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# Design Guide for Truck Escape Ramps

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## Introduction

California's first truck escape ramp was opened for use in August of 1956. It was located on the 5-mile grade section of what was then Highway 99, now Interstate 5, for southbound traffic north of Castaic. It was in service for 13.5 years, during which time it averaged one entry every ten days. Until the late 1970s, California had two or three truck escape ramps that received limited use. Since 1978, the number of truck escape ramps has increased steadily. Currently, there are ten that are operational and another eight that are planned or being designed.

Several recent developments acting in concert have increased the number of runaway trucks on long, steep downgrades. The number of trucks on highways has increased, and the average weight of these vehicles has also increased. Deregulation of the trucking industry has led to increased competition and reduced profit margins, which in turn may cause truckers to reduce their overhead by reducing maintenance. Another factor is the large number of out-of-state trucks using California highways; about 65 percent of the total. These drivers are unfamiliar with California's mountain highways and may descend a grade in too high a gear, thus requiring increased braking to control speeds. This causes properly maintained brakes to overheat and fade, and improperly maintained brakes may fail. As a result, a truck can accelerate until it runs off the road or the grade flattens out.

Before truck escape ramps were available, about the only thing truckers could do besides riding it out was to rub against roadside barriers and cut slopes. In some cases, they have driven up relatively flat cut slopes or made use of side roads that went up and off at an accessible angle.

## Types of Ramps

There are two basic types of truck escape ramps: the gravity ramp and the arrestor bed ramp. The gravity ramp is nothing more than an accessible surfaced side road on an ascending grade. It must be long enough to allow the truck to come to a full stop. They require little maintenance and usually no special equipment to retrieve the truck. There can be a problem where the truck that uses it has no braking capacity at all, and after stopping, rolls backwards down to the highway or jackknifes in the process of doing so. For this reason, gravity ramps are less desirable than arrestor bed ramps.

The second general class of truck escape ramp is the arrestor bed ramp. These ramps have several variants based on the material used to arrest vehicle motion, how it is placed, and the grade of the arrestor bed. The material used can range from sand up to about 1.5-inch aggregate. It may be placed in a basin, in longitudinal windrows, transverse windrows, or even piled up to 4 feet high. The grade of the arrestor bed is

dependent on the terrain and how much earthwork may be required to construct the ramp. Arrestor beds with ascending grades are more efficient and can be shorter, while arrestor beds with a negative grade must be longer to provide the same stopping ability. Also, the steeper the downgrade, the longer the arrestor bed must be.

# Determination of Need

The primary indicator of a runaway truck problem is the number or rate of incidents involving these vehicles. These incidents may be prevalent along grades or occur at specific sites such as sharp curves. Such locations may or may not appear on TASAS Table C. A secondary indicator would be the relative number of trucks with excessively hot or smoking brakes.

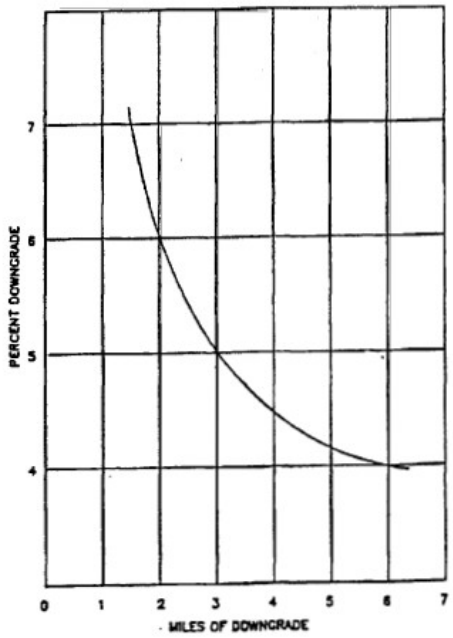
A sequential approach, even if leading to the eventual installation of a truck escape ramp, may be the most effective. First, review the signing by assessing the following:

- Are appropriate curve and grade warning signs in place?
- Is a posted downhill truck speed limit needed?
- Will it be enforced?

If these measures are implemented and are ineffective, then a roadside brake inspection area at the top of the grade is worth considering. The effectiveness of the inspection area may be enhanced if the California Highway Patrol uses it to periodically conduct truck inspections. If these measures are not effective, then install a truck escape ramp. Last, if none of these measures prove to be effective in reducing runaway truck incidents, a final, but highly controversial consideration would be banning trucks from the route or grade.

When a new highway is built, there is no past traffic experience to determine whether a truck escape ramp is needed. Figure No. 1, "Escape Ramps on New Highways," provides some guidance in this area. Where the combination of percent and length of downgrade fall on the right of the curve, an escape ramp should be considered as a part of initial construction. The curve is based on trucks arriving at the start of the downgrade with brakes at normal operating temperatures. Where there is a probability that trucks will arrive at the start of a downgrade with brakes hot from use on previous downgrades, then some lesser combination of percent and length of downgrade, to the left of the curve, may justify consideration of an escape ramp. Additional factors to consider are the volume and nature of truck traffic expected on the route.

**Figure No. 1 Escape Ramps on New Highways "See text for instructions"**




On existing long downgrades with no apparent runaway problem, it is important to confirm that no new features are introduced to the highway that require all trucks to make an increased braking effort. This may cause already overheated brakes to fail, creating a runaway situation. Features to look for are scale facilities, agricultural inspection stations, traffic signals, and maintenance or construction activities.

# Design Considerations

## Location

The location of a truck escape ramp, whether it is an arrestor bed or a gravity ramp, is controlled largely by the terrain. In general, an escape ramp should only be considered on the lower half of a grade because this is where the need becomes most apparent to the operator of a runaway truck, and increases the likelihood that the runaway truck driver will use the ramp. An exception would be on long, sustained downgrades.

Escape ramps should not be located on curves, since curves make it even harder for the driver of a runaway truck to stay in control. Also, a tangent ramp off a curve can, under some conditions, appear to be the through roadway. It is much better to locate an escape ramp along a tangent section of roadway.

On undivided highways, the escape ramp should be on the right side of the roadway. On divided highways, a truck escape ramp should normally be on the right side of the one-way roadway. A left side escape ramp may be worth considering where there are three or more lanes in the downgrade direction. Other factors to be considered are the

density of traffic in the right lane and which lanes the out-of-control trucks are using. A good estimate of a potential runaway truck problem can be obtained by noting the number of trucks passing a point with overheated brakes. On multilane facilities, the out-of-control trucks may be using the left or fast lane and could have easier access to a left-hand ramp rather than try to move through slower traffic to the right.

## Approach

An escape ramp, especially those to the right of traffic, should have an auxiliary lane approaching the escape ramp. This auxiliary lane can give the runaway truck a better chance of getting to the ramp. This auxiliary lane should be posted for "Runaway Vehicles Only" and "No Stopping Anytime" to ensure that it is kept clear. Auxiliary lanes should be at least 1,000 feet long with a greater length where traffic volumes are higher. A computer program is being developed that will allow auxiliary lane length to be evaluated on the basis of the number of traffic lanes and the number of trucks with other vehicles, as well as their speeds.

The approach to the gravel bed should be squared off so that all wheels on an axle enter the gravel at the same time. Also, the gravel bed should start far enough from the through traffic lanes so that gravel is not thrown into the travelled way when a truck enters the gravel bed.

The driver of an out-of-control truck is usually operating in or nearly in a panicked condition. In order for them to feel that the ramp can be navigated safely, they must be able to see as much of the ramp as possible. Grade sags or crests that obscure a portion of the ramp may influence an out-of-control driver to avoid the ramp. Proper signing of the entrance to the escape ramp is essential, and lighting of the ramp entrance is worthy of consideration.

## Ramp Alignment

A ramp should be on one continuous tangent. This may not be entirely possible for a gravity ramp that uses an abandoned logging road. Arrestor beds should not be curved, as any excessive steering maneuver could cause an articulated truck to jackknife and overturn. The connection between the approach roadway and the ramp proper should be on as flat an angle as possible to accommodate a vehicle operating at the design speed of the ramp. Generally, the terrain will do much to control the alignment of a ramp. However, a ramp parallel to the through roadway will require less right-of-way.

Vertical alignment should be reviewed to ensure that there are no hidden parts of an escape ramp. If there are, it could affect a driver's willingness to use the ramp.

## Ramp Width

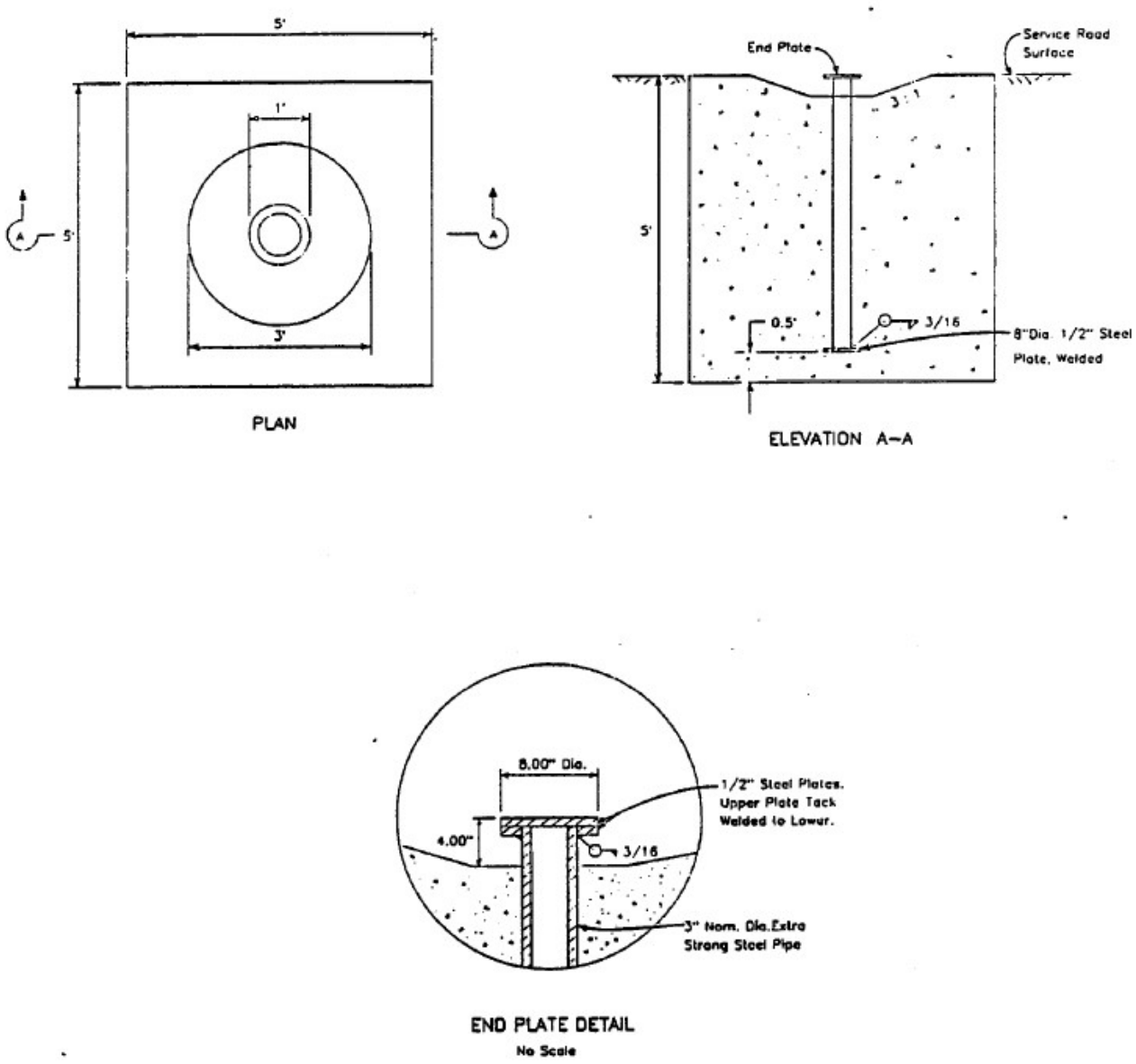
Generally, an arrestor bed width of 26 feet provides ample maneuvering room for an out-of-control truck. In addition, although this width will theoretically accommodate a second vehicle before the first is removed, there is no guarantee that the first vehicle will be positioned to allow the second to pass. A 12- to 14-foot side service road should be provided adjacent to the gravel bed on the same side as the through highway.

This service road allows tow truck access to extricate the trapped vehicle and a hard surface clear of the through lanes to pull the trapped vehicle onto. Anchors for tow trucks should be spaced along the service road at about 150-foot intervals. These anchors should be offset to the side of the service road away from the gravel. This allows the tow truck a better angle for pulling a truck out of the gravel. In addition, an anchor should be placed about 150 feet in advance of the gravel bed on the approach. This will enable a tow truck to extricate a vehicle that has only gone a short distance into the gravel. Details for a typical tow truck anchor are shown in Figure No. 2, "Tow Truck Anchor."

Where possible, it is desirable to have the service road come back to the through roadway. This will allow easier return of the tow truck and extricated vehicle to the through roadway. Also, the service road should have distance marks from the beginning of the gravel painted on it. This will allow the performance of the gravel bed to be monitored.

Gravity ramps may be paved or unpaved. Since a vehicle will be on a gravity ramp for a very short time, there is no need for extra width for possible dual use. Hence, gravity ramps only need to be about 14 feet wide. Where possible, the gravity ramp should continue and return to the through roadway. This eliminates a lot of backing with the chance of jackknifing. However, because of the rollback problem with brakeless trucks, gravity ramps are not recommended.

**Figure No. 2 Tow Truck Anchor**




## Arrestor Bed Design

Arrestor bed performance depends on the out-of-control vehicle sinking into the gravel as it progresses along the bed. This requires gravel that is unstable and has low bearing values. Such properties are usually found in a single-graded, well-rounded stream gravel. Ideally, marbles would be the answer. However, economic limitations prescribe something else. The closer the gravel comes to a completely crushed material, the more bridging and interlocking between aggregate particles occur, and the less the truck will sink into the gravel and be slowed down.

The aggregate for an arrestor bed should be washed, free-draining, uncrushed gravel of uniform shape and size.

The gradation should be as follows or close to it:

| | |
|---|---|
| Passing 1½-inch sieve | 100% |
| Passing 1-inch sieve | 90-100% |
| Passing ¾-inch sieve | 0-10% |
| Passing No. 4 sieve | 0-2% |

Note the low allowable presence of fines. Fine material is one of the principal contaminants of arrestor bed gravel. It can trap moisture and other materials that can cause the gravel to lock up and provide an unyielding driving surface. This is not what the gravel bed is intended to do. Therefore, the arrestor bed must be designed to minimize and slow down the rate at which the gravel becomes contaminated.

Contamination comes from four sources. The first is the ground under the gravel bed. Gravel can be contaminated by fine material coming in from the sides or working up from the bottom of the basin where the gravel is placed. This can be controlled by paving the sides and bottom of the basin with asphaltic concrete or lining the basin with geotextile fabric. Where use of the arrestor bed is expected to be heavy, it may be cost-effective to consider a Portland cement concrete lining. Many trucks experience damage to their fuel lines in the gravel. The diesel fuel that leaks down into the bed can destroy asphalt concrete. For this reason, drainage systems for the gravel beds should have some means of separating or containing contaminants before bed drainage is released into a watercourse.

The second source of contamination is from the surface. Fine material can blow in or be carried in by runoff. Not much can be done about windborne dust, but a high-quality roadway drainage system can minimize contamination from runoff. Roadside runoff should be channeled away from the arrestor bed. Roadway drainage should not be allowed to flow into a gravel bed, especially where sand or cinders are used for ice or snow control. If a dike or curb is necessary between the service road and arrestor bed, it should be no more than 2 inches tall. Anything higher may impede the removal of trucks from the gravel. Also, removal activities can easily damage a high dike.

The third source of contamination comes from the vehicles entering the gravel bed. As noted earlier, fuel lines can be dislodged, allowing diesel fuel to permeate the gravel. Also, parts of a vehicle's load can find their way into the gravel. This is a special maintenance problem, as some of these materials can actually cement the gravel together.

The fourth source of contamination comes from the gravel itself. It is essential that the best quality gravel possible be used. Aggregate that breaks down or degrades readily should not be used. All aggregate breaks down eventually. Aggregate that is subject to

repeated mechanical action, such as vehicle entries and reshaping, breaks down sooner.

The depth of gravel needed in an arrestor bed has not been established with any certainty. Experience has shown that trucks sink at least 12 inches into the gravel. Other experience has shown that in a relatively short while, the bottom 12 inches of a gravel bed can become so contaminated that it is like a cement-treated base. To provide some performance margin, the minimum depth of gravel in an arrestor bed should be about 36 inches, with 30 inches as an absolute minimum. At the beginning of the ramp, the depth of the gravel should be six inches and should taper to full depth at 100 feet. This allows a gradual increase in resistance and minimizes the chance of load shift. One allowable exception is on a gravity escape ramp where a minimal gravel bed is incorporated to keep a brakeless truck from rolling back onto the through highway. Here, the gravel bed may be 18 inches deep.

Some states have constructed gravel beds like French drains. In this design, a substantial layer of 2-inch aggregate underlays the normal arrestor bed aggregate. This design allows contaminants to percolate down and out of the arrestor bed gravel, thus prolonging its effectiveness.

Snow, ice, and freezing weather can cause problems with an arrestor bed. A frozen crust can be formed that impedes a vehicle's penetration downward into the gravel. Also, prolonged freezing weather can freeze a gravel bed to its entire depth. However, these conditions are not expected to be a major problem in California since most of our escape ramps are located below elevations with heavy snow and severe freezing.

## Ramp Length

The AASHTO publication "A Policy on Geometric Design of Highways and Streets," (1984) contains a formula and rolling resistance factors for calculating the desirable length for arrestor beds and gravity truck escape ramps.

$$L = \frac{V^2}{30\ (R + G)}$$

Where: L = Distance to stop in feed (i.e., arrestor bed length).
V = Entering velocity in miles per hour.
G = Percent grade divided by 100 (decimal percent).
R = Rolling resistance of the surface expressed as percent gradient divided by 100. See Table No. 1.

**Table No. 1**

**Values of R factor for several different materials are:**

| **Surfacing Material** | **R** |
|---|---|
| Portland Cement Concrete | 0.010 |
| Asphalt Concrete | 0.012 |
| Gravel Compacted | 0.015 |
| Earth, Sandy, Loose | 0.037 |
| Crushed Aggregate, Loose | 0.050 |
| Gravel, Loose | 0.100 |
| Sand | 0.150 |
| Pea Gravel | 0.250 |

A 90-mile-per-hour entry speed is the minimum that should be used for most situations on an unrestricted highway. A higher speed may be desirable where the escape ramp is preceded by a sustained steep downgrade with no geometric restraints on speed. Another possible safeguard to allow for deterioration in gravel performance is to increase the basic ramp length by 25 percent. The only areas where a lower entry speed may be considered would be where there is no way an out-of-control truck can approach the ramp at high speeds. Such locations would be where the ramp is located close to a location where a truck starts from a full stop or where the ramp is preceded by speed-controlling geometric features such as a short radius curve.

Research is underway in several states that may eventually produce a more precise determination of the necessary ramp length. However, it is doubtful that anything will be forthcoming in the very near future.

## Ramp Surface

Arrestor beds should be as smooth as possible with no bumps or hollows. The transition from the paved approach should be in a plane. Any mounding of the gravel at this point will result in undesirable gravel spray.

## Attenuation

Where a full-length arrestor bed cannot be obtained, it may be desirable to consider some means of attenuation, especially in the last half of the bed. This can be in the form of one or more mounds of gravel across the full width of the arrestor bed. These mounds should be at least two feet and no more than four feet high. The approach slope of the mound should be at the angle of repose of the gravel. Flat slopes tend to act as a ramp.

In some cases, longitudinal windrows of gravel between 18 and 24 inches high have been used. These may cause some problems controlling a truck and probably should not be used until studied further.

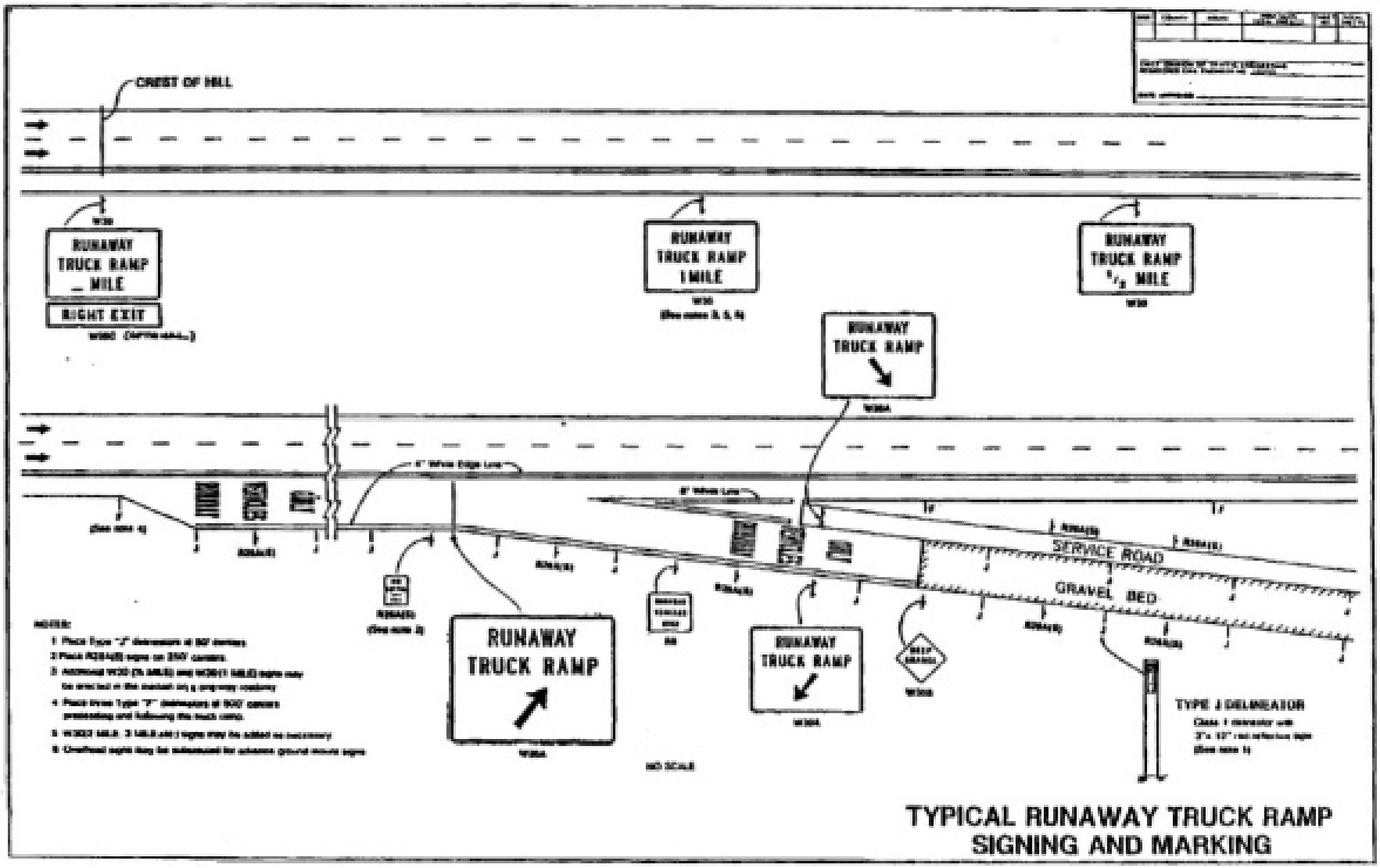
Crash cushions or high mounds of gravel near the end of an arrestor bed may be used as a last resort form of attenuation. However, the resultant problems may offset any advantages. Namely, where an articulated vehicle such as a semi-trailer encounters an abrupt speed change imposed on the front of the vehicle, load shift, fifth-wheel shear, or jackknifing may result. Load shift is also a potential problem for fixed-body trucks. Where sand barrel crash cushions are considered, the eventual contamination of surrounding gravel by sand from shattered sand barrels can be a problem.

Where hard-surfaced gravity ramps are involved, a shallow gravel bed or sand barrel attenuator array may provide additional stopping capability as well as immobilizing a brakeless truck that could roll backwards if not restrained.

## Signing and Marking

The plan shown in Figure 3, "Typical Runaway Truck Ramp Signing and Marking," shows the basic signing and pavement marking to be used with an arrestor bed truck escape ramp. Note that the right edge line for the through lanes is carried past the entrance to the escape ramp and not into it. This is an attempt to minimize unwarranted use of the ramp. There are two W30A signs with down arrows, opposite each other (gate posts), just before the beginning of the gravel bed. This is to better delineate the proper passage. Also, the approach to and from the gravel bed itself is delineated by Class 1 delineators with red reflective sheeting. The red reflective material is a federal requirement. The delineators between the gravel bed and the service road should be set in sockets for easy removal and replacement. This can reduce the need to provide new delineators damaged when pulling a truck out of the gravel. Finally, an illuminated overhead sign is located just before the gore into the escape ramp. This helps out-of-control vehicle operators to better locate the ramp and signifies the purpose of the facility, which discourages use by unwarranted vehicles. Note that the left side W40A sign blocks the view of the service road to minimize the chance it could be mistaken for the arrestor bed or the through roadway.

**Figure No. 3 Typical Runaway Truck Ramp Signing and Marking**



## Supplemental Features

Brake inspection areas, although not a specific part of a truck escape ramp, play an important part in the use of truck escape ramps. Speed down a grade is related to the speed at which a vehicle crests the grade. Thus, if truckers are provided a facility at or near the crest of a grade to pull off and inspect their vehicles' brakes, the trucks will at least start at zero speed. This is practically assured if the brake inspection is made mandatory and enforced.

Another facet of brake performance is brake temperature. As the temperature of the truck brakes exceeds 500 degrees, they lose their ability to slow the truck down. Thus, stopping to inspect brakes allows the brakes to cool somewhat and improves their braking ability.

A feature that has value at a brake inspection area is a sign panel that describes the grade ahead and the location of the escape ramp. Another valuable part of such a sign would be information on the adjustment of slack adjusters on truck brakes. Incidentally, such a sign could increase the time a trucker spends at an inspection area, thereby allowing the brakes to cool further.

A desirable feature that should be considered at every truck escape ramp is a telephone. This would allow the operator of a vehicle stuck in an arrestor bed to call for a tow truck. The arrestor bed must be cleared as soon as possible. The telephone should be discoverable by the truck driver but not so obvious that it becomes an attraction for passing motorists.

In some cases, it may be desirable to illuminate a truck escape ramp to better identify it for an out-of-control vehicle operator. This, however, may lead to unwarranted use of the escape ramp by making it look too much like an interchange or rest area off-ramp. Any decision to provide illumination at an escape ramp should be based on an evaluation of benefits, disadvantages, and costs.

Blank-out or changeable message sign should be located upstream from ramp entrances to warn when an escape ramp is occupied. Such a sign is especially important when the entrance to an escape ramp is hidden behind a curve. The sign warns the driver of the occupancy and provides some protection for a vehicle or workers on the ramp.

A truck escape ramp can be misused by motorists changing drivers, seeking relief, checking their vehicle, pausing for a picnic, or many other reasons. If a motorist becomes immobilized in the gravel, they could be run over by an out-of-control truck or force the truck to bypass the escape ramp, where it may possibly become involved in a severe crash. In order to minimize the probability of a motorist misusing a ramp, the ramp and the adjoining area should be reviewed for conditions that may promote motorist misuse. Conditions to look for can include graded areas outside the escape

ramp, absence of other areas for motorists to stop, inadequate signing, and an overcrowded upstream rest area. Treatment can include fencing or landscaping to screen off a graded area. In any event, corrective action should be directed at the cause of the problem and not the symptoms.

# Escape Ramp Maintenance

Arrestor bed escape ramps require smoothing after every entry. An aggregate bed that contains bumps and hollows can be very difficult to traverse and may unnecessarily damage the truck. Thus, the aggregate bed must be reshaped as soon as possible after a vehicle has been removed from the gravel.

Gravel tends to pack with time or repeated traversals by equipment. Thus, the gravel should be loosened up or scarified after each ten uses of the ramp or every six months (spring and fall), whichever occurs more frequently. Whenever the gravel is scarified, it should be examined for contamination. Then, if an excessive amount of fine material or other contaminants is noted, immediate provisions should be made to replace or reprocess the aggregate to original specifications. Another indicator that the aggregate is becoming contaminated is when vehicles using the ramp travel increasing distances along the ramp.

Maintenance of an arrestor bed escape ramp requires adequate equipment. Hand tools are not acceptable. Proper power equipment assures that the ramp will be back in service in a minimum amount of time. It also ensures that maintenance workers will be minimally exposed to the chance of a runaway truck wanting to use the ramp.

Equipment consideration may include a motor grader with an extension on its blade so the final pass in smoothing the gravel may be made from the service road. Another possibility is using a tracked snow maintenance vehicle or some other light footprint vehicle. Since escape ramps are located in mountainous terrains and their use is more frequent in warm weather, tracked snow maintenance vehicles may be available.