

Dynamic Compaction of Roadways  
Final Report

by

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16. Abstract <p>The report discusses a demonstration of dynamic compaction on a highway in Interior Alaska. The demonstration was an attempt to reconsolidate embankments which had settled and loosened due to the progressive thawing of ice-rich permafrost soils. The objective was to reduce future road maintenance costs and to improve rideability in historically troublesome areas.</p> <p>A 10 ton weight was dropped by a crane, typically from 25 feet. Three sites were treated. The consolidation produced varied between 2 1/2 and 7 inches.</p> <p>Typical costs for this work in Alaska are estimated to be \$9 - \$12 per square yard. Extended observation will be required to determine the cost effectiveness of the demonstration. Calculations indicate, however, that the technique may be cost effective at localized areas with severe problems.</p>					
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## Summary and Conclusions

Dynamic compaction was demonstrated at three test sites on the Elliott Highway near Fox, Alaska during July 1984. The demonstration was an attempt to reconsolidate the road embankment which had settled and loosened due to the progressive thawing of ice-rich permafrost foundation soils. It is hoped that the reconsolidation of the embankment at the test sites will reduce pavement patching requirements in what have historically been maintenance problem areas. Other potential benefits include better performance (safer and smoother ride) and reduced vehicle user costs. These benefits will last only a few years if foundation soils continue to thaw. Dynamic compaction may nevertheless be cost effective.

The compaction was obtained by dropping a 5' diameter steel tank filled with reinforced concrete onto the road surface by use of a crane (See Figures 1 and 2). The 10 ton weight was typically dropped 8 times per location from a height of 25 feet. The number and height of drops were varied on part of the third site for comparative purposes. Drop locations were generally spaced 15 feet apart in each wheelpath; this was reduced to 7-1/2 feet on part of the third site.

The impact of the weight produced craters varying in depth from six to twenty inches. Crater depths were smallest at the first site, where they averaged about 9 inches, corresponding to an average consolidation over the total area of about 2-1/2 inches in the driving lanes. Crater depths were greatest on the portion of the third site which received "normal" crater spacing, where they averaged about 15 inches. In the portion of the third site with 7-1/2 feet crater spacing, the average crater depth was smaller (about 11 inches). Due to the closer crater spacing, however, the embankment consolidation was greatest there (about 7 inches).

After the crane operator became familiar with the technique, the dynamic compaction proceeded at a rate of about 75 square yards per hour without significant problems. The cost of the demonstration, including equipment mobilization, was equivalent to less than \$7 per square yard at this rate. For several reasons, however, this was not felt to be typical

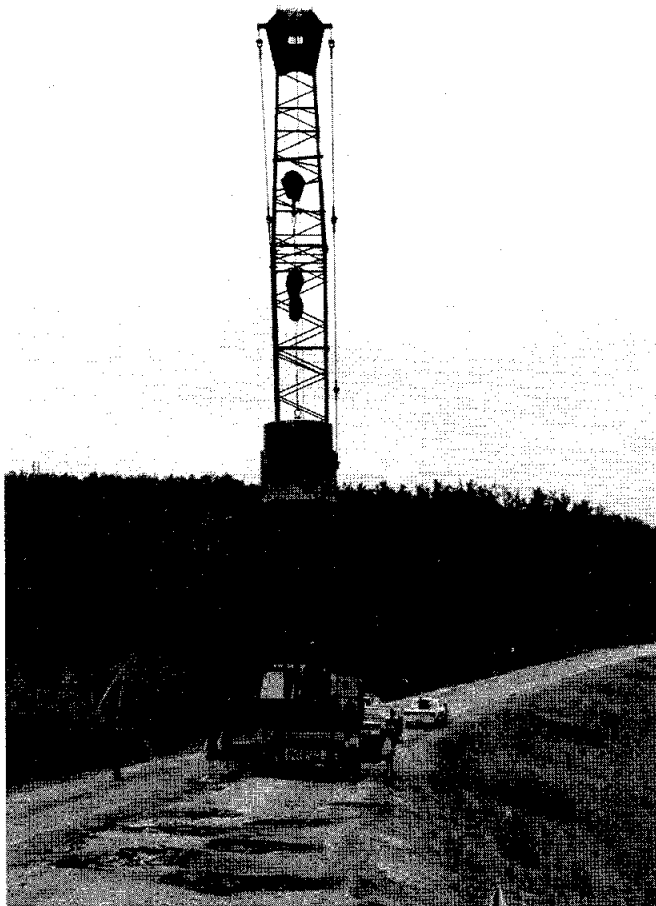


Figure 1.  
Dynamic Compaction Operation

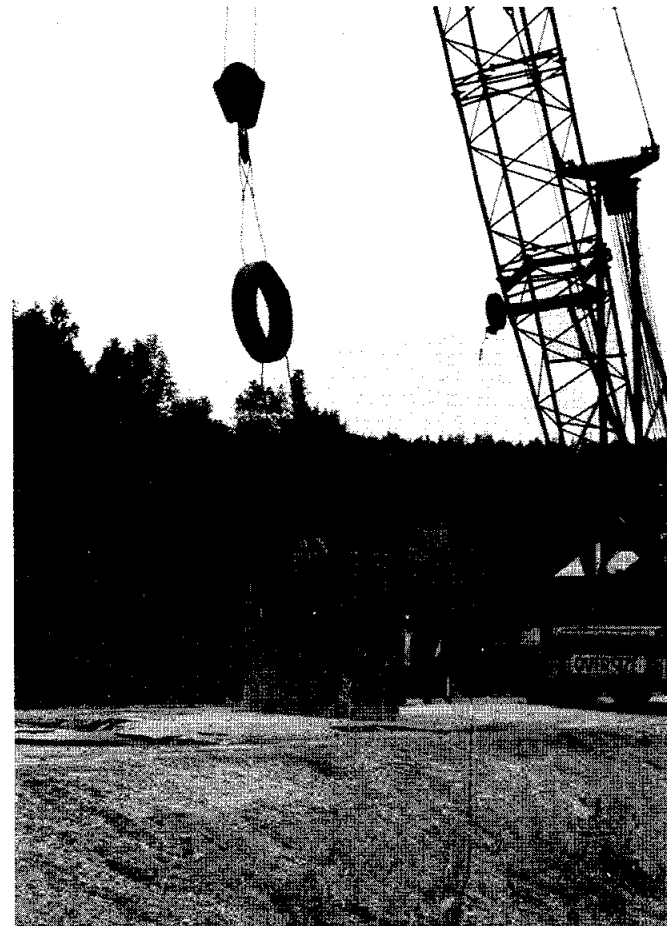


Figure 2.  
Close-up of Dynamic Compaction Operation

of this type of work. The major variables affecting this figure are mobilization charges and the intensity of the treatment (i.e. number of drops per unit of road surface area). More realistic typical costs are estimated to be \$9 - \$12 per square yard (\$65,000 - \$85,000 per lane-mile). The primary reason for the higher costs in most situations is the need for a series of drops from a lower height (an "ironing pass") after the first series.

The cost effectiveness of the dynamic compaction demonstration is uncertain at this time since the benefits of the work will only become known after extended observation of the treated and control areas.

The magnitude of the benefits needed to make dynamic compaction cost effective has been calculated. In an area where pavement patching is normally required every three years, for example, the savings in patching costs alone will offset dynamic compaction costs if patching is not needed for six or seven years after treatment. The amount of consolidation induced during the dynamic compaction demonstration indicates that this magnitude of improvement may have been achieved.

Extensive road areas which require full patching every three years are rare, but short "problem areas" requiring this level of maintenance are fairly common in permafrost areas. Thus there may be a significant number of localized areas on Alaska's roads where dynamic compaction is a cost effective means of reducing road maintenance costs. Less tangible benefits of the technique, such as safer or faster travel and reduced user costs, would add to this effectiveness.

## Site Descriptions

The three test sites for dynamic compaction were all located on the Elliott Highway near its beginning at Fox, Alaska. Fox is a small community about 10 miles north of Fairbanks, at latitude  $64^{\circ}58'N$ , longitude  $147^{\circ}37'W$  (see Figure 3).

The terrain at the sites is hilly. Bedrock is mostly a metamorphic material generically known as Birch Creek Schist. The bedrock surface is often severely weathered. It is overlain by a layer of loess which ranges in thickness from one to three feet on hilltops to more than a hundred feet in low-lying areas.

The Elliott Highway at the test sites is part of the overland supply route to the North Slope oilfields. As a result, it receives the heaviest truck traffic of any Alaskan Highway (well over 100,000 EAL annually).

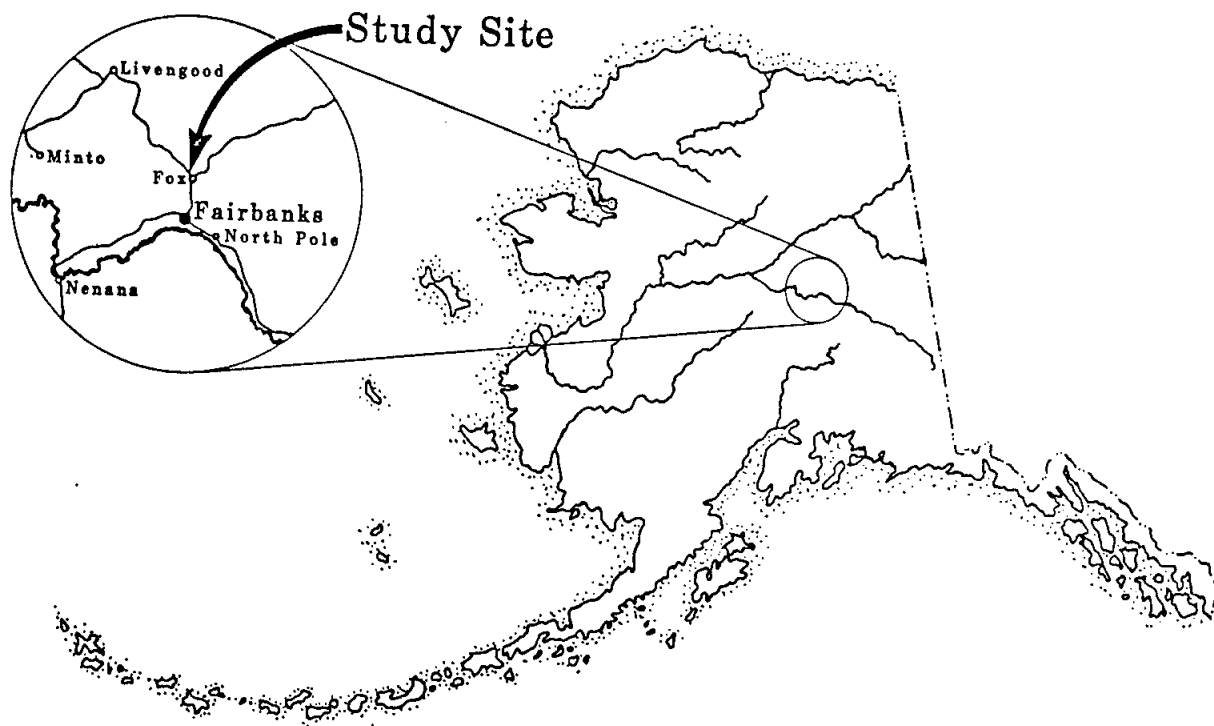


Figure 3.  
Test Site Location Map



The first test site is located 7 miles from Fox (see photo, Figure 4). The road alignment at the site crosses a small, east-facing drainage. The road at the site is in both a horizontal and sag vertical curve. The centerline fill depth exceeds 25 feet at the bottom of the sag<sup>1</sup>.

Throughout this test area, the embankment was thicker than the expected depth of density improvements from the dynamic compaction (see "Discussion of Test Results" below). The densification was thus expected to be entirely in the fill material. Borings showed this to be 1" maximum diameter gravel mixed with sand and traces of silt near the surface. Maximum size increased, and sand and silt content decreased, with depth. All of the material encountered (up to 18' depth) was thawed.

The second and third test sites are both located at approximately 1 mile from Fox (see Figure 5), where 1,500' of roadway was divided into five 300' sections. The second and fourth of these were test sections; the remainder are control sections. The entire 1,500' length is a straight, almost level fill section, with embankment depth at centerline ranging from about 9 to 15 feet.

Borings showed the fill material to be gravels similar to those found at the first test site. Moisture content was low near the surface ( $\approx 2\%$ ) and increased to nearly saturated at the bottom of the fill. 1-1/2 to 2 feet of material at the bottom of the fill was frozen when borings were made on July 1, 1985. This is presumed to have thawed by the time the compaction was done (almost a month later).

Frozen grey silt with traces of sand and/or gravel was encountered below the fill. Moisture contents of this frozen material were between 30 and 40 percent; no segregated ice was observed.

All three test sites were located in problem maintenance areas. At the time of the tests the pavement was badly broken up at all three sites and had been temporarily covered with a thin layer of gravel by maintenance forces to provide a smoother riding surface.

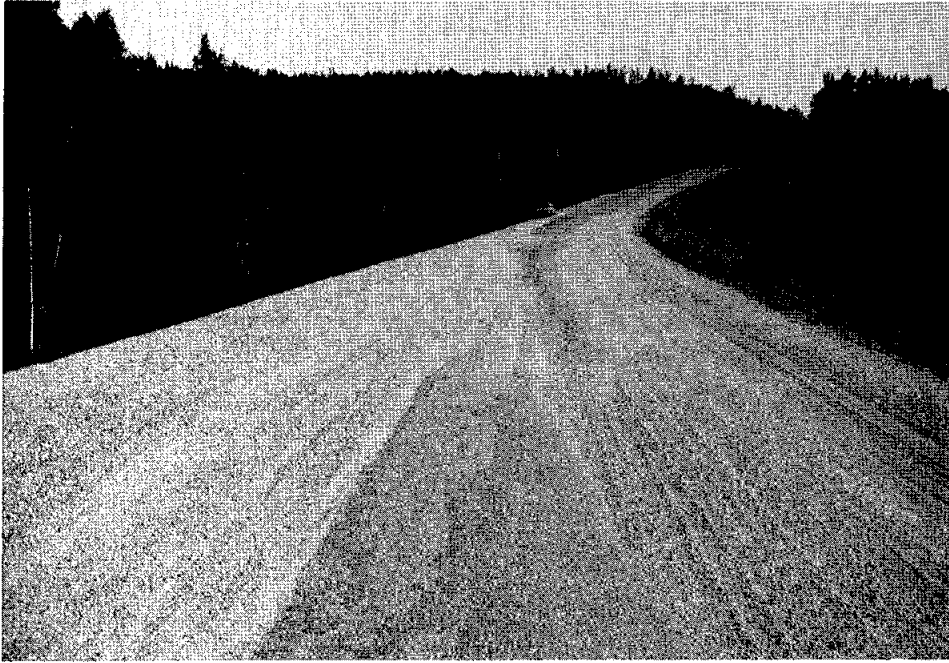


Figure 4.  
7-Mile Test Site



Figure 5.  
1-Mile Test Site

## Testing

The dynamic compaction demonstrations were incorporated by extra work order into the Elliott Highway, Fox to Mile 7 Repair and Resurfacing project.\* Following compaction, the upper 2' of the embankment was removed and rebuilt with two layers of geotextile separated by 12" of borrow. This was topped by 6" of subbase, 4" of asphalt-treated base course, and a 1-1/2" surface of hot asphalt pavement. Surface excavation and geotextile placement was limited to two areas totalling about one mile of the project's seven mile length. The road in these areas has required frequent patching and levelling in the past and has been expensive to maintain. Work on the other six miles of the project was limited to reconditioning and asphalt treatment of the top 4" of the existing roadway followed by surfacing with hot asphalt pavement.<sup>2</sup>

Research demonstration funds were supplemented by incorporating the dynamic compaction with the reconstruction project. Dynamic compaction typically leaves the surface layer in a loosened state between the craters. This would normally be treated by levelling the surface and recompacting the area with a series of closely spaced low drops (termed an "ironing pass") with the compaction weight. On a highway this would typically be followed by conventional compaction and resurfacing.

The surface excavation planned for this area eliminated the need for (and cost of) this work, since the loosened surface material was to be removed and replaced anyhow. This allowed a greater area to be compacted with the funds available than would have been possible otherwise. It should be noted that both test and control areas were rebuilt with geotextile layers. Their future performance may therefore be directly compared with each other, but may not be typical of all potential uses of dynamic compaction.

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\* Federal Project No. F-065-1(5), State Project No. A-20022.

## First Test Site

Work began on the afternoon of July 23, 1985. The afternoon was primarily a learning experience, as none of the personnel were experienced in the work. Only one crater was completed. The next morning measurements were made of crater depth after each drop of the tamper for the first few crater sites. The elevation of the area surrounding the craters was also measured before and after compaction to check for heaving. Based on the measurements, it was decided to make eight drops from 20' at each crater site, with the craters spaced 15' apart in each of the four wheelpaths along the length of the road (see Figure 6). This pattern was followed throughout the demonstration at the first site. The procedure followed was to work on two wheelpaths (i.e. one lane of the road) at a time; flagmen directed traffic past the site in the other lane when drops were not being made. Work at the first site continued through July 25, by which time 77 craters spaced over 285 feet of roadway had been completed.

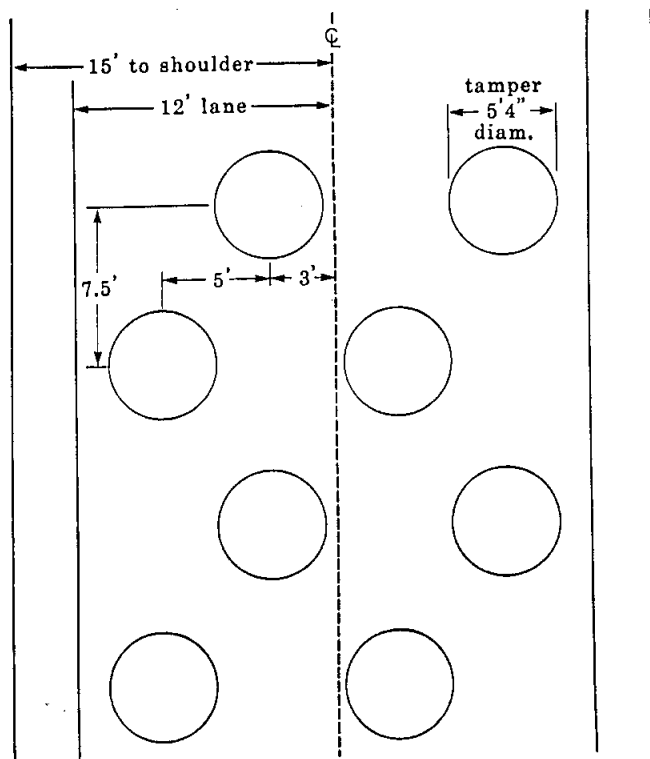


Figure 6.

Dynamic Compaction Crater Spacing Plan

## Second Test Site

The second site was compacted on July 26. Crater spacing and the number and height of drops at each crater site were identical to that of the first site. Seventy-eight craters were completed that day, substantially completing compaction of the 300 foot section.

## Third Test Site

The final day of dynamic compaction demonstrations was July 27th. Sixty craters were completed that day spaced over 230 feet of roadway at the third test site. Crater spacing was reduced from 15 feet to 7-1/2 feet in each of the four rows for a short (25') section of roadway at the site. At another section (50' long) drop height was increased to 30' (from 20') and the number of drops per crater site was reduced to 5 (from 8). At the remainder of this test site, the pattern used at the previous two sites was used.

Other construction work began at the same time as the dynamic compaction tests and continued afterwards. The major work on the project was completed by September 25, when mainline paving was finished.

## Equipment

The tamper was fabricated from a 1,000 gallon, cylindrical steel tank (64" diameter by 73" long) open at one end and filled with heavily reinforced, high-strength concrete. A bent #10 rebar extending above the top of the tank was used for lifting the tamper, which was calculated to weigh 10.1 tons.

A 65 ton (nominal) truck crane equipped with hydraulically operated outriggers was used to drop the weight. This equipment proved to be easily maneuvered; the crane could be relocated in as little as five minutes. Four crater sites could generally be hit by moving the crane's boom before it was necessary to move the crane itself.

Experimentation indicated that the use of a single cable for lifting the weight should be specified. When it first arrived at the site, the crane cable was equipped with a six-stranded pulley system between weight and boom. The friction this system created when the weight was dropped slowed the weight's fall considerably, thus reducing the impact force. After the first few drops, the pulley system was rearranged, and thereafter, the drops were made with a doubled cable between the weight and the boom. In this mode, a single pulley block was attached to the top of the weight.\* A single cable would have created even less friction and allowed the weight to fall faster and provide a greater impact. The cable available on the job site, however, was not sufficiently strong to allow this.

A bulldozer was used to fill the craters and relevel the test areas sufficiently to reopen them to traffic after compaction was completed.

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\* More precisely, the block was attached to an old tire, which was attached to the tamper. The tire protected the pulley block from damage by acting as a shock absorber (see Figures 1 and 2).

## Test Results

Measurements of the size of the craters were made during testing. The results are summarized in Table 1. Individual crater depths ranged from about six inches to over a foot and a half. The average crater depth at different sections ranged from 9 to 15 inches. Generally little deformation of the surface was noted during the first two or three drops at a given location. It appeared that it was necessary to break down a stiff surface "crust" before significant consolidation was achieved.

Measurements were made of ground elevations in the immediate vicinity of some crater sites before and after compaction. These measurements revealed that no substantial heaving of the surrounding ground resulted from the work.

Cross sections were made of the embankment at 50 foot intervals before compaction work began. Stakes were left from these surveys with the intent to re-survey them after compaction. Unfortunately, most of the side slopes were disturbed by other construction activities before the dynamic compaction was completed. Measurements of the few intact stakes remaining after completion, however, revealed no lateral spreading of the embankment at those locations.

Since there was no apparent lateral spreading of the embankment and no heaving of the ground surrounding the craters, the measured volume of the craters is a reasonably accurate measurement of the induced consolidation. The consolidation, averaged over both the 24' wide driving lanes and the 30' width of the top of the embankment, is presented in Table 1.

Table 1:

## DYNAMIC COMPACTION TEST RESULTS

Location	Drops per Crater and drop height	Crater depth Average and range (ft)	Average consolidation <sup>(1)</sup> (based on 24' width driving lanes)	Average consolidation <sup>(1)</sup> (based on 30' width embankment surface)
Site #1 (Sta. 597 + 00 - 599 + 85)	8 @ 20'	0.72' (0.55' - 1.35')	0.21'	0.17'
Site #2 (Sta. 51 + 90 - 54 + 90)	8 @ 20'	0.91' (0.60' - 1.40')	0.27'	0.22'
Site #3 (Sta. 57 + 90 - 58 + 90 and 59 + 15 - 59 + 65)	8 @ 20'	1.21' (0.75' - 1.65')	0.36'	0.29'
Site #3 (Sta. 58 + 90 - 59 + 15)	8 @ 20'	0.92' (0.70' - 1.15')	0.55' (2)	0.44' (2)
Site #3 (Sta. 59 + 65 - 60 + 20)	5 @ 30'	0.83' (0.55' - 1.05')	0.25'	0.20

1. This figure based on 70" average crater diameter and 15' o.c. crater spacing in each wheelpath.
2. Craters were spaced 7' o.c. in each wheelpath in this section only.



## Discussion of Test Results

The test sites and adjacent control areas were inspected in June 1986, nine months after the paving was completed on the reconstructed road. At this time, all test and control areas appeared in nearly new condition (see Figures 7 and 8). No substantial distress of any kind was observed in the roadway.



Figure 7.  
7-mile Test Site, 9 Months After Completion

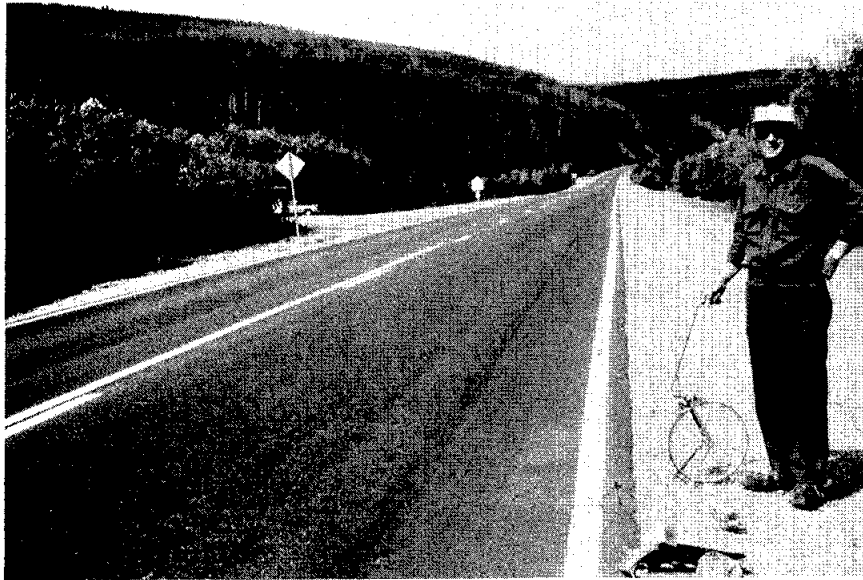


Figure 8.  
1-mile Test Site, 9 Months After Completion

The anticipated result of the dynamic compaction demonstrations is a reduction in future maintenance costs at the sites. The success of these demonstrations, then, will not be known with certainty for several years. Some tentative conclusions regarding the success of the work can be drawn, however, from theoretical considerations.

The reduction in embankment volume obtained by the dynamic compaction may have resulted from a general densification of loose soil or from the collapse of subsurface voids. The data gathered do not indicate which of these occurred or at what depth. The collapse of large isolated voids would presumably have resulted in major differences in crater depths from point to point. As this was not noticed, voids (if they existed) must have been relatively small and well dispersed. The boring logs from the site investigations prior to testing (see Appendix A) do not indicate that any voids were encountered, although small voids might have gone unnoticed.

Evidence of major longitudinal cracking was visible at Site 1. Measurements at other sites in Interior Alaska have shown that in extreme cases this type of crack can extend more than 10 feet into a road embankment. No longitudinal cracking was visible at Sites 2 and 3, but those sites had been covered with a gravel surface which would have obscured such evidence.

Standard penetration tests before and after compaction might have yielded information on general density increases versus depth if the embankments had been built of finer materials. These tests would have had little or no meaning for the coarse gravels found at the sites, however, so they were not performed. More elaborate methods for measuring density increases versus depth were too expensive to be performed within the project budget.

The amount of compactive effort in these demonstrations, measured as energy applied per unit area of surface, was fairly low for this type of work. Well-drained granular soils are, in general, more easily densified by dynamic compaction than other materials. Thus, they usually require less effort than other soils.<sup>3</sup>

The compactive effort was doubled on part of the third site by cutting the crater spacing in half. In this area, the induced consolidation (averaged over the entire road surface) was about 50% greater than those parts of Site 3 which were compacted with the "standard" effort. This indicates that, while there were diminishing returns associated with the extra effort, the extra work did result in additional densification. While the depth at which consolidation occurred was not measured, experience elsewhere with dynamic compaction has led to methods for estimating the depth of improvements. Maximum depths of significant densification can be estimated using the formula  $D = n(W \times H)^{1/2}$  where

D = depth of improvement in meters

W = weight of tamper in metric tons

H = drop height in meters

n = an empirical coefficient which is less than 1.0

For the conditions at the sites tested (granular soils and low water table), a value for n between 0.6 and 0.7 has been recommended.<sup>3</sup> For the

weight used in these tests, this results in an estimated depth of improvement of 12 to 14 feet for a 20' drop height. For the 30' drop height, the corresponding figure is 15 to 17 feet. Densification probably did not occur in the top two or three feet. Due to the disturbance while tamping and the subsequent regrading of the road, the top layer of material may actually have become less dense.

The induced consolidation might, therefore, be expressed as a uniform increase in soil density of a layer about 10 feet thick and as wide as the road. The increase expressed in this way is between 2 and 4 percent for the standard drop pattern and about 5 percent where crater spacing was halved.

Uniform densification would be expected only if relatively uniform density existed before compaction. The differential settlements and longitudinal cracking at the sites make that condition very unlikely, however.

Another way to interpret the results is to assume that all the observed consolidation was due to the collapse of subsurface voids. Viewed this way, the soils themselves would have experienced no densification at all. This opposite extreme in interpreting the results also seems unlikely. It is hypothesized, however, that the latter interpretation is closer to the truth, and that most of the consolidation was the result of the collapse of voids and greatly increased densities in limited pockets of loose material.

## Productivity

The productivity of work increased sharply over the test period as the personnel became familiar with the work and equipment problems were worked out. This can be clearly seen in the data presented in Table 2.

Many of the equipment problems involved the cable. Eventually a cable cut as short as possible and doubled over a pulley block was used. A single stronger cable is recommended for future work (the doubled cable sometimes twisted upon itself while the weight was being lifted, and the pulley block resulted in increased friction). Due to momentum, cable tended to continue paying off of the cable drum after the tamper hit the ground. This resulted in backlash (as on a fishing reel) and caused kinking and other problems. Shortening the cable so that little of it remained on the drum at impact reduced this problem.

Equipment down time was reduced dramatically as problems were worked out, as the table shows. Productivity also increased in terms of actual work time required per crater as the operators became more familiar with the operation.

Overall, the total amount of time required per crater at the second and third test sites (July 26 and 27) was about half that of the first one (July 24 and 25). The slight decrease in productivity on the last day (the 27th) compared to the previous day was partially due to the experimentation with different crater spacings and drop heights, which broke up the "rhythm" of the work.

Table 2

## DYNAMIC COMPACTION WORK PRODUCTIVITY

Date	No. Crater Sites Compacted	Work Time (hrs:mins)	Equipment Down Time (hrs:mins)	Work Time Per Crater (mins)	Down Time Per Crater (mins)	Total Time 1 Per Crater (mins)
July 23	1	0:35	1:30	35	90	125
July 24	27	4:40	2:20	10.4	5.2	15.6
July 25	49	7:55	1:45	9.7	2.1	11.8
July 26	78	9:15	0:00	7.1	0.0	7.1
July 27	60	8:20	0:30	8.3	0.5	8.8
July 24 & 25 (combined)	76	12:35	4:05	9.9	3.2	13.2
July 26 & 27 (combined)	138	17:35	0:30	7.6	0.2	7.9

- Notes: 1) 8 drops from 20' with a 10.1 ton weight were made at each crater site, except for 16 sites on 7/27 where 5 drops from 30' were made.
- 2) Approximately one crater site per 120 ft<sup>2</sup> of roadway surface (90 ft<sup>2</sup> of driving lanes) except for an 800 ft<sup>2</sup> area treated at one crater per 60 ft<sup>2</sup> of roadway surface (45 ft<sup>2</sup> of driving lanes).
- 3) Both exceptional areas above were compacted on July 27.

## Costs

The dynamic compaction work was paid for by the hour. Payment by lump sum or unit area was considered impractical, as neither the contractor nor DOT&PF personnel had enough experience to predict the time and effort that would be required. This may change in the future as more experience is gained with dynamic compaction.

The unit rate of \$415 per hour included the crane with operator and oiler, a bulldozer with operator, and signs and two flagmen for traffic control. This rate was considered a good one by DOT&PF based on Blue Book Equipment Rental Rates and the construction contract's minimum rates of pay.

On July 26 and 27, after the "learning process" with the equipment and technique, it took an average of about 8 minutes to complete a crater (see Table 2). For the spacing used on most of the demonstration, this amounts to just over a minute per lane-foot of roadway, or about \$7.40 per lane-foot at the contract cost of \$415 per hour. This figure is not a good estimate of typical dynamic compaction costs for several reasons. These include the following:

- The contract price included full-time use of a bulldozer to level the road for traffic. Had payment been made only for the time the dozer actually worked, overall costs might have been as much as 20% lower. A 10% reduction may be more realistic, however, since payment would probably be required for "stand-by" time.
- The contract price did not include DOT&PF's engineering and inspection costs. These costs might increase costs by 15% or so. The net effect of this, coupled with reduced dozer costs, would be an hourly cost somewhat higher than the \$415 per hour contract cost for the demonstration.
- No "ironing pass" was required on the demonstration to compact the upper few feet of material, since it was to be excavated to allow for geotextile placement. On a more typical job, an ironing pass would be required. This second pass, with fewer drops from a lower height than the first, might add 50% to the total work time.

Dynamic compaction costs, including the above considerations, might therefore be about \$11.50 per lane-foot, or about \$60,000 per lane-mile. This figure is based on the drop frequency and crater spacing used in the demonstration, which were probably typical for roadway applications of the technique.

Equipment mobilization costs are not included in the above figure. On the demonstration projects this cost was \$4,000, equivalent to 22.5% of the cost of the work itself. Mobilization costs will vary considerably depending on the size and location of a project, and could easily range from 10% to 40% of other costs. This results in a total cost for dynamic compaction of \$65,000 to \$85,000 per lane-mile.

A dynamic compaction consultant has reported average costs of \$1.07 per square foot for 1985 projects in other states.<sup>4</sup> The \$65,000 to \$85,000 figure above is equal to \$0.82 to \$1.07 per square foot for a 15 foot lane width. This estimate for roadway applications is thus somewhat lower than the consultant's average cost. This seems reasonable, as the well-drained granular material in road applications is more easily compacted by the technique than most other materials.

Dynamic compaction was used in 1984 to densify soils beneath a portion of Interstate 90 in Montana. A recent paper about that project reports that 111,282 square yards of road were treated at a total cost of \$6.97 per square yard.<sup>5</sup> This is equivalent to \$61,000 per lane-mile for a 15 foot lane width. Due to the size of that project, equipment mobilization would have been a relatively minor cost component. The cost reported for the Montana project is thus in agreement with the estimate of \$60,000 per lane-mile, exclusive of mobilization, derived from the Alaska demonstration described in this report.



## Cost Effectiveness of Dynamic Compaction

The greatest economic benefit of dynamic compaction is expected to be a reduction in maintenance costs for road patching and leveling. There may be other benefits, such as increased driver safety and comfort and lowered vehicle (user) costs and travel times. The latter benefits, however, are expected to be of smaller economic importance and are difficult to quantify.

An economic analysis may be simplified by ignoring all benefits except for maintenance cost reductions. The analysis may be further simplified by assuming that maintenance costs are reduced by the same amount each year for a certain number of years, after which the costs return to "normal."

Using this simple model, the dynamic compaction is economically effective if its cost is less than the present value of all the annual maintenance savings, i.e. if:

$$C_d < A \left[ \frac{(1+i)^n - 1}{i(1+i)^n} \right]$$

- where  $C_d$  = Cost of dynamic compaction (\$/yd<sup>2</sup>)  
 $A$  = Annual maintenance cost savings (\$/yd<sup>2</sup> - yr)  
 $i$  = Annual discount rate ("real" interest rate)  
 $n$  = Number of years that maintenance costs are reduced

The annual savings 'A' can be expressed as:

$$A = (C_p)(r)$$

- where  $C_p$  = Cost of pavement patching (\$/yd<sup>2</sup>)  
and  $r$  = reduction in annual patching needed (expressed as a fraction of the road surface area)

The cost of full-width pavement patching in DOT&PF's Northern Region has been recently estimated at about \$75,000 per lane-mile.<sup>6</sup> This is in good agreement with a 1982 estimate of \$10 per square yard.<sup>7</sup>

The cost of dynamic compaction, discussed above, might range between \$65,000 and \$85,000 per lane mile, depending upon the cost of equipment mobilization.

The magnitude and longevity of maintenance cost reductions required to make dynamic compaction a cost effective procedure is shown in Figure 9, based on these cost estimates and a 4% discount rate.

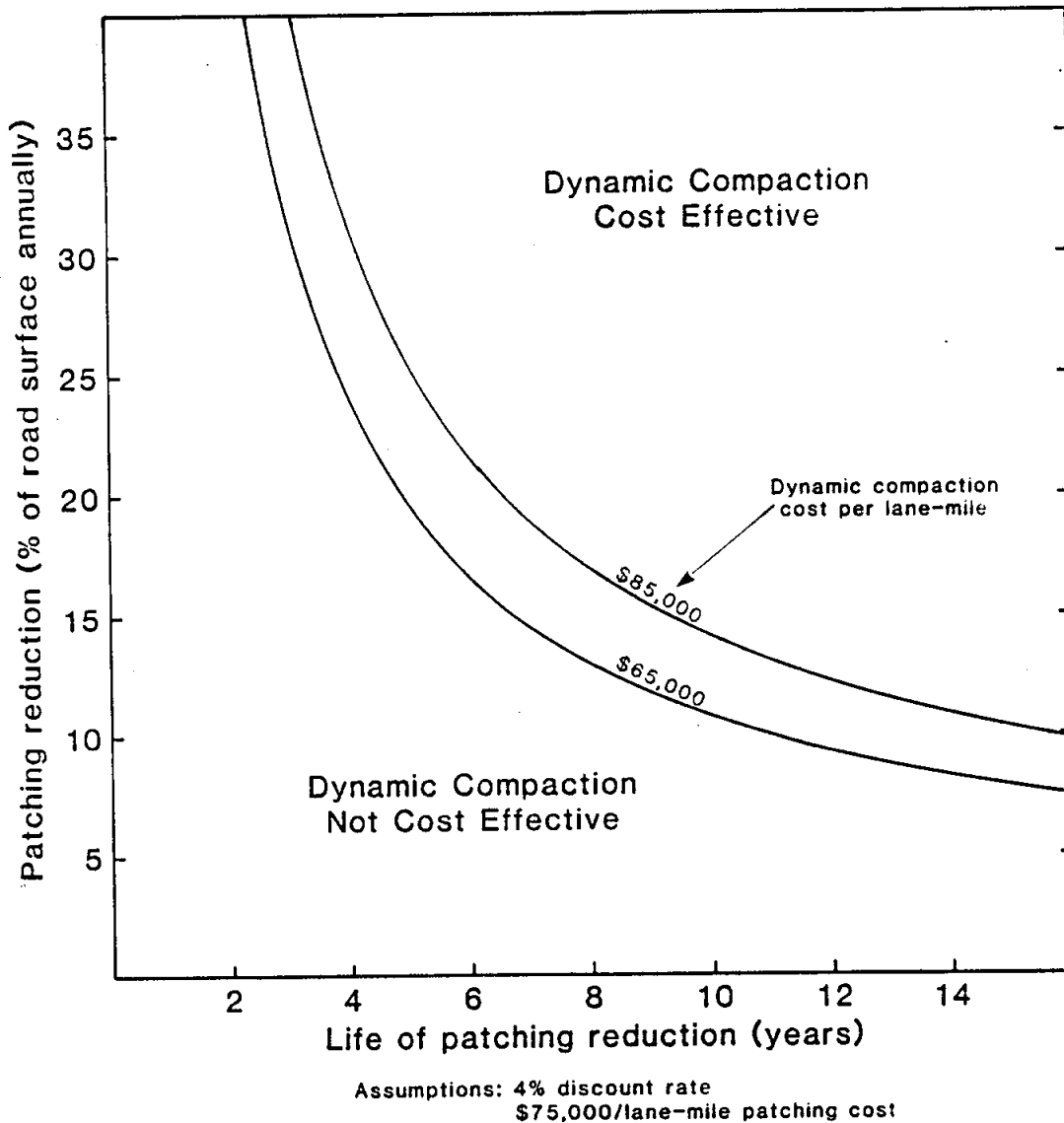
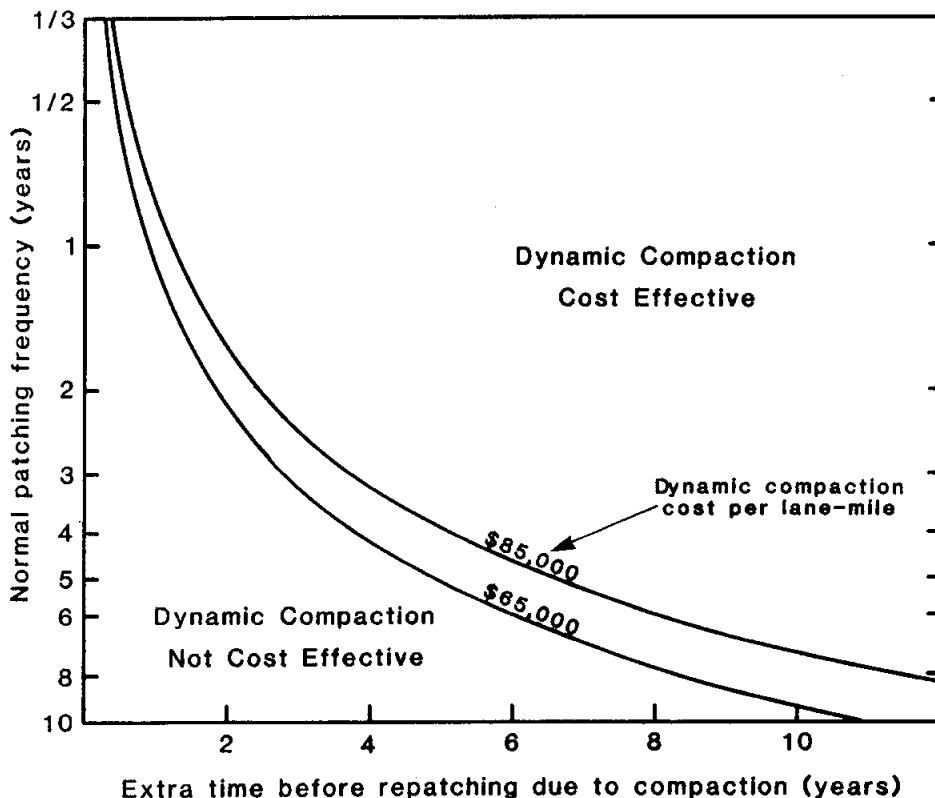


Figure 9.  
 Cost Effectiveness  
 (Based on a Period of Reduced Patching)

It may be that maintenance reductions are modeled better by assuming that dynamic compaction entirely eliminates (rather than reduces) the need for pavement patching for a period of time, and that thereafter the patching needs return to "normal." The economic analysis in this case is similar to the previous one; the present value of future savings is compared to the cost of the compaction.

The results of such an analysis are shown in Figure 10 again based on assumptions of \$75,000 per lane-mile patching costs and a 4% (real) discount rate.



Assumptions: 4% discount rate  
\$75,000/lane-mile patching cost

Figure 10.  
Cost Effectiveness  
(Based on Extension of Time Until Repatching is Required)

It will be some time before there are sufficient results in from the dynamic compaction test sites to make a good judgement as to the treatment's success. It appears from the analyses above, however, that the prospects for such success are reasonably good. At \$65,000 per lane-mile, for example, dynamic compaction appears to be cost effective if a road which would otherwise need to be patched in three years did not need patching until five years after treatment. Roads in most locations do not need major patching with anything like this frequency. There are, however, a significant number of "problem areas" in Interior Alaska where roads crossing ice-rich permafrost require this level of effort.

It is important in making this conclusion to bear the following in mind:

- The analysis assumes that the dynamic compaction is done just prior to when the road would be patched anyhow, so the cost of resurfacing after compaction is little or no more than it would have been without compaction.
- The analysis assumes that a fairly large area is compacted. Costs would be high if only a small area was treated, especially far from town, due to mobilization costs.
- The analysis ignores the additional benefits of faster and more comfortable use of the road due to dynamic compaction and any associated user cost reductions.

It should also be noted that neither method of analysis above assumes permanent benefits are associated with dynamic compaction. If foundation soils continue to thaw, settlement problems will recur after some period of time. Conversely, if the foundation soils have reached a new thermal equilibrium (and stopped thawing), settlement problems will normally cease after some period even without dynamic compaction.

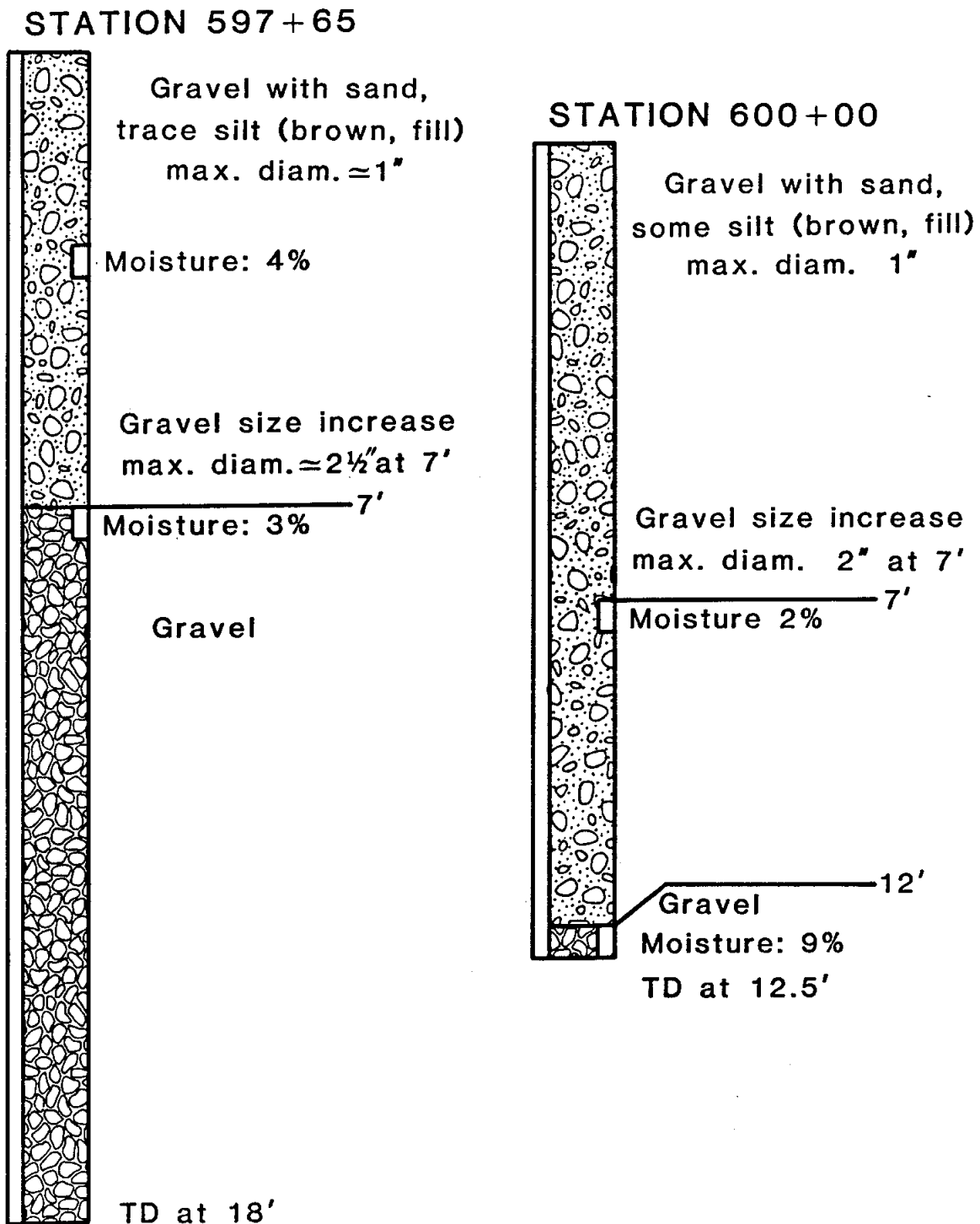
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APPENDIX A

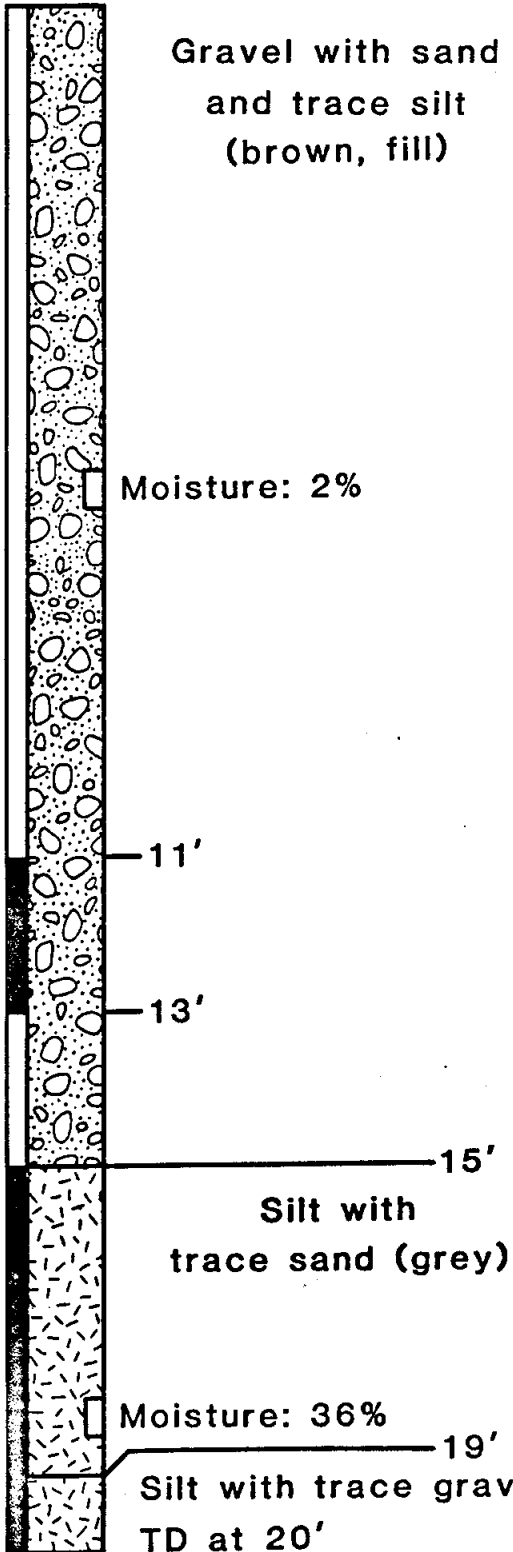
Site Boring Logs

# Figure A-1: Boring Logs, Site 1



# Figure A-2: Boring Logs, Sites 2 & 3

## SITE 3 STATION 53+40



## SITE 2 STATION 59+40

