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Photographic Pavement Distress Record Collection and Transverse Profile Analysis

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Abstract

The use of automated pavement condition survey systems has been a goal of highway managers for many years. With the advent of the Strategic Highway Research Program's Long Term Pavement Performance Study the need for permanent, high resolution, pavement distress records arose. In order to meet this need through the use of state-of-the-art technology, SHRP chose to use PASCO USA's automated ROADRECON Survey systems to obtain permanent, high resolution, records of pavement surface distress and transverse profile.

This report documents the methods used to calibrate the survey systems and develop quality control procedures. In addition, it summarizes the survey operations, and support systems development, performed prior to June 1, 1991.

Executive Summary

Interest in evaluating the condition of pavements began during the conduct of the AASHO Road Test in the late 1950's and early 1960's. A pavement serviceability concept was developed to continuously evaluate the performance of the test pavements which included cracking, patching, rutting, and roughness.

Since that time additional surface distress items and friction have been identified as areas of concern. In the over 35 years since the AASHO Road Test there have been consistent efforts made to automate the collection of pavement condition data. These efforts have resulted in the development of a variety of means to collect roughness, friction, and deflection data with varying degrees of automation.

As early as the 1960's efforts were underway to develop methods to automatically obtain permanent records of pavement surface distress and transverse profile while traveling at highway speeds. These efforts resulted in the development of the techniques used by PASCO Corporation's RoadRecon survey systems.

The first system, completed in 1970, used photogrammetry principles to obtain a continuous high resolution, 35mm strip film of the pavement's surface at highway speeds. The second system, completed in 1975, used 35mm film technology combined with photogrammetry principles and computer digitizing technology to obtain a transverse profile of the pavement's surface with a high level of accuracy. These systems, known as RoadRecon-70 and RoadRecon-75 respectively, have been used since their development to conduct annual surveys of various parts of the roadway systems in Japan.

In 1987 SHRP entered into a contract with PASCO USA, Inc. to use the RoadRecon-70 and RoadRecon-75 systems to obtain permanent surface distress and transverse profile records of the test sections contained in the Long Term Pavement Performance Study. In order to perform these surveys in an efficient manner, PASCO USA constructed two new ROADRECON Survey Units containing both the RoadRecon-70 and RoadRecon-75 systems, which would operate simultaneously while surveying SHRP sites.

After construction in the spring and summer of 1988, the ROADRECON Survey Units were subjected to a series of tests to calibrate the systems and evaluate each unit's degree of accuracy and precision in recording the condition of SHRP sites. The information gathered through these tests was also used to develop control tests and criteria to assure the quality of the survey data. The testing included both ROADRECON Survey Units with variables in operators, speed, and test conditions. Part I of this report deals with the unit evaluation tests and the subsequent development of quality control criteria and procedures.

In the spring of 1989, after final full scale pilot survey on sites in New Jersey and

Pennsylvania, PASCO USA, Inc. commenced full field survey operations with both units. During the following three years the units' systems, procedures, and office procedures were continually fine tuned in order to develop the most efficient, cost-effective, and consistent survey procedures to produce quality data.

Part II of this report covers the field and office operations performed under the original and subsequent contracts. This included the filming, processing, and transverse profile data reduction for those sites filmed between March, 1989, and the end of May, 1992. Also included in Part II, is a description of the system developed to obtain surface distress data from our RR-70 films, in accordance with SHRP's Report SHRP-LTPP/FR-90-001, "Distress Identification Manual for the Long-Term Pavement Performance Studies".

I. SHRP LTPP DEVELOPMENT.

Since the first paved roads were built, there have been efforts to improve their design, construction, rehabilitation, and overall performance. One of the major efforts to develop pavement design models occurred at the AASHO Road Test, 1959-62, in Ottawa, IL. During this study the first method to objectively describe pavement performance was developed and termed Present Serviceability Index (PSI). The PSI evolved into one of the basic elements for Pavement Management.

As highway agencies faced tighter funding and traffic volumes and weights continued to increase the need to more effectively manage pavement systems grew. This need lead to the development and implementation of Pavement Management Systems (PMS), by many agencies. PMS's must have usable accurate and timely information about the pavements in the system. This information must be organized and related to a location referencing system and contain well planned types of data necessary to produce the intended information from the PMS.

Basic to a PMS is data about the pavement's condition and performance. The need to collect pavement condition data in a dependable, safe, economical manner has led to the development of improved methods and equipment to obtain pavement condition data.

As data started to accumulate on the various PMS systems, it became apparent that the highway systems around the country were deteriorating faster than maintenance efforts could keep up with them, thereby emphasizing the need for more highway rehabilitation funding, as well as, better ways of rehabilitating and maintaining the nations highways.

The need for a concerted, nationwide, highway research effort to increase the productivity and safety of the nation's highway system was originally proposed and documented in TRB Special Report 202, "America's Highways: Accelerating the Search for Innovation", July 1984. Sponsored by the Federal Highway Administration and performed by the Transportation Research Board, this Strategic Transportation Research Study recommended the initiation of a five-year, $150 million, research program to provide an intensive, focused research effort on six high priority areas.

The 1987 Surface Transportation and Urban Relocation Assistance Act formed and funded the Strategic Highway Research Program (SHRP) in response to this need. The SHRP was formed as an entity by which to manage an intensive five-year highway research program which would sponsor basic research in the areas of Asphalt Properties, Long-Term Pavement Performance, Maintenance Effectiveness, Bridge Component Protection, Cement and Concrete, and Snow and Ice Control on Highways and Bridges.

All of the research efforts, except the Long-Term Pavement Performance (LTPP) Study, were designed to be completed during the five-year life of the SHRP. The LTPP study was designed as a twenty-year study to evaluate the performance of in-service pavement test sections throughout the United States and Canada. The first five years of this study were to be sponsored by the SHRP within the National Research Council.

When establishing the LTPP study parameters, it was decided that the pavement condition data for the test sections must be collected in a consistent, high quality manner throughout the country, and that permanent records of the distress would be made. In order to determine the best available method of collecting this data, the FHWA sponsored project no. DTFH61-85-C-00115, "Improved Methods and Equipment to Conduct Pavement Distress Surveys". This project evaluated several manual survey methods and four automated survey systems. The project found that in order to obtain a permanent record of distress, be cost-effective, and provide high quality data, survey systems based on the use of high resolution 35mm film to photographically record distress features obtained normal to the pavement's surface were best suited.

In the spring of 1987, the SHRP sent out its program announcement for the first quarter of FY 1988. This announcement contained the RFP for Contract No. P-002: LTPP: Pavement Distress Records. This RFP called for the collection of high resolution visual images of the surface distress, obtained normal to the pavement, and periodic rut depth measurements. All measurements had to be recorded on media suitable for long term storage.

In the summer of 1987, PASCO USA submitted a proposal, in response to SHRP's RFP, to construct and operate survey units equipped with 35mm film survey systems designed to provide the specific survey results required. These survey units would simultaneously collect surface distress and transverse profile data on the SHRP test sites using high resolution 35mm film for the long term storage media.

Subsequently, in 1987, the SHRP contracted with PASCO USA, Inc., to obtain permanent distress records of the GPS and SPS sites throughout the US and Canada. The original contract ran through May, 1991. In June, 1991, the SHRP negotiated a second contract with PASCO USA to extend through the SHRP's initial five year life.

A follow up RFP was issued by SHRP to design and assemble equipment and software to supply SHRP with a work station to be used in the analysis and recording of distress data from the GPS and SPS survey films. As a result of this open procurement a supplemental task was added to PASCO USA's existing contract to provide the completed work station.

II. PART I

Survey Vehicle Construction.

Two Roadrecon Units were constructed in 1988 to perform pavement condition surveys for SHRP. The units incorporated an RR-70 system to continuously photograph the roadway and an RR-75 system to take rut depth photos at 50 foot intervals.

The RR-70 and RR-75 systems use a proven technology but the support system, and the vehicles incorporated advanced technology in other areas. The new units were designed to make the survey process more efficient and functional. Basic truck cabs and chassis were selected and customized bodies were fabricated to mount the systems. Automated, remotely controlled booms were designed to facilitate mounting and servicing the cameras. Power equipment and electronics were designed and built into the body to accommodate crew operation and storage for travel. The survey units were designed to obtain both continuous pavement distress records using an RR-70 system on the front of the vehicle and transverse profile data from an RR-75 system on the rear.

The RoadRecon-70 (RR-70) system consists of a 35mm motion picture camera with a slit apperature and a bank of flood lights. The slit camera is mounted perpendicular to the pavement on a boom which extends from the front of the ROADRECON unit. The slit camera's film speed is synchronized with the vehicle speed so that survey operations can be performed at near prevailing traffic speeds. The flood lights are mounted in a custom front bumper to provide controlled illumination of the pavement's surface.

The RR-70 system uses 35mm film technology coupled with photogrammetry principles to obtain a continuous 35mm image of the pavement's surface. The image recorded is of a sixteen (16) foot width of pavement at a 1:200 (1 ft. of film equals 200 ft. of pavement) longitudinal scale. In addition, this image has such high resolution that transverse and longitudinal cracks 1mm (1/25 inch) wide are visible.

The RoadRecon-75 (RR-75) system consists of a 35mm pulse camera and a strobe projector. The pulse camera is mounted perpendicular to the pavement on a boom that extends from the rear of the ROADRECON unit, and the strobe projector is mounted on the rear bumper. The pulse camera is controlled by the Distance Measuring Instrument (DMI) which triggers the camera at any preset interval. The strobe projector contains a glass plate on which a hairline is etched. The pulse camera is synchronized to the strobe projector such that when the camera is triggered to take a picture, the strobe projects a shadow of a hairline on the pavement's surface. The hairline shadow covers a width of approximately 15.5

feet. This hairline image follows the contours of the pavement's surface and provides a transverse profile of the pavement. The transverse profile at that location is recorded by photographing the hairline image.

Survey Vehicle Calibration and Quality Control Tests.

Background

Construction was started in the spring of 1988, in a fire engine fabrication plant in south central Pennsylvania, on two new Roadrecon Units to perform condition survey work for the SHRP P002 contract held by PASCO USA. The new units incorporated the basic Roadrecon technology which was developed and in use since the 1960's.

While proven technology was incorporated into the new units, there were changes in individual components and in the overall designs. The particular manufacturing tolerances and the specific component properties had to be evaluated and adjusted in relation to the final output of each of the units.

Manufacturing was completed in August and September of 1988 and crew training was started. It was planned to have concurrent shakedown period for the equipment during the crew training.

Manuals were also being written to describe the operation, maintenance and properties of the new units.

Crew training and shakedown proceeded during the last part of September. Calibration of equipment and operational procedures were conducted similar to those routinely used in prior Roadrecon operations. During the last two weeks in September both Units were used to survey nine New Jersey sites in a simulation of future SHRP operations.

A meeting was arranged for SHRP representatives to view the Roadrecon operation after the simulation appeared to be proceeding as expected. It was anticipated that this demonstration and review would precede the start of normal field survey operation.

Several things occurred during the SHRP demonstration exercise. The first thing involved the beginning of a problem in the malfunction of the Digital Distance Meter. This malfunction was readily recognizable because of the interrelationship of both the RR-75 and the RR-70 systems designed operational requirement to locate rut depth at 50-foot intervals at specific markings in the SHRP sections.

The second thing that happened consisted of a series of questions and recommendations which were raised concerning the need for additional tests to meet SHRP requirements.

The tests and recommendations were considered to be most appropriate and plans were made to develop the desired quality statements and to establish operational standards.

Corrective actions were taken for the DDM and a recalibration process was completed. Additional equipment shakedown occurred during the extensive number of test runs made to develop the desired information. A number of minor problems were identified and corrected. At times the minor problems created a need for retesting to re-establish a calibration.

TEST SITES

A series of tests were performed to establish the capability of the equipment and to describe the quality of the information produced. The results of the tests have been used to develop operational procedures which are included in the Manual and to develop a quality control plan to insure that consistent information is produced by each unit and that information is comparable between units.

Low Speed Sites

A tangent section of roadway near PASCO USA's office was selected for a series of tests which could be run safely at uniform speeds of 30 mph.

The roadway was measured and paint marked to facilitate the placement of calibration boards for repeat runs extending over several nights operations. The low speed test site layout is shown in Figure 1.

A series of runs were made using different speeds, operators and units. Both the RR-70 and RR-75 systems were operated to produce film which was used to establish and compare the performance characteristics of the ROADRECON Survey Units.

High Speed Site

A section of New Jersey, Route 202 was measured and marked very similar to a SHRP test section to serve as a test site for speeds of 40 and 45 mph.

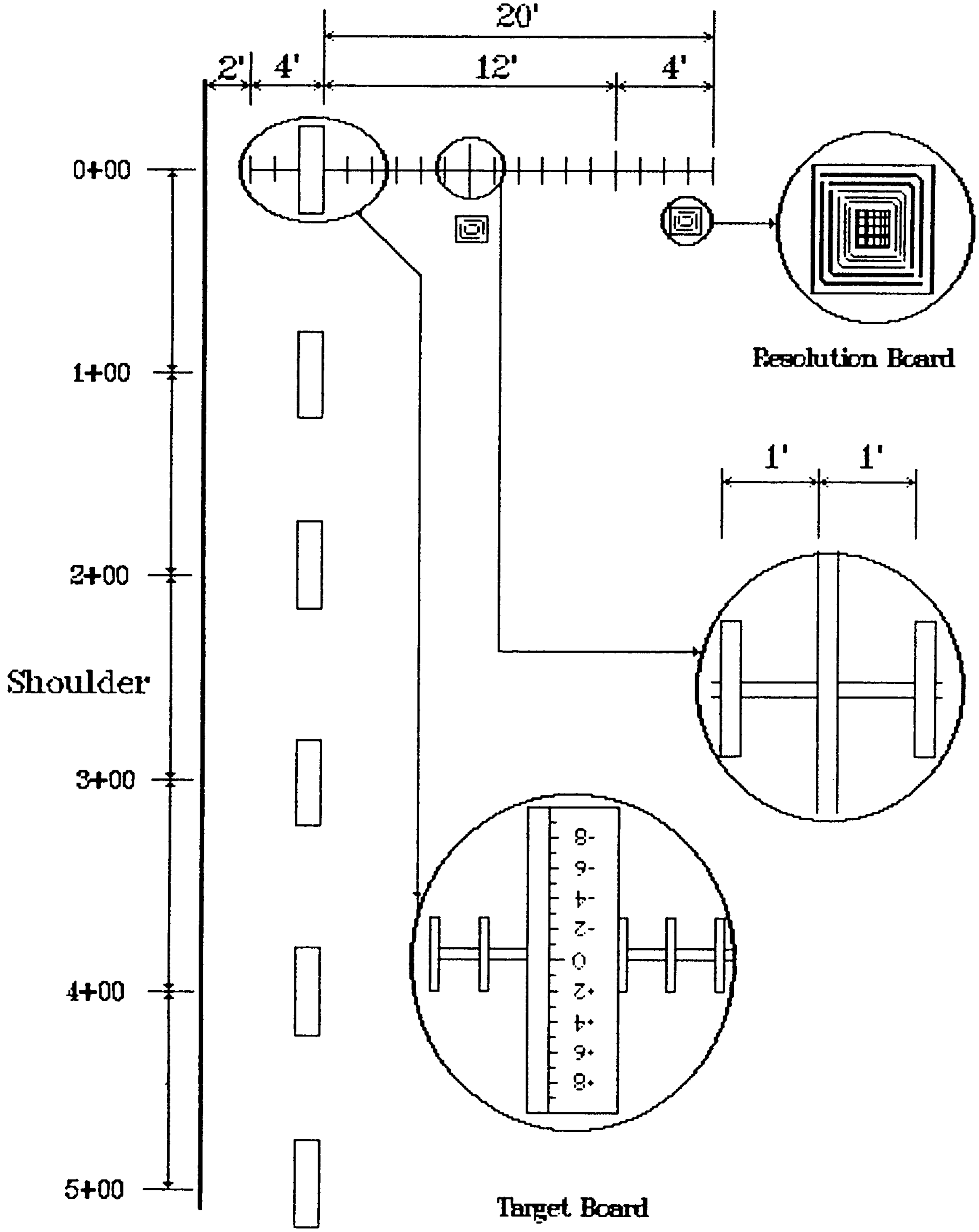

Figure 1. Low Speed Test Site Layout

Repeat runs were made over this site to establish performance criteria outside of the planned SHRP survey speed at 30 mph.

In Service Pavement Rut Depths

Five sites were selected and marked on local roadways which had a range of rut depths and which could be measured using a static string line.

The RR-75 systems were also used to record the depths on film in a static position. It was planned to get an RR-75 picture at different speeds; however, the operational characteristics of the sites and the need to get photos within one foot of the marks proved to be very difficult, and the procedure was terminated. Some rut depth pictures at 10mph were obtained which enabled some comparisons.

A transverse profilometer device was obtained to measure rut depths at field sites. The two part beam used to carry the profiling carriage was defective in manufacture and had a built in deflection at the middle of about 3/18" and the device was not suitable.

A replacement could not be received in time for the tests so a string line and carpenter's square were used to get actual measurements.

Rut Depth Calibration Tests

A series of metal blocks were fabricated with variable thickness to be used to calibrate the RR-75 system. The Roadrecon units were carefully positioned on a relatively flat concrete floor and the position of the hairline projection and the center of focus of the camera lens were marked on the floor.

Variable depth blocks were arranged in a planned pattern transversely across the camera focal point and rut depth photos were taken. The photos were digitized using a film analyzer and rut depth plots were produced. This data provides the basis for system output calibration.

Rut Depth Block Evaluation

A complete series of rut depth photos was taken using the RR-75 system on both ROADRECON Survey Units and the calibration blocks. The set up was similar to the calibration procedure. The photos were digitized with the film analyzer and plotted using the computer program for the respective unit.

At the same time the pictures were taken of the test blocks, a set of measurements were taken using a square and a fixed string line. Several persons made the same measurements to avoid operator error.

The string line measurements were then run through a computation to produce a rut depth measurement similar to the SHRP definition and comparable to the digitized computer processed output from the film analyzer. The set up for these tests is shown in Figure 2.

TEST RESULTS

RR 70 Linear Distortion

Linear distortion is defined as the difference in the measured length of film between pavement marks multiplied by the scale factor (one foot of film equal 200 feet of pavement) and compared with the known length between the actual marks on the pavement. Linear distortion can be controlled by adjusting the DMI counts which are used to control the camera speed and the length of film exposed over a given distance.

Repeated runs were made with different operators, at different speeds to determine the standard deviation under various conditions of test.

Table 1 contains a summary of the data. Appendix A contains the raw data.

A review of the data in Table 1 indicates that there is little "between operator" difference.

The Digital Distance Meter (DDM) on each unit has been adjusted to obtain the highest accuracy at 30mph which is the operating speed for the SHRP surveys. The accuracy is within 1% at 30mph for both units based upon five repeat runs.

Three runs were made at other speeds to evaluate the DDM's performance for comparison with the manufacturer's specifications and to assess the criticality of maintaining speed. The tests indicate that there was a need to stay between 20 and 30 mph to obtain the desired accuracy.

A quality control procedure was established to measure film length on pavement sections and to compare the measurement with known SHRP section lengths as a check on longitudinal distortion.

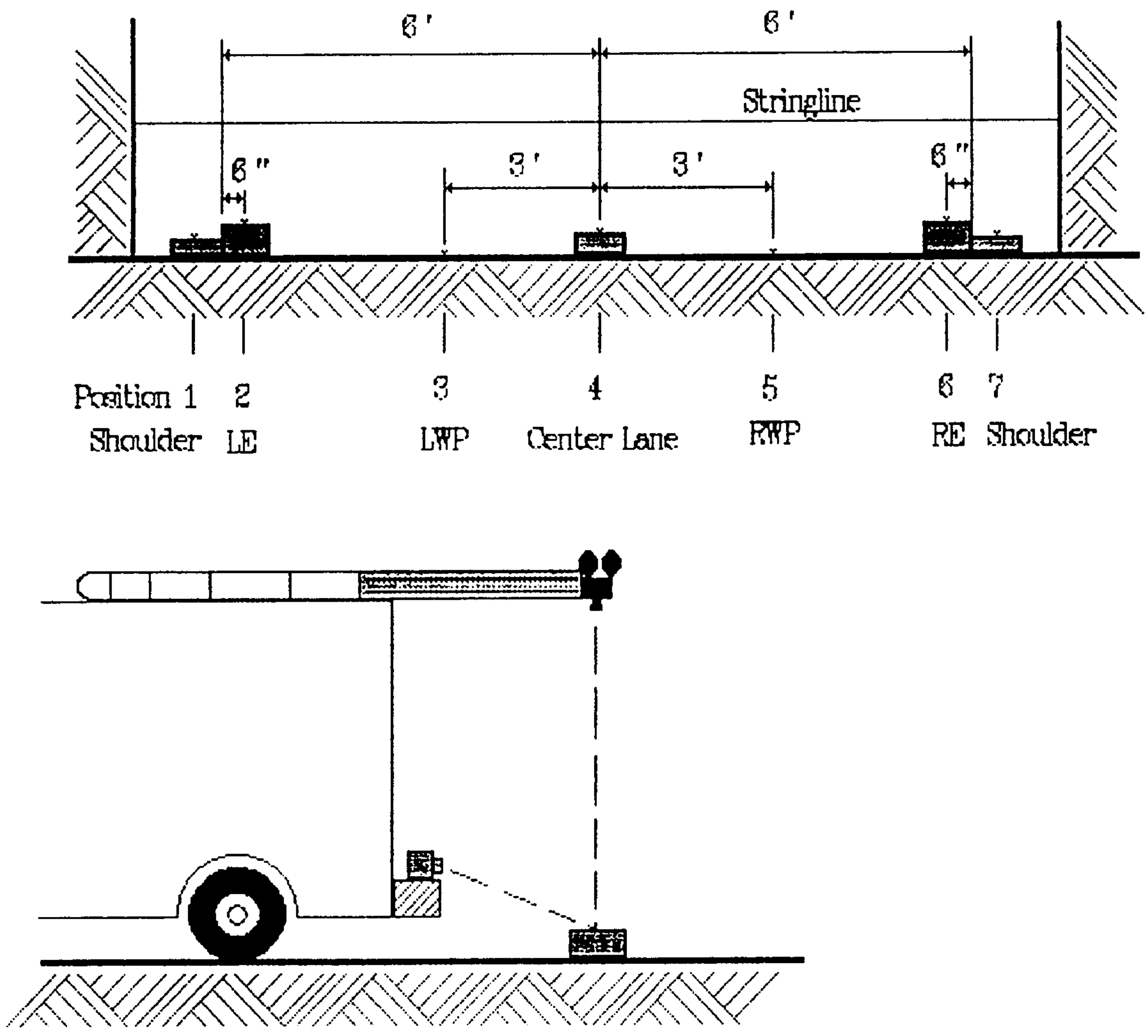

Figure 2. Static Block Test Setup.

Table 1 - Linear Distortion - RR-70

Operators Speed MPH		Unit #1 A	Unit #1 B	Unit #2 A	Unit #2 B	Unit #2 C
10	Ave. Diff Length	+3.20%	+3.57%	+7.57%	+5.90%	---
	3 Standard Deviations	±0.58%	±1.06%	±0.86%	±1.79%	
20	Ave	+1.11%	+1.23%	+2.14%	+2/01%	---
	3 STD	±0.40%	±0.47%	±0.44%	±0.18%	
30	Ave	+0.06%	+0.03%	+0.53%	+0.51%	---
	3 STD	±0.40%	±0.21%	±0.24%	±0.14%	
40	Ave	-4.76%	-3.42%	---	---	-0.05%
	3 STD	±3.33%	±0.43%			±0.15%
45	Ave	-4.73%	-4.13%	---	---	-0.33%
	3 STD	±0.10%	±0.14%			±0.45%

RR 70 Transverse Distortion

Transverse distortion was evaluated by digitizing the one foot tape marks on the transverse scale visible in each RR-70 film taken during the test runs. The transverse scale is shown in Figure 1.

Three operators performed the digitizing of the transverse scale for each run three times. After examination of the data for digitizing errors the data was averaged to determine the length of all one foot segments.

Table 2 shows a summary of the pooled data at the edges and in the center of the lane for each unit. The data as digitized and averaged from the film analyzer is shown as "Digitized" data. Also shown are the data which were corrected using a process to adjust and compensate for the known optical distortion unique to each lens involved in filming and projecting the image.

Table 2. Transverse Distortion of Objects by Location.

		Unit #1 Digitized	Unit #1 Corrected	Unit #2 Digitized	Unit #2 Corrected
Center Edge	Ave.	3.0%	0.0%	2.4%	0.0%
	STD	1.7%	1.6%	1.4%	1.3%
Pavement Center	Ave.	4.5%	0.0%	5.1%	0.1%
	STD	0.8%	0.7%	0.4%	0.5%
Shoulder Edge	Ave.	-1.5%	0.0%	1.6%	0.0%
	STD	1.6%	1.6%	0.8%	0.8%

Table 3 shows the averages of the one foot marks at different speeds showing both the data as digitized and the data corrected for lens distortion.

Appendix B contains the transverse distortion data.

Table 3. Transverse Distortion of Objects by Speed.

		Unit #1 Digitized	Unit #1 Corrected	Unit #2 Digitized	Unit #2 Corrected
10 MPH	Ave.	2.0%	-0.3%	1.7%	-0.3%
	STD	3.7%	2.0%	4.9%	2.6%
20 MPH	Ave.	2.6%	-0.1%	2.6%	0.1%
	STD	1.9%	1.7%	3.6%	0.9%
30 MPH	Ave.	2.9%	0.4%	2.5%	0.2%
	STD	3.0%	1.4%	3.2%	1.5%

The use of a resolution board to check transverse distortions with the help of a Film Motion Analyzer (FMA) was considered but was not used in the evaluation tests. As an alternate the transverse scale with one foot segments was used to obtain greater accuracy. This eliminated the need to use a lupe or magnifier.

The magnifier used in the office has an inner scale of 0.1mm precision. The dimensions of the resolution board are 400mm X 500mm i.e. 2.0mm X 2.5mm on the film at 1/200 scale. Thus the measurement of film with the magnifier may contain an error of ± 4 or 5 percent. The test data indicates that accuracy below this range is needed to evaluate the transverse distortion.

The Film Motion Analyzer (FMA) has 0.25mm (1/100") precision on the projector screen. The projector's magnification is 13.4 times of the film. This means that the measurement of the length on film with FMA has precision of 0.019mm (0.000746"). It has been established that the digitizer operator has an error of ± 0.254mm (1/100") on the screen. Thus a measurement with FMA may contain a measurement error of ± 0.019mm on film and less than 1% after correction for the lens distortion from the FMA.

RR 70 Resolution

Resolution boards were placed in the center of the lane and at the left lane edge about 5 feet beyond the transverse scale shown in Figure 1.

The film location containing these boards from 19 runs at various speeds were viewed by 3 different evaluators using a light table and an 8-power lupe. Each operator made an assessment of his ability to see both the transverse and longitudinal grooves in each board. An evaluation sheet was marked to show the smallest groove discernible in each position and direction.

An inspection of the data indicates there is little or no effect from speed. There is some effect from the operator and there is some effect from the unit; however, these effects are quite small and within plus or minus one millimeter.

Generally, there is a lower resolution of longitudinal grooves and there is lower resolution at the lane edge. It should be emphasized that the differences are within plus or minus one millimeter. The rating sheets are contained in Appendix C.

Table 4 shows the percentage of possible observations when the one millimeter grooves were not readily discernible. The table also shows the actual number of each operator's observation.

RR 70 Transverse Width

The transverse scale shown in Figure 1 was digitized using the film analyzer to determine the width of roadway visible on the film.

Table 5 contains a summary of the data, with a correction for distortion, which were discussed in the previous sections on the Resolution Board and Transverse Distortion.

Table 4. Percentage When Observation of 1mm Grooves are not Discernible

	Left Edge Target Board		Lane Center Target Board	
	Long.	Trans.	Long.	Trans.
Unit #1	92%	8%	0%	0%
Unit #2	70%	33%	13%	25%

Total Number of Observations = 57

Number of Observations when 1mm Grooves not Discernible.

		Left Edge Target Board		Lane Center Target Board	
	Operator	Long.	Trans.	Long.	Trans.
Unit #1	1	8	-	-	-
	2	7	2	-	-
	3	4	-	-	-
Unit #2	1	10	-	-	-
	2	10	7	3	5
	3	5	-	-	1

The driver of the Roadrecon Unit determines the lateral placement of the actual lane width recorded within the viewable 16.2 feet, on the film. Lane widths will normally be 12 feet so if the driver accurately centers the Unit in the lane there will be 2 feet visible outside each lane edge. Monitoring of the drivers performance in positioning the Unit in the lane is a part of the quality control. It is anticipated that normal driver performance can be maintained at ± one foot.

RR-75 Rut Depth Block Evaluation

A series of rut depth photos were taken using the RR-75 system on both ROADRECON Survey Units and the calibration blocks. The set up was similar to the calibration procedure. The photos were digitized with the film analyzer and plotted using the computer program for the respective unit.

At the same time the pictures were taken of the test blocks, a set of measurements were taken using a square and a fixed string line. Several persons made the same measurements to avoid operator error.

The string line measurements were then run through a computation to produce a rut depth measurement similar to the SHRP definition and comparable to the digitized computer processed output from the film analyzer. The set up for these tests is shown in Figure 2.

Table 5. RR 70 Transverse Width

Digitized Y-Cord	ft. (1'=80.4)	Unit #1 ft. after Correction	Cumm. Width	Unit #2 ft. after Correction	Cumm. Width
664	0.2985	0.3107	7.99	0.3252	8.12
640	0.9950	1.0358	7.68	1.0839	7.80
560	0.9950	0.9084	6.64	0.9438	6.71
480	0.9950	0.9651	5.74	0.9711	5.77
400	0.9950	0.9680	4.77	0.9796	4.80
320	0.9950	0.9555	3.80	0.9681	3.82
240	0.9950	0.9509	2.85	0.9537	2.85
160	0.9950	0.9454	1.90	0.9522	1.90
80	0.9950	0.9502	0.95	0.9439	0.94
0					
-80	0.9950	0.9505	0.95	0.9448	0.94
-160	0.9950	0.9608	1.91	0.9556	1.90
-240	0.9950	0.9783	2.89	0.9691	2.87
-320	0.9950	0.9923	3.88	0.9821	3.85
-400	0.9950	1.0063	4.89	0.9859	4.84
-480	0.9950	1.0095	5.90	0.9793	5.82
-662	2.2640	2.2969	8.19	2.2640	8.08
			16.18		16.20

RR 75 Rut Depth Longitudinal Photo Location

The location of Rut Depth Photos in relation to the 100 ft. marks of a typical SHRP section were determined using the target boards shown in Figure 1. The target boards were placed at the right hand edge of a lane with the zero marks at the location where the 100 ft marks would be located.

The proposed procedures for the SHRP section surveys were used to film rut depth photos at 50 foot intervals during each of the runs. A light table and scale were used to analyze the processed film to determine the hairline locations in reference to the zero board mark.

The measured distances were used to calculate the average deviation at the start and at the end of each section. The difference in the deviation from the first mark and the 500 foot mark were also compared to evaluate the drift in the distance from the first to the last. Ranges were also determined.

Table 6 contains a summary of the data. A complete set of data is included in Appendix D.

Table 6. Rut Depth Photo Locations in Relation to 100 ft. Marks.

Operator	Unit #1 A	Unit #1 B	Unit #2 A	Unit #2 B	30 MPH Overall
Ave. Start	+3.5	+3.1	-7.0	+0.35	
Hi/Lo	0 - +5.5	0 - +7	-11 - -6	-4.75 - +8	-11 - +8
Range	(5.5)	(7)	(5)	(12.75)	(19)
Ave. End	+1.8	+2.9	-4.7	+0.85	
Hi/Lo	0 - +6.75	+1 - +7.5	-7 - -1.5	0 - +2.25	-7 - +7.5
Range	(6.5)	(6.5)	(5.5)	(2.25)	(14.5)
Ave. Drift	+0.4	-0.2	+5.7	+0.5	
Hi/Lo	-1 - +5	-2.5 - +1	+3 - +4.5	-7 - +5.25	-7 - +5.25
Range	(6.5)	(3.5)	(1.5)	(12.25)	(12.25)

RR-75 Static Block Comparison

A series of tests were run as a final check of the RR-75 system. The calibration blocks were arranged on a concrete floor behind each of the ROADRECON Units. The blocks were positioned so that the hairline would pass through the center of the marks on the top of the block. This location was an aid in digitizing. The pattern of the blocks was varied through a complete set of positions which represented both inside lane edges; the center of the lane and outside both edges which would be equivalent to a location on a shoulder.

Measurements were taken of all block arrangements using a stringline reference. A set of measurements had seven readings from the setup shown in Figure 2. Eighteen sets of measurements and rut depth photos were made with each unit.

Table 7 contains a comparison of three rut depth values. The theoretical rut depth value is calculated and assumes the floor is dead level. These blocks are accurate in thickness and position. The measured rut depth value is calculated from the string line measurements. The plotted value is taken from computer plots using the data digitized from the RR-75 photos.

Only selected data is included in the table to demonstrate the agreement of RR-75 computer plots with a wide range of measured data. Computer plots are shown in Figure 1 through 19, Appendix E, for the data as shown in Table 7.

Table 7. Comparison of Theoretical and Stringline (Measured) Rut Depths Using RR-75 Computer Plots. (mm)

Set Up	Theoretical Values	Unit #1 Measured Values	Unit #1 Plotted Values	Unit #2 Measured Values	Unit #2 Plotted Values
Left Wheel Path					
B-1	-25.4	-26.7	-27	-26.6	-27
B-2	-11.5	-12.3	-12	-11.4	-12
B-3	-63.5	-63.1	-64	-61.8	-61
B-4	-28.9	-29.0	-29	-28.0	-28
B-5	-101.6	-102.1	-103	-100.3	-98
B-6	-46.2	-46.6	N.D.	-45.2	-46
C-4	-42.7	-43.3	-44	-43.1	-41
C-5	-60.0	-60.9	-61	-60.7	-59
C-6	-80.0	-80.8	-81	-80.0	-78
Right Wheel Path					
B-1	-11.5	-12.7	-13	-11.6	-12
B-2	-25.4	-26.9	-27	-26.3	-26
B-3	-28.9	-29.2	-30	-28.2	-29
B-4	-63.5	-63.5	-64	-62.8	-64
B-5	-46.2	-46.9	-48	-45.4	-46
B-6	-101.6	-101.9	N.D.	-100.9	-102
C-4	-42.7	-43.4	-44	-43.3	-45
C-5	-60.0	-61.1	-62	-66.6	-61
C-6	-80.7	-80.7	-82	-80.5	-82

RR 75 Field Site Comparison

Tables 8 and 9 contain the data comparing rut depth measurements made in the field with values obtained by digitizing the RR-75 Photos using the final calibrated computer programs.

The field measurements were obtained using a transverse taunt wire between two fixed support points and measuring to the pavement with a square perpendicular to the wire at one foot intervals. The measurements were repeated three times and averaged. The average measurements were then normalized to zero at the lane edge positions and the maximum rut depth determined.

The methods used for field measurement introduced several sources of error into the final results. There was an error introduced in averaging the three sets of measurements which had variations ranging up to three-sixteenths of an inch. There was also a source of error in using a one foot interval, since the deepest rut depth point could occur between measurements. The digitizing process would not have this type of error.

While the differences shown in Table 8 are about two mm they are acceptable when the accuracy of the field measurements is considered.

Another measure of performance is included by comparing the plot outputs for the two units. Table 9 contains the average rut depth data for each of the units and shows an average difference of less than one millimeter.

Appendix F contains the detailed information for Tables 8 and 9.

Table 8. Comparison of Field Measured Rut Depth with Digitized Values from RR-75.

	Shoulder Side			Center Side		
Field Site	(1)RR-75 Values	(2)Field Measure	Diff. (1)-(2)	(1)RR-75 Values	(2)Field Measure	Diff. (1)-(2)
Unit #1						
1	20.0	19	1.0	4.3	3	1.3
2	26.7	24	2.7	3.0	3	0.0
3	23.0	21	2.0	7.3	7	0.3
4	34.0	33	1.0	0.0	0	0.0
5	29.3	28	1.3	3.6	3	0.6
	Ave. Diff. = 1.6			Ave. Diff. = 0.44		
Unit #2						
1	21.0	19	2.0	3.3	3	0.3
2	27.3	24	3.3	3.3	3	0.3
3	24.3	21	3.3	8.0	7	1.0
4	35.0	33	2.0	0.0	0	0.0
5	29.3	28	1.3	3.6	3	0.6
	Ave. Diff. = 2.38			Ave. Diff. = 0.44		

Table 9. Comparison of Unit #1 and Unit #2 Digitized Values.

	Shoulder Side			Center Side		
Field Site	Unit #1 (1)	Unit #2 (2)	Diff. (1)-(2)	Unit #1 (1)	Unit #2 (2)	Diff. (1)-(2)
1	20.0	21.0	-1.0	4.3	3.3	1.0
2	26.7	27.3	-0.6	3.0	3.3	-0.3
3	23.0	24.3	-1.3	7.3	8.0	-0.7
4	34.0	35.0	-1.0	0.0	0.0	0.0
5	29.3	29.3	0.0	3.6	3.6	0.0
		Ave. Diff. =	-0.78		Ave. Diff. =	0.0

RR-70 and RR-75 Rut Depth Photo Location Indicators

When a survey run is started with a ROADRECON Unit, both the RR-70 and RR-75 systems are activated and filming begins. Rut Depth photos are taken at 50 foot intervals throughout the survey run with the RR-75 system. It is desirable to locate the rut depth photos as close as possible to the hundred foot marks which designate SHRP sections. In order to get close to the marks, the operator resets the RR-75 system when the vehicle reaches a predetermined position in its approach to the first (0) mark of the survey section.

The reflexes and judgement of the operator determines to a large extent where the first rut depth photo will occur after the reset. There is also an influence within the sequencing of the automatic computer controlled program which takes the rut depth photos at the desired 50 foot interval. The influence from the computer program occurs at the first reset photo, since adequate time for the program to sequence the Rut Depth photo signal must be available. If not the photo will be delayed until the sequencing has been complete and then the following photos will be taken at the proper intervals.

The series of test runs established the distances involved in locating the rut depth photos at the first and subsequent SHRP survey marks. These results were discussed in a preceding section. The location of the rut depth photo in relation to the section marks will not always be apparent in the RR-75 photo since the photo shows about two feet of pavement on both sides of the hairline image, and the offset is greater than two feet at times.

A set of data was developed using a mark(8) automatically placed on the RR-70 film when the RR-75 shot sequence begins. The distance from this mark to the hundred foot points (0) on the target boards was determined for each run and each 100 foot interval. The distance of the rut depth photo for the same location from the hundred foot points was also determined. The algebraic difference between these distances gives the distance on the survey section between the RR-70 mark and the rut depth photo. This distance is then used to establish the rut depth photo offset.

Table 10 shows a summary of the data. It can be seen that there is little operator influence and that a correction can be used for each unit to locate the rut depth photo location within ± 4 feet.

Table 10. Location of RR-75 Rut Depth Photo Related to the RR-70 Automatic Film Marks (ft)

	Unit #1			Unit #2		
Operator	A	B	Ave.	A	B	Ave.
Ave. Dist.(ft)	13.9	14.4	14.2	13.0	13.0	13.0
Range (ft)	-1.5 - +2.5	-2 - +4	---	-1 - +4	-1.5 - +2.5	---

SUMMARY

The results from the various tests are briefly summarized in the following statements.

* RR-70 Longitudinal Distortion - The present performance of the units has been standardized to a SHRP survey speed of 30 mph. Filmed distances are within ± 1%. Film lengths are monitored as a quality control item.

* RR-70 Transverse Width and Lane Placement - There is a standard pavement width of 16.2 feet recorded on the RR 70 film. The survey will normally involve 12 foot lanes giving a ± 2 foot tolerance on each edge. It is expected that drivers operate the Units within ± one foot deviation through the test section.

  Lane placement during survey operations are monitored to achieve these limits and a Quality Control tolerance is used to monitor operations.

* RR-70 Resolution - Resolution boards were used in test runs

and were subjectively evaluated. The resolution board placed in the center of the lane was nearly always discernible at the one millimeter level both transversely and longitudinally. The one millimeter grooves were discernible at the edge only 10 to 30% of the times using combined data of three examiners. There was a large evaluator effect. The resolution boards are considered to be a good control method for judging the overall RR-70 system and are used in a periodic quality control check.

* RR-75 Rut Depth Start-Stop Photo Locations - Testing indicated that rut depth photographing can be controlled to within -11 feet to +8 feet. The variation for an individual section between the beginning and end (referred to in the report as drift) is within -7 to +5.25 ft. The ranges represent the very outer limits of all operators. The rut depth photo location is monitored in survey operations to stay within these limits.

* RR-75 Static Block Tests - A series of rut depth photos were taken of calibration blocks arranged in several combinations. The output of digitizing the photos using the final rut depth programs for each vehicle was compared with measured values of the blocks to establish the digitized rut depths. A theoretical rut depth value was also calculated. Both units showed agreement with the values within one millimeter.

* RR-75 Field Sites - Photos were taken at five rutted pavement sites on in service pavements. The digitizing output from the photos was compared with field measurements. The data agreed to within 2 mm. Inspection of the field data indicated that the actual measurements were accurate to less than ± 3mm.

* RR-70 and RR-75 Rut Depth Photo Location - The RR 70 system was designed to record a mark (8) on the film edge when the RR-75 photo sequence is started. This mark was evaluated for use in locating the actual rut depth location in relation to the 100 foot marks. Using this approach the location of the rut depth photos can be identified within plus or minus 4 feet.

III. PART II.

Field Survey Operations.

Once the ROADRECON Survey Units were built, calibrated, and approved for use by the SHRP, PASCO USA and AVIAR, a subcontractor, obtained a list of the sites to be surveyed and data sheets describing the location of each site from SHRP's Technical Assistance Contractor (TAC), the Texas Research and Development Foundation (TRDF). Survey schedules were then developed for each of the survey units. These schedules also incorporated any priority sites. The schedules were developed for approximately one month of survey operations, and were developed to survey the sites in the most efficient manner possible, while minimizing non-productive travel time between sites. The schedules included such information as, anticipated survey date, section ID number, site location, section type, state, and remarks. The actual survey dates were shown in the remarks column after the site had been surveyed.

Although the survey schedules were prepared several weeks in advance weather conditions and equipment maintenance frequently required adjustments. Allowances for weather and maintenance were made in the schedules for the long run, but short term adjustments, both earlier and later, were required.

Each week an updated survey schedule for each vehicle was faxed to each Region and SHRP headquarters. These schedule updates would show where each unit was currently located, what sites were planned for survey, and what sites had been surveyed. Also, the anticipated survey date was periodically adjusted to show whether the unit was ahead or behind schedule. These schedules were added to and replaced as the sites were surveyed, or schedule changes made due to the weather, or changes in survey priority.

Beginning in March, 1989, PASCO USA, and AVIAR, began production survey operations with both ROADRECON Survey Units. ROADRECON Unit No. 1 was operated by PASCO USA in the eastern half of the USA and Canada, and AVIAR operated ROADRECON Unit No. 2 in the western half of the continent.

Both of the ROADRECON Survey Units were equipped with both the RoadRecon-70 and RoadRecon-75 systems to obtain high resolution, visual, surface distress and transverse profile records, respectively. These survey units operated only at night to allow the highest quality images possible to be obtained, minimize disruption to the traveling public, and increase safety.

Survey Operations

Before beginning survey operations, and after approximately 20 sites were surveyed, the crews would perform quality control tests which consisted of filming the Resolution Board and Calibration Blocks. These tests were used to verify the degree of resolution and accuracy of the RoadRecon-70 and RoadRecon-75 systems, respectively. Detailed descriptions of these procedures are contained in the section on Quality Control Procedures.

Each night, before commencing survey operations, the survey teams would perform nightly equipment and quality control checks. These checks included pre-survey checks, safety checks, illumination checks, and hairline alignment checks. To ensure that nothing had changed since the previous night. These checks are also described in the section on Quality Control Procedures.

Each night the team would keep a record of their activities. This daily record, or report, included weather conditions, a description of each activity, starting time and ending time for each activity, beginning and ending mileage for each activity, sections surveyed, problems encountered and their resolution, and any unusual circumstances encountered. At the end of each night's survey operations this report was faxed to PASCO USA's office.

At the end of each week the crew would send their daily trucker's logs, safety checklists, pre-survey checklists, illumination checks, and any permits which were purchased to PASCO USA's office.

When surveying, the survey teams would start filming prior to the 500 foot lead-in mark and continue surveying until past the runout mark. The survey systems were reset at the 0 foot mark of the test section. By resetting the survey systems at the 0 foot mark and setting the RR-75 interval at 50 feet, transverse profile records were obtained throughout the test section at 50 ft. intervals. Before reaching the 500 foot lead-in mark, the team positioned the survey unit such that the entire test lane would be contained in the image collected.

After surveying approximately 25 sites, and filming calibration blocks and resolution board, the exposed films were shipped by overnight delivery to PASCO USA's offices for developing and processing.

Field Operations Quality Control Procedures.

During field operations the survey crews maintained PASCO USA's high standards of excellence by performing rigorous quality control testing procedures at regular intervals. These quality control procedures were developed through experience and objective measurement of the performance characteristics of each survey vehicle. These quality control checks and records are used to determine when system adjustments, or corrections, are needed to maintain our high quality standards. Any quality control checks involving film images are performed on the negative film. The quality control checks that will be used to control survey quality are described below.

Nightly Checks

Before beginning survey operations each night, the ROADRECON unit's survey crew performed the following quality control procedures:

Safety Check Pre-Survey Check
Illumination Check

The **Safety Check** was a checklist used, while conducting a "Circle-of-Safety", to insure that the ROADRECON unit was in safe operating condition and ready to proceed with the survey.

The **Pre-Survey Check** was a detailed checklist used during survey system set-up to insure that all survey systems were prepared for survey.

The **Illumination Check** was used nightly to insure that the front illumination system, used in conjunction with the RR-70 system, was in proper adjustment.

The front illumination system consists of twelve (12) halogen lamp fixtures mounted in, and on, a custom made front bumper. These lamps provide the required illumination for the RR-70 system's slit camera. Uniformly distributed and positioned lighting is required for the proper 35mm film exposure and resolution to be obtained during survey operations. Therefore, all of the lights must be properly aimed to provide a uniform level of lighting across the full focal band of the slit camera.

The **Illumination Check** was performed after dark prior to the conduct of survey operations. This check was performed in a parking lot away from any direct sources of light. The front illumination system was turned on, and the pavement marked with chalk using a tape measure to locate the proper positions. The lamp position and aiming was checked using a Minolta T-1H Illuminance Meter. The Illuminance Meter was positioned on the pavement at each of the check points, and the readings recorded, and plotted, on the Illuminance Check Sheet.

If the readings were not within the limits shown on the chart, then the team adjusted and repositioned the lamps involved until the required illumination was provided.

The completed Illuminance Check Sheets were sent to headquarters with the Safety and Pre-Survey Checks, each week.

Periodic Checks

After surveying approximately 20 sites the Resolution Board and Calibration Blocks were filmed to insure that the RR-70 and RR-75 survey systems were properly adjusted, and providing the required resolution and accuracy. The survey schedules would show the approximate section to be used for these tests, however the field crew could alter that section based upon the designated nights production.

The **Calibration Blocks** are used with the RR-75, Transverse Profile, system to insure that the hairline placement within the frame is correct and that the alignment of the camera and strobe projector are correct.

In the field, **Calibration Blocks** were used to check the location of the hairline. The blocks are pre-marked with lines positioned for the proper angle of the projected hairline. Figure 3 shows the Calibration Blocks.

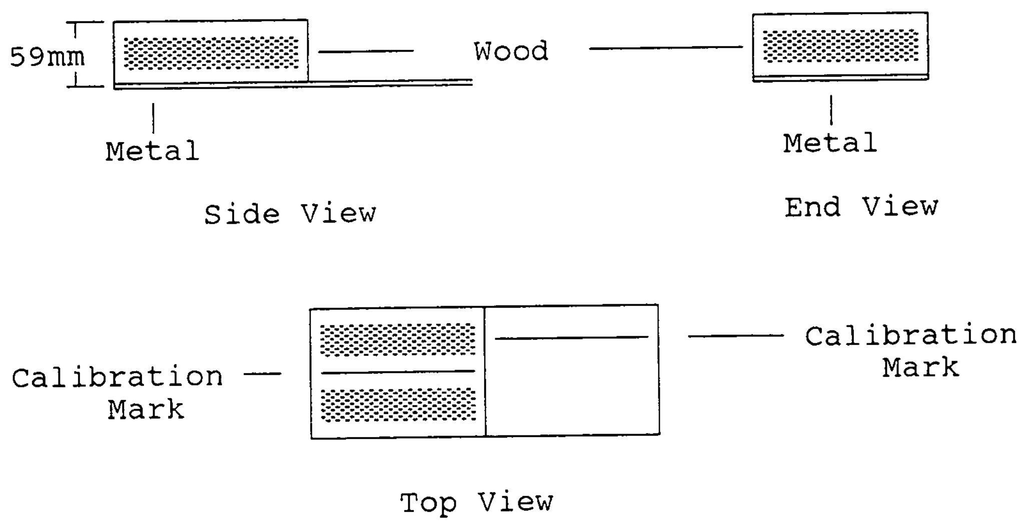

Figure 3. Calibration Block

Pre-survey checks were made by stopping the unit in a level parking area and manually activating the strobe projector. The Calibration Blocks were positioned along the hairline at each lane edge and the center of the lane. The hairline was checked for alignment with the markings on the blocks. The hairline strobe projector was adjusted, as necessary.

The complete RR-75 system was activated to photograph several frames of the Calibration Blocks at each location. The locations are shown in Figure 4. At the end of the nights survey operations this film was shipped to headquarters for processing and analysis.

After the RR-75 film was developed, the frames with the calibration blocks were digitized and compared to known values, for each unit. Adjustments were made to the system as necessary to maintain an accuracy of plus or minus 2mm (± 2mm).

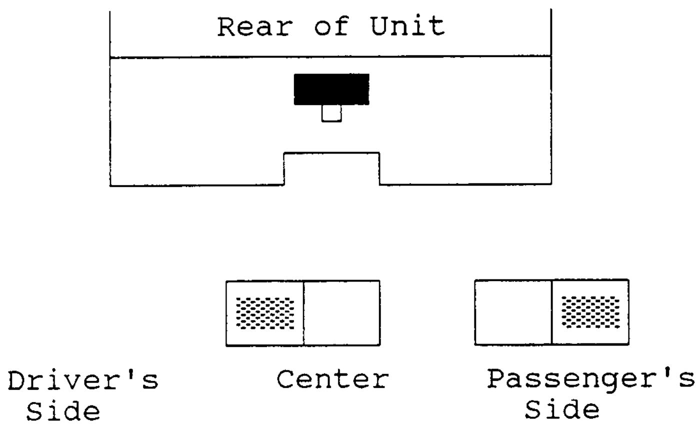

Figure 4.A. Calibration Block Location 'A'

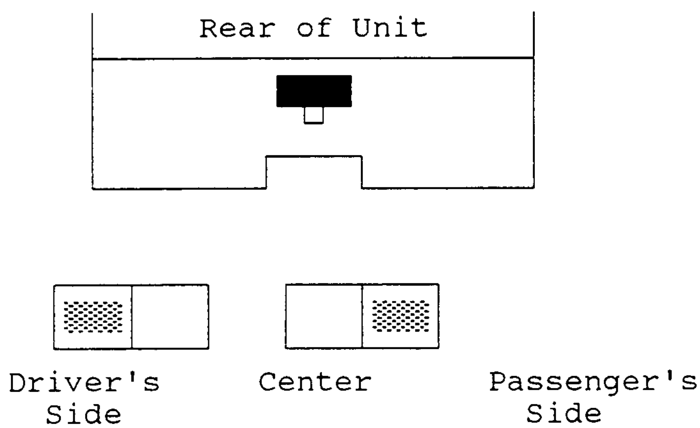

Figure 4.B. Calibration Block Location 'B'

Figure 4. Calibration Block Locations.

Resolution Boards are used to verify that the images on the negative films are of a consistent quality and resolution. The resolution board is a square board that has a standard gray finish (Tru-test XO-15 Machinery Gray) and contains a series of grooves ranging from 1 to 5mm in width. These grooves are accurately cut to size using a laser.

The field crew would place the resolution board within the 500 foot test section, selected to be used, after filming the section, and then film the board. The board was placed fifty (50) feet, longitudinally, from the beginning of the test section and near the outside lane edge. The films containing the resolution board were be shipped to headquarters for processing at the end of that nights survey operations.

After processing the film at headquarters, a visual inspection by the film technician using a lupe was made to determine the ability to discern the 1mm grooves, both longitudinally and transversely. This provided a check for proper focus and resolution.

Based upon the evaluation by the film technician, the following criteria were applied:

(1) If the two (2) mm grooves were not visible on a test section, the field crew was instructed to verify all settings being used.

(2) If the two (2) mm. grooves were not visible in two consecutive test sections, from the same unit, then the crew was instructed to perform a recheck, prior to additional survey operations. If the two (2) mm grooves were not visible on the recheck film, then the survey operations were suspended and the problem identified and corrected.

(3) If the three (3) mm grooves were not visible, the field crew was instructed to suspend survey operations until the problem was identified and corrected.

Sections surveyed since the last acceptable resolution board were resurveyed.

Office Operation Procedures.

Once the exposed films arrived at PASCO USA's offices, they were developed, subjected to quality control testing, edited, labeled, and spliced. Quality Assurance testing was performed and positive copies of the films made.

An automatic film developer was used to develop the exposed 35mm films after they were received in the office. The developer can process up to 2,000 feet of film in one loading of its magazine, and can develop approximately 300 feet of film in one hour. It is also equipped with automated flow regulators for developer, fixer, and water.

Once the film was developed, it was processed through a **Film Processing Work Station** where it was checked for quality and edited. This work station consists of a 48 inch light table, film winders, and a lupe.

At these work stations, the RR-70 film for each section was reviewed to ensure that the longitudinal distortion, lateral lane placement, and exposure were within the quality control standards. The RR-75 film was checked to assure that the hairline placement was within quality control standards, and that there were no skipped frames. The sections actually surveyed were checked against the survey schedule and the team's daily reports to ensure that all sections had been filmed, or to understand the reason why they were not filmed. All of these quality checks were performed on the negative film.

Longitudinal Distortion occurs when the length of film corresponding to a specific length of pavement is longer, or shorter, than the theoretical length of the film using a 1:200 scale. This was checked by measuring the length of the film between the beginning and the end of each 500 foot test section.

The length check was performed at headquarters after the film was processed. The deviation of length for each section was plotted on a control chart to monitor the history and note trends in the daily progress of the survey system's longitudinal accuracy.

Based upon the length measured by the film technician, the following criteria was used:

(1) If the length of the test section exceeded plus or minus one percent (± 1%) of the theoretical length, the crew was instructed to adjust the distance meter.

(2) If a section exceeded the theoretical length by plus or minus three percent (± 3%), the crew was instructed to

adjust the distance meter and the sections outside the 3% tolerance were resurveyed.

Lateral Lane Placement was monitored to determine if the survey vehicle was "wandering" across the lane when surveying the test section.

In this check the vehicle's path was noted using the right hand lane edge or, if no lane edge was visible, the painted lane mark. If the variation in lateral placement throughout the lane exceeded one (1) foot, the crew was instructed to increase the attention being given by the driver to holding position in the lane. If the variation in lateral placement throughout the lane exceeded two (2) feet, the crew was instructed to increase the attention being given by the driver to holding position in the lane, and the section was resurveyed.

Exposure is a measure of how light, or dark, the negative film image is in relation to standard film quality. The exposure was established with an experimentally determined levels of desired exposure and two degrees of both over and under exposure which were set so that on any films, in the acceptable range, the 1mm groove on the resolution board would still be visible. Any films within plus or minus two levels of film quality from our standard were acceptable. Sections with films outside these levels of quality were resurveyed.

Hairline Placement was used to verify that the RR-75 system was taking photographs at the appropriate intervals along the pavement. On this project the target location of the hairline image was passing through of the "+" marks in the section. The hairline placement was checked at the 0 mark and each hundred foot mark throughout the test section. The longitudinal distance from each of the "+" marks to the hairline image was called the offset. This distance was reported as a positive or negative offset, as shown in Figure 5. The allowable range of hairline offsets, for GPS sites, are +11 ft. to -8 ft. This criteria was also applied to SPS sites whenever possible. However, sometimes, due to the SPS site layout, it was not possible to obtain this accuracy because of short, variable spacings between test sections.

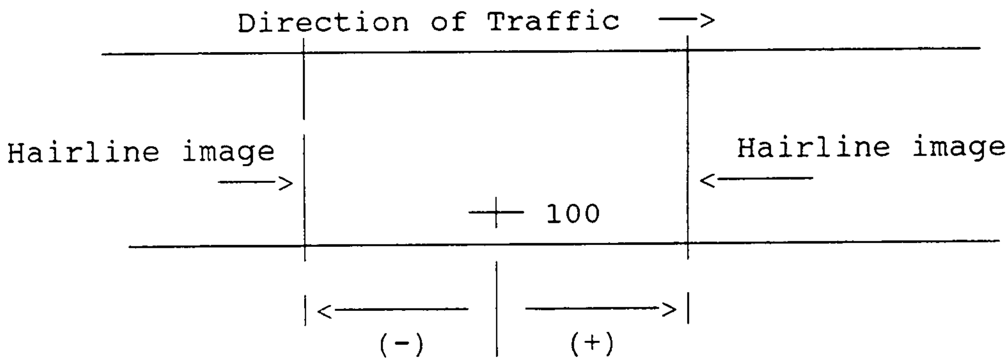

Figure 5. Offset Sign Convention.

The RR-75 film for each section was reviewed to determine if the section "+" marks were visible in the frames of the RR-75 film. If they were visible, then the offsets could be directly measured to the nearest foot. When the "+" marks were visible on the RR-75 film, then the offsets were in the range of +4 ft. to -2 ft. If the "+" marks were not visible, then it was necessary to use the RR-70 film to determine the cross-profile location. The RR-70 system was designed to place a mark (8) on the film edge when the RR-75 photo sequence was started. This mark was used to determine the location of the hairline.

When it is necessary to use the alternative method of offset determination, the "8" marks are used to determine the location of the hairline in relation to the "+" marks. The distance from the "+" mark to this hairline location is then measured to determine the hairline offset.

If, due to equipment problems, neither the "+" marks on the RR-75 film, nor the "8" marks on the RR-70 were available, then the hairline location was determined by matching surface characteristics between the RR-75 and RR-70 films.

Skipped Frames occasionally occur with our RR-75 film system. A skipped frame occurs when the RR-75 system does not take a picture at the required interval. Skipped frames can occur due to initial electrical charge in the projector or in a software missed signal check.

When checking for skipped frames the film technician would check the sequence of the RR-75 frames to ensure that there was a frame containing a hairline image at the appropriate interval.

If one skipped frame occurred within a 500 ft. test section, then the affected section was resurveyed. If for some reason it was impossible to resurvey the section, then the RR-75 film with one skipped frame was accepted. For SPS sites, sections with up to two skipped frames were accepted.

Test Sites Surveyed, were checked by the film technician to verify that the scheduled test sections were surveyed by the team. This was done by comparing the films with the survey schedule, the daily reports, and the SPS site layouts. Any missing or incomplete sections were resurveyed.

For each GPS section, the surface distress film was edited such that the entire 500 foot lead-in, 500 foot test section, and 250 ft runout were contained on the film. This usually meant that the film was edited 32 inches before the 0 ft. mark and 17 inches beyond the 500 ft. mark, as shown in Figure 6. The cross-profile films were edited such that the film contains the cross-profile images for the 500 ft. lead-in, 500 ft. test section, and the 250 ft. runout. This meant that the film would usually be edited nine inches before the first profile in the section and four inches after the last profile in the section, as shown in Figure 7. Also, the counter for each profile contained in the section was circled to show which profiles were to be digitized.

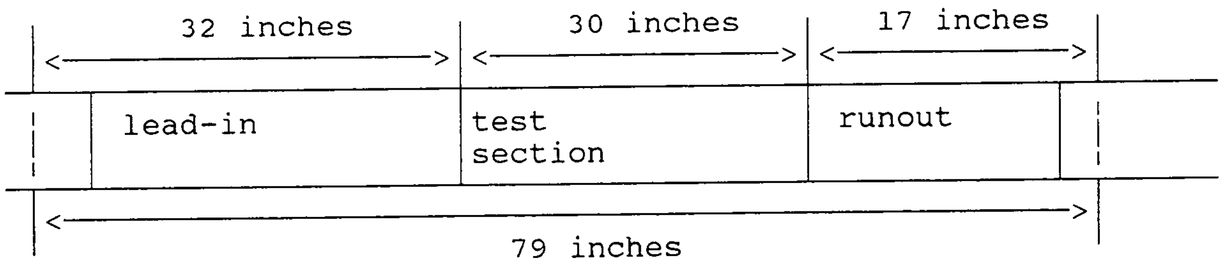

Figure 6. Typical GPS Section Editing, Distress Film.

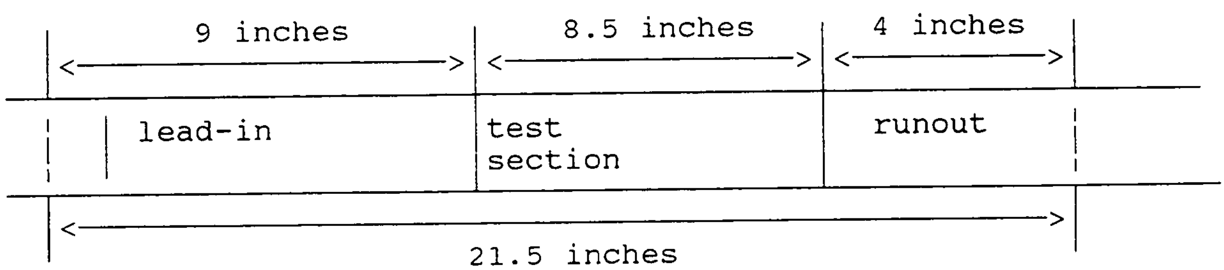

Figure 7. Typical GPS Section Editing, Cross-Profile Film.

Each SPS section was edited to include the entire test section, and as much of the lead-in and runout as possible. When possible, the SPS sections were edited in the same manner as the GPS sections. However, many of the SPS sites have less than 750 feet between their test sections. When this would happen the test sections were edited midway between the sections, as shown in Figure 8.

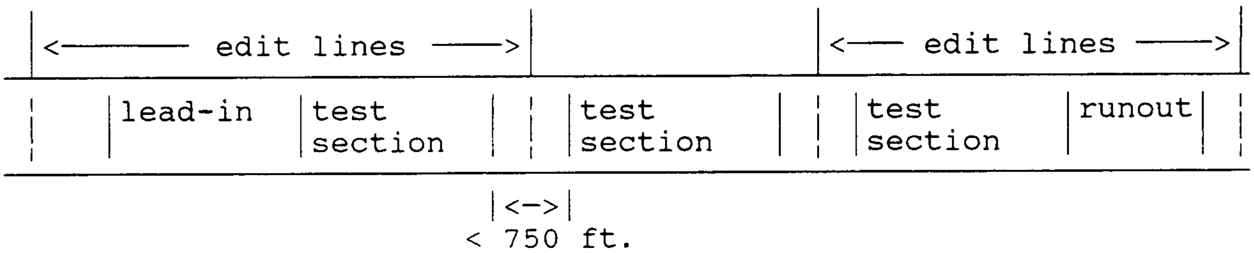

Figure 8. Typical SPS Section Editing, Short Spacing.

All test sections had a film label attached to a one foot piece of clear film leader which was affixed to the beginning of the strip of film for the particular test section, as shown in Figure 9.

Figure 9. Typical Test Section Label Placement.

Each label contained the state name, section ID number, route number and direction, survey date, and surveying unit number. Figure 10 is an example of a typical test section label.

```
State Name:  New Jersey
Section ID  :  341011
Route & Dir.:  I-195  EB
Survey Date :  April 5, 1992
   PASCO USA, Inc.  Unit #1
```

Figure 10. Typical Test Section Label.

In addition to a section label, each SPS site had a site label affixed to the clear leader in front of the first section label for that site, as shown in Figure 11. The site label contained the SPS site number, number of test sections, and survey date, as shown in Figure 12.

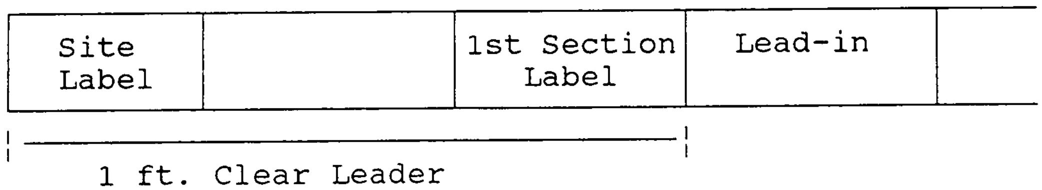

Figure 11. Typical Site and 1st Section Label Placement, SPS

```
State Name     :  New York
Section ID     :  36A3**
# of Sections  :   5
Record Date    :  08/21/91
```

Figure 12. Typical SPS Site Label.

Once all the sites in a state or province had been surveyed, and the films had passed quality control standards and been edited and labeled, the individual sites were spliced into rolls of RR-70 GPS, RR-75 GPS, RR-70 SPS, and RR-75 SPS. These rolls contained no more than 400 feet of film each. When a state or province had enough sites to require a larger roll, then the roll was split into multiple rolls. Each roll of film had three feet of clear leader affixed to the beginning and end of the roll. At the beginning of the roll a roll label was affixed to the clear leader. This label contained the state name, GPS or SPS sites, number of sections surveyed, and the range of survey dates. A sample Roll Label is shown in Figure 13.

```
State Name     :   New Jersey
        GPS  SITES
# of Sections  :   10
Survey Dates   : 08/13/91 to 04/06/92
         PASCO  USA,  Inc.
```

Figure 13. Typical Roll Label.

After splicing, the edited films were reviewed once more for proper editing, labeling, and sorting by exposure. After that positive copies were made of the films.

The positive copies were reviewed for quality to ensure that they were in focus and of appropriate exposure for the distress to be viewed and analyzed. In addition they were rechecked for proper editing and lane placement.

When the positive films had been accepted by our Quality Assurance staff, they, and the negative films, were prepared for shipment to the SHRP Regional Offices, TAC, and SHRP Headquarters. The films were prepared for shipment by placing the rolls of film for each state, or province, into film cans and storage boxes. A list of the sections contained on the roll, and the dates each site was surveyed, was placed inside the film can and on the back of the film box. A sample section list is shown in Figure 14. On the lid of the film can, and the front of the film box, a label was placed to identify the film contained in the can. In addition, another label was placed on the end of the film box so that they may be stored on shelves like books. These labels are shown in Figure 15.

GPS 3rd Round Survey

STATE : 09 - Connecticut UNIT # 2

SECT. ID	ROUTE	DATE	SECT. ID	ROUTE	DATE
091803	ST-117 N	08/22/91			
094008	I-84 W	08/21/91			
094020	ST-2 W	08/22/91			
095001	I-84 S	08/21/91			

Figure 14. Sample Section List.

Box End Label	Can Lid and Box Front Label
09 Connecticut GPS 3rd Round RR-70 & RR-75 Positive Film	PASCO USA, Inc. 09 Connecticut GPS 3rd Round RR-70 & RR-75 Positive Films

Figure 15. Sample Box and Can Labels.

Once the films were prepared for shipment they were stored at our office until the transverse profile data was ready for shipment.

Transverse Profile Digitizing and Analysis.

Once the RR-75 films passed our film quality standards and were edited, they were passed to the RR-75 work station for digitizing. This work station combines a Film Motion Analyzer (FMA), a personnel computer, and custom software to analyze the films obtained from our RR-75 survey system.

At the RR-75 work station, the transverse profile film was processed through the FMA which back projected it onto a digitizing tablet. The operator would then enter the section ID information and digitize each hairline image contained in each test section. The computer would then analyze that data to develop a transverse profile and calculate rut depth.

The Digitizing Operators were prequalified by having the operator digitize a set of sections and compare their results with those of an experienced operator. Operators would periodically redigitize their previously digitized sections to determine if any deviations in performance had occurred.

The prequalified operator would then follow prescribed steps to produce a GPS or SPS test section rut depth record.

Prior to actually digitizing the hairline images for each test section, the operator would adjust the focus for maximum clarity and calibrate the system to determine the appropriate magnification factor for that section. The operator would then enter the section identification information. This information included section ID number, route designation and direction, survey date, surveying unit, lane width, offset, digitizing date, and digitizing operator.

When digitizing a hairline image the operator would begin by digitizing a point on the pavement's surface adjacent to the lane shoulder joint, if it was visible. If the lane shoulder joint was not visible, then a point just outside the outer edge of the painted edge line was used. After that up to 29 additional points were digitized across the pavement lane at approximate six inch intervals to cover the full lane width.

The computer would then analyzes these points to generate a transverse profile for the particular location. This continued throughout the test section at 50 ft. intervals. By assuming the first and last points digitized to be zero, the computer would simulate bending a wire over the high points of the transverse profile using these points as anchor points.

The location and magnitude of the maximum rutting at each location was determined by calculating the distance between the simulated wire and the computer generated transverse profile. The rut depth was determined by beginning at the outside of each half lane and determining the vertical distance between the digitized transverse profile and the wire at each point digitized. The maximum distance encountered in each half lane was the maximum rut depth for that half lane. The transverse location of that measurement was the location of the maximum rut. Rut depth magnitude and transverse location were recorded in millimeters.

During the digitizing process the operator was continually checking the profiles digitized using the following quality control procedures:

* The operator would review each digitized profile on the computer screen, and compares it with the film image.

  If the operator was satisfied with the profile he would go on to the next frame to be digitized.

  If not satisfied, the operator redigitizes the current frame.

* After digitizing and reviewing each of the individual

profiles for a section, the operator would reviews all the profiles for that section by overlaying them on the computer screen.

If all the profiles were reasonably close in shape, then they were accepted and the operator would move on to the next section.

If some of the profiles in the section were greatly different from the others, then these profiles were redigitized. If after redigitizing their shape had not changed, then they were accepted and the operator would move on to the next section.

While digitizing, the operator kept a log of all sections digitized. This log contained the section ID number, digitizing date, and notes of any problems, or unusual circumstances, encountered while digitizing the section. This log was organized by digitized order of the sections.

Once all the test sections in a state or province had been digitized, and accepted by the operator, they were subjected to the transverse profile quality assurance process, described below.

Upon passing the quality assurance reviews, an ASCII data file, Section Summary Report, and set of Transverse Profile Plots were generated for each test section.

The Section Summary Reports were tabular summaries of the rut depths, in mm, for each half lane at each location throughout the test section. In addition, they contained the maximum, minimum, and average rut depth for each half lane, and the standard deviation for each half lane. A sample of the Section Summary Report is shown in Figure 12.

The Transverse Profile Plots were graphical representations of the transverse profile at each location. These plots show the digitized transverse profile, the simulated wire, and the maximum rut depth for each half lane, at each location throughout the test section. A sample of a Transverse Profile Plot is shown in Figure 13.

The ASCII computer files that were generated were ready for uploading into the IMS database, and have the extension of *.RDD, *.RD2, or *.RD3. The file name was the section ID number.

Once these reports were generated, the films and reports were delivered to the SHRP Regional Offices, TAC, and SHRP Headquarters as follows:

Regions - 2 copies of Positive Films
1 copy of Section Summary Report, each section
1 copy of Transverse Profile Plots, each section.

TAC - 1 copy of Positive Film
1 copy of Section Summary Report, each section
1 copy of Transverse Profile Plots, each section.
1 copy of ASCII data files, each section.

SHRP HQ - 1 copy of Negative Film
1 copy of Positive Film

Transverse Profile Quality Assurance.

After all the sections in a state or province had been digitized, and accepted by the operator they were passed to the quality assurance staff, who reviewed the header and the maximum rut depth data for accuracy.

When the header files were reviewed, the QA reviewer would print out the header information for each test section and review the information for accuracy using the data sheets for each section, survey log, and the film QC logs. The items reviewed in the header include:

Section ID Number, Unit Number, Survey Date, Digitizing Date, Digitizing Operator, Number of Profiles, and the Offset of each profile.

If any of this information was incorrect, then it was corrected before moving on to the next section, and the operator's attention was called to the discrepancy and cautioned to be more careful.

After the header information was reviewed, the magnitude of the maximum rut depth of each wheel path was compared to the magnitude of the maximum rut depth of each wheel path from the previous year's survey. If the present year's rut depth for each wheel path of each profile had decreased by more than 3mm, or increased by more than 4mm, it was flagged for further review.

Once a Profile, or Section, had been flagged, the profiles for each year were compared by overlaying them on a computer screen to determine where the discrepancies, if any, were located.

If there were no significant discrepancies, then the present year's profile was accepted.

If significant discrepancies existed between the profiles, the profile for the present year was redigitized.

The redigitized profile was then compared to the previous year's profile and the original present year's profile to determine which profile it more closely matched.

If the redigitized profile more closely matched the previous year's profile than the original present year's profile, then the redigitized profile was accepted as the new present year's profile.

If the redigitized profile more closely matched the original present year's profile than the previous year's profile, then the original present year profile was accepted as the correct present year profile.

In addition, the redigitized and original present year's profiles were compared to ensure that the operator repeatability was within ± 2mm.

PADIAS System Development

In the fall of 1989, in response to a SHRP RFP, PASCO USA proposed to develop a **PA**vement **DI**stress **A**nalysis **S**ystem (PADIAS) to be used in obtaining surface distress data from PASCO USA's RR-70 films. This system combined a Film Motion Analyzer (FMA), a personal computer, and custom software to determine the surface distress on the pavement's surface.

The PADIAS work station used an FMA to back project the image from the RR-70 film onto a digitizing screen for the operator to view, and a personal computer for film control and data recording. The FMA projects an image of the roadway that represents a longitudinal distance of 12.45 ft. The operator would view this roadway image and use the PADIAS software to record the distress types and severities observed.

The PADIAS software was developed to record the distresses discernable from a direct overhead, two-dimensional view, in accordance with the SHRP Distress Identification Manual. This software recorded the distress types and severities observed by the operator using a grid system. Each grid was approximately 1 ft. square and could contain up to four different combinations of distress type and severity.

Using the PADIAS software, the operator would create a header file to identify the section being analyzed. After that the operator selected the header file to be used for distress analysis and entered the interpretation program. Using pop-up menus, and specific definitions, the operator would view each piece of pavement and determine which distress types and severities are present in each grid cell. From the menus the operator would select the distress type and severity present, then they digitize the location of that distress type and severity. The computer automatically records the location of each distress/severity combination in the section. The software also, calculates the extent of the distress for each severity level in each section.

After a section was digitized the data could be reported in Section Summary Reports or Distress Maps. The Section Summary Reports summarize the distress data recorded in each section by severity. The Distress Map plots out a grid showing the location of the distress present in each grid cell of each 12.45 ft. piece of pavement. The Distress Maps generate one page of map for each 12.45 ft. piece of pavement.

In April of 1990, PASCO USA delivered the PADIAS, Rev. 1.0, work station to SHRP's TAC for use in analysis of the RR-70 films.

The actual distress analysis operations were performed by the TAC. These operations are described in report "Procedures for Distress Interpretation From Film" by Rada, Robyak, and Miller.

In May of 1991, after complaints as to image clarity, PASCO USA modified SHRP's PADIAS work station to change it from a back projection system to a downward projection system.

APPENDIX A

LONGITUDINAL DISTORTION DATA

LINEAR DISTORTION - RR-70

		UNIT # 1		UNIT # 2		
		A	B	A	B	C
10mph	Acc.	+ 3.20%	+ 3.57%	+ 7.57%	+ 5.90%	------
	Prec.	± 0.58%	± 1.06%	± 0.86%	± 1.79%	------
20mph	Acc.	+ 1.11%	+ 1.23%	+ 2.14%	+ 2.01%	------
	Pres.	± 0.40%	± 0.47%	± 0.44%	± 0.18%	------
30mph	Acc.	+ 0.06%	+ 0.03%	+ 0.53%	+ 0.51%	------
	Pres.	± 0.40%	± 0.21%	± 0.24%	± 0.14%	------
40mph	Acc.	- 4.76%	- 3.42%	-------	-------	- 0.05%
	Pres.	± 3.33%	± 0.43%	-------	-------	± 0.15%
45mph	Acc.	- 4.73%	- 4.13%	-------	-------	- 0.33%
	Pres.	± 0.10%	± 0.14%	-------	-------	± 0.45%

Unit #1 OPA - 10 mph.

Run	Length		
1	30.88	Ave.	= 30.96"
2	31.00	STD	= ± 0.06
3	31.00	3STD	= ± 0.18

Accuracy=(30.96-30.00)/30.00 x 100 = 3.20%

Precision = (± 0.18/30.96) x 100 = ± 0.58%

Unit #1 OPB - 10 mph.

Run	Length		
1	31.13	Ave.	= 31.07"
2	30.92	STD	= ± 0.11
3	31.16	3STD	= ± 0.33

Accuracy=(31.07-30.00)/30.00 x 100 = 3.57%

Precision = (± 0.33/31.07) x 100 = ± 1.06%

Unit #1 OPA - 20 mph.

Run	Length
1	30.33
2	30.28
3	30.39

Ave. = 30.33"
STD = ± 0.04
3STD = ± 0.12

Accuracy=(30.33-30.00)/30.00 x 100 = 1.10%

Precision = (± 0.12/30.33) x 100 = ± 0.40%

Unit #1 OPB - 20 mph.

Run	Length
1	30.44
2	30.34
3	30.34

Ave. = 30.37"
STD = ± 0.0471
3STD = ± 0.1414

Accuracy=(30.37-30.00)/30.00 x 100 = 1.23%

Precision = (± 0.1414/30.37) x 100 = ± 0.47%

Unit #1 OPA - 30 mph.

Run	Length
1	30.06
2	29.95
3	30.03
4	30.05
5	30.00

Ave. = 30.018"
STD = ± 0.0397
3STD = ± 0.1191

Accuracy=(30.018-30.00)/30.00 x 100 = 0.06%

Precision = (± 0.1191/30.018) x 100 = ± 0.40%

Unit #1 OPB - 30 mph.

Run	Length
1	30.02
2	30.00
3	30.03
4	29.97
5	30.03
6	30.00

Ave. = 30.0083"
STD = ± 0.0211
3STD = ± 0.0633

Accuracy=(30.0083-30.00)/30.00 x 100 = 0.03%

Precision = (± 0.0633/30.0083) x 100 = ± 0.21%

Unit #1 OPA - 40 mph.

Run	Length		
1	28.99	Ave. =	28.57"
2	28.22	STD =	± 0.3175
3	28.51	3STD =	± 0.9526

Accuracy=(28.57-30.00)/30.00 x 100 = - 4.76%

Precision = (± 0.9526/28.57) x 100 = ± 3.33%

Unit #1 OPB - 40 mph.

Run	Length		
1	28.93	Ave. =	28.97"
2	29.03	STD =	± 0.0419
3	28.96	3STD =	± 0.1257

Accuracy=(28.97-30.00)/30.00 x 100 = - 3.42%

Precision = (± 0.1257/28.97) x 100 = ± 0.43%

Unit #1 OPA - 45 mph.

Run	Length		
1	28.60	Ave. =	28.58"
2	28.60	STD =	± 0.0282
3	28.54	3STD =	± 0.0849

Accuracy=(28.58-30.00)/30.00 x 100 = - 4.73%

Precision = (± 0.0849/28.58) x 100 = ± 0.10%

Unit #1 OPB - 45 mph.

Run	Length		
1	28.78	Ave. =	28.76"
2	29.75	STD =	± 0.0141
3	28.75	3STD =	± 0.0424

Accuracy=(28.76-30.00)/30.00 x 100 = - 4.13%

Precision = (± 0.0424/28.76) x 100 = ± 0.14%

Unit #2 OPA - 10 mph.

Run	Length		
1	32.30	Ave. =	32.2667"
2	32.36	STD =	± 0.0929
3	32.14	3STD =	± 0.2786

Accuracy=(32.2667-30.00)/30.00 x 100 = 7.57%

Precision = (± 0.2786/32.2667) x 100 = ± 0.86%

Unit #2 OPB - 10 mph.

Run	Length		
1	31.98	Ave. =	31.77"
2	31.81	STD =	± 0.1899
3	31.52	3STD =	± 0.5697

Accuracy=(31.77-30.00)/30.00 x 100 = 5.90%

Precision = (± 0.5697/31.77) x 100 = ± 1.79%

Unit #2 OPA - 20 mph.

Run	Length		
1	30.64	Ave. =	30.6433"
2	30.59	STD =	± 0.0450
3	30.70	3STD =	± 0.1349

Accuracy=(30.6433-30.00)/30.00 x 100 = 2.14%

Precision = (± 0.1349/30.6433) x 100 = ± 0.44%

Unit #2 OPB - 20 mph.

Run	Length		
1	30.63	Ave. =	30.6033"
2	30.59	STD =	± 0.0189
3	30.59	3STD =	± 0.0566

Accuracy=(30.0633-30.00)/30.00 x 100 = 2.01%

Precision = (± 0.0566/30.0633) x 100 = ± 0.18%

Unit #2 OPA - 30 mph.

Run	Length
1	30.13
2	30.20
3	30.16
4	30.14
5	30.17

Ave. = 30.16"
STD = ± 0.02949
3STD = ± 0.07348

Accuracy=(30.16-30.00)/30.00 x 100 = 0.53%

Precision = (± 0.07348/30.16) x 100 = ± 0.24%

Unit #2 OPB - 30 mph.

Run	Length
1	30.14
2	30.17
3	30.17
4	30.14
5	30.14

Ave. = 30.15"
STD = ± 0.0147
3STD = ± 0.0441

Accuracy=(30.15-30.00)/30.00 x 100 = 0.51%

Precision = (± 0.0441/30.15) x 100 = ± 0.14%

Unit #2 OPC - 40 mph.

Run	Length
1	30.00
2	29.97

Ave. = 29.99"
STD = ± 0.015
3STD = ± 0.045

Accuracy=(29.99-30.00)/30.00 x 100 = - 0.05%

Precision = (± 0.045/29.99) x 100 = ± 0.15%

Unit #2 OPC - 45 mph.

Run	Length
1	29.97
2	29.91
3	29.88
4	29.85

Ave. = 29.90"
STD = ± 0.0444
3STD = ± 0.1331

Accuracy=(29.90-30.00)/30.00 x 100 = - 0.33%

Precision = (± 0.1331/29.90) x 100 = ± 0.45%

APPENDIX B

TRANSVERSE DISTORTION DATA

RoadRecon-70 Transverse Distortion Calibration Data

UNIT #1 - 10 MPH Run ID	Point ID	Length on Screen 1/100"	Variance From Nominal 80.4"(%)	Length After Coor. 1/100"	Variance After Corr. (%)
G63111-1	8	81.12	0.90	84.59	5.21
G63111-1	9	85.23	6.01	82.74	2.91
G63111-1	10	81.68	1.59	79.52	-1.10
G63111-1	11	82.35	2.43	80.17	-0.29
G63111-1	12	83.46	3.81	79.91	-0.61
G63111-1	13	83.89	4.34	79.91	-0.61
G63111-1	14	83.68	4.08	80.08	-0.40
G63111-1	15	84.57	5.19	80.95	0.68
G63111-1	16	83.45	3.79	80.67	0.34
G63111-1	17	82.11	2.13	80.76	0.44
G63111-1	18	80.78	0.47	80.56	0.20
G63111-1	19	80.34	-0.07	81.26	1.07
G63111-1	20	80.22	-0.22	81.40	1.25
G63211-1	**8**	**71.68**	**-10.85**	**74.74**	**-7.03**
G63211-1	9	86.69	7.82	79.75	-0.81
G63211-1	10	82.13	2.15	79.73	-0.83
G63211-1	11	80.79	0.49	78.65	-2.18
G63211-1	12	82.45	2.55	79.30	-1.37
G63211-1	13	83.47	3.82	79.92	-0.59
G63211-1	14	85.23	6.01	81.18	0.97
G63211-1	15	83.01	3.25	79.43	-1.20
G63211-1	16	84.13	4.64	80.52	0.15
G63211-1	17	82.91	3.12	80.15	-0.31
G63211-1	18	81.71	1.63	80.36	-0.05
G63211-1	19	80.60	0.25	80.38	-0.02
G63211-1	20	79.81	-0.73	80.72	0.40
G63211-1	21	80.60	0.25	81.79	1.72
G63311-1	**8**	**71.48**	**-11.09**	**74.54**	**-7.29**
G63311-1	9	86.58	7.69	79.65	-0.94
G63311-1	10	82.03	2.03	79.63	-0.95
G63311-1	11	82.02	2.01	79.85	-0.69
G63311-1	12	82.58	2.71	79.43	-1.21
G63311-1	13	82.59	2.72	79.08	-1.64
G63311-1	14	84.46	5.05	80.45	0.06
G63311-1	15	83.80	4.23	80.19	-0.26
G63311-1	16	84.58	5.20	80.96	0.69
G63311-1	17	83.14	3.41	80.37	-0.03
G63311-1	18	81.72	1.64	80.37	-0.04
G63311-1	19	81.17	0.96	80.95	0.69
G63311-1	20	79.96	-0.55	80.88	0.59
G63311-1	21	79.25	-1.43	80.42	0.02
Average		82.04	2.03	80.14	-0.32
Maximum		86.69	7.82	84.59	5.21
Minimum		71.48	-11.09	74.54	-7.29
Standard Deviation		2.95	3.67	1.60	1.99

RoadRecon-70 Transverse Distortion Calibration Data

UNIT #1 - 20 MPH

Run ID	Point ID	Length on Screen 1/100"	Variance From Nominal 80.4"(%)	Length After Coor. 1/100"	Variance After Corr. (%)
G63221-1	8	79.51	-1.11	82.91	3.12
G63221-1	9	84.53	5.14	77.76	-3.28
G63221-1	10	80.74	0.42	78.38	-2.51
G63221-1	11	81.86	1.82	79.69	-0.88
G63221-1	12	82.97	3.20	79.80	-0.75
G63221-1	13	82.99	3.22	79.46	-1.17
G63221-1	14	83.85	4.29	80.24	-0.20
G63221-1	15	84.39	4.96	80.77	0.46
G63221-1	16	83.83	4.27	81.04	0.80
G63221-1	17	82.28	2.34	80.92	0.65
G63221-1	18	81.93	1.90	81.71	1.63
G63221-1	19	80.70	0.37	81.62	1.52
Average		82.47	2.57	80.36	-0.05
Maximum		84.53	5.14	82.91	3.12
Minimum		79.51	-1.11	77.76	-3.28
Standard Deviation		1.52	1.86	1.39	1.73

RoadRecon-70 Transverse Distortion Calibration Data

UNIT #1 - 30 MPH

Run ID	Point ID	Length on Screen 1/100"	Variance From Nominal 80.4"(%)	Length After Coor. 1/100"	Variance After Corr. (%)
G6331-1	8	75.31	-6.33	78.53	-2.33
G6331-1	9	88.84	10.50	81.72	1.65
G6331-1	10	83.50	3.86	81.06	0.82
G6331-1	11	83.40	3.73	81.19	0.98
G6331-1	12	84.10	4.60	80.89	0.61
G6331-1	13	84.60	5.22	81.00	0.75
G6331-1	14	84.29	4.84	80.29	-0.14
G6331-1	15	84.18	4.70	80.55	0.19
G6331-1	16	83.35	3.67	79.78	-0.77
G6331-1	17	82.20	2.24	79.46	-1.16
G6331-1	18	80.69	0.36	79.36	-1.30
G6331-1	19	79.25	-1.43	79.04	-1.70
G6331-1	20	78.01	-2.97	78.90	-1.86
G63431-1	8	79.18	-1.52	82.57	2.69
G63431-1	9	89.85	11.75	82.65	2.08
G63431-1	10	85.07	5.81	82.59	2.72
G63431-1	11	83.65	4.04	81.43	1.29
G63431-1	12	84.98	5.70	81.73	1.66
G63431-1	13	85.00	5.72	81.39	1.23
G63431-1	14	84.29	4.84	80.29	-0.14
G63431-1	15	84.89	5.58	81.23	1.04
G63431-1	16	83.33	3.64	80.56	0.19
G63431-1	17	81.58	1.47	80.23	-0.21
G63431-1	18	80.27	-0.16	80.05	-0.43
G63431-1	19	78.60	-2.24	79.50	-1.12
G63431-1	20	77.30	-3.86	78.44	-2.44
G63531-1	8	80.05	-0.44	83.47	3.82
G63531-1	9	88.23	9.74	81.16	0.95
G63531-1	10	84.27	4.81	81.81	1.75
G63531-1	11	83.39	3.72	81.18	0.97
G63531-1	12	83.93	4.39	80.72	0.40
G63531-1	13	84.83	5.51	81.22	1.03
G63531-1	14	84.04	4.53	80.05	-0.44
G63531-1	15	84.15	4.66	80.54	0.18
G63531-1	16	83.32	3.63	80.55	0.18
G63531-1	17	81.98	1.97	80.63	0.28
G63531-1	18	80.28	-0.15	80.06	-0.42
G63531-1	19	78.99	-1.75	79.89	-0.63
G63531-1	20	77.82	-3.21	78.97	-1.78

UNIT #1 - 30 MPH (Cont.)

Run ID	Point ID	Length on Screen 1/100"	Variance From Nominal 80.4"(%)	Length After Coor. 1/100"	Variance After Corr. (%)
G63631-1	8	78.50	-2.36	81.86	1.81
G63631-1	9	89.25	11.01	82.10	2.12
G63631-1	10	83.12	3.38	80.69	3.70
G63631-1	11	83.24	3.53	81.04	0.79
G63631-1	12	84.14	4.65	80.93	0.65
G63631-1	13	84.81	5.49	81.21	1.00
G63631-1	14	84.66	5.30	80.64	0.30
G63631-1	15	84.72	5.37	81.07	0.83
G63631-1	16	82.83	3.02	79.28	-1.39
G63631-1	17	81.92	1.89	80.57	0.21
G63631-1	18	80.66	0.32	80.44	0.05
G63631-1	19	79.51	-1.11	80.42	0.03
G63631-1	20	80.21	-0.24	81.39	1.23
Average		82.74	2.91	80.70	0.44
Maximum		89.85	11.75	83.47	3.82
Minimum		75.31	-6.33	78.44	-2.44
Standard Deviation		3.02	3.76	1.06	1.39

RoadRecon-70 Transverse Distortion Calibration Data

UNIT #2 - 10 MPH

Run ID	Point ID	Length on Screen 1/100"	Variance From Nominal 80.4"(%)	Length After Coor. 1/100"	Variance After Corr. (%)
G63112-1	8	70.37	-12.48	77.27	-3.89
G63112-1	9	85.21	5.98	81.04	0.79
G63112-1	10	80.52	0.15	78.63	-2.20
G63112-1	11	81.20	1.00	79.96	-0.54
G63112-1	12	82.36	2.44	80.19	-0.26
G63112-1	13	82.70	2.86	79.40	-1.24
G63112-1	14	83.01	3.25	79.59	-1.01
G63112-1	15	85.19	5.96	81.03	0.78
G63112-1	16	84.70	5.35	80.63	0.28
G63112-1	17	83.37	3.69	80.19	-0.26
G63112-1	18	82.70	2.86	80.60	0.25
G63112-1	19	81.88	1.84	80.83	0.53
G63112-1	20	81.72	1.64	80.97	0.71
G63112-1	21	82.24	2.29	80.96	0.70
G63212-1	**8**	**68.43**	**-14.89**	**75.14**	**-6.54**
G63212-1	9	84.07	4.56	79.95	-0.55
G63212-1	10	81.62	1.52	79.71	-0.86
G63212-1	11	81.10	0.87	79.86	-0.67
G63212-1	12	81.42	1.27	79.28	-1.39
G63212-1	13	83.79	4.22	80.45	0.06
G63212-1	14	84.09	4.59	80.62	0.27
G63212-1	15	83.91	4.37	79.81	-0.74
G63212-1	16	84.77	5.44	80.70	0.37
G63212-1	17	84.68	5.32	81.45	1.31
G63212-1	18	82.47	2.57	80.37	-0.03
G63212-1	19	82.30	2.36	81.08	1.05
G63212-1	20	81.83	1.78	81.08	0.85
G63212-1	21	81.53	1.41	80.26	-0.17
G63312-1	**8**	**66.54**	**-17.24**	**73.07**	**-9.12**
G63312-1	9	80.67	0.34	88.58	10.18
G63312-1	10	82.88	3.08	78.82	-1.96
G63312-1	11	80.53	0.16	79.30	-1.36
G63312-1	12	80.87	0.58	78.74	-2.06
G63312-1	13	83.19	3.47	79.87	-0.66
G63312-1	14	83.55	3.92	80.10	-0.37
G63312-1	15	84.03	4.51	79.92	-0.59
G63312-1	16	85.22	6.00	81.12	0.90
G63312-1	17	83.03	3.27	79.87	-0.66
G63312-1	18	83.75	4.17	81.62	1.52
G63312-1	19	82.08	2.09	81.03	0.78
G63312-1	20	81.73	1.65	80.98	0.73
G63312-1	21	82.44	2.54	81.16	0.94
Average		81.75	1.68	80.13	-0.34
Maximum		85.22	6.00	88.58	10.18
Minimum		66.54	-17.24	73.07	-9.12
Standard Deviation		3.94	4.90	2.06	2.56

RoadRecon-70 Transverse Distortion Calibration Data

UNIT #2 - 20 MPH Run ID	Point ID	Length on Screen 1/100"	Variance From Nominal 80.4"(%)	Length After Coor. 1/100"	Variance After Corr. (%)
G63122-1	8	72.03	-12.05	77.65	-3.43
G63122-1	9	83.91	4.37	79.80	-0.74
G63122-1	10	83.03	3.27	81.08	0.85
G63122-1	11	80.74	0.42	79.51	-1.11
G63122-1	12	82.40	2.49	80.23	-0.21
G63122-1	13	82.72	2.89	79.42	-1.22
G63122-1	14	84.38	4.95	80.90	0.62
G63122-1	15	84.87	5.56	80.72	0.40
G63122-1	16	84.75	5.41	80.68	0.34
G63122-1	17	83.70	4.10	80.51	0.14
G63122-1	18	82.79	2.97	80.69	0.36
G63122-1	19	81.59	1.48	80.54	0.18
G63122-1	20	81.62	1.52	80.87	0.59
G63122-1	21	81.63	1.53	80.36	-0.05
G63222-1	8	72.03	-10.41	79.10	-1.62
G63222-1	9	85.70	6.59	81.50	1.37
G63222-1	10	82.36	2.44	80.43	0.04
G63222-1	11	81.53	1.41	80.29	-0.14
G63222-1	12	83.35	3.67	81.16	0.94
G63222-1	13	83.87	4.32	80.53	0.16
G63222-1	14	84.02	4.50	80.55	0.19
G63222-1	15	85.35	6.16	81.18	0.97
G63222-1	16	84.19	4.71	80.14	-0.32
G63222-1	17	84.05	4.54	80.85	0.56
G63222-1	18	82.91	3.12	80.80	0.50
G63222-1	19	81.89	1.85	80.84	0.54
G63222-1	20	81.41	1.26	80.67	0.33
G63322-1	10	82.90	3.11	78.84	-1.94
G63322-1	11	82.40	2.49	80.47	0.09
G63322-1	12	82.42	2.51	81.16	0.95
G63322-1	13	83.21	3.50	81.02	0.77
G63322-1	14	84.90	5.60	81.51	1.39
G63322-1	15	83.56	3.93	80.11	-0.36
G63322-1	16	84.59	5.21	80.52	0.15
G63322-1	17	83.73	4.14	80.54	0.18
G63322-1	18	82.91	3.12	80.80	0.50
G63322-1	19	81.83	1.78	80.78	0.47
G63322-1	20	80.92	0.65	80.18	-0.27
Average		82.50	2.61	80.45	0.06
Maximum		85.70	6.59	81.51	1.39
Minimum		70.71	-12.05	77.65	-3.43
Standard Deviation		2.90	3.61	0.74	0.92

RoadRecon-70 Transverse Distortion Calibration Data

UNIT #2 - 30 MPH

Run ID	Point ID	Length on Screen 1/100"	Variance From Nominal 80.4"(%)	Length After Coor. 1/100"	Variance After Corr. (%)
G63132-1	8	78.44	-2.44	86.13	7.13
G63132-1	9	84.75	5.41	80.60	0.25
G63132-1	10	81.59	1.48	79.68	-0.90
G63132-1	11	81.46	1.32	80.22	-0.22
G63132-1	12	83.23	3.52	81.04	0.80
G63132-1	13	83.98	4.45	80.63	0.29
G63132-1	14	83.92	4.38	80.46	0.07
G63132-1	15	84.23	4.76	80.11	-0.36
G63132-1	16	85.15	5.91	81.91	1.87
G63132-1	17	81.83	1.78	79.75	-0.81
G63132-1	18	82.14	2.16	81.08	0.85
G63132-1	19	80.96	0.70	80.22	-0.22
G63132-1	20	80.52	0.15	79.27	-1.41
G63232-1	8	74.10	-7.84	81.37	1.20
G63232-1	9	86.58	7.69	82.34	2.41
G63232-1	10	81.62	1.52	79.71	-0.86
G63232-1	11	81.91	1.88	80.66	0.33
G63232-1	12	82.61	2.75	80.44	0.05
G63232-1	13	83.77	4.19	80.43	0.04
G63232-1	14	84.24	4.78	80.76	0.45
G63232-1	15	84.56	5.17	80.43	0.03
G63232-1	16	84.12	4.63	80.08	-0.40
G63232-1	17	83.29	3.59	80.12	-0.35
G63232-1	18	81.80	1.74	79.72	-0.84
G63232-1	19	80.61	0.26	79.57	-1.03
G63232-1	20	80.16	-0.30	79.43	-1.21
G63332-1	8	73.03	-9.17	80.19	-0.26
G63332-1	9	81.78	1.72	77.78	-3.26
G63332-1	10	84.72	5.37	82.73	2.90
G63332-1	11	82.23	2.28	80.98	0.72
G63332-1	12	83.07	3.32	80.89	0.60
G63332-1	13	83.73	4.14	80.39	-0.01
G63332-1	14	83.73	4.14	80.28	-0.16
G63332-1	15	84.05	4.54	79.94	-0.57
G63332-1	16	84.42	5.00	80.36	-0.05
G63332-1	17	83.41	3.74	80.23	-0.21
G63332-1	18	82.08	2.09	79.99	-0.50
G63332-1	19	80.90	0.62	79.86	-0.67
G63332-1	20	80.46	0.07	79.73	-0.84

RoadRecon-70 Transverse Distortion Calibration Data

UNIT #2 - 30 MPH (Cont.) Run ID	Point ID	Length on Screen 1/100"	Variance From Nominal 80.4"(%)	Length After Coor. 1/100"	Variance After Corr. (%)
G63432-1	8	76.56	-4.78	84.07	4.56
G63432-1	9	84.58	5.20	80.44	0.05
G63432-1	10	83.22	3.51	81.27	1.08
G63432-1	11	82.91	3.12	81.65	1.55
G63432-1	12	82.57	2.70	80.40	0.00
G63432-1	13	84.41	4.99	81.04	0.80
G63432-1	14	83.75	4.17	80.29	-0.13
G63432-1	15	84.56	5.17	80.43	0.03
G63432-1	16	84.10	4.60	80.90	0.62
G63432-1	17	82.63	2.77	80.53	0.16
G63432-1	18	81.78	1.72	80.73	0.41
G63432-1	19	80.43	0.04	79.70	-0.88
G63532-1	8	74.52	-7.31	81.83	1.78
G63532-1	9	87.57	8.92	83.28	3.59
G63532-1	10	82.22	2.26	80.29	-0.13
G63532-1	11	82.05	2.05	80.80	0.50
G63532-1	12	83.20	3.48	81.01	0.76
G63532-1	13	84.07	4.56	80.72	0.40
G63532-1	14	84.21	4.74	80.74	0.42
G63532-1	15	84.57	5.19	80.44	0.04
G63532-1	16	83.74	4.15	79.71	-0.85
G63532-1	17	82.38	2.46	79.24	-1.44
G63532-1	18	82.44	2.54	80.35	-0.07
G63532-1	19	80.26	-0.17	79.23	-1.46
G63532-1	20	80.60	0.25	79.34	-1.31
Average		82.38	2.47	80.59	0.24
Maximum		87.57	8.92	86.13	7.13
Minimum		73.03	-9.17	77.78	-3.26
Standard Deviation		2.60	3.24	1.19	1.48

APPENDIX C

RESOLUTION BOARD EVALUATION

EVALUATION OF RESOLUTION BOARD PATTERN - UNIT #1

Operator			#1		#2		#3		Summary	
No.	Speed		Long	Tran	Long	Tran	Long	Tran	Long	Tran
1	10	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	1	1	1	1	1	1
2	10	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	2	1	2	1	2	1
3	10	Center	--	--	--	--	--	--	--	--
		Shoulder	--	--	--	--	--	--	--	--
4	20	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	2	1	1	1	2	1
5	20	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	3	1	2	1	2	1
6	20	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	3	1	2	1	2	1
7	30	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	2	1	1	1	2	1
8	30	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	2	2	2	1	2	1
9	30	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	3	2	1	1	2	1

The numbers in the table represent the smallest groove of the resolution board the operator could observe when viewing the negative 35mm film using a light table and 10X Lupe. These numbers are in millimeters.

EVALUATION OF RESOLUTION BOARD PATTERN - UNIT #2

Operator			#1		#2		#3		Summary	
No.	Speed		Long	Tran	Long	Tran	Long	Tran	Long	Tran
1	10	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	3	1	2	1	2	1
2	10	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	3	1	3	1	3	1
3	10	Center	1	1	2	2	1	1	1	1
		Shoulder	2	1	3	2	1	1	2	1
4	20	Center	1	1	2	2	1	1	1	1
		Shoulder	1	1	2	1	1	1	1	1
5	20	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	3	3	2	1	2	1
6	20	Center	1	1	1	2	1	1	1	1
		Shoulder	2	1	3	3	1	1	2	1
7	30	Center	1	1	2	2	1	1	1	1
		Shoulder	2	1	3	3	1	1	2	1
8	30	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	3	3	2	1	2	1
9	30	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	3	2	2	1	2	1
10	40	Center	1	1	1	2	1	2	1	2
		Shoulder	2	1	1	1	1	1	1	1
11	45	Center	1	1	1	1	1	1	1	1
		Shoulder	2	1	2	2	1	1	2	1

APPENDIX D

RR-75 RUT DEPTH LONGITUDINAL PHOTO LOCATION

RR-75 Accuracy

Unit #1
A-30

Distance						Drift
0	100	200	300	400	500	
0	1 +1	0 -1	0 0	0.5 +0.5	0 -0.5	0
4.0	6 +2	5 -1	5.5 +0.5	6.5 +1.0	5.5 -1.0	+1.5
4.0	5.5 +1.5	5 -0.5	5.5 +0.5	4.5 -1.0	4.0 -0.5	0
4.0	4.5 +0.5	4.0 -0.5	4.0 0	4.0 0	3.0 -1	-1.0
5.5	7.0 +1.5	6.5 -0.5	7.0 +0.5	5.5 -1.5	6.5 +1	+1.5

Ave. +3.5
Start Range 0 to +5.5

0.4
Drift Range -1 to +1.5
End Ave. +1.8
End Range 0 to +6.5

RR-75 Accuracy

Unit #1
B-30

Distance						Drift
0	100	200	300	400	500	
7	9 +2	10 +1	9 -1	8.5 -0.5	7.5 -1.0	+0.5
0	2 +2	2 -1	2.5 +0.5	2 +1.0	1 -1.0	+1.0
2	4 +1.5	3.5 -0.5	4 +0.5	2 -1.0	1.5 -0.5	-0.5
3	5.5 +0.5	5.5 -0.5	4.5 0	4.0 0	3.0 -1	0
4.5	8.0 +3.5	5.5 -2.5	6.0 +0.5	6.0 0	2.0 -4.0	-2.5
2.0	4.0	3.5	3.0	3.5	2.5	+0.5

Ave. +3.1
Start Range 0 to +7

-.4
Drift Range -2.5 to +1.0
End Ave. +2.9
End Range +1 to +7.5

RR-75 Accuracy

<u>Unit #2</u>
A-30

Distance						Drift
0	100	200	300	400	500	
-6	-3 +3	-2 +1	1 +1	0 +1	-1.5 -1.5	+4.5
-7	-5.5 +1.5	-5.5 0	-5.5 0	-5.5 0	-4.0 +1.5	+3.0
-9.0	-8.0 +1	-7.0 +1	-6.0 +1	-6.0 0	-6.0 0	+3.0
-11.0	-8.0 +3	-6.5 +1.5	-6.0 +.5	-8.0 -2	-7.0 +1	+4.0
-9.0	-6.0 +3	-5.5 +0.5	-6.0 -0.5	-5.5 +0.5	-5.0 +0.5	+4.0

Ave. -7
Start Range -6 to -11

+3.7
Drift Range +3 to +4.5
End Ave. -4.7
End Range -7 to -1.5

RR-75 Accuracy

Unit #2
B-30

Distance						Drift
0	100	200	300	400	500	
-4.75	-2.0 +2.75	-1.5 +0.5	-1.25 +0.25	-1.25 --	-0.5 +1.75	+5.25
+8	0 -8	0.75 +.75	1.0 +.25	1.0 --	1.0 --	-7
-0.5	2.75 +3.25	2.0 -.75	-1.5 -.5	0.5 -1.0	0.0 -.5	+0.5
0	2.0 +2	1.0 -1	2.5 +1.5	3.0 +0.5	2.25 -0.75	+2.25
-1.0	0.25 +1.75	0.5 -0.25	1.0 +0.5	0.25 -0.75	0.5 +0.25	+1.5

Ave. 0.35
Start Range -4.75 to +8.00

+0.5
Drift Range -7 to +5.25
End Ave. +0.85
End Range 0 to 2.25

RR-75 **UNIT #1** **UNIT:Ft**

ID NO	SPEED (MPH)	OPERATOR	0	100	200	300	400	500
063111	10	A	-2.0	-2.5	-4.0	-4.75	-6.0	-6.5
063211	10	A	-4.5	-4.5	-6.0	-6.5	-8.5	-9.0
063111	10	A	-2.0	-2.0	-3.5	-4.0	-6.0	-7.0
064111	10	B	-3.0	-4.0	-5.5	-6.0	-8.0	-8.0
064211	10	B	-0.0	-1.0	-2.5	-2.5	-3.0	-4.0
064311	10	B	-1.5	-2.0	-4.0	-5.0	-6.0	-6.5

Distance Between RR-75 Rut Photo and Hundred Foot Marks

RR-75 **UNIT #1** **UNIT:Ft**

ID NO	SPEED (MPH)	OPERATOR	0	100	200	300	400	500
063121	20	A	0.0	0.0	-2.0	-2.0	-2.5	-3.0
063221	20	A	*	2.0	0.0	0.0	-1.0	-1.0
063321	20	A	0.0	-0.5	-2.0	-2.5	-3.0	-4.5
064121	20	B	3.0	3.5	2.5	2.0	0.0	0.0
064221	20	B	2.0	3.5	1.5	0.0	-1.0	0.0
064321	20	B	4.0	4.0	3.5	2.0	-1.5	0.0

Distance Between RR-75 Rut Photo and Hundred Foot Marks

RR-75 **UNIT #1** **UNIT:Ft**

ID NO	Speed-MPH	OPERATOR	0	100	200	300	400	500
063131	30	A	0.0	1.0	0.0	0.0	0.5	0.0
063331	30	A	4.0	6.0	5.0	5.5	6.5	5.5
063431	30	A	4.0	5.5	5.0	5.5	4.5	4.0
063531	30	A	4.0	4.5	4.0	4.0	4.0	3.0
063631	30	A	5.5	7.0	6.5	7.0	5.5	6.5
064131	30	B	7.0	9.0	10.0	9.0	8.5	7.5
064231	30	B	0.0	2.0	2.0	2.5	2.0	1
064331	30	B	2.0	4.0	3.5	4.0	2.0	1.5
064431	30	B	3.0	5.5	5.5	4.5	4.0	3.0
064531	30	B	4.5	8.0	5.5	6.0	6.0	2.0
064631	30	B	2.0	4.0	3.5	3.0	3.5	2.5

Distance Between RR-75 Rut Photo and Hundred Foot Marks

RR-75 **UNIT #1** **UNIT:Ft**

ID NO	SPEED (MPH)	OPERATOR	0	100	200	300	400	500
063140	40	A	-8.3	-4.2	0.78	1.0	4.69	10.4
064240	40	A	-3.65	-0.26	5.21	15.6		
064430	40	A			-2.08	2.08		10.4
063140	40	B	-5.21	0.52	4.2	8.3	8.85	6.25
063240	40	B	-6.25	-0.52	5.21	5.73	8.85	6.25
063440	40	B	0.0					

Distance Between RR-75 Rut Photo and Hundred Foot Marks

RR-75 **UNIT #1** **UNIT:Ft**

ID NO	SPEED (MPH)	OPERATOR	0	100	200	300	400	500
064245	45	A	0.0	5.21	9.38	14.06	17.71	22.40
064345	45	A			10.94		19.27	
064445	45	A	0.52	5.21	10.94	10.94	22.40	17.71
063145	45	B			-4.69	1.56		
063245	45	B				3.65		
063345	45	B	-6.25	-3.65	1.04	5.21	9.38	14.58

Distance Between RR-75 Rut Photo and Hundred Foot Marks

RR-75 **UNIT #2** **UNIT:Ft**

ID NO	SPEED (MPH)	OPERATOR	0	100	200	300	400	500
063112	10	A	-1.0	-1.0	-3.0	-2.0	-2.0	-2.0
063212	10	A	-4.0	-4.0	-6.0	-5.0	-5.0	-5.0
063312	10	A	-3.0	-2.5	-3.0	-3.0	-3.0	-3.0
064112	10	B	-2.25	-2.5	-5.0	-6.0	-5.75	-4.0
064212	10	B	-6.0	-5.5	-6.0	-6.75	-6.0	-6.25
064312	10	B	-1.0	0.0	-1.25	-1.75	-1.5	-1.25

Distance Between RR-75 Rut Photo and Hundred Foot Marks

RR-75 **UNIT #2** **UNIT:Ft**

ID NO	SPEED (MPH)	OPERATOR	0	100	200	300	400	500
063122	20	A	-1.5	0.0	-2.0	-2.5	-2.0	0.0
063222	20	A	-5.0	-3.5	-3.5	-3.5	-4.0	-3.0
063322	20	A	-5.5	-5.0	-6.0	-6.0	-5.0	-5.5
064122	20	B	-2.0	-1.25	-3.0	-3.25	-4.0	-4.75
064222	20	B	0.0	1.0	0.0	-0.5	-1.5	-0.5
064322	20	B	-2.25	-2.0	-3.0	-3.25	-3.0	-2.25

Distance Between RR-75 Rut Photo and Hundred Foot Marks

RR-75 **UNIT #2** **UNIT:Ft**

ID NO	SPEED (MPH)	OPERATOR	0	100	200	300	400	500
063132	30	A	-6.0	-3.0	-2.0	1.0	0.0	-1.5
063232	30	A	-7.0	-5.5	-5.5	-5.5	-5.5	-4.0
063332	30	A	-9.0	-8.0	-7.0	-6.0	-6.0	-6.0
063432	30	A	-11.0	-8.0	-6.5	-6.0	-8.0	-7.0
063532	30	A	-9.0	-6.0	-5.5	-6.0	-5.5	-5.0
064132	30	B	-4.75	-2.0	-1.5	-1.25	-1.25	-0.5
064232	30	B	8.0	0.0	0.75	1.0	1.0	1.0
064332	30	B	-0.5	2.75	2.0	1.5	0.5	0.0
064432	30	B	0.0	2.0	1.0	2.5	3.0	2.25
064532	30	B	-1.0	0.75	0.5	1.0	0.25	0.5

Distance Between RR-75 Rut Photo and Hundred Foot Marks

RR-75 **UNIT #2** **UNIT:Ft**

ID NO	SPEED (MPH)	OPERATOR	0	100	200	300	400	500
192140	40	C	-6.3	-4.7	-4.2	-1.0	-0.5	0.0
192440	40	C	-1.6	-0.5	-1.6	-0.5	-0.5	4.2

Distance Between RR-75 Rut Photo and Hundred Foot Marks

RR-75 **UNIT #2** **UNIT:Ft**

ID NO	SPEED (MPH)	OPERATOR	0	100	200	300	400	500
192245	45	C	6.8	7.3	12.0	12.0	7.8	16.7
192345	45	C	-17.2	-15.6	-14.1	-11.5	-10.4	-7.8
192745	45	C	-14.1	-14.1	-9.9	-8.9	-6.8	-6.3
192845	45	C	-25.0	-27.1	-24.5	-24.5	-25.5	-8.3

Distance Between RR-75 Rut Photo and Hundred Foot Marks

APPENDIX E

STATIC BLOCK COMPARISON

POSITIONS OF CALIBRATION BLOCKS FOR STATIC COMPARISON
(- = 0", L = 1", M = 2 1/2", H = 4")

SETUP	LS 1	LE 2	LWP 3	C 4	RWP 5	RE 6	RS 7
A-1	-	-	-	-	-	-	-
-2	L	L	-	-	-	M	M
-3	M	M	-	-	-	L	L
-4	H	H	-	-	-	L	-
-5	-	M	-	-	-	H	H
B-1	H	L	-	L	-	-	H
-2	H	-	-	L	-	L	H
-3	L	M	-	M	-	-	L
-4	L	-	-	M	-	M	L
-5	M	H	-	H	-	-	M
-6	M	-	-	H	-	H	M
C-1	H	M	-	L	-	M	H
-2	L	H	-	L	-	H	-
-3	-	H	-	M	-	H	L
-4	-	L	-	M	-	L	-
-5	M	L	-	H	-	L	M
-6	-	M	-	H	-	M	-
CA-1	-	-	-	-	-	-	-

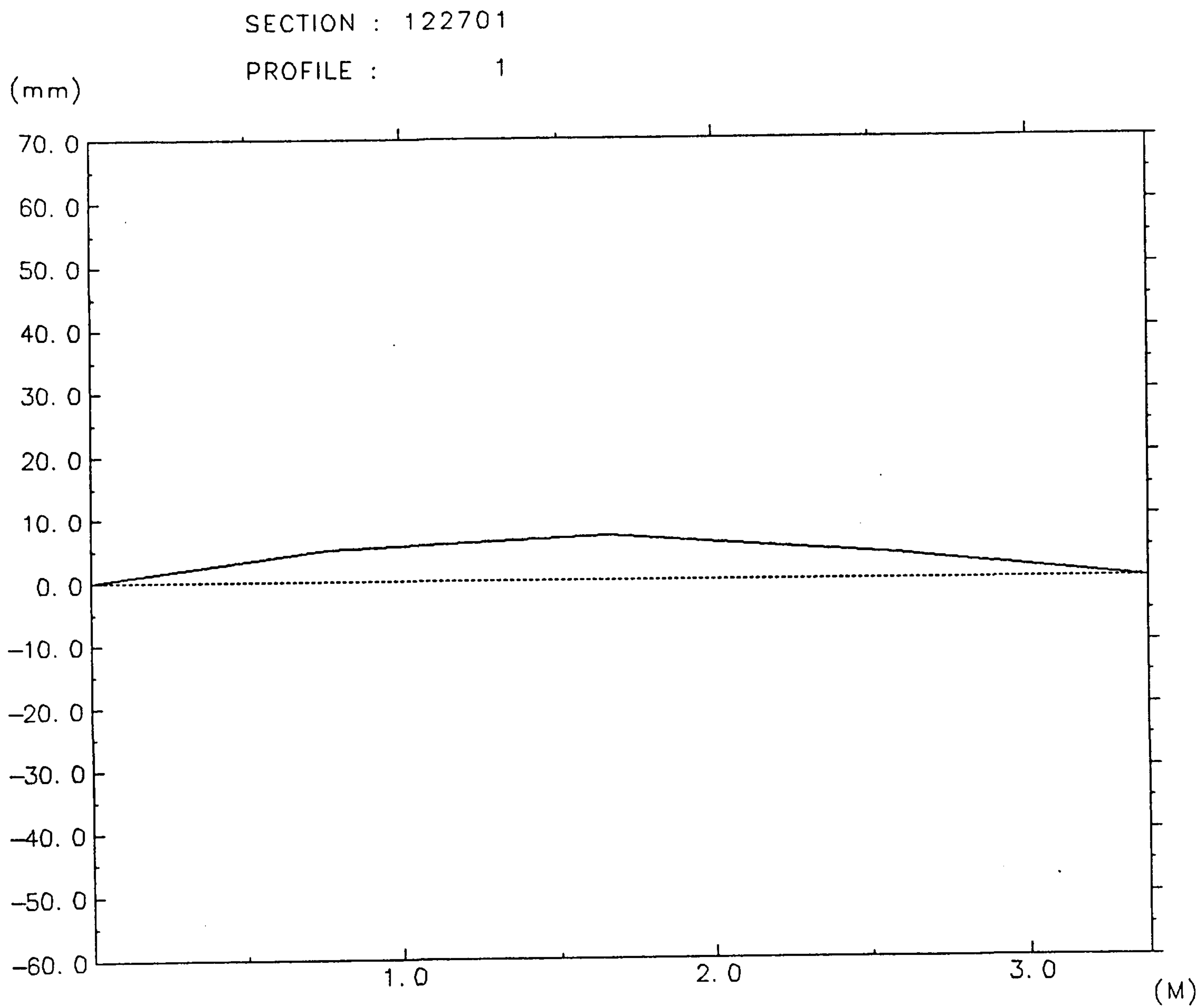

Figure 1. Rut Depth Plot - Unit #1 - A - 1 (No Blocks)

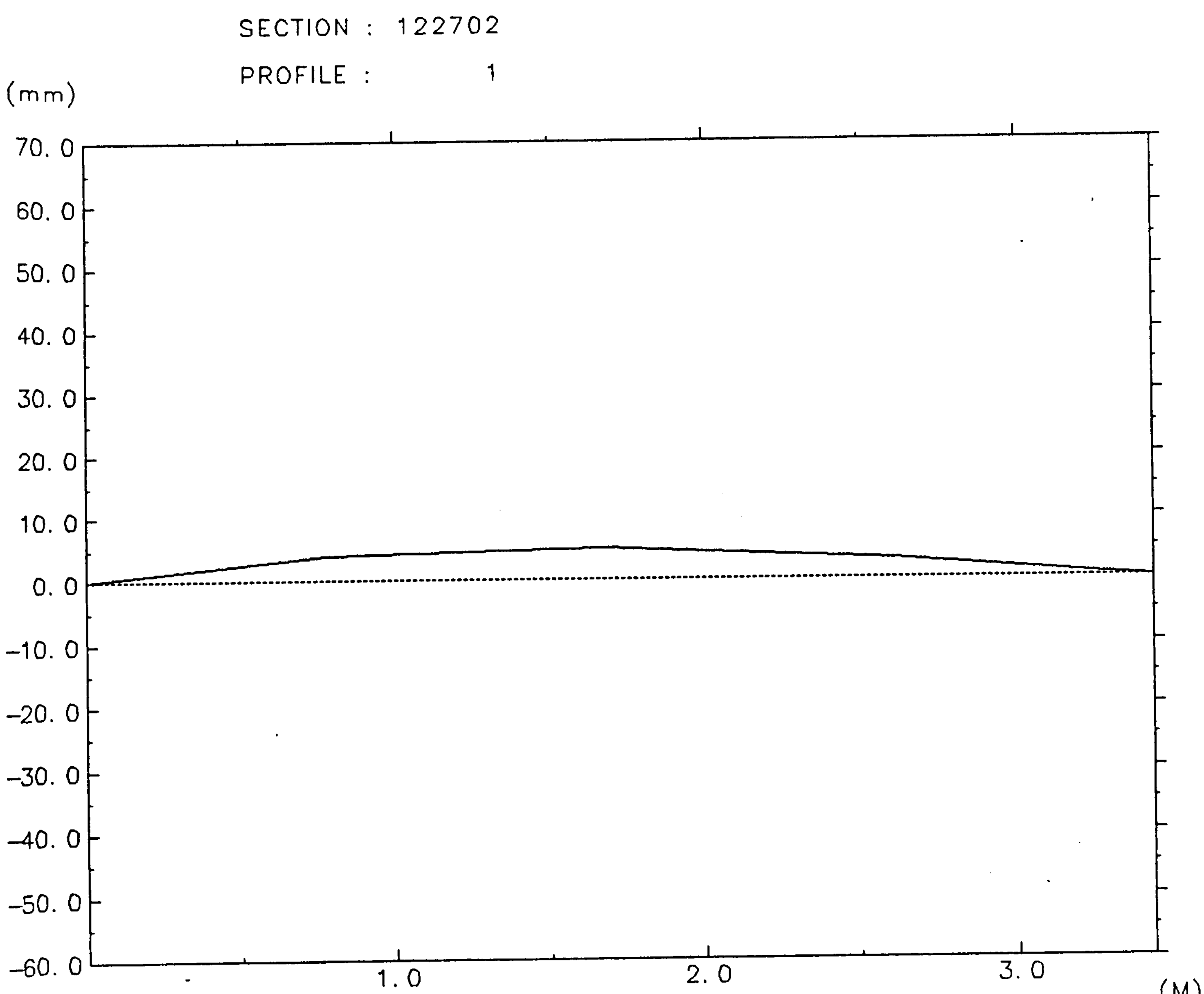

Figure 2. Rut Depth Plot - Unit #2 - A - 1 (No Blocks)

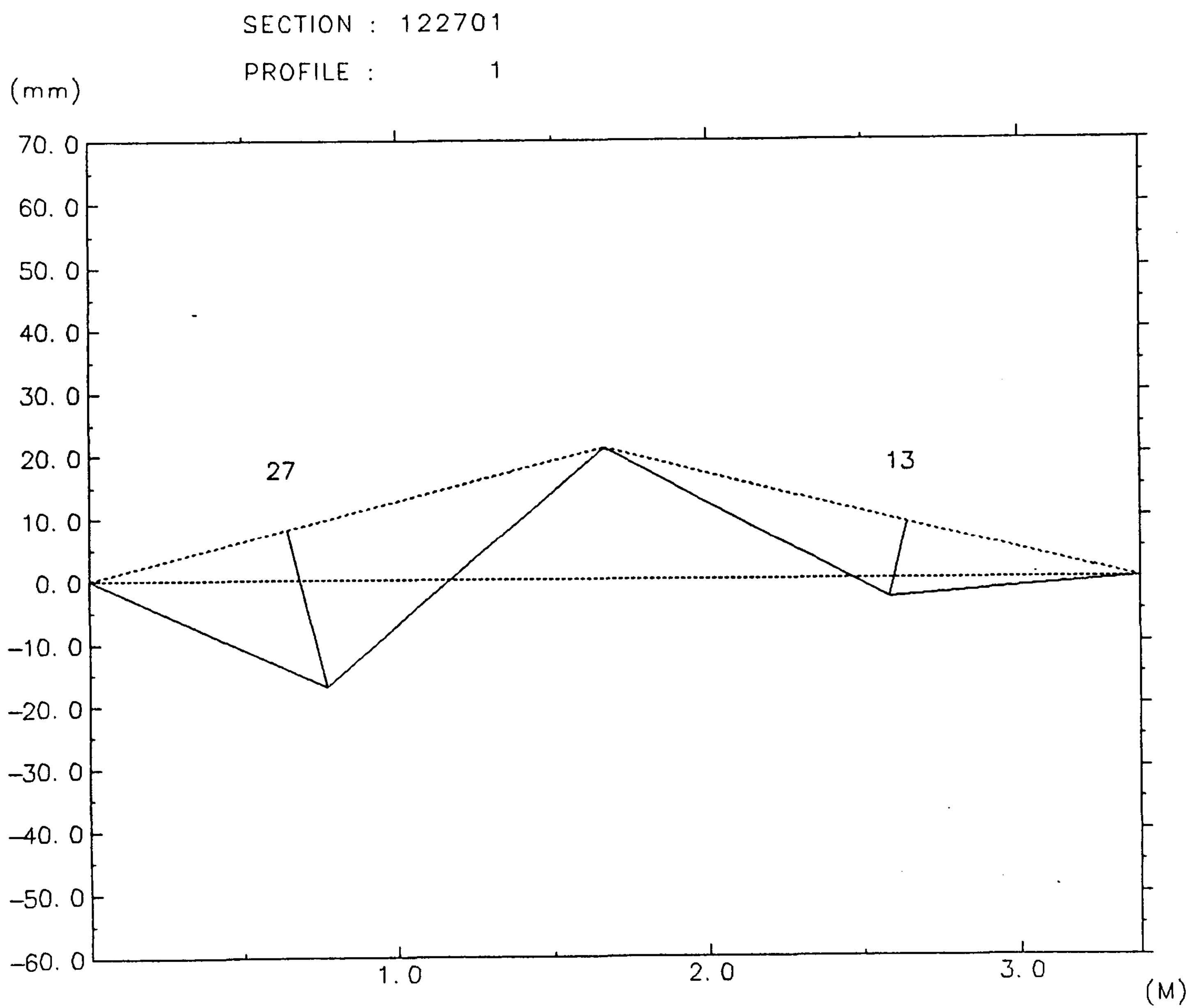

Figure 3. Rut Depth Plot - Unit #1 - B - 1

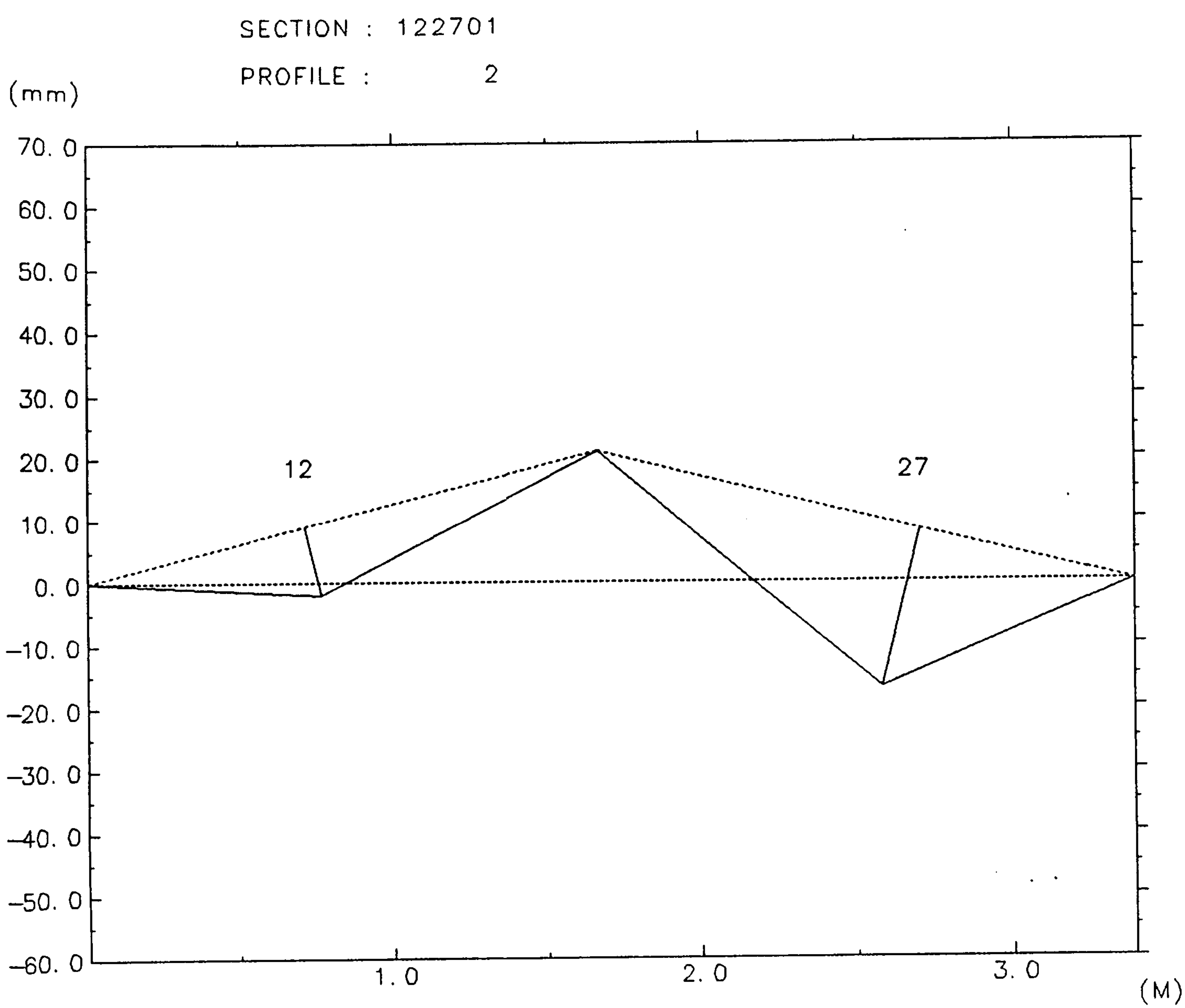

Figure 4. Rut Depth Plot - Unit #1 - B - 2

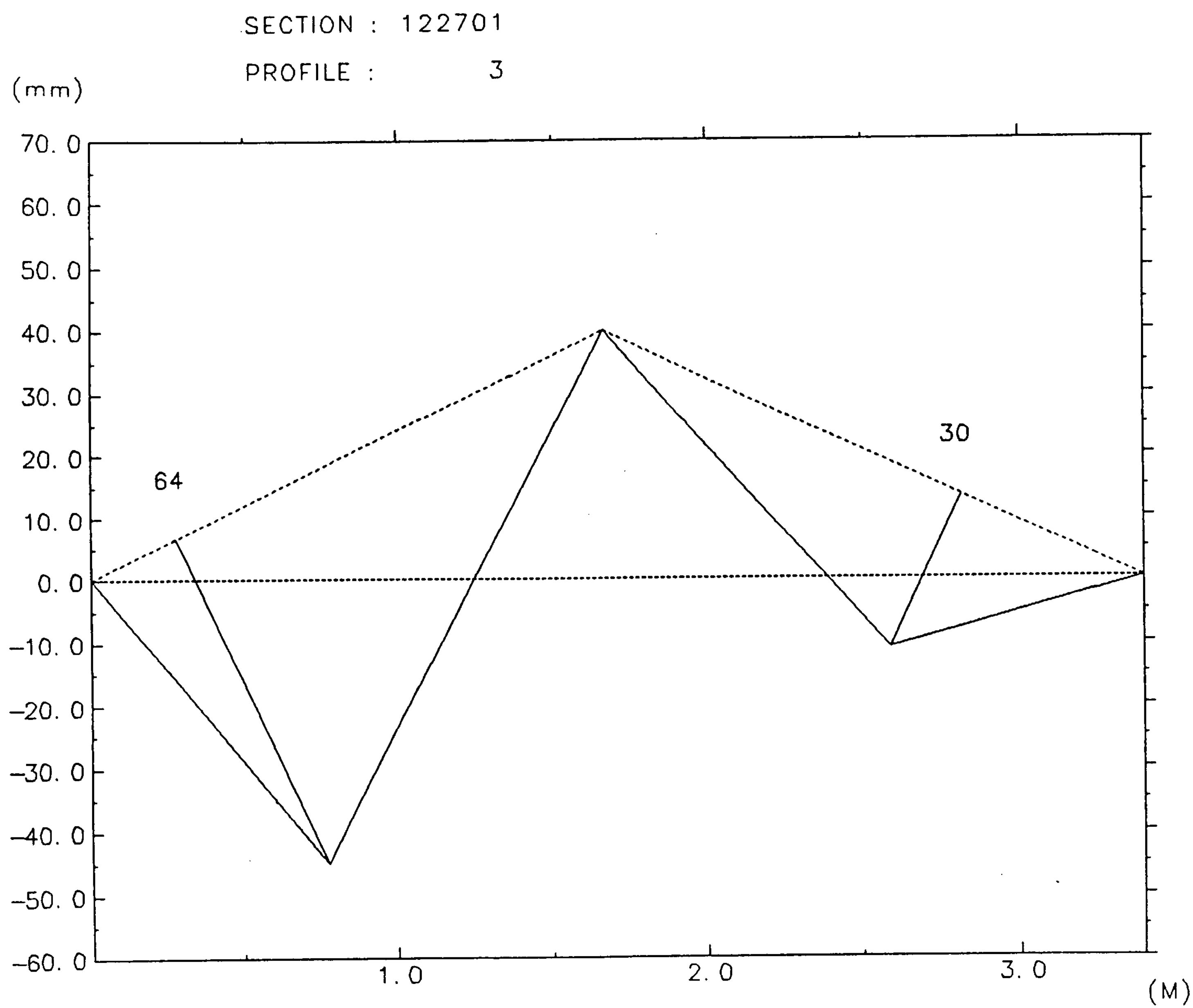

Figure 5. Rut Depth Plot - Unit #1 - B - 3

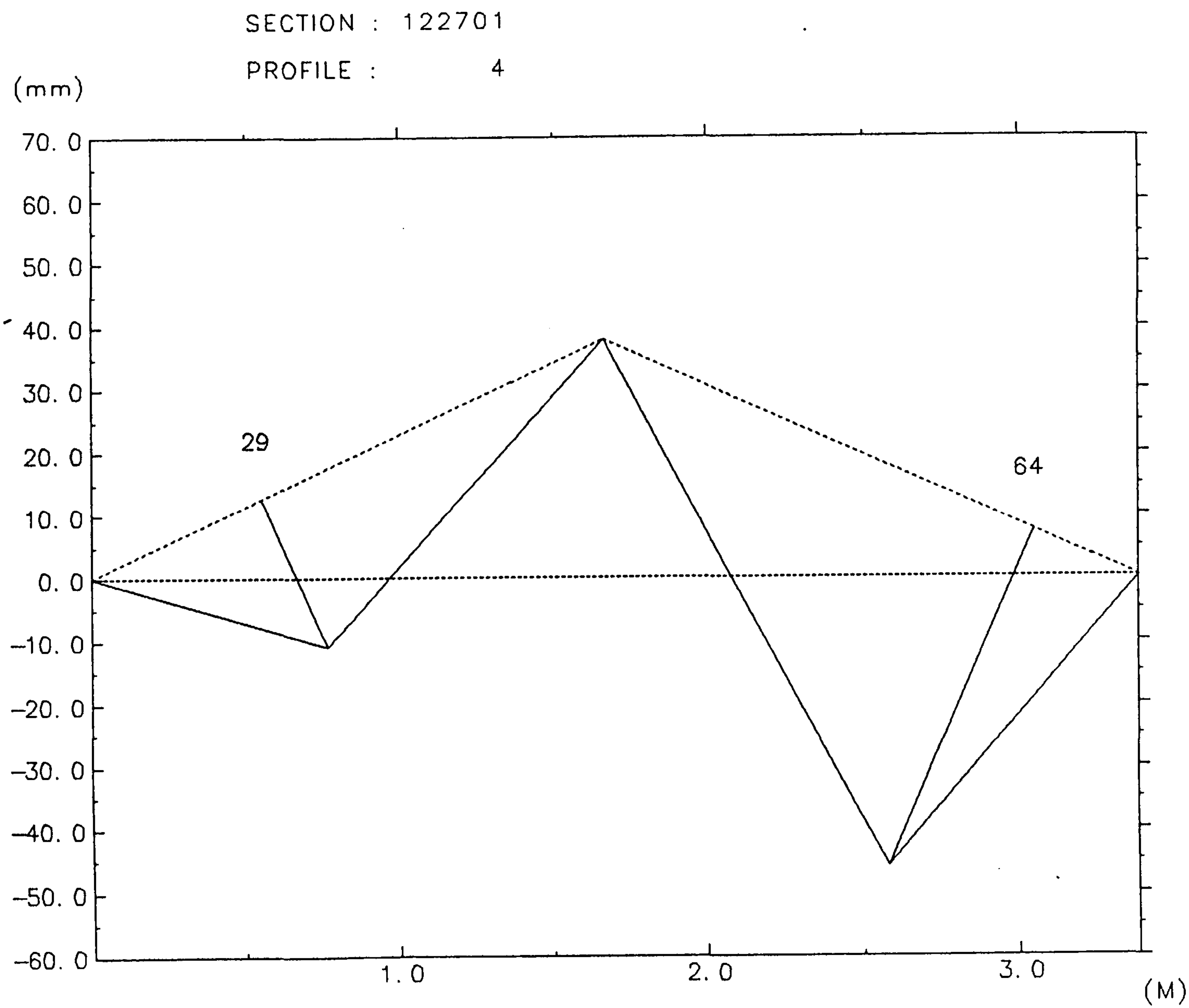

Figure 6. Rut Depth Plot - Unit #1 - B - 4

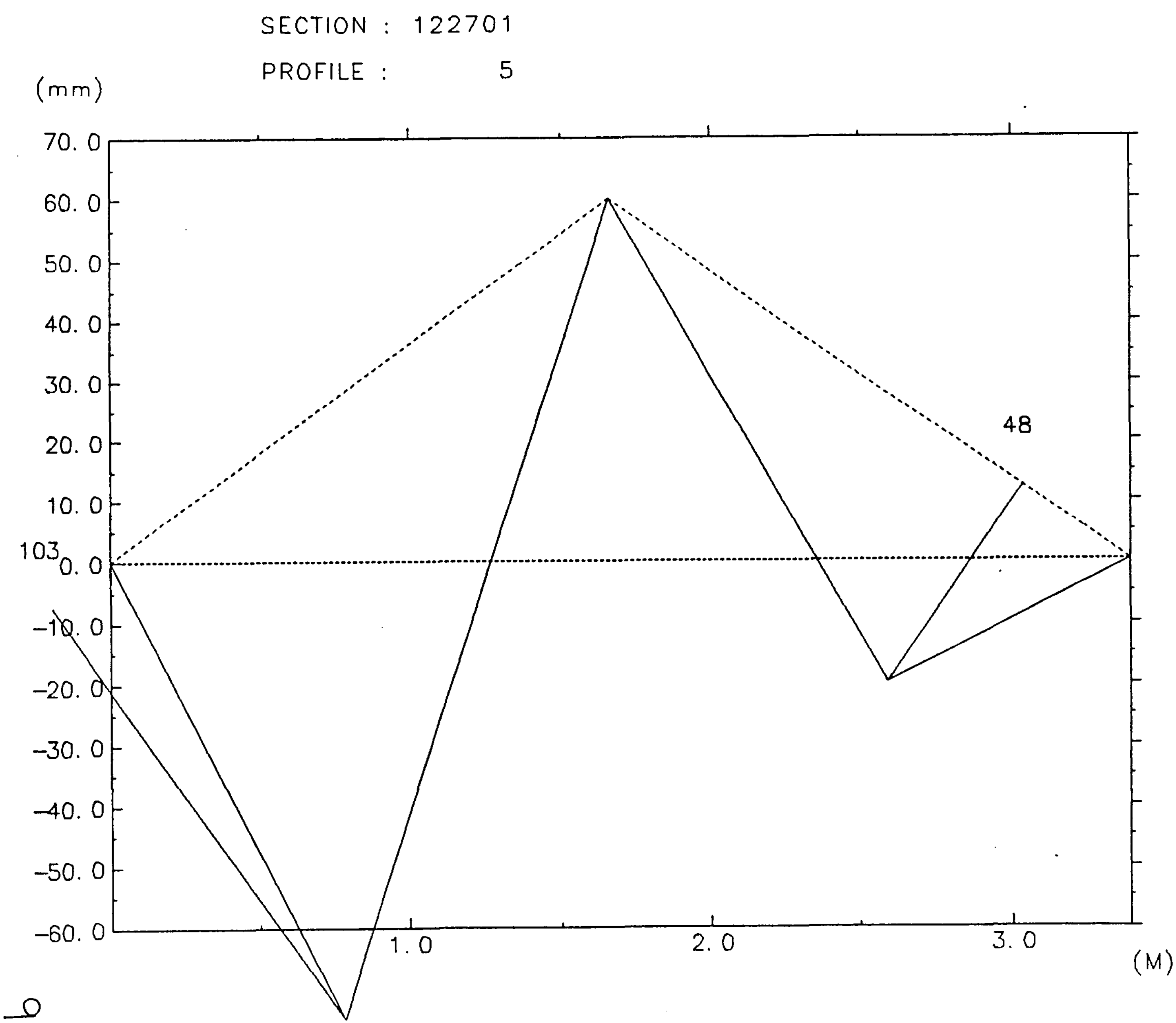

Figure 7. Rut Depth Plot - Unit #1 - B - 5

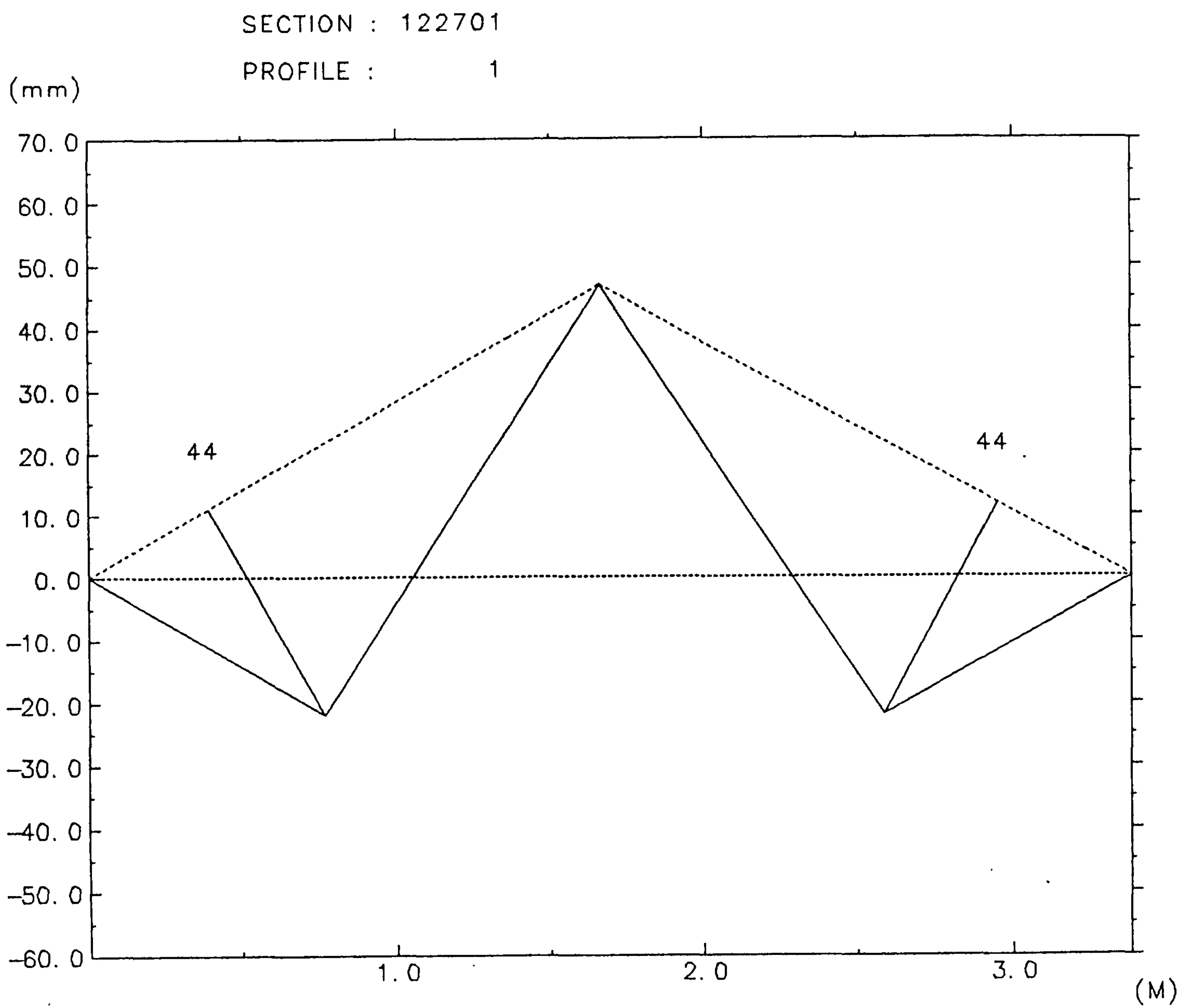

Figure 8. Rut Depth Plot - Unit #1 - C - 4

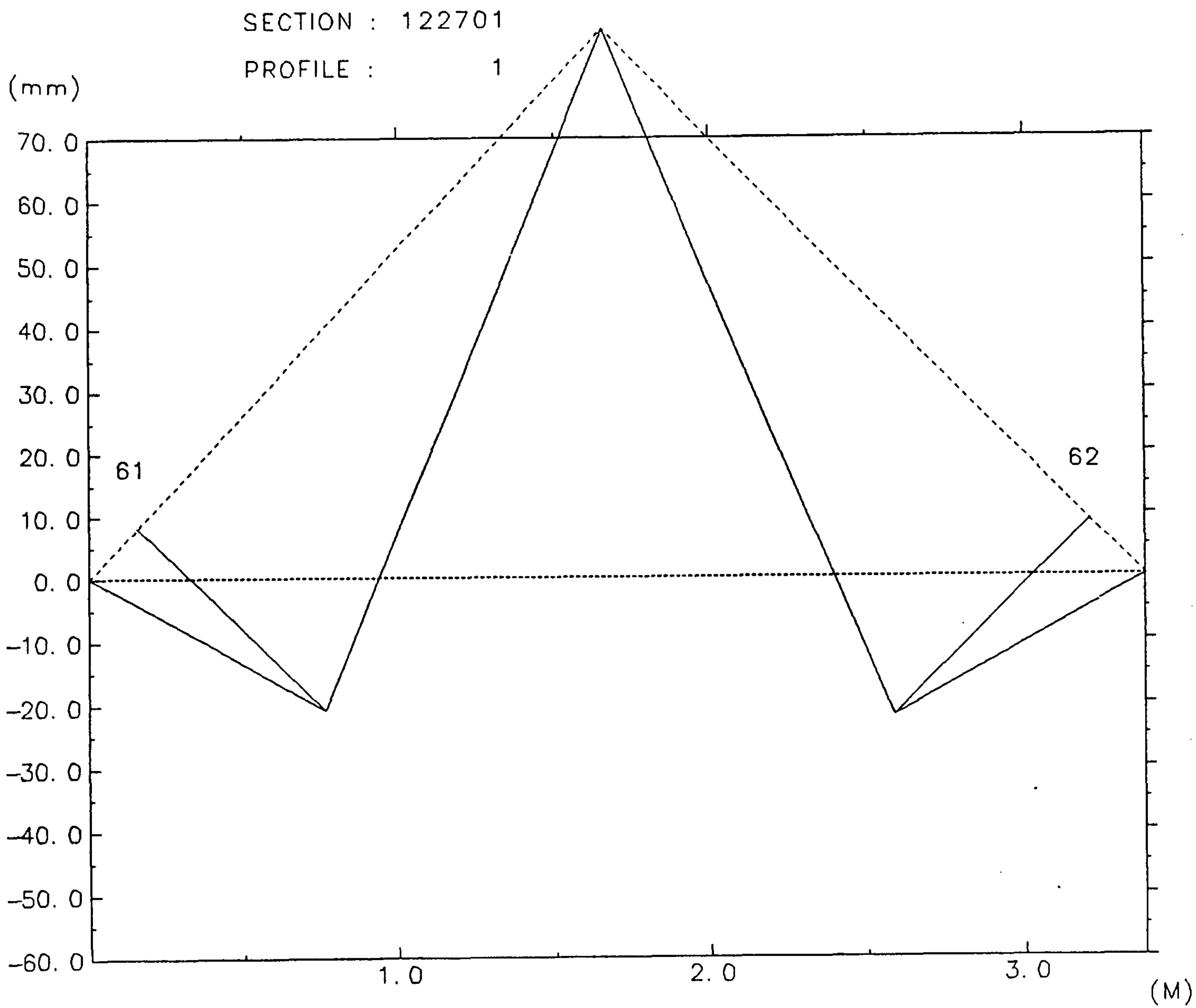

Figure 9. Rut Depth Plot - Unit #1 - C - 5

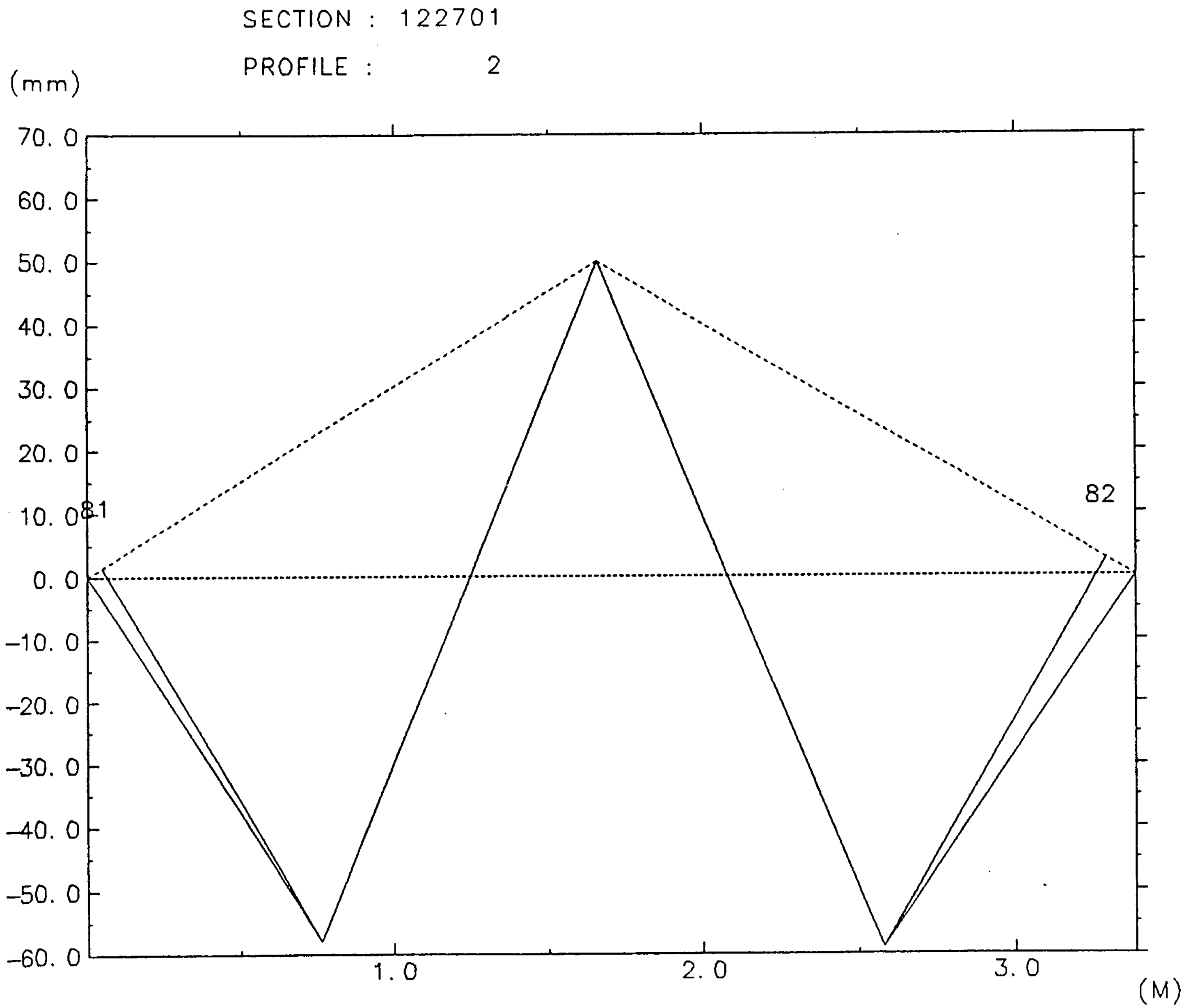

Figure 10. Rut Depth Plot - Unit #1 - C - 6

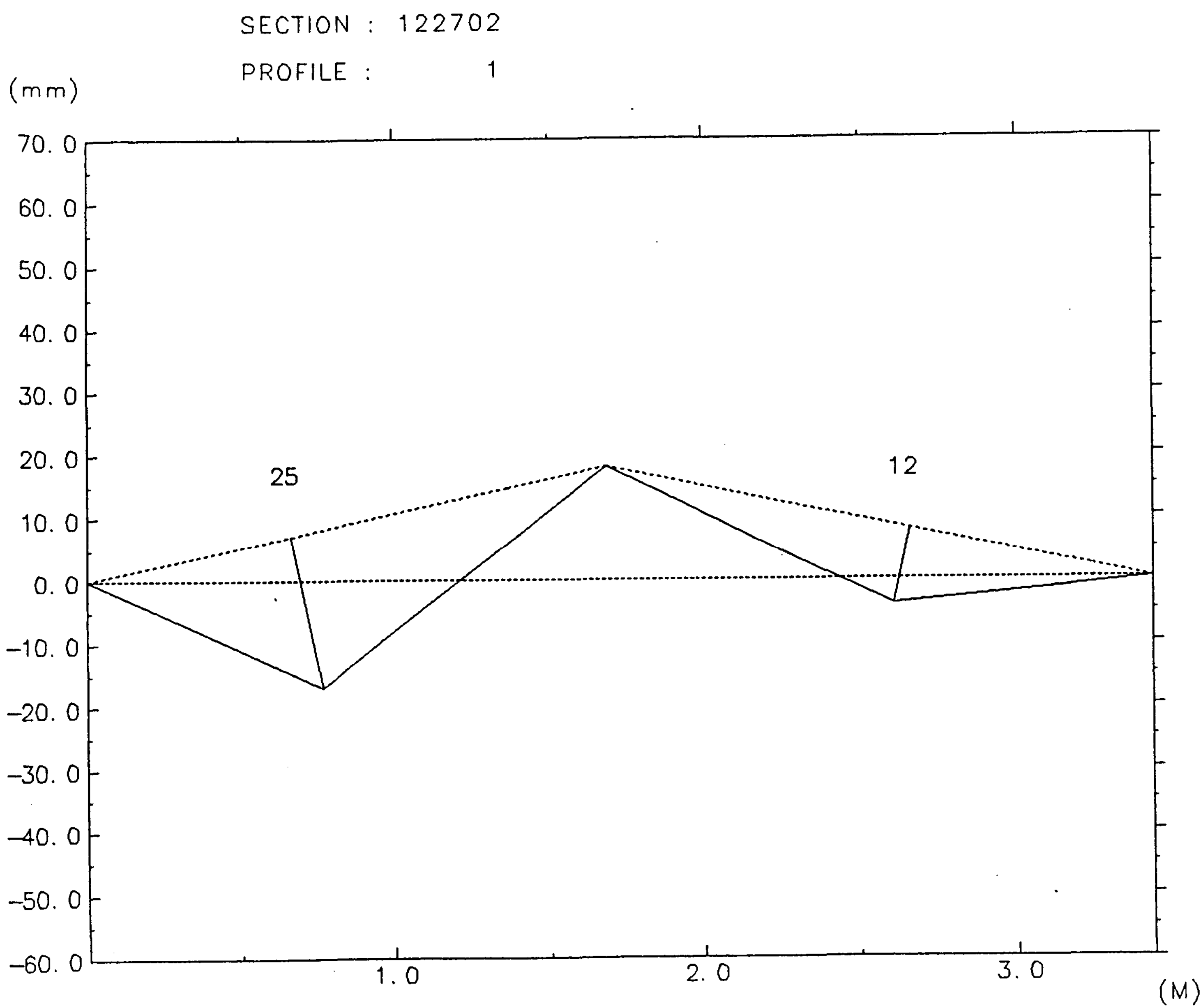

Figure 11. Rut Depth Plot - Unit #2 - B - 1

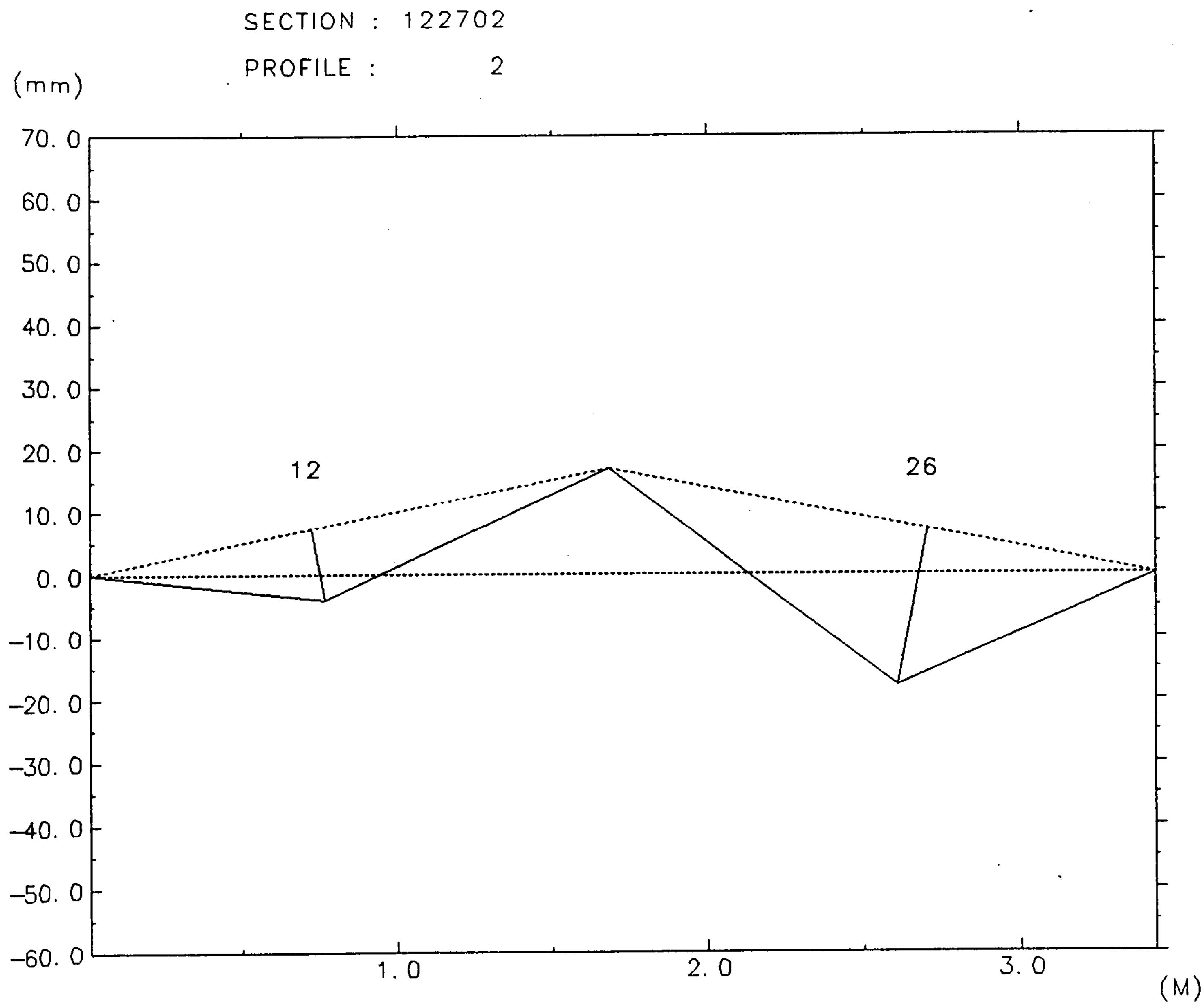

Figure 12. Rut Depth Plot - Unit #2 - B - 2

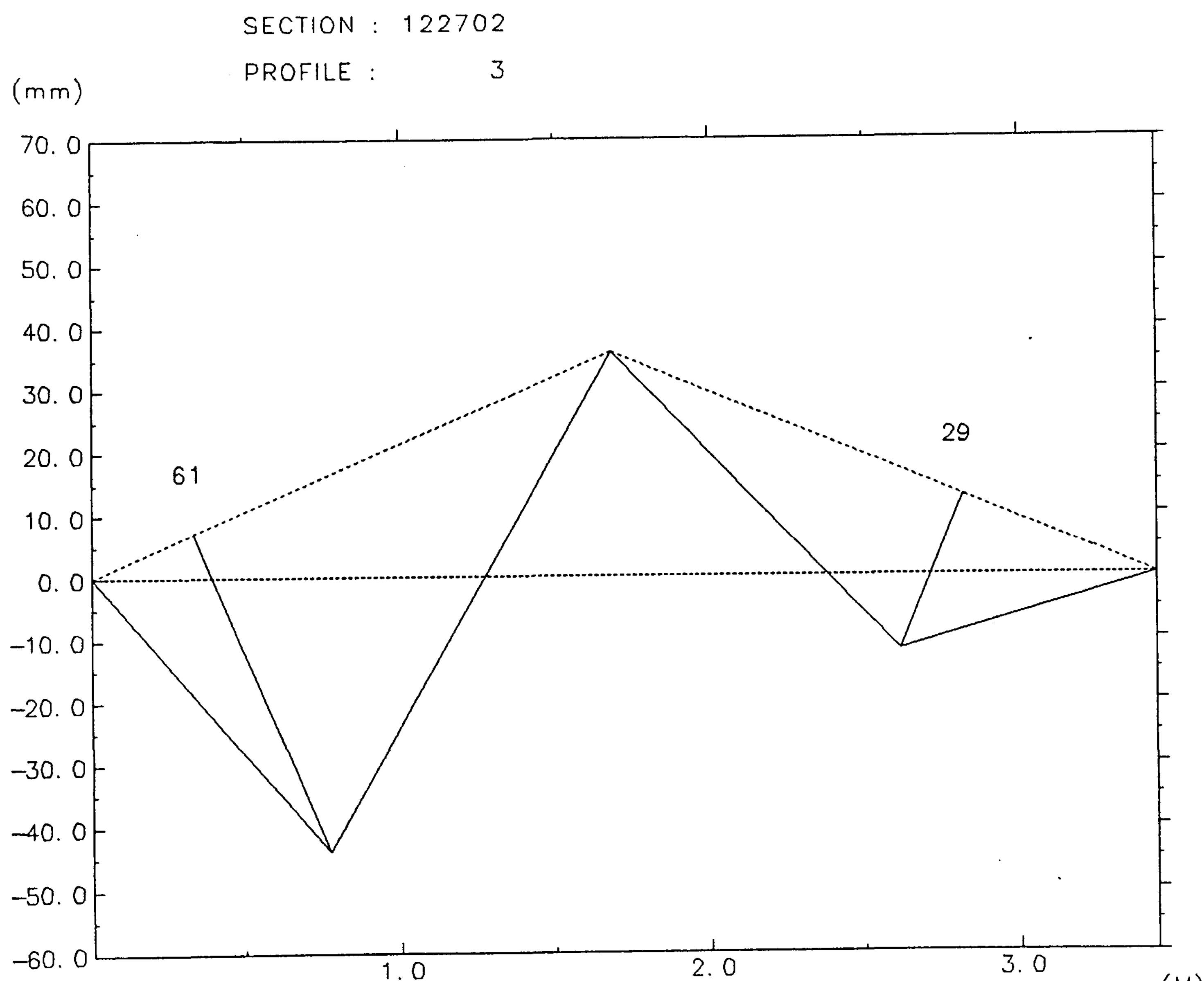

Figure 13. Rut Depth Plot - Unit #2 - B - 3

100

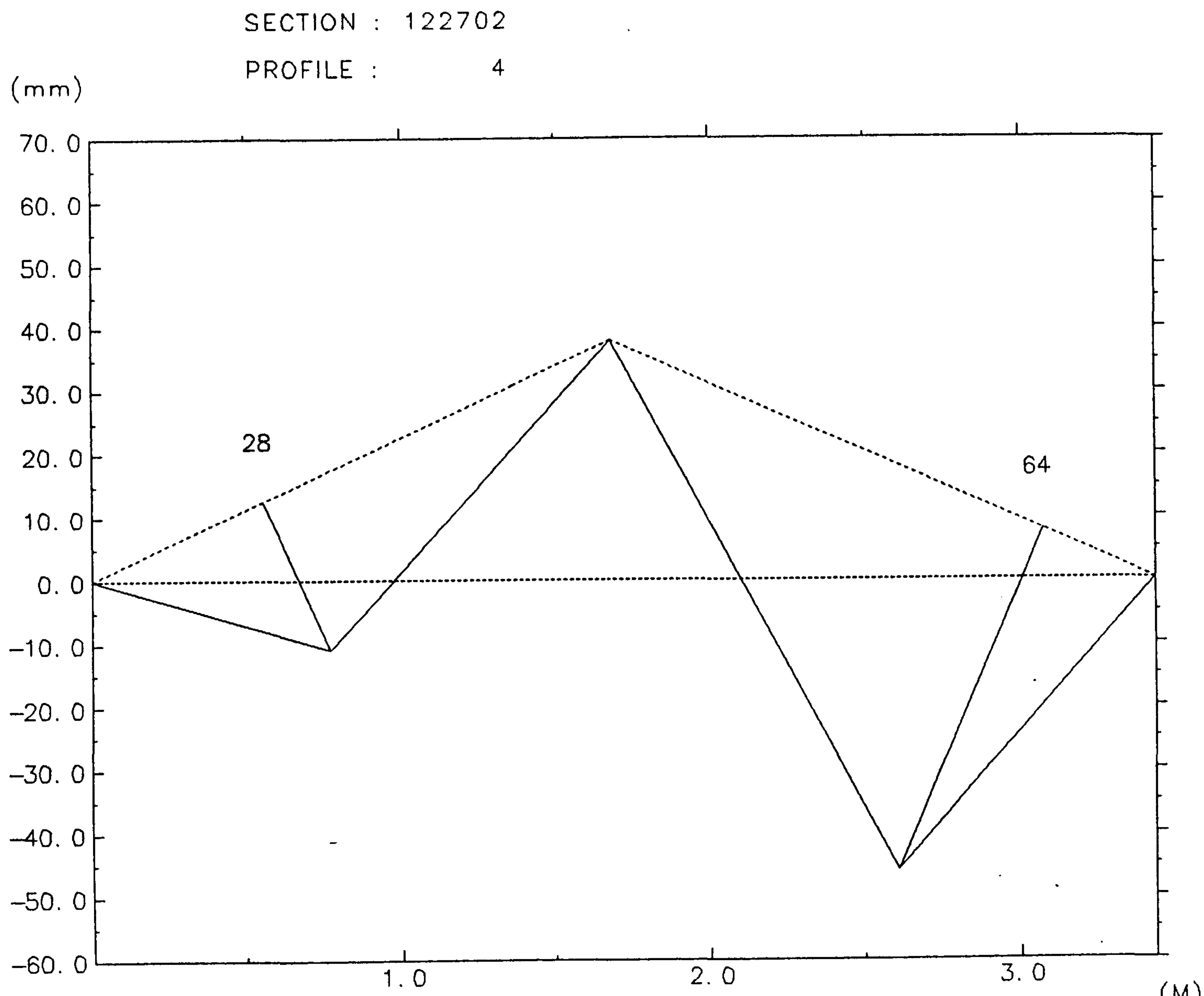

Figure 14. Rut Depth Plot - Unit #2 - B - 4

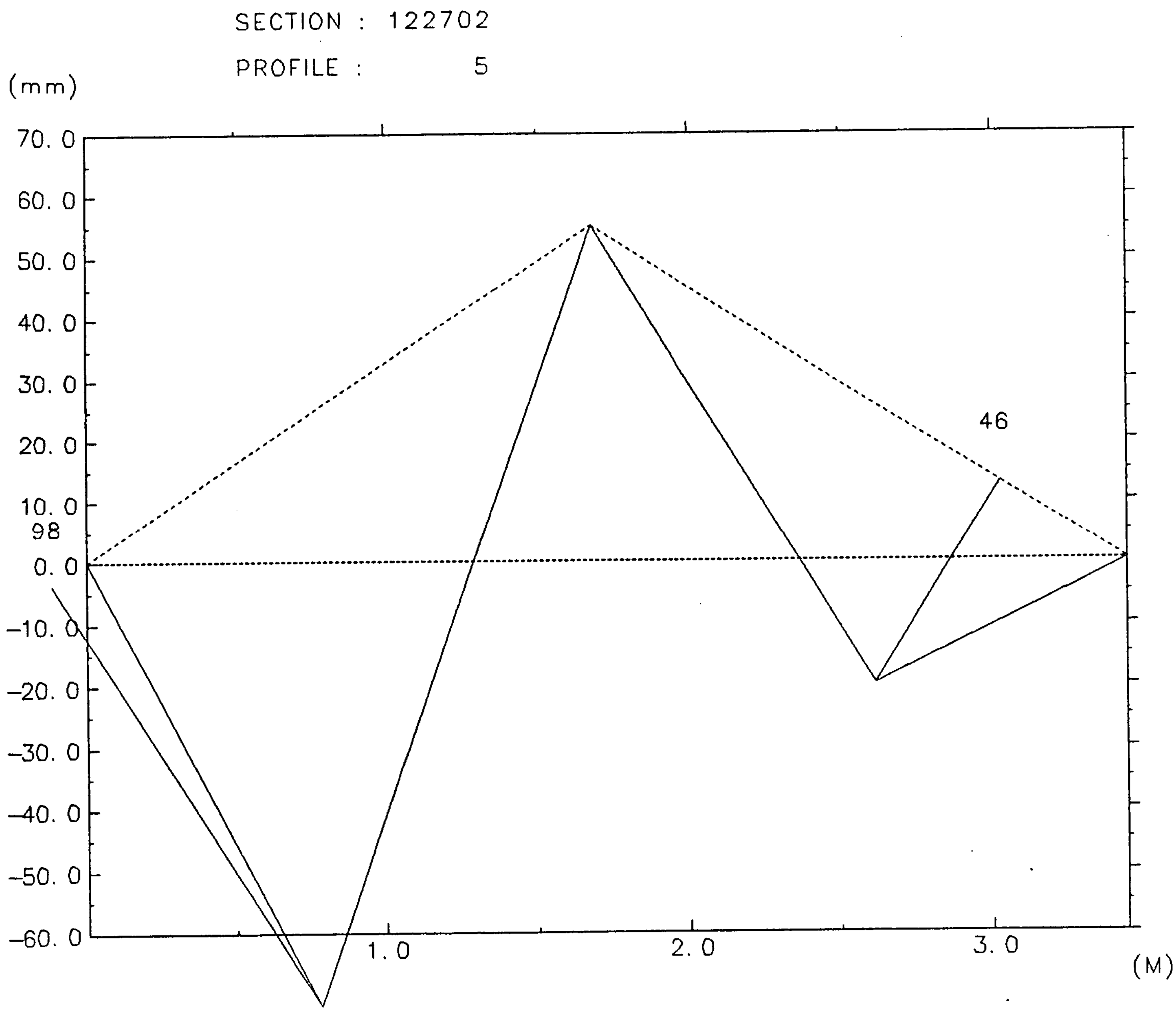

Figure 15. Rut Depth Plot - Unit #2 - B - 5

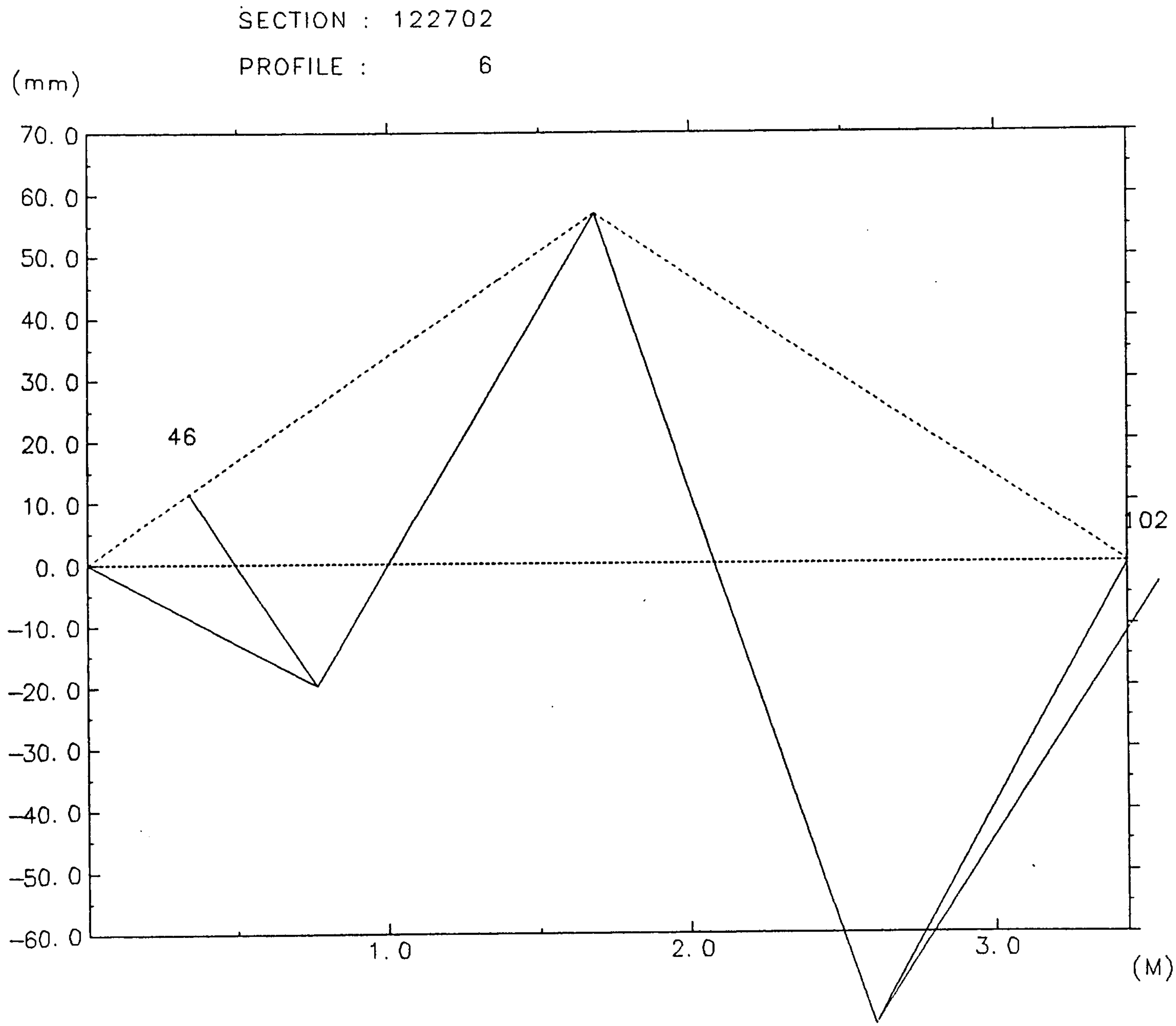

Figure 16. Rut Depth Plot - Unit #2 - B - 6

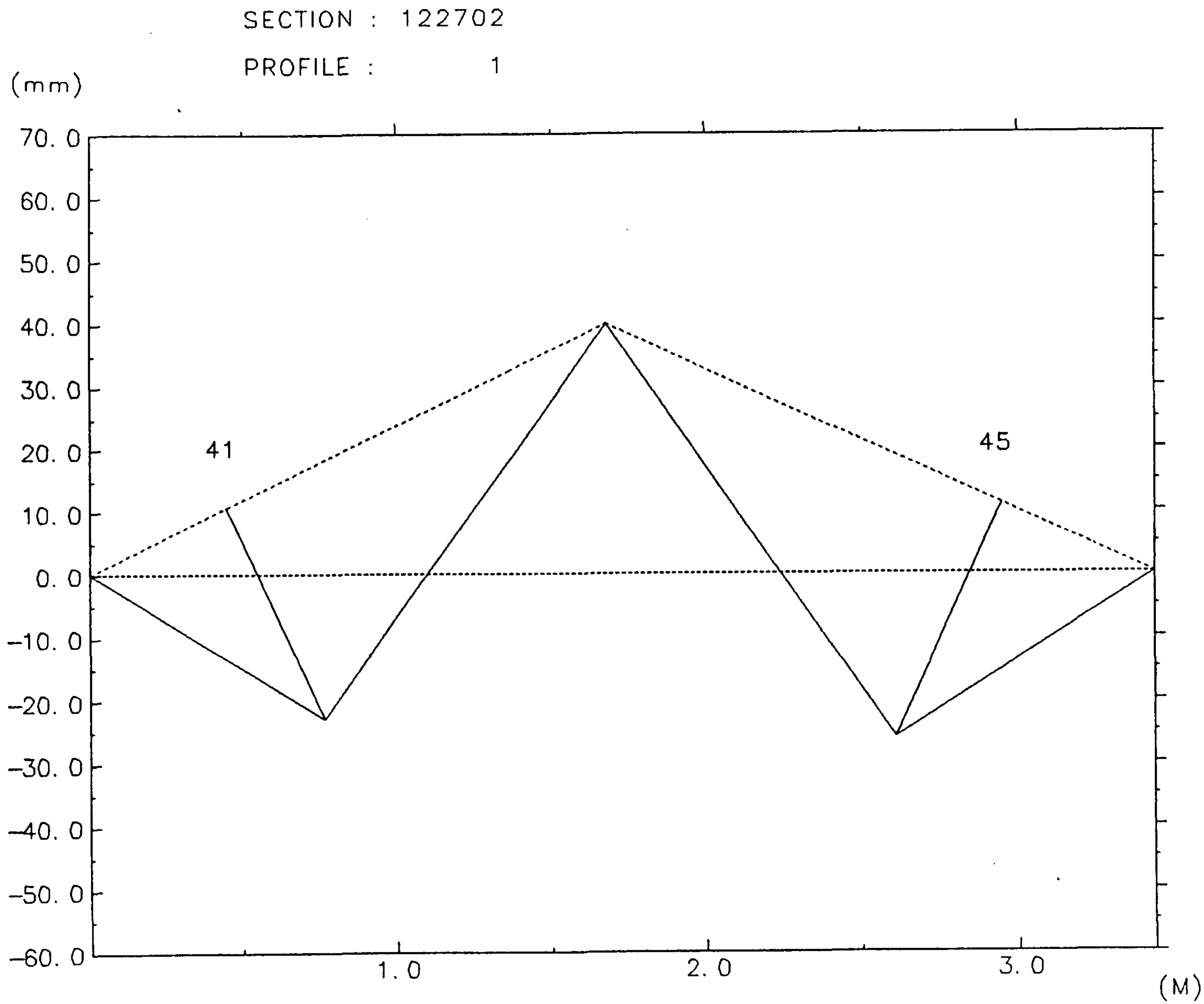

Figure 17. Rut Depth Plot - Unit #2 - C - 4

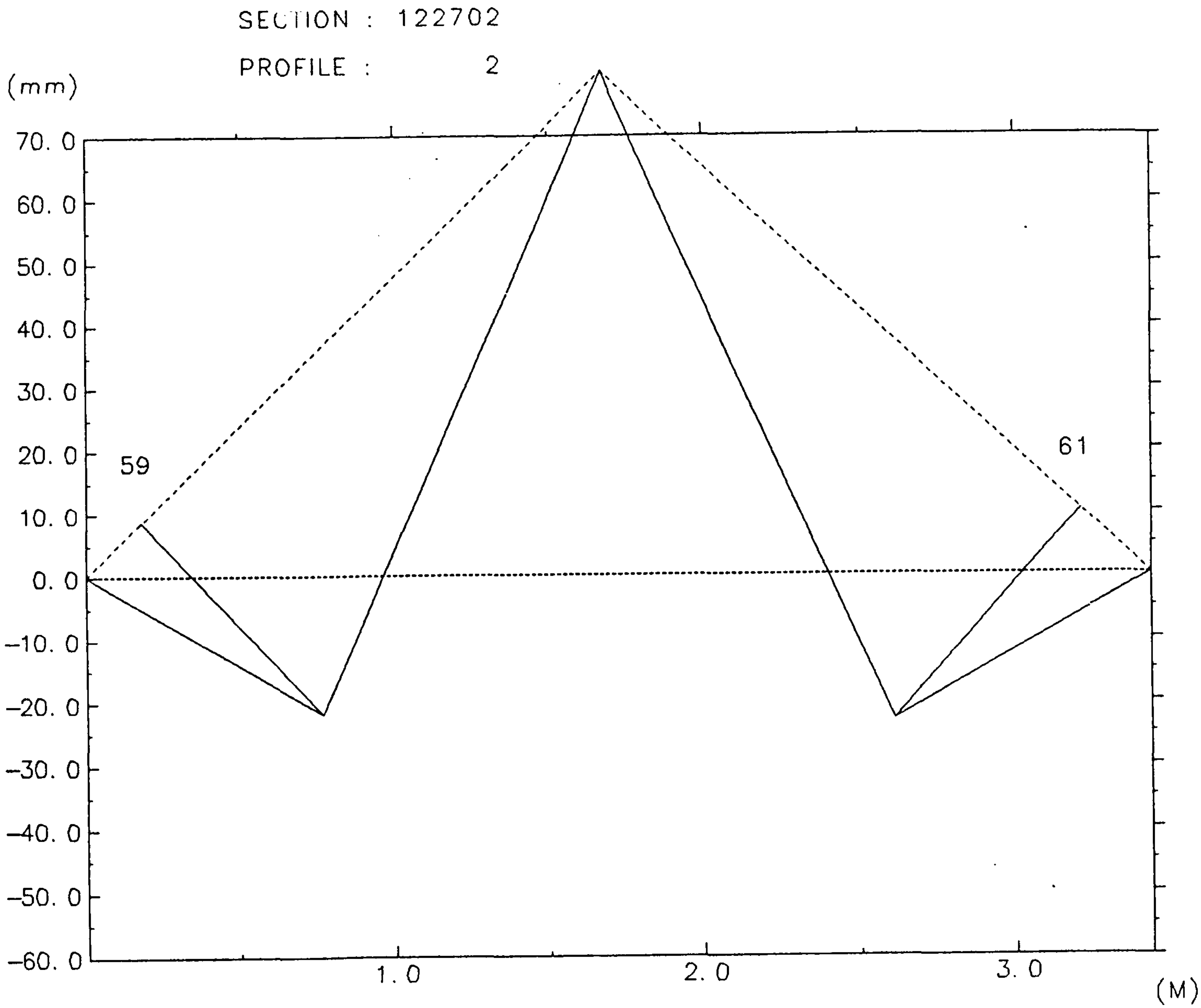

Figure 18. Rut Depth Plot - Unit #2 - C - 5

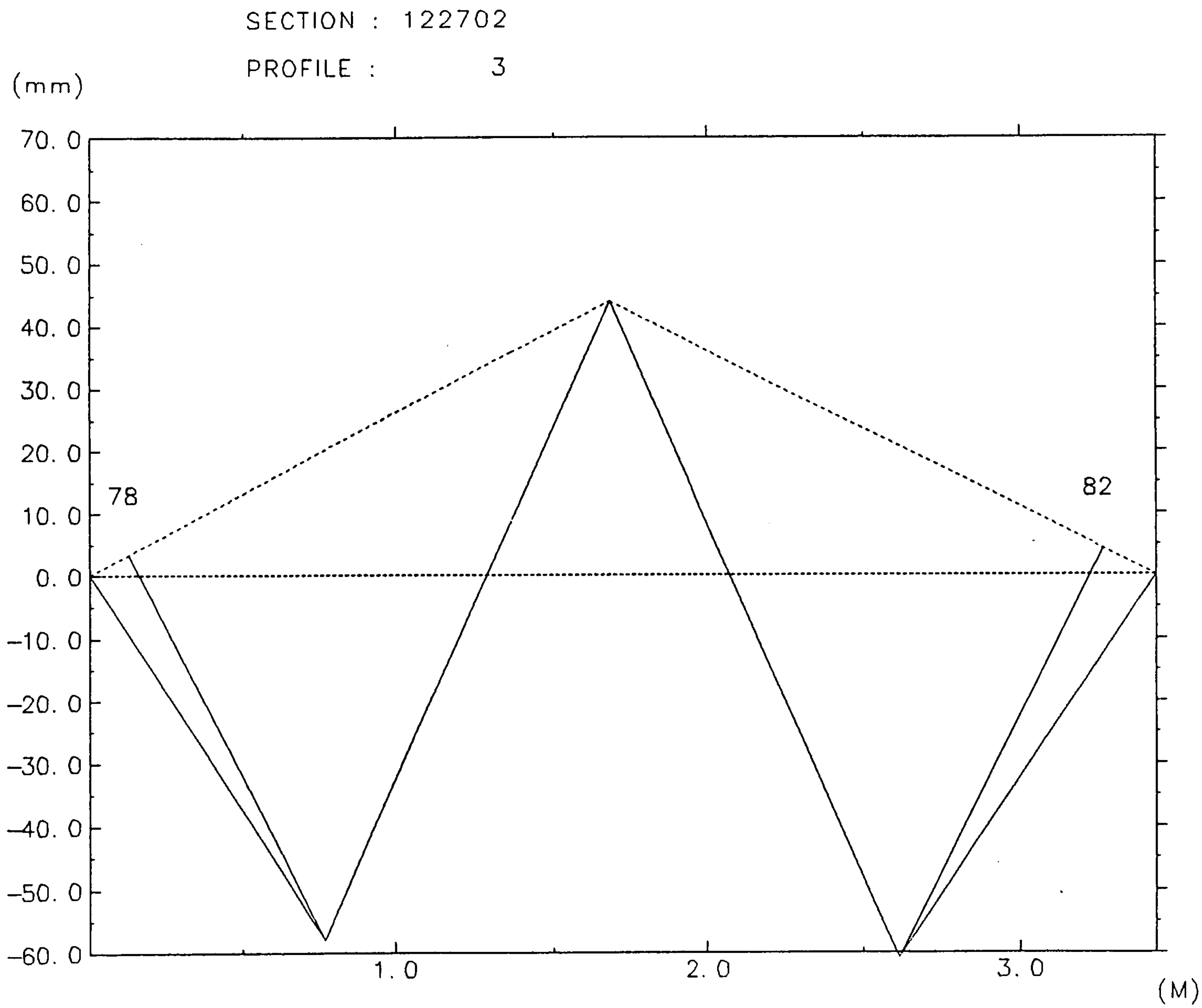

Figure 19. Rut Depth Plot - Unit #2 - C - 6

APPENDIX F

FIELD vs. DIGITIZED RUT DEPTH DATA

Comparison of RR-75 Plots and Measured Rut Depths, Five Sites.

Unit # 1 Date: 12/06/88

		Rut Depths (mm)			
		RR-75		Measured Values	
Section	Profile	Center	Soulder	Center	Shoulder
1	1	5	21	3	19
	2	4	20		
	3	4	19		
2	1	3	27	3	24
	2	3	25		
	3	3	28		
3	1	6	23	7	21
	2	8	23		
	3	8	23		
4	1	3	35	0	33
	2	3	34		
	3	3	33		
5	1	4	29	3	28
	2	4	30		
	3	3	29		
Average		4.27	26.6	4	25

Comparison of RR-75 Plots and Measured Rut Depths, Five Sites.

Unit # 2 Date: 12/06/88

		Rut Depths (mm)			
		RR-75		Measured Values	
Section	Profile	Center	Soulder	Center	Shoulder
1	1	3	21	3	19
	2	3	21		
	3	4	21		
2	1	3	28	3	24
	2	3	27		
	3	4	27		
3	1	8	24	7	21
	2	9	24		
	3	7	25		
4	1	3	35	0	33
	2	3	35		
	3	3	35		
5	1	4	30	3	28
	2	4	29		
	3	3	29		
Average		4.27	27.4	4	25

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