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January 20, 2009
AMEC Job No. 072007010
Letter No. 2

AMEC Earth & Environmental, Inc.
94 Acoma Boulevard South
Suite 100
Lake Havasu City, Arizona 86403

**Attention: Darin Miller**

**Re: Pavement Design Procedure for the WWSE Program**
**Lake Havasu City, Arizona**

Gentlemen:

Transmitted herewith is a Pavement Design Procedure for the Lake Havasu City (LHC) Waste Water System Expansion (WWSE) Program. The procedure was developed at the request of Mr. Mark Clark with Lake Havasu City. Mr. Clark outlined a rough set of procedures which AMEC used as a starting point and guideline for drafting the procedures. The intent was to standardize a set of procedures and incorporate them into construction documents for the remainder of the WWSE Program.

AMEC utilized the AASHTO Guide for Design Pavement Structures (AASHTO, 1993) for development of the procedures. The MCDOT Pavement Design Guide (2004) was used as the additional reference. The AASHTO Guide for Design Pavement Structures (AASHTO, 1993) and ADOT Design Manual (1989) were also utilized.

The design procedures provided in the appendix are in final draft form. AMEC would like to address any remaining review comments and concerns from the City and its oversight engineer before issuing the finalized version.

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Should any questions arise concerning this letter, please do not hesitate to contact the undersigned.

Respectfully submitted,

**AMEC Earth & Environmental, Inc.**

Atish Nadkarni, E.I.T.
Materials Professional

Reviewed by:

Joseph A. Phillips, P.E.
Senior Pavement Design Engineer

Registered Professional Engineer (Civil)
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Expires 12/31/09

c: Addressee (2)

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# PAVEMENT DESIGN PROCEDURES

## TABLE OF CONTENTS

## 1.0 PRE-DESIGN PROCEDURES

### 1.1 Pavement Design Request Memo (to be prepared by AMEC Civil Design Team)

Prior to beginning any design work, several basic project parameters will be defined by the roadway design team. The intent is to define what roadways will be included in a given project and to identify beginning and ending points, as well as lengths of the various roadways included. The specific information to be included in this "Pavement Design Request" memo is described below.

1. Project Name.
2. Location, extent and boundaries of the project area.
3. A complete list of streets that includes the length for each roadway.

### 1.2 Pavement Management Data Memo (to be prepared by Lake Havasu City Staff)

After the Pavement Design Request is prepared, it will be sent to the City Staff. Staff will prepare information from the LHC pavement management data for the roadways included in that project. Specific information to be included in this "Pavement Management Data" memo by the City is described below.

1. PCI ratings for each of the roadways.
2. Anticipated traffic (Average Daily Traffic Counts, growth rate and percentage trucks) for each roadway.
3. Any known problem areas in the pavement such as areas that have had to be repaired.

### 1.3 Field Investigation (by the AMEC Pavement Design Team)

Upon receipt of the pavement design request memo and the pavement management data memo, the pavement design team will review the memos and schedule the field investigation. The investigation will consist of a site visit for visual observations by the pavement design engineer, as well as a subgrade soil investigation with soil borings beneath existing pavements and laboratory testing.

The purpose of the initial site visit will be to observe and document distresses that are apparent on the existing roadways and to plan the subgrade sampling. The field assessment will be done as described in the MCDOT manual to corroborate and add to the PCI data from the LHC database provided with the Pavement Management Data Memo. The pavement designer will use these visual observations to gather information to be used to asses if portions of the existing pavements would be viable for a reasonable time period beyond construction. This information will be used to determine if a "trench and repair" option could be used for installing utilities, thereby allowing the existing pavement to remain in place. The general guidelines to be used by the pavement designer in making this assessment are described below.

1. If the pavement is essentially at the end of its design life, based on excessive non-load associated cracking or by load-related distresses (i.e. rutting, fatigue or cracking), the engineer will determine that that portion of the roadway is not a candidate for the trench and repair option of installing sewer or other utilities.
2. For roadways that are ____feet wide or less will not be a candidate for the trench and repair option of installing sewer or other utilities.
3. Roadways whose pavements are in relatively good condition, and whose width exceeds ______feet will be candidates for the trench and repair option of installing sewer or other utilities.

The pavement designer will also asses the surface roughness, identify the existence of curb and gutter (or other significant drainage information like ponding locations) and identify any areas that will require repair or other special treatment during construction

The field exploration will then continue with a subsurface drilling, sampling and testing program. The soils will be investigated to a depth of 5 feet below the existing pavement by auger sampling. Soils encountered will be visually classified and logged during the exploration.

Sample and test frequencies will be in accordance with the "final" sampling guidelines presented in Table Nos. 1 and 2.

**Table No. 1 – Sampling for Avenues and Boulevards**

| Test / Item | Frequency |
|---|---|
| Number of borings | 4 per mile (3 minimum) |
| Sieve Analysis & Plasticity Index | 4 per mile (3 minimum) |
| R-value | 2 per mile (3 minimum) |
| Swell | As needed for clay soils |

**Table No. 2 – Sampling for Residential Streets**

| Test / Item | Frequency |
|---|---|
| Number of borings | 2 per mile (3 minimum) |
| Sieve Analysis & Plasticity Index | 2 per mile (3 minimum) |
| R-value | 1 per mile (3 minimum) |

The sampling frequencies for residential streets shown above have been reduced by 50% from those recommended in the MCDOT Guide. There are two reasons for this. The first is that the sample frequencies in the MCDOT Guide were established around straight arterial roadways. The winding nature of the LHC streets cause borings on adjacent streets to be closer together than if they were spread out in a linear fashion. The second reason is that soil conditions in the LHC are fairly consistent, and a smaller number of test holes would be expected to give the designer an adequate understanding of the subgrade conditions. The consistency of the subgrade soils in the LHC area has been investigated by AMEC's geologists and presented in several previous pavement design reports. Previous geotechnical investigations also corroborate that consistency.

The following tests are not anticipated to be used for the LHC program.

- One dimensional swell tests - Not anticipated for the non-expansive soil types in the LHC area.
- pH and Minimum Resistivity tests – Not needed since the projects do not include the installation of new metal pipe.
- Density, Moisture Content, and Proctor Tests – Not needed because no earthwork is anticipated.

## 2.0 DESIGN AND ANALYSIS PROCEDURES

### 2.1 Pavement Design Procedure

After completion of the laboratory testing, the data will be evaluated, and the required structural number (SN) will be calculated for each grouping of roadways giving consideration to traffic load and subgrade conditions in accordance with Section 10.2 of the MCDOT Guide. Design assumptions are presented in Table No. 3

**Table No. 3 – Pavement Design Parameters**

| Parameter | Avenues and Boulevards | Residential Streets |
|---|---|---|
| Analysis Period | 20 years | 20 years |
| Heavy Truck Equivalency Factor | 1.2 | 1.2 |
| Car Equivalency Factor | 0.0008 | 0.0008 |
| Traffic Growth | *3% | *1% |
| Reliability | 90% | 80% |
| Acceptable Change in Serviceability | 2.1 | 2.2 |
| Structural Coefficient (Asphalt) | 0.44 | 0.44 |
| Structural Coefficient (Aggregate Base) | 0.14 | 0.14 |
| Minimum Pavement Section | 4.0 inches AC** | 2.0 inches AC** |
| Drainage Coefficient | 1.15 | 1.15 |

*These default values are only to be used in the absence of traffic growth forecast information from LHC staff.

**Assume AC will be placed over compacted granular soils. Six inches of AB or 2 inches of AC should be added to the minimum section in the event that plastic soils are encountered in the subgrade surface. Plastic soils are considered to have a PI > 15 and minus #200's > 20 %.

Pavement design parameters presented in Table No. 3 are consistent with the MCDOT pavement design manual with the exception of the minimum pavement section. The minimum pavement sections in Table No. 3 would appear to be less conservative than the minimum structural numbers in the MCDOT manual. The following discussion is presented to describe why this approach is recommended for Lake Havasu City.

MCDOT's minimum structural numbers were written in anticipation of, and to encourage, the use of a minimum thickness of asphalt concrete (AC) over aggregate base course (ABC) in the final pavement sections. The LHC granular subgrade soils tend to have many of the beneficial characteristics of ABC such as the ability to be free draining and to have very stiff modulus values when compacted. Because of this, placing ABC on the top of these soils would have very little benefit. Additionally, the benefit of the high quality granular subgrade soils is discounted disproportionately by the pavement design procedures with regard to structural support (resilient modulus). This comes about because of the maximum values of design resilient modulus which tend to be much lower than the average tested values on the LHC projects. The impact of the low rainfall in LHC is eliminated by this maximum modulus value because of the way the values are implemented in the design equations. Another point of consideration is the fact that these minimums are structurally based, and, in the case of residential pavements, deterioration is considered to be driven by environmental factors such as temperature fluctuations and aging, as opposed to being caused by traffic loads.

## 2.2 Roadbed Soil Resilient Modulus

The effective roadbed soil resilient modulus will be determined from the laboratory R-values, and sieve and PI data using the calculation procedure in the MCDOT Guide (Section 10.2.2.1). This resilient modulus value, along with the parameter in Table No. 3, will then be used in the formula in the MCDOT Guide (Section 10.2.4.1) to determine the required structural number (SN). This number represents the amount of pavement that is needed to carry the stated traffic on that project's subgrade soils. A higher structural number means a thicker pavement is needed.

## 2.3 Determination of Pavement Sections

A variety of pavement sections will be considered before one is selected for final pavement design recommendation. Each of these sections will be designed to have the structural capacity to match or exceed the required structural number developed in the previous section. For the LHC projects, the following 3 pavement options will be considered.

1. Full Depth Asphalt Concrete (No aggregate base)
2. Asphalt Concrete on Aggregate Base
3. Rehabilitation of existing pavements after sewer trenches are cut and repaired

Cost estimates will be developed for each of the three pavement section alternatives. These cost estimates will be made on a square yard basis for the cost of the pavement. Life cycle cost analyses will then be provided for each alternative section, and the sections that provide the most cost effective pavement to the City will be recommended giving consideration to the need for consistency for construction. Life cycle costs will be made based on overall construction costs for a given treatment.

The analysis parameters listed in Table No. 3 will be used in the Life Cycle Cost Analysis.

**Table No. 4 – Life Cycle Cost Analysis Parameters**

| Parameter Description | Value |
|---|---|
| Analysis Period | 20 Years |
| Discount Rate | 3% |
| Inflation Rate | 3% |
| User Costs | Ignore user costs |
| Analysis Method | Present Worth |
| Major Rehabilitation or Reconstruct | Every 25 years |

## 3. 0 PAVEMENT DESIGN REPORT

The pavement design report will be presented either in a stand alone fashion or as part of the geotechnical investigation report. The report will include the following items.

- Description of the geologic setting of the area
- Description of the condition of the pavements at the time of the design
- Boring logs from the soils beneath the pavements
- Description of the site soils
- Test results from the subgrade soils
- Calculations used to determine required structural numbers and pavement sections
- Pavement design alternatives
- Cost estimates for construction of each alternative (per square yard)
- Life cycle cost analysis for each alternative
- Recommended alternative