their colour) and at Thorney, almost all thought that the measures spoiled the look of the village or were unsightly.

Negative comments about the Thorney scheme were made more strongly by those living on the main road than elsewhere, particularly by those living close to measures more likely to generate noise and vibration i.e. the mini-roundabout (with its domed island), and the east gateway and zebra crossing (both with the slightly raised, imprinted surfacing). They were also more likely to claim there had been no problems prior to scheme installation.

Responses were broadly similar between age groups at both Craven Arms and Thorney, but there were some exceptions: in Craven Arms, younger respondents (aged under 40) were more likely to (a) express dissatisfaction with the scheme, (b) think that the measures disadvantaged drivers and cyclists and (c) not support similar measures in other villages. They were also slightly more likely to favour other changes. In Thorney, respondents aged 60 and over were more likely to think that the part-time 20mph speed limit was useful, and to express concern about the kerb realignment in the village centre.

4.6.2 Costessey

The opinion surveys revealed a relatively elderly population in Costessey, more than half of the 100 people interviewed before and after scheme installation being over 60. Over 90% of respondents had heard about the scheme prior to its installation, and a similar percentage thought it necessary before scheme installation to control the speed and amount of HGV traffic and traffic in general.

Residents generally had high hopes that the scheme would reduce traffic levels and speeds, particularly of lorries, but afterwards were less enthusiastic - the average score for overall satisfaction with the scheme was only 2.13 (Table 9[iv]). There was less concern about the speed of vehicles than previously, but more were now bothered by traffic congestion. This may have resulted from vehicles having to give way to opposing traffic at the narrowings, or perhaps from moving queues forming behind vehicles crossing cushions particularly slowly. There were mixed views about the appearance of the scheme, again with about 40% voicing concern (Table 9[vii]).

Overall, safety was believed to have improved, especially for pedestrians (from three-quarters concerned about their safety before to just over half after), but the scheme as a whole seemed to be perceived to have little else to commend it. However, when asked specifically about the individual measures, most people considered most of them to be useful. The road hump outside the school was extremely popular, followed by the mini-roundabout and the road narrowings (Table 9[v]). The speed cushions were disliked by about three-quarters of respondents, mainly because they were perceived to be ineffective at reducing speed as most vehicles could straddle them (Table 9[vi]). Since the cushions were the most frequently used measure in the scheme as a whole, their unpopularity may be responsible for much of the negative reaction towards the scheme. Most respondents favoured speed controls (in particular speed cameras and speed limits) as a means of reducing both the speed and volume of traffic.

The traffic calming scheme had little effect on the noise levels perceived by respondents either in their homes or as pedestrians. Slightly fewer respondents were bothered by windows and doors vibrating, and the nuisance from dust and dirt in the street was thought to have reduced. Bother from noise and vibration did not vary according to where respondents lived in relation to the measures.

4.6.3 Reaction from the emergency services

Shropshire County Council wrote to the Police, Ambulance and Fire/Rescue Services to canvas their opinions on the Craven Arms scheme. The Police stated that their response times had not been affected, but the Ambulance and Fire/Rescue services were concerned. Both services claimed that response times had been increased, especially by the mini-roundabouts, where delays were alleged to occur in peak periods. Confusion in other drivers over who had the right-of-way was mentioned as a primary cause. Ambulances being forced to mount the speed cushions, by drivers pulling over to allow them to overtake, could cause discomfort to patients.

No comments were made on the Thorney and Costessey schemes.

4.7 Accidents

Table 10 shows, for each scheme, the number of reported injury accidents occurring on the length of road within the current village speed limit before and after scheme installation, together with the number of years to which they relate, and the implied accident frequencies.

Overall, there has been a small reduction in overall accident frequency since the introduction of the schemes, but this result is not statistically significant. The schemes with physical measures (Costessey, Craven Arms and Thorney) saw a (non-significant) combined reduction in frequency from 4.3 to 3.2 per year whereas at the other schemes there was little change (2.9 to 2.8 accidents per year).

Considering, however, accident severity, the results are very encouraging, with no fatal accidents and only one serious accident occurring altogether after scheme installation. There has been a reduction in severity [(fatal + serious)/all injury] from 0.30 to 0.02.

5 Summary and discussion

Traffic flows

None of the traffic calming schemes was introduced with a realistic objective of reducing the flow of heavy goods, or other, traffic passing through the villages. Rather, they were intended to reduce the impact of that traffic, in particular on residents. It is unsurprising, therefore, that traffic flows were unaffected. In Costessey, the use of speed cushions and carriageway narrowings appears to have stemmed an expected increase in flow levels.

Table 10 Injury accidents and their frequencies for each scheme

Village	*Before scheme installation* Number (serious, fatal)	Years	Accidents/ year	*After scheme installation* Number (serious, fatal)	Years	Accidents/ year
Copster Green	18 (6, 3)	5.0	3.6	8 (0, 0)	2.4	3.3
Costessey	15 (2, 0)	5.0	3.0	0 (0, 0)	1.0	0.0
Craven Arms	23 (5, 0)	5.0	4.6	6 (0, 0)	2.7	2.2
Dorrington	2 (0, 0)	5.0	0.4	2 (0, 0)	1.5	1.3
Great Glen	24 (2, 1)	5.0	4.8	9 (0, 0)	2.3	4.0
Hayton	10 (4, 1)	5.0	2.0	1 (0, 0)	1.5	0.7
Pant	9 (4, 1)	5.0	1.8	0 (0, 0)	0.8	0.0
Thorney	26 (9, 1)	5.0	5.2	13 (1, 0)	2.2	6.0
West Wellow	25 (4, 2)	5.0	5.0	9 (0, 0)	1.7	5.4
All	152 (36, 9)	45.0	3.4	48 (1, 0)	16.1	3.0

Vehicle speeds

Vehicle speeds have been reduced almost everywhere. With the exception of one of the gateways at Great Glen, 85th percentile speeds decreased by between 3 mph and 15 mph, both inbound at gateways, and in the villages themselves. However, they remained above the new/ retained speed limit, albeit generally by only a few mph within the village. Mean speed reductions were generally up to about 2mph less then reductions in 85th percentile speeds, the faster drivers therefore being affected the most.

A range of different measures have been used in combination, making it difficult to compare their effect, particularly as the circumstances in which they were installed varied considerably between villages. In particular, measures were accompanied by a reduction in the speed limit in some villages but not others. As was concluded from the VISP study (Wheeler *et al*, 1994) physical measures have the greatest effect on speeds; the present study has demonstrated their application on trunk roads in Craven Arms and Thorney, and in a rather different situation in Costessey.

Large inbound speed reductions at gateways occurred with the cushioned narrowings at the entry to the new 20mph zone in Costessey. Reductions of the order of 10mph also occurred where there was significant signing and marking at the gateway. A strong visual impact (for example, with 'dragon teeth' and roundels on coloured surfacing) was necessary to achieve this scale of reduction; additional approach signing ('countdown' signs, for example) was beneficial, as was speed camera signing. Large reductions were also obtained where Before speeds were particularly high, and accompanied by a big reduction in the speed limit as at Hayton.

Within the villages, physical measures resulted in mean and 85th percentile speed reductions of 7-12mph. Without such measures, reductions were more modest and large proportions of vehicles still exceeded the speed limit at some locations. The addition of speed cameras had a small effect. At Costessey, speed cushions were used effectively to reduce speeds and to maintain them at a constant level, through optimum spacing.

In common with previous studies of village calming measures, the schemes were also found to affect outbound speeds at gateways (but to a lesser extent than inbound speeds) and to often have a slightly greater effect on speeds at night and at weekends. This latter result reflects the fact that the schemes tend to affect the speeds of faster vehicles the most.

The fact that only a small erosion in speed reductions was observed after a year suggests that the measures studied are likely to have long term impact.

Vehicle journey times

In Craven Arms and Thorney there was evidence that journey times had increased with the introduction of the measures. This would be expected, due to the speed reductions. The largest increase was about half-a-minute at Craven Arms. The shorter journey times occurring in the Before situation resulted from many drivers exceeding the speed limits both in terms of the national speed limit for goods vehicles (40mph) and the local speed limit (30mph).

Vehicle and traffic noise

The speed reductions have resulted directly in decreased noise levels at the locations in Hayton, Costessey, Craven Arms and Thorney where noise was measured. Maximum vehicle noise levels, for light and for heavy vehicles, reduced by up to about 10dB(A), and traffic noise levels reduced typically by up to about 5dB(A).

An important finding from this study concerns changes in the noise climate resulting from the introduction of vertical deflections (speed cushions, mini-roundabouts) and textured surfacing. None of the results indicated an increase in either maximum vehicle noise or overall traffic noise levels, recorded using standard procedures, with the schemes in place. However, many residents were of the opinion that noise levels had in fact increased (see below). Further investigation suggested reasons for this:

i in heavy traffic flows, vertical deflections may increase the number of short-duration, high noise events, resulting for example from heavy vehicles 'clipping' the measure, and these may be perceived as annoying to residents, particularly at night;

ii the change in driver behaviour (increased braking/gear changing) or use of different surface materials causes a change in the characteristics of noise emitted; this may also be perceived as annoying to nearby residents;

iii variability of low frequency noise from heavy vehicles.

The extensive investigation of noise characteristics in Costessey suggests that even when no source of increased noise can be identified the reductions in vehicle and traffic noise levels measured are not perceived by residents.

Ground-borne vibration

Heavy vehicles at Craven Arms produced 'worst case' vibration levels in a house near the speed cushions no greater than those generated by normal household activities, and below the threshold for human perception. However, the soil conditions in Thorney resulted in peak levels of ground-borne vibration in a house adjacent to the imprinted surface at the gateway which marginally exceeded the threshold for human perception. The level was nowhere near that which would result in structural damage.

Opinion surveys

Reactions from residents in the villages with schemes comprising extensive physical measures were less encouraging than the measured speed reductions would have suggested. It would appear that even quite large speed reductions are not widely recognised. Although mean and 85th percentile speeds had been reduced by 10mph, residents in Costessey were particularly disappointed: they had high expectations of what the calming scheme would achieve and these had not been realised, with 85th percentile speeds largely remaining well above the new 20mph speed limit. In Thorney, the plans for a long-awaited bypass that had recently been scrapped are likely to have influenced views.

Despite the general lack of enthusiasm for the schemes, some of the component measures were regarded favourably, although the circumstances in which they were used was important. For example, mini-roundabouts were disliked where there were very heavy traffic levels, but favoured at Costessey (low flows). Speed cushions were particularly disliked at Costessey, where they were perceived to be ineffective at reducing speeds. In Craven Arms, where coloured surfacing was extensively used, this was associated with displeasure about the appearance of the scheme. In all three villages, about 40% of residents expressed concern about the look of the scheme.

In Craven Arms, increased response times have been experienced by the fire and ambulance sevices, with the mini-roundabouts and speed cushions cited as the cause. This is consistent with the increased vehicle journey times observed (see above). Care needs to be exercised in the use of these measures where there is significant emergency service vehicle activity.

Accidents

Taking all the schemes together, there is a suggestion of a small overall reduction (not statistically significant) in injury accident frequency in the periods immediately following installation (between 1 and 3 years). The reduction for the three schemes with extensive physical measures is greater (about 25%). However, there is a much stronger indication of a reduction in accident *severity*, with only one serious accident occurring since scheme installation, across all 9 schemes.

6 Conclusions and recommendations

i The size of the speed reductions following the installation of a traffic calming scheme at a village on a main road is likely to be affected by the pre-existing speed limit, the magnitude of the Before speeds, the new speed limit and the traffic calming measures used.

ii Signing and marking measures can bring about large speed reductions at entries to villages on trunk roads, when used in combination to give high visual impact. Repeated use through the village can also reduce speeds there but is unlikely to achieve 85th percentile speeds below the posted speed limit.

iii Speed cushions, mini-roundabouts and chicanes can be used in trunk road villages to bring about greater speed reductions than signing and marking measures alone. However, care is needed, particularly with the design and siting of vertical deflections, where there are high flows of heavy vehicles or emergency service vehicles, or where the soil type is especially prone to transmit vibration. It is important that measures are appropriately spaced, so as to induce constant speeds.

iv Narrow cushions (1.5m wide) allow heavy vehicles and emergency vehicles to straddle them. They can be effective in bringing mean speeds down to below 30mph but the results presented here support other work (Layfield and Parry, 1998) which suggests that they are generally unsuitable for reducing speeds to 20mph.

v Residents are unlikely to be satisfied with schemes that do not achieve their expectations of reducing speeds below the new/retained speed limit and it is important not to raise their hopes unrealistically. They often do not perceive even quite large reductions in vehicle speeds and noise levels, with changes in the characteristics of the noise generated apparently nullifying reductions in overall noise levels in terms of the annoyance created.

vi There is an indication that injury accident severity can be reduced through the introduction of the measures used in the schemes studied. If sustained, it is possible that this could ultimately lead to an improvement in residents' reactions to the schemes.

As far as the design of new traffic calming schemes in villages is concerned, the study has highlighted the importance of involving residents in the development of schemes and providing them with an understanding of what can be achieved. Inevitably there will usually be a trade-off between scheme effectiveness (in terms of vehicle speed and accident reduction) and potential unwanted effects (such as visual intrusion). The optimum solution will vary widely according to the situation.

7 Acknowledgements

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Joan Franklin, Linda Chinn, and interviewers (opinion surveys).

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KEY TO MEASURES SHOWN IN APPENDICES

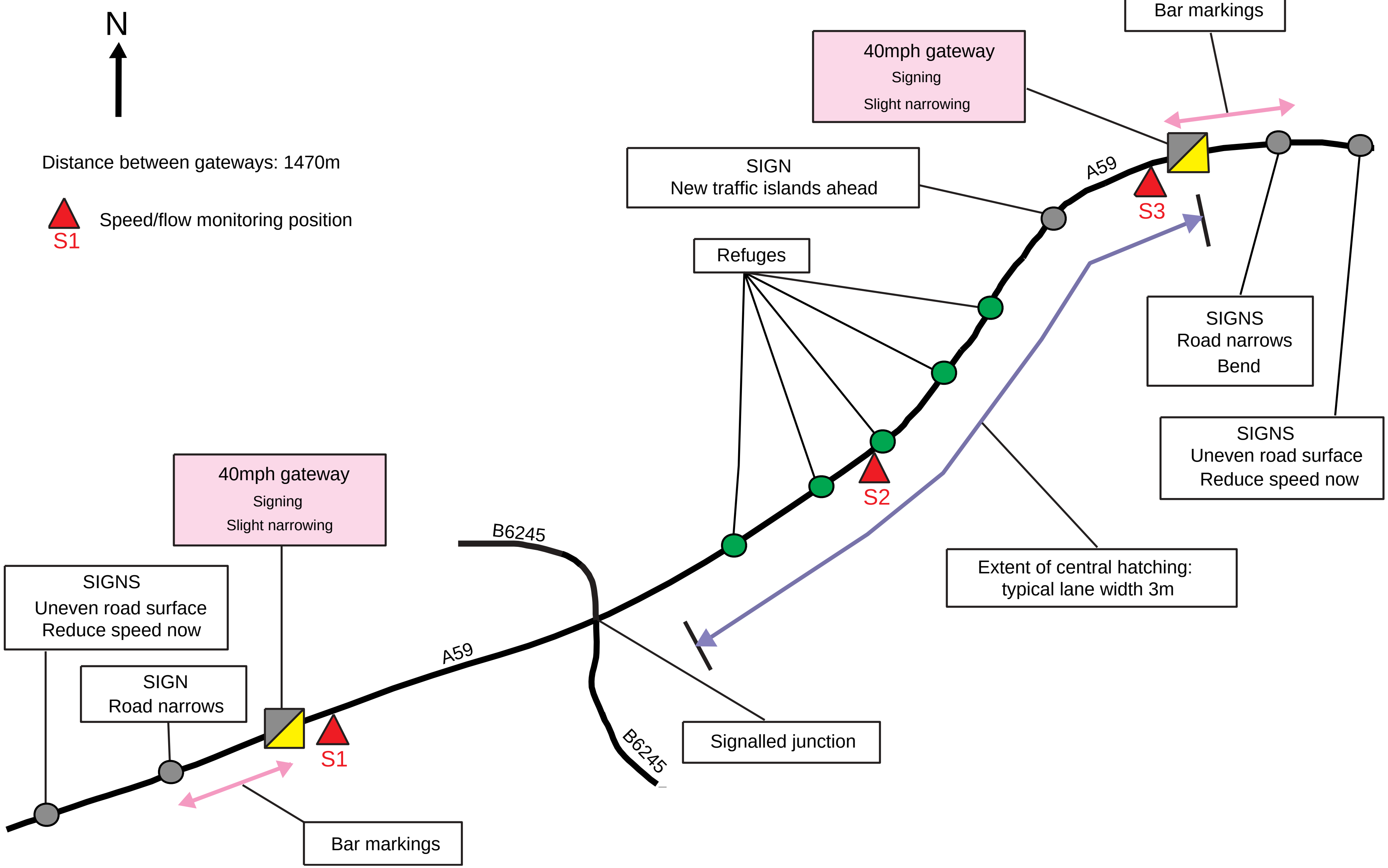
GATEWAYS

- surface treatment, signing, markings
- dragon teeth, surface treatment, signing, markings
- surface treatment, signing, narrowing
- signing, narrowing
- narrowing + cushion

OTHER MEASURES

- signing
- coloured surfacing with speed limit repeaters
- coloured surfacing with painted speed limit roundels
- speed camera
- part-time speed camera site
- island/refuge
- pedestrian crossing
- narrowing (one-way working)
- mini-roundabout
- speed cushion
- flat-top hump
- island chicane

Appendix A: Measures at Copster Green, Lancashire



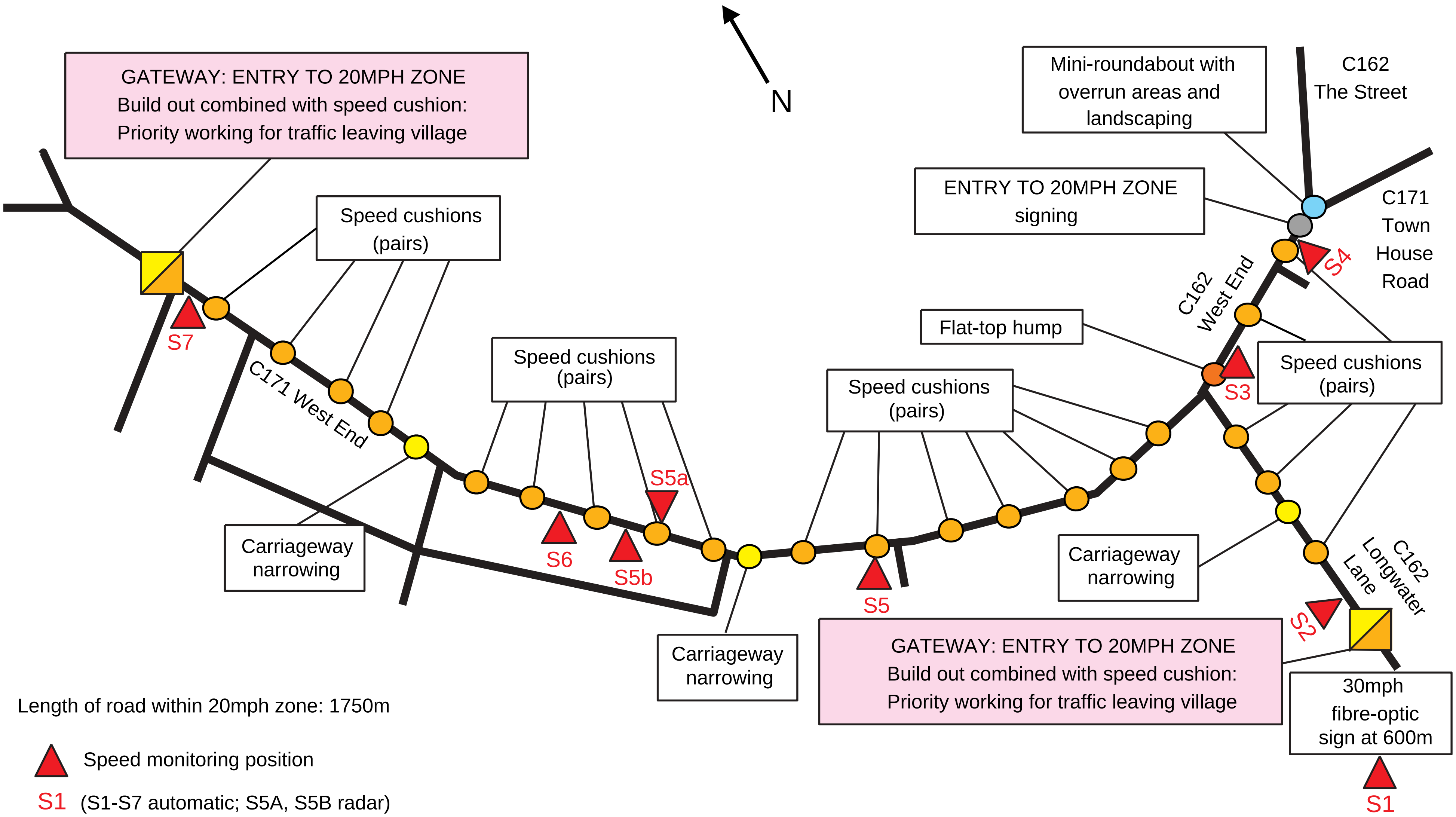
Bar markings in advance of the east gateway

East gateway, showing slight carriageway narrowing

Signing for refuges in the village (looking west) 125m inside the east gateway

One of the refuges in the village; another can be seen in the far distance (looking west)

Appendix B: Measures at Costessey, Norfolk



Southern entry to the 20mph zone, with a speed cushion within the narrowing (Longwater Lane)

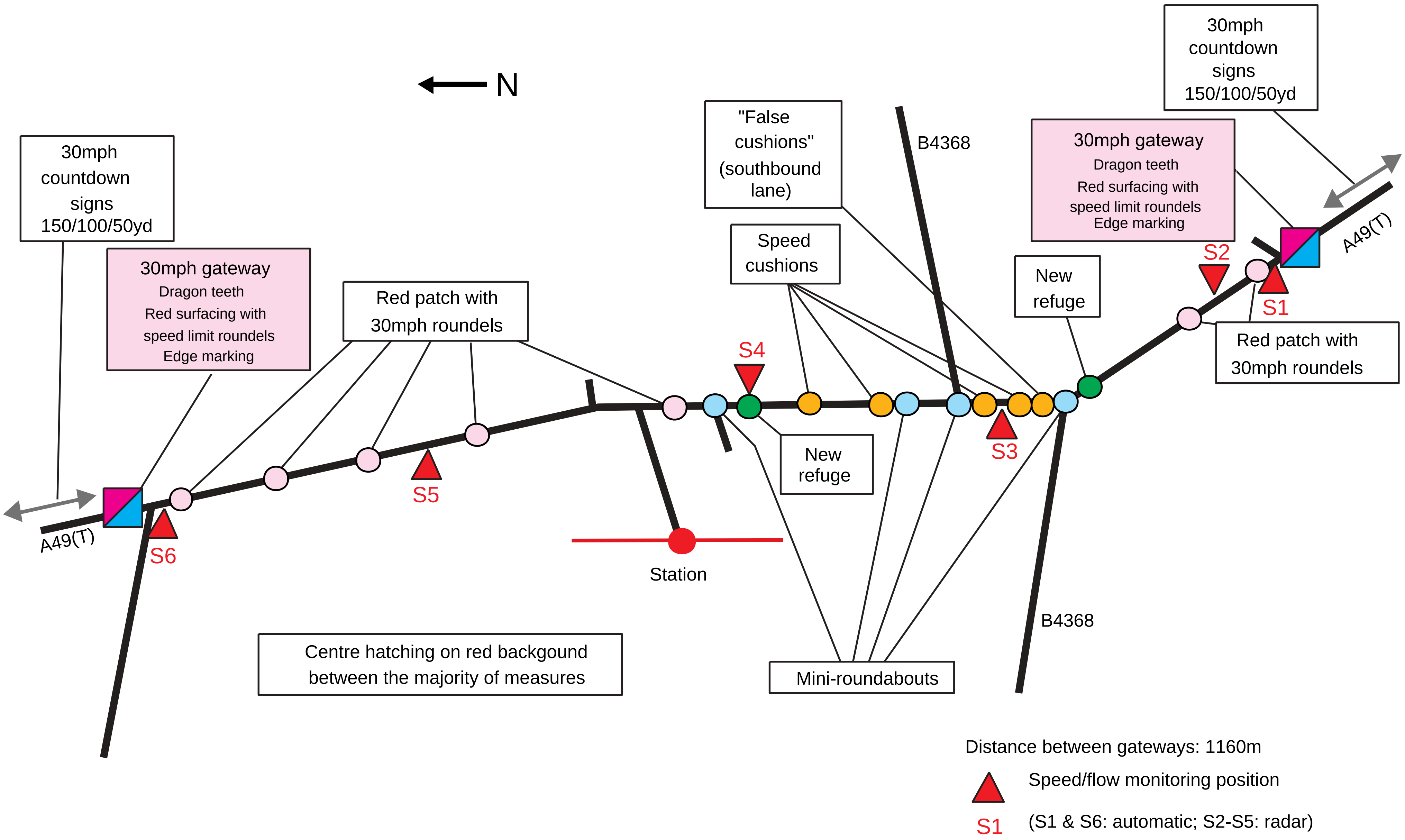
Mini-roundabout at the junction of West End, The Street and Town House Road, the eastern exit from the 20mph zone

Speed cushions (West End)

Flat-top hump (West End) outside school access

Single lane working narrowing (West End)

Appendix C: Measures at Craven Arms, Shropshire



Countdown signs to the 30mph speed limit at the south gateway

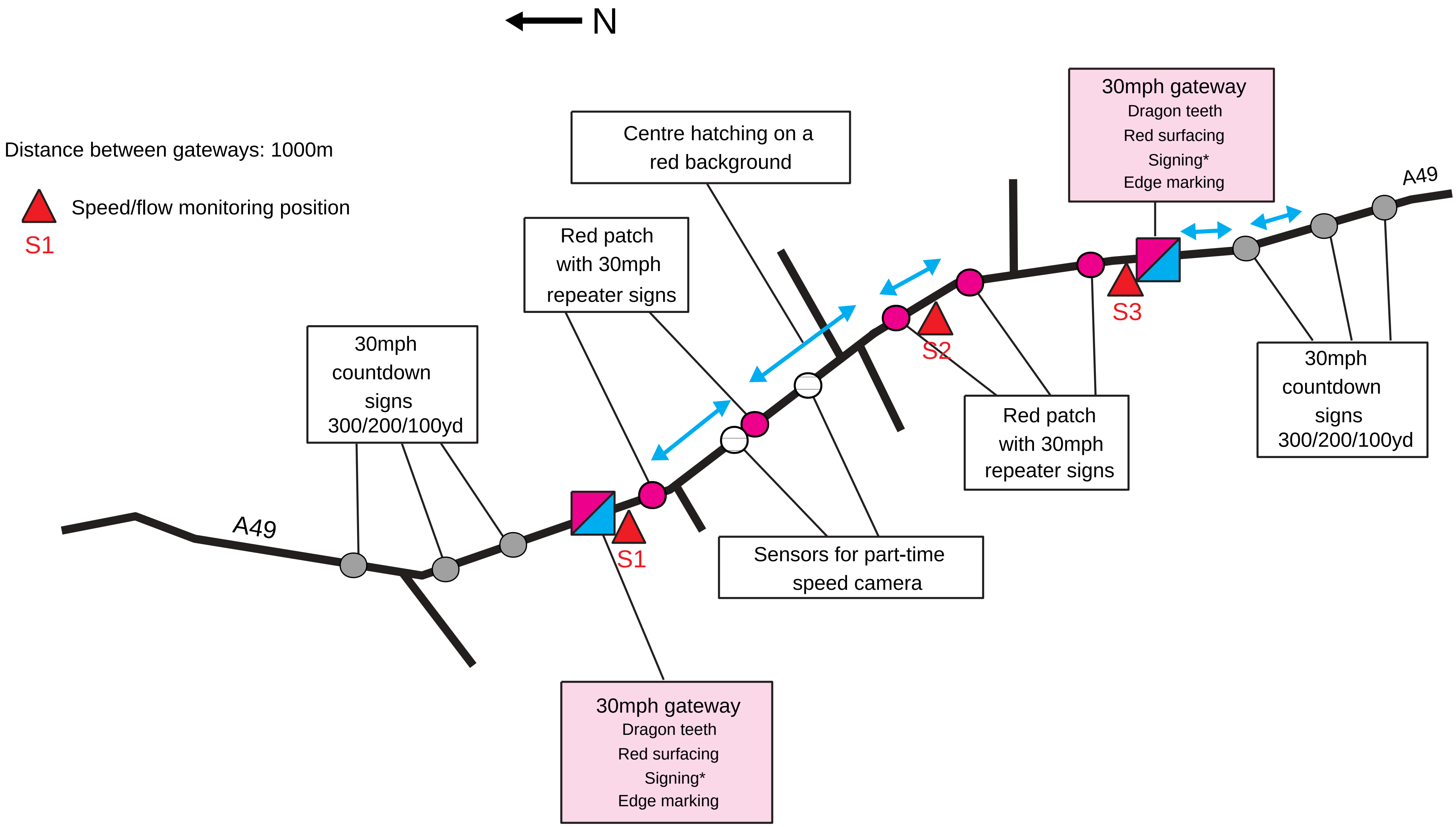
Speed cushions and mini-roundabouts in the village centre (looking north)

'Dragon teeth' markings at the south gateway

Repeated red patch in the village

Speed cushion, pedestrian refuge and centre hatching just north of the village centre (looking north)

Appendix D: Measures at Dorrington, Shropshire



*Including speed camera signing

Countdown signs to the 30mph speed limit at the south gateway

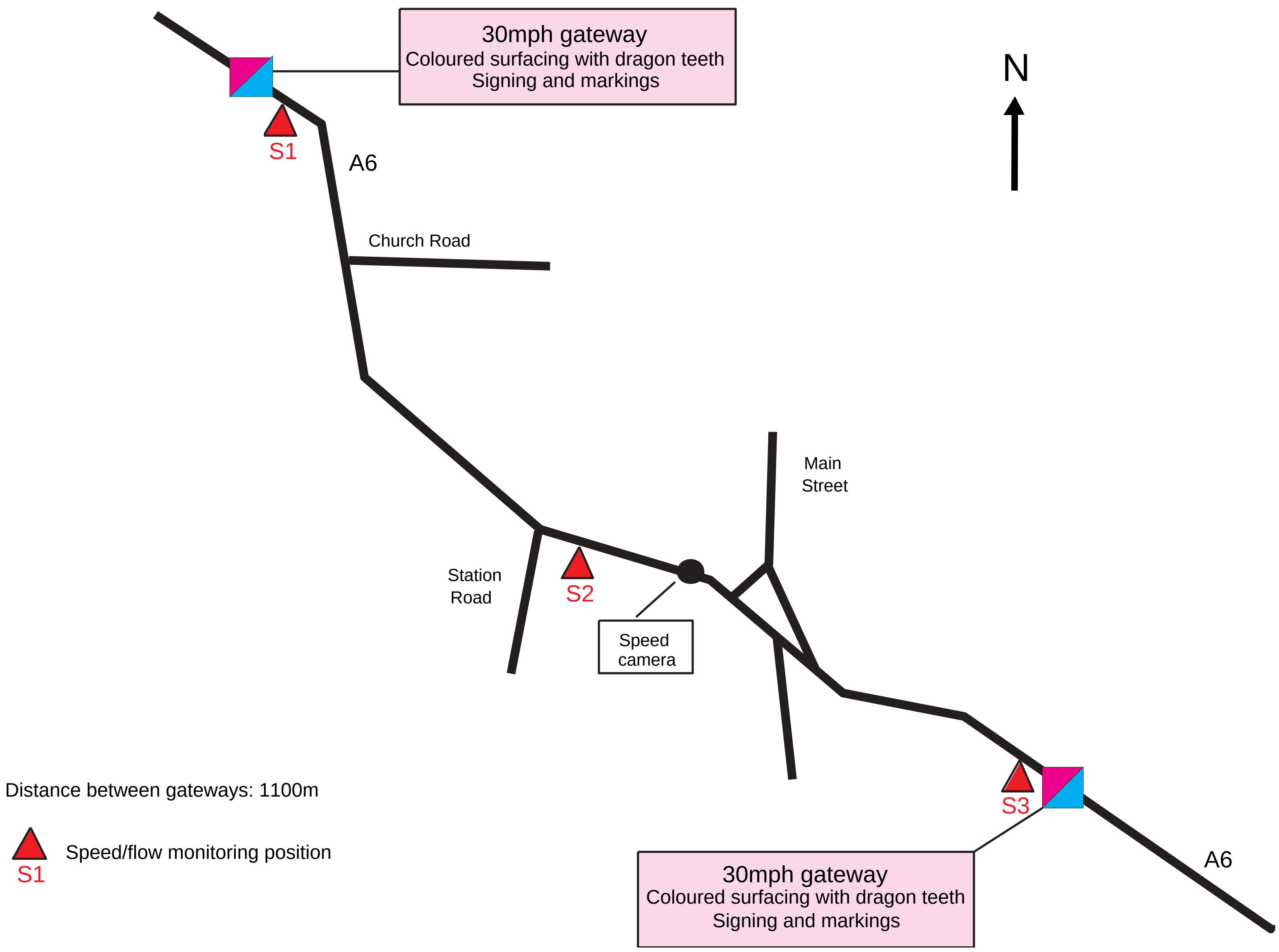
'Dragon teeth' markings at the south gateway

South gateway: red surface treatment and markings are repeated through the village

Repeated red patch with 30mph repeater signs in the village (looking north)

Centre hatching within the village (looking north)

Appendix E: Measures at Great Glen, Leicestershire



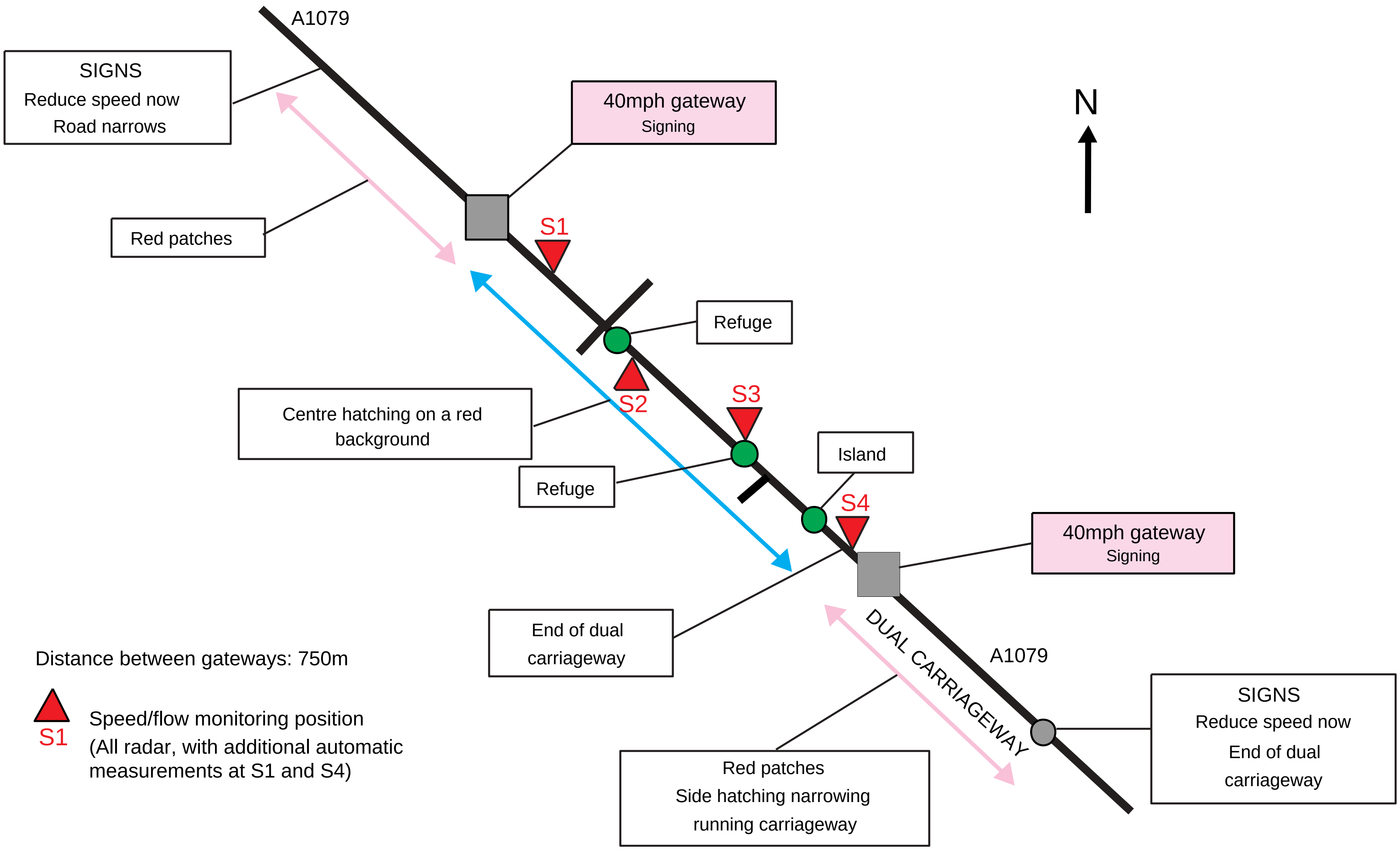
South gateway

South gateway surface treatment

North gateway with speed camera signing added

Speed camera in village

Appendix F: Measures at Hayton, East Riding of Yorkshire



Start of the features in advance of the northwest gateway

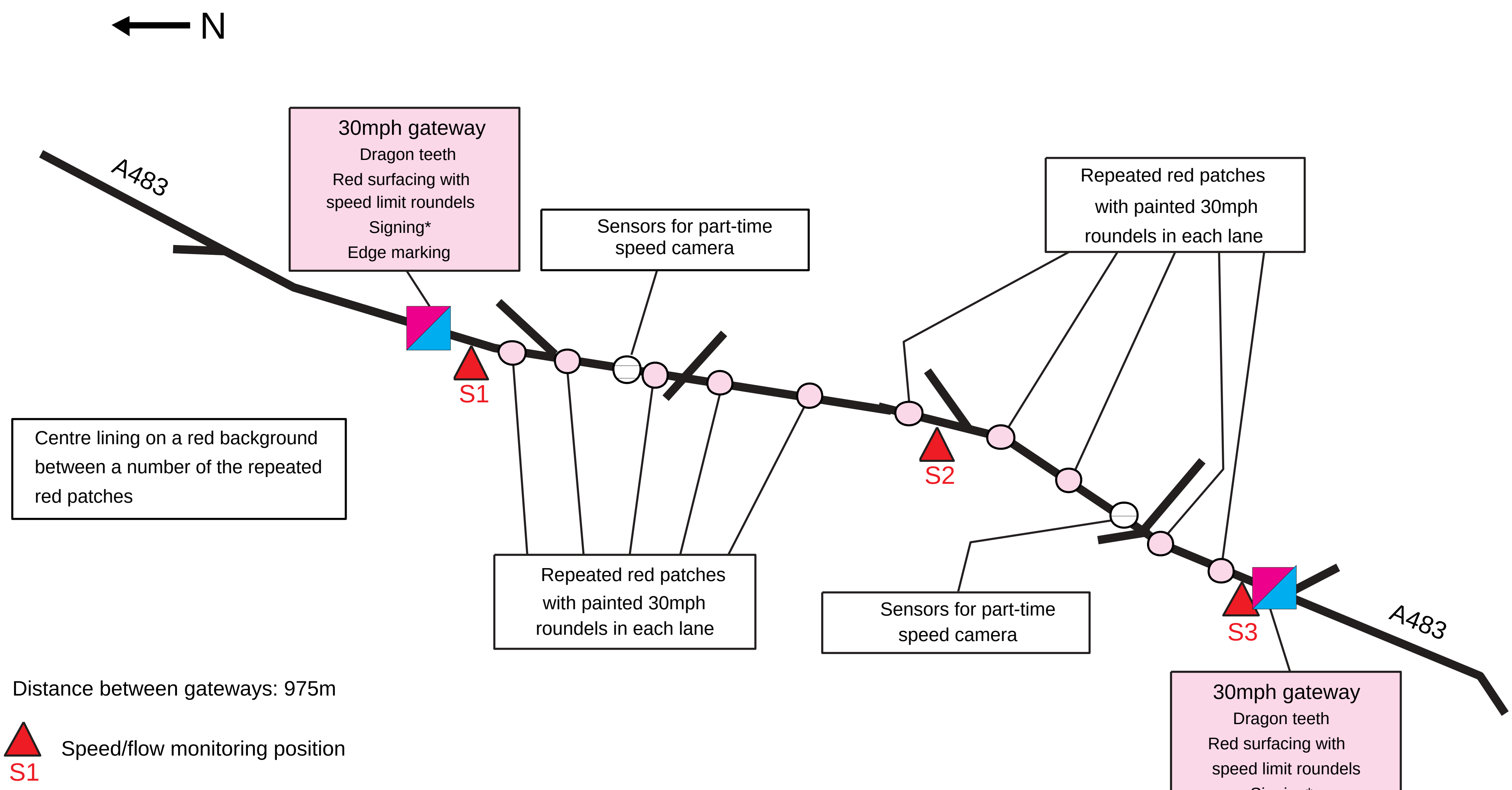
The northwest gateway

About halfway along the red patches in advance of the southeast gateway on the dual carriageway approach

The southeast gateway

Pedestrian refuge in the village (looking southeast)

Appendix G: Measures at Pant, Shropshire



*including speed camera signing

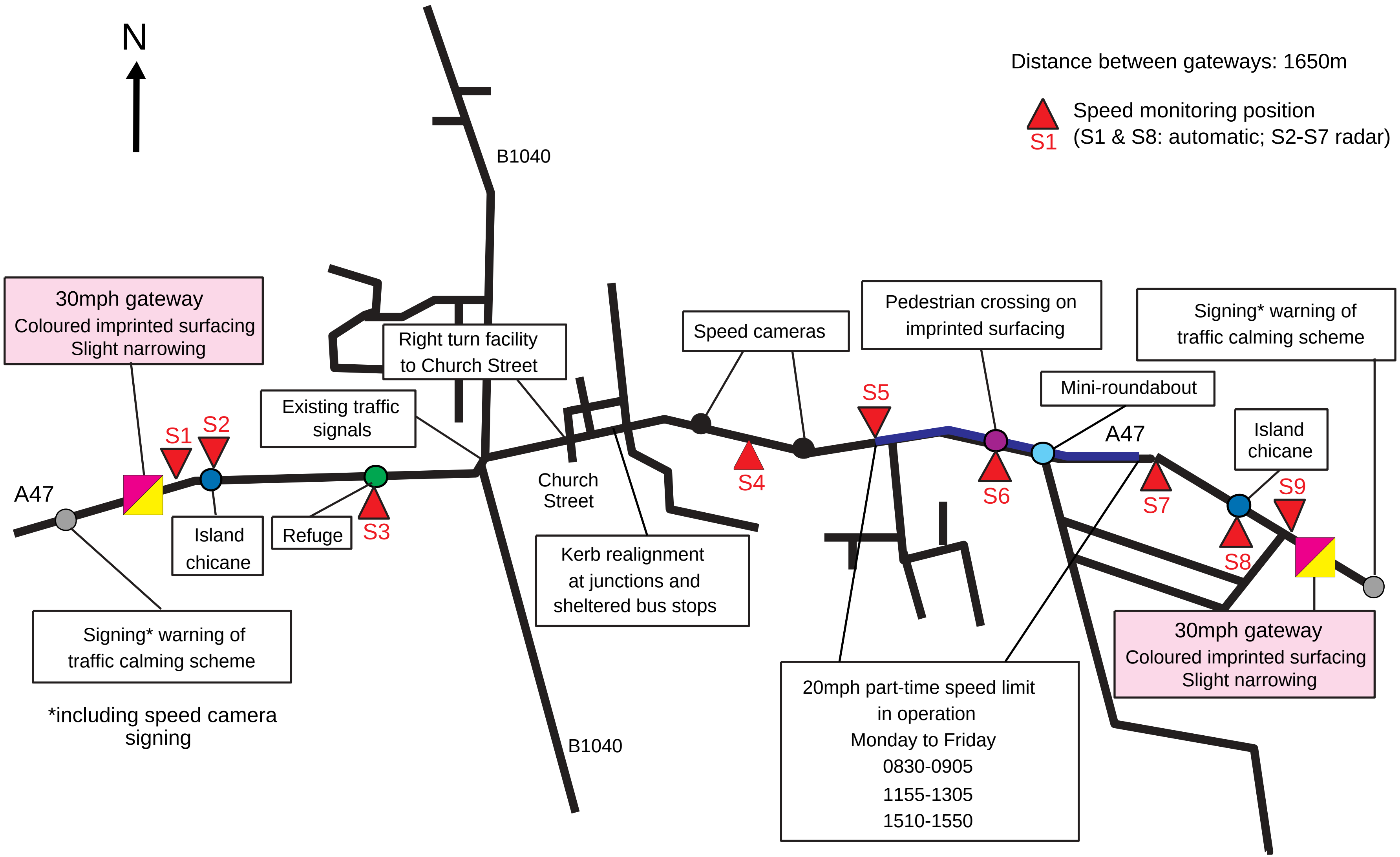
‘Dragon teeth’ markings at the south gateway

South gateway showing red surface treatment and markings which are repeated through the village

Repeated red patch in the village

Centre lining on red background between repeated red patches within the village

Appendix H: Measures at Thorney, Cambridgeshire



*including speed camera signing

Advance signing on the approach to the east gateway

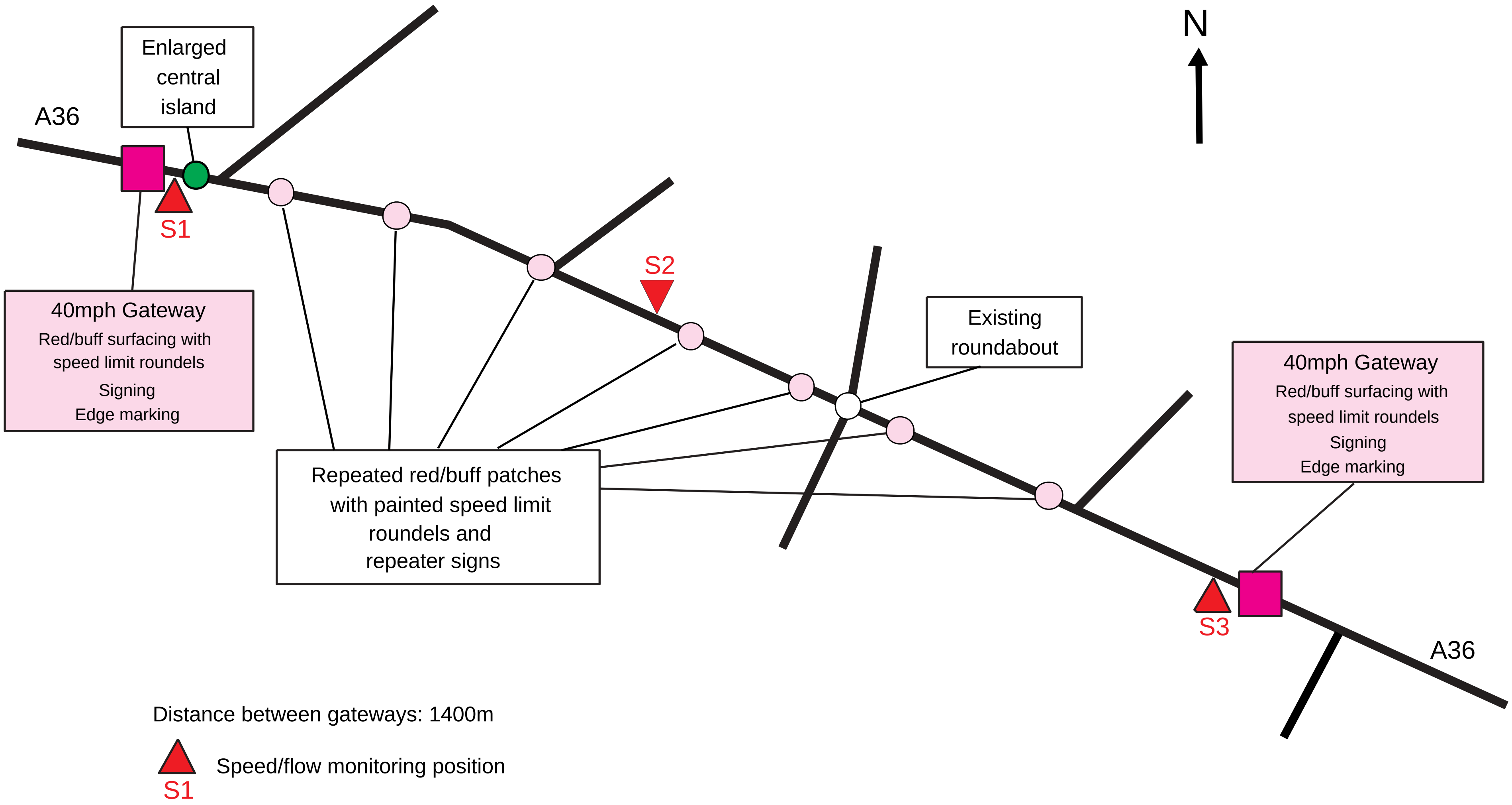
Variable message signing showing 20mph speed limit during school arrival and leaving periods (conventional 'school' sign at other times)

East gateway

Chicane, eastern end of the village (looking outbound)

Mini-roundabout

Appendix I: Measures at West Wellow, Hampshire



East gateway showing surface treatment intended to create the illusion of a flat-top hump (treatment repeated at intervals through village)

West gateway and enlarged central island

Repeated gateway surface treatment with low level 40mph repeater signs (looking west)

Start of footway converted to shared use by pedestrians and cyclists, just inside east gateway

Abstract

TRL has assessed the effectiveness of nine comprehensive schemes aimed at reducing traffic speeds on the main road through villages. Eight schemes were on a trunk road, and two-way traffic flows typically exceeded 8,000 per day with between 10-20% heavy vehicles. The schemes were designed to improve safety and the quality of life of residents, and involved a range of features. All schemes included ‘gateways’, mainly comprising prominent signing and marking measures and coloured surfacing. Within some villages, extensive physical measures, including narrow speed cushions and mini-roundabouts, were used. In several cases the village speed limit was reduced when the scheme was introduced.

The Report describes the results from surveys carried out before and after scheme installation. All of the schemes were successful in reducing speeds and, at the schemes with physical features, where noise levels were monitored, reductions were observed. Despite the measured benefits, some residents were dissatisfied with these more extensive schemes. Overall there is a strong indication of an improvement in accident severity.

Related publications

TRL364 A *traffic calming scheme at Costessey, Norfolk* by A Wheeler, G Harris, L Chinn, M Taylor and P Abbott. 1998 (price £35, code J)

TRL312 *Traffic calming — speed cushion schemes* by R E Layfield and D I Parry. 1998 (price £35, code H)

TRL313 *Traffic calming — an assessment of selected on-road chicane schemes* by I A Sayer, D I Parry and J K Barker. 1998 (price £25, code E)

TRL238 *Traffic calming on major roads: the A47 trunk road at Thorney, Cambridgeshire* by A H Wheeler, P G Abbott, N S Godfrey, S M Phillips and R Stait. 1997 (price £50, code L)

TRL235 *Traffic calming: vehicle generated ground-borne vibration alongside speed control cushions and road humps* by G R Watts, G J Harris and R E Layfield. 1997 (price £35, code H)

TRL212 *Traffic calming on major roads: the A49 trunk road at Craven Arms, Shropshire* by A H Wheeler, P G Abbott, N S Godfrey, D J Lawrence and S M Phillips. 1996 (price £50, code L)

TRL186 *Traffic calming — road hump schemes using 75 mm high humps* by David C Webster and Roger E Layfield. 1996 (price £35, code H)

TRL177 *Traffic calming — vehicle activated speed limit reminder signs* by D C Webster. 1995 (price £25, code E)

TRL180 T*raffic calming: vehicle noise emissions alongside speed control cushions and road humps* by P Abbott, J Tyler and R Layfield. 1995 (price £35, code H)

CT1.2 Traffic calming update (1994-1997) *Current Topics in Transport: Abstracts selected from TRL Library’s database.* (price £15)

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