FOR CONTRACT NO.: 08-489304

INFORMATION HANDOUT

MATERIALS INFORMATION

GEOTECHNICAL DESIGN REPORT

ROUTE: 08-SBd-40-R151.7/R153.3

State of California Business, Transportation and Housing Agency

Memorandum

To : Ms. RENEE SASSE
Senior Transportation Engineer
Office Chief
Design A

Date: July 11, 2005
File No.: 08-SBd-40-KP 244/246
EA – 489300
Rehabilitation Alternatives

From : **DEPARTMENT OF TRANSPORTATION**
ENGINEERING SERVICE CENTER
Office of Geotechnical Design – South 2

Subject : Geotechnical Design Report

Introduction

As requested by your Office, in a memorandum dated January 13, 2005, our Office has prepared this Geotechnical Design Report to present the finding of our geotechnical investigation and to provide four rehabilitation alternative designs. The rehabilitation alternative designs are intended to address the recurring roadway heaving problems on Route 40 between Whale Mountain Bridge and Park Moabi Road Bridge in San Bernardino County. This report compliments our Feasibility Report (Reference 3) and our Geotechnical Report (Reference 4) in which our office provided four alternatives rehabilitation designs. This report did not investigate prohibitively expensive alternatives such as, relocating the alignment or constructing a viaduct.

History

The 2.25 km (1.4 mi.) section of Route 40 studied for this report has had 2 major rehabilitation projects within the last 25 years and recently has incurred yearly maintenance costs of up to $100,000. Pavement undulations, due to heaving, are a result of moisture content changes within the subsurface foundation soils. The subsurface foundation soils within the project limits consist of highly expansive silty and clayey shales including a large percentage of calcium montmorillonite, which expands and swells subsequent to increases in moisture content.

In 1980 three rehabilitation alternatives were proposed to reduce roadway heaving, they included; 1) cutting the slopes back and increasing the width of the paved shoulders, 2) providing a horizontal rubberized membrane and underdrains and, 3) providing a vertical cut off trench with impermeable membrane and underdrains. The roadway rehabilitation of 1980 placed a horizontal membrane 4 inches below the roadway surface and underdrains in a shallow trench. The trench holding the Corrugated Metal Pipe(CMP) underdrain was lined with a filter fabric sprayed with a rubberized emulsion, which in theory would be impermeable. Unfortunately the rubberized membrane and CMP are still in place and are leaking.

In the early 1990 roadway heaves were blamed for accidents and the Director called for a rehabilitation. The 1995 rehabilitation design included removal of the existing under drain system, complete removal of approximately the top 0.75 m (2 ft.) of base, sub-base and native material, placement of a thicker membrane from edge-of-shoulder to edge-of-shoulder, and (0.75 m (4 ft) of granular fill placed between the top of the membrane and the roadway surface. Unfortunately due to problems in the field during construction of the 1995 rehabilitation, the CMP underdrains drains were not removed and membranes were only placed from edge-of-traveled-way to edge-of-traveled-way. The existing horizontal membrane is a Serot 40 Mil HDPE smooth geomembrane. In order to increase the longevity and durability of the membrane a thick membrane was used in 1995, unfortunately the thicker membrane was not workable and difficult to install. Adding to the problems was the fact that when the membrane was delivered to the site it was in rolls bound by metal banding strips, the banding strip left creases and permanent wrinkles in the membrane that could not be worked out even after being warmed by the sun. Welding the membrane seams together was very challenging do to the creases and wrinkles.

More recently, as sloughing material has fallen onto the paved shoulder following rain events, the unpaved shoulders have been cut back vertical, producing a flat unpaved shoulder ideal for rain runoff to pond, percolate into the soil, and migrate through the permeable base materials an reach the expansive clays below.

References

The pertinent geotechnical information reviewed for this report is as follows.

1. "Expansive Soil Distress to 08-SBd-40 West of the Park Moabi OC", Department of Transportation, Office or Geotechnical Engineering, August 20, 1993.

2. "Investigation of Expansive Soil Problems Near Needles, California", Department of Transportation, Office of Transportation Laboratory, April 16, 1979.

3. "Feasibility Study for Rehabilitation of Roadway Heaving on Route 40 near Needles", Department of Transportation, Office of Roadway Geotechnical Engineering – South, May 22, 2000.

4. "Flexible Pavement Deflection Study Report" Department of Transportation, Division of Materials Engineering and Testing Services, February 8 2001.

5. U.S. Geological Survey publication "Swelling Clays Map Of The Conterminous United States" by W.W. Olive, A.F. Chleborad, C.W. Frahme, Julius Schlocker, R.R. Schneider, and R.L Shuster; 1989

2005 Geotechnical Investigation and Laboratory Testing

This geotechnical investigation included a review of existing geotechnical data, site reconnaissance, subsurface investigation, laboratory testing, and geotechnical engineering analysis. During March of 2005, members of this office logged 10 holes drilled through the shoulder pavement within the project limits in order to obtain samples for laboratory testing. The impermeable membrane, which was placed in 1995, was consistently identified in each of the 10 holes at a depth of approximately 0.7 m (2 ft) below the roadway surface. Silty Clays and Clayey Silts were encountered in 9 of the 10 holes and typically extended to a depth of 9 m (30 ft) below the roadway surface. Maximum depth of exploration was 12m (40 ft) below roadway surface elevation.

The lab had a very difficult time preparing an undisturbed sample, the result was that all of the samples tested for swell were remolded to some degree. Because the tested samples produced the anticipated results, which closely mimicked previously tested samples, only 9 samples were tested; see Figure 1 below, Summary of Test Results. The average pressure required to keep the samples at a constant volume while submerged in water was 3.5 tsf. The average depth of the swelling clays sampled was 4m (12 ft) below roadway surface. The average liquid limit (LL) for the samples tested was 87%, while the average plastic limit (PL) was 36%, the average plastic index (PI) was 51 and the average moisture content was 26%. Lastly, when comparing soil properties of some what relative samples from similar locations from the 2005 investigation and the 1995 investigation it became apparent the soil properties such as PI and moisture contents seem to have only slightly changed.

Figure 1
Summary of Test Results

Location Sta. offset	Sample ID	Date	Depth M (ft)	Swell pressure Tsf.	LL %	PL %	PI	Moisture Content
427 R 100ft	B-1-3	3-10-05	2 (6.6)	17	NA	NA	NA	NA
427 R 100ft	B-1-10	3-10-05	5 (15)	6.4	73	40	33	31
433 R 100ft	B-2-05	3-9-05	1 (3)		68	40	28	29
446 R 100	B-2-80	1980	1.5 (5)		NA	NA	NA	24.5
448 R 100ft	B-3-05	3-9-05	3 (9.6)	3.7	78	23	45	29
448 R 50	D-2-93	2-22-93	3.5 (11)		87	41	46	32.7
455 R 50	D2-3-93	2-22-93	2.1 (6.5)		137	40	97	34.7
457 R 100ft	B-4-05	3-9-05	3.3 (10)	3.5	101	39	62	28.9
455 R 50	D2-3-93	2-22-93	5.5 (16.5)		132	34	98	27.4
457 R 100ft	B-4-05	3-9-05	4 (13)	1.9	113	38	75	27.9
461 R 50	D-5-93	2-23-93	6.3(19)		N/A	N/A	N/A	30.6
472+85 R50	D-7-93	2-23-93	5(15)		107	40	67	33.6
473 R100	B-4-80	1980	5 (15)	1.7	NA	NA	NA	25.2
484 R50	D-9-93	2-23-93	2.2 (7)		186	64	122	42.1
484 R50	D-9-93	2-23-93	4 (13)		152	38	114	38.7
442+50 L100	B-9-05	3-10-05	3 (9.6)	1.75	NA	NA	NA	13.3
445+50 L50	D-12-93	3-24-93	2.1 (6.5)		100	43	57	38.1
457+45 L50	D-11-93	3-24-93	3 (9.5)		131	34	97	31.7
475 L 50	D-10-93	2-24-93	2.7 (8)		112	42	70	37.3
480 L 100ft	B-5-05	3-9-05	1.5 (5.2)	1.5	103	40	63	35.1
490 L 100ft	B-6-05	3-9-05	3 (9.6)	10.2	106	35	71	10.6
462 L 100ft	B-8-05	3-10-05	3 (9.6)	0.15	NP	NA	NA	4.2

Discussion of swelling clay

Numerous laboratory-testing methods such as constant volume and constant pressure tests have been devised for quantitatively evaluating swell and swelling pressures to be anticipated under field conditions. The advantages and disadvantages of many of these methods were reviewed by Woodward-Clyde and Associates (Reference #5 1967, p. 75-107), who noted: In most cases, the tests provide indications of the general magnitude of problems to be anticipated in the field: however, the test indications may be drastically misleading of what really happens in natural conditions especially when testing remolded samples. (Hamilton, 1965). A more accurate method of predicting the swell potential of expansive clays is to compare a samples' moisture content to the samples' Plasticity Index (PI). As noted by Seed and others in Reference #5, the "PI is generally a good indicator of swelling potential", and found the "PI to be the single most useful indicator of swelling potential", (1967, p. 117). Dry swelling clays, like the clays in the project area, have the ability to absorb large quantities of water before becoming plastic and they also remain plastic over a wider range of moisture content all the way up to the liquid limit.

Typically the swelling pressure generated by a clay with a moisture content on the dry side of the plastic limit is much greater than pressures generated by the same clay with a moisture content near the liquid limit. The dryer the moisture content is from the liquid limit the greater the potential is for the clay to absorb water and swell.

Conclusions and Recommendations

By comparing the PI and moisture contents of the 1980, 1995 and 2005 lab results we can conservatively conclude that the expansive soils underlying the roadway are still relatively dry, posses a great potential for swelling and will continue to swell for an indefinite period of time unless positive action is taken to control the moisture content of the soils. This Office believes the in place horizontal impermeable membrane has been very effective in reducing roadway heaving and that any new design and or construction should take great care to protect the integrity of the membrane. The following recommendations will help to hold the moisture content of the sub surface expansive materials constant by building on the in place system. Basic recommendations are to provide increased surface and subsurface drainage and to encapsulate the problematic clay soils in an attempt to maintain a constant moisture content.

1. Cut back all existing (2:1) (H:V) slopes and increase width of the paved shoulder an additional 4 meters where possible. Finished slopes will match existing slopes approximately (2:1) (H:V). Finished paved shoulder will be sloped at 5% to 10% away from the roadway and will allow the maintenance crew to drive their sweeper machine safely and effectively.
2. Install a non-permeable membrane such as 40 mill calendared polyvinyl chloride (PVC) sheeting with geotextile cushion fabrics to encapsulate the native sub surface base vertically.

3. A 100 mm diameter fully perforated PVC drainpipe will be placed on top of membrane and filter fabric. Permeable back fill will be placed around the drainpipe and "burrito wrapped" with engineering filter fabric.
4. Brow ditches will also be provided along the bench of the slopes.
5. The existing asphalt drains, located in the center of the medians, are badly cracked, broken or missing, these should be replaced with concrete channels.
6. This office recommends the CMP underdrain system be replaced or removed and backfill with Controlled Low Strength Material, as in Section 19-3.062 "Slurry Cement Backfill" of Standard Specifications dated July 1999.
7. A representative of this Office be requested to provide oversight during the construction.
8. The natural erosion channel at EB 40 Station 425+00 should be either lined with concert or fitted with an inlet and drainpipe directing flow into culverts. The current practice of discharging onto soil is unacceptable.
9. The culvert inlet at EB 40 Station 447+25 should be removed and replaced with a water tight connection to the culvert and apron, a new concrete apron should be installed at the culvert inlet, this is critical.
10. Along EB 40 between stations 453+00 and 459+00, the crown slope of the roadway and shoulders must be increased to at least 5%. Additional side culverts and catch basins should be placed along Lane 1 shoulder. Existing culverts and inlets along Lane #2 will need to be replaced and upgraded if slope is cut back.

Rehabilitation Alternatives

Following is a presentation of possible rehabilitation alternatives. Figures 2 through 5 are provided to visually present possible conceptual alternatives and are not to be construed as final designs. Once District selects an alternative, this Office will provide final design details of a selected rehabilitation alternative I requested by District. Of the following 4 Alternatives, this Office recommends Alternative 1A.

Alternative 1. Widen paved shoulder

The objectives of Alternative 1 is to move any future heaves away form the traveled way and to reduce future heaves by directing any surface runoff away from the roadway an into the culverts. Heaves should still be anticipated in the proposed paved shoulders, grinding shoulder heaves should be anticipated for safety and drainage. General components of Alternative 1 are as follows.

1. Widen existing paved shoulders in cut sections by 4 meters increasing paved shoulder to a total of 7 meters. The paved shoulder should slope down and away from the roadway at 5% to a new drainage system. See Schematic 1.
2. Place impermeable membrane so as to extend existing membrane to slope toe.
3. Provide under drain system at slope toe.
4. Alternative 1 may require the shoulders in fill sections to also be widened and existing culverts extended for safety reasons.

Alternative 2. Provide vertical cut off wall.

The objectives of Alternative 2 are to reduce future heaves by encapsulating the problematic clays with a vertical cut off wall. General components of Alternative 2 are as follows

1. Excavate a 0.5 to 1.0 meter wide trench to a depth of 2 to 3 meters below the final profile grade in the paved shoulder. See Schematic 2.
2. Place impermeable membrane so that the existing impermeable membrane overlaps it. Extend membrane 0.5 meters vertically up the cut slope side of the trench.
3. Use engineering filter fabric to wrap or encapsulate the trench backfill material.
4. Place a perforated drainpipe in the bottom of the trench on top of the impermeable membrane.
5. Backfill trench using a non-expansive permeable material.

Alternative 1A. Widen paved shoulder and provide vertical cut off trench

Alternative 1A combines Alternative 1 and Alternative 2 although it uses a shallower version of the vertical cut off trench at the edge of proposed widened shoulder not at the edge of traveled way. General components of Alternative 1A are as follows.

1. Widen existing paved shoulders in cut sections. The paved shoulder should slope down and away from the roadway on a 5% slope to a new drain system. See Schematic 3.
2. Place impermeable membrane so as to extend existing membrane at least 7 meters beyond edge of traveled way
3. Excavate a 0.5 to 1.0 meter wide trench to a depth of 1.5 to 2 meters below the final profile grade in the paved shoulder, provide under drain system at slope toe and extend impermeable membrane.
4. Alternative 3 may require the shoulders in fill sections to also be widened and existing culverts extended.

Alternative 4. Place overburden to counteract swelling

Alternative 4 would combine methods of removing expansive material and placing enough overburden fill to counteract the average swelling pressure of 3.5 tests. Alternative 4 would alleviate the roadway-heaving problem but the enormous earthwork needed may make it cost prohibitive. General components of Alternative 4 are as follows.

1. Remove roadway edge of shoulder to edge of shoulder, remove existing impermeable membrane.
2. Deep excavations of up to 3 meters edge of shoulder to edge of shoulder to remove expansive material may require temporary shoring or temporary 1:1 cuts.
3. Import and place sub base material and compact.
4. Replace roadway surface.

Construction Notes

Weather patterns, both hot and cold, were problems during the 1995 construction. Construction scheduling must take weather conditions into consideration. Excavations less than 1.5 m (5 ft) in depth in the hard native clay material should stand vertical, and temporary shoring should not be required. Excavations should not be left open overnight and should be backfilled the same day excavated. It should be anticipated that excavations into the native hard clay material will be angular and sharp, which may make it difficult for the membrane to lay flat on cut surface. It is not anticipated that groundwater will be encountered during excavations.

It is our belief that several of the current issues associated with the roadway heaving stem from construction related problems that arose during the past rehabilitation construction process and also from deviations from the initial rehabilitation design. In closing we recommend a representative of this Office be requested to provide oversight during construction.

If you have any questions or comments, please call Brian Gutierrez at (916) 227-1222 or (CalNet) 8-498-1222.

Prepared by: Date:

7-11-05

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Geotechnical Design South -2

ATTACHMENTS – Figures 2 through 5

cc: AAbghari – GDS2
SWei - GDS2
Project File - South
Project – North

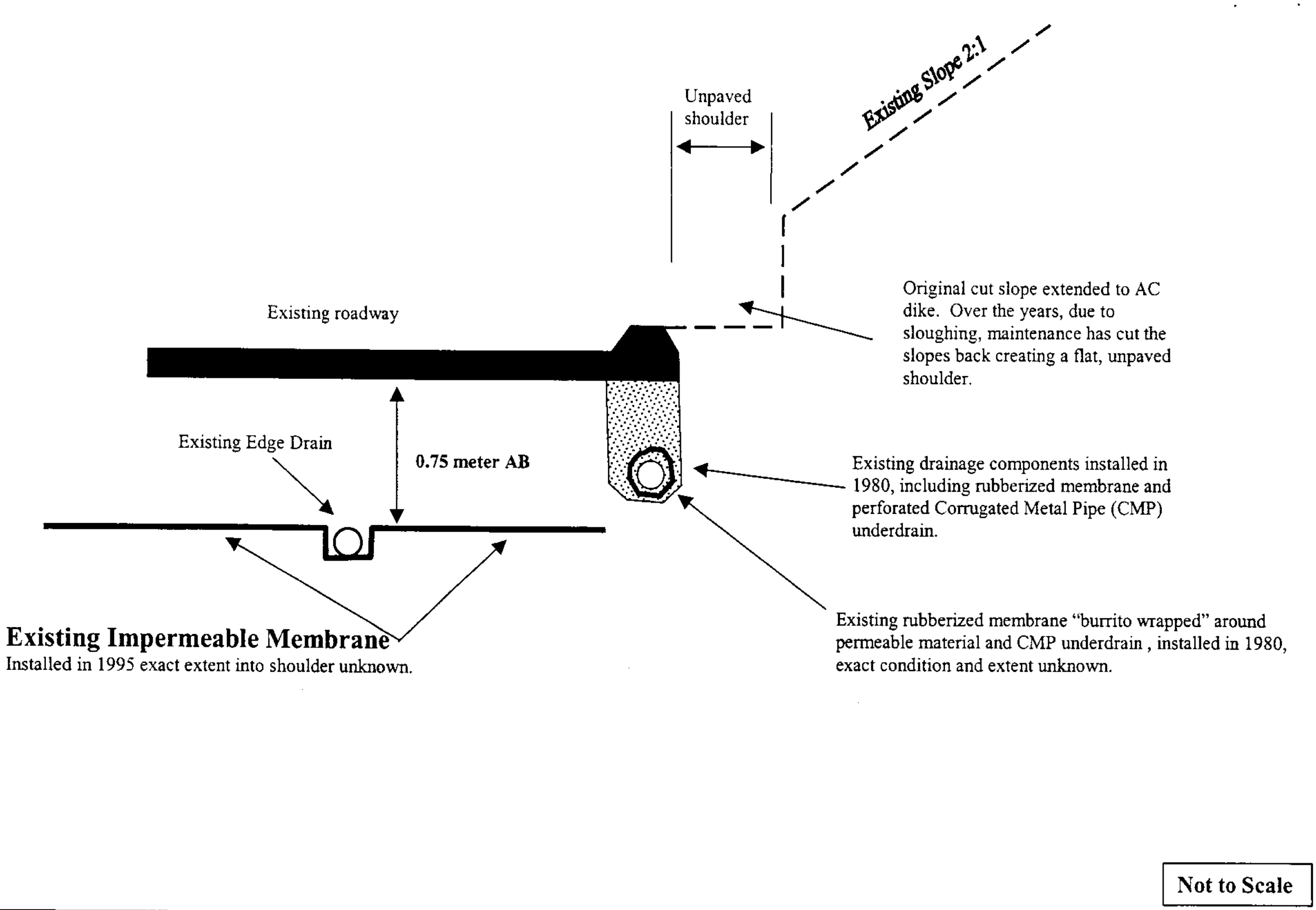


FIGURE 2. **Schematic of assumed existing conditions along cut sections of Route 40 approximately between post miles 152+00 and 153+00.**

DIST	COUNTY	ROUTE	Post Mile
08	SBd	40	152+00/153+00
EA 08 – 489300			July 2005
ROUTE 40 near Needles 2005 GDR			

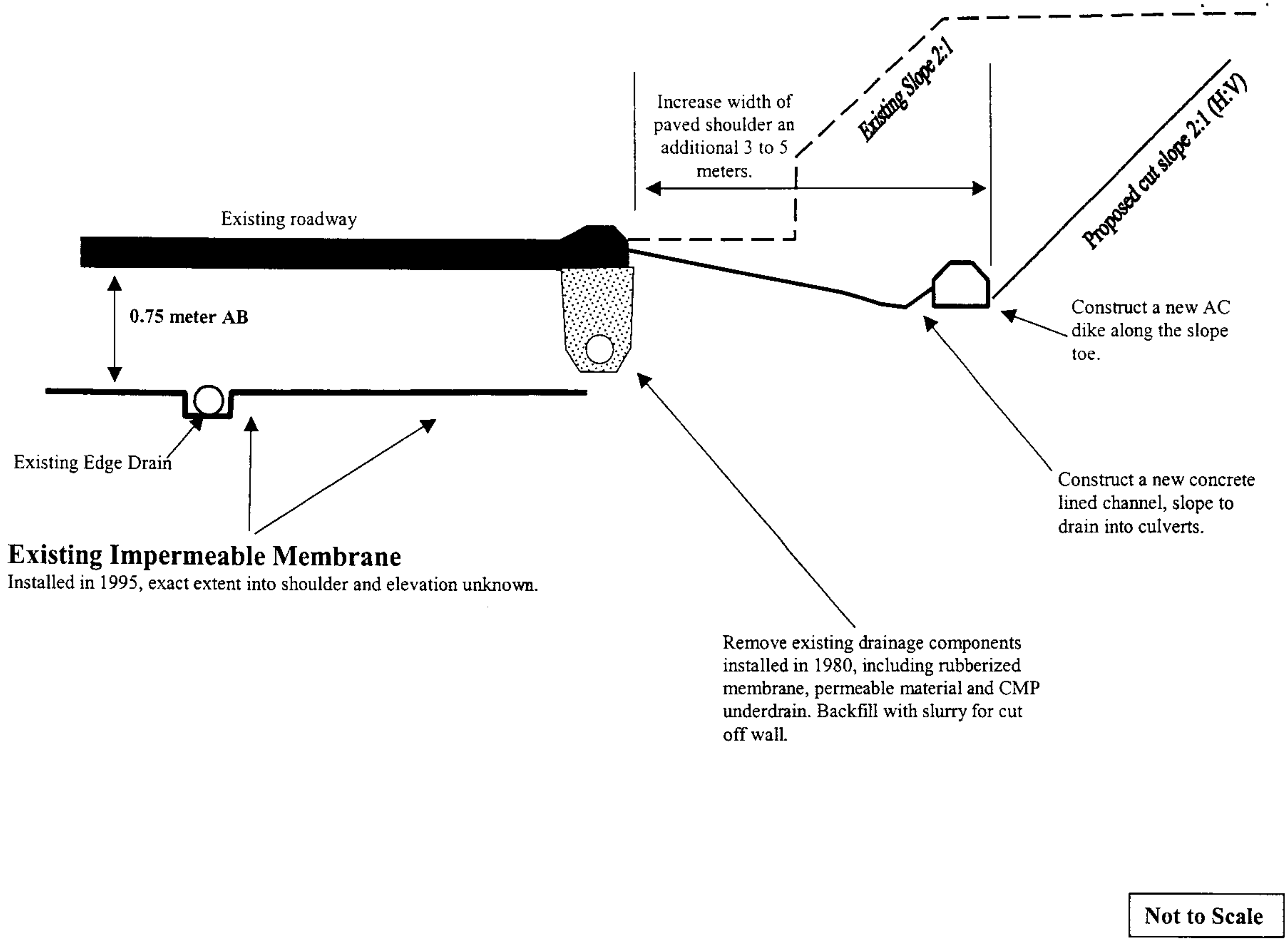


FIGURE 3. **Schematic of Alternative 1 –Remove underdrain, widen paved shoulders and provide slurry cut off wall.**

DIST	COUNTY	ROUTE	Post Mile
08	SBd	40	152+00/153+00
EA 08 – 489300			July 2005
ROUTE 40 near Needles 2005 GDR			

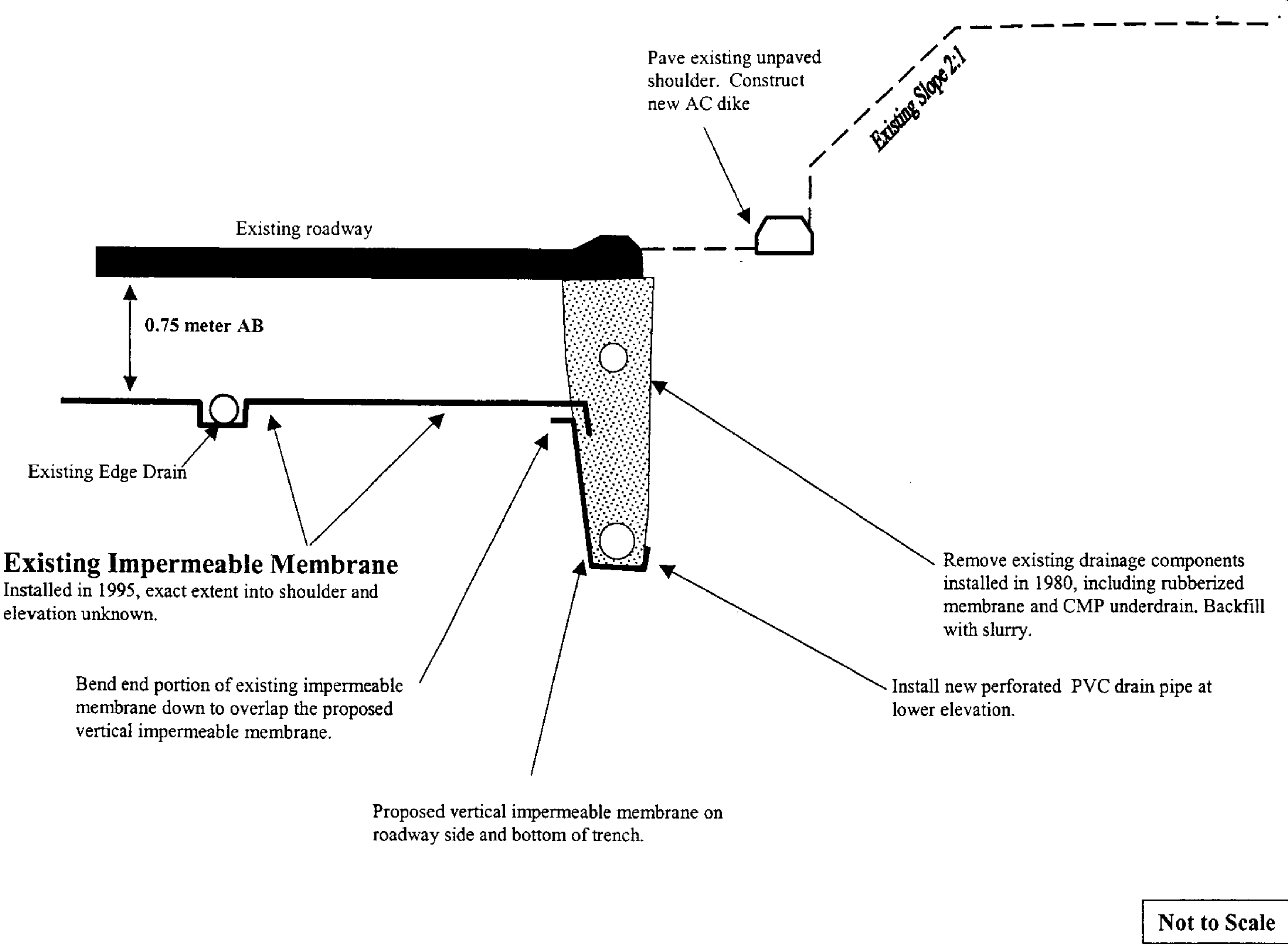


FIGURE 4. **Schematic of Alternative 2 – Replace underdrain with deeper underdrain, add vertical impermeable membrane.**

DIST	COUNTY	ROUTE	Post Mile
08	SBd	40	152+00/153+00
EA 08 – 489300			July 2005
ROUTE 40 near Needles 2005 GDR			

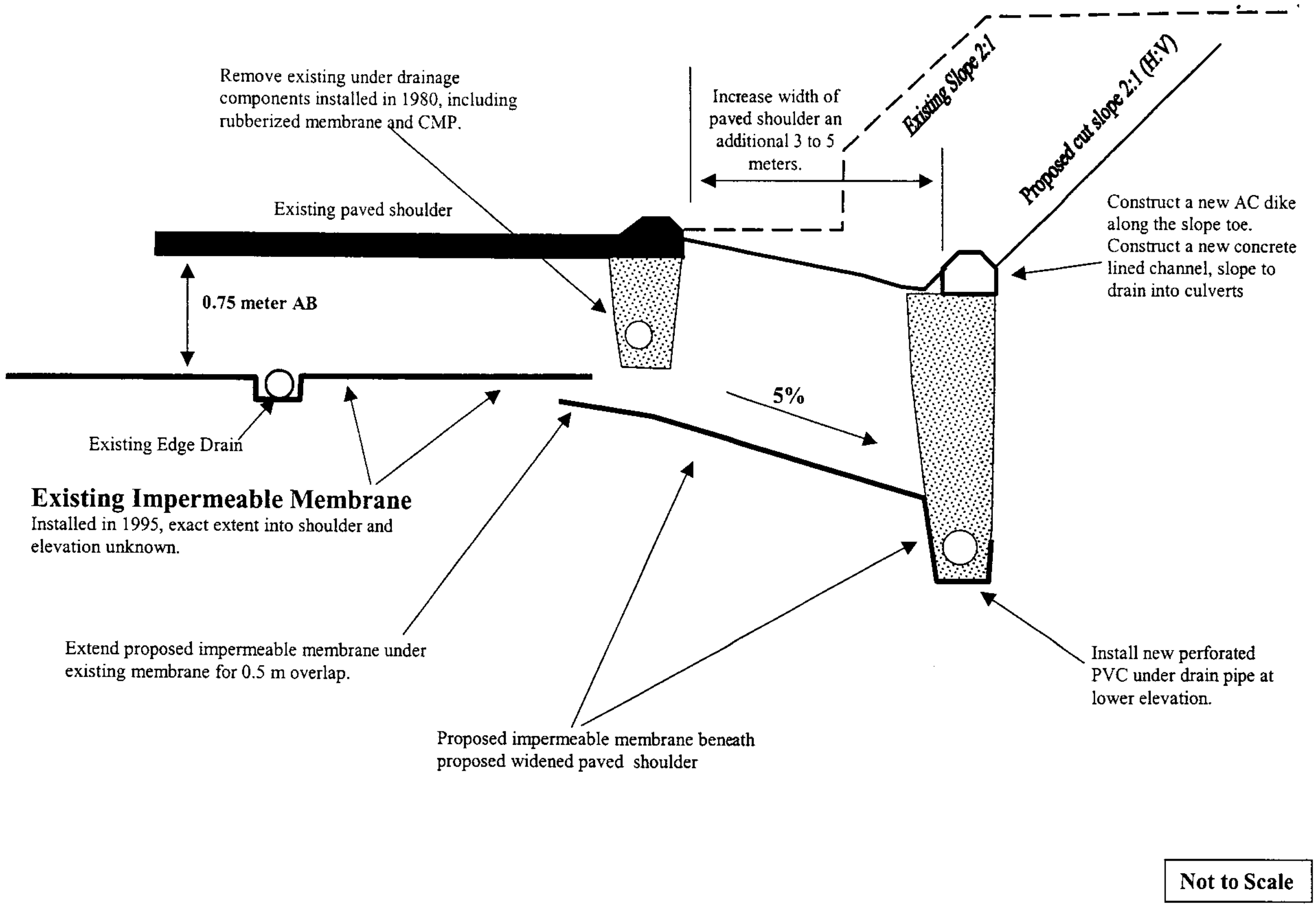
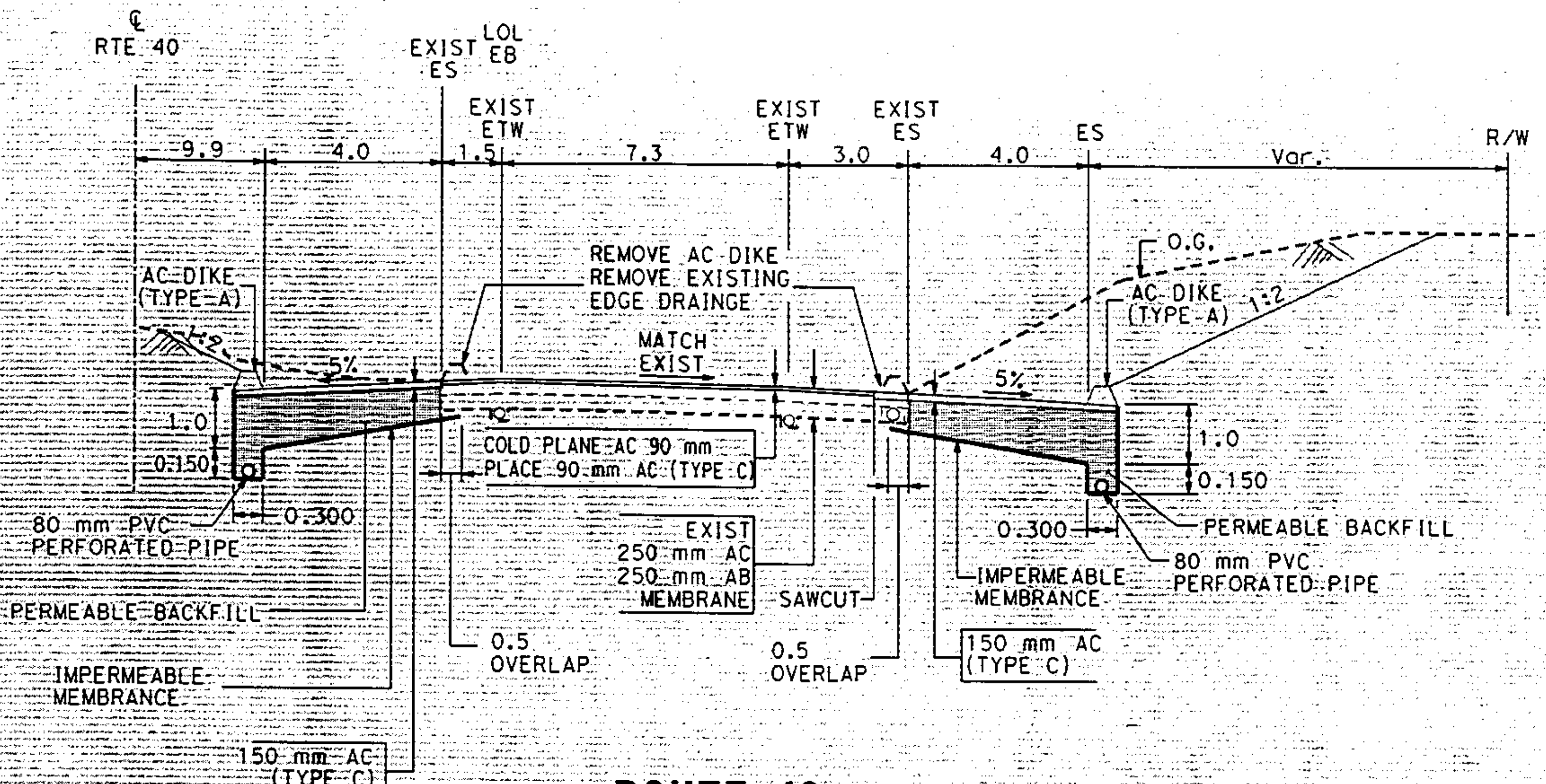


FIGURE 5. **Schematic of Alternative 1A –Widen paved shoulders, replace drain with deeper drain, add vertical cut off trench lined with impermeable membrane.**

DIST	COUNTY	ROUTE	Post Mile
08	SBd	40	152+00/153+00
EA 08 – 489300			July 2005
ROUTE 40 near Needles 2005 GDR			

ALTERNATIVE 1A



ROUTE 40

STA 2434+00 TO 2458+00

NOTE:

IDENTICAL FOR WEST BOUND DIRECTION

ALL DIMENSIONS ARE IN
METERS UNLESS OTHERWISE SHOWN

TYPICAL CROSS SECTION

NO SCALE