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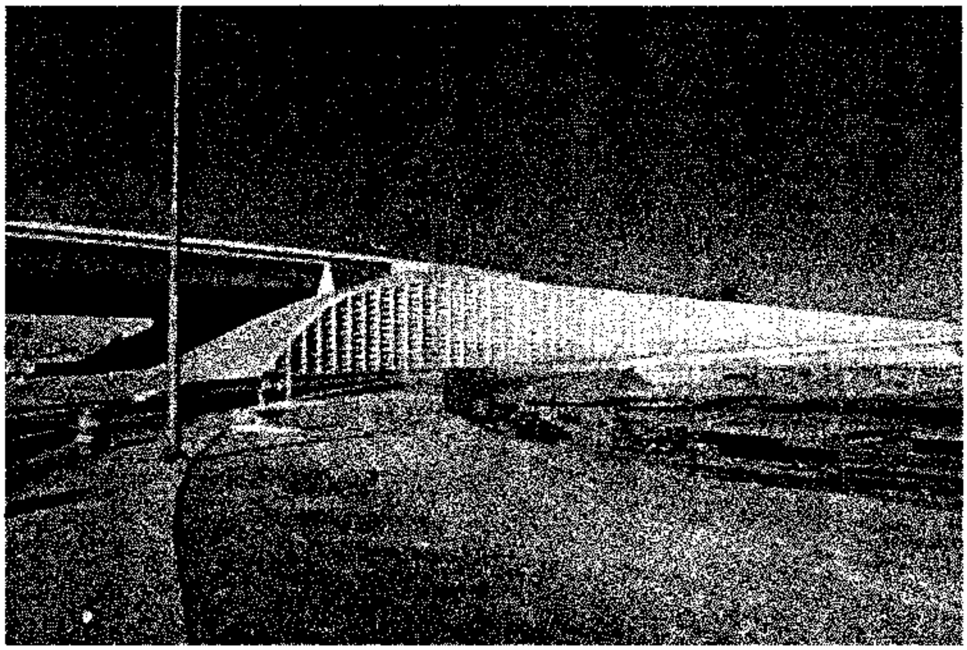
CONSULTANT'S REPORT
CORROSION EVALUATION OF MSE WALLS
I-515/FLAMINGO ROAD
LAS VEGAS, NEVADA

NDOT AGREEMENT NO. P068-04-020



Prepared for:

The Nevada Department of Transportation
Materials Division
Carson City, Nevada

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April 29, 2005

Project No. 04-005

Parviz Noori, P.E.
Nevada Department of Transportation
Materials Division
1263 South Stewart Street
Carson City, NV 89712

RE: Corrosion Evaluation Of Existing MSEW on the East Side of I-515 at the Northbound Flamingo Road On-Ramp, Las Vegas, Nevada; Agreement No. P068-04-020

Dear Mr. Noori:

In accordance with our agreement with the State of Nevada dated February 26, 2004, please find the attached report for the above referenced project. The report includes a summary of the study, results, conclusions and recommendations. Five appendices are attached to the report presenting details of our scope of services, backfill sampling and testing, assessment of reinforcement condition, corrosion monitoring, and estimation of remaining service life.

All three walls at the site appear to have experienced elevated levels of corrosion. These elevated levels of corrosion may be attributed to the aggressiveness of the backfill utilized on this project, and the presence of moisture within the backfill. If the aggressiveness of the backfill is recognized, the observed rate of corrosion is predictable and consistent with estimates of metal loss from mathematical models of service-life, and observations available in the literature describing the performance of plain steel reinforcements at other sites.

Considering the calculated reinforcement tension and loss of reinforcement capacity from corrosion, we estimate that some reinforcements along Walls #2 and #3 are stressed to between 0.69 and 0.78 times the yield stress. This exceeds the allowable working stress considered for design of MSE walls. We recommend that NDOT implement retrofit measures for these walls, or otherwise remove these walls from service.

A reasonable comparison between direct physical observation of metal loss and corrosion monitoring with nondestructive tests was observed. This demonstrates that nondestructive testing with the FHWA Polarization Resistance (PR) monitor (described in the report) provides a means to evaluate the condition of MSE walls and observe elevated levels of corrosion.

We recommend that corrosion monitoring using the PR monitor be continued at the I-515/Flamingo Road site to document the variation of corrosion rate with respect to time, and establish a baseline of corrosion rate measurements. The data developed from the I-515/Flamingo Road site could be used with the PR test to identify other walls that may be experiencing elevated levels of corrosion, perform additional corrosion monitoring at selected sites, identify sources of backfill that may be problematic, and conditions related to wall construction that could adversely affect service-life.

Please call if you have any questions or comments regarding the report, results from condition assessment and corrosion monitoring, or our recommendations.

Very truly yours,

McMahon & Mann Consulting Engineers, P.C.

Kenneth L. Fishman

Kenneth L. Fishman, Ph.D., P.E.
Principal

Attachment

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I. INTRODUCTION

In 1985, three metallically stabilized earth (MSE) retaining walls were constructed along the East Side of I-515 beginning at the Northbound Flamingo Road on-ramp, in Las Vegas, Nevada. These walls were constructed as part of the Nevada Department of Transportation (NDOT) Project Number F-095-1(2). Figure 1 is a vicinity map showing the site location. Figure 2 shows a detail of the wall system, supplied by Hilfiker Retaining Walls (Hilfiker), which incorporates welded wire fabric as soil reinforcement. Hilfiker used cold drawn steel wire (ASTM A 82) to fabricate the welded wire fabric, which was not galvanized for this particular project.

In response to concerns over excessive noise, NDOT planned to construct sound barriers along the east edge of I-515's northbound lanes between Flamingo Road and Desert Inn Road (NDOT Project Number EA 72993 (9)). One of the planned sound walls was a twelve feet tall, integrated slab/soundwall, founded on MSE fill just north of the Flamingo Road/I-515 intersection. During January 2004, a shallow excavation for this sound wall foundation exposed reinforcements near the top of the existing MSE wall, and corrosion was observed. The NDOT was concerned about the remaining service-life of the reinforcements, and the need to demonstrate a service life of 75 years for the new sound wall and MSE wall system. Based on these concerns, the NDOT decided to assess the condition of the reinforcements and implemented corrosion monitoring at the site.

After initial fieldwork was performed under the supervision of the FHWA, the Nevada DOT contracted with McMahon and Mann Consulting Engineers, P.C. (MMCE) to perform a condition assessment of the MSE walls at this site and estimate the remaining useful service-life of the metallic reinforcements. This report describes the scope of services performed by MMCE, results of our condition assessment, conclusions regarding the expected service-life of reinforcements and the need for further monitoring. Appendix I describes items that NDOT provided to MMCE in support of the study, and a detailed description of MMCE's scope of services.

A. MSE Wall Details

As shown in Figure 2, a typical reinforcement is 4 feet ten-inches wide and includes ten longitudinal wires spaced approximately six inches center to center on either side of a ten-inch gap through the center of the reinforcement. The longitudinal wires are tied together with transverse wires spaced approximately 2 feet center to center to create a bar mat. Each of the transverse and longitudinal wire intersections is spot welded, and a plate including steel pin connectors is welded to the proximal end of each grid for attachment to the wall facing units. Longitudinal wire sizes vary from W7 to W14, and transverse wires are either W7 or W9.5.

Typical precast concrete wall panels are 12.5 feet long and 2 feet high. Each unit contains two column sections located approximately 3' 1 ½" from each end. Panels are stacked during construction and are separated by an approximate ½ inch gap. Widened sections along the top and bottom portion of the panels facilitate attachment of soil reinforcements. Plans call for a nonwoven geotextile to cover the vertical panel joints, but a slit film, woven geotextile was observed in the field. Grids are spaced behind the wall facing such that a grid spans across each panel joint, with one grid in the center of the panel separated by an approximately 1' 5 " inches gap. Thus, the area of the backfill behind the wall columns defines a space that is not covered by soil reinforcement.

Figure 3 (a) is a site plan depicting the alignment of the MSE walls. Points at the site are located with reference to the "Pe" line, which is the centerline of I-515, or with respect to the "F1" line, which is along the shoulder of the on-ramp from westbound Flamingo Road to northbound I-515.

Three MSE walls are identified in Figure 3(a) including Walls #1 and #2 along the Northbound Flamingo Road on-ramp, and Wall #3, which is North of the Viking Road/I-515 intersection, along the east side of the I-515 highway embankment. Wall #1 supports the approach to the I-515 viaduct crossing Flamingo Road. Wall #2 is beneath Wall #1 and supports the northbound on-ramp from Flamingo Road. Wall #3 supports the highway embankment, and although the height of the wall facing is less than twelve feet, the wall supports a sloping backfill that extends twenty to thirty feet above the top of the wall facing to the crest of the embankment.

Wall #1 is the largest of the three at 800 feet long with a maximum height of 32 feet and soil reinforcement lengths that vary from 11 feet to 23 feet. Plans for locating a sound wall on top of Wall # 1 include a shallow foundation integrated with the pavement slab. Corroded reinforcements were observed during construction activities related to construction of the integral footing for the sound wall atop Wall #1.

II. APPROACH TO METAL-LOSS STUDY

The objectives of the study are to assess factors that contribute to corrosion and estimate the remaining service life of the MSE walls at the site. In general, the approach to the metal loss study involves the following steps:

1. Sample, test, and evaluate the aggressiveness of the MSE backfill relative to corrosion.
2. Observe the condition of reinforcements at the site with direct physical observations supplemented with results from nondestructive tests (NDT),
3. Identify existing mathematical models of service-life and verify their ability to describe the observed metal loss given the aggressiveness of the backfill determined in Step (1) and observations of metal loss made in Step (2).
4. Compute tensions in the reinforcements and estimate the remaining service-life using service-life prediction models that have been verified in Step (3).
5. Propose a protocol that can be used for evaluation and condition assessment of reinforcements at other MSE sites in the Las Vegas, NV area.

A. Subsurface Exploration and Soil Sampling

Soils at the site were sampled from (1) shallow excavations (test pits) and (2) soil borings advanced behind the wall facing, and (3) access holes advanced through the MSE wall facing. Shallow excavations were used to observe materials within the pavement structure, backfill within the top five or six feet of the MSE wall, and the first three layers of soil reinforcement. Soil borings advanced behind Wall #1 allowed pavement materials, MSE backfill and native soils to be sampled to depths of approximately 40 feet from the top of the wall. Additional MSE backfill samples were obtained by chipping holes through the MSE concrete wall face during preparation of corrosion monitoring sites. Appendix II presents details of the sampling locations, which are shown on Figures 3(b), (c) and (d).

B. Backfill Testing

The following tests were used to evaluate the characteristics and properties of the backfill:

- Sieve Analysis
- Moisture Content
- pH
- Resistivity
- Sulfate Ion Concentration
- Chloride Ion Concentration

Forty-three samples were included in the test program as described in Appendix II.

C. Observation of Reinforcements

Test pits TP-2 through TP-11 were used to observe the top three layers of MSE reinforcements, and retrieve samples for direct physical observation and metallurgical analysis. Appendix III describes details of test pit locations and reinforcement samples, measurements of metal loss and remaining grid capacity, and metallurgical studies of wire specimens extracted from the reinforcements.

D. Corrosion Monitoring

Corrosion monitoring on this project includes measurement of half-cell potential and corrosion rate of in-service reinforcements and "dummy" coupons. Measurements of corrosion rate were performed using the FHWA's PR MONITOR (Polarization Resistance Monitor PR4500 Operating Manual, 1999), which is an instrument specifically designed to measure polarization resistance of a corroding electrochemical interface. These measurements require electrical connections to reinforcements and placement of a standard reference electrode for monitoring potentials. Therefore, corrosion monitoring points must be established whereby reinforcements are wired for monitoring and access is provided for reference electrodes. Appendix IV describes details of the corrosion monitoring points and the half-cell potential and corrosion rate measurements. Corrosion monitoring sites (S1 though S19) are shown on Figures 3(b), (c) and (d). Forty-five reinforcements were wired for monitoring, and twenty-seven steel coupons and nine galvanized coupons were distributed within the backfill along Walls #1, #2, and #3.

III. RESULTS

A. Site Details and Soil Profile

Details of the test borings and interpretation of subsurface conditions are described in the report "Geotechnical Exploration Report MSE Wall Remediation I-515 at Flamingo Road (North Bound Entrance), Clark County, Nevada, revised June 8, 2004 and prepared by Terracon. Salient details describing the MSE backfill are repeated here, in addition to conditions that may impact the backfill.

The area behind the crest of Wall #1 is relatively flat and includes the pavement for I-515. The pavement structure sits atop the MSE backfill and includes a 10-inch thick Portland Cement Concrete (PCC) surface, and a 10-inch thick processed aggregate base coarse. An approximately 10 to 30 inch thick embankment cap, described as clayey sand with gravel, is found beneath the pavement structure. Beneath the cap is the MSE backfill, which is well-graded silty, sand with fine gravel. The cap and MSE backfill were slightly moist to moist and generally medium dense to dense in consistency. Below the top layer, reinforcements are placed within the MSE backfill, but possibly the top layer is located within the embankment cap. According to Terracon, the MSE backfill is characteristic of screened aggregate derived from Las Vegas Valley concrete and aggregate sources, whereas the cap and embankment material are characteristic of natural soils encountered in the Las Vegas Valley.

Similar MSE backfill conditions were encountered in the test pits advanced behind Walls #2 and #3. These walls retain the sloped highway embankment, covered with an approximately six-inch thick concrete slope paving. The pavement structure is located behind the embankment slope and beyond the limits of the MSE backfill at many locations.

Drainage for the pavement structure includes a number of drainage inlets located behind the retaining wall as shown in Figures 3(a), (b) and (c). Test Station #4 is located near a drainage inlet denoted DI-6. A reinforced concrete drainage pipe (RCP) runs between the drainage inlets along Wall #1 (DI-4, DI-5, DI-6 and DI-7). The depth of this drainage pipe ranges from approximately three to nine feet beneath the pavement surface. Test Station #10 is located near a drainage inlet denoted DI-4 behind Wall #2. These drainage facilities may have been a source of moisture within the backfill.

B. Backfill Test Results

Appendix II includes details from laboratory testing on forty-three backfill samples retrieved from the site. All of the samples discussed in this report are for MSE backfill. A few tests were performed on the embankment cap material, and, with the exception of the grain size analysis, these results are similar to those for the MSE backfill. Test data include grain size analysis, and measurements of moisture content, chloride and sulfate concentration, pH and resistivity. In general, the data suggest that the backfill is very aggressive relative to corrosion as discussed in Section IV(A).

Results from grain size analysis indicate that relatively coarser, more uniform, backfill is placed in proximity to the wall face. Samples retrieved further from the wall face appear to include a greater finer faction as indicated by the percent passing the No. 8 sieve. It appears that the backfill material ranges from a poorly graded sand in proximity to the wall face, becoming a poorly graded silty, sand at some distance behind the wall face. A possible scenario is that a uniform size backfill was placed near the wall face to minimize the required compaction effort. During construction, use of heavy compaction equipment near the wall face of a retaining wall must be avoided, so using uniformly graded, processed aggregate near the wall face is an attractive alternative. However, this practice can have an adverse effect on the vulnerability of the reinforcements to corrosion. The change in gradation and density, corresponding to differences in the porosity of the backfill, promotes development of macrocells due to differences in oxygen and moisture conditions. Development of these macrocells can promote corrosion of the reinforcements.

The observed moisture content of the samples ranges from one to thirteen percent with a median of six percent. These measurements appear to have a random spatial variation. If we assume that the density or porosity of the backfill varies with respect to uniformity of gradation, these data suggest that the degree of saturation varies with respect to distance from the wall face. Assuming approximate densities of 100 pounds per cubic foot (pcf) and 120 pcf for material closer to, and further from, the wall face renders an estimated degree of saturation of approximately 25% and 40%, respectively. The possibility for the degree of saturation to vary over time in response to infiltration from storm events also exists. Moisture may infiltrate into the backfill through the pavement subdrain described in Section III(A).

The measured electrochemical parameters including pH, resistivity, sulfates and chlorides also appear to have a random spatial variation. The measured pH indicates that the backfill is alkaline with a minimum, maximum and median measurement of 8, 10 and 9, respectively. Salt concentrations are observed in terms of chloride and sulfate ion concentrations. Chloride concentrations are slightly elevated at several locations (>50 ppm), and the measured sulfate concentrations range from less than 200 parts per million (ppm) to 9075 ppm with a median of 660 ppm. The median measured resistivity is approximately 1000 Ω-cm. Generally, soil resistivity is inversely proportional to salt concentration, and these measurements compare very well with published correlations between resistivity and sulfate concentration (NACE, 2001; Rehm, 1980).

adhered to the wire samples; observation of the steel microstructure; and, mechanical testing including hardness and tension tests on selected wire samples. These results indicate that the relatively high rate of corrosion observed at the site is likely due to conditions within the backfill, and may not be attributed to any particular anomaly associated with the steel wire used to reinforce the backfill.

Three distinct products adhered to the wires were analyzed using the scanning electron microscope with energy dispersive x-ray spectroscopy techniques combined with x-ray diffraction investigation. Black and red corrosion products were identified as magnetite (Fe_3O_4) and hematite or ferric oxide (Fe_2O_3), respectively. A third, whitish, material adhered to the wires was identified as dolomite ($CaMg(CO_3)$). The dolomite is most likely the result of condensation of minerals present within the aggregate backfill. Another interesting result was the detection of significant concentrations of chlorine and sulfur within the red corrosion product (hematite). The fact that dolomites, chlorines and sulfur materials are present means that, at some time, enough moisture was present within the backfill to cause the corresponding minerals to dissolve before condensing or precipitating on the wires.

No other anomalies or abnormalities were observed with respect to the steel composition, structure, hardness or tensile strength.

D. Corrosion Rate Measurements

Appendix IV includes a summary of corrosion rate measurements, obtained with the PR monitor, for each of the monitoring points established along Walls #1, #2 and #3. The range, average, and distribution of corrosion rates measured for reinforcements within Walls #1, 2 and #3 are similar. Corrosion rate measurements range from 0.75 μm/yr to 76 μm/yr. On average the corrosion rates observed in March (μ = 11.8 μm/yr, σ = 13.9 μm/yr) were higher than those obtained in August (μ = 8.9 μm/yr, σ = 8.6μm/yr). The corrosion rate measured with the PR monitor corresponds to a uniform corrosion rate at an instant in time. Thus, corrosion rates measured with the PR monitor compare reasonably well with direct observation of uniform metal loss as discussed in Section III (C).

In particular, significantly higher rates of corrosion were observed during March in the vicinity of drainage facilities located within the backfill behind Wall #1. The area behind Wall #1 was capped with flowable fill in February 2004 and may have still been relatively moist in March of 2004. However, by August 2004 the backfill may have lost moisture, due to lack of recharge, increasing the transient resistivity of the backfill and affecting a lower corrosion rate. Higher corrosion rates were also observed behind Wall #2 in the vicinity of a drainage inlet (DI-4).

Observed corrosion potentials appear to correlate well with respect to station. Most of the reinforcement corrosion potentials are in the range associated with corroded steel surfaces. Half-cell potential for steel coupons are lower than those for reinforcements, and are expected to increase as coupons corrode over time. Also, the half-cell potentials of galvanized steel coupons are lower (more negative) than steel coupons installed at the same location. The half-cell potential of the zinc coupons will increase as the zinc is consumed. Future monitoring of galvanized and steel coupons will be useful for documenting the durability of zinc coating in this environment.

On average, the corrosion rate measured for steel coupons was similar to that for the steel reinforcements. At stations where corrosion rates of galvanized coupons and steel coupons could be compared, similar corrosion rates were observed.

IV. DISCUSSION

A. Corrosiveness of Backfill

Generally, ground conditions are considered aggressive if the resistivity of the backfill is less than 2000 Ω-cm and if sulfates and chlorides are present in sufficient quantities. Chloride concentrations above 50 ppm and sulfate concentrations higher than approximately 200 ppm to 500 ppm are cause for concern (Rehm, 1980). The following table provides general measures of corrosion potential based on the results of resistivity testing (NACE, 1985).

Corrosiveness of Soils (NACE, 1985)

Corrosiveness	Resistivity (Ω-cm)
Very Corrosive	0 to 1000
Corrosive	1000 to 2000
Mildly Corrosive	2000-10000
Progressively Less Corrosive/Noncorrosive	>10000

Based on the resistivity (1000 Ω-cm) and sulfate ion concentrations (700 ppm) measured on the samples, the backfill at the I-515/Flamingo Road site is considered very corrosive in terms of established measures of corrosion potential.

B. Corrosion Mechanism

Corrosion of metal buried in soil depends on the presence of an electrolyte because electricity must flow from anodic areas, which lose metal atoms, to cathodic areas that collect them. Corrosion cells can be formed by micro-irregularities in the metal surface, such as a variation in crystalline structure, the presence of an impurity, or even a trace amount of oxide. These micro-irregularities exhibit micro-differences in electrical potential, causing metal ions to leave the anode, flow through the electrolyte, and be deposited on the cathode. The circuit is completed by the electrons returning to the anode through the body of the metal.

also observed, which indicates that corrosion activity has been going on for a relatively long period, since this is one of the last corrosion products to form.

C. Corrosion Rate

Several models are available in the literature for computing metal loss and rate of corrosion applicable to MSE reinforcements. Constants for describing corrosion rate are based on electrochemical parameters measured for the MSE backfill such that corrosion rates and metal loss may be computed for normal, moderate and aggressive backfill environments. In 1984, CALTRANS implemented the following metal loss model in their Interim Design Criteria for considering durability of plain steel reinforcements (Jackura et al., 1987):

$$\mathbf{A = (D\text{-}2K(Y\text{-}C))^2/D^2 \times 100\%} \qquad (1)$$

where,

A = % of the original cross-sectional area remaining
D = Original diameter, (inches)
Y = Time of exposure, years
K= General Corrosion Rate factor (K=0.0028 for corrosive backfill, and 0.0011 for alkaline soils with R > 1000 Ω-cm)
C = Useful life of Coating, years (For Bare Steel, C=0).

Equation (1) accounts for localized corrosion and can be used to compare with the remaining capacity observed for reinforcements described in Section III (C). According to the shop drawings, the smallest wire size used at the I-515/ Flamingo Road site is W7, corresponding to an original diameter, D, of 0.298 inches. Calculations with Equation (1) predict that 40 percent of the original cross sectional area remains after 20 years of service at the site. Considering a mean remaining wire diameter at critical locations of 0.183 inches, the remaining capacity (μ = 38% = $(0.183)^2/(0.298)^2 \times 100\%$) observed from reinforcements exhumed at the I-515/Flamingo Road site compares very well with expectations based on use of Equation (1). If backfill conditions at the I-515/Flamingo Road site are assumed to be nonaggressive, Equation (1) predicts that approximately 73 percent of the original cross section would remain after twenty years of service, and the remaining cross section would not degrade to 40 percent of the original until reaching a service life of fifty years.

Corrosion rate measured with the PR monitor may also be compared with expectations based on an "idealized" uniform loss of cross section. This comparison must also consider that the PR monitor provides an instantaneous measure of the corrosion rate. The possibility that corrosion rates were higher at an earlier point in time may be considered with an appropriate mathematical model for uniform corrosion rate.

Based on the work of Romanoff (1957), the following uniform corrosion rate model is proposed for steel reinforcements in aggressive ground conditions (Elias, 1997):

$$X= 40t^{0.8} \tag{2}$$

and,

$$r = 0.8\ (40)\ t^{(-0.2)} \tag{3}$$

where,

X = metal loss, i.e. loss of radius (μm),
t= time (years), and
r = corrosion rate (μm/year)

Equation (3) renders a corrosion rate of 17 μm/year at t= 20 years. This compares reasonably well with the average corrosion rate measured with the PR monitor (12 μm/year). Thus, it appears the measurements obtained with the PR monitor are consistent with direct physical observations at the I-515/Flamingo Road site, and expectations based on corrosion rate models applicable to aggressive backfill conditions. This demonstrates that, if interpreted properly, and with knowledge of age and type of reinforcements, corrosion rate measurements with the PR monitor may be used to identify unusually high rates of corrosion at a site. These interpretations should still be verified with direct physical observations on exhumed reinforcements. However, fewer destructive samples are needed if they are supplemented with NDT results from the PR monitor.

Using Equation (2), the expected uniform metal loss for reinforcements at the site is 0.017 inches (439 μm) after 20 years of service. The average loss of thickness at critical locations is 0.058 inches ((0.298-0.183)/2 = 0.058 inches). The mean of the uniform corrosion rate measurements obtain with the PP monitor is approximately 70% of the expected uniform rate using Equation (3). Thus, the ratio between the observed average of the maximum loss of wire thickness and the expected or observed uniform loss of thickness is between 3 and 5.

D. Computed Factors of Safety

The anticipated tensile forces in the reinforcement layers are computed using the stiffness method described by the FHWA (1989) and AASHTO (2002). Both static and seismic loading conditions are considered. The computed tensile forces (T_s and T_d) are compared to the estimated remaining capacity of the reinforcements assuming an allowable stress of $0.48f_y$. Calculations are not presented for Wall #1, which was retrofitted, and the original bar mats are no longer relied upon to carry the earth loads. Results from calculations for the tallest sections of Wall #2 (H= 27 feet at Sta. "Pe" 158+10) and #Wall 3 (H= 13 feet at Sta. "Pe" 165 +70) are presented in Appendix V. Both of these walls retain a sloping backfill.

In general, reinforcement sizes vary with depth (z) corresponding to the increase in computed tension, and a critical depth controls the selection of reinforcement size. According to the shop drawings for the project, W7 xW7 wire grid reinforcements are used to a depth of thirteen feet, W9.5 x W 9.5 grids are used between fifteen and twenty-three feet and W12 x W 9.5 grids are used below depths of twenty-three feet.

For Wall #2, the computed tension exceeds the allowable capacity of the corroded W7 x W7 reinforcements beneath a depth of five feet. Considering the average remaining diameter, the most highly stressed reinforcements are at a depth of thirteen feet where the estimated stress is 55ksi, corresponding to $0.78f_y$. Equation (1) is used to estimate the remaining capacity of W9.5x W9.5 and W12 x 9.5 reinforcements. Compared to the allowable stress of $0.48F_y$, the W9.5 x W 9.5 reinforcements are currently overstressed from z= 15 feet to z = 23 feet, but the W12 x W 9.5 reinforcements, beneath z = 23 feet, are not.

For Wall # 3 the computed tension exceeds the observed average remaining capacity of a W7 x W7 wire grid reinforcement beneath the depth of five feet. At the base of the wall, where the computed tension is highest, the stress in the reinforcements considering the average remaining diameter for a W7 x W7 reinforcement is 48 ksi, corresponding to $0.69f_y$.

Seismic loads consider peak ground acceleration equal to 0.15 g and Type II soil as specified in our agreement with NDOT. For seismic loading considerations, the allowable tensile load is increased by 33% as allowed by AASHTO (2002). According to the procedure described by FHWA (1989) and AASHTO (2002), seismic loads have a greater impact on the total computed tension near the top of the wall, where the demand from static loading is less. Thus, for the seismic parameters corresponding to the site, and considering the increased strength allowed for the seismic load case, consideration of seismic loading does not have a significant impact on remaining service life for the reinforcements at the site.

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. Summary

1. Based on results from laboratory testing of forty-three samples, the backfill at the site is considered to be very corrosive. Metallurgy tests conducted on samples of exhumed reinforcements reveal that the relatively high rate of corrosion observed at the site is likely due to conditions within the backfill, and may not be attributed to any particular anomaly associated with the reinforcements. The maximum metal loss observed along reinforcements exhumed from the test pits occurred at locations at least two feet behind the wall face. This observation is consistent with development of macrocells between the front and rear portions of the reinforcements; possibly due to variation in the porosity of backfill.

2. Direct observations of metal loss were made from twenty-two samples of corroded reinforcements exhumed from eleven test pits. These data are useful to assess the

nature of corrosion, loss of reinforcement capacity from corrosion, and the idealized uniform corrosion rate. All of the reinforcement samples were exhumed from depths within five feet from the top of the wall face. The PR monitor was used to monitor corrosion for reinforcements located at other depths.

3. The PR monitor was used to monitor idealized uniform corrosion rate for forty-five reinforcements distributed along Walls #1, #2 and #3. Thirty-six coupons were also installed and monitored to serve as a basis for comparison. These data are useful to: (a) assess the spatial distribution of corrosion severity, and (b) further assess backfill conditions, and serve as a guide for selecting appropriate parameters for corrosion rate models and estimating remaining service-life.

4. Data from the PR monitor indicate that corrosion is similar between Walls #1, #2 and #3 and similar corrosion rates are observed with respect to the top and bottom of the walls. Higher corrosion rates were observed in proximity to drainage structures placed within the backfill. Observations of reinforcement samples exhumed from test pits also indicate that Walls #1, #2 and #3 are in similar condition, and more metal loss is apparent for reinforcements exhumed near drainage structures.

5. The PR monitor measures uniform corrosion rate at an instant in time and does not render maximum loss of section, or directly provide an estimate of remaining service life. Results may be used to select or calibrate appropriate corrosion rate models for estimating existing condition and projecting loss of section. Estimated rates for idealized uniform corrosion are consistent between direct observations of exhumed reinforcements, measurements obtained with the PR monitor, and equations available in the literature. Based on these estimates, the average uniform loss of thickness (wire radius) after twenty years of service ranges from 0.010 inches to 0.017 inches, corresponding to a uniform corrosion rate of 0.0005 in/yr to 0.0008 in/yr (12 μm/yr to 20 μm/yr).

6. The average of the maximum metal losses observed at critical locations along the exhumed reinforcement samples corresponds to loss of thickness equal to 0.0575 inches. The maximum metal loss relates to the remaining grid capacity, which on average is approximately 38 percent of the original grid capacity (i.e. on average the reinforcements have lost 62% of their capacity from corrosion). This is consistent with design equations available in the literature for estimating the necessary thickness of sacrificial steel for reinforcements within a corrosive backfill environment.

7. The ratio between idealized uniform loss of thickness and the average of the maximum loss of thickness observed from these data ranges from 3 to 5. This is consistent with the statistical correlation for round bar elements cited in the literature (Romanoff, 1957; Jackura et al., 1987; Smith et al., 1996).

8. The allowable stress for welded wire fabric reinforcements is $0.48f_y$. Considering the calculated reinforcement tension and loss of reinforcement capacity from corrosion,

we calculate that, at the worst locations along Walls #2 and #3, the reinforcements are stressed between $0.69f_y$ and $0.78f_y$.

B. Conclusions

The highest remaining capacity observed from any of the reinforcement samples retrieved at the site is 63%, and on average the remaining capacity is 38% of the estimated original capacity of the reinforcements. Calculations of tension in the reinforcements for the MSE walls indicate that at some locations the computed reinforcement tension exceeds the allowable when metal loss from corrosion is considered. Essentially, the reinforcements are now in the condition anticipated at the end of 50 years, i.e. approximately two and a half times the anticipated corrosion rate (assuming that in 1984 the design objective was 50 years).

All three walls at the site appear to have experienced elevated levels of corrosion. These elevated levels of corrosion may be attributed to the aggressiveness of the backfill utilized on this project, and the presence of moisture within the backfill. If the aggressiveness of the backfill is recognized, the observed rate of corrosion is predictable and consistent with estimates of metal loss from mathematical models of service-life, and observation of the performance of plain steel reinforcements at other sites available in the literature.

A reasonable comparison between direct physical observation of metal loss and NDT was observed. Results from NDT must be interpreted carefully in terms of the age of the reinforcements, the tendency for corrosion rate to attenuate with respect to time, and the relationship between idealized uniform corrosion and loss of reinforcement capacity. Nondestructive testing with the PR monitor provides a means to evaluate the condition of MSE walls and determine if elevated levels of corrosion have occurred, if details of the reinforcements, wall construction and age of the wall are known. Results from NDT must be verified with direct physical observations, albeit less than would be necessary in the absence of NDT.

C. Recommendations

We recommend that NDOT conduct further studies of corrosion of MSE walls in the Las Vegas area to identify the extent of the corrosion problem, sources of backfill that may be problematic, and conditions related to wall construction that could contribute to elevated corrosion. Simple methods are needed to quickly assess the condition of an MSE wall, identify the need for retrofit and optimize resources expended for retrofit. Future efforts should include additional fieldwork, laboratory studies, and engineering analysis.

Additional Fieldwork

Corrosion monitoring should be continued at the I-515/Flamingo Road site to document the variation of corrosion rate with respect to time and establish a baseline of corrosion rate measurements. The baseline will serve as a useful comparison for corrosion monitoring at other MSE walls in the Las Vegas area. Steel and galvanized coupons placed at the site provide an opportunity to evaluate the performance of galvanized versus plain steel reinforcements in this environment. These observations will indicate if either metal becomes passivated.

The possibility exists for advanced corrosion and abbreviated service-lives for other MSE walls constructed in the Las Vegas area. Sites should be identified, screened and prioritized for corrosion monitoring and possible retrofit on the basis of backfill source and reinforcement details. The number of monitoring points must achieve a good statistical sampling of reinforcements at a site. If drainage facilities are incorporated within the MSE backfill, these locations should be identified and included in the monitoring program. Levels of humidity within the backfill should also be monitored and compared with measurements of corrosion rate.

At sites where elevated levels of corrosion are observed with the PR monitor, a limited number of reinforcement samples should be exhumed to check if the metal loss is predictable with available mathematical models of service-life. Compared to the I-515/Flamingo Road site, fewer test pits will be required at other sites, as confidence has been gained in the use of the PR monitor for identifying elevated levels of corrosion. Once verified, service-life prediction models and estimates of reinforcement demand may be applied to estimate remaining service life of reinforcements at a given site. Retrofit may be applied selectively at locations where it is necessary to achieve the desired service life. It may be possible that only a limited surface area of the wall face needs to be remediated to achieve a specified service-life. This could represent a considerable savings compared to a total retrofit of the wall system.

If continued observations of metal loss and corrosion rate are consistent with expectations, detailed monitoring may not be necessary at every site identified from the screening exercise. As more confidence is gained with the service-life prediction models, the level of corrosion monitoring may be reduced to a level needed as a check on estimated service life. Reduced monitoring might include installation of coupons and wiring of a few reinforcements at selected sites to monitor activity and compare with expectations. The effectiveness of implementing a limited amount of monitoring needs to be investigated. It may take several years to get stable readings and establish trends from coupons installed within the backfill.

Laboratory Studies

In addition to the field explorations, laboratory studies should be conducted to gain a better understanding of the corrosion mechanism and contributing factors. Supplies of reject concrete sand aggregate and other backfill sources common to the Las Vegas area should be evaluated in terms of electrochemical parameters known to correlate well with corrosion activity. Laboratory corrosion testing may be helpful to rank the aggressiveness of different backfill sources, estimate the effect of humidity on corrosion rate inherent in these materials, and better quantify the relationship between corrosion and the remaining tensile strength of reinforcements. Factors that contribute to the development of macrocells should be further investigated, and the effect that this may have on corrosion rate for the sources for backfill encountered in the Las Vegas area.

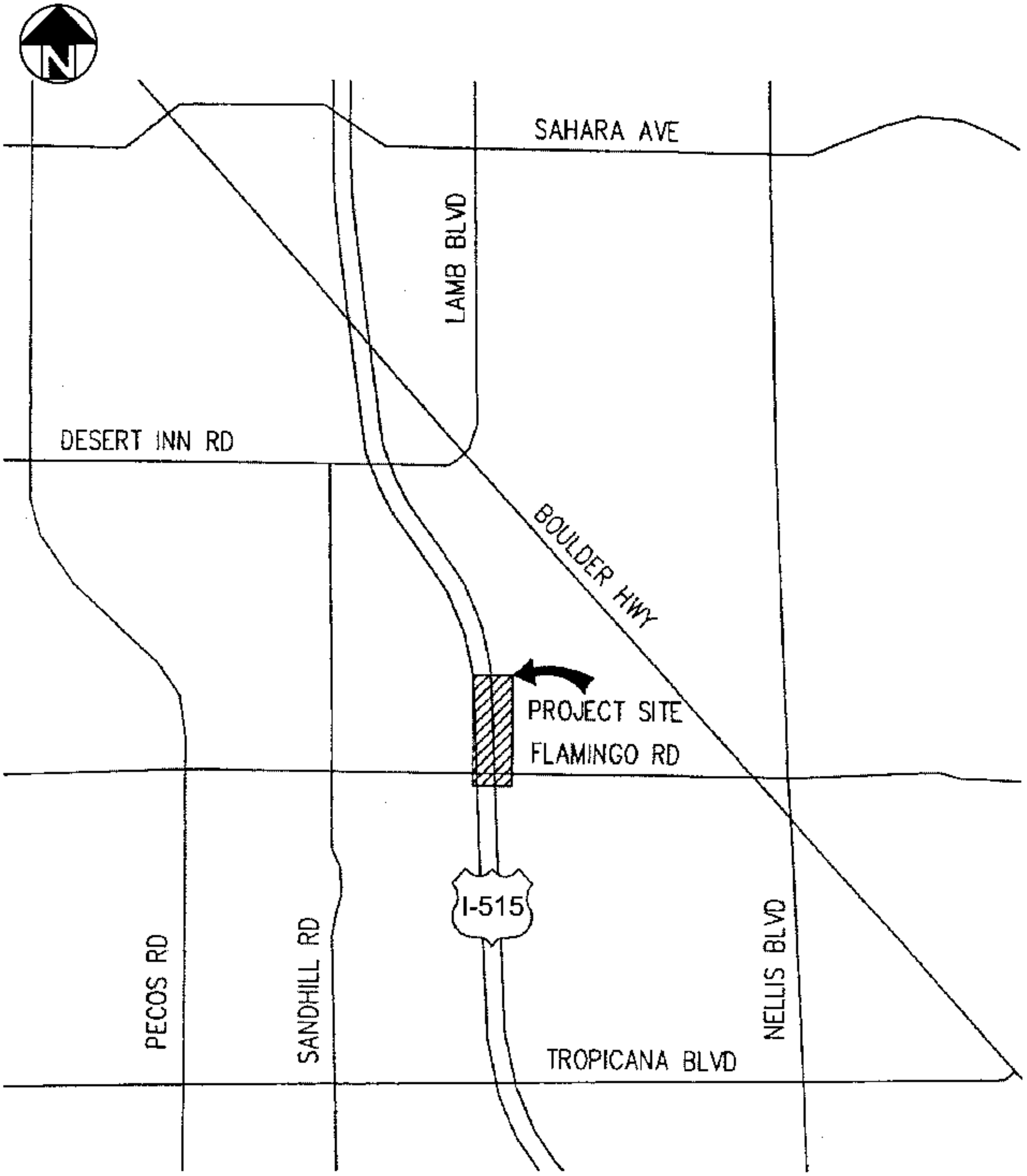
Engineering Analysis

Some deformation of the wall face may accompany the transfer of load between reinforcements as corrosion occurs. Thus, deformations observed at the wall face may be a useful indicator of corrosion. To be useful, the anticipated amount of deformation must be quantified and considered in terms of metal loss for corrosion.

VI. REFERENCES

1. American Association of State Highway and Transportation Officials (AASHTO), 2002, Standard Specifications for Highway Bridges, 17th Edition, AASHTO, Washington, D.C.
2. Berkovitz, B.C. and Healey, E.A. (1997) "A Rational Process for Corrosion Evaluation of Mechanically Stabilized Earth Walls," Mechanically Stabilized Backfill, J.T. Wu, Editor, Balkema, Rotterdam, the Netherlands, pp. 259-287.
3. Elias, V. (1990) "Durability/Corrosion of Reinforced Soil Structures," Report No. FHWA-RD-89-186, National Technical Information Service, Springfield, VA.
4. Elias, V. (1997) "Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Slopes," FHWA Report No. FHWA-SA-96-072, NTIS, Springfield, VA, 105 p.
5. Federal Highway Administration, FHWA, 1989, Reinforced Soil Structures, Volume I. Design and Construction Guidelines, FHWA-RD-89-043, NTIS, Springfield, VA.
6. Jackura, J.A., Garofalo, G. and Beddard, D., 1987, *Investigation of Corrosion at 14 Mechanically Stabilized Embankment Sites,* Report No. CA/TL-87/12, California Department of Transportation, Sacramento, CA.
7. NACE, National Association of Corrosion Engineers, 1985, Basic Course, Appalachian Underground Corrosion Short Course , West Virginia University, Morgantown, WV.
8. Polarization Resistance Monitor PR4500 Operating Manual (1999) Version 2.0, CC Technologies, Inc., Dublin, OH.
9. Rehm, G., 1980, The Service Life of Reinforced Earth Structures from a Corrosion Technology Standpoint, Expert Report, The Reinforced Earth Company, Vienna, VA. (unpublished).
10. Romanoff, M. (1957) Underground Corrosion, National Bureau of Standards Circular 959, NTIS PB 168 350, US Department of Commerce, National Bureau of Standards, April.
11. Smith, A., Jailloux, J.M., and Segrestin, P., 1996, "Durability of Galvanized Steel Reinforcements as a Function of their Shape," Earth Reinforcement, Ochiai, Yasufuku & Omine eds., Balkema, Rotterdam, pp. 55-60.
12. Stern, M. and Geary, A.L. (1957) "Electrochemical Polarization," Journal of the Electrochemical Society, 104(1), p.56.

FIGURES

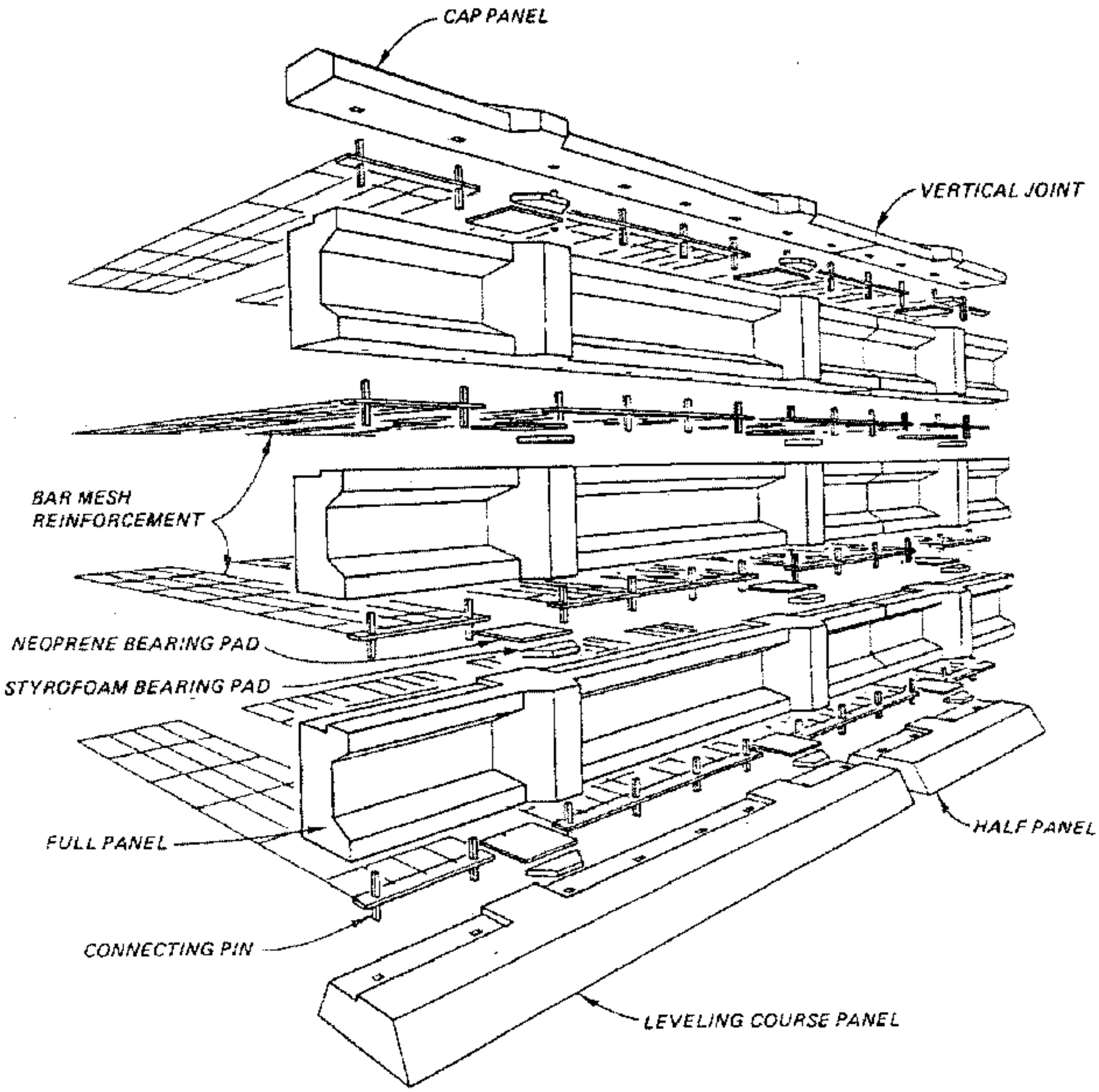


NOTE:

SCALE: N.T.S.

1. Base map adapted from Terracon Geotechnical Report dated June 2004.

SITE LOCATION	CORROSION STUDY INTERSTATE 515 AND FLAMINGO RD. LAS VEGAS NEVADA	McMahon & Mann Consulting Engineers, P.C. 2495 MAIN STREET, SUITE 432 (716) 834-8932 BUFFALO, NY 14214 FAX: (716) 834-8934
DWG. NO. 04005-003		
FIGURE 1		

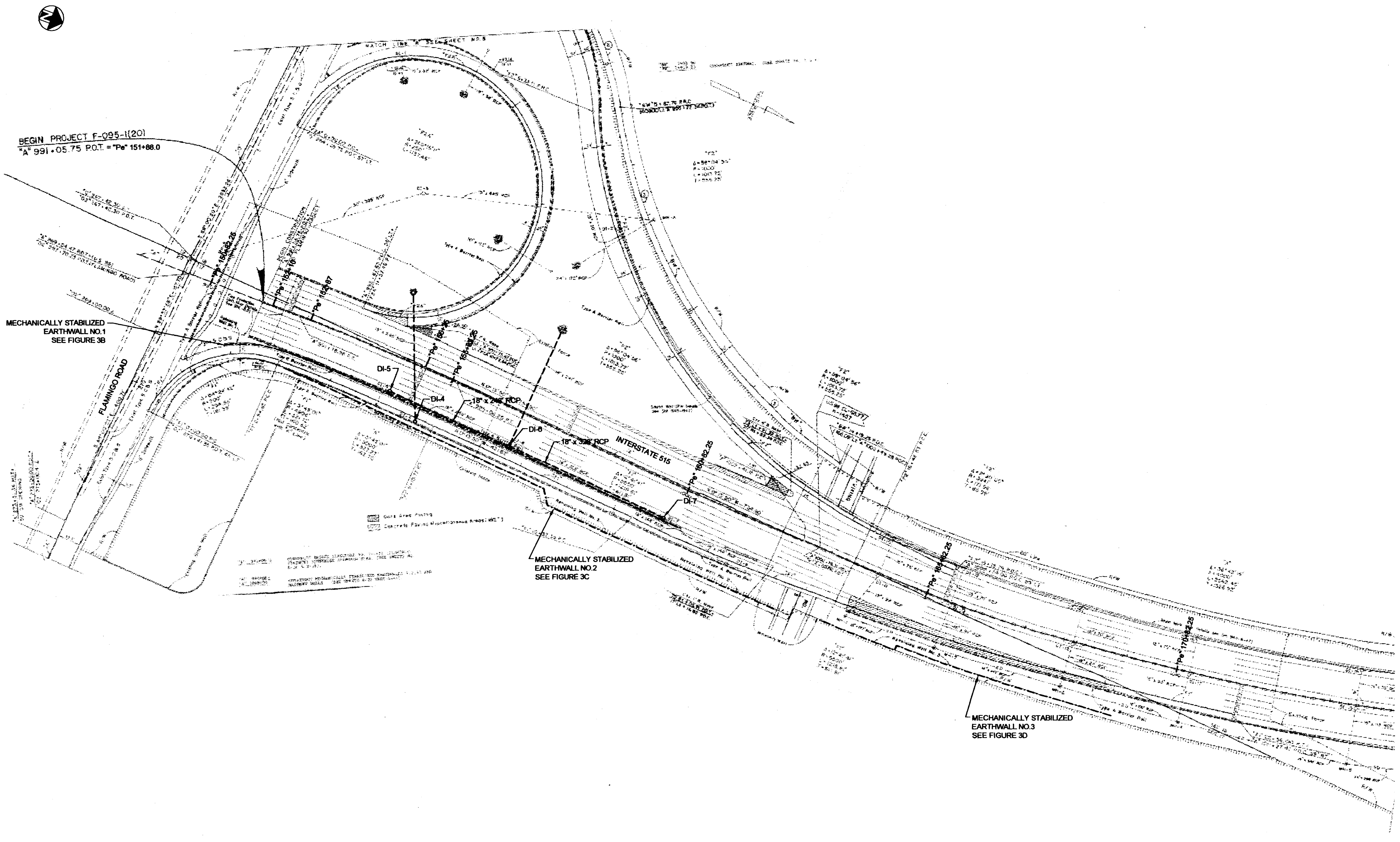


NOTES:

SCALE: N.T.S.

1.Figure Adpated from US Army Corps of Engineers, Engineering and design manual titled "Retaining and Flood Walls", EM 110-2-2502 dated September 29, 1989.

DETAILS OF MSE WALL SYSTEM	CORROSION STUDY INTERSTATE 515 AND FLAMINGO RD. LAS VEGAS NEVADA	McMahon & Mann Consulting Engineers, P.C. 2495 MAIN STREET, SUITE 432 (716) 834-8932 BUFFALO, NY 14214 FAX: (716) 834-8934
DWG. NO. 04005-004		
FIGURE 2		



DRAWING NOTE:

1. This plan was adapted form NDOT construction plans dated 1984 project F-095-1(20), sheets 1 and 6.

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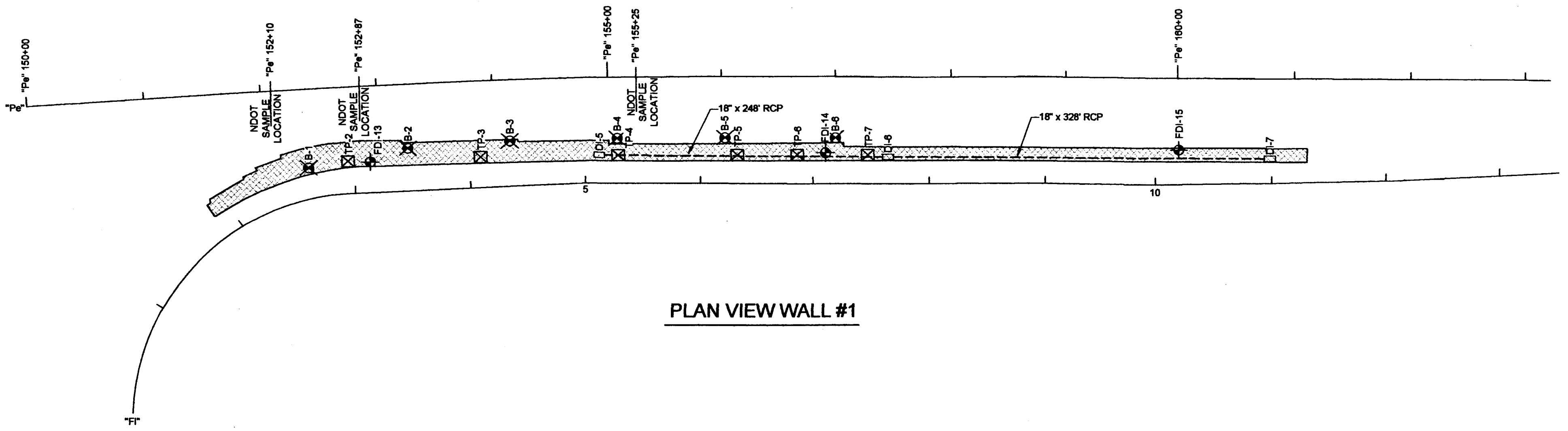
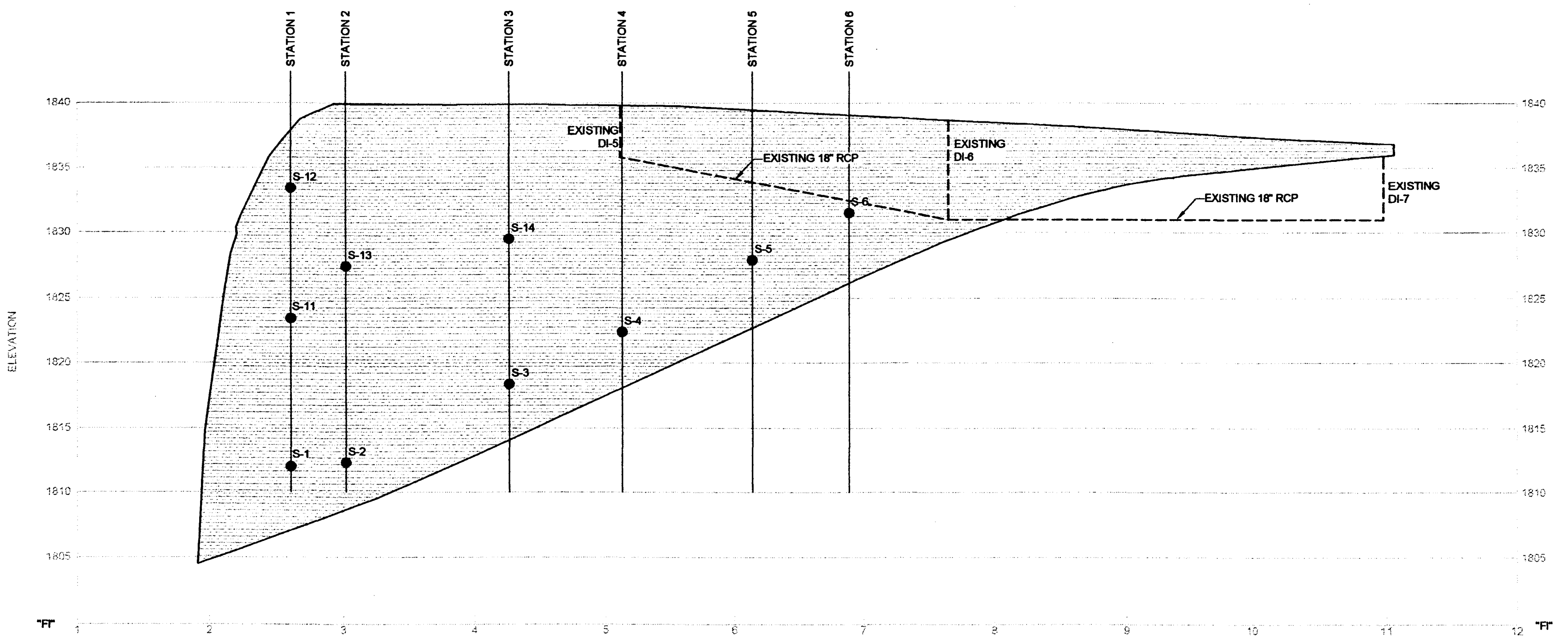
CORROSION STUDY
INTERSTATE 515 AND FLAMINGO RD.
SITE PLAN

LAS VEGAS NEVADA

DESIGNED BY: C.R.G.
CHECKED BY: K.L.F.
SCALE: N.T.S.
DATE: April 2005
JOB NO. 04005
FIGURE 3A
DWG. NO. 04005-002
REVISION NUMBER - 0



PLAN VIEW WALL #1



ELEVATION VIEW WALL #1

LEGEND

▤	MECHANICALLY STABILIZED EARTHWALL
▨	LIMITS OF EARTHWALL BACKFILL
▨	MASONARY WALL
☒ TP 7	TEST PIT LOCATION AND DESIGNATION
FDI-15 B-6	BORING LOCATION AND DESIGNATION
● S-6	CORROSION MONITORING SITE LOCATION
▭ DI-6	DRAINAGE INLET LOCATION

ADAPTED FROM:

1. NDOT construction plans dated 1984, project F-095-1(20), sheets no. 4 and B33.
2. Boring locations from NDOT Geotechnical Report dated May 2003, "I-515 Northbound Soundwalls between Flamingo Road and Desert Inn Road", and Terracon Geotechnical Report dated June 2004, "Geotechnical Exploration Report MSE Wall Remediation I-515 at Flamingo Road (North Bound Entrance), Clark County, Nevada."
3. TP-1 through TP-7, "Pe" sampling locations and corrosion monitoring site locations S-1, S-2, S-3, S-4, S-5, S-6 identified on site plans and shop drawings provided by NDOT.
4. Corrosion monitoring site locations S-11, S-12, S-13 and S-14 locations by McMahon and Mann Consulting Engineers P.C.

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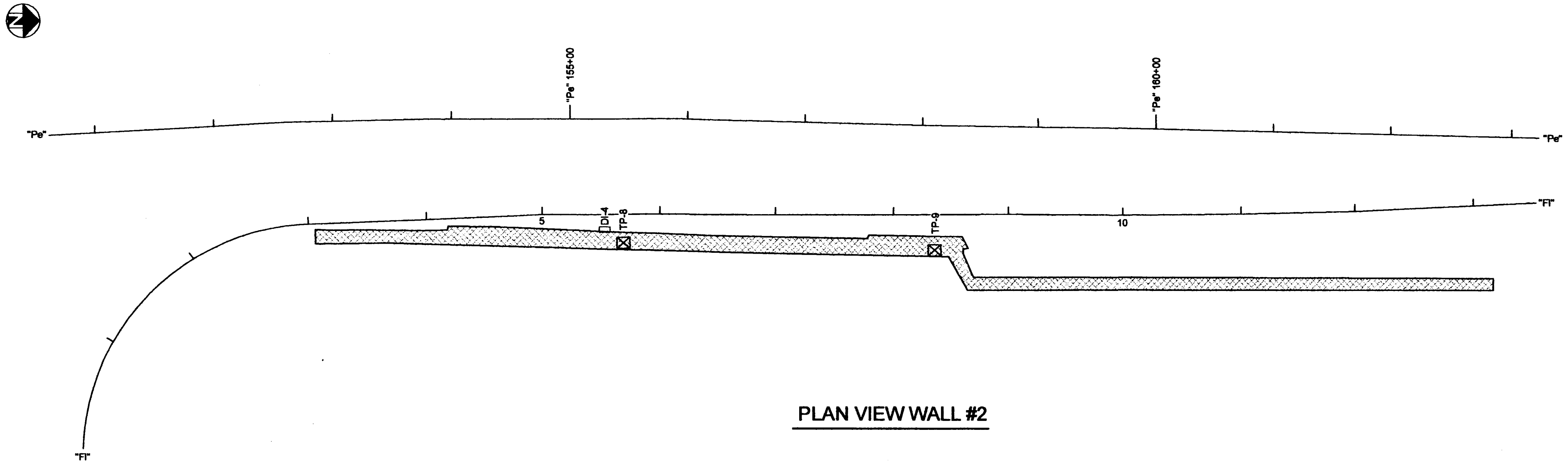
CORROSION STUDY
INTERSTATE 515 AND FLAMINGO RD.
STABILIZED EARTHWALL #1

LAS VEGAS NEVADA

DESIGNED BY: C.R.G.
CHECKED BY: K.L.F.
SCALE: N.T.S.
DATE: APRIL 2005
JOB NO. 04-005
FIGURE 3B
DWG. NO. 04005-001a
REVISION NUMBER - 0



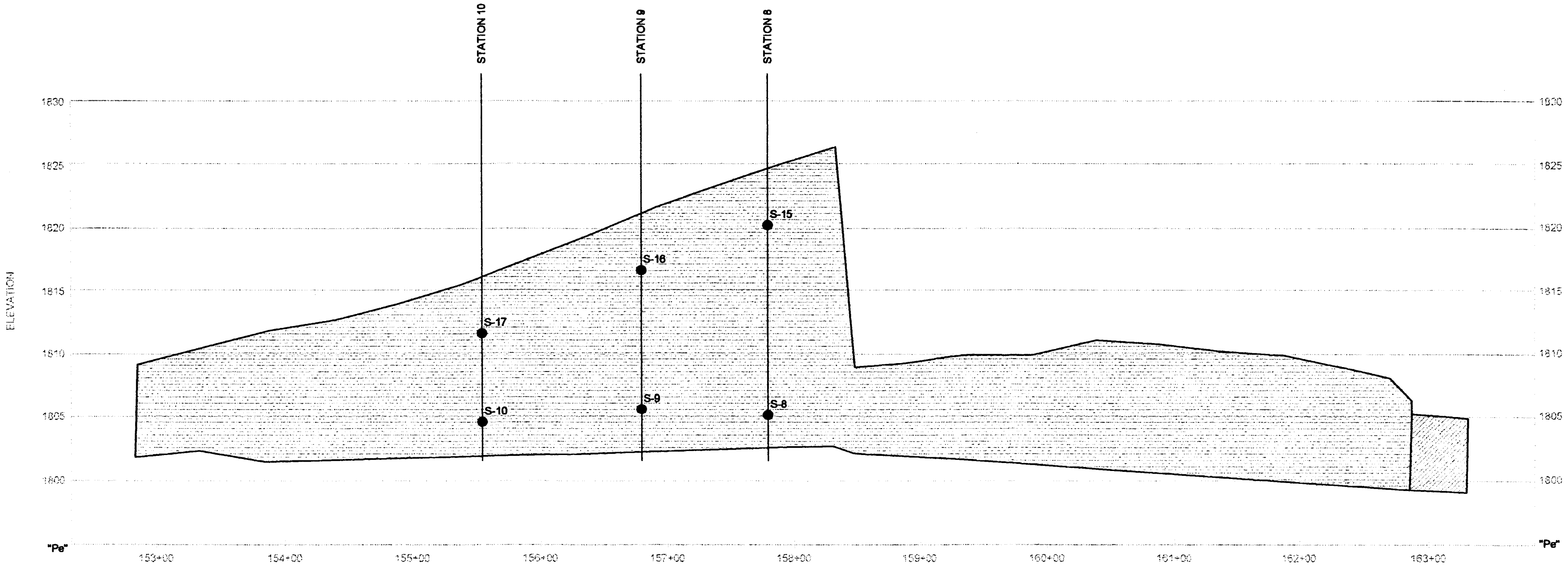
PLAN VIEW WALL #2

LEGEND

▨ MECHANICALLY STABILIZED EARTHWALL
▨ LIMITS OF EARTHWALL BACKFILL
▨ MASONARY WALL
☒ TP 7 TEST PIT LOCATION AND DESIGNATION
● S-6 CORROSION MONITORING SITE LOCATION
DI-4 ☐ DRAINAGE INLET LOCATION

ADAPTED FROM:

1. NDOT construction plans dated 1984, project F-095-1(20), sheets no. 4, B34 and B35.
2. Corrosion monitoring sites S-8, S-9 and S-10 were identified on the site plans and shop drawings by NDOT.
3. TP-8, TP-9 and corrosion monitoring points S-15, S-16 and S-17 are located by McMahon and Mann Consulting Engineers P.C.



ELEVATION VIEW WALL #2

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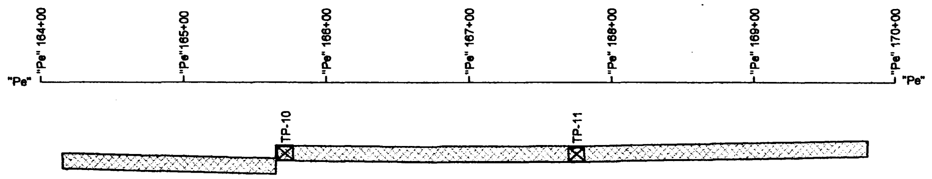
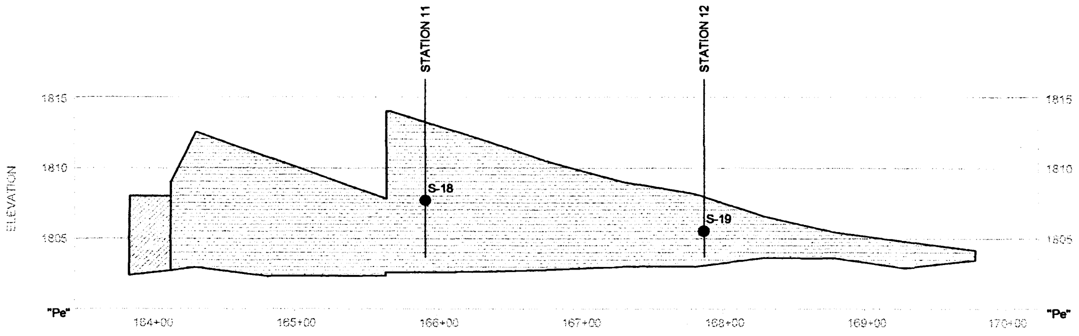
CORROSION STUDY
INTERSTATE 515 AND FLAMINGO RD.
STABILIZED EARTHWALL #2

LAS VEGAS NEVADA

DESIGNED BY: C.R.G.
CHECKED BY: K.L.F.
SCALE: N.T.S.
DATE: APRIL 2005
JOB NO. 04-005
FIGURE 3C
DWG. NO. 04005-001b
REVISION NUMBER - 0



PLAN VIEW WALL #3



ELEVATION VIEW WALL #3

LEGEND

▤	MECHANICALLY STABILIZED EARTHWALL
▩	LIMITS OF EARTHWALL BACKFILL
▨	MASONARY WALL
☒ TP 7	TEST PIT LOCATION AND DESIGNATION
● S-6	CORROSION MONITORING SITE LOCATION

ADAPTED FROM:

1. NDOT construction plans dated 1984, project F-095-1(20), sheets no. 6 and B36.
2. Test pits TP-10, TP-11 and corrosion monitoring sites S-18 and S-19 established by McMahon and Mann Consulting Engineers P.C.

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CORROSION STUDY
INTERSTATE 515 AND FLAMINGO RD.
STABILIZED EARTHWALL #3

LAS VEGAS NEVADA

DESIGNED BY: C.R.G.
CHECKED BY: K.L.F.
SCALE: N.T.S.
DATE: APRIL 2005
JOB NO. 04-005
FIGURE 3D
DWG. NO. 04005-001b
REVISION NUMBER - 0

APPENDICES

I - IV

LIST OF APPENDICES

APPENDIX I

I. Summary of MMCE's Engineering Services

A. Background

After they observed corroded soil reinforcements, NDOT contacted Mr. Barry Berkovitz, FHWA Geotechnical Engineer, and expert on condition assessment and corrosion monitoring of MSE structures. Mr. Berkovitz advised NDOT to evaluate conditions surrounding the reinforcements and collect soil samples for preliminary testing and evaluation. During the period from January 26 through January 31, 2004, Mr. Berkovitz and personnel from NDOT initiated fieldwork including corrosion monitoring and condition assessment of soil reinforcements at the site. Initial fieldwork included advancing six test pits near the top of the wall, observing portions of the top three layers of soil reinforcement, exhuming samples of reinforcement, obtaining backfill samples, and preparing locations for corrosion monitoring and nondestructive testing.

Based on his examination of corroded MSE soil reinforcements at the site, Mr. Berkovitz concluded that the MSE wall was at the end of its useful service life. Mr. Berkovitz recommended that (1) no additional loads be imposed along the MSE wall, and (2) plans to replace the Portland Cement Concrete (PCC) pavement and Jersey barrier be postponed pending further evaluation and possible retrofit of the MSE walls at the site.

Subsequently, Nevada DOT contracted with MMCE for corrosion monitoring and condition assessment of reinforcements at the site. The purpose of MMCE's study is to render an opinion about the condition of Walls #2 and #3 relative to that of Wall #1 (i.e. are reinforcements along Walls #2 and #3 experiencing the same levels of corrosion as Wall #1?), evaluate parameters that may contribute to corrosion, estimate the remaining capacity of the reinforcements, and to establish reference measurements and a protocol for evaluating other MSE walls in the Las Vegas area.

NDOT also contracted with HDR Engineering, Inc. to evaluate alternatives and design a system to retrofit Wall #1. Terracon, from Las Vegas, Nevada, performed a geotechnical exploration in support of the retrofit design.

NDOT provided MMCE with the following:

- construction plans dated 1984 describing the construction surrounding the three MSE walls at the site associated with Project F-095-1(20) US 95 CL 68.55 to 69.67 including sheet No's 1, 4, 6, 11, 12, and B32 through B44,

- shop drawings dated 1985 prepared by Hilfiker describing details of the MSE wall construction including Sheet No's 1 through 8 and E-1 through E-7,

- test pit and test site locations established during the initial fieldwork were identified on the site plans and shop drawings provided by NDOT.

- results from preliminary testing of backfill samples performed by NDOT,

- samples of soil reinforcements and backfill samples retrieved from the site during the preliminary fieldwork,

- a Geotechnical report dated May 2003 entitled "I-515 Northbound Soundwalls Between Flamingo Road and Desert Inn Road," dated May 2003 and prepared by NDOT,

- the "I-515/Flamingo Road, MSE Wall Draft Rehabilitation Alternatives Report," dated March 19, 2004, prepared by HDR,

- the "Geotechnical Exploration Report MSE Wall Remediation I-515 at Flamingo Road (North Bound Entrance), Clark County, Nevada, dated April 1, 2004, revised June 8, 2004 and prepared by Terracon, Las Vegas, and

- Preliminary construction plans prepared by HDR Engineering, Inc. for NDOT Project SPI-515-1(031) including Sheets No. 1, 1A, 3, 3A, 3B, 4, 5 and 6, D1 thru D3, ST01 thru ST02, TC01 thru TC09, SW-1 thru SW-4, W1 thru W14, S-1 thru S-2, and BL01 thru BL-03. These plans describe remediation of Wall #1, construction of the sound wall on top of Wall #1, and proposed locations for exploratory test pits behind Walls #2 and #3 (Test Pits #1 thru #4 on HDR drawings renamed Test pits #8 through #11 for this report).

B. Scope of MMCE's Engineering Services

MMCE performed the following engineering services in support of corrosion monitoring and condition assessment:

1. Developed a plan for studying the conditions that may have contributed to corrosion and the nature of the corrosion process.

2. Logged samples of metallic reinforcements retrieved from the site including photographs, sketches, and measurements of diameter (loss of section) at a number of locations including many where loss of cross section was visible.

3. Selected a typical metal reinforcement sample, and transported this sample to a metallurgy lab (Adirondack Environmental Services, Inc.) for testing. MMCE visited the lab and discussed details of the project, and the test requirements with a metallurgist.

4. Observed backfill samples; planned and implemented a laboratory test program to evaluate backfill conditions. MMCE retained Geotechnics, Inc. and Terracon, Inc. to perform the appropriate laboratory tests. MMCE received results from the geotechnical engineering laboratories and interpreted and reported these results.

5. Visited the site during March 29, 2004 to April 7, 2004. MMCE prepared seven additional locations for corrosion monitoring, obtained additional backfill samples, and monitored corrosion at test stations established along Walls #1 and #2. MMCE

subcontracted with Las Vegas Paving, Inc. for field services to access the reinforcements through precast concrete wall facing units.

6. MMCE made another field trip between August 25, 2004 and September 2, 2004, and took additional readings of corrosion activity at each of the test stations established to date. MMCE coordinated activities with HDR Engineering, Inc. (HDR), and prepared a wiring scheme considering the new wall facing planned by HDR (as described in HDR's "Draft Rehabilitation Alternatives Report" dated March 19, 2004 and Preliminary plans, Project No. SPI-515-(031), Sheets 1 – 14, undated).

7. MMCE made a third site visit from December 7, 2004 until December 17, 2004 as Capriatti Construction Inc., the contractor retained to remediate Wall #1 and construct the Integrated Sound wall/foundation on top of the wall, advanced four test pits located behind Walls #2 and #3. MMCE observed the condition of reinforcements exposed within the test pits, retrieved reinforcement and backfill samples, established additional stations behind Wall #3 for corrosion monitoring, and obtained initial readings of corrosion activity for these stations.

8. Reviewed and interpreted the data collected for the study and estimated the corrosion rate and remaining service life of the existing reinforcements.

9. Prepared this report, describing the results, deriving conclusion and making recommendations for future activities including corrosion monitoring.

APPENDIX II

II. BACKFILL SAMPLING AND TESTING

A. Subsurface Exploration and Soil Sampling

Soils at the site were sampled from (1) shallow excavations (test pits) and (2) soil borings advanced behind the wall facing, and (3) access holes advanced through the MSE wall facing. Shallow excavations were used to observe materials within the pavement structure, backfill within the top five or six feet of the MSE wall, and the first three layers of soil reinforcement. Soil borings advanced behind Wall #1 allowed pavement materials, MSE backfill and native soils to be sampled to depths of approximately 40 feet from the top of the wall. Additional MSE backfill samples were obtained by chipping holes through the MSE concrete wall face. Forty-three MSE backfill samples were retrieved for observation, physical, and electrochemical testing.

Figure 3 (b) – (d) include plan views of Walls #1,#2 and #3 depicting the locations of test pits and test borings. The NDOT advanced test borings numbered FDI-13, 14 and 15 into the MSE fill behind Wall #1 on December 18, 2002 as part of the subsurface exploration in support of design for the sound wall foundation. These test borings are located behind the wall, within approximately 10 feet from the face; and were advanced to depths between 5.5 and 8 feet, penetrating the first layer of reinforcement. Boring logs for FDI-13, FDI-14 and FDI-15 are reproduced and included in this appendix.

During their initial investigation of corrosion in December, 2003, NDOT removed the concrete pavement to a distance of approximately 10 feet behind Wall #1 and retrieved samples of aggregate base, embankment cap, and MSE backfill from two locations identified as "Pe" 152+10, and "Pe" 155+25; and samples of embankment cap and MSE backfill from another location identified as "Pe" 152 +87. The aggregate base layer was from 10" to 16", the embankment cap from 16" to 36" and the MSE backfill was encountered at depths greater than 3 feet beneath the existing Portland cement concrete pavement.

Test pits TP-2 through TP-7 were advanced behind Wall #1 under the direction of the FHWA during their preliminary fieldwork conducted in January 2004. No test pit is located at Station #1 due to an obstruction near the top of the wall at this location. Test pits were placed within a 10 foot wide strip behind the retaining wall where the pavement was removed. Test pits were approximately 8 feet long, 4 feet wide, and four feet deep; i.e. advanced to depths approximately six feet below the top of the existing concrete pavement.

In support of design and selection of rehabilitation alternatives, Terracon advanced six test borings designated B-1 through B-6 during the period from February 20 – 23, 2004. The locations of B-1 through B-6 are shown in Figure 3 (b) and these locations are at approximately the same Test Pit Stations 1 through 6, respectively. Figure 3 (b) shows the estimated extent of the MSE backfill placed behind Wall #1 taken from sheet B-33 of the NDOT construction plans for project F-095-1(20), dated 1984. The estimated width of the backfill ranges between 11.5 feet and 23 feet and varies with respect to wall height maintaining an aspect ration of at least 0.7 (reinforcement length/wall height). As shown in Figure 3 (b), B-1, B-2, and B-3 were advanced within the MSE backfill but B-4, B-5 and B-6 were located behind the limits of the backfill and penetrated the embankment material. Tests borings B-1, B-2 and B-3 penetrated the backfill to depths of 41.5 feet, 29.0 feet and 31.5 feet, respectively. Boring logs for B-1, B-2 and B—3 are reproduced and included in this appendix.

Test Pits TP-8 through TP-11 were advanced behind Walls #2 and #3, as shown in Figures 3 (c) and (d), by Capriatti Construction, and observed by MMCE during their site visit from December 7, 2004 to December 17, 2004. Both Walls #2 and #3 support a sloped highway embankment and Capriatti removed the concrete slope paving to expose the embankment fill behind the wall. Test pits were approximately five feet square and were advanced to depths of approximately five feet below the top of the wall, exposing the first three layers of reinforcement.

Figure 3 (b) and (c) includes profiles of Wall #1 and Wall #2 depicting locations where backfill samples were retrieved by advancing an opening through the concrete wall face. These same locations were also prepared for corrosion monitoring and are numbered S1 though S17. FHWA retrieved samples from S1 through S10, and MMCE retrieved samples from S11 though S17. Sites S1 through S6 and S11 though S 14 are located along Wall #1 and in general these sites are along the same stations as TP1 through TP6. Thus, samples are retrieved near the wall face at three elevations corresponding to the bottom, middle and top of the wall at Stations #1, 2 and 3 and samples are retrieved near the bottom and top of the wall at Stations 4, 5 and 6. Access holes were not advanced at site 7 due to the proximity of TP #7 to the bottom of the wall at this location. Along Wall #2 samples were retrieved from near the bottom and top of the wall at Station 8, 9 and 10 through access holes advanced through the wall face at sites 8, 9, 10, 15, 16 and 17. Samples of backfill retrieved through the wall face were stored in zip-lock plastic bags for transport to the laboratory.

B. Backfill Testing

The following tests were used to evaluate the characteristics and properties of the backfill:

- Sieve Analysis
- Moisture Content
- Organics Content
- pH
- Resistivity
- Sulfate Ion Concentration
- Chloride Ion Concentration

Forty-three samples were included in the test program. Terracon in Sparks, NV tested the majority of the samples, but Terracon in Las Vegas, NV, NDOT, MMCE and Geotechnics, Inc. also participated. Terracon in Las Vegas, NV tested seven samples retrieved from test borings during their subsurface exploration. For the most part, NDOT's contribution is with respect to samples of aggregate base, embankment cap material and MSE fill obtained during NDOT's initial sample collection. NDOT also made pH and resistivity measurements on samples from three of the test pits and one of the test sites located along Wall #1. MMCE sent one sample retrieved from Site 9 to Geotechnics, Inc. for testing. MMCE tested sixteen samples retrieved from Test Pits 8,9,10 and 11 for moisture content and one sample from TP 11 for gradation. The remaining samples were sent to Terracon in Sparks, NV for further testing under the direction of MMCE.

Generally, AASHTO test procedures were followed, however other test procedures were also employed as described in Table II-1. In particular, ion exchange chromatography (EPA Method 300) was used to measure sulfate and chloride ion concentrations in place of the AASHTO standards, which use turbidity measurements and an electrometric method, respectively. Ion exchange chromatography is more efficient and less prone to error than the AASHTO methods (Elias, 1997), and is commonly employed by the chemical analysis laboratory that made these measurements.

Table II-1. Test Methods.

Test	**Laboratory**			
	NDOT	Terracon Las Vegas, NV	Terracon Sparks, NV	Geotechnics, Inc.
Sieve Analysis			ASTM C117, C136	AASHTO T-27
Atterberg Limits			N.A.	N.A.
Moisture Content			AASHTO	N.A.
Organics Content	N.A.	N.A.	AASHTO T267	N.A.
pH	NDOT T238A or AASHTO T-289	AWWA 4500H	AASHTO T-289	AASHTO T-289
Resistivity	NDOT T235B or AASHTO T-288	ASTM G57	AASHTO T-288	AASHTO T-288
Sulfate Content	Unnumbered NDOT Procedure[1]	AWWA 4500 - SO_4 E	EPA 300	CAL 417
Chloride Content	Unnumbered NDOT Procedure[1]	AWWA 4500 - Cl B	EPA 300	CAL 422

[1] Unnumbered NDOT Procedure for Determination of Water Soluble Carbonates & Bicarbonates, Chlorides, & Sulfates in Soil Filtrates.

C. Backfill Test Results

Test results obtained by each laboratory are included in this appendix following the boring logs. Table II-2 presents a summary of the test results organized according to test station. For each station the results are listed in descending order with respect to depth, and the setback, or distance behind the wall face for each sample location is also indicated. In general, the data in Table II-2 suggest that the backfill is very aggressive relative to corrosion as discussed in Section IV(A).

Table II-2. Summary of Backfill Test Results

Sample	Set Ft.	Depth Ft.	% pass #4	% pass #8	w%	Organics %	pH	R Ω-cm	CL^- ppm	SO_4 ppm
STATION #1 – Wall # 1 – Sta. 0+75										
1. "Pe" 152+10	10.0	3.5	61.9	15.8			8.7	7092	30	0
2. S-12	0.0	6.5	35	11	5.6		9.37		<15	910
3. B-1	10.0	10.0	76	42	6.0		8.71	1950	50	3740
4. S-11	0.0	16.5	45	7	6.7		9.50		19	3700
5. B-1	10.0	20.0			5.4		8.91	5200	75	1238
6. S-1	0.0	27.5	59	9	7.2	2.3	8.86	450	<15	1400
STATION #2 – Wall #1 – Sta. 1 +25										
7. "Pe" 152+87	10.0	3.5	59.9	16.5	5.7		8.8	5618	20	542
8. TP-2B	3.0	3.5	67	17	6.6		8.98	5200	<15	<15
9. S13	0.0	12.5	51	7	6.7	5.2	9.01		18	7500
10. B-2	20.0	15.0			6.2		9.27		75	660
11. B-2	20.0	25.0	71	42	6.6		9.21		100	1513
12. S-2	0.0	27.5	58	10	7.0		8.06		<15	430
STATION #3 – Wall #1 – Sta. 2+50										
13. TP-3B	3.0	3.5	72	22	6.5	1.3	8.14	420	<15	380
14. B-3	20.0	5.0			13.2		8.46		100	8773
15. S14	0.0	10.5	44	6	6.4		9.08		25	2900
16. B-3	20.0	15.0			6.2			3000		
17. B-3	20.0	20.0	81	43	6.7		8.53		225	9075
18. S-3	0.0	21.5	56	8	4.2		8.62	410	20	300
STATION #4 – Wall #1 – Sta. 3+ 37.5										
19. "Pe" 155+25	10.0	3.5	66.0	15.5			8.3	1018	30	600
20. TP-4B	3.0	3.5	60.0	20	6.5		8.28	1247	<15	1100M^2
21. S-4	0.0	17.5	50	8	6.9		8.23	420^3	<15	390
STATION #5 – Wall #1- Sta. 4+32.5										
22. TP-5B	3.0	3.5	68	16	6.2		8.12		78	4600
23. S-5	0.0	11.5	56	8	1.3		8.48	420^3	<15	470
STATION #6 – Wall #1 – Sta. 5 + 12.5										
24. TP-6B	3.0	3.5	64.1	20	6.2		8.4	1307	<15	160
25. S-6	0.0	7.5	57.6	8	3.3		8.4	1234		
STATION #7 – Wall #1 – Sta. 5 + 75										
26. TP-7B	3.0	3.5	60.5	20	6.2		8.4	1134	<15	340

[1] Sample pulverized for pH, Resistivity, Cl^-, and SO_4

[2] The reported value for this analyte demonstrated a matrix effect

[3] Resistivity test performed on mixed sample of S4 + S5

Table II-2. Summary of Backfill Test Results (Cont.)

Sample	Set Ft.	Depth Ft.	% pass #4	% pass #8	w%	Organics %	pH	R Ω-cm	CL^- ppm	SO_4 ppm
STATION #8 – Wall #2 – Sta. 4 + 93.75										
27. TP-9-G1[1]	3	1.0			7.0					
28. S15	0.0	4.5	59	13	6.4		9.38		<15	240
29. S-8	0.0	19.5								
STATION #9 – Wall #2 – Sta. 3 + 93.7										
30. S16	0.0	4.5	55	6	6.4	4.0	9.14		<15	3000
31. S-9[1]	0.0	15.5	53	5			9.5	7800	<70	93
STATION #10 – Wall # 2 – Sta. 2 + 68.7										
32. TP-8-G1[2]	3	1.0			7.0					
33. S17	0.0	4.5	56	12	6.4		8.46		230	6900
34. S-10	0.0	11.5								
STATION #11 – Wall # 3 – Sta. 1+64										
35. TP-10-G1Z1	1	1			5					
36. TP-10-G1Z2	3	1			5					
37. TP-10-G2Z2	3	3			5					
STATION #12 – Wall #3 – Sta. 3+69										
38. TP-11-G1Z1	1	1			5					
39. TP-11-G1Z2	3	1			4					
40. TP-11-G1Z3	5	1			4					
41. TP-11-G2Z1	1	3	72	25	6					
42. TP-11-G2Z2	3	3			5					
43. TP-11-G2Z3	5	3			5					

[1] TP-9-G1 at approx. Sta. 5 + 28

[2] TP-8-G1 at approx. Sta. 2 + 65

D. Boring Logs

NEVADA DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING

EXPLORATION LOG

SHEET 1 OF 1

START DATE 12/18/02
END DATE 12/18/02
JOB DESCRIPTION Northbound I 515 Soundwalls, Desert Inn to Flamingo
LOCATION Milepost CI 68.45 to 69.55, Las Vegas Urban Area
BORING FDI 13
E.A. # 72993 (9)
GROUND ELEV. 1839.00 (ft)
HAMMER DROP SYSTEM AUTOMATIC

GROUNDWATER LEVEL

DATE	DEPTH ft	ELEV. ft
12/18/02	dry	

STATION "A" 991+99 (Contract 2066)
OFFSET 66.4' Right
ENGINEER Salazar
EQUIPMENT Mobile B-57
OPERATOR Marshall
DRILLING METHOD 6" HSA
BACKFILLED Yes DATE 12/18/2002

ELEV. (ft)	DEPTH (ft)	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT 6 inch Increments	BLOW COUNT Last 1 foot	Percent Recov'd	LAB TESTS	USCS Group		MATERIAL DESCRIPTION	REMARKS
									0.92	**Portland Cement Concrete Pavement** 11" thick	
								GM	1.17	**Type 2 Aggregate Base** dense, moist, moderate brown, minor silt content, 3" thick	
								GP		**MSE Backfill** dense, moist to dry, sandy fine angular gravel with minor silt content. welded wire reinforcement layer at 3.2' below concrete pavement surface	
1834.0	5										
									8.00		
										B.O.H.	
1829.0	10										
1824.0	15										
1819.0	20										
1814.0	25										

NEVADA
DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING

EXPLORATION LOG

SHEET 1 OF 1

START DATE 12/18/02
END DATE 12/18/02
JOB DESCRIPTION Northbound I 515 Soundwalls, Desert Inn to Flamingo
LOCATION Milepost Cl 68.45 to 69.55, Las Vegas Urban Area
BORING FDI 14
E.A. # 72993 (9)
GROUND ELEV. 1837.40 (ft)
HAMMER DROP SYSTEM AUTOMATIC

GROUNDWATER LEVEL		
DATE	DEPTH ft	ELEV. ft
12/18/02	dry	

STATION "A" 996+00 (Contract 2066)
OFFSET 66.3' Right
ENGINEER Salazar
EQUIPMENT Mobile B-57
OPERATOR Marshall
DRILLING METHOD 6" HSA
BACKFILLED Yes DATE 12/18/2002

ELEV. (ft)	DEPTH (ft)	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT 6 inch Increments	BLOW COUNT Last 1 foot	Percent Recov'd	LAB TESTS	USCS Group		MATERIAL DESCRIPTION	REMARKS
									0.90	**Portland Cement Concrete Pavement** 10.8" thick	
								GM	1.70	**Type 2 Aggregate Base** dense, moist, moderate brown, minor silt content, 9.6" thick	
								GP		**MSE Backfill** dense, moist to dry, sandy fine angular gravel with minor silt content. welded wire reinforcement layer at 2.2' below concrete pavement surface	
1832.4	5								5.50		
										B.O.H.	
1827.4	10										
1822.4	15										
1817.4	20										
1812.4	25										

NEVADA
DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING

EXPLORATION LOG

SHEET 1 OF 1

START DATE 12/18/02
END DATE 12/18/02
JOB DESCRIPTION Northbound I 515 Soundwalls, Desert Inn to Flamingo
LOCATION Milepost CI 68.45 to 69.55, Las Vegas Urban Area
BORING FDI 15
E.A. # 72993 (9)
GROUND ELEV. 1835.60 (ft)
HAMMER DROP SYSTEM AUTOMATIC

STATION "F$_1$"10+17' (Contract 2066)
OFFSET 29.6' Left
ENGINEER Salazar
EQUIPMENT Mobile B-57
OPERATOR Marshall
DRILLING METHOD 6" HSA
BACKFILLED Yes DATE 12/18/2002

GROUNDWATER LEVEL		
DATE	DEPTH ft	ELEV. ft
12/18/02	dry	

ELEV. (ft)	DEPTH (ft)	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT 6 inch Increments	BLOW COUNT Last 1 foot	Percent Recov'd	LAB TESTS	USCS Group		MATERIAL DESCRIPTION	REMARKS
									0.83	**Portland Cement Concrete Pavement** 10" thick	
								GM	1.35	**Type 2 Aggregate Base** dense, moist, moderate brown, minor silt content, 6.25" thick	
								GP	5.50	**MSE Backfill** dense, moist to dry, sandy fine angular gravel with minor silt content. welded wire reinforcement layer at 2.15' below concrete pavement surface	
1830.6	5										
										B.O.H.	
1825.6	10										
1820.6	15										
1815.6	20										
1810.6	25										

LOG OF BORING NO. 1

CLIENT: **HDR Engineering**

PROJECT: **MSE Wall Distress Investigation**

BORING LOCATION: **See Plot Plan**

ELEVATION: **1839.3**

SITE: **Flamingo Road MSE Wall @ I-515**

SOIL DESCRIPTION	CONSISTENCY	GRAPHIC	USCS SYMBOL	DEPTH (FT.)	SAMPLES			TESTS		
					SAMPLE	BLOWS/FT.	TYPE*	MOISTURE %	DRY DENSITY PCF	NOTES
CONCRETE - 10 inches										
FILL- AGGREGATE BASE COURSE - 10 inches			FILL	1						
FILL-CLAYEY SAND-w/gravel, dry to sl. moist, lt. brown	med. dense			2						
				3						
FILL-WELL GRADED SILTY SAND -w/fine gravel, sl. moist, lt. brown to brown				4						
				5	⧗	24	SPT	5.2		
				6						
				7						
	med. dense			8						
				9						
				10	⧗	13	SPT	6.0		
				11						
				12						
				13						
				14						
Continued Next Page				15						

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

SAMPLE TYPES: R=Ring B=Bag S=Shelby Tube J=Jar PT=Perc Test
SPT = Standard Penetration Test CPT = Cone Penetration Test

NOTES:
Groundwater not encountered.

Hammer Weight (lbs): **140**

Terracon

DATE DRILLED: **2-20-04**

PAGE NUMBER: **Page 1 of 3**

PROJECT NO.: **64045036**

PLATE: **A-1**

LOG OF BORING NO. 1

CLIENT: **HDR Engineering**

PROJECT: **MSE Wall Distress Investigation**

BORING LOCATION: **See Plot Plan**

ELEVATION: **1839.3**

SITE: **Flamingo Road MSE Wall @ I-515**

SOIL DESCRIPTION	CONSISTENCY	GRAPHIC	USCS SYMBOL	DEPTH (FT.)	SAMPLES: SAMPLE	SAMPLES: BLOWS/FT.	SAMPLES: TYPE*	TESTS: MOISTURE %	TESTS: DRY DENSITY PCF	NOTES
FILL-POORLY GRADED SILTY SAND -w/fine gravel, sl. moist to moist, brown		▨	FILL		⧗	13	SPT	5.4		
		▨		16	⧗					
		▨		17						
		▨		18						
		▨		19						
		▨		20	⧗	15	SPT	5.4		
		▨		21	⧗					
	med. dense	▨		22						
		▨		23						
		▨		24						
		▨		25	⧗	22	SPT	6.0		
		▨		26	⧗					
		▨		27						
		▨		28						
		▨		29						
Continued Next Page				30						

THIS SUMMARY APPLIES ONLY AT THIS LOCATION AT THE TIME OF LOGGING. CONDITIONS MAY DIFFER WITH TIME OR AT OTHER LOCATIONS.

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

SAMPLE TYPES: R=Ring B=Bag S=Shelby Tube J=Jar PT=Perc Test SPT = Standard Penetration Test CPT = Cone Penetration Test

NOTES:
Groundwater not encountered.

Hammer Weight (lbs): 140

Terracon

DATE DRILLED: **2-20-04**

PAGE NUMBER: **Page 2 of 3**

PROJECT NO.: **64045036**

PLATE: **A-2**

LOG OF BORING NO. 1

CLIENT: **HDR Engineering**	PROJECT: **MSE Wall Distress Investigation**
BORING LOCATION: **See Plot Plan** — ELEVATION: **1839.3**	SITE: **Flamingo Road MSE Wall @ I-515**

SOIL DESCRIPTION	CONSISTENCY	GRAPHIC	USCS SYMBOL	DEPTH (FT.)	SAMPLES			TESTS		
					SAMPLE	BLOWS/FT.	TYPE*	MOISTURE %	DRY DENSITY PCF	NOTES
FILL-POORLY GRADED SILTY SAND -w/fine gravel, sl. moist to moist, brown		▩	FILL		⧗	18	SPT	5.9		
		▩		31						
		▩		32						
	med. dense	▩		33						
		▩		34						
		▩		35	⧗	22	SPT	6.6		
SILTY SAND -w/tr. clay, sl. moist to moist, lt. brown to brown		░	SM	36						
		░		37						
CLAYEY SAND -sl. moist to moist, reddish brown to brown	med. dense to dense	▨	SC	38						
		▨		39						
SANDY CLAY -w/silt, moist to v. moist, reddish brown	very stiff	▨	CL	40	⧗	30	SPT	17.1		
		▨		41						
Bottom Depth at 41.5 feet										
				42						
				43						
				44						
				45						

THIS SUMMARY APPLIES ONLY AT THIS LOCATION AT THE TIME OF LOGGING. CONDITIONS MAY DIFFER WITH TIME OR AT OTHER LOCATIONS.

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

SAMPLE TYPES: R=Ring B=Bag S=Shelby Tube J=Jar PT=Perc Test SPT = Standard Penetration Test CPT = Cone Penetration Test

NOTES:
Groundwater not encountered.

Hammer Weight (lbs): **140**

Terracon

DATE DRILLED: **2-20-04**	PAGE NUMBER: **Page 3 of 3**
PROJECT NO.: **64045036**	PLATE: **A-3**

LOG OF BORING NO. 2

CLIENT: **HDR Engineering**

PROJECT: **MSE Wall Distress Investigation**

BORING LOCATION: **See Plot Plan**

ELEVATION: **1838.9**

SITE: **Flamingo Road MSE Wall @ I-515**

SOIL DESCRIPTION	CONSISTENCY	GRAPHIC	USCS SYMBOL	DEPTH (FT.)	SAMPLES: SAMPLE	SAMPLES: BLOWS/FT.	SAMPLES: TYPE*	TESTS: MOISTURE %	TESTS: DRY DENSITY PCF	TESTS: NOTES
CONCRETE - 10 inches										
FILL-AGGREGATE BASE COURSE - 10 inches	med. dense to dense		FILL	1						
FILL-CLAYEY SAND -w/gravel and silt, sl. moist to moist, brown				2						
FILL-POORLY GRADED SILTY SAND -w/fine gravel, sl. moist to moist, brown				3						
				4						
				5	⧗	16	SPT	7.7		
-w/thin layer of clayey sand and gravel fill				6						
				7						
	med. dense			8						
				9						
				10	⧗	18	SPT	5.8		
				11						
				12						
				13						
				14						
Continued Next Page				15						

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

SAMPLE TYPES: R=Ring B=Bag S=Shelby Tube J=Jar PT=Perc Test
SPT = Standard Penetration Test CPT = Cone Penetration Test

NOTES:
Groundwater not encountered.

Hammer Weight (lbs): **140**

Terracon

DATE DRILLED: **2-23-04**

PAGE NUMBER: **Page 1 of 2**

PROJECT NO.: **64045036**

PLATE: **A-4**

LOG OF BORING NO. 2

CLIENT: HDR Engineering	PROJECT: MSE Wall Distress Investigation
BORING LOCATION: See Plot Plan / ELEVATION: 1838.9	SITE: Flamingo Road MSE Wall @ I-515

SOIL DESCRIPTION	CONSISTENCY	GRAPHIC	USCS SYMBOL	DEPTH (FT.)	SAMPLES			TESTS		
					SAMPLE	BLOWS/FT.	TYPE*	MOISTURE %	DRY DENSITY PCF	NOTES
FILL-POORLY GRADED SILTY SAND -w/fine gravel, sl. moist, brown			FILL			28	SPT	6.2		
				16						
	med. dense to dense			17						
				18						
				19						
				20		35	SPT	6.3		
				21						
				22						
				23						
	dense									
GROUTED ANCHOR -24 to 29 feet. Tested 3/4/04				24						
				25		41	SPT	6.6		
				26						
				27						
				28						
Bottom Depth at 29.0 feet				29						
				30						

THIS SUMMARY APPLIES ONLY AT THIS LOCATION AT THE TIME OF LOGGING. CONDITIONS MAY DIFFER WITH TIME OR AT OTHER LOCATIONS.

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

SAMPLE TYPES: R=Ring B=Bag S=Shelby Tube J=Jar PT=Perc Test SPT = Standard Penetration Test CPT = Cone Penetration Test

NOTES:
Groundwater not encountered.

Hammer Weight (lbs): **140**

Terracon

DATE DRILLED: **2-23-04**	PAGE NUMBER: **Page 2 of 2**
PROJECT NO.: **64045036**	PLATE: **A-5**

LOG OF BORING NO. 3

CLIENT: **HDR Engineering**	PROJECT: **MSE Wall Distress Investigation**
BORING LOCATION: **See Plot Plan** / ELEVATION: **1838.5**	SITE: **Flamingo Road MSE Wall @ I-515**

SOIL DESCRIPTION	CONSISTENCY	GRAPHIC	USCS SYMBOL	DEPTH (FT.)	SAMPLES: SAMPLE	SAMPLES: BLOWS/FT.	SAMPLES: TYPE*	TESTS: MOISTURE %	TESTS: DRY DENSITY PCF	TESTS: NOTES
CONCRETE - 10 inches										
FILL- AGGREGATE BASE - 10 inches			FILL	1						
FILL-CLAYEY SAND -w/gravel, moist, brown				2 3						
FILL-POORLY GRADED SILTY SAND -w/fine gravel, sl. moist, lt. brown to brown				4 5		8	SPT	13.2		
	loose to med. dense			6 7 8 9 10 11 12 13			CPT			
	med. dense to dense			14 15						
Continued Next Page										

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

SAMPLE TYPES: R=Ring B=Bag S=Shelby Tube J=Jar PT=Perc Test
SPT = Standard Penetration Test CPT = Cone Penetration Test

NOTES:
Groundwater not encountered.

Hammer Weight (lbs): **140**

Terracon

DATE DRILLED: **2-20-04**	PAGE NUMBER: **Page 1 of 3**
PROJECT NO.: **64045036**	PLATE: **A-6**

LOG OF BORING NO. 3

CLIENT: **HDR Engineering**	PROJECT: **MSE Wall Distress Investigation**
BORING LOCATION: **See Plot Plan**	ELEVATION: **1838.5**
SITE: **Flamingo Road MSE Wall @ I-515**	

SOIL DESCRIPTION	CONSISTENCY	GRAPHIC	USCS SYMBOL	DEPTH (FT.)	SAMPLES			TESTS		
					SAMPLE	BLOWS/FT.	TYPE*	MOISTURE %	DRY DENSITY PCF	NOTES
FILL-POORLY GRADED SILTY SAND -w/fine gravel, sl. moist to moist, brown		▨	FILL		⧗	38	SPT	6.2		
		▨		16	⧗					
		▨		17						
		▨		18						
		▨		19						
		▨		20	⧗	36	SPT	6.1		
		▨		21	⧗					
	dense	▨		22						
		▨		23						
		▨		24						
		▨		25	⧗	33	SPT	6.7		
		▨		26	⧗					
		▨		27						
		▨		28						
		▨		29						
		▨		30						

Continued Next Page

THIS SUMMARY APPLIES ONLY AT THIS LOCATION AT THE TIME OF LOGGING. CONDITIONS MAY DIFFER WITH TIME OR AT OTHER LOCATIONS.

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

SAMPLE TYPES: R=Ring B=Bag S=Shelby Tube J=Jar PT=Perc Test
SPT = Standard Penetration Test CPT = Cone Penetration Test

NOTES:
Groundwater not encountered.

Hammer Weight (lbs): **140**

DATE DRILLED: **2-20-04**	PAGE NUMBER: **Page 2 of 3**
PROJECT NO.: **64045036**	PLATE: **A-7**

LOG OF BORING NO. 3

CLIENT: **HDR Engineering**

PROJECT: **MSE Wall Distress Investigation**

BORING LOCATION: **See Plot Plan**

ELEVATION: **1838.5**

SITE: **Flamingo Road MSE Wall @ I-515**

SOIL DESCRIPTION	CONSISTENCY	GRAPHIC	USCS SYMBOL	DEPTH (FT.)	SAMPLES			TESTS		
					SAMPLE	BLOWS/FT.	TYPE*	MOISTURE %	DRY DENSITY PCF	NOTES
SILTY SAND -w/gravel, tr. clay, sl. moist, greenish brown	very dense	▨	SM	31	⧗	64	SPT	8.0		
Bottom Depth at 31.5 feet				32 33 34 35 36 37 38 39 40 41 42 43 44 45						

THIS SUMMARY APPLIES ONLY AT THIS LOCATION AT THE TIME OF LOGGING. CONDITIONS MAY DIFFER WITH TIME OR AT OTHER LOCATIONS.

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

SAMPLE TYPES: R=Ring B=Bag S=Shelby Tube J=Jar PT=Perc Test
SPT = Standard Penetration Test CPT = Cone Penetration Test

NOTES:
Groundwater not encountered.

Hammer Weight (lbs): **140**

Terracon

DATE DRILLED: **2-20-04**

PAGE NUMBER: **Page 3 of 3**

PROJECT NO.: **64045036**

PLATE: **A-8**

E. Laboratory Test Data

NDOT

Sample	% pass #4	% pass #10	w%	pH	Ω-cm	CL$^-$ (ppm)	SO_4 (ppm)
MSE Fill 152+10	61.9	11.8		8.7 (NDOT T238A)	7092 (NDOT T235B)	30 (NDOT-?)	0 (NDOT-?)
MSE Fill 155+25	66.0	10.9		8.3 (NDOT T238A)	1018 (NDOT T235B)	30 (NDOT-?)	600 (NDOT-?)
MSE Fill 152+87	59.9	12.7	5.7	8.8 (NDOT T238A)	5618 (NDOT T235B)	20 (NDOT-?)	542 (NDOT-?)
TP-2B			6.6				
TP-3B			6.5				
TP-4B	60.0	11.6	6.5	7.8 (AASHTO T-289)	1247 (AASHTO T-288)		
TP-5B			6.2				
TP-6B	64.1	12.3	6.2	8.2 (AASHTO T-289)	1307 (AASHTO T-288)		
TP-7B	60.5	12.1	6.2	8.3 (AASTO T-289)	1134 (AASHTO T-288)		
S-1			7.2				
S-2			7.0				
S-3			4.2				
S-4			6.9				
S-5			1.3				
S-6	57.6	7.6	3.3	8.4 (AASHTO T-289)	1234 (AASHTO T-288)		

TERRACON – SPARKS, NV

Sample	% pass #4	% pass #8	organics %	pH	Ω-cm	CL$^-$ (ppm)	SO_4 (ppm)
TP-2B	67	17		8.98	5200	<15	<15
TP-3B	72	22	1.3	8.14	420	<15	380
TP-4B				8.28		<15	1100M
TP-5B				8.12 (EPA 9045B)		78 (EPA 300)	4600 (EPA 300)
TP-5B	68	16		8.1 (AASHTO T289)		83 (AASHTO T291)	140 (AASHTO T290)
TP-6B				8.39		<15	160
TP-7B				8.42		<15	340
S1	59	9.1	2.3	8.86	450	<15	1400
S2	58	10		8.06		<15	430
S3	56	7.8		8.62	410	20	300
S4	50	7.8		8.23		<15	390
S5	56	7.5		8.48	420	<15	470

Sample	% pass #4	% pass #8	w%	Org. %	pH	Ω-cm	CL^- (ppm)	SO_4 (ppm)
S11	45	7	6.7		9.50		19	3700
S12	35	11	5.6		9.37		<15	910
S13	51	7	6.7	5.2	9.01		18	7500
S14	44	6	6.4		9.08		25	2900
S15	59	13	6.4		9.38		<15	240
S16	55	6	6.4	4.0	9.14		<15	3000
S17	56	12	6.4		8.46		230	6900

TERRACON – LAS VEGAS NEVADA

Sample	% pass #4	% pass #8	w%	pH	Ω-cm	CL^- (ppm)	SO_4 (ppm)
B-1 D=10'	76	42	6.0	8.71 (AWWA 4500H)	1950 (ASTM G57)	50 (AWWA 4500-C1 B)	3740 (AWWA 4500-SO_4 E)
B-1 D=20'			5.4	8.91 (AWWA 4500H)	5200 (ASTM G57)	75 (AWWA 4500-C1 B)	1238 (AWWA 4500-SO_4 E)
B-2 D=15'			6.2	9.27 (AWWA 4500H)		75 (AWWA 4500-C1 B)	660 (AWWA 4500-SO_4 E)
B-2 D=25'	71	42	6.6	9.21 (AWWA 4500H)		100 (AWWA 4500-C1 B)	1513 (AWWA 4500-SO_4 E)
B-3 D=5'			13.2	8.46 (AWWA 4500H)		100 (AWWA 4500-C1 B)	8773 (AWWA 4500-SO_4 E)
B-3 D=15'			6.2		3000 (ASTM G57)		
B-3 D=20'	81	43	6.7	8.53 (AWWA 4500H)		225 (AWWA 4500-C1 B)	9075 (AWWA 4500-SO_4 E)
B-5 D=5'			11.2		1300 (ASTM G57)		
B-5 D=30'			10.0	8.81 (AWWA 4500H)	585 (ASTM G57)	500 (AWWA 4500-C1 B)	9625 (AWWA 4500-SO_4 E)

GEOTECHNICS

Sample	% pass #4	% pass #8	w%	pH	Ω-cm	CL^- (ppm)	SO_4 (ppm)
S-9[1]	53	5		9.5 (AASHTO T289)	7800 (AASHTO T288)	<70 (CAL 422)	93 (CAL 417)

[1] Sample pulverized for pH, Resistivity, Cl^-, and SO_4

[2] The reported value for this analyte demonstrated a matrix effect

SUMMARY OF RESULTS
N.D.O.T. GEOTECHNICAL SECTION

EA/Cont # 3181 **Job Description** MSE Retaining Wall @ I-515 & Flamingo

Boring No. Test Pits **Elevation (ft)** Existing PCCP Surface Elevation **Station** See Test Pit Location Map

SAMPLE NO.	SAMPLE* DEPTH (ft)	SAMP-LER TYPE	N BLOWS per ft.	SOIL GROUP	W%	DRY UW pcf	% PASS #200	LL %	PL %	PI %	STRENGTH TEST TEST TYPE	STRENGTH TEST φ deg.	STRENGTH TEST C psi	STRENGTH TEST φ deg.	STRENGTH TEST C psi	OTHERS
												Peak		Residual		
TP-2A	1.5'-3.0',Panel 1				7.1											Gave sample to Terracon for further tests
TP-2B	3.0'-4.0',Panel 2				6.6											Gave sample to Terracon for further tests
TP-3A	2.0'-4.0',Panel 1				3.5											Gave sample to Terracon for further tests
TP-3B	3.0'-4.0',Panel 2				6.5											Gave sample to Terracon for further tests
TP-4A	1.0'-3.0',Panel 1				5.0											Gave sample to Terracon for further tests
TP-4B	3.0'-4.0',Panel 2			SP	6.5		2.7	23	NP	NP						Ch
TP-5A	1.0'-3.0',Panel 1				4.8											Gave sample to Terracon for further tests
TP-5B	3.0'-4.0',Panel 2				6.2											Gave sample to Terracon for further tests
TP-6A	1.5'-3.0',Panel 1			GP-GC	3.5		5.5	27	21	6						Ch
TP-6B	3.0'-4.0',Panel 2			SP	6.2		2.1	24	22	2						Ch
TP-7A	1.0'-3.0',Panel 1			GP-GC	5.3		7.6	26	21	5						Ch
TP-7B	3.0'-4.0',Panel 2			SP	6.2		2.4	24	23	1						Ch

*** Depth from from PCCP surface. Panel No. identifies sample location with regard to existing MSE wall panels, with Panel No.1 being the topmost panel,Panel No. 2 being below Panel No. 1 & so on**

CMS = California Modified Sampler 2.40" ID
SPT = Standard Penetration 1.38" ID
CS = Continuous Sample 3.23" ID
RC = Rock Core
PB = Pitcher Barrel
CSS = Calif. Split Spoon 2.42" ID
CPT = Cone Penetration Test
TP = Test Pit
P = Pushed, not driven
R = Refusal
Sh = Shelby Tube 2.87" ID

U = Unconfined Compressive
UU = Unconsolidated Undrained
CD = Consolidated Drained
CU = Consolidated Undrained
DS = Direct Shear
φ = Friction
C = Cohesion
N = No. of blows per ft., sampler
N = Field SPT
N = (N_{cms})(0.62)

H = Hydrometer
S = Sieve
G = Specific Gravity
PI = Plasticity Index
LL = Liquid Limit
PL = Plastic Limit
NP = Non-Plastic
OC = Consolidation
Ch = Chemical
RV = R - Value
MD = Moisture Density

CM = Compaction
E = Swell/Pressure on Expansive Soils
SL = Shrinkage Limit
UW= Unit Weight
W = Moisture Content
K = Permeability
O = Organic Content
D = Dispersive
RQD = Rock Quality Designation
X = X-Ray Defraction
HCpot = Hydro-Collapse Potential

SUMMARY OF RESULTS
N.D.O.T. GEOTECHNICAL SECTION

EA/Cont # 3181 **Job Description** MSE Retaining Wall @ I-515 & Flamingo

Boring No. Test Sites **Elevation (ft)** **Station** See RSE Wall Details and Erection Drawings for Site Locations

SAMPLE NO.	SAMPLE* DEPTH (ft)	SAMP-LER TYPE	N BLOWS per ft.	SOIL GROUP	W%	DRY UW pcf	% PASS #200	LL %	PL %	PI %	STRENGTH TEST					OTHERS
											TEST TYPE	φ deg.	C psi	φ deg.	C psi	
												Peak		Residual		
S-1	Panel 13	Bulk			7.2											Gave sample to Terracon for further tests
S-2	Panel 13	Bulk			7.0											Gave sample to Terracon for further tests
S-3	Panel 10	Bulk			4.2											Gave sample to Terracon for further tests
S-4	Panel 8	Bulk			6.9											Gave sample to Terracon for further tests
S-5	Panel 5	Bulk			1.3											Gave sample to Terracon for further tests
S-6	Panel 3	Bulk		SP	3.3		1.6	25	23	2						Ch

*** Panel No. identifies sample location with regard to existing MSE wall panels, with Panel No.1 being the topmost panel, Panel No. 2 being below Panel No. 1 and so on**

CMS = California Modified Sampler 2.40" ID
SPT = Standard Penetration 1.38" ID
CS = Continuous Sample 3.23" ID
RC = Rock Core
PB = Pitcher Barrel
CSS = Calif. Split Spoon 2.42" ID
CPT = Cone Penetration Test
TP = Test Pit
P = Pushed, not driven
R = Refusal
Sh = Shelby Tube 2.87" ID

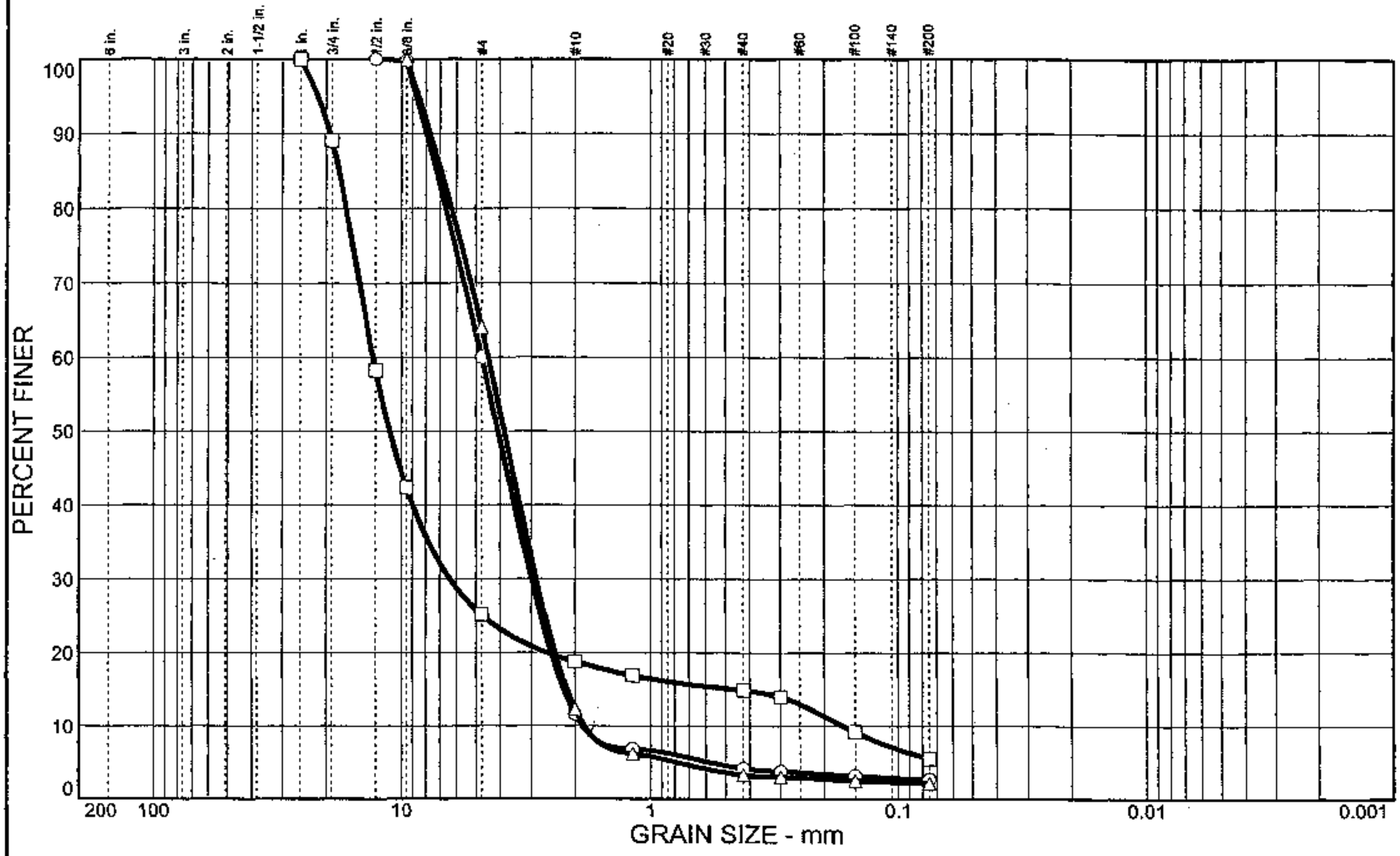
U = Unconfined Compressive
UU = Unconsolidated Undrained
CD = Consolidated Drained
CU = Consolidated Undrained
DS = Direct Shear
φ = Friction
C = Cohesion
N = No. of blows per ft., sampler

N = Field SPT $N = (N_{css})(0.62)$

H = Hydrometer
S = Sieve
G = Specific Gravity
PI = Plasticity Index
LL = Liquid Limit
PL = Plastic Limit
NP = Non-Plastic
OC = Consolidation
Ch = Chemical
RV = R - Value
MD = Moisture Density

CM = Compaction
E = Swell/Pressure on Expansive Soils
SL = Shrinkage Limit
UW= Unit Weight
W = Moisture Content
K = Permeability
O = Organic Content
D = Dispersive
RQD = Rock Quality Designation
X = X-Ray Defraction
HCpot = Hydro-Collapse Potential

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	LL	PI
○		40.0	57.3			SP		23	NP
□		74.8	19.7			GP-GC		27	6
△		35.9	62.0			SP		24	2

SIEVE	PERCENT FINER		
inches size	○	□	△
1		100.0	
3/4		89.1	
1/2	100.0	58.3	
3/8	99.8	42.4	100.0
	GRAIN SIZE		
D_{60}	4.75	13.0	4.46
D_{30}	2.99	6.36	2.86
D_{10}	1.87	0.167	1.84
	COEFFICIENTS		
C_c	1.00	18.61	1.00
C_u	2.54	77.68	2.42

SIEVE	PERCENT FINER		
number size	○	□	△
#4	60.0	25.2	64.1
#10	11.6	18.8	12.3
#16	6.9	16.9	6.2
#40	4.2	14.9	3.3
#50	3.8	14.0	3.0
#100	3.2	9.2	2.5
#200	2.7	5.5	2.1

SOIL DESCRIPTION

○ Poorly graded sand with gravel

□ Poorly graded gravel with silty clay and sand

△ Poorly graded sand with gravel

REMARKS:

○ MSE fill

□ Borrow cap over MSE fill

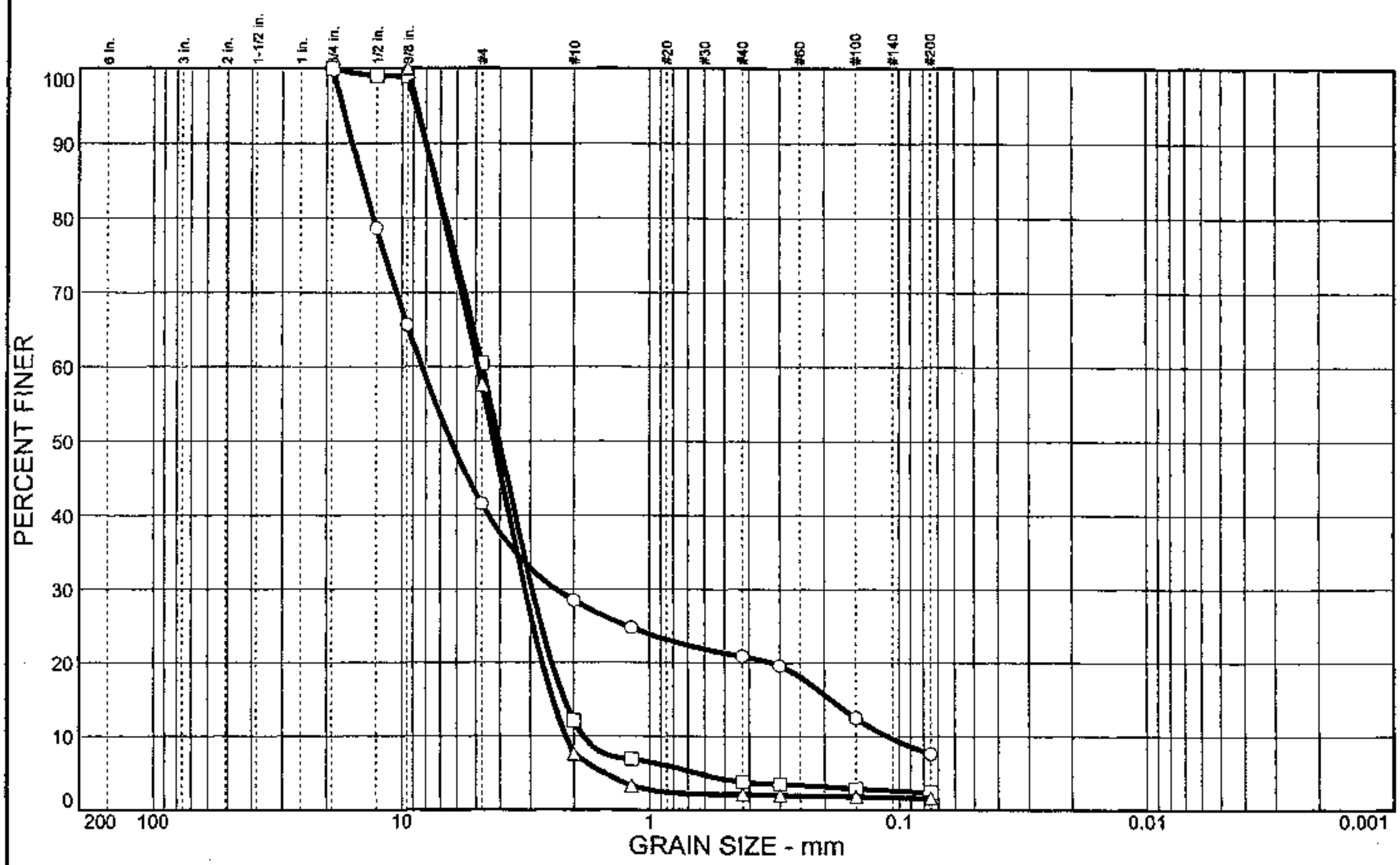
△ MSE fill

○ Source: Test Pit 4, Panel 2 Sample No.: TP-4B
□ Source: Test Pit 6, Panel 1 Sample No.: TP-6A
△ Source: Test Pit 6, Panel 2 Sample No.: TP-6B

NEVADA DEPARTMENT OF TRANSPORTATION

Client: Mark Salazar
Project: I-515 MSE Walls
Project No.: Contract 3181
Plate

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	LL	PI
○		58.4	34.0			GP-GC		26	5
□		39.5	58.1			SP		24	1
△		42.4	56.0			SP		25	2

SIEVE	PERCENT FINER		
inches size	○	□	△
3/4	100.0	100.0	
1/2	78.7	99.0	
3/8	65.7	98.9	100.0
	GRAIN SIZE		
D_{60}	8.29	4.71	4.92
D_{30}	2.35	2.95	3.16
D_{10}	0.111	1.83	2.15
	COEFFICIENTS		
C_c	5.99	1.01	0.94
C_u	74.47	2.57	2.29

SIEVE	PERCENT FINER		
number size	○	□	△
#4	41.6	60.5	57.6
#10	28.5	12.1	7.6
#16	24.8	6.9	3.3
#40	20.9	3.8	2.1
#50	19.6	3.5	2.0
#100	12.5	2.9	1.8
#200	7.6	2.4	1.6

SOIL DESCRIPTION

○ Poorly graded gravel with silty clay and sand

□ Poorly graded sand with gravel

△ Poorly graded sand with gravel

REMARKS:

○ Borrow cap over MSE fill

□ MSE fill

△ MSE fill

○ Source: Test Pit 7, Panel 1 Sample No.: TP-7A
□ Source: Test Pit 7, Panel 2 Sample No.: TP-7B
△ Source: Site 6, Panel 13 Sample No.: S-6

NEVADA DEPARTMENT OF TRANSPORTATION

Client: Mark Salazar
Project: I-515 MSE Walls
Project No.: Contract 3181 Plate

NEVADA DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL SECTION

CHEMICAL ANALYSIS

Contract No. 3181

PROJECT MSE Retaining Wall @ I-515 and Flamingo

SOURCE Test Pits & Sites

Sample No.	Chlorides ppm	Sulfates ppm	Ph*	Resistivity* Ohm - cm	Conductivity
TP-4B			7.8	1,247	
TP-6A			8.2	1,107	
TP-6B			8.2	1,307	
TP-7A			8.4	1,354	
TP-7B			8.3	1,134	
S-6			8.4	1,234	

*pH test method AASHTO T-289, Resistivity test method AASHTO T-288

SUMMARY OF RESULTS
N.D.O.T. GEOTECHNICAL SECTION

EA/Cont # 3181

Job Description MSE retaining Wall @ I-515 & Flamingo

Boring No. Bulk Samples

Elevation (ft)

Station See Contract 3181 "Pe" Alignment Sheets

SAMPLE NO.*	SAMPLE* DEPTH	SAMP-LER TYPE	N BLOWS per ft.	SOIL GROUP	W%	DRY UW pcf	% PASS #200	LL %	PL %	PI %	STRENGTH TEST					OTHERS
											TEST TYPE	φ deg.	C psi	φ deg.	C psi	
												Peak		Residual		
152+ 10	Aggregate Base?	Bulk					6.6									Ch
152+ 10	Borrow Cap	Bulk					6.8									Ch
152+ 10	MSE Fill	Bulk					1.6									Ch
155+ 25	Aggregate Base?	Bulk					6.2									Ch
155+ 25	Borrow Cap	Bulk					7.3									Ch
155+ 25	MSE Fill	Bulk					1.1									Ch
152+ 87	Borrow Cap	Bulk		GP-GC	3.8		7.0	25	20	5						Ch
152+ 87	MSE Fill	Bulk		SP	5.7		2.2	24	23	1						Ch

*** Samples identified by location along Contract 3181 "Pe" alignment stationing. Aggregate Base layer from 10" to16", Borrow cap from 16" to 3', and MSE Fill from 3' to 4' below existing PCCP surface**

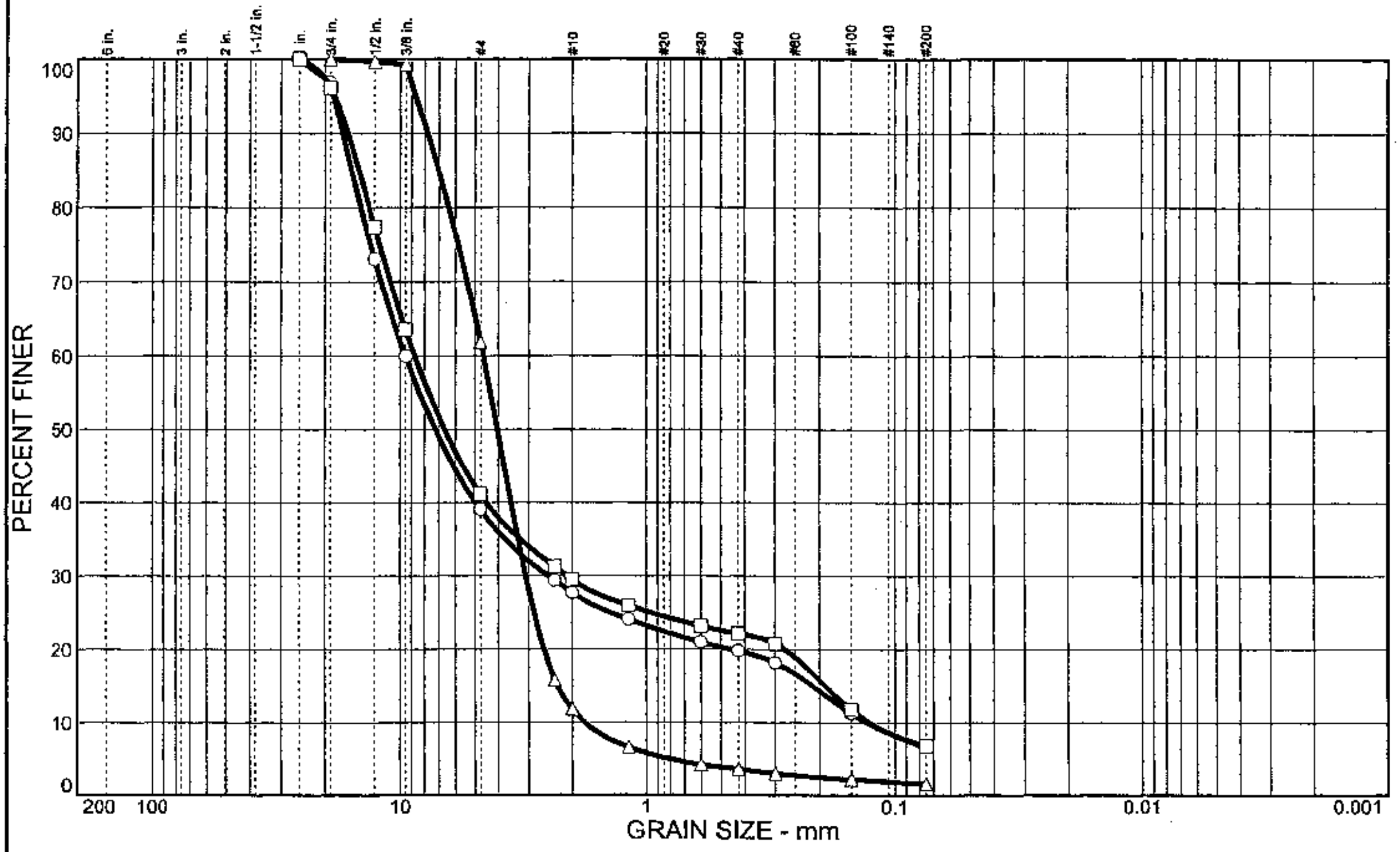
CMS = California Modified Sampler 2.40" ID
SPT = Standard Penetration 1.38" ID
CS = Continuous Sample 3.23" ID
RC = Rock Core
PB = Pitcher Barrel
CSS = Calif. Split Spoon 2.42" ID
CPT = Cone Penetration Test
TP = Test Pit
P = Pushed, not driven
R = Refusal
Sh = Shelby Tube 2.87" ID

U = Unconfined Compressive
UU = Unconsolidated Undrained
CD = Consolidated Drained
CU = Consolidated Undrained
DS = Direct Shear
φ = Friction
C = Cohesion
N = No. of blows per ft., sampler
N = Field SPT $N = (N_{cms})(0.62)$

H = Hydrometer
S = Sieve
G = Specific Gravity
PI = Plasticity Index
LL = Liquid Limit
PL = Plastic Limit
NP = Non-Plastic
OC = Consolidation
Ch = Chemical
RV = R - Value
MD = Moisture Density

CM = Compaction
E = Swell/Pressure on Expansive Soils
SL = Shrinkage Limit
UW= Unit Weight
W = Moisture Content
K = Permeability
O = Organic Content
D = Dispersive
RQD = Rock Quality Designation
X = X-Ray Defraction
HCpot = Hydro-Collapse Potential

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	LL	PI
○		60.9	32.5			GP-GM			
□		58.8	34.4			GP-GM			
△		38.1	60.3			SP			

SIEVE inches size	PERCENT FINER		
	○	□	△
1	100.0	100.0	
3/4	96.9	96.2	100.0
1/2	73.1	77.4	99.7
3/8	60.0	63.6	99.3
	GRAIN SIZE		
D_{60}	9.52	8.74	4.62
D_{30}	2.50	2.10	3.08
D_{10}	0.129	0.126	1.78
	COEFFICIENTS		
C_c	5.07	4.00	1.16
C_u	73.78	69.34	2.60

SIEVE number size	PERCENT FINER		
	○	□	△
#4	39.1	41.2	61.9
#8	29.4	31.3	15.8
#10	27.7	29.5	11.8
#16	24.1	26.0	6.6
#30	21.0	23.2	4.2
#40	19.8	22.2	3.6
#50	18.2	20.8	3.0
#100	11.3	11.8	2.2
#200	6.6	6.8	1.6

SOIL DESCRIPTION

○ Poorly graded gravel with silt and sand

□ Poorly graded gravel with silt and sand

△ Poorly graded sand with gravel

REMARKS:

○ Aggregate base layer?

□ Borrow cap on MSE fill

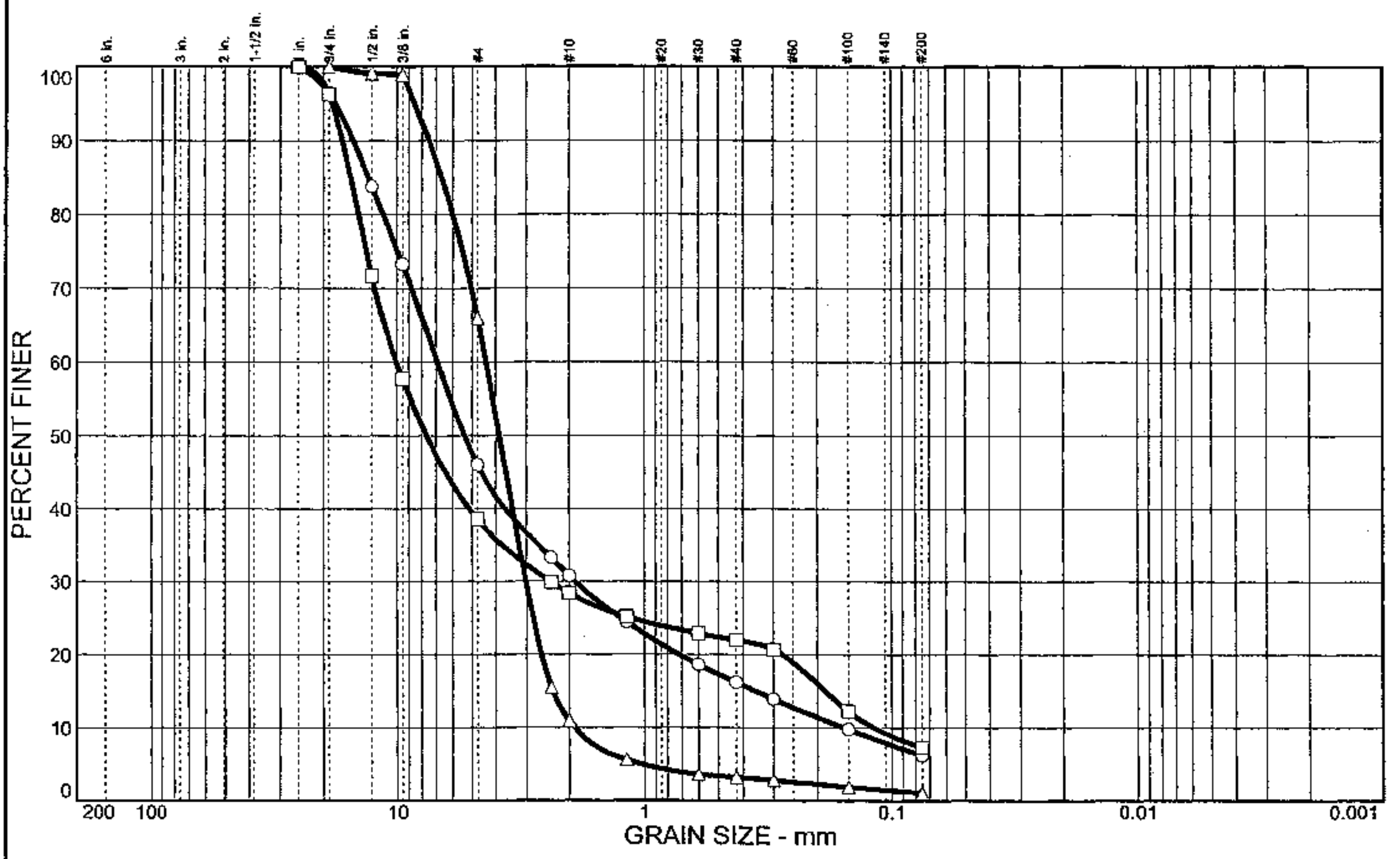
△ MSE fill

○ Source: Sta. 152+10, 70' +/- Right Sample No.: Top Layer
□ Source: Sta. 152+10, 70' +/- Right Sample No.: Second Layer
△ Source: Sta. 152+10, 70' +/- Right Sample No.: Bottom Layer

NEVADA
DEPARTMENT OF
TRANSPORTATION

Client: Mark Salazar
Project: I-515 MSE Walls
Project No.: Contract 3181
Plate

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	LL	PI
○		53.9	39.9			GP-GM			
□		61.4	31.3			GP-GM			
△		34.0	64.9			SP			

SIEVE inches size	PERCENT FINER ○	□	△
1	100.0	100.0	
3/4	96.5	96.3	100.0
1/2	83.8	71.7	99.1
3/8	73.3	57.8	98.9
	GRAIN SIZE		
D_{60}	6.91	10.1	4.38
D_{30}	1.89	2.39	3.02
D_{10}	0.156	0.118	1.90
	COEFFICIENTS		
C_c	3.33	4.81	1.09
C_u	44.39	85.48	2.30

SIEVE number size	PERCENT FINER ○	□	△
#4	46.1	38.6	66.0
#8	33.3	29.9	15.5
#10	30.8	28.4	10.9
#16	24.5	25.2	5.6
#30	18.6	22.9	3.6
#40	16.2	22.0	3.2
#50	13.9	20.7	2.8
#100	9.8	12.3	1.9
#200	6.2	7.3	1.1

SOIL DESCRIPTION

○ Poorly graded gravel with silt and sand

□ Poorly graded gravel with silt and sand

△ Poorly graded sand with gravel

REMARKS:

○ Aggregate base layer?

□ Borrow cap on MSE fill

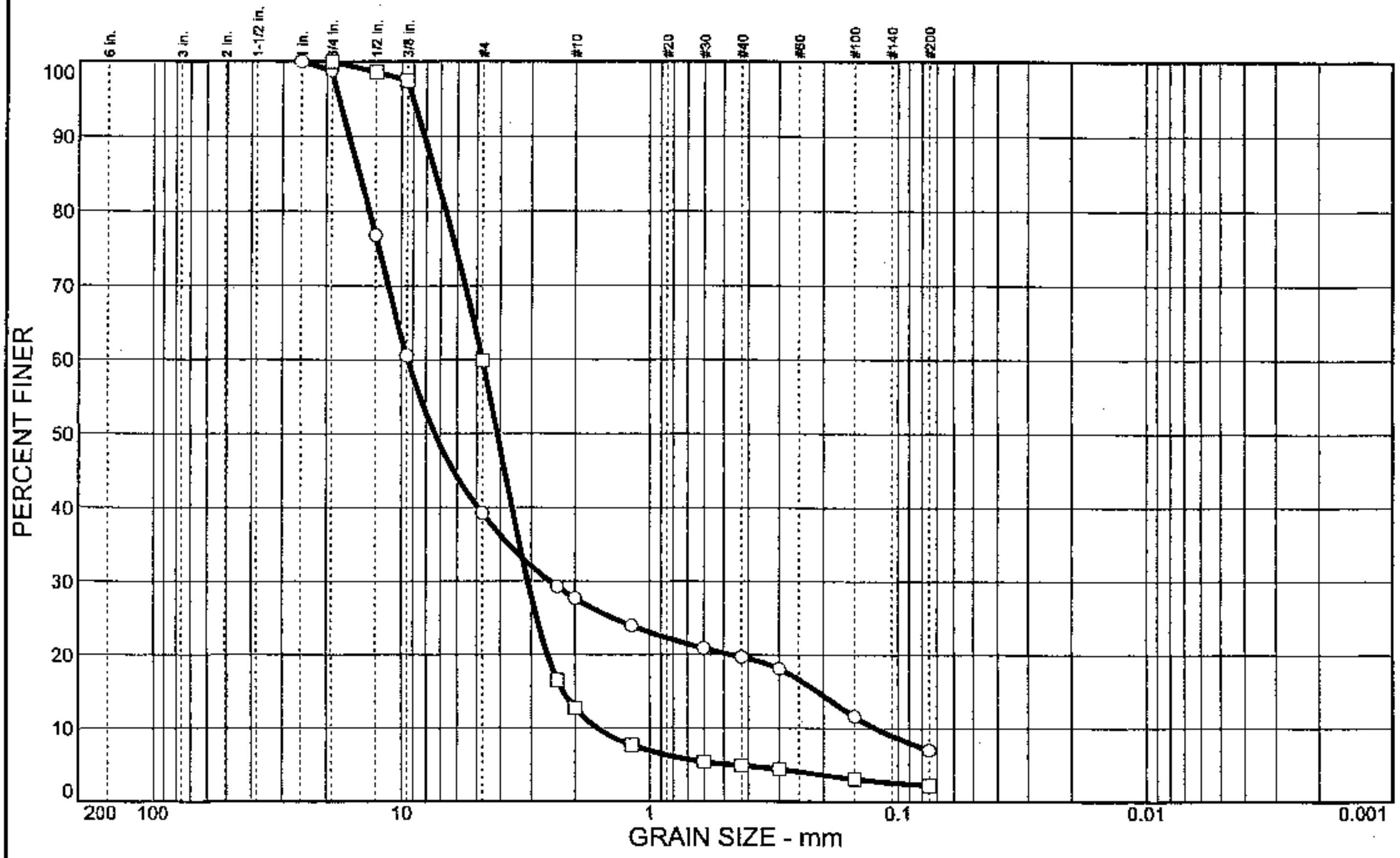
△ MSE fill

○ Source: Sta. 155+25, 70' +/- Right   Sample No.: Top
□ Source: Sta. 155+25, 70' +/- Right   Sample No.: Second Layer
△ Source: Sta. 155+25, 70' +/- Right   Sample No.: Bottom Layer

NEVADA DEPARTMENT OF TRANSPORTATION

Client: Mark Salazar
Project: I-515 MSE Walls
Project No.: Contract 3181
Plate

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	LL	PI
○		60.7	32.3			GP-GC		25	5
□		40.1	57.7			SP		24	1

SIEVE inches size	PERCENT FINER ○	PERCENT FINER □	
1	100.0		
3/4	98.8	100.0	
1/2	76.8	98.6	
3/8	60.6	97.5	
	GRAIN SIZE		
D_{60}	9.41	4.76	
D_{30}	2.52	3.09	
D_{10}	0.123	1.63	
	COEFFICIENTS		
C_c	5.48	1.24	
C_u	76.48	2.92	

SIEVE number size	PERCENT FINER ○	PERCENT FINER □	
#4	39.3	59.9	
#8	29.3	16.5	
#10	27.7	12.7	
#16	24.0	7.7	
#30	20.9	5.4	
#40	19.7	4.9	
#50	18.1	4.4	
#100	11.6	3.1	
#200	7.0	2.2	

SOIL DESCRIPTION

○ Poorly graded gravel with silty clay and sand

□ Poorly graded sand with gravel

REMARKS:

○ Borrow cap and aggregate base on MSE fill

□ MSE fill

○ Source: Sta. 152+87, 70' +/- Right   Sample No.: Top & Second Layer

□ Source: Sta. 152+87, 70' +/- Right   Sample No.: Bottom Layer

NEVADA DEPARTMENT OF TRANSPORTATION

Client: Mark Salazar

Project: I-515 MSE Walls

Project No.: Contract 3181

Plate

NEVADA DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL SECTION

CHEMICAL ANALYSIS

Contract No. 3181

PROJECT MSE Retaining Wall @ I-515 and Flamingo

SOURCE Bulk Samples

Sample No.	Chlorides ppm	Sulfates ppm	Ph	Resistivity Ohm - cm	Conductivity
152+10					
Aggregate Base	40	0	8.5	3,937	D 254
Borrow Cap	30	170	8.3	2,217	D 451
MSE Fill	30	0	8.7	7,092	D 141
155+25					
Aggregate Base	20	<100	8.7	3,984	D 251
Borrow Cap	30	<100	8.4	2,294	D 436
MSE Fill	30	600	8.3	1,018	D 982
152+87					
Borrow Cap	30	249	8.9	5,000	D200
MSE Fill	20	542	8.8	5,618	D178

NDOT Test Methods used: T238A for Soil pH, T235B for Soil Resistivity, & unnumbered NDOT Procedure for Determination of water Soluble Carbonates & Bicarbonates,Chlorides, & Sulfates in Soil Filtrates. Procedures are enclosed within.

TABULATION OF TEST RESULTS

Client: McMahon and Mann
Project: Las Vegas Corrosion Study
Source: MSE Wall Backfill
Terracon Project No.: 67041013
Page: 1 of 1

Location, Depth	Organic Cont., %, T267	pH, T289	Resistivity, ohm-cm, T288	Chloride Ion Content, mg/L, EPA 300	Sulfate Ion Content, Mg/L, EPA 300	InSitu Moist.(%)	LL	PI	Sieve Analysis – Cumulative % Passing															
									3"	2"	1 1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#10	#16	#30	#40	#50	#100	#200
4A 1st Panel												100	97	77	64	42	32		27	24		22	13	7.0
5B 2nd Panel	See Attached												100	99.9	99.7	68	16		5.9	2.9		2.0	1.4	0.9

M – The reported value for this analyte demonstrated a matrix effect.

Western Environmental Testing Laboratory
Analytical Report

Terracon
1380 Greg St., Suite 233
Sparks, NV 89431
Attn: Tom Adams

EPA Lab ID NV004
Received: 03/04/04
Lab Sample ID: 403-027
Reported: 03/15/04

Phone: (775) 351-2400 Fax: (775) 351-2423

SB

Project Name/Number: NDOT Contract 3181
Client Sample ID/Location: TP 513 2nd Panel
Date/Time Collected: 03/04/04
Sampled By: Client

Parameter	Method	Results	Units	Analyzed
pH	9045B	8.12	SU	03/05/04
pH	AASHTO/T289	8.10	SU	03/05/04
Soluble Chloride	300.0	78	mg/Kg	03/08/04
Soluble Chloride	AASHTO/T291	83	mg/Kg	03/06/04
Soluble Sulfate	300.0	4600	mg/Kg	03/09/04
Soluble Sulfate	AASHTO/T290	140	mg/Kg	03/08/04

Andy Smith, Lab Manager

TABULATION OF TEST RESULTS

Client: McMahon and Mann **Material:** Pea Gravel **Terracon Project No.:** 67041013
Project: Las Vegas Corrosion Study **Source:** MSE Wall Backfill **Page:** 1 of 1

Location, Depth	Organic Cont., %, T267	pH, T289	Resistivity, ohm-cm, T288	Chloride Ion Content, mg/L, EPA 300	Sulfate Ion Content, Mg/L, EPA 300	InSitu Moist (%)	LL	PI	Sieve Analysis – Cumulative % Passing															
									3"	2"	1 1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#10	#16	#30	#40	#50	#100	#200
2B		8.98	5200	<15	<15										100	67	17		6.4	3.8		2.7	1.8	1.1
3B	1.3	8.14	420	<15	380									100	99.8	72	22		8.4	4.7		3.2	2.1	1.3
4B		8.28		<15	1100M																			
6B		8.39		<15	160																			
7B		8.42		<15	340																			
S1	2.3	8.86	450	<15	1400									100	99.6	59	9.1		4.5	2.6		2.1	1.3	0.9
S2		8.06		<15	430									100	99.4	58	10		3.7	2.2		1.6	1.3	0.9
S3		8.62	410	20	300									100	99.6	56	7.8		2.2	1.4		1.2	1.0	0.8
S4		8.23	420	<15	390									100	99.4	50	7.8		3.2	2.0		1.5	1.1	0.8
S5		8.48		<15	470									100	99.6	56	7.5		1.9	1.3		1.1	0.9	0.7

M – The reported value for this analyte demonstrated a matrix effect.

MINIMUM LABORATORY SOIL RESISTIVITY
AASHTO Designation: T288-91

Client: McMahon & Mann

Project: Las Vegas Corrosion Study

Source: MSE Wall Backfill

Terracon Project No.: 67041013

Page 1 of 1

TP-2B		TP-3B		S1		S3		S4-S5 Composite	
H_2O (mL)[1]	R (Ω–cm)	H_2O (mL)	R (Ω–cm)	H_2O (mL)	R (Ω–cm)	H_2O (mL)	R (Ω–cm)	H_2O (mL)	R (Ω–cm)
150	28000	150	14000	150	11500	150	2700	150	4200
250	7500	250	1200	250	1300	250	1000	250	1150
350	6500	350	700	350	800	350	620	350	660
450	5200	450	490	450	490	450	480	450	470
550	5800	550	420	550	450	550	420	550	450
650	—	650	460	650	480	650	410	650	420
750	---	750	—	750	---	750	440	750	450

Note 1: Amount of water added to air dried sample

Western Environmental Testing Laboratory
Analytical Report

Terracon
1380 Greg St., Suite 233
Sparks, NV 89431
Attn: Rob Valceschini
Phone: (775) 351-2400 Fax: (775) 351-2423

EPA Lab ID NV004
Received: 03/31/04
Lab Sample ID: 403-178-1/5
Reported: 04/12/04

Project Name/Number: Not Specified
Client Sample ID/Location: See Below
Date/Time Collected: Not Specified
Sampled By: Client

Parameter	Method	Results	Units	Analyzed
TP 2B				
pH	AASHTO T289	8.98	SU	04/01/04
Chloride	300.0	<15	mg/L	04/01/04
Chloride -#40	300.0	<15	mg/L	04/01/04
Sulfate	300.0	<15	mg/L	04/01/04
Sulfate -#40	300.0	130	mg/L	04/01/04
TP 3B				
Organic Content	AASHTO T267	1.3	%	04/07/04
pH	AASHTO T289	8.14	SU	04/01/04
Chloride	300.0	<15	mg/L	04/01/04
Sulfate	300.0	380	mg/L	04/01/04
TP 4B				
pH	AASHTO T289	8.28	SU	04/01/04
Chloride	300.0	<15	mg/L	04/01/04
Sulfate	300.0	1100 M	mg/L	04/02/04
TP 6B				
pH	AASHTO T289	8.39	SU	04/01/04
Chloride	300.0	<15	mg/L	04/01/04
Sulfate	300.0	160	mg/L	04/01/04
TP 7B				
pH	AASHTO T289	8.42	SU	04/01/04
Chloride	300.0	<15	mg/L	04/01/04
Sulfate	300.0	340	mg/L	04/01/04

M = The reported value for this analyte demonstrated a matrix effect.

Andy Smith, Lab Manager

Western Environmental Testing Laboratory
Analytical Report

Terracon
1380 Greg St., Suite 233
Sparks, NV 89431
Attn: Rob Valceschini
Phone: (775) 351-2400 Fax: (775) 351-2423

EPA Lab ID	NV004
Received:	03/31/04
Lab Sample ID:	403-178-6/10
Reported:	04/09/04

Project Name/Number:	Not Specified
Client Sample ID/Location:	See Below
Date/Time Collected:	Not Specified
Sampled By:	Client

	Parameter	Method	Results	Units	Analyzed
S1					
	Chloride	300.0	<15	mg/L	04/01/04
	Sulfate	300.0	1400	mg/L	04/02/04
S2					
	pH	AASHTO T289	8.48	SU	04/01/04
	Chloride	300.0	<15	mg/L	04/01/04
	Sulfate	300.0	430	mg/L	04/01/04
S3					
	Chloride	300.0	20	mg/L	04/01/04
	Sulfate	300.0	300	mg/L	04/01/04
S4					
	Chloride	300.0	<15	mg/L	04/01/04
	Sulfate	300.0	390	mg/L	04/01/04
S5					
	Chloride	300.0	<15	mg/L	04/01/04
	Sulfate	300.0	470	mg/L	04/01/04

Andy Smith, Lab Manager

QUALITY CONTROL REPORT

Sample ID: 403-178
Reported: 04/09/04

PARAMETER	METHOD	UNITS	METHOD BLANK RESULTS	LABORATORY FORTIFIED BLANK			DUPLICATE		
				RESULT	ACTUAL	% RECOVERY	SAMPLE RESULT	DUPLICATE RESULT	% RPD
pH	150.1	SU	n/a	7.08	7.00	101	8.42	8.40	<1
Chloride	300.0	mg/L	<1.0	5.05	5.0	101	1.23	1.24	<1
Sulfate	300.0	mg/L	<1.0	9.87	10.0	99	30.1	30.2	<1
Sulfate	300.0	mg/L	<1.0	9.72	10.0	97	21.6	21.9	2

PARAMETER	METHOD	UNITS	MATRIX SPIKE RESULTS					DATE ANALYZED
			SPIKED SAMPLE	SAMPLE RESULT	SPIKE RESULT	SPIKE VALUE	% RECOVERY	
Chloride	300.0	mg/L	403-178-07	0.270	1.23	1.00	96	04/01/04
Sulfate	300.0	mg/L	403-187-07	28.9	30.1	1.00	123	04/01/04
Sulfate	300.0	mg/L	403-178-03	14.4	21.6	1.00	NC	04/02/04

NC = Not calculated due to matrix interference.

TABULATION OF TEST RESULTS

Client: McMahon & Mann Consulting Engineers
Project: Las Vegas Corrosion Study

Material: Site Soils
Source: Bag Samples

Terracon Project No.: 67041013
Page: 1 of 2

				w %					3"	2"	1½"	1"	3/4	1/2"	3/8	#4	#8	#10	#16 ~~80~~	#30	#40	#50	#100	#200
SPECIFICATION																								
S11				6.7							100	99.1	98.8	98.3	97.6	45.3	7.0	5.6	2.8	2.0	1.7	1.4	0.8	0.4
S12				5.6							100	99.7	94.5	80.5	72.7	34.8	11.2	10.0	8.2	7.1	6.6	6.0	3.7	1.9
S13				6.7								100	99.7	99.3	98.8	51.1	7.1	4.7	2.5	1.9	1.8	1.6	1.3	0.9
S14				6.4							100	99.6	99.2	98.7	98.4	43.8	6.1	4.4	2.7	2.1	2.0	1.7	1.3	0.8
S15				6.4									100	99.7	99.3	58.6	12.7	9.4	4.6	2.7	2.3	2.0	1.6	1.0
S16				6.4									100	99.0	98.9	55.0	5.9	3.7	1.9	1.5	1.4	1.3	1.1	0.7

TABULATION OF TEST RESULTS

Client: McMahon & Mann Consulting Engineers
Project: Las Vegas Corrosion Study

Material: Site Soils
Source: Bag Samples

Terracon Project No.: 67041013
Page: 2 of 2

													3/4	1/2	3/8	4	8	10	16	30	40	50	100	200
SPECIFICATION																								
S17				6.4									100	99.7	99.4	56.0	12.4	9.2	5.1	3.3	2.8	2.5	1.8	1.2

Western Environmental Testing Laboratory
Analytical Report

Terracon
1380 Greg St., Suite 233
Sparks, NV 89431
Attn: Tom Adams
Phone: (775) 351-2400   Fax: (775) 351-2423

EPA Lab ID   NV004
Received: 05/13/04
Lab Sample ID: 405-058 01/05
Reported: 06/14/04

Project Name/Number: Las Vegas Corrosion Study / 67041013
Client Sample ID/Location: see below
Date/Time Collected: not specified
Sampled By: Client

	Parameter	Method	Results	Units	Analyzed
S11					
	pH	AASHTO T289	9.50	SU	05/14/04
	Chloride	EPA 300.0	19	mg/kg	05/24/04
	Sulfate	EPA 300.0	3700	mg/kg	05/20/04
S12					
	pH	AASHTO T289	9.37	SU	05/14/04
	Chloride	EPA 300.0	<15	mg/kg	05/24/04
	Sulfate	EPA 300.0	910	mg/kg	05/20/04
S13					
	pH	AASHTO T289	9.01	SU	05/14/04
	Chloride	EPA 300.0	18	mg/kg	05/24/04
	Sulfate	EPA 300.0	7500	mg/kg	05/24/04
	Organic Content	AASHTO T267	5.2	%	05/18/04
S14					
	pH	AASHTO T289	9.08	SU	05/14/04
	Chloride	EPA 300.0	25	mg/kg	05/24/04
	Sulfate	EPA 300.0	2900	mg/kg	05/20/04
S15					
	pH	AASHTO T289	9.38	SU	05/14/04
	Chloride	EPA 300.0	<15	mg/kg	05/20/04
	Sulfate	EPA 300.0	240	mg/kg	05/20/04

Andy Smith, Lab Manager

Western Environmental Testing Laboratory
Analytical Report

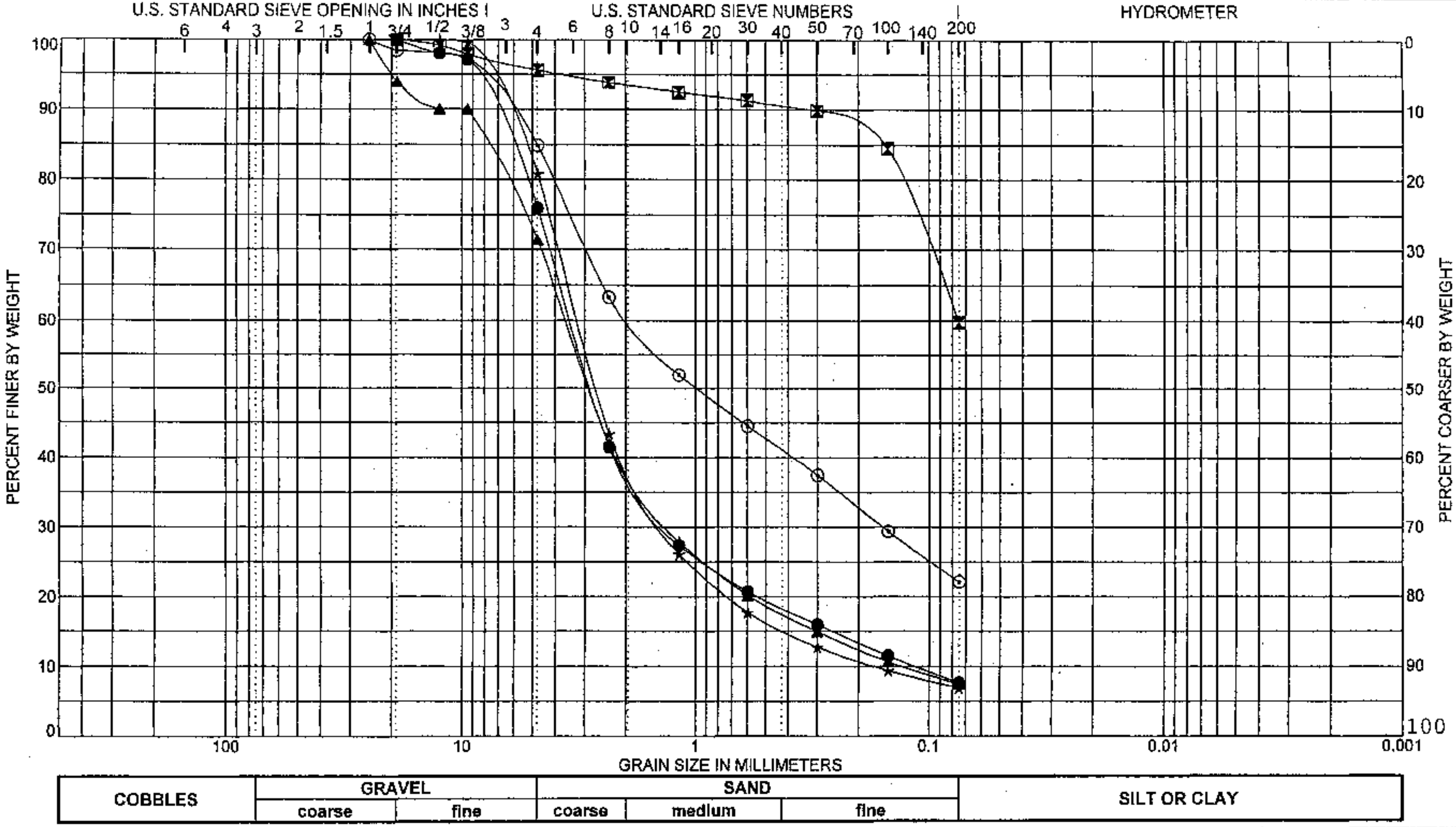
Terracon
1380 Greg St., Suite 233
Sparks, NV 89431
Attn: Tom Adams
Phone: (775) 351-2400 Fax: (775) 351-2423

EPA Lab ID NV004
Received: 05/13/04
Lab Sample ID: 405-058 06/07
Reported: 06/14/04

Project Name/Number: Las Vegas Corrosion Study / 67041013
Client Sample ID/Location: see below
Date/Time Collected: not specified
Sampled By: Client

Parameter	Method	Results	Units	Analyzed
S16				
pH	AASHTO T289	9.14	SU	05/14/04
Chloride	EPA 300.0	<15	mg/kg	05/24/04
Sulfate	EPA 300.0	3000	mg/kg	05/20/04
Organic Content	AASHTO T267	4.0	%	05/18/04
S17				
pH	AASHTO T289	8.46	SU	05/14/04
Chloride	EPA 300.0	230	mg/kg	05/20/04
Sulfate	EPA 300.0	6900	mg/kg	05/24/04

Andy Smith, Lab Manager



	Specimen Identification		Classification	WC%	LL	PL	PI	Cc	Cu
●	B-1	10.0 ft.	POORLY GRADED SAND with SILT and GRAVEL SP-SM		NP	NP	NP	4.63	30.3
☒	B-1	40.0 ft.	SANDY LEAN CLAY CL		31	19	12		
▲	B-2	25.0 ft.	POORLY GRADED SAND with SILT and GRAVEL SP-SM		NP	NP	NP	3.69	28.2
★	B-3	20.0 ft.	POORLY GRADED SAND with SILT and GRAVEL SP-SM		NP	NP	NP	3.50	19.1
⊙	B-3	30.0 ft.	SILTY SAND with GRAVEL SM		NP	NP	NP		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	B-1	10.0	19.00	3.43	1.342	0.1134	24.0	68.3	7.7	
☒	B-1	40.0	19.00	0.08			4.4	35.8	59.8	
▲	B-2	25.0	25.00	3.62	1.311	0.1286	28.5	64.0	7.5	
★	B-3	20.0	12.50	3.22	1.379	0.1689	19.2	73.9	6.9	
⊙	B-3	30.0	25.00	1.93	0.158		15.1	62.8	22.1	

Terracon

Client:	HDR Engineering	Project No.	64045036
Project:	MSE Wall Distress Investigation	Date	March 2004
Project Site	Flamingo Road MSE Wall @ I-515	SIEVE ANALYSES	Plate: D-1

Atlas Consultants, Inc.

6000 S. Eastern Avenue, Suite 10J • Las Vegas, Nevada 89119
(702) 383-1199 • Fax (702) 383-4983

member of
AMERICAN SOCIETY FOR
TESTING MATERIALS

LABORATORY NO: 12145(k)

SAMPLE: Soil

MARKED: 64045036

SUBMITTED BY: Terracon, Inc.

DATE: February 26, 2004

P.O.:

LAB ID:

SOIL SIEVE = -10

REPORT OF DETERMINATION

BORING NUMBER	B-2	B-2	B-3			
SAMPLE NUMBER						
DEPTH (feet)	15.0	25.0	20.0			
pH VALUE	9.27	9.21	8.53			
RED-OX (mv)	+589	+593	+616			
SULFATE (mg/Kg)	660	1,513	9,075			
SULFIDE (mg/Kg)	Nil	Nil	Nil			
TOTAL SALTS (mg/Kg)	1,736	2,946	12,880			
CHLORIDE (mg/Kg)	75	100	225			

Respectfully submitted,

Robert L Summers

Robert L. Summers
Analytical Chemist

NOTES:

1. The soil:water extract ratio was 1:5, the results are in mg/Kg in the soil.
2. The standard methods used for the determinations are AWWA 4500 H pH Value, ASTM D 1498 Red-Ox, AWWA 4500-SO_4 E Turbidimetric, AWWA 4500-S D Methylene Blue, AWWA 2540 C TDS and AWWA 4500-C1 B Argentometric.
3. Nil is less than 1.0 mg/Kg.

Atlas Consultants, Inc.

6000 S. Eastern Avenue, Suite 10J • Las Vegas, Nevada 89119
(702) 383-1199 • Fax (702) 383-4983

member of
AMERICAN SOCIETY FOR
TESTING MATERIALS

LABORATORY NO: 12145(e)
SAMPLE: Soil
MARKED: 64045036
SUBMITTED BY: Terracon, Inc.

DATE: February 24, 2004
P.O.:
LAB ID:
SOIL SIEVE = -10

REPORT OF DETERMINATION

BORING NUMBER	B-3					
SAMPLE NUMBER						
DEPTH (feet)	5.0					
pH VALUE	8.46					
RED-OX (mv)	+711					
SULFATE (mg/Kg)	8,773					
SULFIDE (mg/Kg)	Nil					
TOTAL SALTS (mg/Kg)	11,872					
CHLORIDE (mg/Kg)	100					

Respectfully submitted,

Robert L. Summers

Robert L. Summers
Analytical Chemist

NOTES:

1. The soil:water extract ratio was 1:5, the results are in mg/Kg in the soil.
2. The standard methods used for the determinations are AWWA 4500 H pH Value, ASTM D 1498 Red-Ox, AWWA 4500-SO_4 E Turbidimetric, AWWA 4500-S D Methylene Blue, AWWA 2540 C TDS and AWWA 4500-C1 B Argentometric.
3. Nil is less than 1.0 mg/Kg.

Atlas Consultants, Inc.

6000 S. Eastern Avenue, Suite 10J • Las Vegas, Nevada 89119
(702) 383-1199 • Fax (702) 383-4983

member of
AMERICAN SOCIETY FOR
TESTING MATERIALS

LABORATORY NO:	12145(f)	**DATE:**	February 25, 2004
SAMPLE:	Soil	**P.O.:**	
MARKED:	64045036	**SAMPLE NO:**	
SUBMITTED BY:	Teracon, Inc.	**SOIL SIEVE =**	-10

REPORT OF DETERMINATION

BORING NUMBER	B-1	B-1	B-5			
SAMPLE NUMBER						
DEPTH (feet)	10.0	20.0	30.0			
pH VALUE	8.71	8.91	8.81			
RED-OX (mv)	+622	+609	+627			
SULFATE (mg/Kg)	3,740	1,238	9,625			
SULFIDE (mg/Kg)	Nil	Nil	Nil			
TOTAL SALTS (mg/Kg)	5,796	2,369	14,560			
CHLORIDE (mg/Kg)	50	75	500			
RESISTIVITY (Ohm-cm)	1,950	5,200	585			

Respectfully submitted,

Robert L Summers

Robert L. Summers
Analytical Chemist

NOTES:

1. The soil:water extract ratio was 1:5, the results are in mg/Kg in the soil.
2. The standard methods used for the determinations are AWWA 4500 H pH Value, ASTM D 1498 Red-Ox, AWWA 4500-SO_4 E Turbidimetric, AWWA 4500-S D Methylene Blue, AWWA 2510 Electrical Conductivity, AWWA 4500-Cl B Argentometric and ASTM G 57.
3. Nil is less than 1.0 mg/Kg.

Atlas Consultants, Inc.

6000 S. Eastern Avenue, Suite 10J • Las Vegas, Nevada 89119
(702) 383-1199 • Fax (702) 383-4983

member of
AMERICAN SOCIETY FOR
TESTING MATERIALS

LABORATORY NO:	12145(g)	**DATE:**	February 25, 2004
SAMPLE:	Soil	**P.O.:**	
MARKED:	64045036		
SUBMITTED BY:	Terracon, Inc.		

REPORT OF DETERMINATION

ASTM G 57

CONSTITUENT	LOCATION	DEPTH (feet)	RESULTS
Resistivity (Ohm-cm)	B-3	15.0	3,000
Resistivity (Ohm-cm)	B-5	5.0	1,300

Respectfully submitted,

Robert L. Summers

Robert L. Summers
Analytical Chemist

geotechnics
INTEGRITY IN TESTING

LABORATORY TEST REPORT

March 22, 2004

Project No. 2004-060-01

Mr. Kenneth Fishman
McMahon & Mann
2495 Main St., Suite 432
Buffalo, NY 14214

RECEIVED
MAR 25 2004
McMahon & Mann
Consulting Engineers, P.C.

RE: Soils Testing – NDOT Corrosion Evaluation

Transmitted herein are the results of the soils testing performed for McMahon & Mann verified on the Project Verification Form, submitted March 2, 2004. The testing was performed in general accordance with the ASTM methods listed on the enclosed data sheets. The remaining sample materials for this project will be retained for a minimum of 90 days as directed by the Geotechnics' Quality Program.

Disclaimer

The test results are believed to be representative of the samples submitted but are indicative only of the specimens which were evaluated. Geotechnics has no direct knowledge of the origin of the samples, implies no position with regard to the disposition of the test results, i.e., pass/fail, and makes no claims as to the suitability of the material for its intended use.

The test data and all associated project information provided shall be held in strict confidence and disclosed to other parties only with authorization of the Client and Geotechnics. The test data submitted herein is considered integral with this report and is not to be reproduced except in whole and only with the authorization of the Client and Geotechnics.

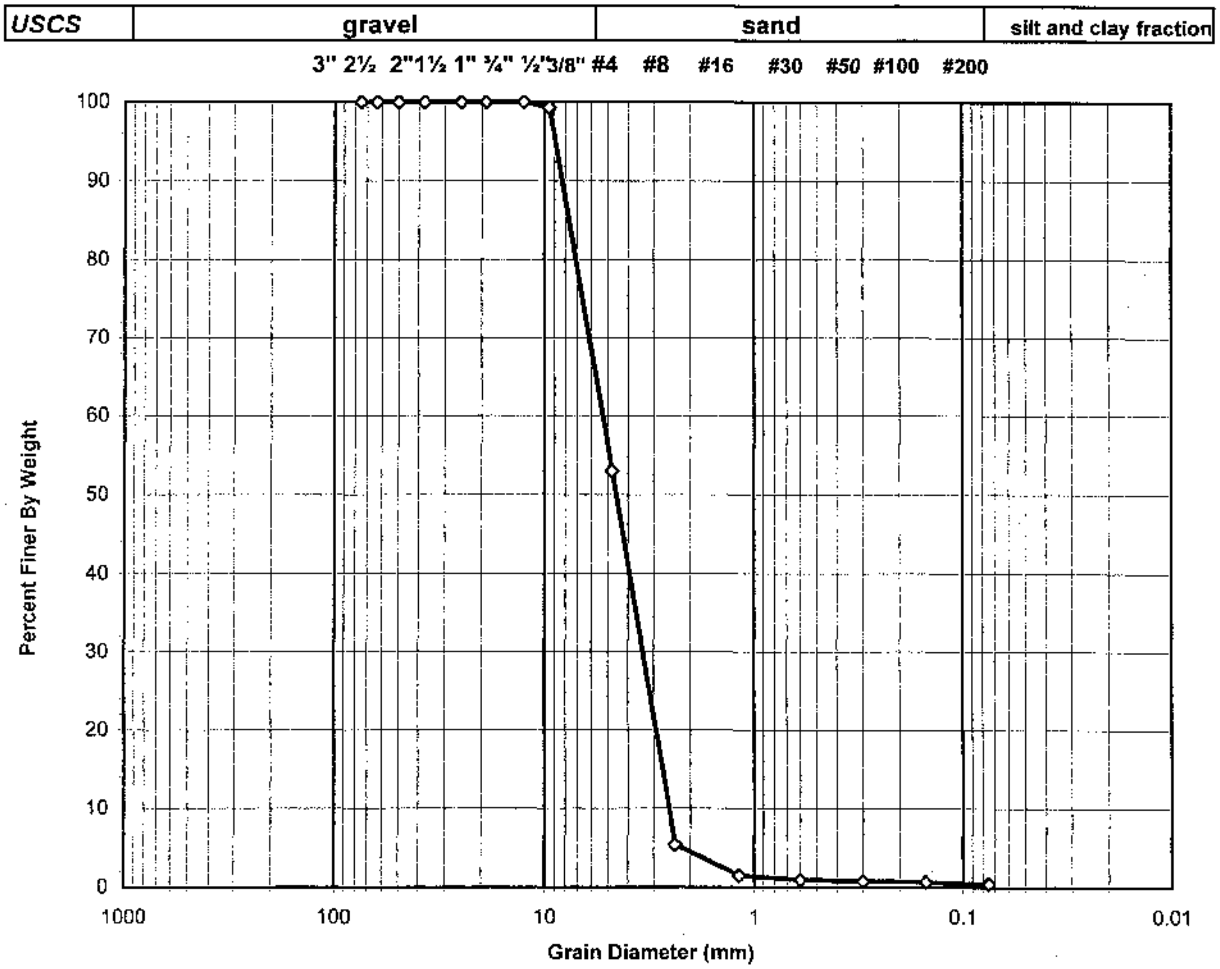
We are pleased to provide these testing services. Should you have any questions or if we may be of further assistance, please do not hesitate to contact our office.

Respectively submitted,

David R. Backstrom
Laboratory Director

DRY SIEVE ANALYSIS
AASHTO T27-99

Client	McMAHON & MANN	Boring No.	I-515
Client Reference	NDOT CORROSION EVALUATION	Depth(ft.)	BACKFILL
Project No.	2004-060-01	Sample No.	FLAMINGO RD
Lab ID	2004-060-01-01		
	Color	**BROWN**	



USCS Symbol: ***sp, ASSUMED***

USCS Classification: ***POORLY GRADED SAND WITH GRAVEL***

D60 = 5.275

D30 = 3.388 CC = 0.86

D10 = 2.525 CU = 2.09

Tested By JP Date 02/04/04 Checked By Jim Date 3-4-04

geotechnics
INTEGRITY IN TESTING

DRY SIEVE ANALYSIS
AASHTO T27-99

Client	McMAHON & MANN	Boring No.	I-515
Client Reference	NDOT CORROSION EVALUATION	Depth(ft.)	BACKFILL
Project No.	2004-060-01	Sample No.	FLAMINGO RD
Lab ID	2004-060-01-01		
		Color	**BROWN**

Tare No.	2342	Wt. of Dry Specimen (gm)	556.87
Wt. Tare + DS.	653.80	Wt. of +#200 Specimen(gm)	554.38
Wt.Tare +Dry,Unwashed specimen	653.80	Wt. of -#200 Specimen(gm)	2.49
Wt Tare	96.93		
Wt. Dry, specimen	556.87		

Total Wt. Retained After Sieving 556.88

% Difference Wt. Dry,Washed specimen vs Total Wt. Retained After Sieving 0.0

Note: % Difference must not be more than 0.3

Sieve	Sieve Opening (mm)	Weight Retained (gm.)	Percent Retained	Accumulated Percent Retained	**Percent Finer**
3"	75	0.00	0	0	100
2 1/2"	63	0.00	0	0	100
2"	50	0.00	0	0	100
1 1/2"	37.50	0.00	0	0	100
1"	25.00	0.00	0	0	100
3/4"	19.00	0.00	0	0	100
1/2"	12.50	0.00	0	0	100
3/8"	9.50	3.63	1	1	99
#4	4.75	258.19	46	47	53
#8	2.36	264.95	48	95	5
#16	1.18	21.78	4	99	1
#30	0.60	2.86	1	99	1
#50	0.30	0.88	0	99	1
#100	0.15	0.80	0	99	1
#200	0.075	1.30	0	100	0
Pan	-	2.49	0	100	-

Tested By JP Date 02/04/04 Checked By Jcm Date 3-4-04

geotechnics
INTEGRITY IN TESTING

pH OF SOILS
AASHTO T 289-91
(SOP- S36)

Client	McMAHON & MANN
Client Reference	NDOT CORROSION EVALUATION
Project No.	2004-060-01

Lab ID		01
Boring No.		I-515
Depth (ft)		BACKFILL
Sample No.		FLAMINGO RD.
Drying Tare No.		729
Testing Tare No.		F
Temperature (° C)		20
pH of Sample	***Test 1***	**9.4**
	Test 2	**9.5**
Agreement (+/- 0.2 units)		**-0.1**

Meter Calibration

Buffer pH	Meter Reading	Meter Model
4.00	4.00	ORION 720A
7.00	7.00	
10.0	10.05	

pH of Deionized Water (Acceptable range 6.5-7.5)	6.5

Tested By KBL Date 03/04/04 Checked By Jm Date 3-4-04

Minimum Resistivity

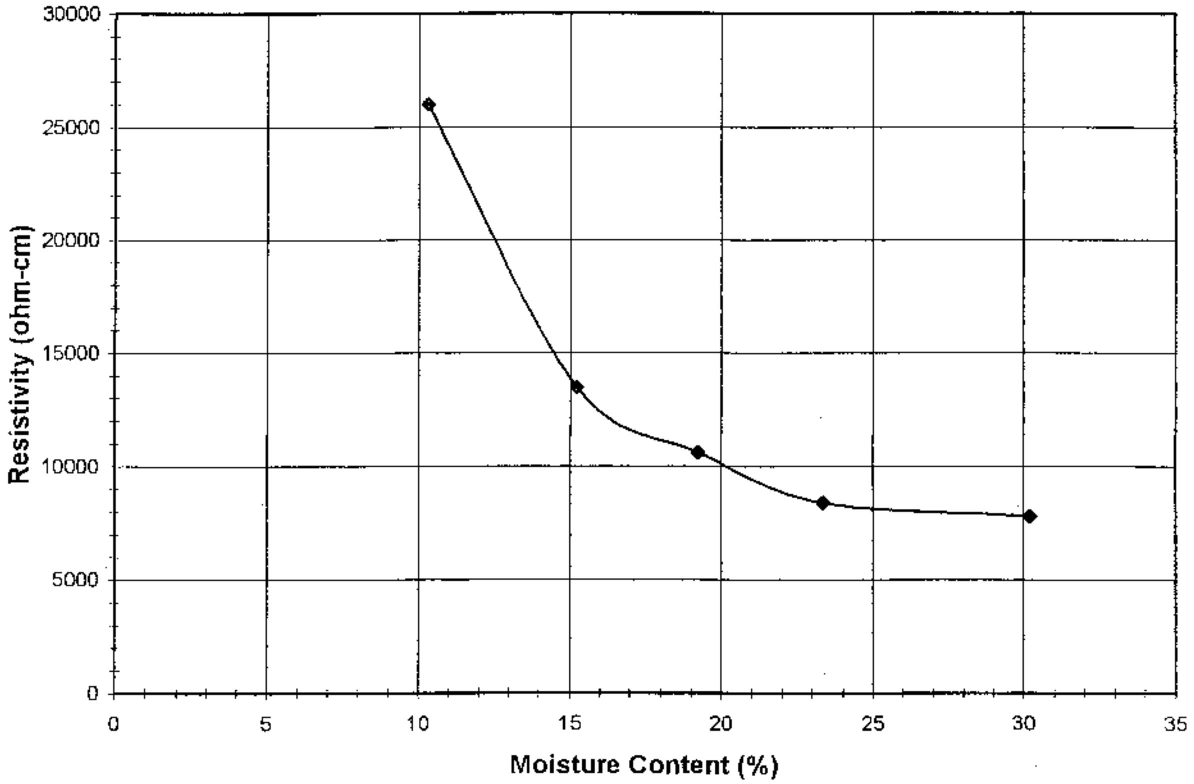
AASHTO T288 (SOP - S56)

geotechnics
INTEGRITY IN TESTING

Client	McMAHON & MANN	Boring No.	I-515
Client Reference	NDOT Corrosion Evaluation	Depth (ft)	BACKFILL
Project No.	2004-060-01	Sample No.	FLAMINGO RD.
Lab ID	2004-060-01-01	Visual Description	BROWN SAND (- #10 Sieve material)

Tare No.	789	2365	86	65	2301
Tare & Wet Specimen (gm)	43.34	43.34	48.13	50.97	65.75
Tare & Dry Specimen (gm)	40.94	39.94	42.99	44.65	55.09
Tare Weight (gm)	17.65	17.60	16.28	17.59	19.79
Moisture Content (%)	**10.3**	**15.2**	**19.2**	**23.4**	**30.2**
Resistance (ohm)	**26000**	**13500**	**10600**	**8400**	**7800**
Resistivity (ohm-cm)	**26000**	**13500**	**10600**	**8400**	**7800**

Note: The ratio of Miller Box area versus distance between electrodes is equal to 1.



Soil Class	*Corrosion Resistance*	*Specific Resistivity (ohm-cm)*
1	Excellent	10,000 - 6,000
2	Good	6,000 - 4,500
3	Fair	4,500 - 2,000
4	Bad	2,000 - 0

Tested By KBL *Date* 03/04/04 *Checked By* *Date* 3-5-04

UEC Technologies LLC
IH and Environmental Laboratories
4000 Tech Center Drive
Monroeville, PA 15146
Phone: (412) 825-2400 Fax: (412) 825-2407
AIHA Accreditation #322 *http://www.uec.com*

Final Report
UEC Tracking Sheet: 15510

Clark
Laboratories LLC

Geotechnics, Inc.
Geotechnics, Inc.
544 Bradock Avenue
East Pittsburgh, PA 15112

Customer Code: 1300 - 0001
Attention: James Moyer
Work Req By: Kevin Lichtenfels
Customer P.O.:
Project Number: NDOT CORROSION EVALUATION

Phone: (412) 823-7600
Fax: (412) 823-8999
Email: klichtenfels@geotechnics.net
Loc:
Date Rcvd: 03/03/04

UEC Sample Id: **000103596** Client Sample Id: **FLAMINGO RD** Sampling Date: 03/03/04

Analyte	Method	Analysis Date	An. Init.	**Reporting Limit**	Results **Total**
Chloride	Cal 422	03/09/04	JJM	**mg/kg**	< **70 mg/kg**
Sulfate	Cal 417	03/09/04	JJM	**mg/kg**	**93 mg/kg**

Analyst: James J. Miller Date: 03/09/04
Jim Miller - General Chemistry

Approved: Date: 03/11/04
Rachelle Hergenroeder - Project Coordinator

Time, flow rate, and/or sample volume data are based on client supplied information, unless otherwise noted.

***** END OF REPORT *****

WATER CONTENT NEVADA CORROSION STUDY

TEST PIT,GRID #	CUP + WET SOIL	MASS OF CUP	MASS WET SOIL	CUP + DRY SOIL	MASS DRY SOIL	MASS OF WATER	WATER CONTENT	
TP-8, G-1	64	12.77	51.23	60.77	48	3.23	7%	
TP-8, G-1 DEPOSITS	38.73	12.77	25.96	37.8	25.03	0.93	4%	
TP-9 EMB FILL	56.75	12.75	44	48.97	36.22	7.78	21%	⇦ FILL
TP-9, G-1	72.26	12.72	59.54	68.41	55.69	3.85	7%	
TP-10, G-1, N	54.62	12.84	41.78	53.93	41.09	0.69	2%	
TP-10, G-1, N, Z-1	61.39	12.7	48.69	59.07	46.37	2.32	5%	
TP-10, G-1, N, Z-2	64.93	12.67	52.26	62.53	49.86	2.4	5%	
TP-10, G-1, S, Z-2	69.21	12.67	56.54	66.65	53.98	2.56	5%	
TP-10, G-2	64.06	12.82	51.24	61.43	48.61	2.63	5%	
TP-11, FILL	95.66	26.85	68.81	90.4	63.55	5.26	8%	⇦ FILL
TP-11, G-1	52.33	27.05	25.28	51.92	24.87	0.41	2%	
TP-11, G-1, Z-1	61.77	12.54	49.23	59.35	46.81	2.42	5%	
TP-11, G-1, Z-2	68.32	12.75	55.57	66	53.25	2.32	4%	
TP-11, G-1, Z-3	96.08	26.67	69.41	93.55	66.88	2.53	4%	
TP-11, G-2, Z-1	97.41	26.53	70.88	93.66	67.13	3.75	6%	
TP-11, G-2, Z-2	69.38	12.75	56.63	66.66	53.91	2.72	5%	
TP-11, G-2, Z-3	98.57	27.18	71.39	95.31	68.13	3.26	5%	

APPENDIX III

III. Assessment of Reinforcement Condition

A. Observe Reinforcements

Test pits TP-2 through TP-11 were used to observe the top three layers of MSE reinforcements, and samples were retrieved for direct physical observation and metallurgical analysis.

FHWA supervised the retrieval of reinforcement samples for TP-2 through TP-7, and NDOT shipped the samples to MMCE for examination. MMCE observed and retrieved samples from TP 8 through TP 11. MMCE photographed the samples, measured the wire diameter at selected locations along the samples and sent one sample to Adirondack Environmental Testing Services, Inc. for examination and metallurgical analysis.

B. Exhume Reinforcements

A total of 29 samples were retrieved from Test Pits 2 through 7 located behind Wall #1, as summarized in Table III-1. Photographs of the samples are presented in this appendix depicting the condition and geometry of the samples. Samples are identified by Test Pit Number, Layer Number and A,B,C,D or E where the final letter indicates how many samples were retrieved at this level of the test pit, e.g. TP2-II-C is the third sample retrieved from the second reinforcement layer unearthed during excavation of Test Pit #2.

Nineteen of the samples were specifically identified with respect to a test pit and layer number, and ten of the samples, tagged as miscellaneous, were assortments retrieved from different nonspecific locations. Four of the samples including TP3-II-A, TP4-II-D, TP5-III-A and TP7-II-B are more substantial samples having lengths of approximately five feet, including two longitudinal wires and two or three 1.5' long transverse wires.

Table III-1. Reinforcement Sample Log for Wall #1.

Test Pit #	Layer #	No. of Samples	Comments
TP-2	II	3	W9.5 x 9.5; 3' to 5' long samples including one longitudinal wire and one to three 0.5' to 1' transverse wires
TP-3	II	3	W9.5 x 9.5; 2' to 5' long samples with one or two longitudinal wires and one or two 0.5' to 1.5' transverse wires
TP-3	III	2	W9.5 x 9.5; 1.5' and 3' long single longitudinal wire; one sample includes a 0.5' long transverse wire
TP-4	I	1	W7.0 x W7.0; 2.5' long longitudinal wire with 0.5' transverse wire; bent sample
TP-4	II	5	W7.0 x W7.0; 1' to 5' long; one 5 feet long sample includes two longitudinal wires and three 1.5' long transverse wires. Generally, more whitish-tan condensate is adhered to samples from TP-4 levels II and III
TP-4	III	1	W9.5 x W9.5; One 3' longitudinal wire with one 1.5' long transverse wire. Generally, more whitish-tan condensate is adhered to samples from TP-4 levels II and III
TP-5	III	1	W7.0 x W7.0; two 5' longitudinal wires with three 1' long transverse

			wire. This sample was selected for metallurgy testing.
TP-7	I	1	W7.0 x W7.0; 1.5' long wire; bent
TP-7	II	2	W7.0 x W7.0; 5' long samples; one sample includes two longitudinal wires and three 1.5' long transverse wires.
			MISCELLANEOUS
TP 2 & 3	II & III	6	Assorted pieces of wire 6 inches to 30 inches long; some bent during extraction
TP 4 - 7	Unknown	4	Assorted pieces of wire 3 inches to 30 inches long; some bent during extraction; one sample from TP-4 is coated with whitish-tan and rust colored condensate and aggregate.
Sample Total =		29	

MMCE collected eighteen additional reinforcement samples from TP 8 through TP 11. All of these samples were W7.0 x W 7.0 welded wire fabric. Figures III-1 (a) and (b) illustrate the geometries of samples retrieved from TP-8 or TP-9, and TP-10 or TP-11, respectively. Each sample is greater than four feet long incorporating two transverse wires. Each wire is numbered, and the location along a wire is identified as Zone 1, Zone 2 or Zone 3. With respect to the wall face, Zone 1 is within two feet (i.e. between the wall face and the first transverse wire), Zone 2 is between two and four feet (i.e., between the first and second transverse wires), and Zone 3 is between four and five feet from the wall face (i.e., beyond the second transverse wire). Test pits were advanced behind the wall face and locations were varied with respect to the location of facing joints to reveal either the central portion of a grid, or the edges from two grids. Test pits TP-8 and TP-9 were excavated between facing columns along Wall #2, and roughly centered about a facing joint. Thus, samples from TP-8 and TP-9 include widths from the central portions of grids spanning the facing joint at each layer encountered. Test pits TP-10 and TP-11 were each centered about a facing column along Wall #3 exposing portions of two grids; one north and one south of the facing column. Thus, for TP-10 and TP-11, portions from two grids were sampled at each layer encountered. Table III-2 is a summary of reinforcement samples retrieved from test pits advanced behind Walls #2 and #3.

Table III-2. Reinforcement Sample Log for Walls #2 and #3.

Test Pit #	Layer #	No. of Samples	Comments
TP-8	I	1	Sample includes 10 longitudinal wires.
TP-8	II	1	Sample includes 8 longitudinal wires.
TP-8	III	1	Sample includes 8 longitudinal wires.
TP-9	I	1	Sample includes 10longitudinal wires.
TP-9	II	1	Sample includes 8 longitudinal wires.
TP-9	III	1	Sample includes 9 longitudinal wires.
TP-10	I	2	North sample includes 5, and south sample includes 3 longitudinal wires.
TP-10	II	2	North sample includes 4, and south sample includes 2 longitudinal wires.
TP-10	III	2	North sample includes 4, and south sample includes 2 longitudinal wires.
TP-11	I	2	North sample includes 3, and south sample includes 5 longitudinal

			wires.
TP-11	II	2	North sample includes 3, and south sample includes 4 longitudinal wires.
TP-11	III	2	North sample includes 2, and south sample includes 4 longitudinal wires.
Sample Total =		18	

C. Loss of Section Measurements

MMCE observed each of the samples identified in Tables III-1 and III-2 and measured the remaining diameter at selected locations using a pair of calipers with a sensitivity of ± 0.0005 inches. Corrosion deposits and precipitate were removed from the surface of the samples using a pair of pliers and a wire brush prior to making measurements. In cases where the loss of section appeared to be unsymmetrical, three measurements of diameter, spaced approximately 120° apart, were obtained along the perimeter of the section and averaged to estimate the loss of section. The study described in this report includes measurement of section loss at approximately twenty-eight hundred locations, distributed among thirty-seven samples. Detailed data sheets describing all of the section loss measurements are included in this appendix.

D. Observations and Loss of Section

Two quantities are estimated based on the measurements of remaining diameter including:

1. remaining capacities of the exhumed reinforcements, and
2. "statistical" or "idealized" uniform metal loss.

Estimated Capacity of Exhumed Reinforcements

Along each wire specimen included in a grid sample (see Tables III-1 and III-2) a critical location is identified corresponding to the smallest remaining diameter observed at any point along the specimen. The remaining diameters at each critical section for all the wires included within a corresponding grid sample are averaged to render the average remaining wire diameter for the grid sample. Remaining grid capacity is computed as the ratio of the average remaining capacity of the wires to the initial wire capacity. In general, the initial wire capacity is computed based on a initial wire diameter of 0.298 inches, which is consistent with the shop drawings showing the top layers of reinforcements along Walls #1, 2 and 3 to be W7 x W7 welded wire fabric.

Observations made on exhumed reinforcements indicate there were some deviations from the shop drawings. Reinforcements number TP2-II, TP3-II, TP3-III and TP4-III appeared to be W9.5 x W9.5 (initial diameter 0.348 in). All other exhumed reinforcements appeared to be W7 x W7. Data included in Table III-3 describe the range and mean of the measurements.

Out of a total of 78 wires distributed between Test Pits 8, 9, 10 and 11, approximately half of the maximum section losses were observed in zone 2 and half in zone 3. Thus, the maximum loss of section was most often observed at least two feet behind the wall face. This is consistent with the development of macrocells due to higher porosity of backfill placed near the wall facing.

Table III-3. Summary of Observed Reinforcement Condition

Grid	Range of Remaining Wire Diameter Measurements[1] (in)	Average Remaining Wire Diameter (in)	Remaining Grid Capacity [2] %
Wall #1			
TP2-II	0.11 to 0.21	0.157	16%
TP3-II	0.11 to 0.23	0.182	27%
TP3-III	0.05 to 0.08	0.065	3%
TP-4 II	0.10 to 0.24	0.190	30%
TP7-II	0.10 to 0.17	0.133	20%
Wall #2			
TP8-I	0.026 to 0.116	0.06	4%
TP8-II	0.076 to 0.145	0.104	12%
TP8-III	0.096 to 0.298	0.179	36%
TP9-I	0.141 to 0.228	0.186	38%
TP9-II	0.049 to 0.196	0.151	25%
TP9-III	0.168 to 0.286	0.238	63%
Wall #3			
TP10-I-N	0.037 to 0.266	0.178	35%
TP10-I-S	0.000 to 0.176	0.111	14%
TP10-II-N	0.202 to 0.246	0.223	55%
TP10-II-S	0.067 to 0.239	0.129	18%
TP10-III-N	0.082 to 0.202	0.162	29%
TP10-III-S	~	~	~
TP11-I-N	0.186 to 0.208	0.195	42%
TP11-I-S	0.149 to 0.201	0.181	36%
TP11-II-N	0.186 to 0.233	0.203	46%
TP11-II-S	0.217 to 0.248	0.233	60%
TP11-III-N	0.207 to 0.261	0.234	61%
TP11-III-S	0.084 to 0.194	0.142	22%

[1] smallest remaining diameter observed along each wire

[2] estimated remaining capacity based on W7 xW7 welded wire fabric excepting TP-2, TP-3 and TP-4 as noted in the text.

Figure III-2 is a histogram of the remaining capacities observed from the grids excluding the observations from TP8-I, TP8-II and from Wall #1. TP8-I and TP8-II, are considered outliers affected by drainage conditions specific to these locations, and samples from Wall #1 are excluded due to uncertainty relative to the initial size of the wires and too few wires included in the samples. Figure III-2 indicates that the data are randomly distributed and symmetric with respect to the median (i.e. gaussian normal distribution). On average, the grids have a remaining capacity of 39% (0.183 remaining diameter) with a standard deviation of 16%.

Uniform Metal Loss

Estimation of metal loss is in terms of the loss of thickness neutralized through corrosion, which is often expressed in terms of a "idealized" or "statistical" uniform metal loss. If we consider metal loss as uniformly distributed, we may compute a corresponding uniform remaining diameter for all the wires included in the sample. The concept is useful for interpretation of corrosion rate measurements and comparison to available mathematical models of uniform corrosion. In fact, because these losses in thickness are nonuniform, the ratio "relative loss of capacity/relative uniform loss of section" is higher than one.

Measurements of the remaining diameter are made at close intervals along each wire to assess the uniform loss of cross section of a sample. The remaining uniform diameter is the integration of the measured diameters divided by the total length of the wires included in the sample. Uniform loss of thickness is computed as the initial radius minus the remaining uniform radius.

Table III-4 presents the remaining uniform loss of thickness observed from six selected samples. Uniform rates of corrosion are estimated by dividing the uniform loss by the age of the samples (≈20 years). Uniform rates of corrosion range between 5.2 μm/yr and 29 μm/yr, with a mean of approximately 14 μm/yr.

Table III-4. Average Loss of Radius

Sample	Uniform Loss (in)	Uniform Loss (μm)	Uniform Rate (μm/yr)
TP2-II-C	0.023	584	29
TP8-I	0.022	559	28
TP10-I-A	0.0044	112	5.6
TP10-I-B	0.0059	150	7.5
TP11-1-A	0.0041	104	5.2
TP11-1-B	0.0049	124	6.2

E. Metallurgical Testing of Reinforcements

Sample TP-5-II-A was selected for metallurgical analysis and microscopic examination of the steel crystalline lattice and corrosion deposits. The sample was delivered to Adirondack Environmental Services, Inc. for preparation of test specimens and testing. Testing was performed to evaluate (1) the chemical composition of the steel and corrosion deposit, (2) the nature of condensate (corrosion deposit) adhered to the wires, and (3) the microstructure of the steel and nonuniformities apparent within the microstructure.

The following laboratory procedures were performed to evaluate the reinforcement sample:

a) Preparation of longitudinal metallographic sections of wire that included corroded and noncorroded areas. Three metallographic sections were prepared and subjected to microhardness measurements and micrographic examination described in (b) and (c).

b) Knoop Micro-Hardness measurements (ASTM E384-99) were obtained on the longitudinal sections. Micro-Hardness measurements were performed on corroded and noncorroded areas with a minimum of 5 indentations per area.

c) Micrographic analysis of the sections to give an analysis of the chemical composition of the corrosion deposit and characteristics of the microstructure in corroded and noncorroded areas using scanning electron microscopy (SEM) examination with energy dispersive X-ray fluorescence spectroscopy (EDXRF), and X-ray diffraction (XRD). Condensate and corrosion by-products that were adhered to the wires were separated into three distinct groups, based on color, for analysis: (1) white or whitish-tan, (2) black and (3) red or rust colored.

d) Chemical analysis of the steel wire material was performed. Leco gas analysis was performed on one specimen, and another was subjected to direct current plasma (DCP) optical omission spectroscopy.

e) Tension testing (ASTM A370-03a) was performed on specimens extracted from corroded and noncorroded areas of the sample to study the relationship between loss of strength and loss of cross-section, and to evaluate if the material has become embrittled. Six specimens were selected for tension testing; 3 from noncorroded and 3 from corroded areas. Subsequent to failure from tension testing, two of the samples were evaluated with SEM to study the fracture surfaces and mode of failure.

Detailed results and the reports prepared by Adirondack Environmental Services relative to metallurgical analysis are included in this appendix. The reports describe sample preparation, test methods, and results from metallurgical testing.

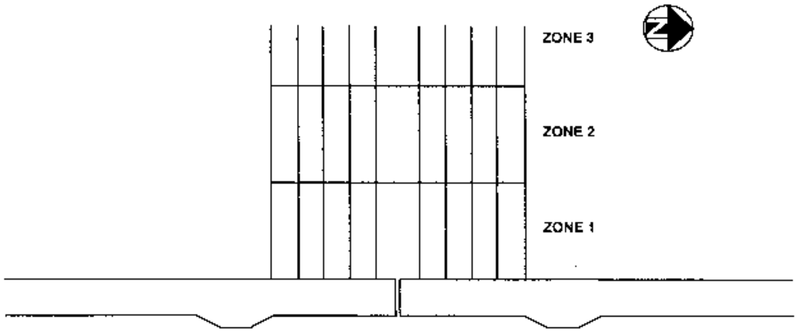


Figure III-1 (a). Sample Retrieved from TP8 and TP9 Spanning Panel Joint.

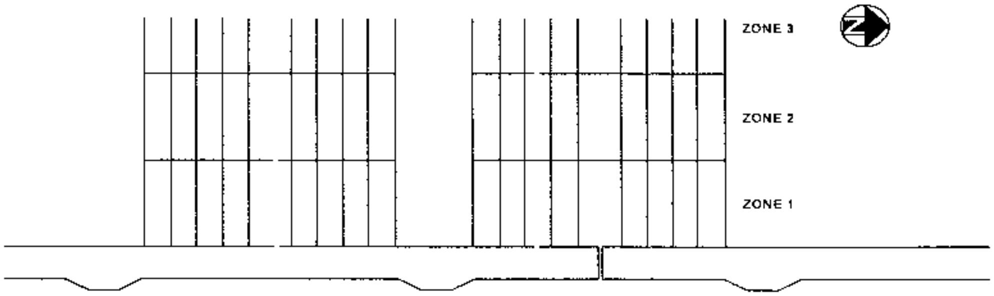


Figure IIi-1 (b). Sample Retrieved from TP10 and TP11 on Either Side of Wall Facing Column.

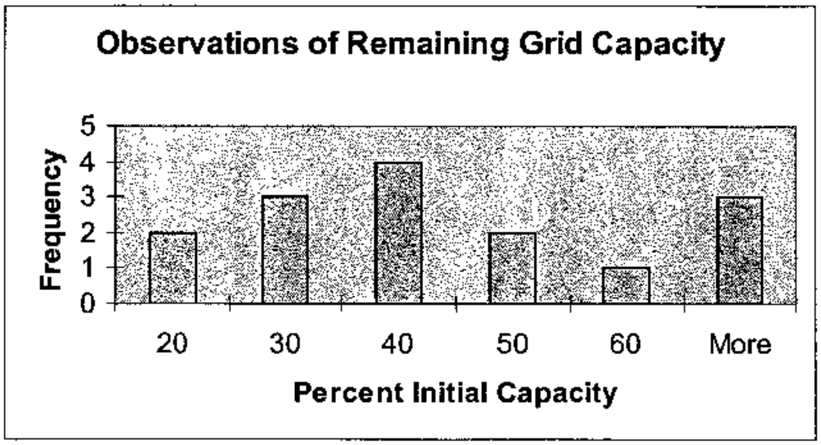


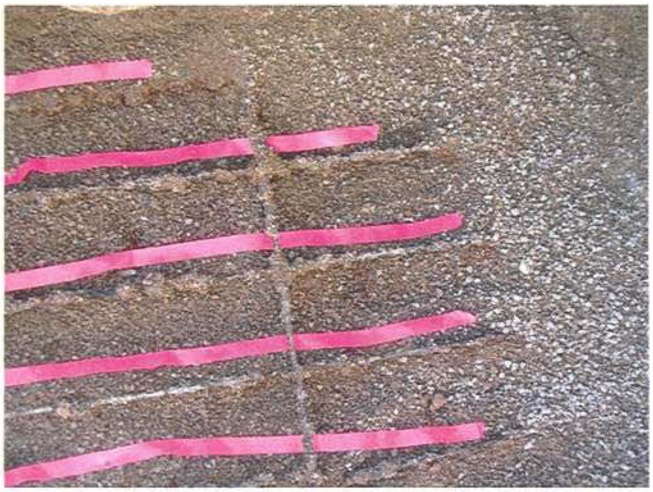
Figure III-2. Histogram of Remaining Capacities Observed from Exhumed Samples of Reinforcements

F. Photographs of Reinforcement Samples

TEST PIT 8

Test Pit 8, Grid 1, Zone 1, Bars 1 - 4

Test Pit 8, Grid 1, Zone 2, Bars 1 - 4

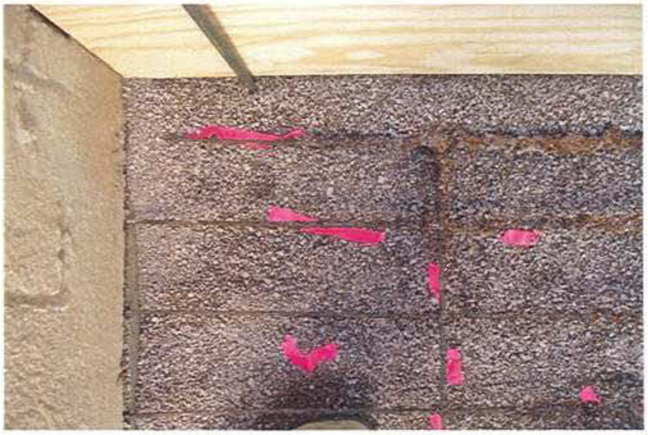


Test Pit 8, Grid 1, Zone 3, Bars 1 - 4

Test Pit 8, Grid 1, Zone 1, Bars 5 - 7

Test Pit 8, Grid 1, Zone 2, Bars 5 - 7

Test Pit 8, Grid 1, Zone 3, Bars 5 – 7



Test Pit 8, Grid 2, Zone 1, Bars 1 - 4

Test Pit 8, Grid 2, Zone 2, Bars 1 – 4

Test Pit 8, Grid 2, Zone 3, Bars 1 – 4

Test Pit 8, Grid 2, Zone 1, Bars 5 – 7

Test Pit 8, Grid 2, Zone 2, Bars 5 – 7

Test Pit 8, Grid 2, Zone 3, Bars 5 – 7

Test Pit 8, Grid 3, Zone 1, Bars 1 - 4

Test Pit 8, Grid 3, Zone 2, Bars 1 – 4

Test Pit 8, Grid 3, Zone 3, Bars 1 – 4

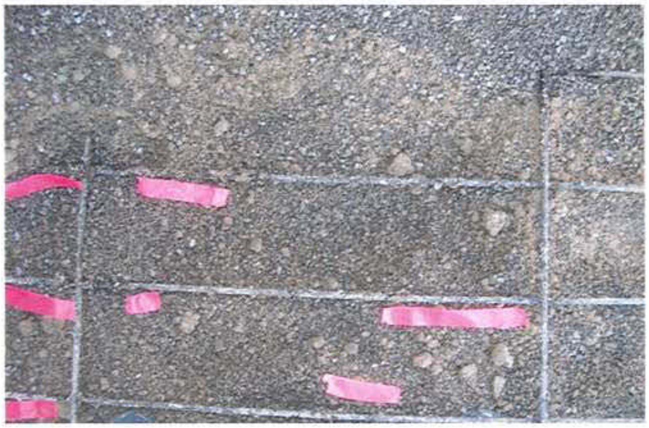
TEST PIT 9

Test Pit 9, Grid 1, Zone 1, Bars 1 - 4

Test Pit 9, Grid 1, Zone 2, Bars 1 – 4

Test Pit 9, Grid 1, Zone 3, Bars 1 – 4

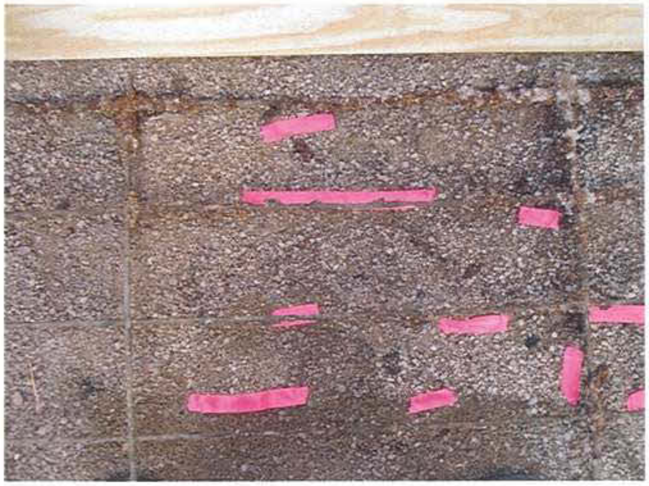
Test Pit 9, Grid 1, Zone 1, Bars 5 - 8



Test Pit 9, Grid 1, Zone 2, Bars 5 - 7

Test Pit 9, Grid 1, Zone 3, Bars 5 - 7

Test Pit 9, Grid 2, Zone 1, Bars 1 – 4



Test Pit 9, Grid 2, Zone 2, Bars 1 – 4

Test Pit 9, Grid 2, Zone 3, Bars 1 – 4

Test Pit 9, Grid 2, Zone 1, Bars 5 – 8

Test Pit 9, Grid 2, Zone 2, Bars 5 – 8

Test Pit 9, Grid 2, Zone 3, Bars 5 – 8

Test Pit 9, Grid 3, Zone 1, Bars 1 – 4

Test Pit 9, Grid 3, Zone 2, Bars 1 - 4

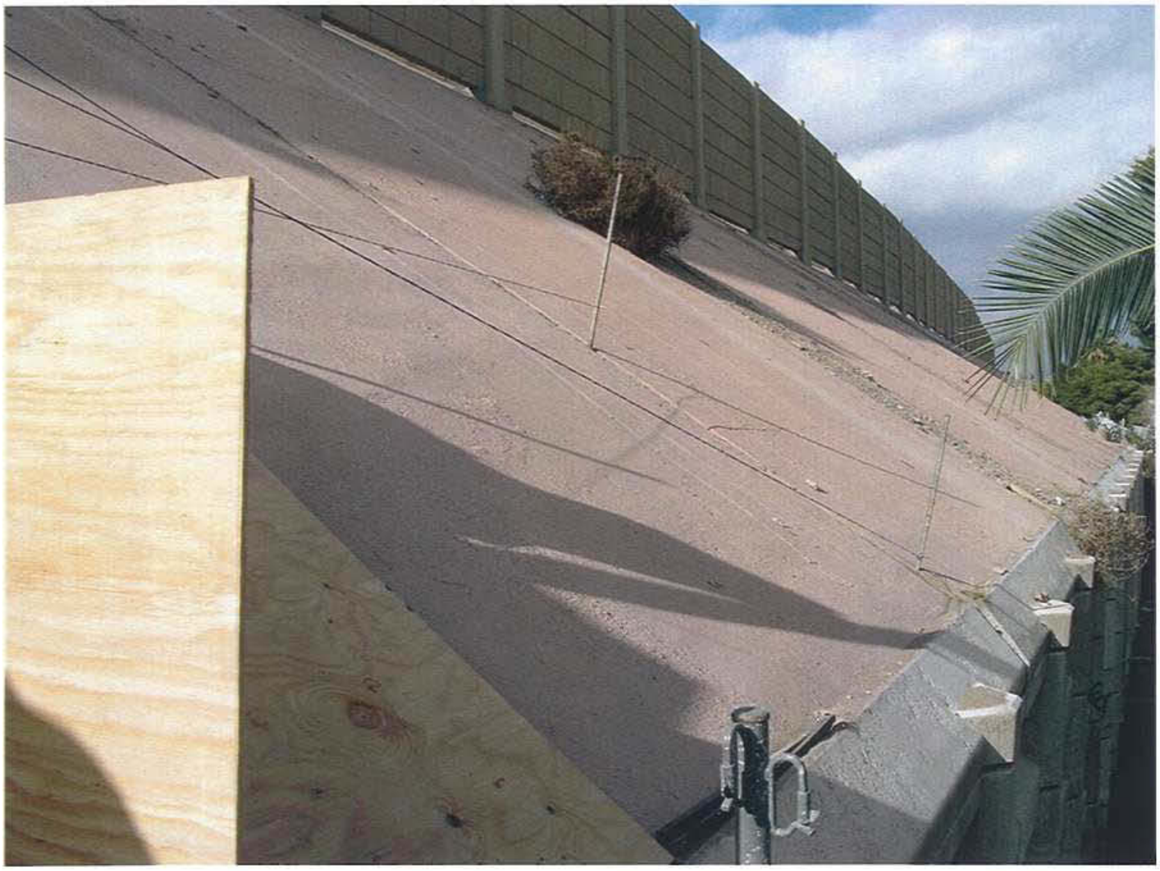
Test Pit 9, Grid 3, Zone 3, Bars 2 - 4

Test Pit 9, Grid 3, Zone 1, Bars 5 – 8

Test Pit 9, Grid 3, Zone 2, Bars 5 – 8

Test Pit 9, Grid 3, Zone 3, Bars 5 – 8

TEST PIT 10



Test Pit 10, Grid 1, Zone 1, South

Test Pit 10, Grid 1, Zone 2, South

Test Pit 10, Grid 1, Zone 3, South

Test Pit 10, Grid 1, Zone 1, North

Test Pit 10, Grid 1, Zone 2, North

Test Pit 10, Grid 1, Zone 3, North

Test Pit 10, Grid 2, Zone 1, South

Test Pit 10, Grid 2, Zone 2, South

Test Pit 10, Grid 2, Zone 3, South

Test Pit 10, Grid 2, Zone 1, North

Test Pit 10, Grid 2, Zone 2, North

Test Pit 10, Grid 2, Zone 3, North

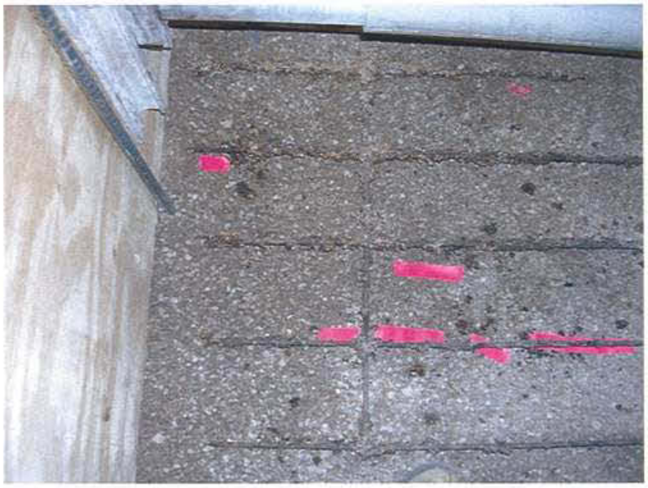
Test Pit 10, Grid 3, Zone 1, South

Test Pit 10, Grid 3, Zone 2, South

Test Pit 10, Grid 3, Zone 3, South

Test Pit 10, Grid 3, Zone 1, North

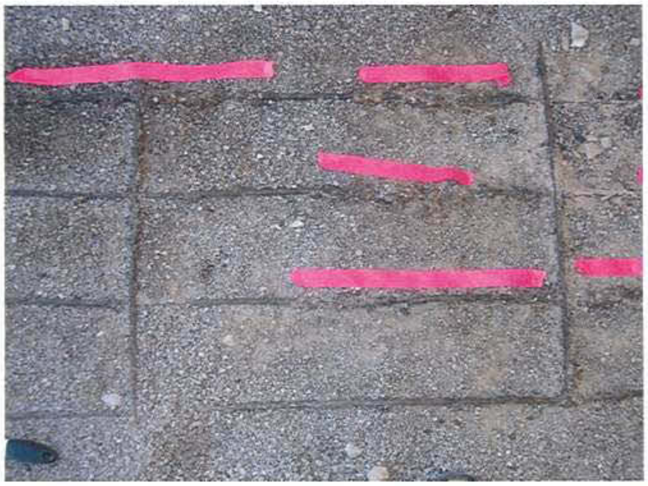
Test Pit 10, Grid 3, Zone 2, North



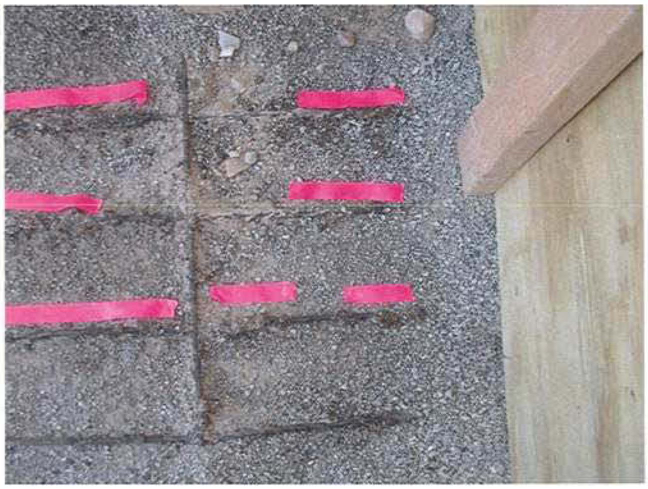
Test Pit 10, Grid 3, Zone 3, North

TEST PIT 11

Test Pit 11, Grid 1, Zone 1, South

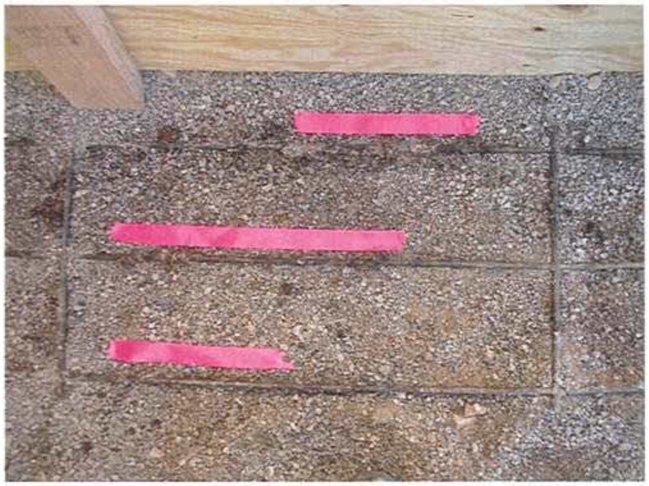


Test Pit 11, Grid 1, Zone 2, South

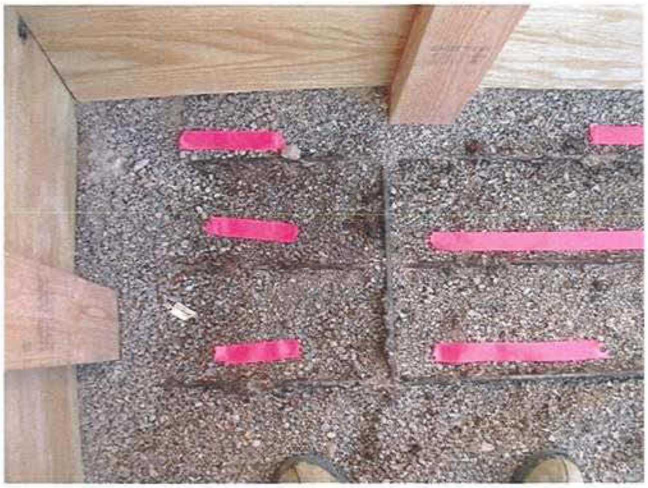


Test Pit 11, Grid 1, Zone 3, South

Test Pit 11, Grid 1, Zone 1, North



Test Pit 11, Grid 1, Zone 2, North



Test Pit 11, Grid 1, Zone 3, North

Test Pit 11, Grid 2, Zone 1, South

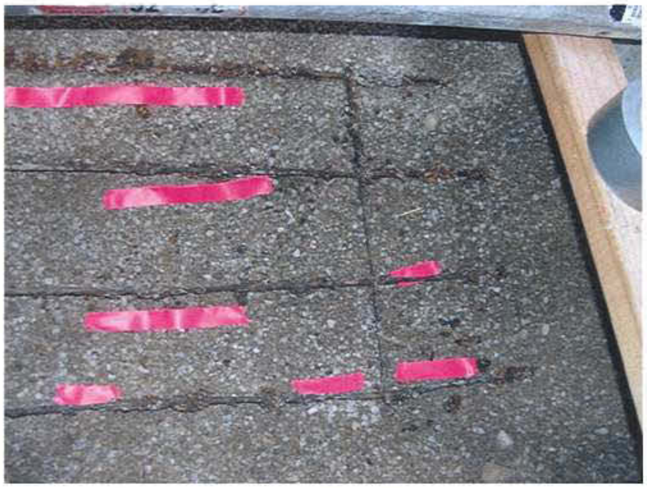
Test Pit 11, Grid 2, Zone 2, South

Test Pit 11, Grid 2, Zone 3, South

Test Pit 11, Grid 2, Zone 1, 2 and 3 North

Test Pit 11, Grid 3, Zone 1, South

Test Pit 11, Grid 3, Zone 2, South

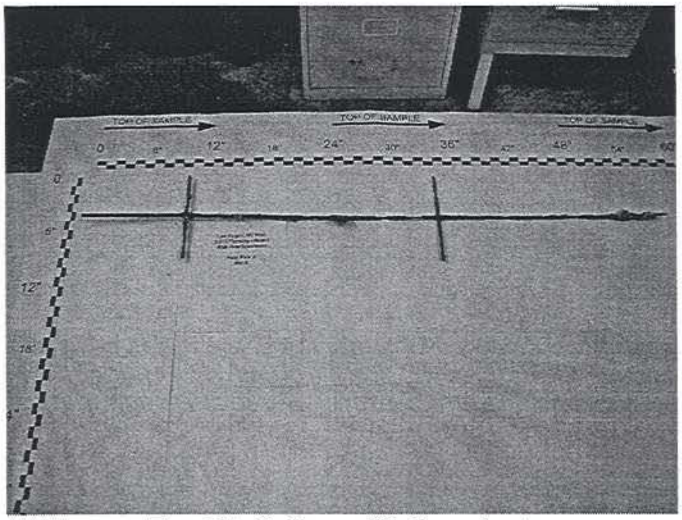


Test Pit 11, Grid 3, Zone 3, South

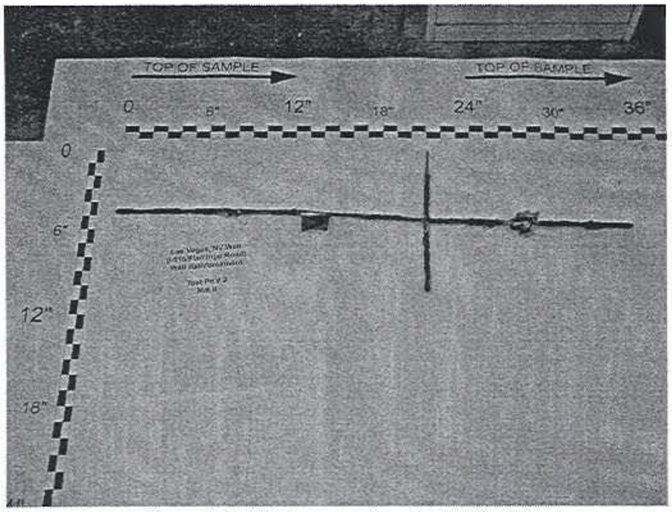
Test Pit 11, Grid 3, Zone 1, North

Test Pit 11, Grid 3, Zone 2, North

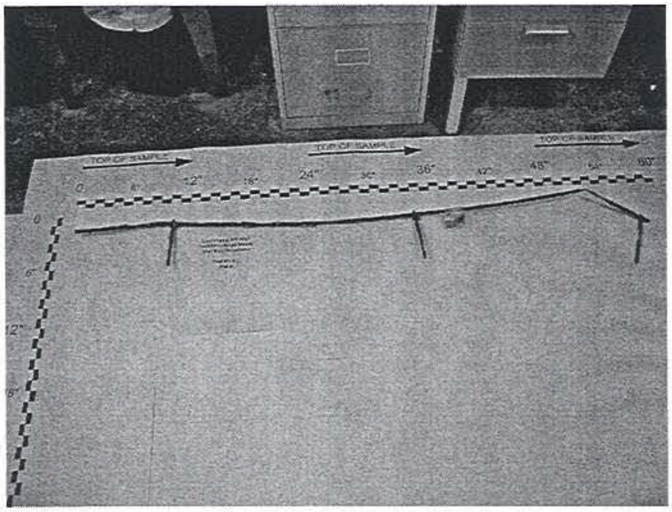
Test Pit 11, Grid 3, Zone 3, North



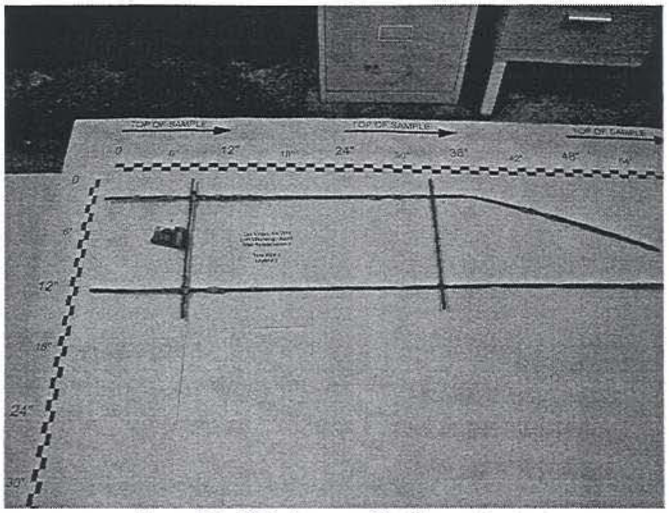
Test Pit II, Layer II, Sample A



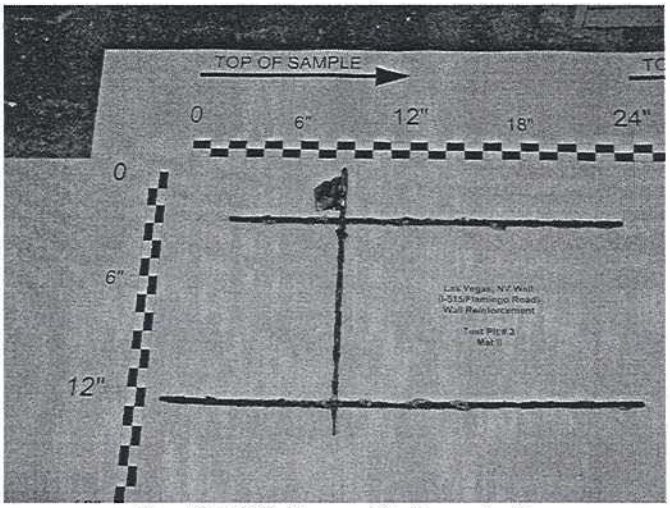
Test Pit II, Layer II, Sample B



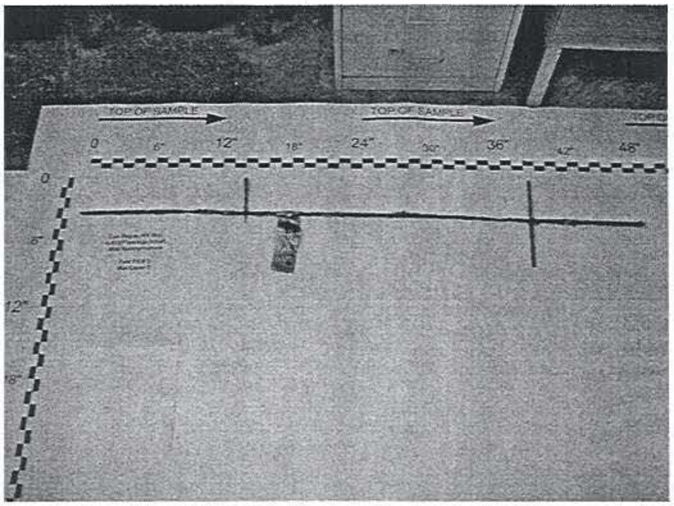
Test Pit II, Layer II, Sample C



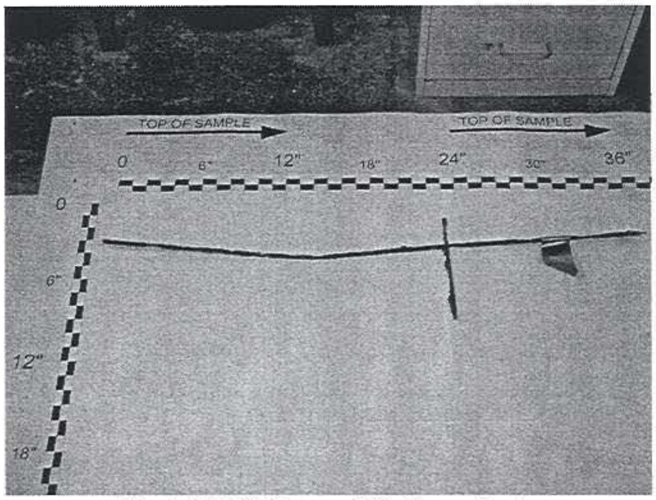
Test Pit III, Layer II, Sample A



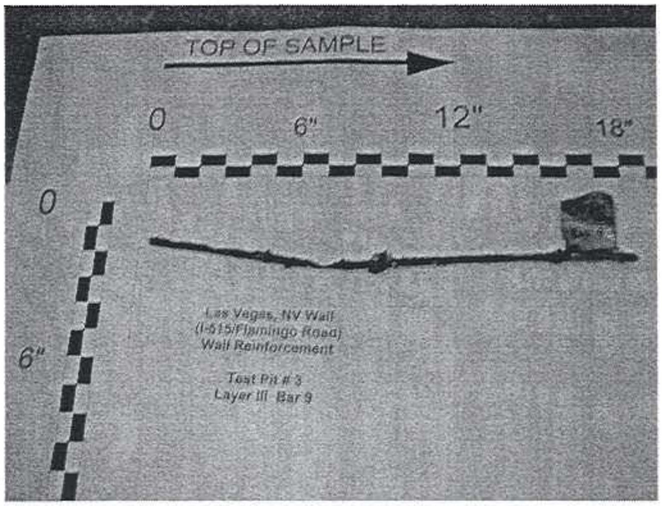
Test Pit III, Layer II, Sample B



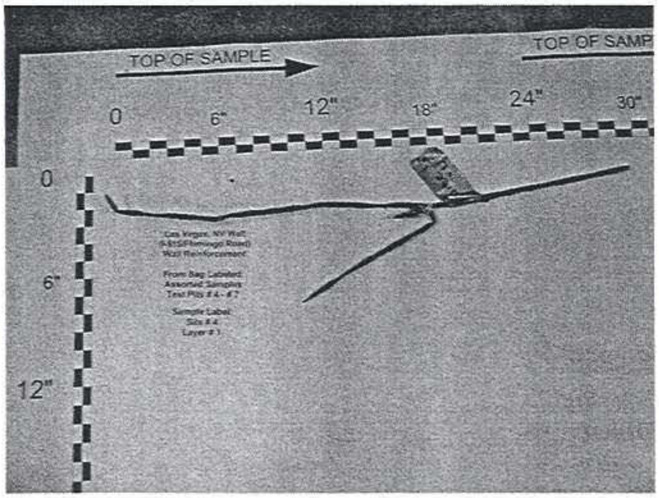
Test Pit III, Layer II, Sample C



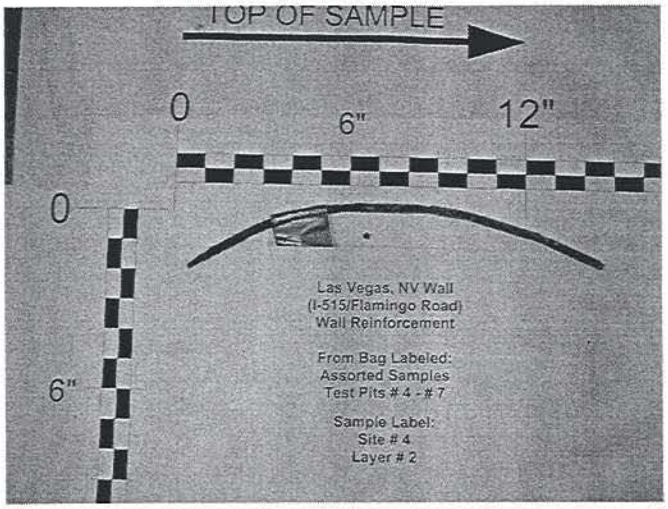
Test Pit III, Layer III, Sample A



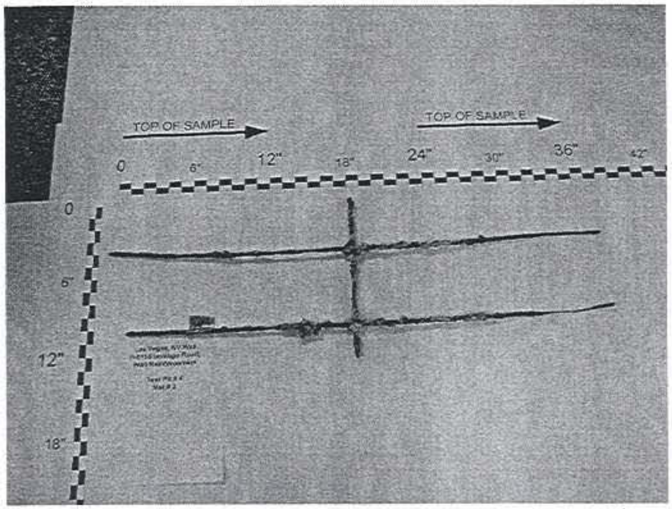
Test Pit III, Layer III, Sample B



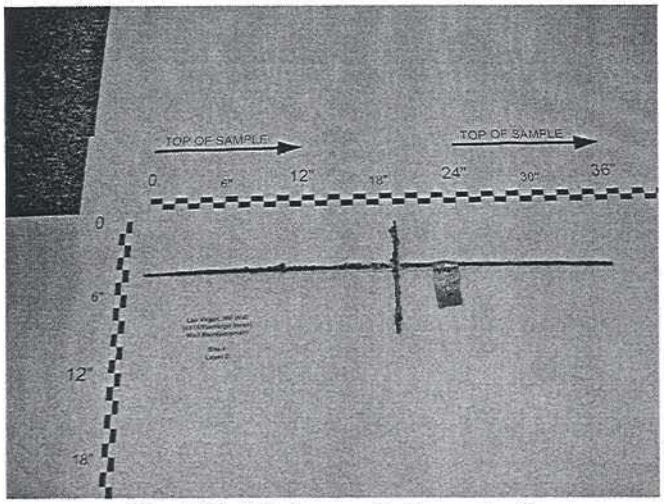
Test Pit IV, Layer I, Sample A



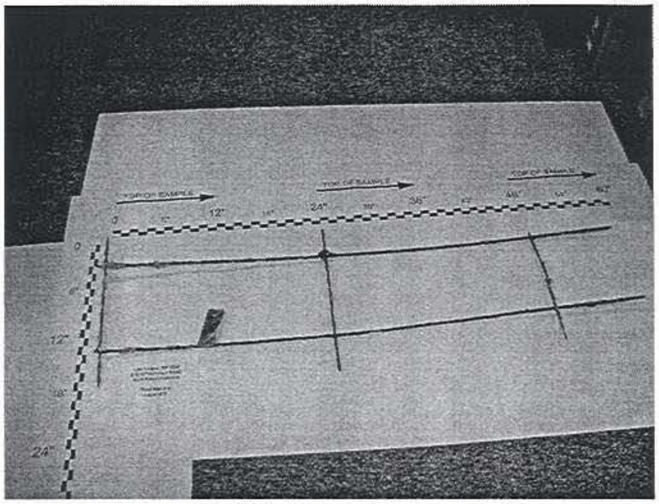
Test Pit IV, Layer II, Sample A



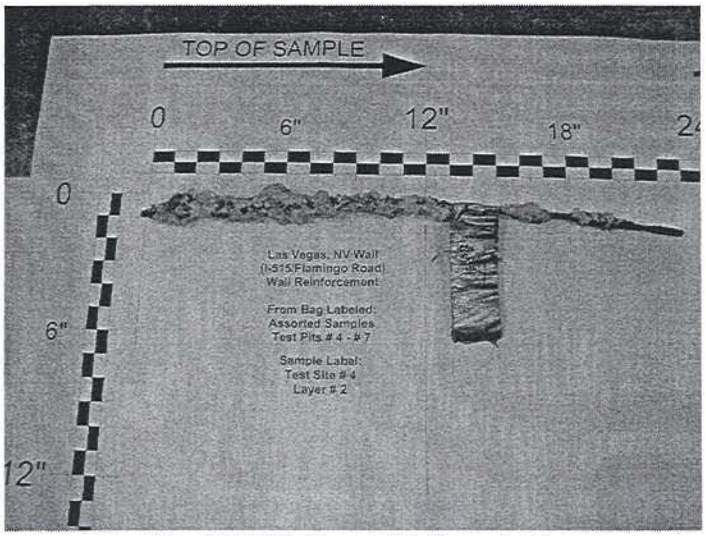
Test Pit IV, Layer II, Sample B



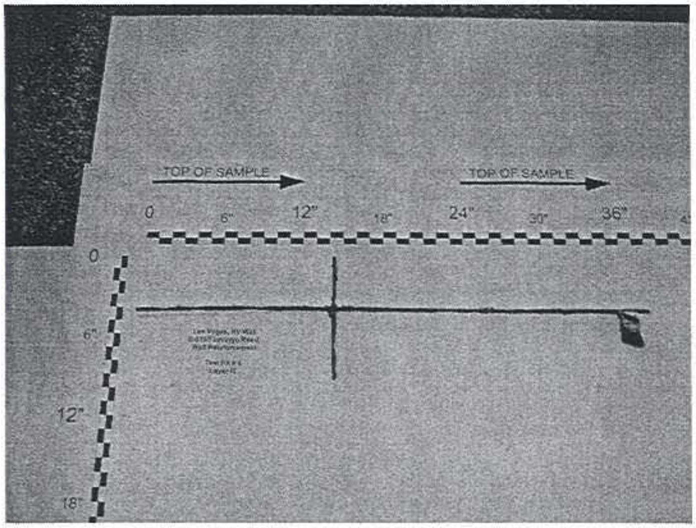
Test Pit IV, Layer II, Sample C



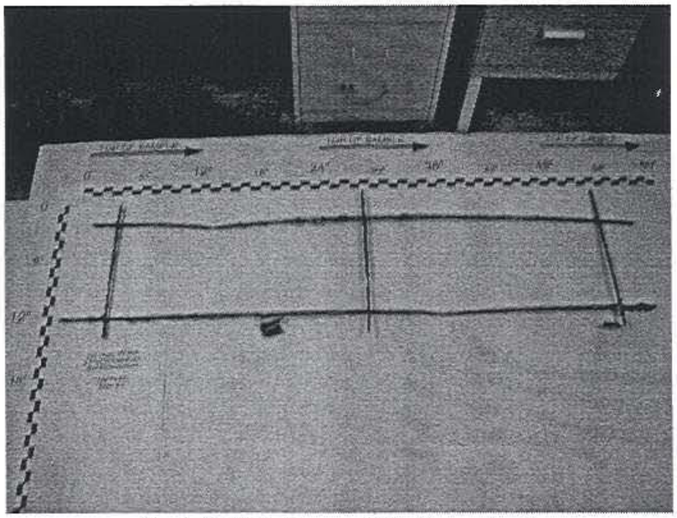
Test Pit IV, Layer II, Sample D



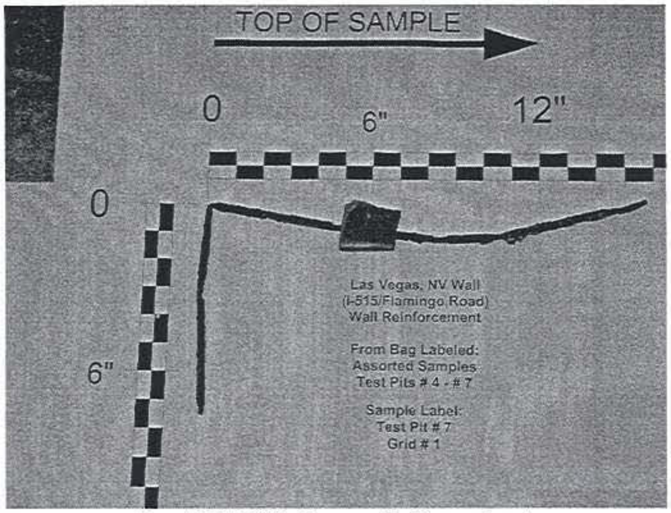
Test Pit IV, Layer II, Sample E



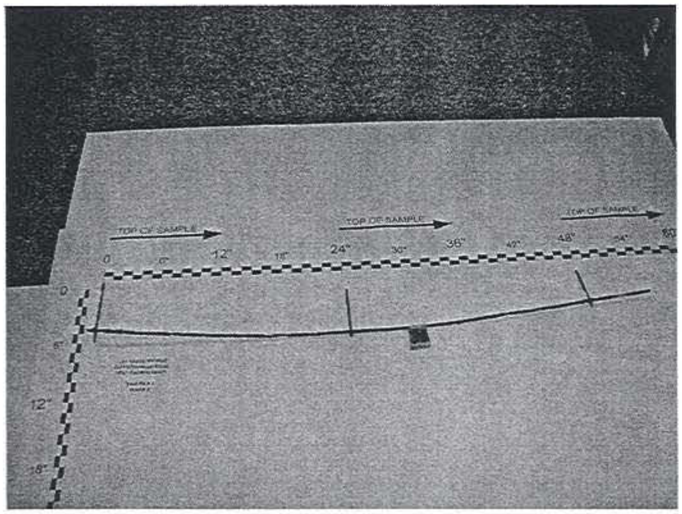
Test Pit IV, Layer III, Sample A



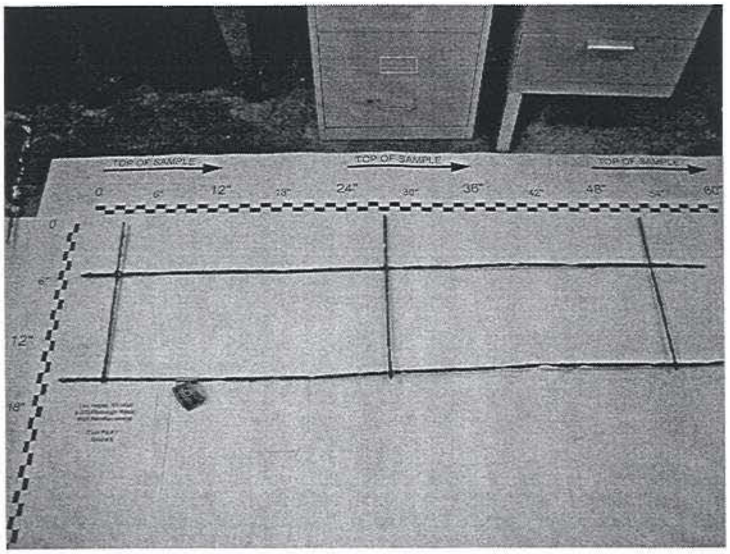
Test Pit V, Layer III, Sample A



Test Pit VII, Layer I, Sample A



Test Pit VII, Layer II, Sample A



Test Pit VII, Layer II, Sample B

G. Data from Section Loss Measurements

Max Section Loss for bars by bar

Grid, Bar	Bar ID	Diameter	Min. Diameter
TP-8, G-1, B-1	TP-8, G-1, B-1, Z-1	0.143	
	TP-8, G-1, B-1, Z-2 A	0.048	0.047
	TP-8, G-1, B-1, Z-2 B	0.047	
	TP-8, G-1, B-1, Z-3	0.1	
TP-8, G-1, B-2	TP-8, G-1, B-2, Z-1	0.116	
	TP-8, G-1, B-2, Z-2 A	0.129	0.116
	TP-8, G-1, B-2, Z-2 B	0.142	
	TP-8, G-1, B-2, Z-3	0.121	
TP-8, G-1, B-3	TP-8, G-1, B-3, Z-1	0.11	
	TP-8, G-1, B-3, Z-2 A	0.076	0.06
	TP-8, G-1, B-3, Z-2 B	0.06	
	TP-8, G-1, B-3, Z-3	0.17	
TP-8, G-1, B-4	TP-8, G-1, B-4, Z-1	0.138	
	TP-8, G-1, B-4, Z-2	0.126	0.09
	TP-8, G-1, B-4, Z-3	0.09	
TP-8, G-1, B-5	TP-8, G-1, B-5, Z-1	0.1	
	TP-8, G-1, B-5, Z-2	0.056	0.056
	TP-8, G-1, B-5, Z-3	0.146	
TP-8, G-1, B-6	TP-8, G-1, B-6, Z-1	0.09	
	TP-8, G-1, B-6, Z-2	0.054	0.051
	TP-8, G-1, B-6, Z-3	0.051	
TP-8, G-1, B-7	TP-8, G-1, B-7, Z-1	0.175	
	TP-8, G-1, B-7, Z-2	0.067	0.049
	TP-8, G-1, B-7, Z-3	0.049	
TP-8, G-1, B-8	TP-8, G-1, B-8, Z-1	0.143	
	TP-8, G-1, B-8, Z-2	0.149	0.06
	TP-8, G-1, B-8, Z-3	0.06	
TP-8, G-1, B-9	TP-8, G-1, B-9, Z-1	0.263	
	TP-8, G-1, B-9, Z-2	0.026	0.026
	TP-8, G-1, B-9, Z-3	0.111	
TP-8, G-1, B-10	TP-8, G-1, B-10, Z-1	0.133	
	TP-8, G-1, B-10, Z-2	0.067	0.046
	TP-8, G-1, B-10, Z-3	0.046	
TP-8, G-2, B-1	TP-8, G-2, B-1, Z-1 S	0.238	
	TP-8, G-2, B-1, Z-2	0.144	0.144
	TP-8, G-2, B-1, Z-3	0.203	
TP-8, G-2, B-2	TP-8, G-2, B-2, Z-1	0.231	
	TP-8, G-2, B-2, Z-2	0.076	0.076

	TP-8, G-2, B-2, Z-3	0.13	
TP-8, G-2, B-3	TP-8, G-2, B-3, Z-1	0.232	
	TP-8, G-2, B-3, Z-2	0.055	0.055
	TP-8, G-2, B-3, Z-3	0.255	
TP-8, G-2, B-4	TP-8, G-2, B-4, Z-1	0.194	
	TP-8, G-2, B-4, Z-2	0.122	0.122
	TP-8, G-2, B-4, Z-3	0.284	
TP-8, G-2, B-5	TP-8, G-2, B-5, Z-1	0.242	
	TP-8, G-2, B-5, Z-2	0.145	0.145
	TP-8, G-2, B-5, Z-3	0.15	
TP-8, G-2, B-6	TP-8, G-2, B-6, Z-1	0.249	
	TP-8, G-2, B-6, Z-2	0.128	0.107
	TP-8, G-2, B-6, Z-3	0.107	
TP-8, G-2, B-7	TP-8, G-2, B-7, Z-1	0.171	
	TP-8, G-2, B-7, Z-2	0.079	0.079
	TP-8, G-2, B-7, Z-3	0.193	
TP-8, G-2, B-8	TP-8, G-2, B-8, Z-1	0.161	
	TP-8, G-2, B-8, Z-2	0.102	0.102
TP-8, G-3, B-1	TP-8, G-3, B-1, Z-1	0.214	
	TP-8, G-3, B-1, Z-2	0.222	0.096
	TP-8, G-3, B-1, Z-3	0.096	
TP-8, G-3, B-2	TP-8, G-3, B-2, Z-1	0.224	
	TP-8, G-3, B-2, Z-2	0.188	0.188
	TP-8, G-3, B-2, Z-3	0.234	
TP-8, G-3, B-3	TP-8, G-3, B-3, Z-1	0.207	
	TP-8, G-3, B-3, Z-2	0.214	0.146
	TP-8, G-3, B-3, Z-3	0.146	
TP-8, G-3, B-4	TP-8, G-3, B-4, Z-1	0.232	
	TP-8, G-3, B-4, Z-2	0.236	0.196
	TP-8, G-3, B-4, Z-3	0.196	
TP-8, G-3, B-5	TP-8, G-3, B-5, Z-1	0.256	
	TP-8, G-3, B-5, Z-2	0.187	0.187
	TP-8, G-3, B-5, Z-3	0.283	
TP-8, G-3, B-6	TP-8, G-3, B-6, Z-1	0.269	
	TP-8, G-3, B-6, Z-2	0.245	0.202
	TP-8, G-3, B-6, Z-3	0.202	
TP-8, G-3, B-7	TP-8, G-3, B-7, Z-1	0.239	
	TP-8, G-3, B-7, Z-2	0.261	0.208
	TP-8, G-3, B-7, Z-3	0.208	

TP-8, G-3, B-8	TP-8, G-3, B-8, Z-1	0.223	
	TP-8, G-3, B-8, Z-2	0.205	0.205
TP-9, G-1, B-1	TP-9, G-1, B-1, Z-1	0.303	
	TP-9, G-1, B-1, Z-2	0.202	0.181
	TP-9, G-1, B-1, Z-3	0.181	
TP-9, G-1, B-2	TP-9, G-1, B-2, Z-1	0.302	
	TP-9, G-1, B-2, Z-2	0.215	0.215
TP-9, G-1, B-3	TP-9, G-1, B-3, Z-1	0.304	
	TP-9, G-1, B-3, Z-2	0.195	0.141
	TP-9, G-1, B-3, Z-3	0.141	
TP-9, G-1, B-4	TP-9, G-1, B-4, Z-1	0.29	
	TP-9, G-1, B-4, Z-2	0.226	0.148
	TP-9, G-1, B-4, Z-3	0.148	
TP-9, G-1, B-5	TP-9, G-1, B-5, Z-1	0.276	
	TP-9, G-1, B-5, Z-2	0.228	0.228
TP-9, G-1, B-6	TP-9, G-1, B-6, Z-1	0.295	
	TP-9, G-1, B-6, Z-2	0.254	0.197
	TP-9, G-1, B-6, Z-3	0.197	
TP-9, G-1, B-7	TP-9, G-1, B-7, Z-1	0.3	
	TP-9, G-1, B-7, Z-2	0.25	0.25
TP-9, G-1, B-8	TP-9, G-1, B-8, Z-1	0.275	
	TP-9, G-1, B-8, Z-2	0.256	0.163
	TP-9, G-1, B-8, Z-3	0.163	
TP-9, G-1, B-9	TP-9, G-1, B-9, Z-1	0.301	
	TP-9, G-1, B-9, Z-2	0.248	0.15
	TP-9, G-1, B-9, Z-3	0.15	
TP-9, G-1, B-10	TP-9, G-1, B-10, Z-1	0.302	
	TP-9, G-1, B-10, Z-2	0.277	0.191
	TP-9, G-1, B-10, Z-3	0.191	
TP-9, G-2, B-1	TP-9, G-2, B-1, Z-1	0.248	
	TP-9, G-2, B-1, Z-2	0.241	0.128
	TP-9, G-2, B-1, Z-3	0.128	
TP-9, G-2, B-2	TP-9, G-2, B-2, Z-1	0.279	
	TP-9, G-2, B-2, Z-2	0.196	0.196
	TP-9, G-2, B-2, Z-3	0.229	
TP-9, G-2, B-3	TP-9, G-2, B-3, Z-1	0.26	
	TP-9, G-2, B-3, Z-2	0.172	0.172
	TP-9, G-2, B-3, Z-3	0.214	

TP-9, G-2, B-4	TP-9, G-2, B-4, Z-1	0.251	
	TP-9, G-2, B-4, Z-2	0.193	0.193
	TP-9, G-2, B-4, Z-3	0.215	
TP-9, G-2, B-5	TP-9, G-2, B-5, Z-1	0.28	
	TP-9, G-2, B-5, Z-2	0.053	0.049
	TP-9, G-2, B-5, Z-3	0.049	
TP-9, G-2, B-6	TP-9, G-2, B-6, Z-1	0.272	
	TP-9, G-2, B-6, Z-2	0.221	0.125
	TP-9, G-2, B-6, Z-3	0.125	
TP-9, G-2, B-7	TP-9, G-2, B-7, Z-1	0.261	
	TP-9, G-2, B-7, Z-2	0.241	0.177
	TP-9, G-2, B-7, Z-3	0.177	
TP-9, G-2, B-8	TP-9, G-2, B-8, Z-1	0.272	
	TP-9, G-2, B-8, Z-2	0.22	0.165
	TP-9, G-2, B-8, Z-3	0.165	
TP-9, G-3, B-1	TP-9, G-3, B-1, Z-1	0.3	
	TP-9, G-3, B-1, Z-2	0.247	0.237
	TP-9, G-3, B-1, Z-3	0.237	
TP-9, G-3, B-2	TP-9, G-3, B-2, Z-1	0.3	
	TP-9, G-3, B-2, Z-2	0.234	0.175
	TP-9, G-3, B-2, Z-3	0.175	
TP-9, G-3, B-3	TP-9, G-3, B-3, Z-1	0.3	
	TP-9, G-3, B-3, Z-2	0.277	0.262
	TP-9, G-3, B-3, Z-3	0.262	
TP-9, G-3, B-4	TP-9, G-3, B-4, Z-1	0.3	
	TP-9, G-3, B-4, Z-2	0.248	0.168
	TP-9, G-3, B-4, Z-3	0.168	
TP-9, G-3, B-5	TP-9, G-3, B-5, Z-1	0.3	
	TP-9, G-3, B-5, Z-2	0.255	0.24
	TP-9, G-3, B-5, Z-3	0.24	
TP-9, G-3, B-6	TP-9, G-3, B-6, Z-1	0.3	
	TP-9, G-3, B-6, Z-2	0.274	0.225
	TP-9, G-3, B-6, Z-3	0.225	
TP-9, G-3, B-7	TP-9, G-3, B-7, Z-1	0.3	
	TP-9, G-3, B-7, Z-2	0.29	0.27
	TP-9, G-3, B-7, Z-3	0.27	
TP-9, G-3, B-8	TP-9, G-3, B-8, Z-1	0.3	
	TP-9, G-3, B-8, Z-2	0.293	0.277
	TP-9, G-3, B-8, Z-3	0.277	

TP-10, G-2, B-5	TP-10, G-2, B-5, Z-3 N	0.224	0.224
TP-10, G-2, B-7	TP-10, G-2, B-7, Z-3 S	0.082	0.082
TP-10, G-3, B-1	TP-10, G-3, B-1, Z-1	0.217	
	TP-10, G-3, B-1, Z-1 N	0.282	
	TP-10, G-3, B-1, Z-2 N	0.216	
	TP-10, G-3, B-1, Z-2 S	0.171	0.171
	TP-10, G-3, B-1, Z-3	0.198	
	TP-10, G-3, B-1, Z-3 N	0.24	
TP-10, G-3, B-2	TP-10, G-3, B-2, Z-1 N	0.162	
	TP-10, G-3, B-2, Z-2 N	0.255	0.162
	TP-10, G-3, B-2, Z-3 N	0.224	
TP-10, G-3, B-3	TP-10, G-3, B-3, Z-1 N	0.229	
	TP-10, G-3, B-3, Z-2 N	0.202	0.202
	TP-10, G-3, B-3, Z-3 N	0.213	
TP-10, G-3, B-4	TP-10, G-3, B-4, Z-1 N	0.164	
	TP-10, G-3, B-4, Z-2 N	0.216	0.164
	TP-10, G-3, B-4, Z-3 N	0.204	
TP-10, G-3, B-5	TP-10, G-3, B-5, Z-2 N	0.164	
	TP-10, G-3, B-5, Z-3 N	0.131	0.131
TP-11, G-1, B-1	Z-1 N	0.27	
	Z-2 N	0.19	0.19
	Z-3 N	0.26	
	Z-1 S	0.299	
	Z-2 S	0.201	
	Z-3 S	0.246	
TP-11, G-1, B-2	Z-1 N	0.27	
	Z-2 N	0.208	0.149
	Z-3 N	0.26	
	Z-1 S	0.295	
	Z-2 S	0.149	
	Z-3 S	0.214	
TP-11, G-1, B-3	Z-1 N	0.275	
	Z-2 N	0.186	
	Z-3 N	0.24	
	Z-1 S	0.279	
	Z-2 S	0.185	0.185
	Z-3 S	0.201	
TP-11, G-1, B-4	Z-1 S	0.254	
	Z-2 S	0.227	
	Z-3 S	0.177	0.177
TP-11, G-1, B-5	Z-1 S	0.264	

	Z-2 S	0.235		
	Z-3 S	0.191	0.191	
TP-11, G-2, B-1	TP-11, G-2, B-1, Z-1 N	0.25		
	TP-11, G-2, B-1, Z-1 S	0.248		
	TP-11, G-2, B-1, Z-2 N	0.186		
	TP-11, G-2, B-1, Z-2 S	0.251	0.186	
	TP-11, G-2, B-1, Z-3 N	0.219		
	TP-11, G-2, B-1, Z-3 S	0.266		
TP-11, G-2, B-2	TP-11, G-2, B-2, Z-1 N	0.27		
	TP-11, G-2, B-2, Z-1 S	0.244		
	TP-11, G-2, B-2, Z-2 N	0.233	0.233	
	TP-11, G-2, B-2, Z-2 S	0.241		
	TP-11, G-2, B-2, Z-3 N	0.242		
TP-11, G-2, B-3	TP-11, G-2, B-3, Z-1 N	0.26		
	TP-11, G-2, B-3, Z-1 S	0.257		
	TP-11, G-2, B-3, Z-2 N	0.195		
	TP-11, G-2, B-3, Z-2 S	0.217	0.19	
	TP-11, G-2, B-3, Z-3 N	0.19		
	TP-11, G-2, B-3, Z-3 S	0.23		
TP-11, G-2, B-4	TP-11, G-2, B-4, Z-1 S	0.236		
	TP-11, G-2, B-4, Z-2 S	0.227	0.227	
	TP-11, G-2, B-4, Z-3 S	0.233		
TP-11, G-3, B-1	TP-11, G-3, B-1, Z-1, N	0.207		
	TP-11, G-3, B-1, Z-1, S	0.234		
	TP-11, G-3, B-1, Z-2, N	0.216		
	TP-11, G-3, B-1, Z-2, S	0.084	0.084	
	TP-11, G-3, B-1, Z-3, N	0.209		
	TP-11, G-3, B-1, Z-3, S	0.278		
TP-11, G-3, B-2	TP-11, G-3, B-2, Z-1, N	0.261		
	TP-11, G-3, B-2, Z-1, S	0.229		
	TP-11, G-3, B-2, Z-2, N	0.222		
	TP-11, G-3, B-2, Z-2, S	0.194	0.194	
	TP-11, G-3, B-2, Z-3, N	0.281		
	TP-11, G-3, B-2, Z-3, N	0.272		
TP-11, G-3, B-3	TP-11, G-3, B-3, Z-1, S	0.27		
	TP-11, G-3, B-3, Z-2, S	0.141	0.141	
	TP-11, G-3, B-3, Z-3, S	0.208		
TP-11, G-3, B-4	TP-11, G-3, B-4, Z-1, S	0.255		
	TP-11, G-3, B-4, Z-2, S	0.149	0.149	
	TP-11, G-3, B-4, Z-3, S	0.207		
				MAX
	Average Min Diameter		**0.158**	MIN
				MEAN

Calculation of Idealized Uniform Metal Loss

TP-10, G1, B-2, Z-3 N	0.298	13	3.874	
TP-10, G1, B-3, Z-3 N	0.292	13	3.796	
TP-10, G1, B-4, Z-3 N	0.298	13	3.874	
TP-10, G1, B-5, Z-3 N	0.291	13.5	3.9285	
	Total	**273.75**	**79.129**	**0.289056**

Bar ID	Avg$_W$	Sum Wf	Avg$_W$ *Sum Wf	
TP-10, G1, B-1, Z-1 S	0.298	18	5.364	
TP-10, G1, B-2, Z-1 S	0.293	18.5	5.4205	
TP-10, G1, B-3, Z-1 S	0.293	19	5.567	
TP-10, G1, B-1, Z-2 S	0.266	17.13	4.55658	
TP-10, G1, B-2, Z-2 S	0.288	23.5	6.768	
TP-10, G1, B-3, Z-2 S	0.292	22.75	6.643	
TP-10, G1, B-1, Z-3 S	0.273	14.63	3.99399	
TP-10, G1, B-2, Z-3 S	0.279	13	3.627	
TP-10, G1, B-3, Z-3 S	0.286	13	3.718	
	Total	**159.51**	**45.65807**	**0.28624**

Bar ID	Avg$_W$	Sum Wf	Avg$_W$ *Sum Wf	
TP-11, G1, B-1, Z-1 N	0.289	21	6.069	
TP-11, G1, B-2, Z-1 N	0.296	20	5.92	
TP-11, G1, B-3, Z-1 N	0.29	20	5.8	
TP-11, G1, B-1, Z-2 N	0.292	23	6.716	
TP-11, G1, B-2, Z-2 N	0.287	21	6.027	
TP-11, G1, B-3, Z-2 N	0.284	22	6.248	
TP-11, G1, B-1, Z-3 N	0.296	12	3.552	
TP-11, G1, B-2, Z-3 N	0.296	12	3.552	
TP-11, G1, B-3, Z-3 N	0.28	12	3.36	
	Total	**163**	**47.244**	**0.28984**

Bar ID	Avg$_W$	Sum Wf	Avg$_W$ *Sum Wf	
TP-11, G1, B-1, Z-1 S	0.298	18	5.364	
TP-11, G1, B-2, Z-1 S	0.298	18	5.364	
TP-11, G1, B-3, Z-1 S	0.295	18	5.31	
TP-11, G1, B-4, Z-1 S	0.292	18	5.256	
TP-11, G1, B-5, Z-1 S	0.295	18	5.31	
TP-11, G1, B-1, Z-2 S	0.285	22	6.27	
TP-11, G1, B-2, Z-2 S	0.28	22	6.16	
TP-11, G1, B-3, Z-2 S	0.282	22	6.204	
TP-11, G1, B-4, Z-2 S	0.286	22	6.292	
TP-11, G1, B-5, Z-2 S	0.292	22	6.424	
TP-11, G1, B-1, Z-3 S	0.289	12	3.468	
TP-11, G1, B-2, Z-3 S	0.286	12	3.432	
TP-11, G1, B-3, Z-3 S	0.274	13	3.562	
TP-11, G1, B-4, Z-3 S	0.275	15	4.125	
TP-11, G1, B-5, Z-3 S	0.294	14	4.116	
	Total	**266**	**76.657**	**0.288184**

Maximum Section Loss Measurements for Wall #1

Maxiumum Section Loss Measurements

1	Test Pit # 4	Loss of radius
0.298	Mat # 2	(in)
	0.20	0.0473
	0.10	0.1007
	0.21	0.0440
	0.25	0.0240
o	0.30	0.0000
2	Site 4	
0.298	Layer 2	
	0.18	0.0590
o	0.31	0.0000
	0.28	0.0107
3	Layer III	
0.298	Test Pit # 4	
	0.20	0.0490
	0.21	0.0440
o	0.32	0.0000
	0.22	0.0390
	0.27	0.0140
	0.25	0.0257
	0.24	0.0290
	0.25	0.0240
o	0.31	0.0000
4	Test Pit # 7	
0.298	Grid # 2	
	0.23	0.0365
	0.24	0.0290
	0.28	0.0090
	0.21	0.0440
	0.20	0.0490
o	0.32	0.0000
o	0.30	0.0000
o	0.31	0.0000
	0.18	0.0590
o	0.32	0.0000
	0.20	0.0490
	0.11	0.0940
5	Test Site 4	
0.298	Layer 2	
	0.24	0.0290
o	0.31	0.0000
	0.25	0.0240
	0.22	0.0390
	0.28	0.0090
	0.27	0.0140
	0.23	0.0340
o	0.31	0.0000
	0.17	0.0640
	0.16	0.0690
o	0.30	0.0000
o	0.31	0.0000

Maximum Section Loss Measurements for Wall #1

	0.27	0.0140
	0.27	0.0140
	0.28	0.0090
	0.28	0.0090
6	Test Pit # 7	
0.298	Grid # 2	
	0.22	0.0390
o	0.31	0.0000
	0.26	0.0190
o	0.31	0.0000
	0.18	0.0615
	0.22	0.0390
	0.23	0.0365
	0.22	0.0415
	0.20	0.0515
o	0.31	0.0000
	0.10	0.0990
	0.13	0.0840
	0.13	0.0840
	0.18	0.0590
	0.26	0.0190
	0.14	0.0790
7	Test Pit # 5	
0.298	Layer # 3	
o	0.32	0.0000
	0.19	0.1080
	0.26	0.0380
	0.14	0.1580
	0.21	0.0880
o	0.30	0.0000
	0.21	0.0880
	0.21	0.0880
	0.29	0.0080
	0.27	0.0280
o	0.30	0.0000
	0.24	0.0580
	0.07	0.2280
o	0.31	0.0000
	0.29	0.0080
8	Test # 3	
0.298	Layer III	
o	0.31	0.0000
	0.19	0.0565
	0.25	0.0240
	0.19	0.0540
	0.28	0.0115
	0.19	0.0565
	0.27	0.0165
o	0.29	0.0000
	0.24	0.0315
	0.17	0.0640
	0.05	0.1240

Maximum Section Loss Measurements for Wall #1

9	Test Pit 3	
0.298	Mat Layer 2	
o	0.30	0.0000
	0.21	0.0465
	0.23	0.0340
	0.12	0.0890
	0.28	0.0090
o	0.30	0.0000
	0.21	0.0440
	0.21	0.0440
	0.24	0.0290
o	0.31	0.0000
	0.26	0.0190
o	0.30	0.0000
10	Test Pit # 3	
0.298	Layer III Bar 9	
	0.27	0.0140
	0.24	0.0315
o	0.32	0.0000
	0.08	0.1090
o	0.32	0.0000
o	0.32	0.0000
	0.24	0.0290
11	Test # 3	
0.298	Mat II	
o	0.31	0.0000
	0.29	0.0040
	0.24	0.0290
	0.24	0.0290
	0.18	0.0590
	0.24	0.0290
	0.23	0.0340
	0.19	0.0540
	0.26	0.0190
	0.23	0.0340
	0.28	0.0090
o	0.31	0.0000
12	Test # 2	
0.348	Mat II	
o	0.35	0.0000
	0.26	0.0440
	0.32	0.0140
	0.28	0.0340
	0.32	0.0140
	0.19	0.0790
	0.15	0.0990
	0.21	0.0690
o	0.35	0.0000
o	0.35	0.0000
	0.25	0.0490
	0.21	0.0715
	0.28	0.0340

Maximum Section Loss Measurements for Wall #1

	0.28	0.0340
	0.08	0.1340
13	Test Pit # 2	
0.348	Mat 2	
	0.21	0.0690
	0.26	0.0440
	0.29	0.0290
	0.21	0.0690
	0.27	0.0390
	0.14	0.1040
	0.21	0.0690
o	0.37	0.0000
	0.32	0.0140
o	0.35	0.0000
14	Test Pit # 2	
0.348	Mat II	
o	0.36	0.0000
	0.31	0.0190
	0.30	0.0240
	0.28	0.0340
	0.26	0.0440
	0.27	0.0390
	0.25	0.0490
	0.22	0.0640
o	0.35	0.0000
o	0.36	0.0000
	0.34	0.0040
	0.34	0.0040
	0.11	0.1190
	0.16	0.0940
	0.16	0.0940
	0.34	0.0040
15	Test Pit # 3	
0.298	Layer # 2	
	0.26	0.0190
	0.19	0.0540
o	0.30	0.0000
	0.23	0.0340
	0.15	0.0740
o	0.30	0.0000
	0.26	0.0190
o	0.30	0.0000
	0.24	0.0290
	0.15	0.0740
	0.18	0.0590
	0.24	0.0290
	0.19	0.0565
	0.17	0.0640
	0.15	0.0740
	0.24	0.0290
16	Test Sites 2 & 3	
0.298	II & III Mat	

Maximum Section Loss Measurements for Wall #1

	0.27	0.0140
	0.22	0.0390
	0.26	0.0190
	0.24	0.0290
o	0.30	0.0000
	0.21	0.0440
	0.16	0.0690
	0.24	0.0290
	0.20	0.0490
	0.19	0.0540
	0.24	0.0290
	0.19	0.0540
	0.20	0.0490
	0.08	0.1090
17	Test Sites 2 & 3	
0.298	II & III Mat	
	0.18	0.0590
	0.29	0.0040
	0.23	0.0340
	0.22	0.0390
	0.22	0.0390
	0.22	0.0390
	0.22	0.0390
o	0.30	0.0000
	0.29	0.0040
o	0.30	0.0000
	0.22	0.0390
	0.25	0.0240
	0.22	0.0390
	0.20	0.0490
	0.16	0.0690
18	Test Sites 2 & 3	
0.298	II & III Mat	
	0.20	0.0490
	0.26	0.0190
	0.26	0.0190
	0.26	0.0190
	0.19	0.0540
	0.27	0.0165
o	0.30	0.0000
	0.29	0.0040
	0.16	0.0690
o	0.30	0.0000
	0.12	0.0890
	0.21	0.0440
	0.12	0.0890
	0.16	0.0690
	0.20	0.0490
	0.02	0.1390
19	Test Sites 2 & 3	
0.298	II & III Mat	
	0.08	0.1090

Maximum Section Loss Measurements for Wall #1

	0.21	0.0440
	0.28	0.0090
	0.06	0.1190
	0.29	0.0040
	0.15	0.0740
	0.26	0.0190
	0.09	0.1040
	0.24	0.0290
	0.18	0.0590
	0.15	0.0740
	0.16	0.0690
	0.28	0.0090
	0.21	0.0440
	0.13	0.0840
20	Test Sites 2 & 3	
0.298	II & III Mat	
	0.26	0.0190
	0.24	0.0290
	0.23	0.0340
	0.29	0.0040
	0.28	0.0115
o	0.31	0.0000
o	0.32	0.0000
	0.28	0.0090
	0.25	0.0240
	0.28	0.0090
	0.23	0.0340
21	Test Sites 2 & 3	
0.298	II & III Mat	
	0.09	0.1040
	0.04	0.1290
	0.14	0.0790
	0.16	0.0690
o	0.31	0.0000
	0.26	0.0190
	0.21	0.0440
	0.22	0.0390
	0.07	0.1140
	0.13	0.0840
	0.12	0.0890
	0.29	0.0040
	0.11	0.0940
	0.23	0.0340
	0.29	0.0040
	0.29	0.0040
22	Test Site # 4	
0.298	Layer # 2	
	0.26	0.0190
	0.24	0.0290
	0.25	0.0240
	0.28	0.0090
	0.28	0.0090

Maximum Section Loss Measurements for Wall #1

	0.28	0.0090
23	Test Site # 4	
0.298	0.31	0.0000
24	Test Pit # 6	
0.298	0.24	0.0290
	0.25	0.0240
	0.29	0.0040
	0.08	0.1090
	0.16	0.0690
	0.26	0.0190
	0.19	0.0540
	0.19	0.0540
	0.23	0.0340
	0.16	0.0690
o	0.32	0.0000
	0.13	0.0840
	0.22	0.0390
	0.25	0.0240
	0.16	0.0690
	0.18	0.0590
25	Test Pit # 7	
0.298	Grid # 1	
	0.18	0.0590
o	0.31	0.0000
	0.23	0.0340
	0.23	0.0340
	0.18	0.0590
	0.21	0.0440
	0.20	0.0490
	0.19	0.0540
	0.18	0.0590
	0.15	0.0740
	0.10	0.0990
26	Test Pit # 7	
o	0.31	0.0000
0.298	0.19	0.0540
	0.19	0.0540
o	0.31	0.0000
	0.22	0.0390
	0.24	0.0290
o	0.31	0.0000
o	0.30	0.0000
	0.11	0.0940
	0.06	0.1190
	0.12	0.0890
	0.10	0.0990
	0.12	0.0890
	0.20	0.0490
	0.20	0.0490
27	Site # 4	
0.298	Layer # 1	
	0.21	0.0440

Maximum Section Loss Measurements for Wall #1

	0.16	0.0690
	0.25	0.0240
	0.20	0.0490
o	0.31	0.0000
	0.21	0.0440
	0.18	0.0590
	0.18	0.0590
	0.11	0.0940
	0.07	0.1140
	0.22	0.0390
	0.24	0.0290
28	Test Site # 4	
0.298	Layer # 2	
	0.19	0.0540
	0.28	0.0090
o	0.30	0.0000
	0.25	0.0240
o	0.31	0.0000
	0.27	0.0140
	0.29	0.0040
	0.23	0.0340
o	0.30	0.0000
29	Assorted Samples	
0.298	Test Pits # 4 - # 7	
	0.21	0.0440
	0.31	0.0000
	0.31	0.0000
	0.28	0.0090
o	0.33	0.0000
	0.28	0.0090
	0.29	0.0040
o	0.29	0.0000
	0.21	0.0440
	0.24	0.0290
o	0.29	0.0000
	0.24	0.0290
	0.29	0.0040
	0.19	0.0540
o	0.32	0.0000
	0.21	0.0440

Idealized Uniform Metal Loss for Wall #1

30	Test Pit # 2	Loss of Radius
0.348	Mat II	(in)
	0.31	0.0190
	0.34	0.0040
	0.35	0.0000
	0.30	0.0240
	0.36	0.0000
	0.32	0.0140
	0.28	0.0340
	0.35	0.0000
	0.31	0.0190
	0.29	0.0290
	0.34	0.0040
	0.31	0.0190
	0.30	0.0240
	0.26	0.0440
	0.35	0.0000
	0.34	0.0040
	0.25	0.0490
	0.34	0.0040
	0.28	0.0340
	0.26	0.0440
	0.32	0.0140
	0.31	0.0190
	0.30	0.0240
	0.37	0.0000
	0.31	0.0190
	0.23	0.0590
	0.28	0.0340
	0.30	0.0240
	0.32	0.0140
	0.34	0.0040
	0.35	0.0000
	0.31	0.0190
	0.34	0.0040
	0.34	0.0040
	0.34	0.0040
	0.28	0.0340
	0.32	0.0140
	0.35	0.0000
	0.34	0.0040
	0.34	0.0040
	0.33	0.0090
	0.34	0.0040
	0.29	0.0290
	0.32	0.0140
	0.33	0.0090
	0.32	0.0140
	0.30	0.0240
	0.36	0.0000
	0.29	0.0290
	0.31	0.0190

Idealized Uniform Metal Loss for Wall #1

	0.16	0.0940
	0.11	0.1190
	0.25	0.0490
	0.17	0.0890
	0.36	0.0000
	0.29	0.0290
	0.28	0.0340
	0.26	0.0440
	0.32	0.0140
0.348	0.34	0.0040
	0.30	0.0240
	0.35	0.0000
	0.31	0.0190
	0.30	0.0240
	0.31	0.0190
	0.30	0.0240
0.348	0.36	0.0000
	0.28	0.0340
	0.32	0.0140
	0.37	0.0000
	0.36	0.0000
	0.25	0.0490
	0.35	0.0000
0.348	0.21	0.0690
	0.32	0.0140
	0.17	0.0890
	0.17	0.0890
	0.35	0.0000
	0.34	0.0040
	0.26	0.0440

H. Results from Metallurgy Laboratory

Adirondack
Environmental Services, Inc.
Experience is the solution
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LABORATORY REPORT

MATERIALS TESTING: Metallography/SEM&EDXRF/Micro-Hardness/XRD and Tension Testing

04/21/2004 Attn: Ken Fishman

McMahon & Mann Consulting Engineers PC
2495 Main Street / Suite 432
Buffalo, New York 14214

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Albany, NY

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ABSTRACT

One cross-hatched re-bar specimen designated TEST PIT 5 - LAYER 4 was submitted for materials testing. The purpose of the examination was to provide physical and chemical data to define the corrosion mechanism and evaluate the material degradation.

TEST RESULTS

The following observations were noted during materials analysis:

1. The surface corrosion was analyzed using the scanning electron microscope (SEM) with energy dispersive x-ray (EDXRF) spectroscopy techniques combined with x-ray diffraction investigation. Corrosion material was separated into three distinct groups: (1) white, (2) black and (3) red.

2. The white corrosion material produced x-ray data which indicates calcium-silicate concentration with traces of magnesium, aluminum, potassium, manganese and iron. Subsequent x-ray diffraction analysis indicates this material is dolomite ($CaMg(CO_3)$) with some quartz (SiO_2).

3. The black corrosion product is comprised of iron with traces of silicon, sulfur, calcium and manganese. The XRD profile indicates a significant amount of magnetite (Fe_3O_4) attributed to the black corrosion product.

4. The x-ray data obtained during analysis of the red corrosion material reported concentrations of iron and copper with traces of silicon, sulfur, chlorine, calcium, chromium, manganese and nickel. The crystalline component of this red scale material has been identified as hematite (Fe_2O_3).

5. The SEM/EDXRF examination of the longitudinal cross-section of a corroded wire section reported an iron oxide scale approximately 1 to 2 millimeters thick.

6. The longitudinal cross-sections provided surfaces for micro-structure examination (grain size/shape and micro-hardness testing).

7. Six sub-samples removed from the cross hatch for tension testing provided comparison at necked (heavily corroded) versus matrix (lightly corroded) areas.

CONCLUSIONS

The physical and chemical data provided during materials examination indicates the following:

1. There is three distinct types of corrosion products involved with the steel cross-hatched re-bar specimen. In addition to magnetite, hematite and dolomite concentrations were reported. Two significant suspect component within the red (hematite) corrosion material have been identified as chlorine and sulfur.

2. The longitudinal sections were embedded, polished and etched with 2% Nital to exhibit the microstructure, Subsequent Knoop Micro-Hardness measurements were obtained using 400X magnifications following ASTM E384-99 test procedures. Variation in grain size and shape is evident among the three specimens; however, the hardness values reported vary only slightly.

3. The tension test data reported following ASTM A370-03a methods reporting condition, approximate diameter and maximum load are reported. The test was applied using a maximum full-scale load range of 25,000 pounds; a constant crosshead speed of 0.05 in. per minute was used until failure. The test data exhibits correlation between sample diameter and maximum load to failure.

TEST DATA

SCANNING ELECTRON PHOTOMICROGRAPHS

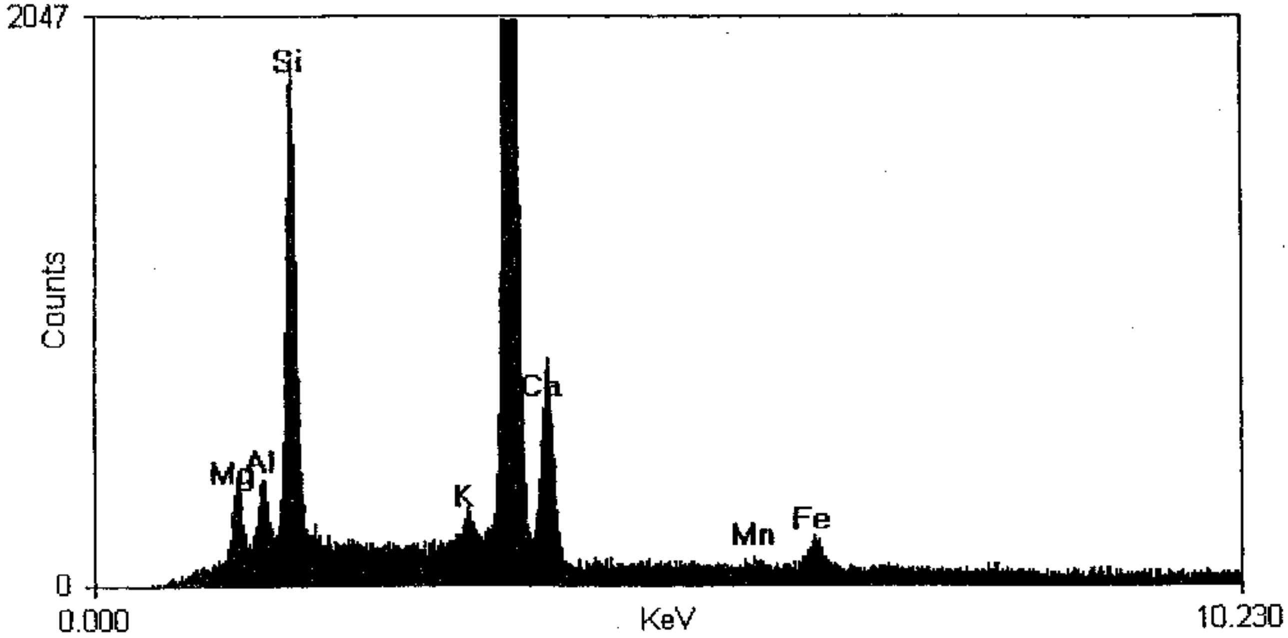
ENERGY DISPERSIVE X-RAY PROFILES

X-RAY DIFFRACTION PROFILE

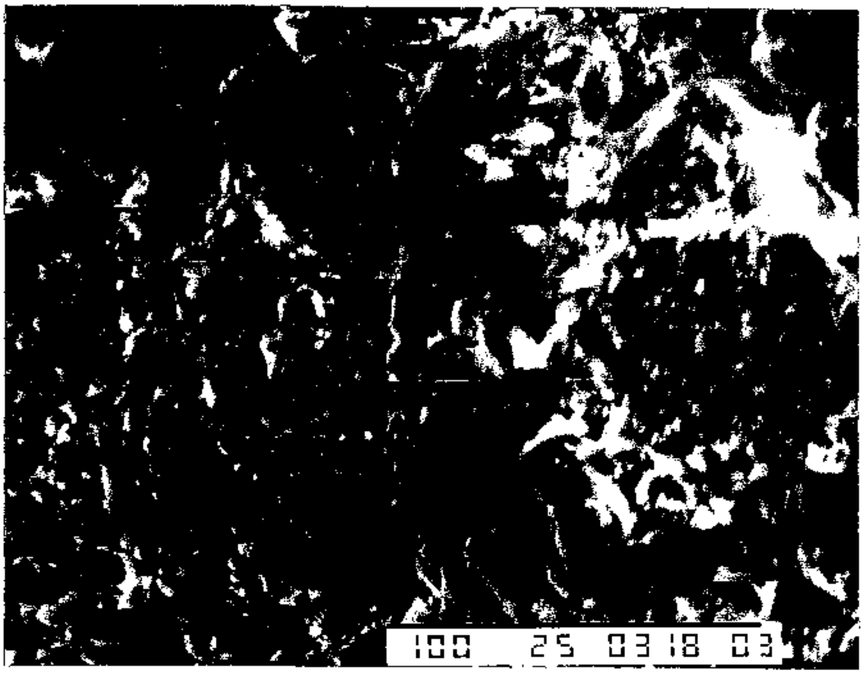
METALLOGRAPHY

Micro-HARDNESS DATA

TENSION TESTING DATA



McMahon&Mann: LV Steel Wire White Corrosn.



SEM: 500X **SURFACE CORROSION - WHITE**

```
Quantitative Analysis Results - Standardless Analysis:
Spectrum 1 - McMahon&Mann: LV Steel Wire White Corrosn. 18-Mar-2004
EDS Parameters - 25KeV, Takeoff Angle: 56°, Fit Index: 4.59
Correction: ZAF, Cycles: 4

element    line        kratio    error     zaf         weight    error     ovolt
                                                                 (+/-)
Mg         Ka:EDS      0.0316    0.0012    0.5021      0.0546    0.0024    19.19
Al         Ka:EDS      0.0204    0.0011    0.5766      0.0307    0.0019    16.02
Si         Ka:EDS      0.1503    0.0021    0.6952      0.1862    0.0030    13.58
K          Ka:EDS      0.0141    0.0016    1.0184      0.0120    0.0016    6.94
Ca         Ka:EDS      0.7468    0.0063    0.9402      0.6782    0.0067    6.20
Mn         Ka:EDS      0.0060    0.0024    0.8041      0.0065    0.0030    3.83
Fe         Ka:EDS      0.0307    0.0037    0.8410      0.0317    0.0043    3.52

<total>                                                1.0000
* =< 2 Sigma

element    atoms      compound  wt%       error%     norm%
                                          (+/-)
Mg         0.40       Mg        5.46      0.12       5.46
Al         0.20       Al        3.07      0.11       3.07
Si         1.18       Si        18.62     0.21       18.62
K          0.05       K         1.20      0.16       1.20
Ca         3.00       Ca        67.82     0.63       67.82
Mn         0.02       Mn        0.65      0.24       0.65
Fe         0.10       Fe        3.17      0.37       3.17

<total>    4.95                 100.00               100.00
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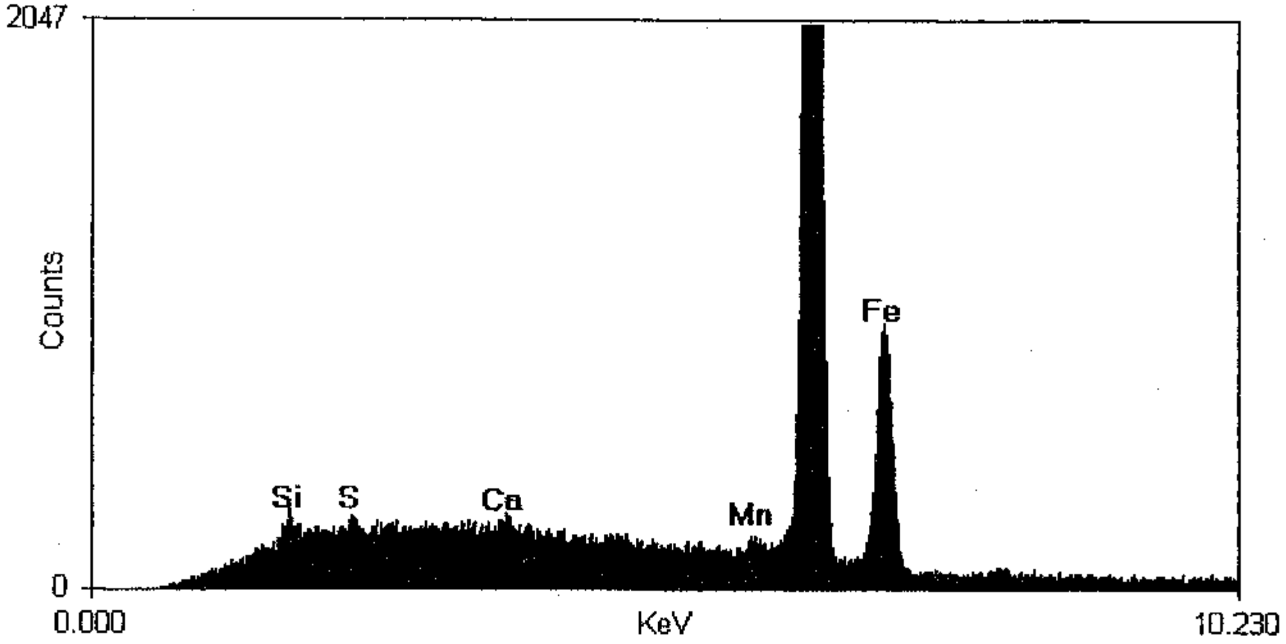
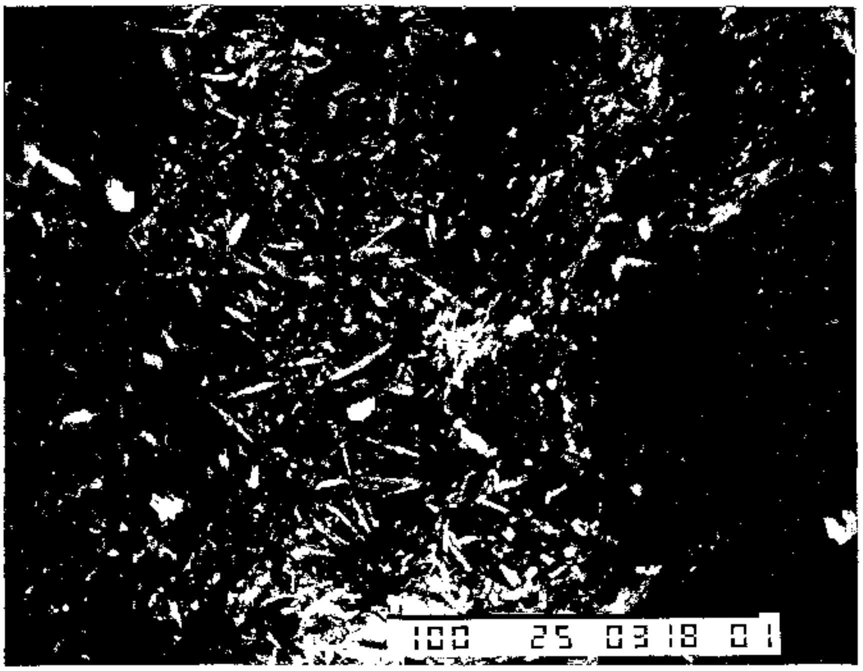


McMahon&Mann: LV Steel Wire Black Corrosn.



SEM: 500X **SURFACE CORROSION - BLACK**

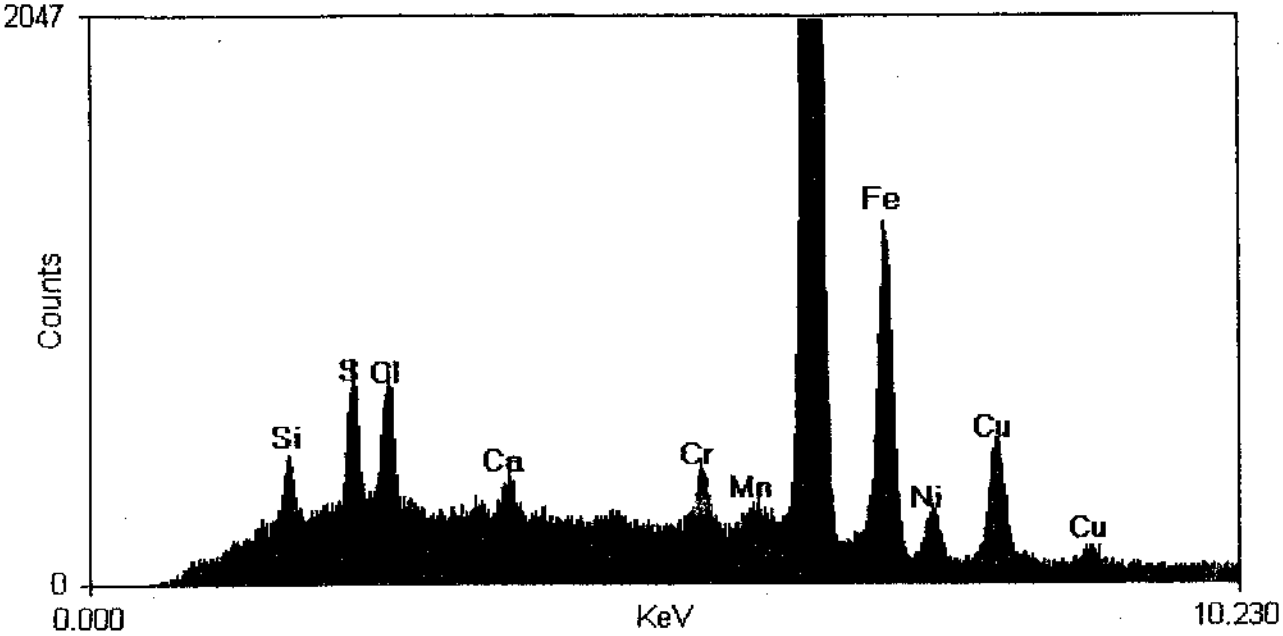
```
Quantitative Analysis Results - Standardless Analysis:
Spectrum 1 - McMahon&Mann: LV Steel Wire Black Corrosn. 18-Mar-2004
EDS Parameters - 25KeV, Takeoff Angle: 56°, Fit Index: 5.58
Correction: ZAF, Cycles: 2

element    line       kratio    error     zaf        weight    error     ovolt
                                                               (+/-)
Si         Ka:EDS     0.0025    0.0004    0.4854     0.0051    0.0009    13.58
S          Ka:EDS     0.0019    0.0005    0.7339     0.0026    0.0007    10.10
Ca         Ka:EDS     0.0038    0.0009    1.0605     0.0035    0.0008    6.20
Mn         Ka:EDS     0.0061    0.0016    0.9733     0.0063    0.0016    3.83
Fe         Ka:EDS     0.9858    0.0086    0.9983     0.9826    0.0086    3.52

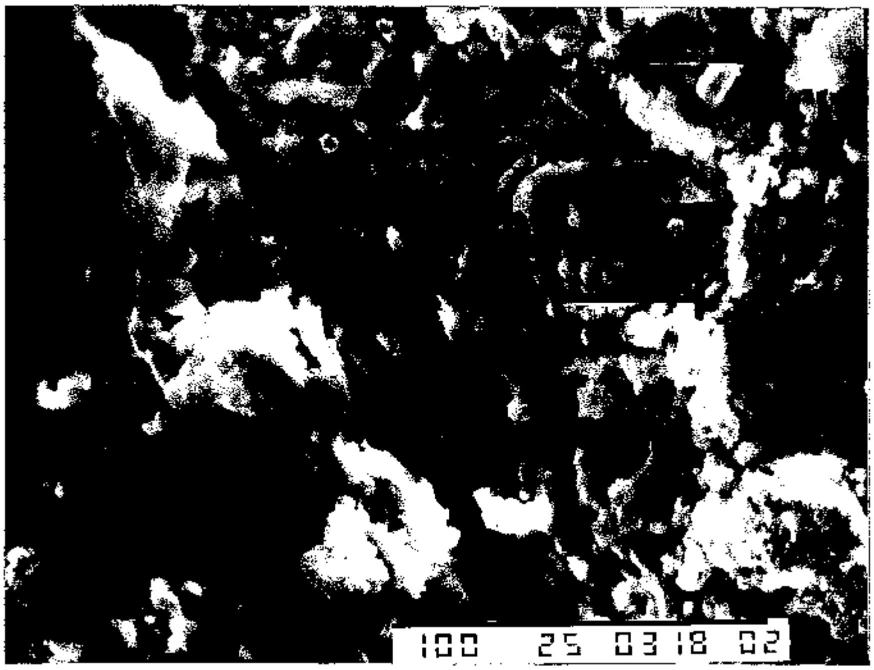
<total>                                              1.0000
* =< 2 Sigma

element    atoms     compound   wt%       error%     norm%
                                          (+/-)
Si         0.01      Si         0.51      0.04       0.51
S          0.00      S          0.26      0.05       0.26
Ca         0.01      Ca         0.35      0.09       0.35
Mn         0.01      Mn         0.63      0.16       0.63
Fe         1.00      Fe         98.26     0.86       98.26

<total>    1.03                 100.00               100.00
```



McMahon&Mann: LV Steel Wire Red Corrosn.



SEM: 500X **SURFACE CORROSION - RED**

```
Quantitative Analysis Results - Standardless Analysis:
Spectrum 1 - McMahon&Mann: LV Steel Wire Red Corrosn. 18-Mar-2004
EDS Parameters - 25KeV, Takeoff Angle: 56°, Fit Index: 5.43
Correction: ZAF, Cycles: 3

element   line      kratio    error     zaf       weight    error     ovolt
                                                            (+/-)
Si        Ka:EDS    0.0053    0.0004    0.4868    0.0107    0.0008    13.58
S         Ka:EDS    0.0162    0.0006    0.7306    0.0217    0.0008    10.10
Cl        Ka:EDS    0.0163    0.0006    0.7849    0.0204    0.0008    8.84
Ca        Ka:EDS    0.0070    0.0007    1.0277    0.0066    0.0007    6.20
Cr        Ka:EDS    0.0164    0.0013    1.2624    0.0127    0.0010    4.18
Mn        Ka:EDS    0.0042    0.0014    0.9751    0.0042    0.0014    3.83
Fe        Ka:EDS    0.8414    0.0067    1.0026    0.8213    0.0067    3.52
Ni        Ka:EDS    0.0254    0.0020    0.9067    0.0274    0.0022    3.00
Cu        Ka:EDS    0.0679    0.0033    0.8853    0.0750    0.0038    2.78

<total>                                           1.0000
* =< 2 Sigma

element   atoms     compound  wt%       error%    norm%
                                        (+/-)
Si        0.10      Si        1.07      0.04      1.07
S         0.18      S         2.17      0.06      2.17
Cl        0.16      Cl        2.04      0.06      2.04
Ca        0.05      Ca        0.66      0.07      0.66
Cr        0.07      Cr        1.27      0.13      1.27
Mn        0.02      Mn        0.42      0.14      0.42
Fe        4.00      Fe        82.13     0.67      82.13
Ni        0.13      Ni        2.74      0.20      2.74
Cu        0.32      Cu        7.50      0.33      7.50

<total>   5.02                100.00              100.00
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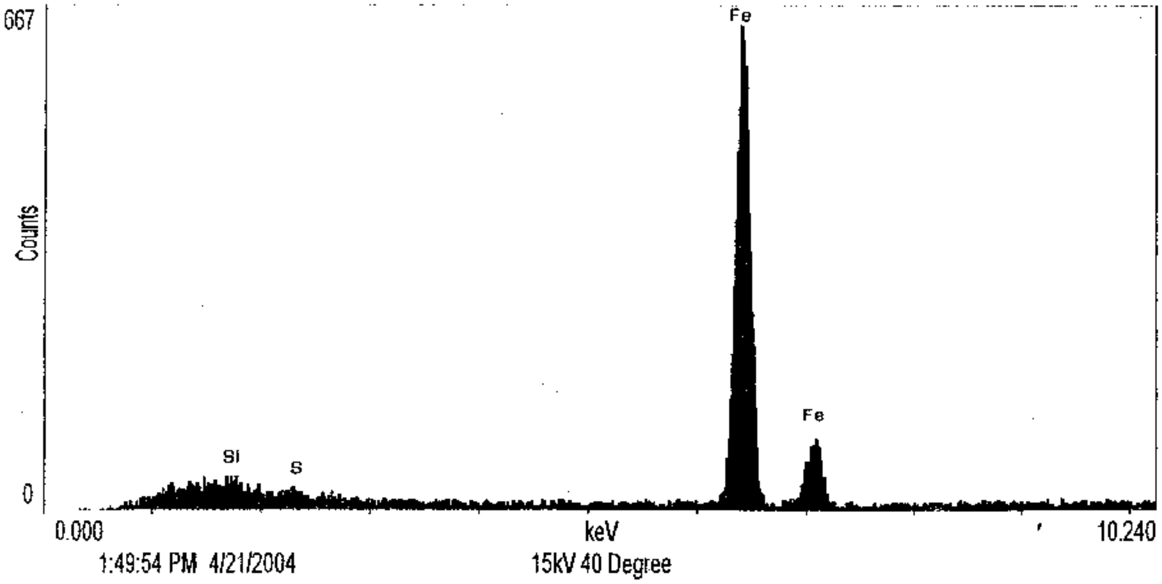
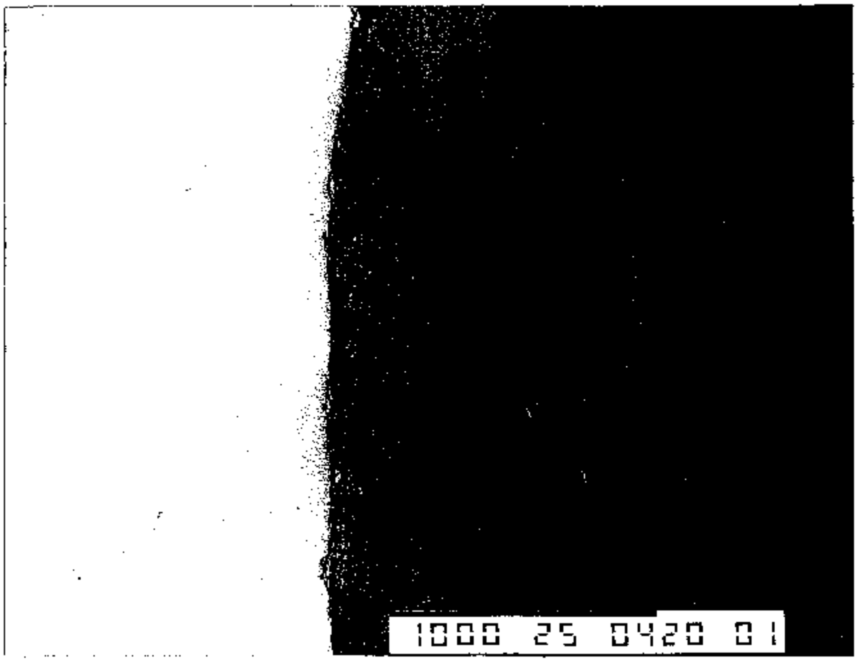
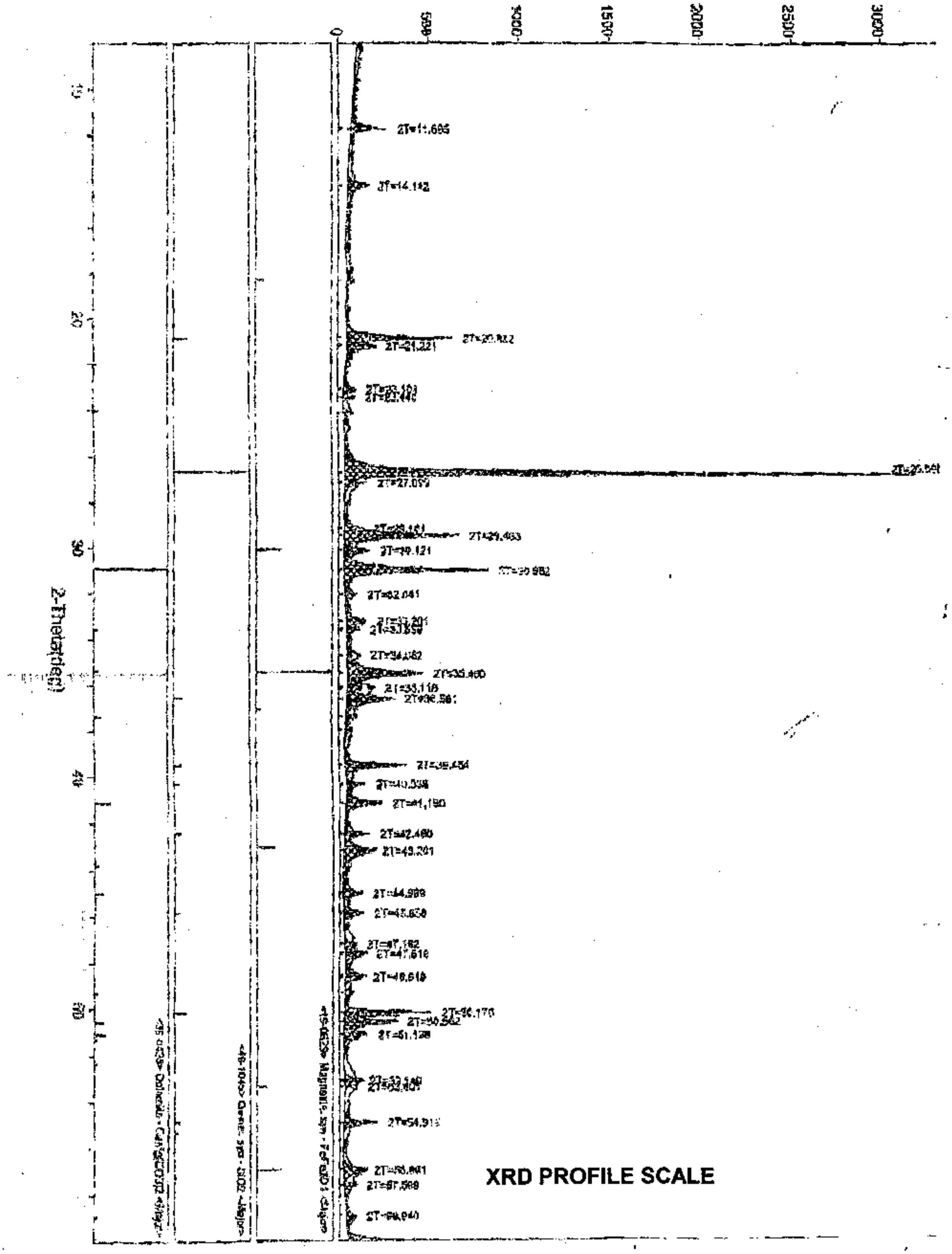
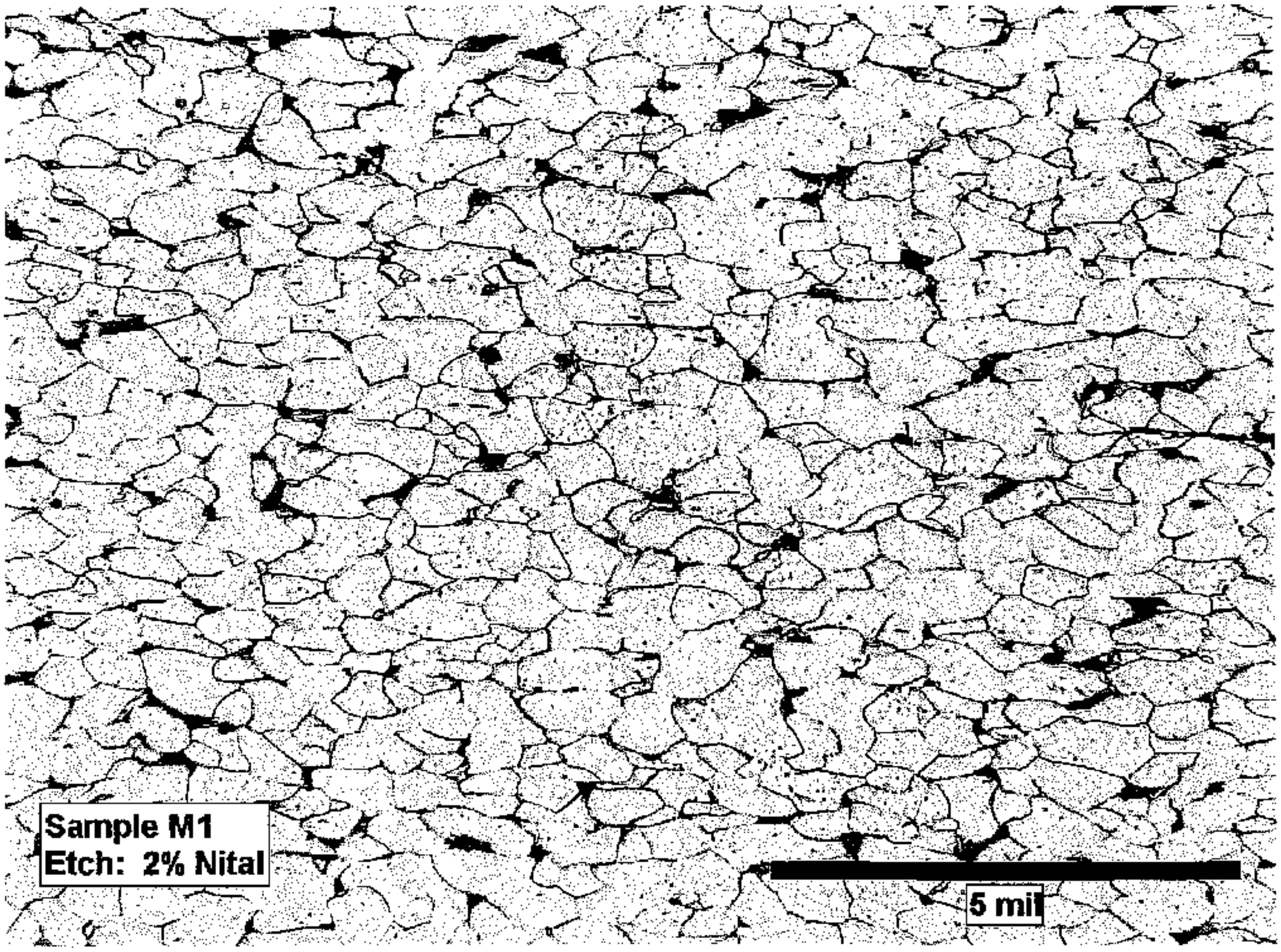


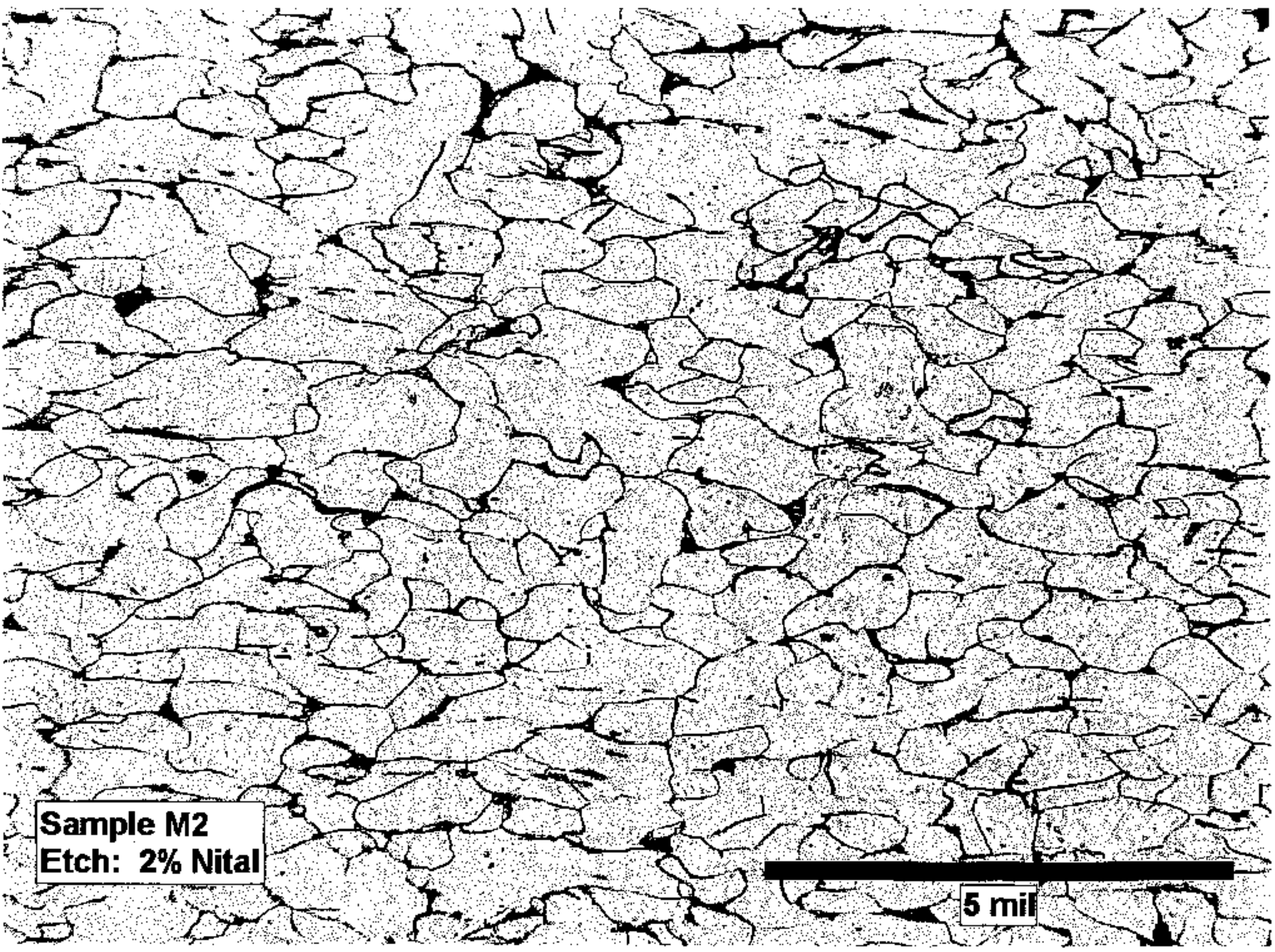


SEM: 35X **LONGITUDINAL SECTION - SCALE**



XRD PROFILE SCALE


Sample M1
Etch: 2% Nital
5 mil


Sample M2
Etch: 2% Nital
5 mil

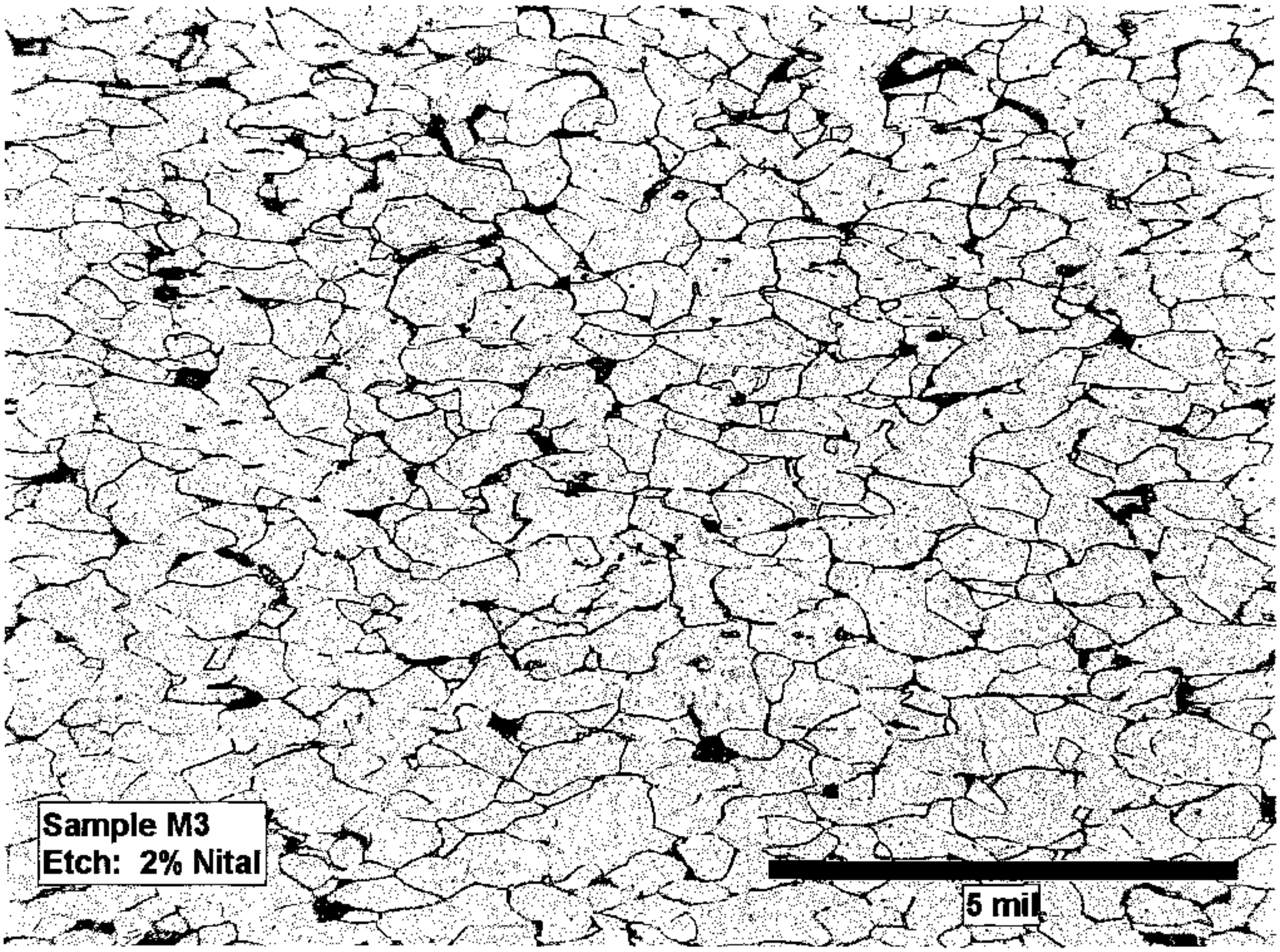

Sample M3
Etch: 2% Nital
5 mil

TABLE ONE

MicroHARDNESS - VALUES (500 gf)				
SAMPLE ID	**Location**	**HK 1**	**HK 2**	**HK 3**
Mount 1	Thin Area	265	270	267
Mount 1	Thick Area	269	272	270
Mount 2	Thin Area	286	283	278
Mount 2	Thick Area	277	277	273
Mount 3	Nominal	283	275	273

TABLE TWO

CORRODED REBAR TENSION TEST RESULTS

SAMPLE ID	CONDITION	DIAMETER (in.)	MAX LOAD (lbs)
1	THICK WIRE	0.305	5115
2	THICK WIRE	0.317	5273
3	THICK WIRE	0.320	4939
4	THINNED WIRE	0.210	2695
5	THINNED WIRE	0.215	3281
6 *	THINNED WIRE	0.165	1294

* Sample 6 had a slight bend through the mid-section.

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TEST METHODS

Scanning electron microscopy provides images formed by rastering a beam of electrons over the specimen surface and, using an electron or x-ray detector, records secondary, backscattered or x-ray signals. The images formed provide high resolution (20 Angstrom) with magnifications of 15 to 200,000 diameters. In addition to secondary and backscattered electrons, characteristic x-rays are also emitted during electron beam/sample surface interactions.

Energy dispersive x-ray fluorescence spectroscopy using a conventional silicon-lithium detector is capable of analyzing elemental concentrations from atomic number 9 (fluorine) through 94 (plutonium) as they appear on the Periodic Table of Elements. The integral counts beneath the peaks are processed through use of a microcomputer to provide semi-quantitative composition profiles following matrix, specimen/detector geometry and instrumentation correction factors.

Adirondack Environmental Services, Inc.

Thomas K. Hare
Laboratory Manager/Microscopy

AES Report No. 040317LE

AES No: 040317 LE

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Project Name (Location)

Samplers: (Names)

Client Phone No:

PO Number:

Samplers: (Signature)

Client Fax No:

AES Sample Number	Client Sample Identification & Location	Date Sampled	Time A=a.m. P=p.m.		Sample Type Matrix	Comp	Grab	Number of Cont's	Analysis Required
040317 LE 01	LV STEEL WIRE			A P				1	CORROSION TESTING
				A P					
				A P					
				A P					
				A P					
				A P					
				A P					
				A P					
				A P					
				A P					
				A P					
				A P					
				A P					
				A P					

Turnaround Time Request:

☐ 1 Day ☐ 3 Day [✓ Normal]

☐ 2 Day ☐ 5 Day

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Date/Time 4/16/04

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Notes:

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Y N

Notes:

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LABORATORY REPORT

MATERIAL TESTING: SEM

Date:May 20, 2004 Attn: Ken Fishman

McMahon & Mann Consulting Engineers PC
2495 Main Street / Suite 432
Buffalo, New York 14214

AES Report No. 040317LE

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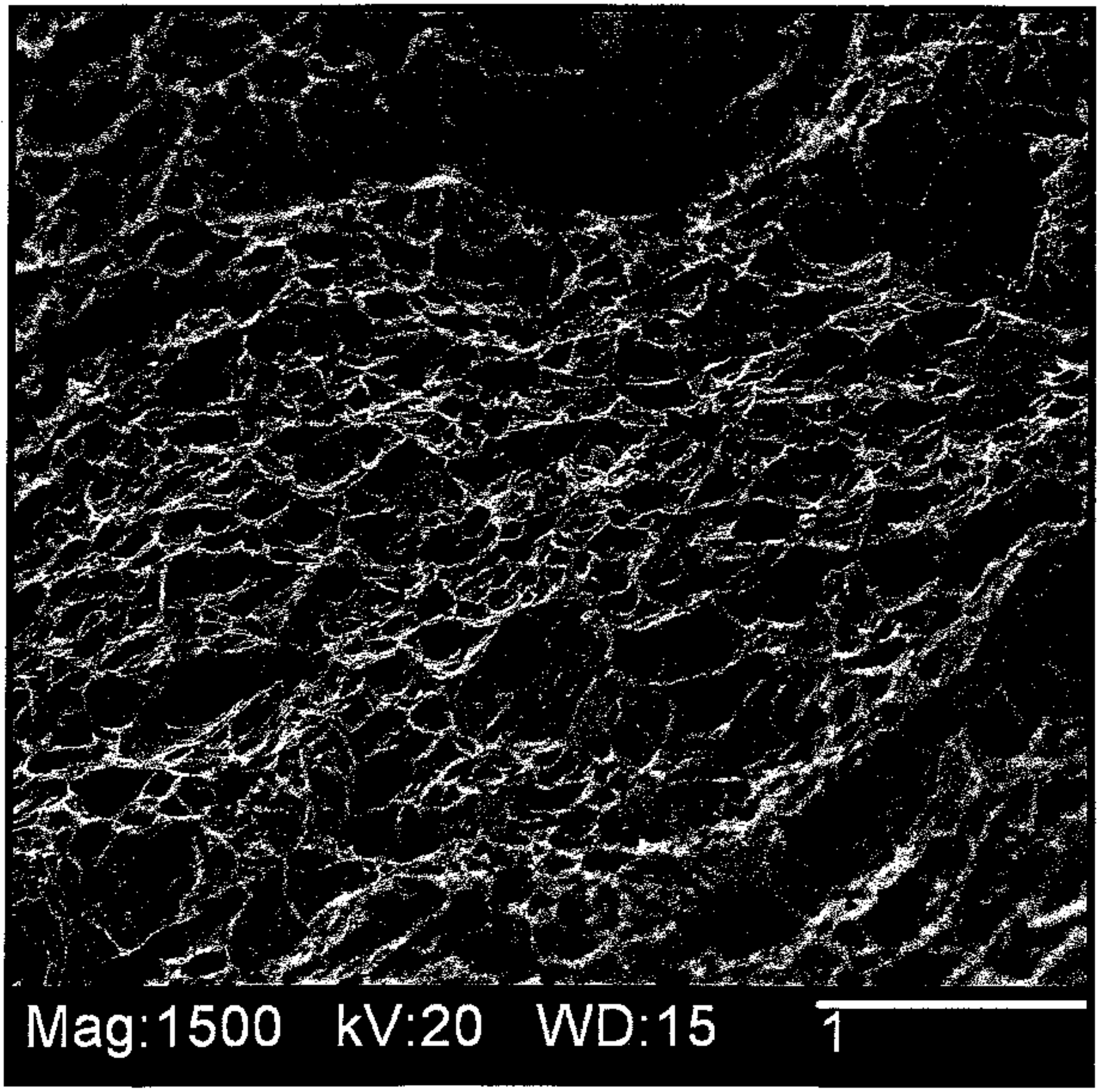
TABLE OF CONTENTS

CONCLUSIONS

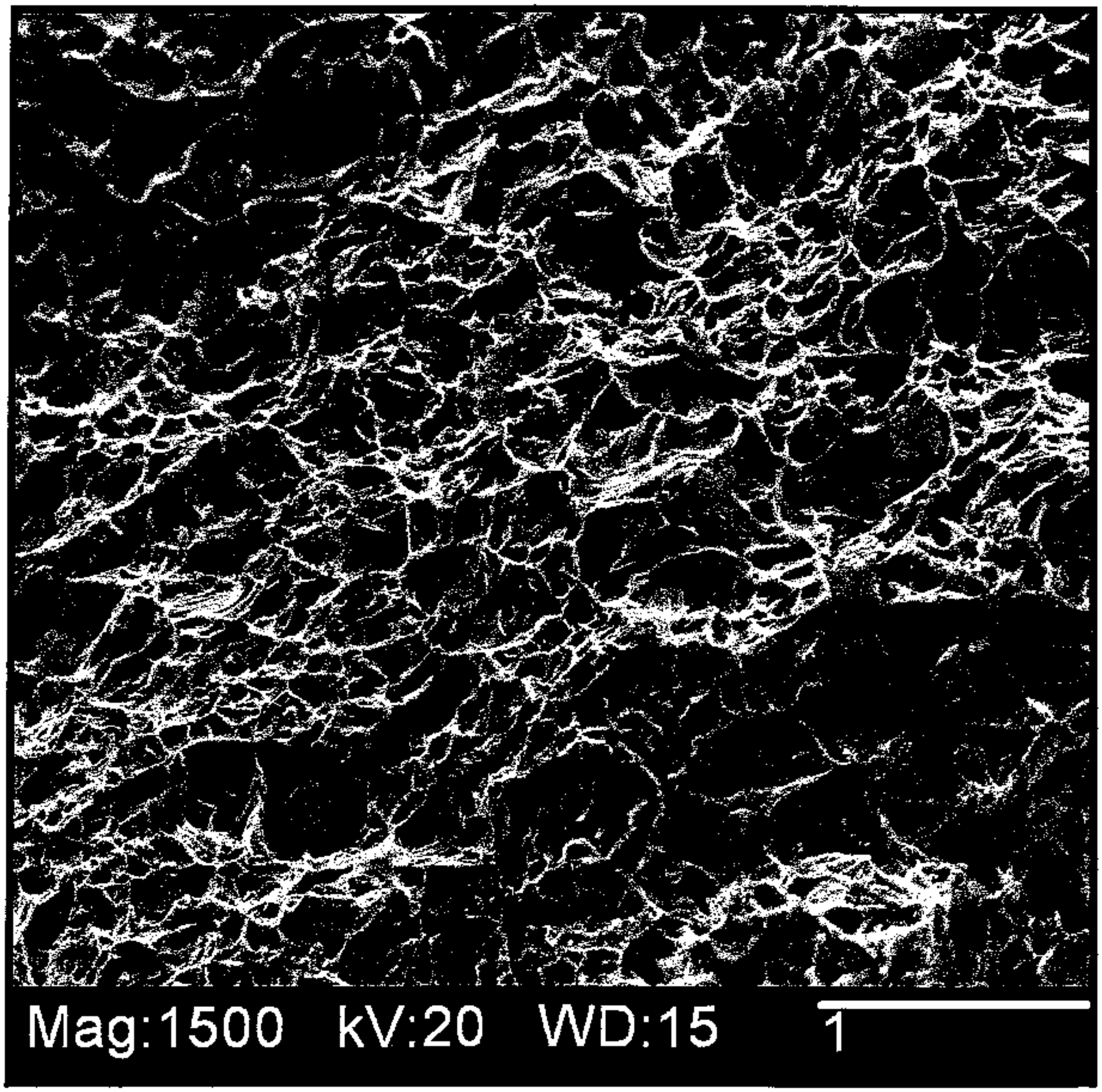
The SEM digital beam interface was used to collect secondary electron images of the two tension test specimens designated as SAMPL 3 and SAMPLE 5. Both samples provided images from fracture surface areas which are indicative of ductile fracture mode.

TEST DATA

SCANNING ELECTRON PHOTOMICROGRAPHS



SEM IMAGE SAMPLE TENSION TEST # 3



SEM IMAGE SAMPLE TENSION TEST # 5

TEST METHODS

Scanning electron microscopy provides images formed by rastering a beam of electrons over the specimen surface and, using an electron or x-ray detector, records secondary, backscattered or x-ray signals. The images formed provide high resolution (20 Angstrom) with magnifications of 15 to 200,000 diameters. In addition to secondary and backscattered electrons, characteristic x-rays are also emitted during electron beam/sample surface interactions.

Energy dispersive x-ray fluorescence spectroscopy using a conventional silicon-lithium detector is capable of analyzing elemental concentrations from atomic number 9 (fluorine) through 94 (plutonium) as they appear on the Periodic Table of Elements. The integral counts beneath the peaks are processed through use of a microcomputer to provide semi-quantitative composition profiles following matrix, specimen/detector geometry and instrumentation correction factors.

Adirondack Environmental Services, Inc.

Thomas K Hare
Laboratory Manager/Microscopy

AES Report No. 040317LE

AES No: 040317 LE

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Samplers: (Names)
Client Phone No:
PO Number:
Samplers: (Signature)
Client Fax No:

AES Sample Number	Client Sample Identification & Location	Date Sampled	Time A=a.m. P=p.m.		Sample Type			Number of Cont's	Analysis Required
					Matrix	Comp	Grab		
040317 LE01	LV STEEL WIRE			A P				1	CORROSION TESTING
				A P					
				A P					
				A P					
				A P					
				A P					
				A P					
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Date/Time 4/16/04

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Notes:

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Notes:

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LABORATORY REPORT

MATERIALS TESTING: STEEL TYPING

06/10/2004 Attn: Ken Fishman

McMahon & Mann Consulting Engineers PC
2495 Main Street / Suite 432
Buffalo, New York 14214

AES Report No. 040518LB
Filename: C:\MyFiles\mcmann mtls.wpd

Albany, NY

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ABSTRACT

One sample designated STEEL WIRE was submitted for materials testing. The purpose of the examination was to provide chemical data to define the steel type using ASTM specifications.

TEST RESULTS

The following observations were noted during materials analysis:

1. The surface corrosion was successfully removed to enable analysis of the steel matrix. There was sufficient sample for both Leco gas analysis and direct current plasma (DCP) optical emission spectroscopy.

2. The Leco gas analysis reported concentrations of carbon and sulfur. The DCP analysis reported concentrations of phosphorus, manganese, nickel, molybdenum, chromium, copper and silicon.

3. These quantitative test results were cross-referenced against ASTM steel specifications to determine that the STEEL WIRE specimen indexes well with an 1008 low carbon steel.

CONCLUSIONS

The quantitative elemental data provided from Leco gas analysis and DCP optical emission spectroscopy indexed well with an 1008 low carbon steel as specified in the ASTM A29-03 requriements.

TEST DATA

TABLE OF ANALYTICAL TEST RESULTS

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ANALYTICAL RESULTS FOR: STEEL WIRE SPECIMEN		
Element	Wt.%	ASTM A29-03 1008 Specifications
Carbon	0.060	0.10 max
Sulfur	0.041	0.050 max
Phosphorus	<0.01	0.040 max
Manganese	0.44	0.30 - 0.50
Nickel	0.18	-
Molybdenum	0.02	-
Chromium	0.07	-
Copper	0.35	-
Silicon	0.16	-

TEST METHODS

The Leco gas analyzer provides quantitative elemental concentrations for carbon and sulfur using a sample combustion method infrared detection. The direct current plasma (DCP) optical emission spectroscopy method provides quantitative elemental concentrations following sample preparation methods which include acid digestion.

Adirondack Environmental Services, Inc.
Thomas K. Hare
Laboratory Manager/Microscopy

AES Report No. 040518LB

AES No: 040518 LB

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Samplers: (Names) —

Client Phone No: 716-834-8932

PO Number: —

Samplers: (Signature) —

Client Fax No: 716-834-8934

AES Sample Number	Client Sample Identification & Location	Date Sampled	Time A=a.m. P=p.m.		Sample Type			Number of Cont's	Analysis Required
					Matrix	Comp	Grab		
040518LB01	Steel Wire	—	—	A P				1	Chem. ID.
				A P					
				A P					
				A P					
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Temperature	Properly Preserved	Received Within Holding Times
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Notes:	Notes:	Notes:

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APPENDIX IV

IV. Corrosion Monitoring

A. Corrosion Monitoring

Corrosion monitoring on this project includes measurement of half-cell potential and corrosion rate of in-service reinforcements and "dummy" coupons. These measurements require electrical connections to reinforcements and placement of a standard reference electrode for monitoring potentials. Therefore, corrosion monitoring points must be established whereby reinforcements are wired for monitoring and access is provided for reference electrodes.

"Dummy' coupons are also placed at each monitoring location and monitored for corrosion activity. Monitoring of "dummy" coupons is interesting because they represent the initial response of the metallic reinforcements to the backfill environment at the site. Dummy coupons were supplied by the Hilfiker Company, and were made from one foot long pieces of W9 size cold-drawn wire, similar to that used to manufacture the soil reinforcements employed on this project. Hilfiker provided plain steel and galvanized steel coupons. Galvanized coupons were used so the performance of zinc coating in this environment can be observed. These data may be useful to assess the vulnerability of other sites where galvanized reinforcements may be used.

Forty-five existing reinforcements and thirty-six "dummy" coupons are included in the monitoring program. The following sections describe preparation of corrosion monitoring points and how these points are organized into test stations. Salient details of corrosion monitoring including measurement of half-cell potential and corrosion rate are also described.

B. Preparation of Corrosion Monitoring Points

The FHWA, NDOT and MMCE established twenty-three corrosion monitoring points distributed among twelve monitoring stations along Walls #1, #2 and #3. Test points are organized whereby reinforcements and "dummy" coupons from different elevations are incorporated into a monitoring station. In general, monitoring points are prepared near the top, and base of the wall at each monitoring station; and, at stations where the wall height is greater than 20 feet, a third point is established near midheight. At each monitoring station, necessary connections are accessible near the base of the wall such that data from all monitoring points can be acquired from access at ground level, i.e. without the need for hoists, ladders, etc. Figure 3 (b), (c) and (d) shows the location of the monitoring points along Walls #1, 2 and 3, respectively. Details for each monitoring station are included in this appendix.

In general, monitoring stations are established at 50 to 100 foot intervals along the wall face. Monitoring Stations 1 thru 7 nearly coincide with the Test Pit Locations 1 through 7 along Wall #1. Monitoring Stations 8,9 and 10 are established along Wall #2 and Stations 8 and 10 are in proximity to Test Pits 9 and 8, respectively. Monitoring Stations 11 and 12 are located along Wall #3 in proximity to Test Pits 10 and 11, respectively. Tables IV-1(a), IV-1(b) and IV-1(c) describe the test points established along each monitoring station and summarize the instrumentation installed along Walls #1 #2 and #3, respectively.

Table IV-1(a). Corrosion Monitoring Locations- Wall #1

Station #	Site	Location[1]	Element[2]	Joint #	Depth (ft)	Access Hole Loc.
1	S12	"F1" 2+55.91±	Grid Layer- III	6	5.0	Panel #12
1	S12	"F1" 2+55.91±	Grid Layer -IV	6	7.0	Panel #12
1	S12	"F1" 2+53.64±	SC	NA	6.0	Panel #12
1	S12	"F1" 2+58.18±	GC	NA	6.0	Panel #12
1	S12	"F1" 2+55.46±	CSE	NA	6.0	Panel #3
1	S11	"F1" 2+55.91±	Grid Layer -VIII	6	15.0	Panel #12
1	S11	"F1" 2+55.91±	Grid Layer- IX	6	17.0	Panel #12
1	S11	"F1" 2+53.64±	SC	NA	16.0	Panel #12
1	S11	"F1" 2+58.18±	GC	NA	16.0	Panel #12
1	S11	"F1" 2+55.46±	CSE	NA	16.0	Panel #8
1	S1	"F1" 2+61.59±	Grid Layer – XIII	7	26.0	Panel #12
1	S1	"F1" 2+61.59±	Grid Layer- XIV	7	28.0	Panel #13
1	S1	"F1" 2+55.91±	SC x 2	6	28.0	Panel #13
1	S1	"F1" 2+55.91±	CSE	6	26.0	Panel #13
2	TP-2	"Pe" 152+62.25±	Grid Layer II	10	3.5	Panel #12
2	TP-2	"Pe" 152+62.25±	Grid Layer III	10	5.5	Panel #12
2	S13	"F1" 3+02.01±	Grid Layer VI	10	11.5	Panel #11
2	S13	"F1" 3+02.01±	Grid Layer VII	10	13.5	Panel #11
2	S13	"F1" 2+99.50±	SC	NA	12.5	Panel #11
2	S13	"F1" 3+04.51±	GC	NA	12.5	Panel #11
2	S13	"F1" 3+01.60±	CSE	NA	12.5	Panel #6
2	S2	"F1" 3+02.01±	Grid Layer XIII	10	25.5	Panel #13
2	S2	"F1" 3+02.01±	Grid Layer XIV	10	27.5	Panel #13
2	S2	"F1" 3+02.01±	SC x 2	10	27.5	Panel #13
2	S2	"F1" 3+00.01±	CSE	NA	26.5	Panel #13
3	TP-3	"Pe" 153+82.25±	Grid Layer II	20	3.5	Panel #9
3	TP-3	"Pe" 153+82.25±	Grid Layer III	20	5.5	Panel #9
3	S14	"F1" 4+26.50±	Grid Layer V	20	9.5	Panel #8
3	S14	"F1" 4+26.50±	Grid Layer VI	20	11.5	Panel #8
3	S14	"F1" 4+24.50±	SC	NA	10.5	Panel #8
3	S14	"F1" 4+28.50±	GC	NA	10.5	Panel #8
3	S14	"F1" 4+26.00±	CSE	NA	10.5	Panel #5
3	S3	"F1" 4+26.50±	Grid Layer X	20	19.5	Panel #10
3	S3	"F1" 4+26.50±	Grid Layer XI	20	21.5	Panel #10
3	S3	"F1" 4+26.50±	SC x 2	20	20.5	Panel #10
3	S3	"F1" 4+27.50±	CSE	NA	20.5	Panel #10
4	TP-4	"Pe" 154+97.25±	Grid Layer II	27	3.5	Panel #7
4	TP-4	"Pe" 154+97.25±	Grid Layer III	27	5.5	Panel #7
4	S4	"F1" 5+13.64±	CSE	27	14.5	Panel #7
4	S4	"F1" 5+13.64±	Grid Layer VIII	27	15.5	Panel #8
4	S4	"F1" 5+13.64±	Grid Layer IX	27	17.5	Panel #8
4	S4	"F1" 5+13.64±	SC x2	27	16.5	Panel #8
5	TP-5	"Pe" 156+02.25±	Grid Layer II	35	3.5	Panel #4
5	TP-5	"Pe" 156+02.25±	Grid Layer III	35	5.5	Panel #4
5	S5	"F1" 6+13.23±	CSE	35	10.5	Panel #5
5	S5	"F1" 6+13.23±	Grid Layer V	35	9.5	Panel #5
5	S5	"F1" 6+13.23±	Grid Layer VI	35	11.5	Panel #5
5	S5	"F1" 6+12.23±	SC x 2	NA	11.5	Panel #5
6	TP-6	"Pe" 156+57.25±	Grid Layer II	41	3.5	Panel #2
6	TP-6	"Pe" 156+57.25±	Grid Layer III	41	5.5	Panel #2
6	S6	"F1" 6+88.22±	CSE	41	6.5	Panel #3
6	S6	"F1" 6+88.22±	Grid Layer III	41	5.5	Panel #3
6	S6	"F1" 6+88.22±	Grid Layer IV	41	7.5	Panel #3
6	S6	"F1" 6+88.22±	SC x 2	41	7.5	Panel #3

[1] all "F1" Locations are 20'Lt. and all "Pe" Locations are 70' Rt.

[2] SC is steel coupon, GC is galvanized coupon and CSE is copper-sulfate electrode

Table IV-1(b). Corrosion Monitoring Locations – Wall #2

Station #	Site	Location	Element	Joint #	Depth (ft)	Access Hole Loc.
8	15	"Pe" 157+76.25 ±	Grid Layer- II	40	3	Panel #8
8	15	"Pe" 157+76.25 ±	Grid Layer- III	40	5	Panel #8
8	15	"Pe" 157+73.75 ±	SC	NA	4	Panel #8
8	15	"Pe" 157+78.75 ±	GC	NA	4	Panel #8
8	15	"Pe" 157+75.75 ±	CSE	NA	4	Panel #8
8	8	"Pe" 157+76.25 ±	Grid Layer- X	40	19	Panel #9
8	8	"Pe" 157+76.25 ±	SC x 2	40	19	Panel #9
8	8	"Pe" 157+75.75 ±	CSE	NA	18	Panel #9
9	16	"Pe" 156+76.25 ±	Grid Layer- II	32	3	Panel #6
9	16	"Pe" 156+76.25 ±	Grid Layer- III	32	5	Panel #6
9	16	"Pe" 156+73.75 ±	SC	NA	4	Panel #6
9	16	"Pe" 156+78.75 ±	GC	NA	4	Panel #6
9	16	"Pe" 156+75.75 ±	CSE	NA	4	Panel #6
9	9	"Pe" 156+76.25 ±	Grid Layer-VIII	32	15	Panel #7
9	9	"Pe" 156+76.25 ±	SC x 2	32	15	Panel #7
9	9	"Pe" 156+75.75 ±	CSE	NA	15	Panel #7
10	17	"Pe" 155+51.25 ±	Grid Layer- II	22	3	Panel #4
10	17	"Pe" 155+51.25 ±	Grid Layer- III	22	5	Panel #4
10	17	"Pe" 155+48.75 ±	SC	NA	4	Panel #4
10	17	"Pe" 155+53.75 ±	GC	NA	4	Panel #4
10	17	"Pe" 155+50.75 ±	CSE	NA	4	Panel #4
10	10	"Pe" 155+51.25 ±	Grid Layer- VI	22	11	Panel #5
10	10	"Pe" 155+51.25 ±	SC x 2	22	11	Panel #5
10	10	"Pe" 155+50.75 ±	CSE	NA	10	Panel #5

[1] "Pe" Locations are 109 ' Rt. at Sta. 10, 111' Rt. at Sta. 9, and 113' Rt. at Sta. 8

Table IV-1(c). Corrosion Monitoring Locations – Wall #3

Station #	Site	Location	Element	Joint[1] #	Depth (ft)	Access Hole Loc.
11	18	"Pe" 165+89 ±	Grid Layer II	2	3	Panel #3
11	18	"Pe" 165+89 ±	Grid Layer III	2	5	Panel #3
11	18	"Pe" 165+89 ±	Grid Layer IV	2	7	Panel #3
11	18	"Pe" 165+75 ±	SC	2	5	Panel #3
11	18	"Pe" 165+75 ±	GC	2	5	Panel #3
11	18	"Pe" 165+87 ±	CSE	2	6	Panel #3
12	19	"Pe" 167+89 ±	Grid Layer – I	18	1	Panel #1
12	19	"Pe" 167+89 ±	Grid Layer – II	18	3	Panel #1
12	19	"Pe" 167+89 ±	Grid Layer – III	18	5	Panel #1
12	19	"Pe" 167+80 ±	SC	18	5	Panel #1
12	19	"Pe" 167+80 ±	GC	18	5	Panel #1
12	19	"Pe" 167+87 ±	CSE	18	2	Panel #1

[1] Joints are counted from jog in wall
[2] all "Pe" locations are approx. 115" Rt.

Monitoring stations are roughly correlated to the "Pe" and "F1" alignments, but prior to remediation of Wall #1, locations are most easily identifiable in terms of precast panel joint and panel level. Figure 2 shows how typical precast concrete panels, 12.5 feet long and 2 feet high, are stacked to create the wall facing. Panel joints are located approximately every 12.5 feet along the wall, beginning with Joint #1 at the south end of the wall. Panel level is with respect to the top of the wall starting with Level #1. Subsequent to placement of a new wall facing along Wall #1, as part of the retrofit design by HDR, Inc., MSE wall panels and joints will no longer be visible, and reference to the "Pe" and "F1" alignments will be necessary for locating the instruments.

Where two reinforcements are wired at a monitoring point, they are usually located at the top and bottom of a wall panel. Grid layers wired for monitoring are identified by Roman numerals indicating the position of the reinforcement layer with respect to the top of the wall. "Dummy" coupons are one-foot long, W9, wires and include plain steel (SC) and galvanized steel coupons (GC). At some locations, two steel coupons (SC x2) were installed to facilitate verification of measurement repeatability. Locations for placement of a copper/copper sulfate reference electrode (CSE) are also indicated in Tables IV-1(a), (b) and (c).

FHWA and NDOT established the locations of Monitoring Stations 1 thru 10. Fourteen monitoring points were prepared by FHWA and NDOT including TP 2 thru TP 6, and Sites 1,2,3,4,5,6,8,9 and 10. Monitoring points were not established at Station 7. MMCE prepared seven additional monitoring points during our first site visit, March 29, 2004 to April 7, 2004. Four of the new locations were prepared along Wall #1; near midheight (Site 11) and near the top (Site 12) of Station 1, and near midheight of Stations 2 (Site 13) and 3 (Site 14). Three of the new locations were established along Wall #2; near the top of the wall at Stations 8 (Site 15), 9 (Site 16) and 10 (Site 17).

MMCE established the locations of Monitoring Stations 11 and 12 along Wall #3, and prepared the monitoring points during their site visit December 7, 2004 through December 17, 2004. The wall facing at Stations 11 and 12 is thirteen feet and four feet high, respectively, and for these cases, three grids are instrumented at each monitoring point. These monitoring points were established ten to fifteen feet north of the locations of Test Pits 10 and 11.

Photographs depicting preparation of corrosion monitoring points are included in this appendix. Details of the methods used by FHWA, NDOT and MMCE to install instrumentation are similar, and, generally include the following steps similar to those described by Berkovitz and Healy (1997):

1. Advance access holes to sample backfill, access reinforcements, install coupons and place CSE reference electrodes.
2. Grind and clean surface of exposed reinforcement or steel connecting pins.
3. Check continuity between reinforcements, connecting pins, and concrete facing reinforcement.
4. Solder wire to reinforcement/connecting pins and protect with epoxy coating and liquid tape.
5. Solder wire to coupons and protect with epoxy coating and liquid tape.
6. Insert coupons into backfill.
7. Regrout holes in wall face units
8. Route wires to junctions accessible from the ground surface for future monitoring.

Details of a monitoring point established by MMCE are included with this appendix. At each monitoring point prepared by MMCE along Walls #1 and #2, five holes were advanced into the precast concrete panels near the panel joint. Holes were advanced using a pneumatic hammer equipped with a chipping tool. Two of the holes penetrated approximately half way through the wall panel near the top and bottom to expose steel connecting pins that are part of the bar assembly at the ends of the soil reinforcements (see Figure 2). Once exposed, these connecting pins were checked to verify continuity with individual reinforcements, isolation between reinforcements connected to the top and bottom of the facing unit, and isolation from reinforcing steel embedded within the facing units. Three holes, spaced approximately 2.5 feet apart were advanced through the central portion of the facing unit to access the backfill. Two of these access holes were used for placement of "dummy" coupons which were pushed into the backfill, and the third provides access for a copper/copper sulfate reference electrode (CSE) with a porous tip that must contact the backfill during measurement of half-cell potential and LPR. These same access holes were used to obtain samples of backfill as described in Appendix II.

MMCE followed a similar procedure for establishing monitoring points along Wall #3 with the following exceptions. Another connection pin was exposed to access and wire a third grid for corrosion monitoring. This connection pin was exposed through a second wall panel, located beneath the first. Also, steel and galvanized coupons were not installed through the wall face, but were placed within nearby Test Pits 10 and 11, respectively, as they were backfilled.

FHWA and NDOT did not attach wires to the steel dowels as described above at every monitoring point. At some points wires were attached directly to reinforcements accessed through the wall face units or via the test pits, or to the plate attached to the bar assembly at the ends of the reinforcements.

Solder connections to the coupons and reinforcements were made by grinding or filing the steel surface to expose bright metal, wrapping the stripped end of a wire around the element, securing the wire by twisting, and heating the element with a MappGas torch to apply the solder to the joint. MMCE applied epoxy coating and liquid tape to protect the solder joint. The wire leading from the solder joint was completely insulated such that bare wire was not exposed to the backfill, or within the facing unit.

After the wires were soldered and "dummy" coupons installed, the holes in the facing units were regrouted. A length of PVC pipe was grouted into the CSE access hole. NDOT backfilled the test pits at the top of Wall #1 on approximately February 27, 2004 after the reinforcements were wired for monitoring. Backfill was capped with flowable fill to control surface water and infiltration into the MSE backfill.

Wires from instrumented reinforcements and coupons were routed along the nearest vertical joint to the bottom of the wall to facilitate access for future monitoring. At the base of the wall, wires were collected in a conduit penetrating the existing wallface. MMCE prepared the conduits such that they would penetrate the new wall facing planned for retrofit of Wall #1. Wires are color coded to be consistent with nationwide practice (Berkovitz and Healy, 1997) and to aid in identifying the instrumentation:

- Red wires – in-service reinforcements
- Black wires – plain steel coupons

- White wires – galvanized coupons

Corrosion monitoring includes visual observation of reinforcements and steel connection pins during preparation of monitoring points. Electrochemical measurement techniques may be used to monitor the presence, and/or rate of corrosion for wired reinforcements and coupons placed within the backfill. Results from electrochemical tests are useful for indicating if the corrosion process is currently active, and at what rate. Several nondestructive tests are available for corrosion monitoring including measurements of half-cell potential (E_{corr}), and linear polarization resistance (LPR). Salient details of these measurement techniques are described in the following sections.

C. Half-Cell Potential Measurements

The half-cell potential, E_{corr}, is the difference in potential between the metal element and a reference electrode. In this study, measurements are made with respect to a copper/copper sulfate reference electrode (CSE). The primary purpose of potential measurements in MSE structures is to establish when significant portions of the reinforcements have lost zinc coverage and steel is exposed to the soil environment (Elias, 1997). Typical values for a galvanized reinforcement are between –1.10 to –0.80 V (CSE). The half-cell potential of clean, shiny, low carbon steel ranges from –500 mV to –800 mV (CSE), and the half-cell potential of rusted, low carbon steel in neutral soils and water is generally between –200 mV and –500 mV (CSE) in neutral soils and water.

At the Las Vegas site, plain steel reinforcements are installed and potential differences can be used to discern corroded from noncorroded steel surfaces, and areas where the potential for corrosion is highest. In general, as corrosion of a reinforcement progresses, the half-cell potential becomes increasingly positive. Also, large spatial variation in half-cell potentials may indicate the presence of macrocells and corrosion from galvanic activity.

Half-cell potential measurements do not indicate severity of corrosion and measurement of linear polarization resistance, i.e. corrosion rate, are used for this purpose.

D. LPR

Linear polarization resistance (LPR) measurements involve impressing a current between two electrically isolated reinforcements and observing the corresponding change in potential along the surface of one of the reinforcements via a copper/copper sulfate reference electrode. Three electrodes are required to perform the test including working, counter and references electrodes. The working electrode is the reinforcement being monitored and a nearby reinforcement is used as a counter electrode. The potential at the interface of the working electrode is varied through current impressed between the working and counter electrodes. A copper/copper sulfate (CSE) half-cell serves as a reference electrode to monitor the changing potential of the working electrode. The measurement technique involves scanning or stepping the potential from (-5 to –20 mV) to (+5 to +20 mV) around the free corrosion potential while simultaneously measuring the applied current. The measured resistance is actually the sum of the interface and soil resistance, and a correction for soil resistance is applied.

The PR MONITOR (Polarization Resistance Monitor PR4500 Operating Manual, 1999), used on this project, is an instrument specifically designed to measure polarization resistance of a corroding electrochemical interface. If the surface area of the working electrode is known, corrosion current density may be determined from the measured polarization resistance and used to compute corrosion rate.

Stern and Geary (1957) showed that for small deviations from the free corrosion potential (± 20 mV), the corrosion current density is inversely proportional to polarization resistance as:

$$R_p = \left[\frac{d\varepsilon}{di_{app}}\right]_{\varepsilon\to 0} = \left[\frac{\Delta\varepsilon}{\Delta i_{app}}\right]_{\varepsilon\to 0} = \frac{\beta_a\beta_c}{2.3\times i_{cor}(\beta_a+\beta_c)} = \frac{B}{i_{cor}} \qquad \text{(IV-1)}$$

where:

- i_{cor} is the corrosion current density (amperes/cm^2)
- β_a is the anodic Tafel constant
- β_c is the cathodic Tafel constant
- B is the environmental constant (B ≈ 0.05 Volts for galvanized steel and B≈ 0.035 Volts for steel)
- R_p is polarization resistance normalized for area which involves multiplying the measured polarization resistance (PR) by the reinforcement surface area (A_s) in contact with backfill (ohm x cm^2); i.e., R_p = PR x A_s.

Corrosion rate for steel can be estimated (within a factor of 2) from i_{cor} using Equation (2) as follows:

$$CR(mpy) = {}^{i_{cor}}\!/_{2.2} \qquad \text{(IV-2)}$$

where i_{cor} is expressed in μA/cm^2 and corrosion rate, CR, is in mils per year (mpy; one mil is 0.001 inches, and one mil ≈ 25 μm). The corrosion rate measured with the PR monitor corresponds to a uniform corrosion rate at an instant in time.

E. Corrosion Rate Measurements

Table IV-2 is a summary of corrosion rate measurements for each of the monitoring points established along Walls #1, #2 and #3. The measurements along Walls #1 and #2 were obtained between August 26, 2004 and August 31, 2004. The measurements along Wall #3 were obtained between December 15, 2004 and December 16, 2004. The PR monitor renders the polarization resistance (PR) from which corrosion rate is computed

In general, similar corrosion rates were observed between Walls #1, #2 and #3. Corrosion rate measurements on twenty-five reinforcements along Walls #1 and #2 were repeated between the monitoring events in late March and late August, 2004. On average the corrosion rates observed in March (μ = 11.8 μm/yr, σ = 13.9 μm/yr) were higher than those obtained in August (μ = 8.9 μm/yr, σ = 8.6μm/yr). Corrosion rate measurements obtained with the PR monitor are considered accurate within a factor of two (Elias, 1990). Fourteen of the twenty-five measurements in the temporal comparison are within a factor of two, which is within the expected random error of measurement. Nine of the corrosion rates observed in March are more than two times higher than those observed in August. Seven of these observations are located along Wall #1 at Stations 4,5 and 6. The highest corrosion rate observed in March is 76 μm/yr at Station #5. The apparently higher corrosion rates observed along these stations may be attributed to the presence of the drainage facilities along Stations #4, 5 and 6. The area behind the wall was capped with flowable fill in February 2004 and may have still been relatively moist in March of 2004. However, by August 2004 the backfill may have lost moisture, due to lack of recharge, increasing the transient resistivity of the backfill and affecting a lower corrosion rate.

Two of the corrosion rate measurements made long Wall # 2, Stations 9 and 10, in August were higher than observations made in March by more than a factor of two. The reason for the increase may be related to the presence of a drainage inlet in this vicinity (DI-4). The observation of higher corrosion rates in these areas is consistent with direct physical observations made on reinforcements exhumed from Test Pits #8 and #9.

Observed corrosion potentials range between −650 mV and −130 mV, with a median value of −369 mV and standard deviation 133 mV. The corrosion potentials appear to correlate well with respect to Station. With the exception of Station 6, all measured half-cell potentials are greater than −500 mV, and in the range associated with corroded steel surfaces. The most positive half-cell potentials are recorded at Stations 5 and 12, while the most negative potentials are recorded at Stations 2,4, and 6. At some stations there appears to be a slight decrease in corrosion potential with respect to depth, but in general there is not a significant variation of corrosion potential with respect to depth.

In general the half-cell potential of reinforcements were observed to increase between readings taken in March and August 2004. The increase ranges from 16 mV to 143 mV with an average increase of approximately 50 mV. Most of the increases were within 100 mV. Larger variations were evident at Stations 5, 6 and 8. Increases range between 120 mV and 170 mV at Stations 5 and 8. Half-cell potentials at Station 6 decreased by approximately −200 mV. These trends are consistent with the observations that corrosion activity is higher at Stations 5 and 8.

For comparison, Table IV-3 shows measurements of half-cell potential for steel and galvanized coupons including temporal variation. Only data obtained after coupons have been in-place for at least two months are presented in Table IV-3.

Table IV-3. Half-Cell Potential Measurements for Coupons

Station	Site	Steel Coupons		Galvanized Coupons (mV)
		March 2004 (mV)	August 2004 (mV)	
1	12	new	-534	-924
1	11	new	-546	-885
1	1	-584/-583(1)	-480/-486	–
2	13	new	-564	-933
2	2	-636/-656	-498/-537	–
3	14	new	-526	-896
3	3	-554/-547	-277/ out	~
4	4	-541/-568	-635/-639	~
5	5	-451/out	-439/ out	~
6	6	out/ -472	out/-426	~
8	15	new	-428	-645
8	8	-526/-539	out/out	–
9	16	new	-533	-969
9	9	-541/-551	out /out	–
10	17	new	-200	-615
10	10	-392/-296	out /out	~

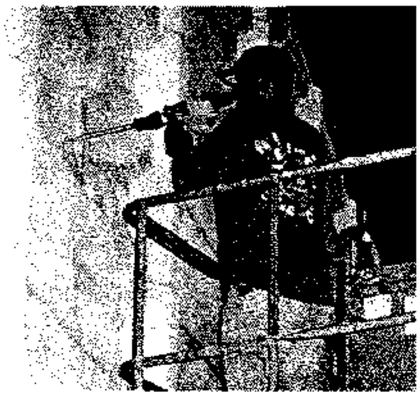
[1] SC1/SC2

Results presented in Table IV-3 indicate that the half-cell potential of steel coupons on average (μ = -527 mV and -484 mV for March and August) are lower (more negative) than those of the reinforcements listed in Table IV-2. In March 2004 all corrosion potential are less than −500 mV, with the exception of Station 10. In general, half-cell potentials tend to increase during the five months between March and August indicative that corrosion is occurring. The half cell potential of the galvanized steel samples are lower (more negative) than steel coupons installed at the same location by approximately −400 mV. Monitoring the galvanized and steel coupons over time at these locations will indicate the durability of the zinc coating in this environment.

On average, the corrosion rate measured for steel coupons was similar to that for the steel reinforcements. At stations where corrosion rates of galvanized coupons and steel coupons could be compared similar corrosion rates were observed.

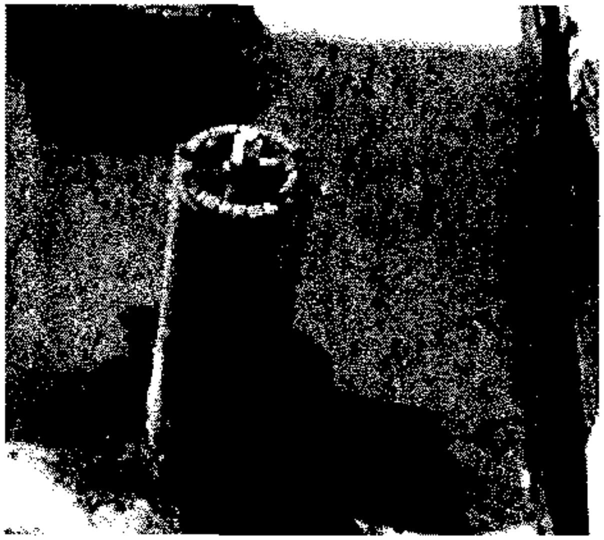
F. Photo Log for Preparation of Monitoring Stations

TYPICAL SEQUENCE TO PREPARE CORROSION STUDY SITE

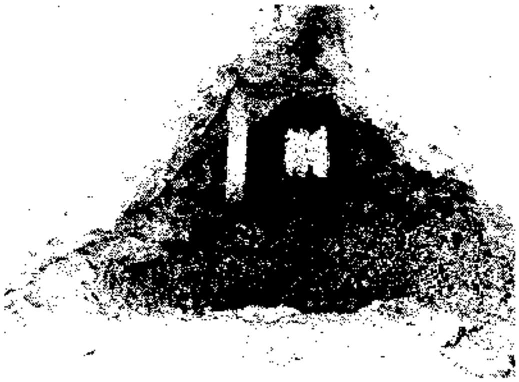


Access reinforcements and backfill through wall face.

Completed hole exposing MSE backfill.

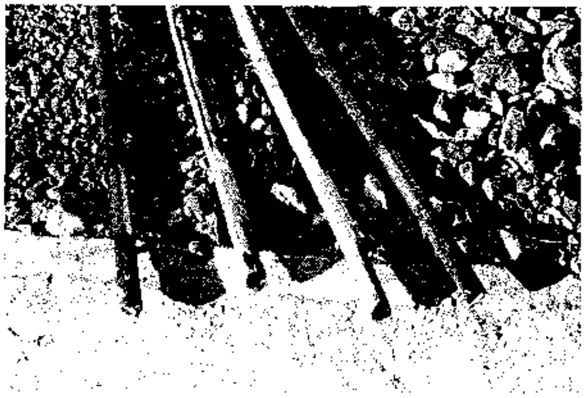


2" PVC pipe and cap grouted into access hole,
provides half-cell location.

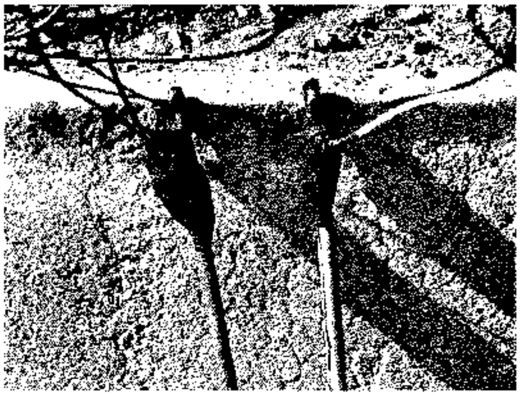


MSE Grid components (grid to wall face connecting pin) exposed and cleaned for soldering.

Soldering to reinforcing connecting pin complete.

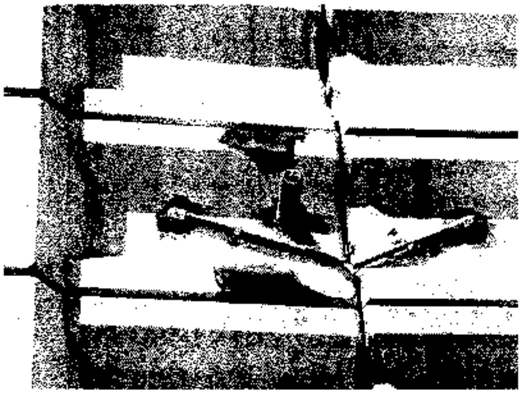


Steel and galvanized coupons cleaned for soldering.

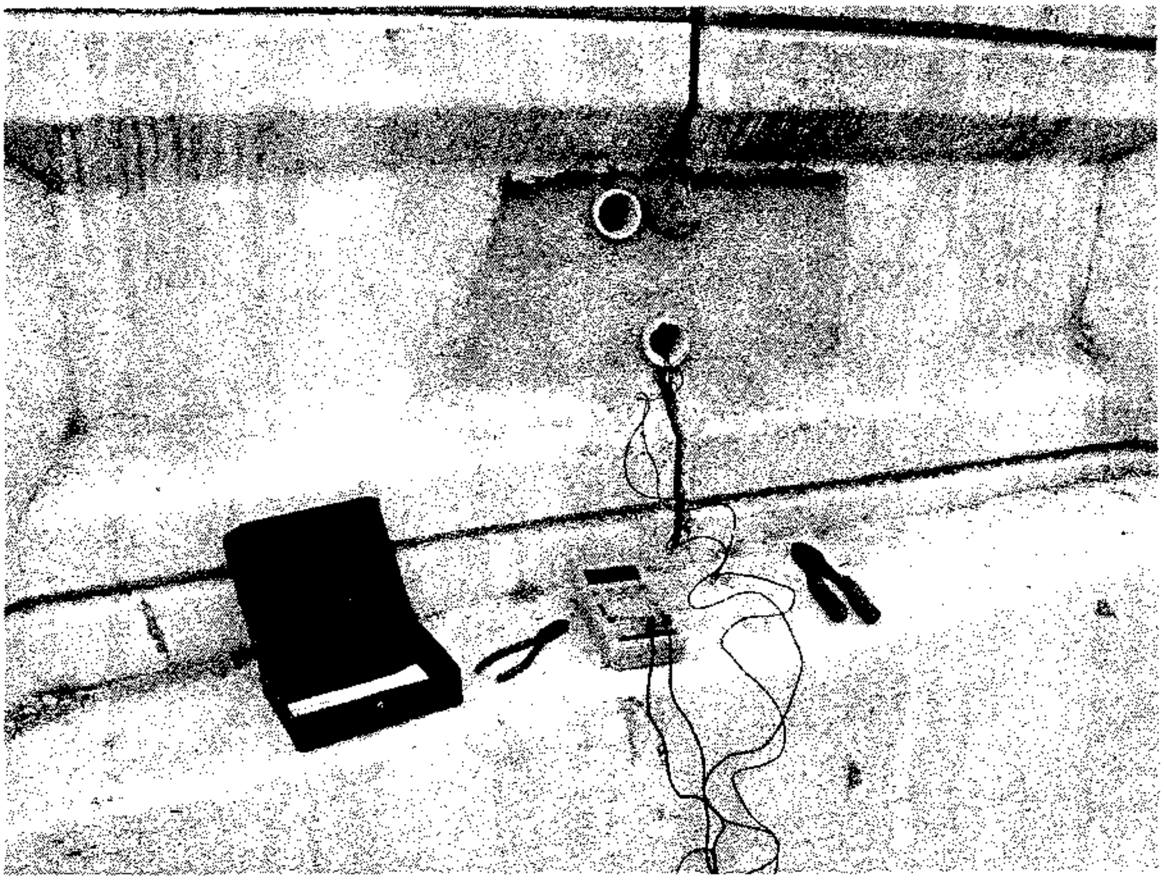


Soldering complete on coupons and connection sealed with epoxy putty and liquid electrical tape.

Steel and Galvanized coupons in place for burial in MSE backfill.

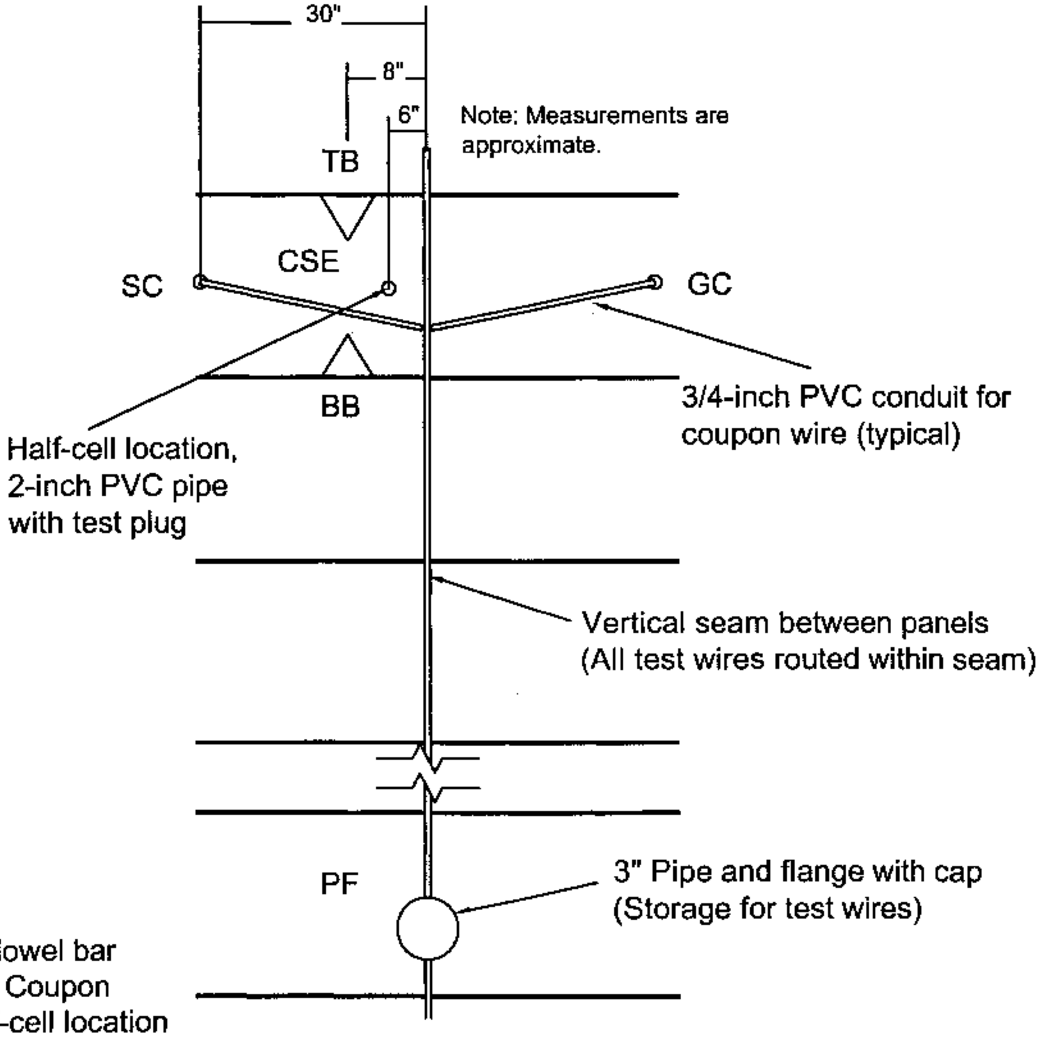


Complete installation with half cell access, and conduits protecting coupon wires.



Check Connections.

G. Monitoring Station Details



Note: Measurements are approximate.

Half-cell location, 2-inch PVC pipe with test plug

3/4-inch PVC conduit for coupon wire (typical)

Vertical seam between panels (All test wires routed within seam)

3" Pipe and flange with cap (Storage for test wires)

LEGEND:

TB - Top dowel bar
SC - Steel Coupon
CSE - Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
PF - 3 inch pipe and flange

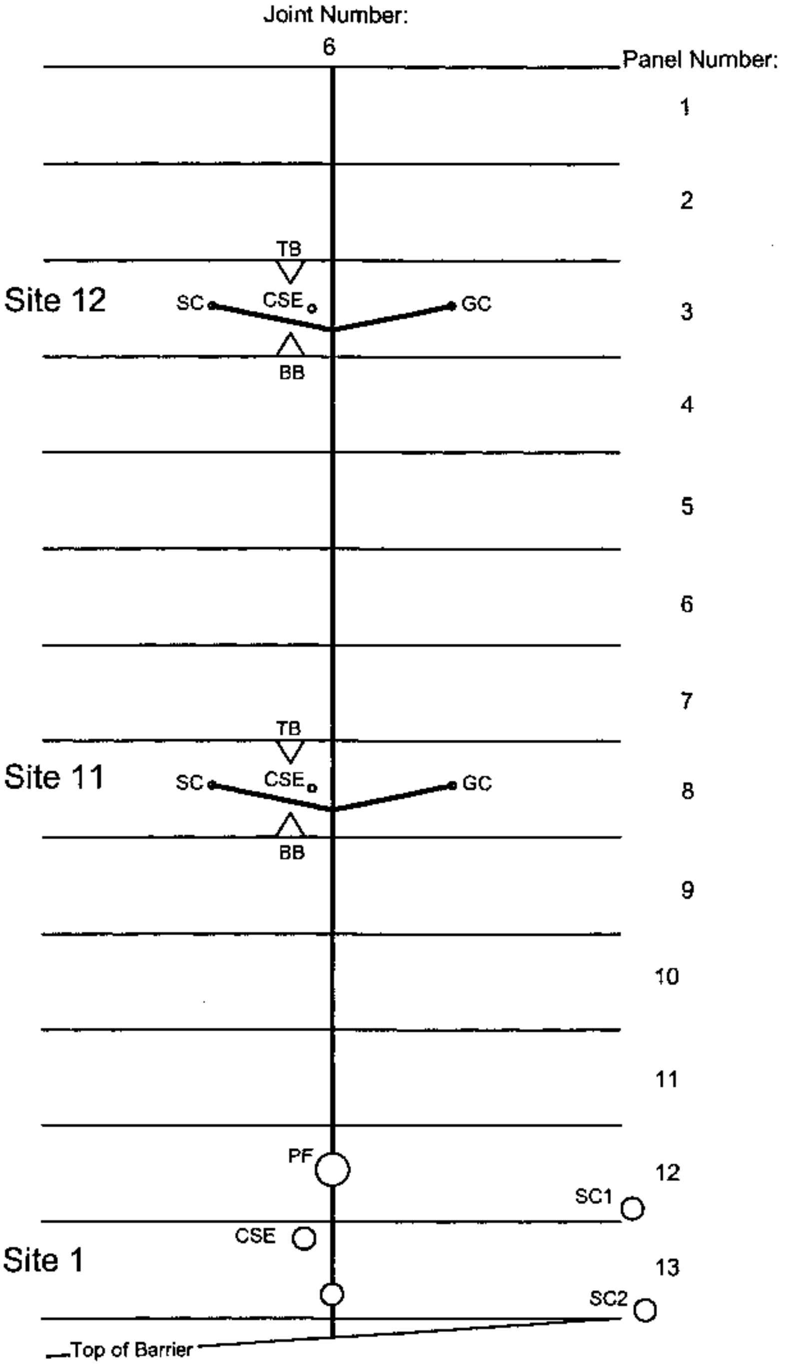
Typical Detail

DWG. NO. 04005-G1

FIGURE IV-G-1

CORROSION STUDY
Interstate 515 and Flamingo Rd.
Las Vegas Nevada

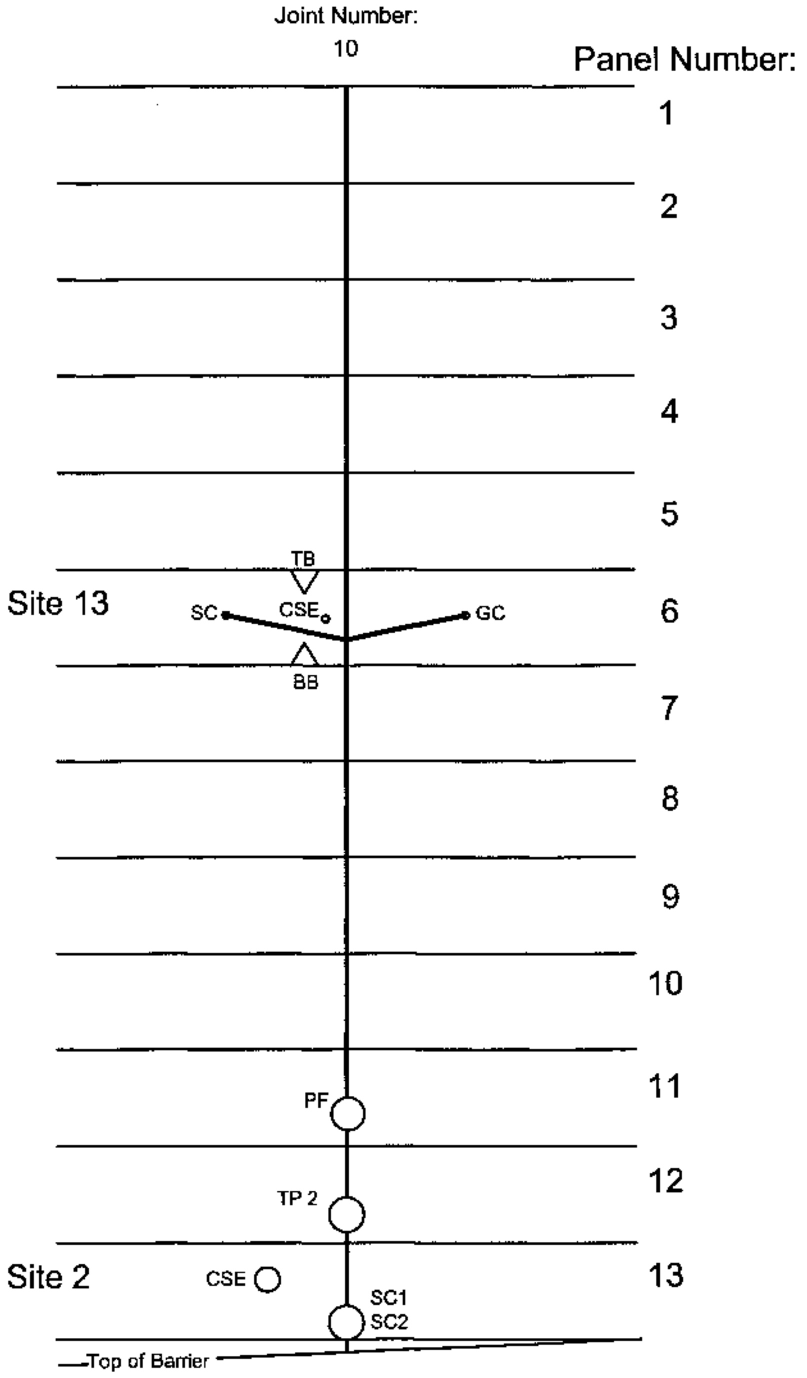
McMahon & Mann
Consulting Engineers, P.C.
2495 MAIN STREET, SUITE 432 (716) 834-8932
BUFFALO, NY 14214 FAX: (716) 834-8934



LEGEND:
TB - Top dowel bar
SC - Steel Coupon
CSE - Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
SC1 - Steel Coupon 1
SC2 - Steel Coupon 2
PF - 3 inch pipe and flange

Wall Station 0+75
Wall 1

Station 1	CORROSION STUDY	McMahon & Mann Consulting Engineers, P.C.
DWG. NO. 04005-G2	Interstate 515 and Flamingo Rd.	2495 MAIN STREET, SUITE 432 (716) 834-8932
FIGURE IV-G-2	Las Vegas Nevada	BUFFALO, NY 14214 FAX: (716) 834-8934



LEGEND:
TB - Top dowel bar
SC - Steel Coupon
CSE - Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
SC1 - Steel Coupon 1
SC2 - Steel Coupon 2
PF - 3 inch pipe and flange
TP 2 - Test Pit 2

Wall Station 1+25

Wall 1

Station 2
DWG. NO. 04005-G3
FIGURE IV-G-3

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Las Vegas Nevada

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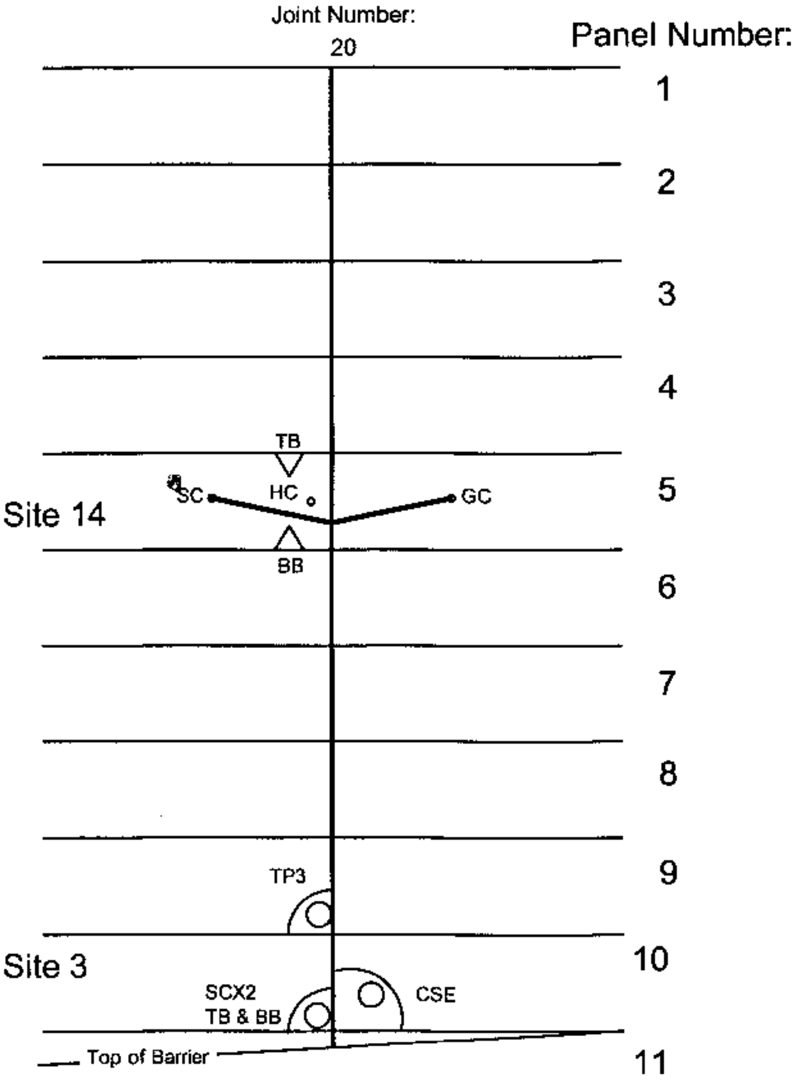

LEGEND:
TB - Top dowel bar
SC - Steel Coupon
CSE - Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
TB3 - Test Pit 3
SCX2 - Two Steel Coupons

Wall Station 2+50

Wall 1

Station 3

DWG. NO. 04005-G4

FIGURE IV-G-4

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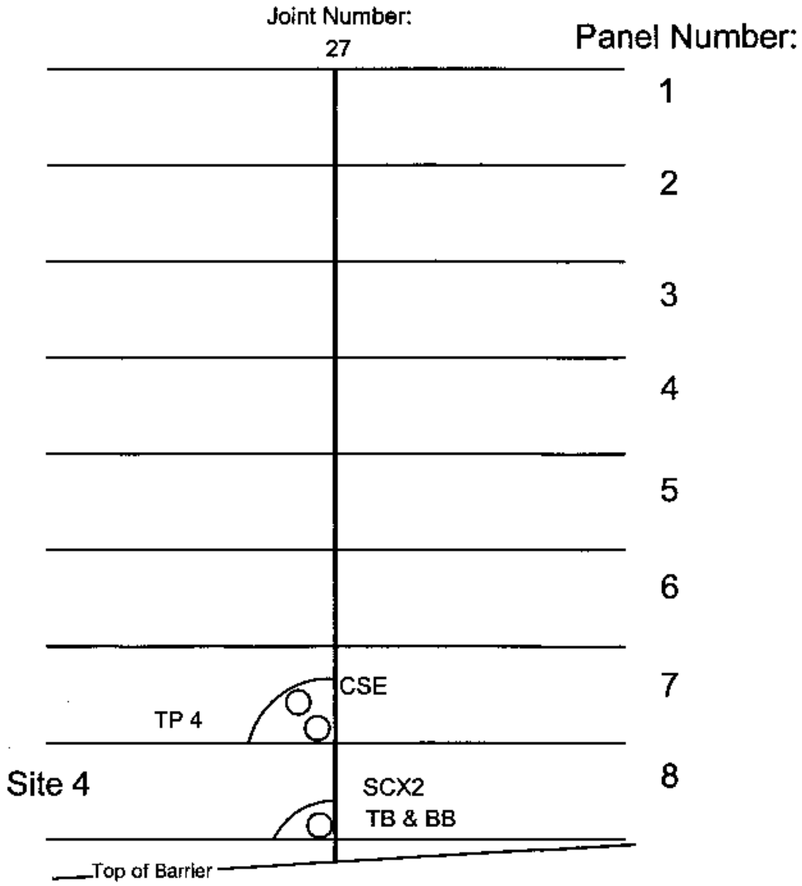

LEGEND:
TB - Top dowel bar
SC - Steel Coupon
CSE - Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
TP 4 - Test Pit 4

Wall Station 3+37.5

Wall 1

Station 4
DWG. NO. 04005-G5
FIGURE IV-G-5

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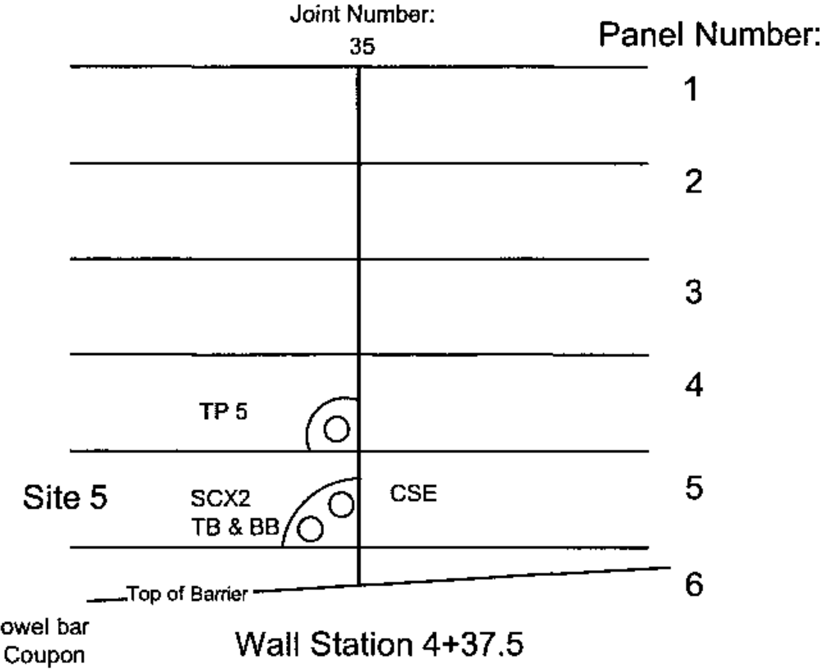
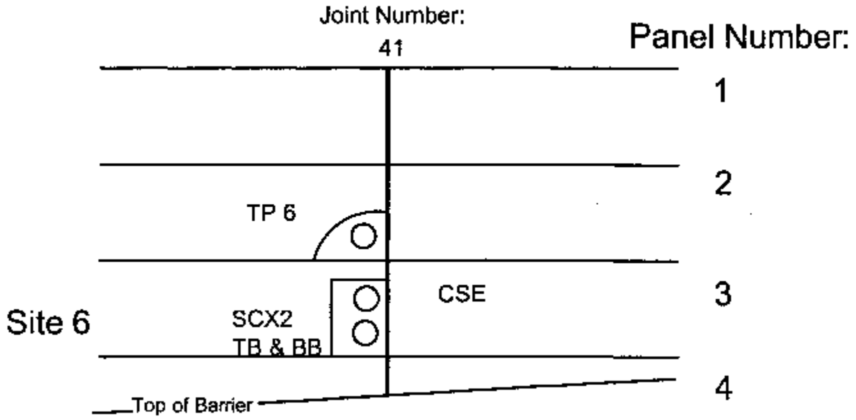


LEGEND:
TB - Top dowel bar
SC - Steel Coupon
CSE- Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
SCX2 - Two steel Coupons

Station 5	CORROSION STUDY Interstate 515 and Flamingo Rd. Las Vegas Nevada	McMahon & Mann Consulting Engineers, P.C. 2495 MAIN STREET, SUITE 432 (716) 834-8932 BUFFALO, NY 14214 FAX: (716) 834-8934
DWG. NO. 04005-G6		
FIGURE IV-G-6		



LEGEND:
TB - Top dowel bar
SC - Steel Coupon
CSE - Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
SCX2 - Two steel Coupons

Wall Station 5+12.5

Wall 1

Station 6

DWG. NO. 04005-G7

FIGURE IV-G-7

CORROSION STUDY

Interstate 515 and Flamingo Rd.

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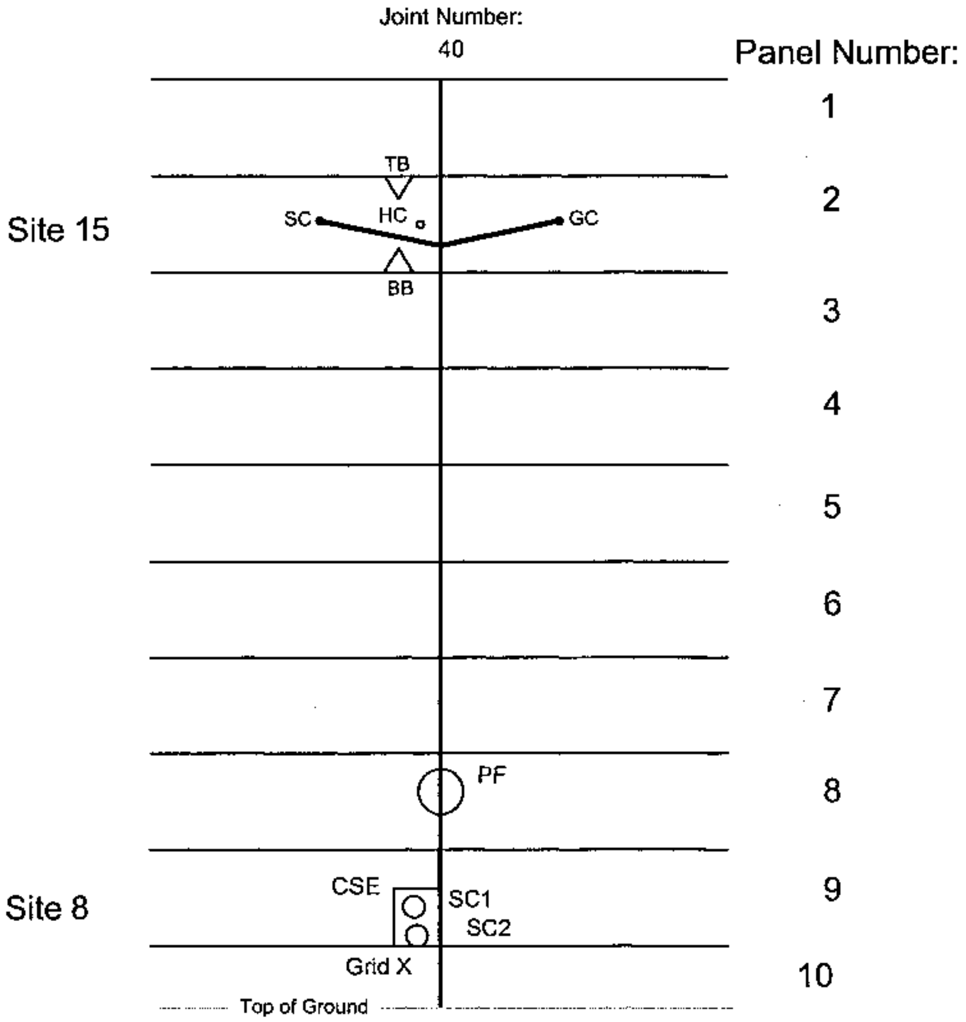
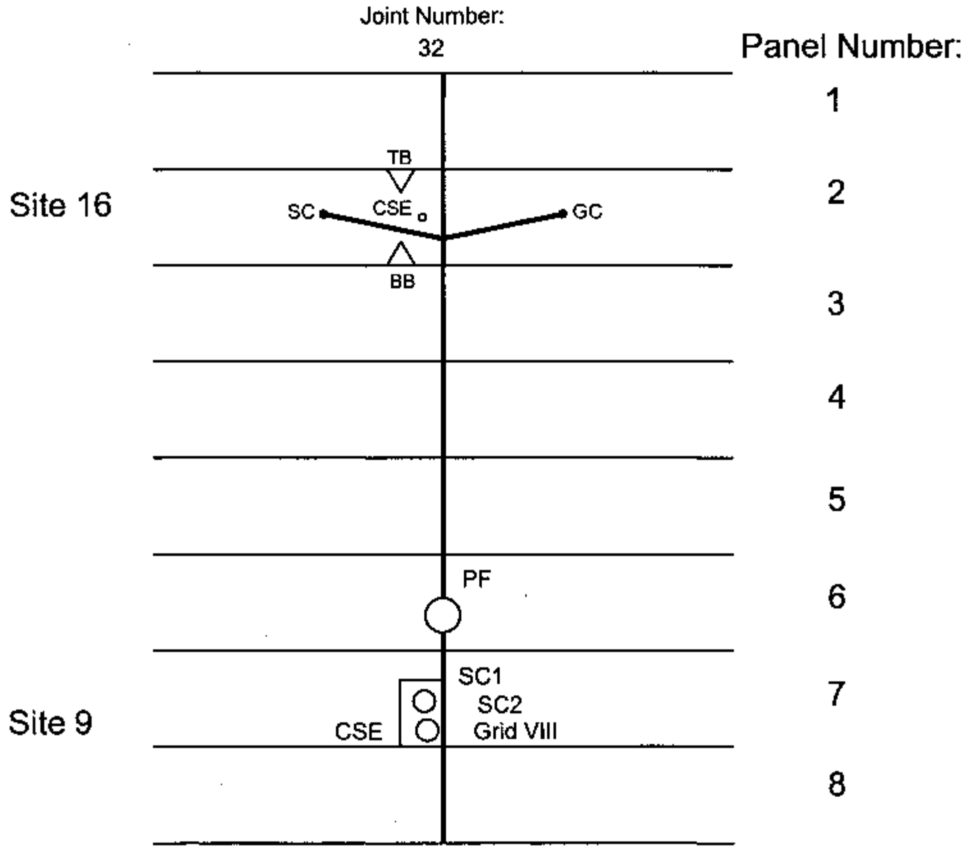


LEGEND:
TB - Top dowel bar
SC - Steel Coupon
CSE - Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
PF - 3 inch pipe and flange
SC1 - Steel Coupon 1
SC2 - Steel Coupon 2

Wall Station 4+94

Wall 2

Station 8	CORROSION STUDY	**McMahon & Mann** Consulting Engineers, P.C.
DWG. NO. 04005-G8	Interstate 515 and Flamingo Rd.	2495 MAIN STREET, SUITE 432 (716) 834-8932 BUFFALO, NY 14214 FAX: (716) 834-8934
FIGURE IV-G-8	Las Vegas Nevada	

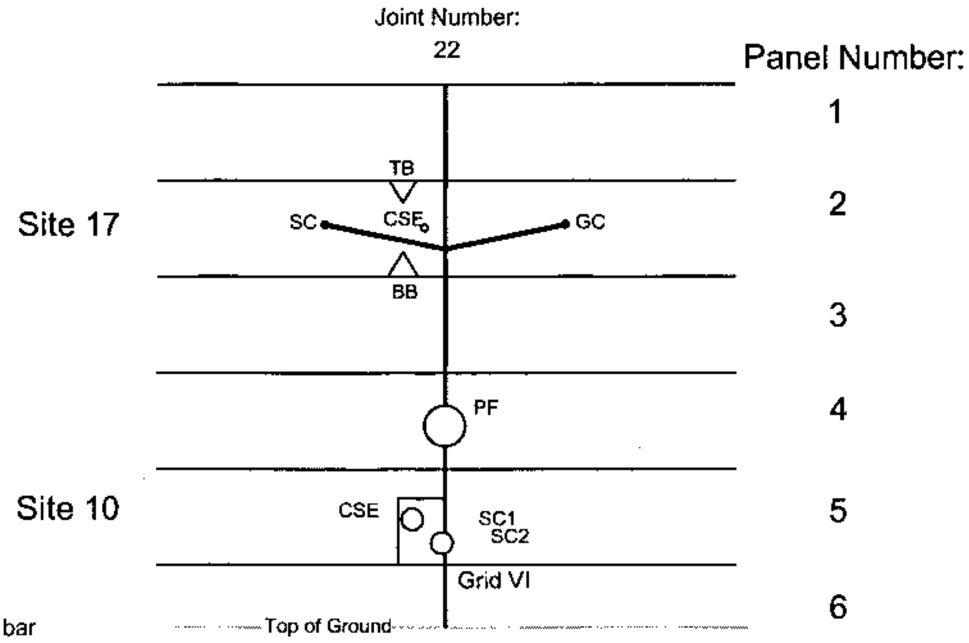


LEGEND:
TB - Top dowel bar
SC - Steel Coupon
HC - Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
PF - 3 inch pipe and flange
SC1 - Steel Coupon 1
SC2 - Steel Coupon 2

Wall Station 3 + 94

Wall 2

Station 9	CORROSION STUDY	McMahon & Mann Consulting Engineers, P.C.
DWG. NO. 04005-G9	Interstate 515 and Flamingo Rd.	2495 MAIN STREET, SUITE 432 (716) 834-8932
FIGURE IV-G-9	Las Vegas Nevada	BUFFALO, NY 14214 FAX: (716) 834-8934

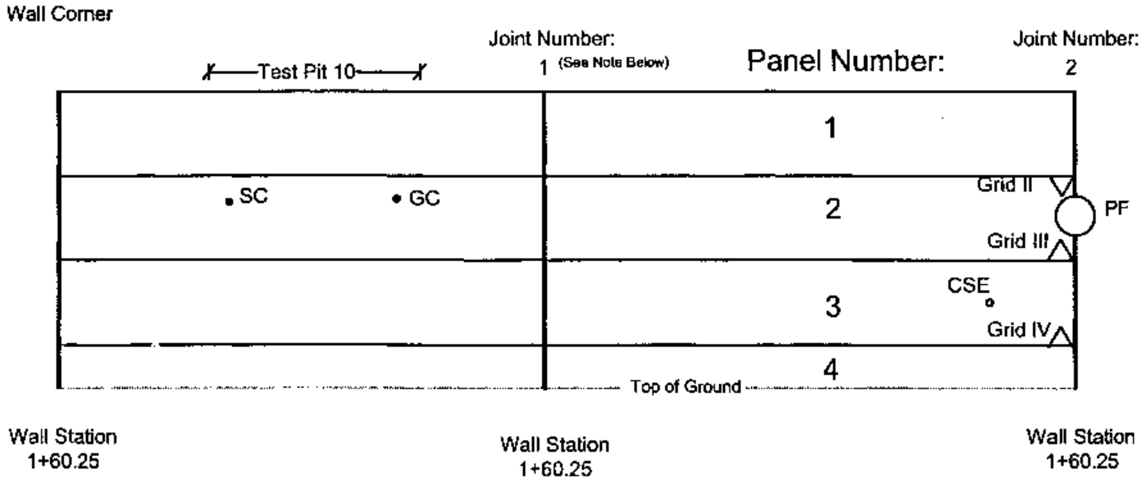


LEGEND:
TB - Top dowel bar
SC - Steel Coupon
CSE - Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
SC1 - Steel Coupon 1
SC2 - Steel Coupon 2
PF - 3 inch pipe and flange

Wall Station 2 + 69

Wall 2

Station 10	CORROSION STUDY	McMahon & Mann Consulting Engineers, P.C.
DWG. NO. 04005-G10	Interstate 515 and Flamingo Rd.	2495 MAIN STREET, SUITE 432 (716) 834-8932
FIGURE IV-G-10	Las Vegas Nevada	BUFFALO, NY 14214 FAX: (716) 834-8934



Wall 3 Site 11

LEGEND:
- TB - Top dowel bar
- SC - Steel Coupon
- CSE - Half-cell location
- GC - Galvanized Coupon
- BB - Bottom dowel bar
- PF - 3 inch pipe and flange

NOTE: Joint numbers are referenced to corner at Wall Station 1 + 60.25.

Station 11

DWG. NO. 04005-G11

FIGURE IV-G-11

CORROSION STUDY

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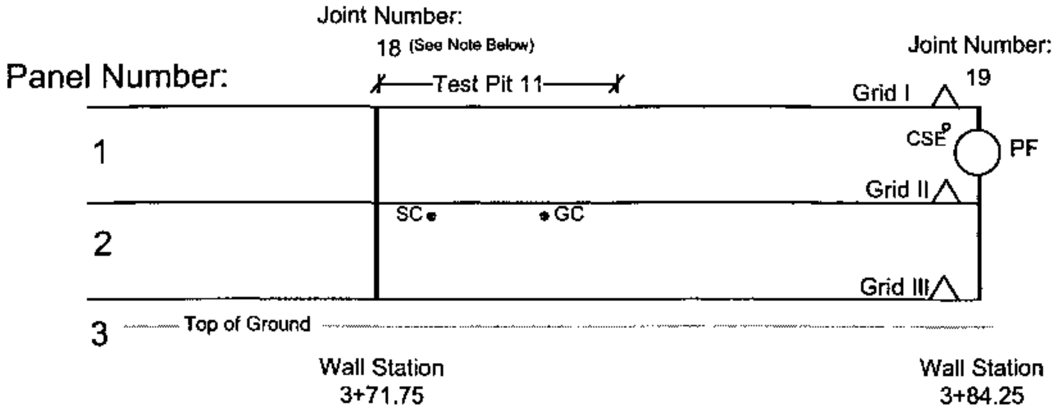

Wall 3 Site 12

LEGEND:
TB - Top dowel bar
SC - Steel Coupon
CSE - Half-cell location
GC - Galvanized Coupon
BB - Bottom dowel bar
PF - 3 inch pipe and flange

NOTE: Joint numbers are referenced to corner at Wall Station 1 + 60.25.

Station 12
DWG. NO. 04005-G12
FIGURE IV-G-12

CORROSION STUDY
Interstate 515 and Flamingo Rd.
Las Vegas Nevada

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APPENDIX V

V. Calculation of Remaining Service Life

A. Computed Factors of Safety

MMCE estimated the maximum tensile forces in the reinforcement layers using the stiffness method described by the FHWA (1989) and AAHSTO (2002). Both static and seismic loading conditions are considered. Lateral stresses considered in the calculation of reinforcement tension include lateral earth pressure from the sloping backfill. Seismic loads consider peak ground acceleration equal to 0.15 g and Type II soil as specified in our agreement with NDOT. For seismic loading considerations, the allowable tensile load is increase by 33% as allowed by AASHTO (2002). Figures V-1 and V-2 show the cross sections analyzed for Walls #2 and #3. The following parameters were used in the analysis:

Friction angle for backfill, $\phi_w = 34°$
Unit weight for backfill, $\gamma_w = 120$ lb/ft^3
Back slope angle, $\beta = 28°$
Lateral earth pressure coefficient, $K_{ar} = 0.283$
Vertical spacing of reinforcements, $S_v = 2.0$ ft
Reinforcement geometry factor, $\Omega_1 = 1.5$
Reinforcement geometry factor, $\Omega_2 = 1.5$
Young's modulus of steel reinforcement, E = 29,000 ksi
Allowable stress for bar mat reinforcements, $t_{all} = 0.48f_y$
Yield stress of reinforcements, $f_y = 70$ ksi

According to the shop drawings prepared by Hilfiker, the top grids to a depth of approximately 13 feet along Wall #2 are W7 x W7, six inch by twenty-four inch, welded wire fabric. Beyond a depth of 13 feet, the grid sizes increased to W9.5 x W9.5 (13< D < 25 ft), and W12 x W9.5 (D > 25 ft).

Dimensional standards for cold drawn wire described in ASTM A82 (2004) are as follows:

Wire Size	Nominal Diameter (in)	Range of Diameter (in)
7	0.298	0.294 to 0.302
9.5	0.348	0.344 to 0.352
12	0.391	0.387 to 0.395

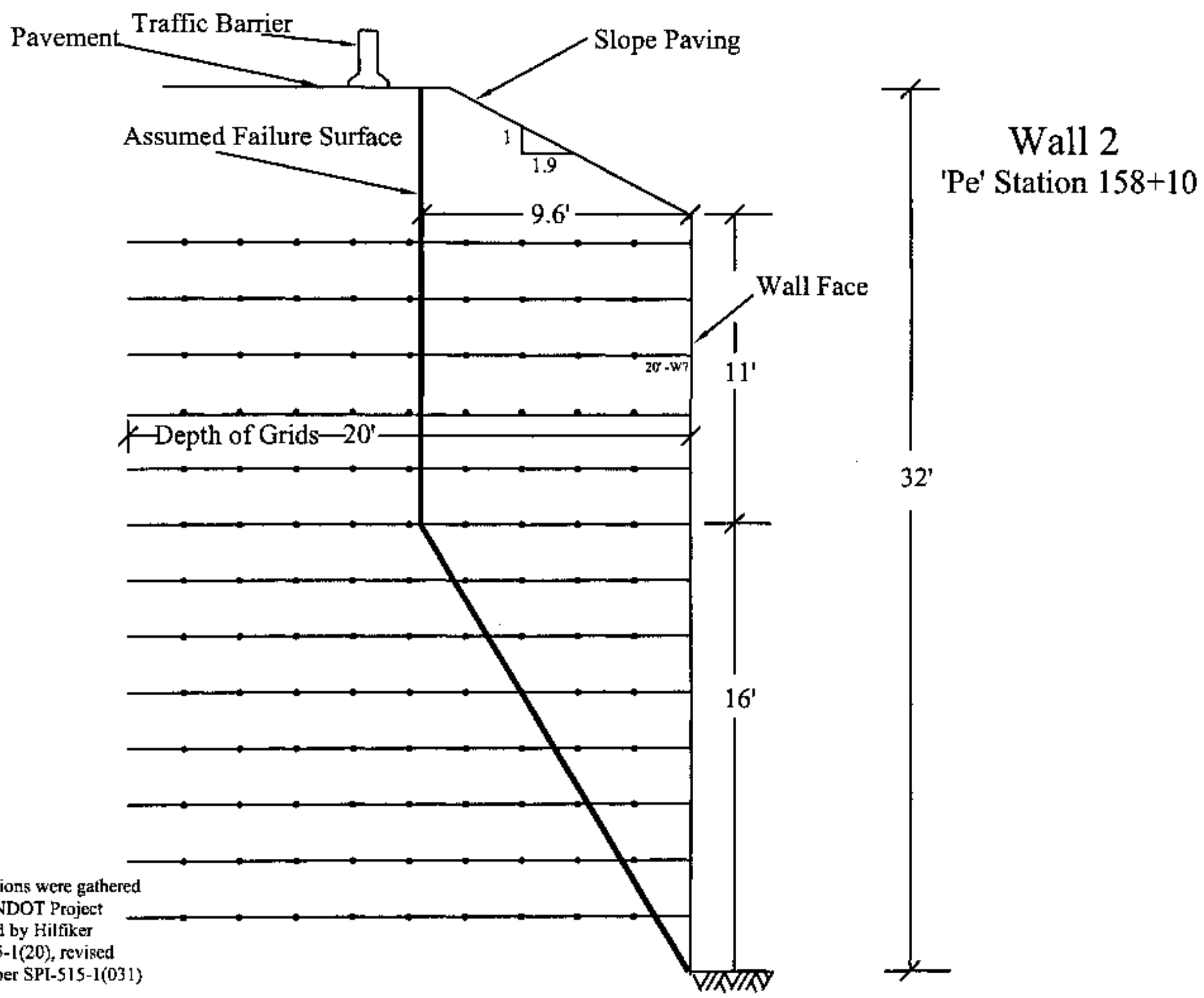
For the purpose of estimating remaining service life we assume that the bar mat sizes shown on the shop drawings are correct.

Results from calculation on the tallest sections of Walls #2 (Sta. Pe 158+10) and #3 (Sta. Pe 165 +70) are presented in Table V-1. Results are subscripted with "s" or "d" for static or dynamic (seismic) considerations, respectively.

Table V-1. Computed Safety Factors for Reinforcements at t= 20yrs (i.e. 2005).

Depth (ft.)	**Wire Size**	**T_s (k/ft)**	**T_d^{total} (k/ft)**	**$A_{remaining}$ (in^2/ft)**	**f_s/f_y[1] (ksi)**	**f_d/f_y[1] (ksi)**
Wall #2 – Sloping Backfill						
1	W7	1.03	1.30	0.042	0.35	0.44
3	W7	1.30	1.58	0.042	0.44	0.54
5	W7	1.56	1.84	0.042	0.54	0.62
7	W7	1.78	2.06	0.042	0.61	0.70
9	W7	2.03	2.31	0.042	0.69	0.78
11	W7	2.15	2.43	0.042	0.73	0.83
13	W7	2.29	2.60	0.042	0.78	0.89
15	W9.5	2.53	2.87	0.070	0.51	0.59
17	W9.5	2.58	2.95	0.070	0.53	0.60
19	W9.5	2.64	3.04	0.070	0.54	0.62
21	W9.5	2.68	3.12	0.070	0.55	0.63
23	W9.5	2.89	3.35	0.070	0.59	0.69
25	W12	3.09	3.59	0.098	0.45	0.53
27	W12	3.29	3.82	0.098	0.48	0.56
WALL #3 – Sloping Backfill						
1	W7	0.69	0.82	0.042	0.24	0.28
3	W7	0.98	1.11	0.042	0.33	0.38
5	W7	1.18	1.32	0.042	0.40	0.45
7	W7	1.45	1.60	0.042	0.49	0.55
9	W7	1.61	1.79	0.042	0.55	0.61
11	W7	1.77	1.98	0.042	0.60	0.68
13	W7	2.01	2.24	0.042	0.69	0.76

[1] Shaded results indicate reinforcements are overstressed compared to the allowable load of $0.48f_y$. T_{all} increased by 33% for seismic loading case



Note: Dimensions shown are approximate. Approximate dimensions were gathered from plans prepared by others, including construction plans for NDOT Project Number F-095-1(20) dated Nov.5, 1984, shop drawings prepared by Hilfiker Retaining Walls for State of Nevada DOT Project Number F-095-1(20), revised March 20, 1985, and construction plans for NDOT Project Number SPI-515-1(031) prepared by HDR Engineering, Inc. and not dated.

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CORROSION STUDY
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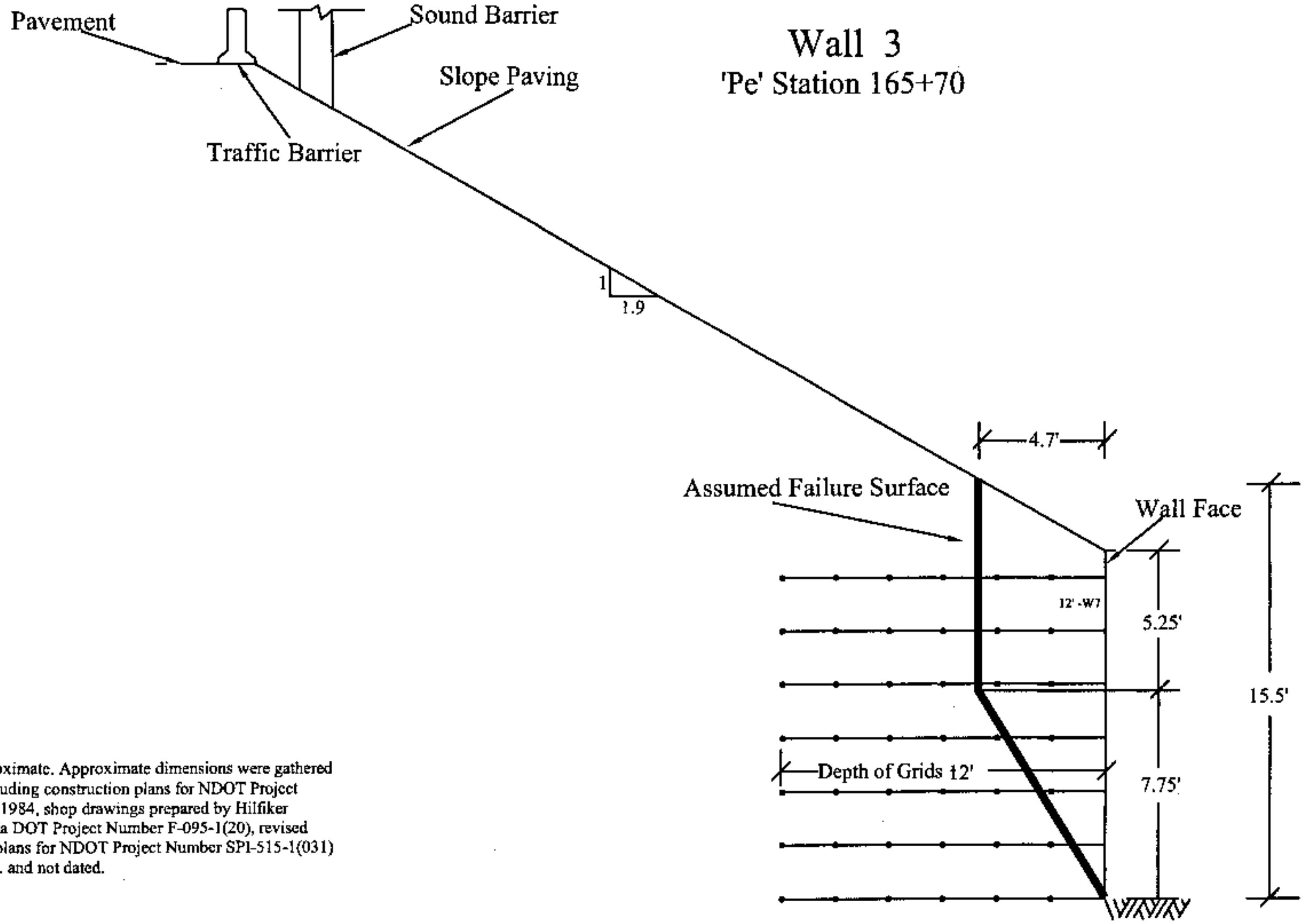
Las Vegas Nevada

Cross Section MSE Wall 2

DWG. NO. 04005-20

FIGURE V-1



Note: Dimensions shown are approximate. Approximate dimensions were gathered from plans prepared by others, including construction plans for NDOT Project Number F-095-1(20) dated Nov.5, 1984, shop drawings prepared by Hilfiker Retaining Walls for State of Nevada DOT Project Number F-095-1(20), revised March 20, 1985, and construction plans for NDOT Project Number SPI-515-1(031) prepared by HDR Engineering, Inc. and not dated.

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CORROSION STUDY
Interstate 515 and Flamingo Rd.
Las Vegas Nevada

Cross Section MSE Wall 3

DWG. NO. 04005-21

FIGURE V-2