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Cleveland Pavement Management Survey 2015

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Michael Baker INTERNATIONAL

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CLEVELAND PAVEMENT MANAGEMENT SURVEY 2015/2016
FINAL REPORT
CLEVELAND, OHIO

EXECUTIVE SUMMARY

This report presents the results of a Pavement Management Survey conducted by Michael Baker International (Michael Baker) for the City of Cleveland (City). The work was conducted in accordance with the City's agreement with Michael Baker dated October 7, 2015 (CT 0103 PS 2015-10) embodying the scope presented in Michael Baker's proposal dated June 5, 2015 and the City's Request for Proposal dated May 8, 2015. The scope of the project included the survey and inventory of 1,300 centerline miles of City pavements, including associated curbs and sidewalks, using Ohio Department of Transportation (ODOT) Pavement Condition Rating (PCR) methodology; updated data for inclusion in the City's existing RoadManager CPMS™ pavement management system (developed in 2008); training City staff on data collection and processing procedures; and development of a resurfacing work plan that considers existing pavement conditions and expected funding availability over 20 years to achieve an average PCR of 75.

Separate engineering analyses were determined necessary to address two distinct groups of streets: minor and major that are subject to different pavement management strategies and funding sources. Minor streets in this report are also referred to as "Residential" and designated as "Local" by ODOT and NOACA. This means the City of Cleveland is the sole funding source. Major streets are also referred to as "Arterials" a functional classification of collector or higher, and have additional funding sources.

Summary of Recommendations

Michael Baker has prepared several long term planning models for the City's consideration. These models will help the City compare long term approaches and funding levels at the network level. It is important for the City to decide on network level decisions before individual projects can be planned judiciously. These models will clarify for the City two major questions that should be answered before individual projects are planned:

A. How will a "Fix-It-First" approach affect the City's Inventory compared to a "worst-first" approach?

B. What level of long-term funding is required for the City to reach its goal of a systemwide PCR of 75 in 20 years?

Michael Baker recommends that the City adopt a "Fix-It-First" approach. This approach takes a part of the repair budget and applies it to maintenance. Our models show that a "Fix-It-First" approach will be the most cost effective approach to address long-term problems within its inventory. We recognize the importance of showing ***immediate*** progress, such that all the proposed "Fix-It-First" scenarios include addressing the worst streets for the first four years. We compare "Worst-First" to "Fix-it-First", and in year five the scenarios begin to diverge.

Michel Baker recommends that ***for the Minor road inventory***, the City's projected annual budget of $10 million will not be enough for the City to meet its goal of an average PCR of 75 within 20 years. ***Michael Baker recommends a budget between $12-18.5 million (adjusted for inflation), paired with a "Fix-It-First" approach to meet its goal.*** This budget range can be refined as more data is collected annually to determine the City's actual inventory deterioration rate. This budget range will be higher if paired with a "Worst-First" approach.

Michael Baker recommends that for the Major road inventory, an annual budget of $30 million (adjusted for inflation) is adequate for the City to maintain its goal of an average PCR of 75. The City will see the best results in its Major road inventory at the network level with a "Fix-It-First" approach, in the terms that maintenance should be applied as permitted with available funding.

Michael Baker recommends that the City perform pavement condition surveys for one-third of the roadways on an annual basis. This will result in every roadway being resurveyed within every three years. This will allow for refinements to the pavement management program going forward and will advise the City on whether or not it is on track to achieve its Pavement Rating Goals. The effort for the annual survey is included in Section 8.

Michael Baker recommends that the City implement the proposed changes to the D-Specifications and City Standard Drawings as included in Appendix E.

The Northeast Ohio Areawide Coordinating Agency (NOACA) provides certain external funding opportunities and publishes pavement condition information every 1 to 2 years. General consistency between NOACA and City survey data for similar areas within the roadway network is important.

ODOT developed an evaluation system that differentiates 7 distinct pavement types, each with up to 17 distress features. When scored for a segment of interest and aggregated, these observations combine to produce a pavement condition rating (PCR) value. The 2015/16 survey updated the City's 2009 survey of ~16,000 city street segments. The 2015/2016 survey scored for the presence and severity of the 8 to 17 distresses that are appropriate for that construction classification.

Data collection involved three survey teams comprised of two people (a driver and a rater). The collection team was equipped with a vehicle, electronic tablet, mapping, and required safety equipment. The tablet was pre-loaded with the LPAT application used to identify roadway segments for evaluation and to record visible distress, visible pavement type, and curb and sidewalk conditions. Assessment of pavement condition using ODOT's Pavement Condition Rating (PCR) system followed a well-prescribed protocol that relies on documentation of frequency and severity of various distress features. The survey effort was organized into the 17 Cleveland City Council wards. A quality assessment (QA) program was implemented during the analysis and raw field PCRs were adjusted as a result of the QA.

Assessment of pavement conditions is a visual approach to rating, starting with identification of the distress, severity of the distress and frequency of the distress through the segment being rated. The summation of the distresses results in the PCR.

For the City of Cleveland, a large network of roadway segments, the overall results provide a good system-wide assessment of the pavement condition that can be used to track progress towards performance goals. However, it must be recognized that individual values vary on the individual ratings, particularly at low PCRs where multiple forms of distress are present. Use of these individual scores for pavement maintenance planning should include a field inspection, which is essential to validate that selection prior to the pavement program being finalized.

Minor streets are managed independently from Major roads. The following indicates the separation of pavement types in each program.

Distribution of Pavement Types and Condition - Minor Streets

Pavement Type	Segments	Length (ft)	Length (miles)	% of total	Avg PCR
BRICK	725	329,680	62.6	6.7	70.4
CRC	30	9,278	1.8	0.2	89.6
LOCAL	8873	4,211,790	798.5	86.1	68.9
Gravel	2	360	0.05	0	53.6
JCP	727	341,022	64.9	7.0	73.4
Total Locals Scored	10,357	4,892,130	926.5	100.0	

CRC – Continuously Reinforced Concrete ; JCP Jointed Concrete Pavement; LOCAL – Asphalt covered

Distribution of Pavement Types and Conditions - Major Streets

<table>
<tr><th>Pavement Type</th><th>Segments</th><th>Length (ft)</th><th>Length (miles)</th><th>Total Length (miles)</th><th>Percent of Total (%)</th><th>Average PCR</th></tr>
<tr><td>BRICK - MBI</td><td>1</td><td>360</td><td>0.1</td><td rowspan="2">0.2</td><td rowspan="2">0.1</td><td>77.3</td></tr>
<tr><td>BRICK - NOACA</td><td>2</td><td>475</td><td>0.1</td><td>62.0</td></tr>
<tr><td>CRC - MBI</td><td>9</td><td>5,700</td><td>1.1</td><td>1.1</td><td>0.4</td><td>93.1</td></tr>
<tr><td>LOCAL - MBI</td><td>330</td><td>128,030</td><td>24.2</td><td rowspan="2">239.9</td><td rowspan="2">86.3</td><td>76.7</td></tr>
<tr><td>LOCAL - NOACA</td><td>770</td><td>1,138,843</td><td>215.7</td><td>70.5</td></tr>
<tr><td>JCP - MBI</td><td>83</td><td>20,050</td><td>3.8</td><td rowspan="2">36.7</td><td rowspan="2">13.2</td><td>83.9</td></tr>
<tr><td>JCP - NOACA</td><td>173</td><td>173,765</td><td>32.9</td><td>84.5</td></tr>
<tr><td>Total</td><td>1368</td><td>1,467,233</td><td colspan="2">277.9</td><td>100.0</td><td></td></tr>
</table>

The City expressed a desire to have Minor streets and Major streets split into separate inventories to reflect the management structure within the City. Michael Baker developed various maintenance/rehabilitation scenarios. The scope of services requested an analysis of Minor streets (those not on the Federal Aid system) with an anticipated budget of $10 million/year or the required budget if that amount is insufficient. Our analysis indicates to raise the current quality of these streets to an acceptable level (PCR = 75) will require funding at $12-18.5 million/year. Major street upgrades and maintenance appear feasible within the anticipated budget of $30 million/year. Michael Baker developed and presented a list of Minor eligible streets on October 14, 2016 for use as a starting point for the 2017/2018 Minor streets pavement management program.

Michael Baker provided training for City staff that covered: Pavement Condition Rating (consisting of both classroom and field instruction), use of ODOT's LPAT on delivered tablets and uploading future survey data to the City's GIS system (RoadManager).

Michael Baker reviewed the current City standards, specifications and notes and included recommendations for improvement in design, materials and construction practices.

1. INTRODUCTION

1.1 General

This report presents the results of a Pavement Management Survey conducted by Michael Baker for the City. The work was conducted in accordance with the City's agreement with Michael Baker dated October 7, 2015 (CT 0103 PS 2015-10) embodying the scope presented in Michael Baker's proposal dated June 5, 2015 and the City's Request for Proposal dated May 8, 2015. The scope of the project included the survey and inventory of 1,300 centerline miles of City pavements, including associated curbs and sidewalks, using ODOT Pavement Condition Rating (PCR) methodology; reviewing the City's existing RoadManager CPMS™ pavement management system (developed in 2008); training City staff on data collection and processing procedures; and development of a resurfacing work plan that considers existing pavement conditions and expected funding availability.

Separate engineering analyses were determined necessary to address two distinct groups of streets: minor and major that are subject to different pavement management strategies and funding sources. Minor streets in this report are also referred to as "Residential" and designated as "Local" by ODOT and NOACA. This means the City of Cleveland is the **only** funding source. Major streets are also referred to as "Arterials" a functional classification of collector or higher, and have additional funding sources, such as Cuyahoga County and ODOT. Minor and Major are used in this report, and the differences are discussed more fully in the body of the report.

The report describes how the goals have been achieved and is divided into the following sections:

- Description of Distresses
- Data Collection
    - Surface Methodology
    - Inventory Process
- Summary of Findings
- Training
- Evaluation of Pavement Degradation
- Capital Improvement Plan
- Resurvey
- Appendices

1.2 Background

A systematic city wide pavement management program is a major undertaking for all metropolitan areas and requires a significant commitment of capital and maintenance funding on an annual basis. The efficient use of these funds is achieved by cities that utilize pavement management planning processes that frequently include the use of geographical information systems (GIS) and database management programs to provide timely data to those charged with managing their program. These systems are used to record, analyze and graphically display the condition of pavement, curbs and sidewalks throughout the city.

The City of Cleveland initiated use of a city wide systematic pavement management system in 2008 when it initially surveyed the streets in all (at that time) 23 wards, and archived the data in a GIS based application called RoadManager CPMS™ that operates within the ESRI ArcGIS framework. A pavement condition survey includes consideration of the type of construction (e.g. flexible or concrete) and, for each pavement type, a suite of possible distress features that are then documented (e.g. rutting, raveling). These are graded for severity and frequency and eventually aggregated to give an overall pavement condition rating (PCR) - a number on a scale of 0 - 100 - for the segment being surveyed. The City can then prioritize maintenance work using the PCR score as a guide.

It is the City's intent to update the 2008 survey and associated database with the results of the current (2015/2016) survey. In addition, the City has elected to develop the capability for future surveys using in-house resources and required implementation of a training program for its staff. The study also includes an engineering analysis of the overall pavement network with a view to introducing applicable new technologies or methods to its suite of pavement repair and management alternatives. Finally a management plan detailing, street by street, the scope of necessary repairs and their cost for the next few years is required.

1.3 The Existing Database

As indicated above, Michael Baker's scope of services included updating the pavement condition database (RoadManager CPMS™) that was developed in 2008. A spreadsheet version of the database was provided to Michael Baker after award and was assumed to be a reliable and complete dataset. Two important characteristics were ultimately found to include:

- Over 16,000 roadway segments. On detailed analysis it has been found that there are approximately 2,000 instances of duplication and repeat of segments, and instances of very short segments [some as short as 8 feet (ft)]. It is likely that appropriate segmentation of the streets would yield a population on the order of 10,000 or less. This anomaly presented challenges to the collection and reliable interpretation of survey data provided.

- Classification of the pavement in each segment was Flexible, Jointed Concrete, Continuous Reinforced Concrete, Brick or Gravel (see Section 2 for details of the assessment system). These classifications were assumed to meet the City's requirements and, given the need to 'update' the system, they were used as presented.

As the project progressed, the City identified another important source of pavement condition information that is available to it, and which represents an important benchmark when considering certain external funding opportunities. NOACA interfaces with the federal government on matters of regional transportation planning and currently receives $49 million in funding from the Federal Highway Administration for use in its 12-county area of responsibility. The City is eligible to apply for a share of this money for its roadway maintenance and rehabilitation. The agency also publishes pavement condition information on its web site, abstracted from ODOT statewide records that are compiled every 1 to 2 years. General consistency between NOACA and City survey data for similar areas within the roadway network is therefore important for the credibility of any funding applications that relate to reconstruction of badly deteriorated roads. Pavement condition records for many of the arterial streets within the City are available for the survey years 2010, 2011, 2012, 2013 and 2014 from ODOT as shape files that can be downloaded and displayed in GIS.

1.4 Use of NOACA Data

In view of the importance of consistency between the survey results and NOACA data, Michael Baker proposes that the most recent NOACA data be incorporated. We used the NOACA information where streets are categorized as Major streets. Segments listed as Major, but which are not rated by NOACA, were rated by Michael Baker.

1.5 City Specifics

To distinguish streets that are primarily residential, the term of Minor is used and Major is used for those streets that are collectors. This is to minimize any potential confusion to the terms that are used in the PCR rating system developed by ODOT (see Section 2). The City requires that a separate pavement management plan be developed for each of the two categories of city streets.

1.5.1 Minor Streets

The City's existing program is to spend on the order of $10,000,000 per year on upgrading Minor streets through re-surfacing, on a "Worst First" basis. These streets have been rated as LOCAL classification to determine their PCR scores. It is expected that these funds will be spent entirely on asphalt overlays using mill and fill technology, casting adjustments and ADA ramp upgrades. The cost of upgrading sidewalks and curbs is not included in this dollar amount.

1.5.2 Major Streets

City Major streets include a large number of streets that are also of interest to ODOT (US and State routes). ODOT surveys the condition of their streets every 1 to 2 years as part of a statewide pavement management program. A smaller number are important collectors, but have no state or federal designation and are therefore of interest exclusively to the City. NOACA relies on the ODOT survey data and publishes it on their website (ODOT, 2016(1)).

2. DESCRIPTION OF DISTRESSES

Pavement condition is predicated on the type, frequency and severity of distress features. ODOT developed an evaluation system, which the City has adopted, that differentiates 7 distinct pavement types, each with up to 17 distress features (ODOT, 2006). When scored for a segment of interest and aggregated, these observations combine to produce a PCR value. The 2015/16 survey requires that each segment of a city street be separately observed and, using the appropriate pavement type, scored for the presence and severity of the 8 to 17 available distresses that are appropriate for that pavement classification (see Tables 2.1, 2.2, 2.3).

Table 2.1: Pavement Classifications Used for PCR Analysis

Rating Form Number	Pavement Classification	Number of Distresses to Be Rated
1	CRC (Continuous Reinforced Concrete Pavement)	10
2	JTCP (Jointed Concrete Pavement)	14
3	FLEX (Flexible Pavement - Asphalt over base)	15
4	COMP (Composite - Asphalt over concrete or brick)	17
5	LOCAL (Residential or non-state route)	15
6	BRICK	8
7	GRAVEL	8

Distresses were identified for the 4 pavement types used in the 2008 survey: FLEX (including composite), jointed concrete (JTCP), continuous concrete (CRPC), and BRICK pavement using ODOT's distress definitions from ODOT's *Pavement Condition Rating System* manual dated April 2006 (ODOT, 2006). Table 2.2 provides a list of Distresses by Pavement Type (2008 survey). Table 2.3 provides a list of distresses by pavement type (added for 2016 survey).

Table 2.2: Distresses by Pavement Type (2008 Survey)

Pavement Classifications			
Flexible (FLEX)	Jointed Concrete (JTCP)	Continuous Concrete (CRC)	Brick (BRICK)
Raveling	Surface Deterioration	Surface Deterioration	Brick Deterioration
Bleeding	Longitudinal Joint Spalling	Popouts	Discoloration
Patching	Patching	Patching	Patching
Debonding	Pumping	Pumping	Pumping
Crack Sealing Deficiency	Faulting	Settlement and Waves	Rutting
Rutting	Settlement	Transverse Crack	Corrugations

		Spacing	
Settlement	Transverse Joint Spalling	Longitudinal Cracking	Joint Erosion
Potholes	Transverse Cracking	Punchouts or Edge Breaks	Settlement
Wheel Track Cracking	Pressure Damage	Spalling	
Block and Transverse Cracking	Longitudinal Cracking	Pressure Damage	
Longitudinal Cracking	Corner Breaks		
Edge Cracking			
Thermal Cracking			
Corrugation			

Representative distress features - i.e. those commonly observed in this survey are described in Appendix A. For others, the reader is referred to the ODOT handbook available for download at:

https://www.dot.state.oh.us/Divisions/Planning/TechServ/TIM/Documents/PCRManual/2006PCRManual.pdf

Initial survey results suggested that pavement condition had improved markedly from 2008 levels. This unlikely situation resulted in additional testing of data. Existing Composite pavements were presented as Flexible in the 2008 database, so Michael Baker conducted a test, but there was no significant difference in the resulting PCR scores. Further in-depth analysis of the data showed that the LOCAL classification should be used. (See Appendix F)

There are no true FLEX pavements in Cleveland and that they are predominantly COMP. The ODOT LOCAL category (asphalt covered) that includes consideration of base failure and pressure damage as indicators of poor travel speed ride quality, argues in favor of its adoption for most of the streets. This is consistent with ODOT's approach to the survey of many of the non-freeway urban segments that it rates. For these reasons, the LOCAL classification was used in the survey.

Table 2.3: Distresses by Pavement Type (Added for 2016 Survey)

Pavement Type	
Composite (COMP)	**Local (LOCAL)**
Raveling	Raveling
Bleeding	Bleeding
Patch	Patch
Surface disintegration or debond	Surface disintegration or debond

Rutting	Rutting
Pumping	Base failure
Shattered Slab	Settlement
Settlement	Transverse crack
Transverse crack, unjointed base	Wheel track crack
Joint reflective crack	Longitudinal crack
Intermediate transverse crack	Edge cracking
Longitudinal crack	Pressure damage
Pressure damage	Crack seal deficiency
Crack seal deficiency	Map cracking
Corrugation	
Punchout and edge breaks	

3. DATA COLLECTION

The City provided the pavement condition geo-database produced in 2009, containing 2008 survey data, and which forms the basis for the existing RoadManager CPMS. Michael Baker modeled its data collection program to dovetail with this data and the database schema.

3.1 Survey Methodology

The survey and inventory were conducted using ODOT's PCR methodology, part of its larger system to collect and maintain pavement condition data for the State of Ohio. That system is based on the Infrastructure Management and Assessment Tool (IMAT), a custom-designed package of software programs. Provided below is a list of the programs used by ODOT with a brief description of how they are used.

- Pavement Condition Rating (PCR) Route Manager – Used in-office for managing pavement condition ratings. Route Manager provides data validation and reporting provisions for combining the statewide inventory and loading it into ODOT's Pavement Management System (PMS).
- PCR Field Rater – Primarily used by the field inventory staff. It utilizes route information checked-out from Route Manager as a means to perform pavement inventory assessment. The PCR rating system is an ODOT devised scoring system that is a variation of the American Society for Testing Materials (ASTM) Pavement Condition Index (PCI) standard.
- Local Pavement Assessment Tool (LPAT) – A unified manager and rating tool for local

agencies to perform pavement inventory assessment. It follows the same scoring system as the PCR Field Rater and is intended to not only support local agencies, but allow a common platform to which data can be aggregated into a statewide inventory database.

- Core Manager – A stand-alone software tool for inventorying and maintaining pavement coring samples performed by ODOT.

ODOT's data collection is managed through Route Manager, in which an inventory coordinator provides database checkout files for field crews to utilize in the Field Rater software. Route segmentation and the previous year's ratings are included in the checkout so that field rating staff can leverage existing route detail and ratings. Users can also "mark-up" rating screens using their device's touch screen for field notations. Once a pavement assessment is completed, it is checked-in to Route Manager and prepared for submission to ODOT's PMS. ODOT makes its results available to local agencies in Ohio such as NOACA that includes the Cleveland city area.

For the City's 2015 Pavement Management Survey, Michael Baker utilized ODOT's LPAT. This was selected because it combines the functionally of ODOT's Route Manager and Field Rater to allow users to inventory, as well as manage the overall pavement condition assessment. A single database can track multiple years, and users can break-up inventories as separate database files depending on what best suits their needs. The software includes basic reporting and exporting/importing capabilities, which includes the ability for local agencies to import their roadway segmentation rather than having to manually enter them. The LPAT software is designed for deployment on a Windows 7 ruggedized laptop, but can be installed on Microsoft Surface tablets with Window 10 operating systems. The inventory involved the following steps: Segment Identification, Assumptions and Constraints, Data Collection, QA/QC, Data Processing, and Data Reporting.

3.2 Segment Identification

The City's pavements were broken into ~16,000 rate-able segments of varying length primarily based on roadway intersection spacing for the 2008 survey. After utilizing NOACA's ratings and removing duplicates and overlapping segments from the previous survey, ~10,000 segments were surveyed.

3.3 Assumptions and Constraints

Pavement distress types and their significance have been discussed in earlier sections of the report. However, the subject is revisited here because of its importance to the selection of survey mode for a particular street segment and the potential variability in rating results.

The PCR system requires observation of between 8 and 17 of available distress factors for each segment, depending on the pavement type and composition. These differences are characterized by the 'Pavement Type' (Table 2.2), which dictates the rating form to be completed.

The 2008 survey recorded all asphalt data as “FLEX” pavement. Since it was determined that there are no true “flexible” pavements in the City, “LOCAL” classification was used to align with ODOT’s pavement inventory as well as to account for the additional pavement base distresses.

Directional lanes of multi-lane roadways were considered as a single roadway for inventory purposes. To help maximize the ability to identify stresses, data collection was limited to daylight hours.

3.4 Data Collection

ODOT’s automated LPAT application was used to collect inventory data on 956 centerline miles (not including NOACA’s ratings) of city roadways, segmented based on the 2008 survey street inventory.

Data collection involved three survey teams comprised of two people (a driver and a rater). The collection team was equipped with a vehicle, electronic tablet, mapping, and required safety equipment. The tablet was pre-loaded with the LPAT application used to identify roadway segments for evaluation and to record visible distress, visible pavement type, and curb and sidewalk conditions.

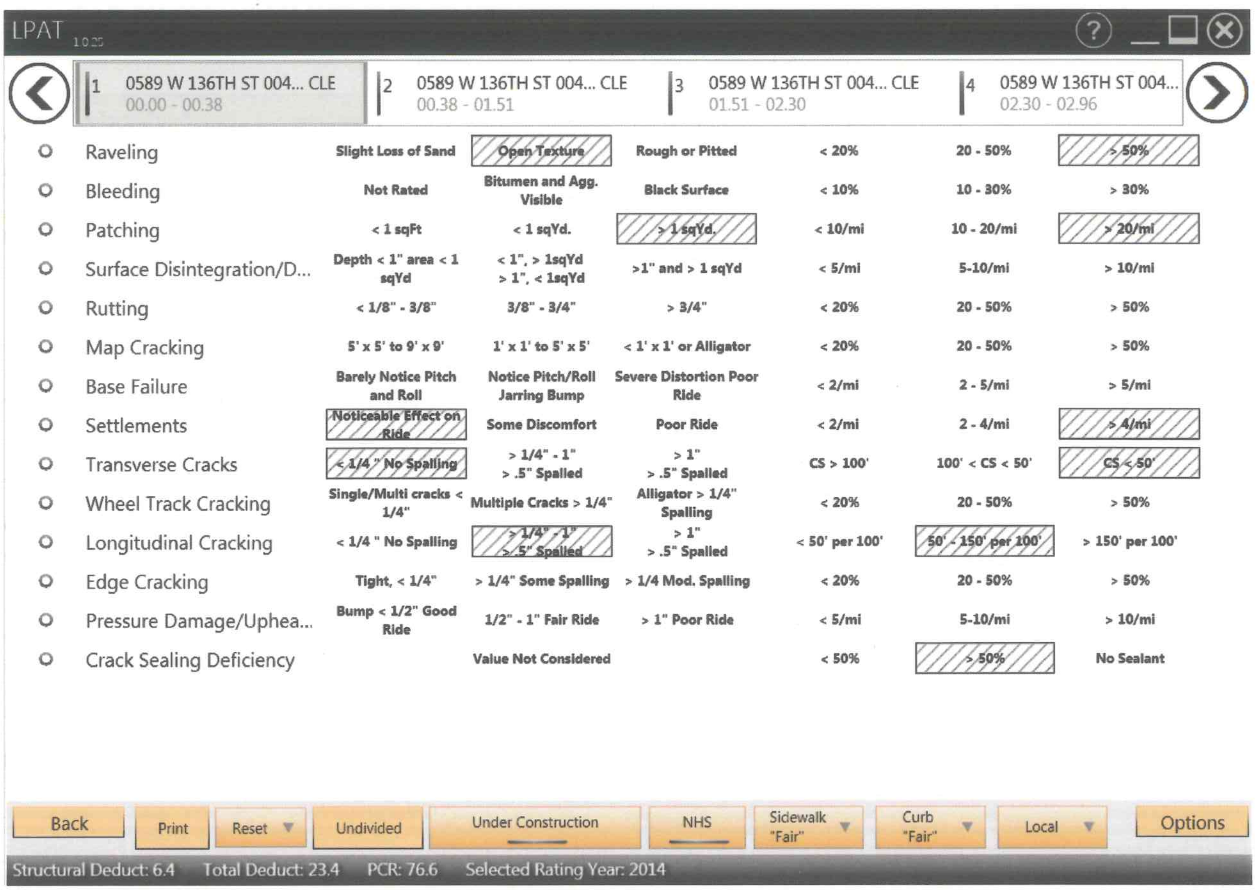
The survey effort was collected on the basis of the 17 Cleveland City Council wards (ward), as shown in Exhibit 1, and segments were loaded on to the tablets by ward. Survey teams utilized the ward maps (Cleveland City Council website: http://www.clevelandcitycouncil.org/) to assist in a systematic approach of identifying roadway segments that had or needed to be surveyed by highlighting sections of streets once rated. The maps were also used for field notes, such as streets that have been vacated or removed, or changes in street names or roadway configurations. These field observations were also recorded in the tablets, as appropriate.

Prior to driving a section of roadway, a visual verification of visible pavement surface type was conducted and compared to the 2008 inventory. The City of Cleveland 2008 Pavement Inventory classified roadways with a visible asphalt layer as flexible pavement. While differences between continuous reinforced concrete (CRC), jointed concrete pavement (JCP) and flexible pavements were verified visually, no testing or coring was conducted to determine the actual pavement composition. For consistency with ODOT's survey as well as accounting for the additional distresses, the ODOT "LOCAL" pavement classification was used for the rating of all pavements with an asphalt surface.

The survey teams drove each section of pavement at a pre-determined maximum speed of approximately 25-35 mph, and using a combination of observed distresses and ride quality, rated the section. Readily visible distresses such as potholes, bleeding, settlement, faulting, spalling, and surface deterioration would be rated. Ratings would include assessing both the severity (low, medium, high) and extent (occasional, frequent, extensive) levels for each distress. As needed, team members exited the vehicle to inspect the condition of the pavement where it was obscured by debris, parked vehicles, or high traffic volumes. A second pass along the roadway section was occasionally necessary to determine ride quality. The presence/absence and condition (best, good, adequate, poor, worst) of curbs and (best, good, traversable, poor, worst) sidewalks were also recorded for each roadway segment. This included addresses of sidewalks that were in extremely poor condition, primarily due to tree root disturbance. Observations were then entered into LPAT on the tablets. Once a segment rating was completed, the rater would save the information and close the data set for processing. An example of a calculated score in the LPAT application is presented in Figure 3.1.

The LPAT tool automatically calculates PCR, Structural Deduction and Total Deduction for each roadway segment. All distresses have a severity and extent level with corresponding deduction values related to what was entered into the LPAT program. The PCR scale has a maximum value of 100 and is determined by the distresses found on each segment. Tablets were backed up daily to portable jump drives and backed up to the network project file once a Ward was completed.

Figure 3.1: Example of 1 Page of a Calculated Score in LPAT



3.5 QA/QC Process

The assessment of pavement condition using the ODOT Pavement Condition Rating (PCR) system followed a well-prescribed protocol (ODOT, 2006) that relies on documentation of frequency and severity of various distress features. This information is then converted into numerical values that are combined and weighted to compute a score that, when deducted from 100, produces a

PCR value for that roadway segment. The rating criteria requires an assessment of the distress severity (low, medium or high), as well as extent of the distress (occasional, frequent or extensive) within a segment. While these terms are defined in the protocol, the opportunity for difference in rating a segment exists. In some cases, the change from medium to high severity and from frequent to extensive can create a change in PCR value of 7-8 points for a single distress type (and several distress types may be present in a given segment) (Pierce et al, 2013).

For a large system (for example - Cleveland, with rating ~10,000 roadway segments), the overall results are likely to provide a very good system-wide assessment of the pavement condition that can be used to track progress towards performance goals. A ward-by-ward evaluation with ~1,000 segments, or a pavement type assessment for the major pavement categories is also likely to yield similarly useful results. However, it must be recognized that individual values vary on the individual ratings, particularly at low PCRs where multiple forms of distress are present. Use of these individual scores for pavement maintenance planning should include a field inspection, which is essential to validate that selection prior to the pavement program being finalized.

The quality assurance process for the data collection focused on both the survey teams and the data. Teams met on a weekly basis to discuss issues that arose during the survey efforts and distress evaluations, and how these issues were resolved. Members of survey teams were rotated or changed based on inventory needs. This rotation of staff also helped build collaboration among team members and ensured consistency of distress evaluations.

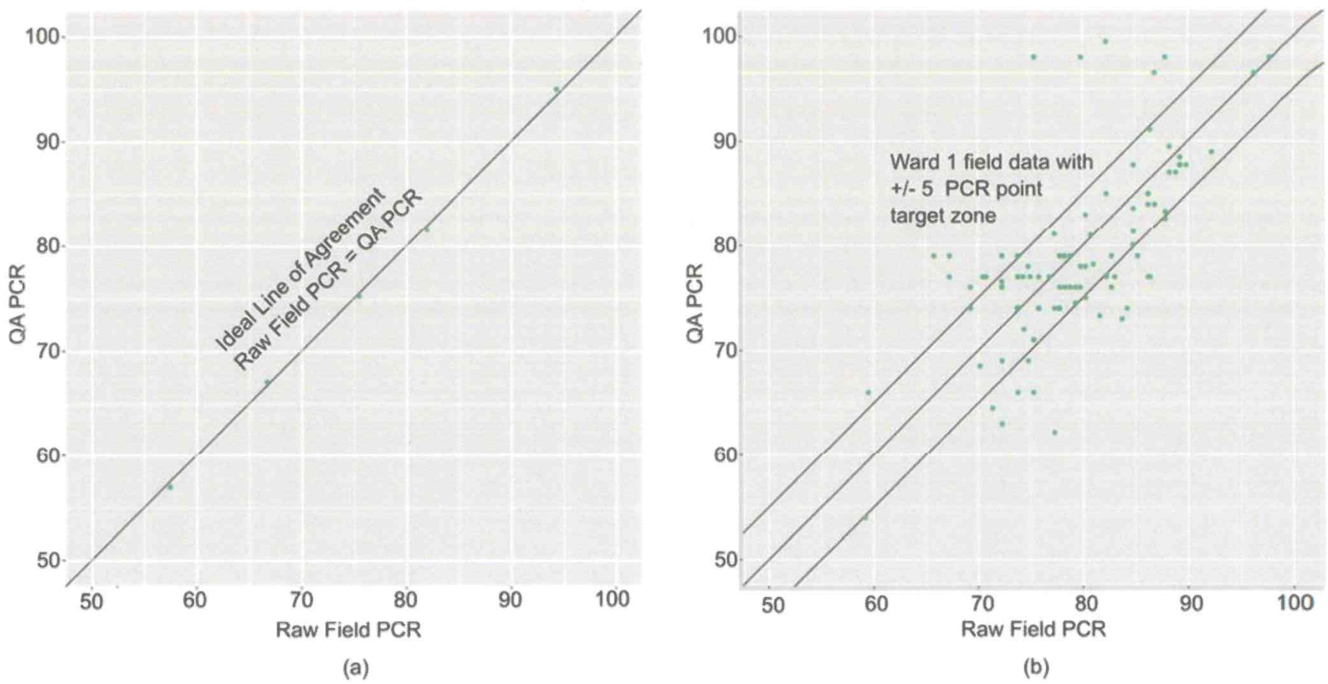
Pavement widths were given as part of the City of Cleveland 2008 Pavement Inventory data information provided by the City of Cleveland. Pavement widths were verified to determine if the current widths of the segments were consistent with the information in the City of Cleveland 2008 Pavement Inventory or if they had been modified by widening or roadway reconstruction.

Upon completion of the initial data collection, a QA/QC survey team of two people re-rated approximately 10% of the roadways (based on the number of sections and miles) within a ward. The QA/QC team involved raters that had not previously rated that ward. PCR scores from the initial ratings and QA/QC PCR ratings were compared to ensure an accurate rating. A deviation threshold of +/- 5 points was the goal.

A quality assessment (QA) program was implemented to examine the 2015 field data quality using random replicate, (or repeat) samples of 10-20% of the roadway segments in each ward.

Ideally, the values obtained by the original raters would be the same as those obtained by the checkers, such that when the QA data are plotted against the field data, all lie on a straight line between 0,0 and 100,100 [Figure 3.2(a)]. As indicated above, there are physical constraints that can reduce the quality of observations and cause variance in the data such that it plots on either side of this line [Figure 3.2(b)].

Figure 3.2: Example of a Quality Assurance Graphs



Data for each ward were plotted for observation (see Appendix B). A general positive bias was noted in many of the wards wherein the QA data were typically lower than the corresponding field data, biasing the plotted points to the right. Statistically, for the QA and field data to be derived from the same population (as they clearly are by design), their averages must be substantially equivalent (among other factors) - suggesting that no systemic bias should be present.

Average PCR values were calculated for the field and QA data in each ward together with the difference between them (Δ average PCR). These results are presented in Table 3.1. Six of the 17 wards are within +/- 1 PCR point of the QA averages and do not indicate a significant bias. Seven are in the range -1.0 to -3.0 and four are in excess of -3. An unexplained positive outlier in Ward 15 completes the set. **Our goal of +/- 5 points in each ward was accomplished.**

The precise cause of the bias is not known. However, it is reasonable to assume that the QA checks were made under similar conditions to the original rating for pavement distresses. This would tend to maximize deductions in the resulting PCR based on the survey team's experience and ongoing collaboration, thereby creating opportunity for the observed biases.

Table 3.1: Comparison of Field and QA PCR Values

Ward	Average PCR-QA	Average PCR-Field	Δ Average PCR	Ward	Average PCR – QA	Average PCR – Field	Δ Average PCR
1	78.75	79.67	-0.92	10	74.74	78.93	-4.18
2	75.51	79.20	-3.69	11	77.92	80.19	-2.28
3	75.21	75.35	-0.14	12	76.24	75.70	+0.54
4	76.20	80.62	-4.41	13	76.94	81.23	-4.29
5	78.08	79.08	-1.00	14	77.14	76.40	+0.74
6	78.66	80.37	-1.60	15	78.96	76.22	+2.75
7	75.25	77.19	-1.94	16	77.45	78.44	-0.98
8	76.51	79.27	-2.76	17	76.40	78.61	-2.21
9	78.68	81.38	-2.70				

In order to eliminate the bias indicated by the QA measurements, all individual raw field PCRs have been adjusted by the 'Δ average PCR' value for the ward in which they are located. This has had the effect of reducing the apparent overall system-wide PCR by approximately 2 points for the data. Graphs of the QA and adjusted field PCRs for each QA data subset are shown adjacent to the corresponding raw data graph in Appendix B.

Possible causes for the spread of data away from the target are discussed above. The parallel lines above and below the target line are +/- 5 PCR points. Approximately 80% of the data lie within this band.

3.6 Data Processing

Raw field data that was collected using LPAT was exported to an Excel spreadsheet. Several export files were generated, as inventory was performed on multiple tablets. As such, data from each export file was combined and merged into two master files (minor and major), which contained a total of 10,775 individual records. Each record consisted of pavement data from one segment. Once the inventory was complete and all data was merged into the master files, QA/QC checks were performed to verify inventory completion and data abnormalities, such as missing values.

Michael Baker provided the survey results as shape files that can be displayed on most GIS platforms (ArcGIS, QGIS, GRASS etc), some of which are open source and require no licensing fees. Each of these systems is capable of archiving the data, displaying it and facilitating analysis over a large range of complexity depending on the skill level of the user. An alternative graphical display capability is also available using kmz files that can be displayed in Google Earth.

An effort was made to import post-processed data from the field inventory into the RoadManager system. Michael Baker staff visited the City offices on December 20, 2016 to review the RoadManager system, determine data import requirements and perform the Extract, Transfer and Load (ETL) process.

The first step required making a connection to RoadManager was to review the database schema. No documentation was available, but the following information was provided in Appendix A of the RFP:

- System needs GIS route system (centerline with LRS), this must have 'routeid' field which will link database.
- Route system data gets duplicated into databases PavementRoute table.

Once having made a connection, the PavementRoute table was reviewed. It was determined that the 'routeid' field was not a unique record identifier for pavement segments. However, Michael Baker derived a unique key from a combination of the following fields: RouteID, Street Name, FrStation, and ToStation.

Using these fields, inventoried field data was connected (joined) to RoadManager. Once successfully joined, spatial representations of the new inventory data became accessible in GIS.

The next step was to determine the appropriate RoadManager tables and fields to update, and develop the methodology to perform the update within the RoadManager system. Since no RoadManager documentation or data dictionary was provided, the data mappings were deduced based on available table and field names. A data review on the RoadManager schema revealed that current pavement condition inventory is stored in the *Pavement* table within the database. Table 3.2 identifies the fields for update within the *Pavement* table from the LPAT output.

Table 3.2: Road Manager Fields Identified for Update

Field	Assumed Definition	LPAT Output
[Comment]	General comment field	'2016 Local' for all values
[CurbRatingID]	Curb rating number	[PCRCompact_Curb]
[DataYear]	Year of the rating	'2015' for all values
[DtSurvey]	Date of the pavement survey	[PCRCompact_PCRDate]
[PaveTypeID]	Pavement type	[PCRCompact_PavementType]
[PCI]	PCR of the pavement	[PCRCompact_PCRScore]
[StructDeduct]	Structural deduction score	[PCRCompact_StructuralDeduction]
[SWRatingID]	Sidewalk rating number	[PCRCompact_Sidewalk]
[TotalDeduct]	Total deduction score (100 – this value = PCR)	[PCRCompact_TotalDeduction]

Prior to the system update, a complete backup of the database was performed and archived in cooperation with the Cleveland Water Department, whose GIS group administers the RoadManager database. The data update was successfully performed on matching segments within City's database. At the City's approval, only non-NOACA segments were updated within the database. Documentation and training was provided to the City for these processes so that they can continue to be utilized and updated annually.

4. SUMMARY OF FINDINGS

The 2015/2016 pavement condition survey has updated the RoadManager inventory and provided the PCR status of the City streets so that future planning can be undertaken for their continued maintenance and repair. The completed survey resulted in ~2,000 segments that were not scored as they are duplicate locations and/or segments overlapping other segments, and suggest the need for a database maintenance review and rationalization.

The citywide distribution of pavement types is shown in Table 4.1.

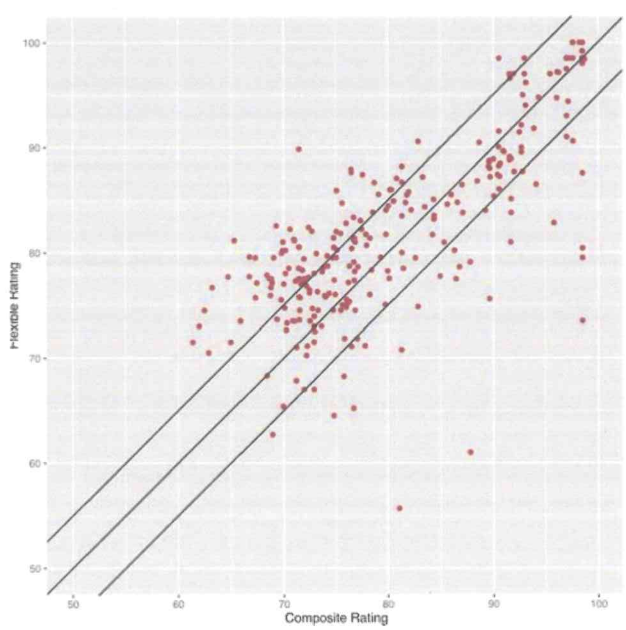
Table 4.1: Distribution of Pavement Types by Length - Citywide (Minor + Major)

Pavement Type	Segments	Length (ft)	Length (miles)	% of Total
BRICK	726	330,040.00	62.51	6.54%
CRC	39	14,978.00	2.84	0.30%
LOCAL	9198	4,338,620.00	821.71	86.00%
Gravel	2	360.00	0.07	0.01%
JCP	810	361,072.00	68.38	7.16%
Total Scored	10775	5,045,070.00	955.51	100.00%

As discussed in Section 1, Minor streets are managed independently from Major roads. The remaining discussion of findings is divided accordingly to address these two categories separately.

It should be noted that the majority of the City's asphalt surfaced pavements are composite. A large sample of roads was rated using the composite (COMP) classification to compare it to the flexible (FLEX) classification and it was noted that the overall ratings comparing flexible or composite produced nearly the same result (Fig. 4.1). In other words, no discernable difference between these two pavement classifications was discovered. This is the reason why the LOCAL classification, with distresses concerning the pavement base, was used to gather the PCR's.

Figure 4.1: Composite Rating v/s Flexible Rating



4.1 Minor Streets

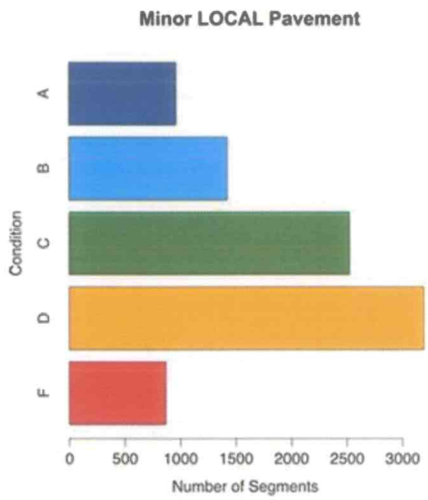
Minor streets are those that are primarily in residential areas and do not serve as significant collectors. 10,357 segments of Minor streets were rated representing ~2,250 individual streets with a total length of 4,892,130 ft. (926.5 miles), or ~80% of the City street centerline miles.

Table 4.2: Distribution of Pavement Types and Conditions - Minor Streets

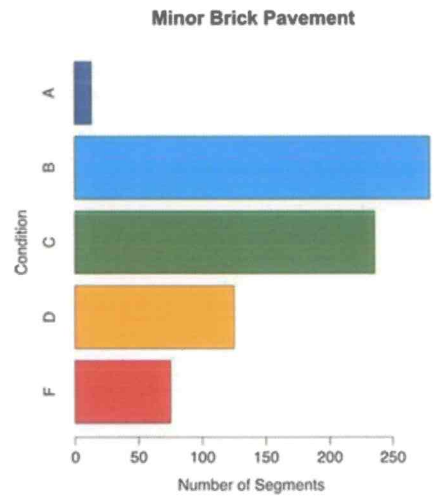
Pavement Type	Segments	Length (ft)	Length (miles)	% of total	Avg PCR
BRICK	725	329,680	62.6	6.7	70.4
CRC	30	9,278	1.8	0.2	89.6
LOCAL	8873	4,211,790	798.5	86.1	68.9
Gravel	2	360	0.05	0	53.6
JCP	727	341,022	64.9	7.0	73.4
Total Locals Scored	10,357	4,892,130	926.5	100.0	

The condition of the various pavement types varies as shown in the graphs below (Figure 4.2). However, the asphalt surfaced streets, rated as LOCAL, comprise the largest percentage by far, representing over 85% of the total local centerline miles. The condition of all Minor roads is depicted graphically by color-coding on a ward-by-ward basis in Exhibits 2-18 (following the main body of text).

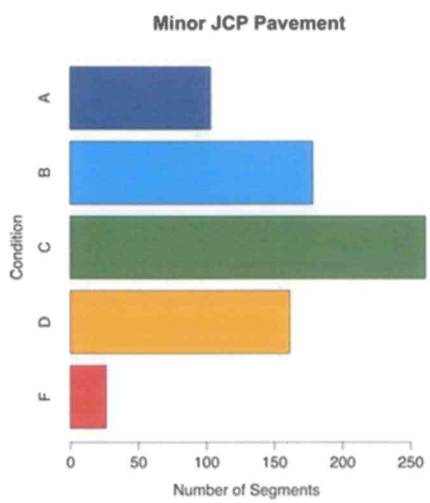
Figure 4.2: Overall Condition Assessment of Pavement Types (Local Streets)



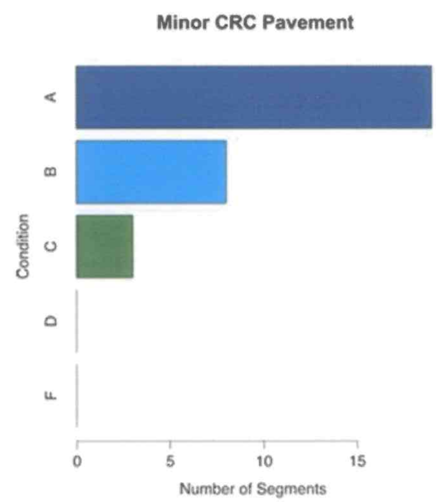
(a) LOCAL Pavement - Clearly the most prevalent type, scoring C or D



(b) Brick Pavement - Overall a minor pavement, typically scoring B or C



(c) JCP Pavement - Similar in number to brick segments, with a large percentage in the range B – D.



(d) CRC Pavement - The smallest pavement subset, but in the best condition on a percentage basis.

Legend:

Condition	PCR Range
A	91-100
B	76-90
C	66-75
D	56-65
F	0-55

4.2 Major Streets

A total of 423 segments of Major streets were rated representing ~50 individual streets with a total length of 154,140 ft (29.2 miles), or 2.5% of the City street centerline miles. NOACA ratings were used for the remaining 17.5% of the City streets that are classified as Major. The distribution of pavement types for the Major roads is shown in Table 4.3, together with average PCR values for each.

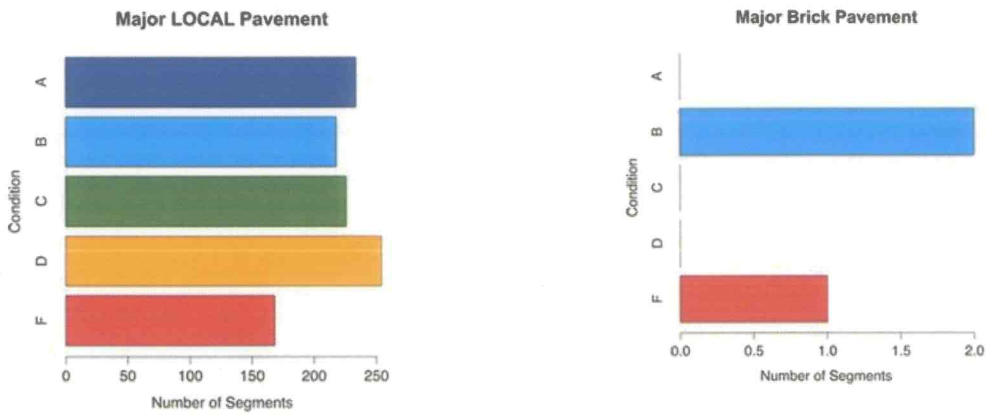
Table 4.3: Distribution of Pavement Types and Conditions - Major Streets

<table>
<tr><th>Pavement Type</th><th>Segments</th><th>Length (ft)</th><th>Length (miles)</th><th>Total Length (miles)</th><th>Percent of Total (%)</th><th>Average PCR</th></tr>
<tr><td>BRICK - MBI</td><td>1</td><td>360</td><td>0.1</td><td rowspan="2">0.2</td><td rowspan="2">0.1</td><td>77.3</td></tr>
<tr><td>BRICK - NOACA</td><td>2</td><td>475</td><td>0.1</td><td>62.0</td></tr>
<tr><td>CRC - MBI</td><td>9</td><td>5,700</td><td>1.1</td><td>1.1</td><td>0.4</td><td>93.1</td></tr>
<tr><td>LOCAL - MBI</td><td>330</td><td>128,030</td><td>24.2</td><td rowspan="2">239.9</td><td rowspan="2">86.3</td><td>76.7</td></tr>
<tr><td>LOCAL - NOACA</td><td>770</td><td>1,138,843</td><td>215.7</td><td>70.5</td></tr>
<tr><td>JCP - MBI</td><td>83</td><td>20,050</td><td>3.8</td><td rowspan="2">36.7</td><td rowspan="2">13.2</td><td>83.9</td></tr>
<tr><td>JCP - NOACA</td><td>173</td><td>173,765</td><td>32.9</td><td>84.5</td></tr>
<tr><td>Total</td><td>1368</td><td>1,467,233</td><td colspan="2">277.9</td><td>100.0</td><td></td></tr>
</table>

MBI – Rated by Michael Baker
NOACA – Rated by ODOT

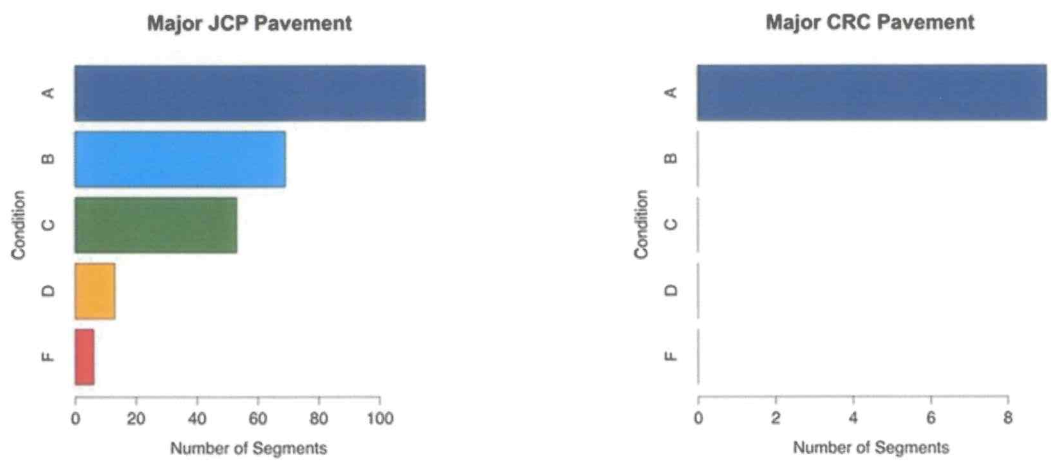
The condition of the various pavement types varies as shown in the graphs below in Figure 4.3. The condition of the Major roads is depicted graphically by color-coding in Exhibits 19-23 (following the main body of text).

Figure 4.3: Overall Condition Assessment by Pavement Type (Arterial Streets)



(a) LOCAL pavement – Dominant pavement type; condition uniformly distributed to all grades.

(b) Brick Pavement – Minor component.



(c) JCP Pavement – Second largest pavement type; condition generally fair.

(d) CRC Pavement – Minor component, performing well.

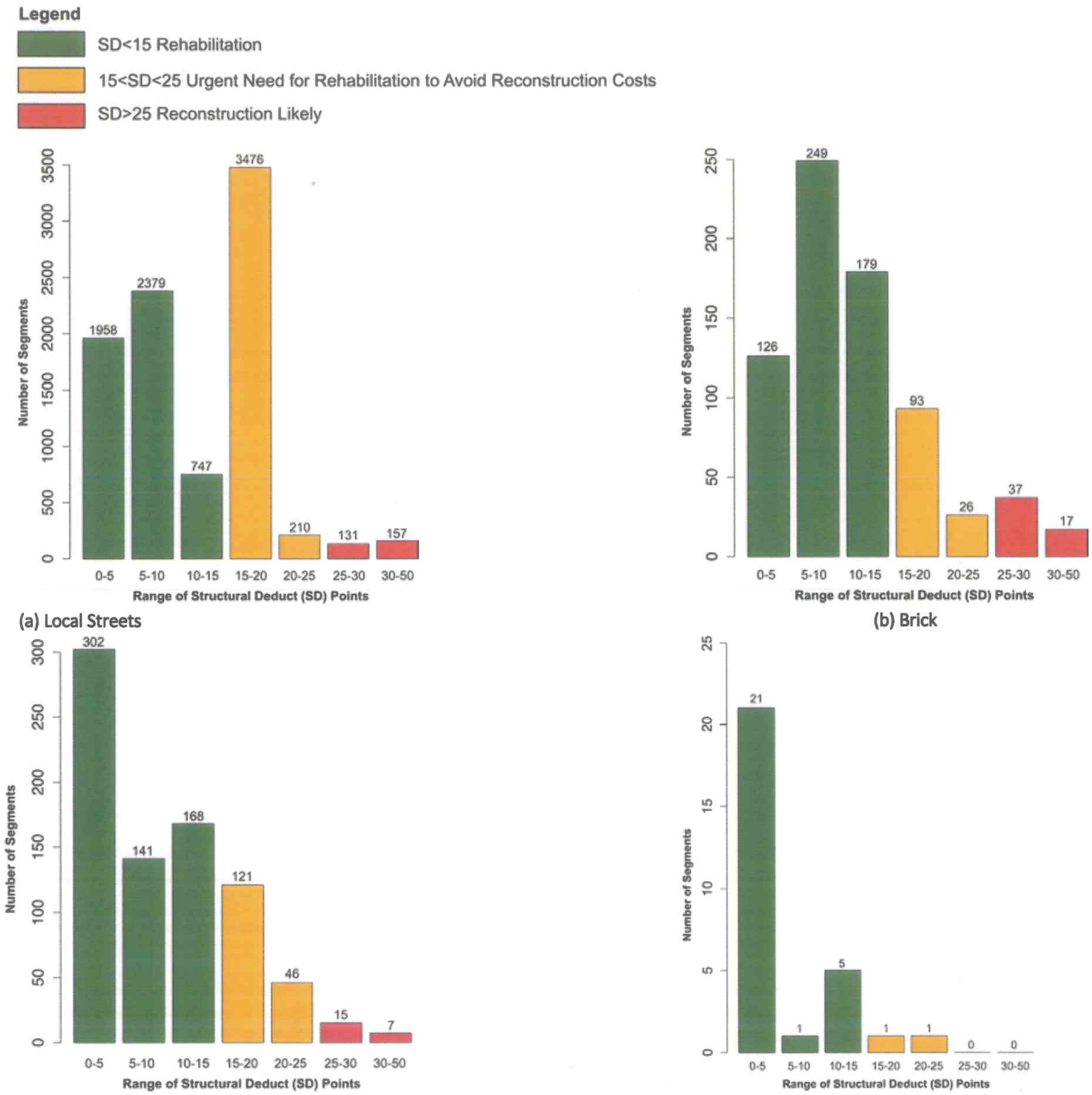
Legend:	Condition	PCR Range
	A	91-100
	B	76-90
	C	66-75
	D	56-65
	F	0-55

4.3 Structural Deduct Value

A subset of the distress ratings used to compute a PCR are also totaled to produce a 'structural deduct (STR)' value. This number is derived from distress categories selected by ODOT for each pavement type. The STR is used to differentiate distresses that are largely due to deterioration of the pavement surface from those that indicate structural failure of the pavement system. These typically include distresses such as base failure for LOCAL pavement, and major cracking of rigid pavement. ODOT recommends that a pavement with an STR equal to or greater than 25 be considered for reconstruction. Rehabilitation is likely to be uneconomical because of the extensive structural repair work required.

Graph (a) in Figure 4.4 shows the distribution of STR values for the LOCAL rated streets. The numbers of segments that are currently over the 25 threshold are relatively small (288), but the largest category (3,476 segments) is in the 15-20 range suggesting that there is a large number of these streets that are approaching the critical level where rehabilitation may be substantially more costly. Streets in this category should be considered priorities for rehabilitation in the short term to reduce the potential for further critical deterioration. Graphs (b) through (d) in Figure 4.4 present the distribution of STR values for Brick, JCP and CRC streets.

Figure 4.4: Distribution of Structure Defect Ratings



(a) Local Streets

(b) Brick

(c) JCP

(d) CRC

4.4 Analysis of Distresses by Pavement Type

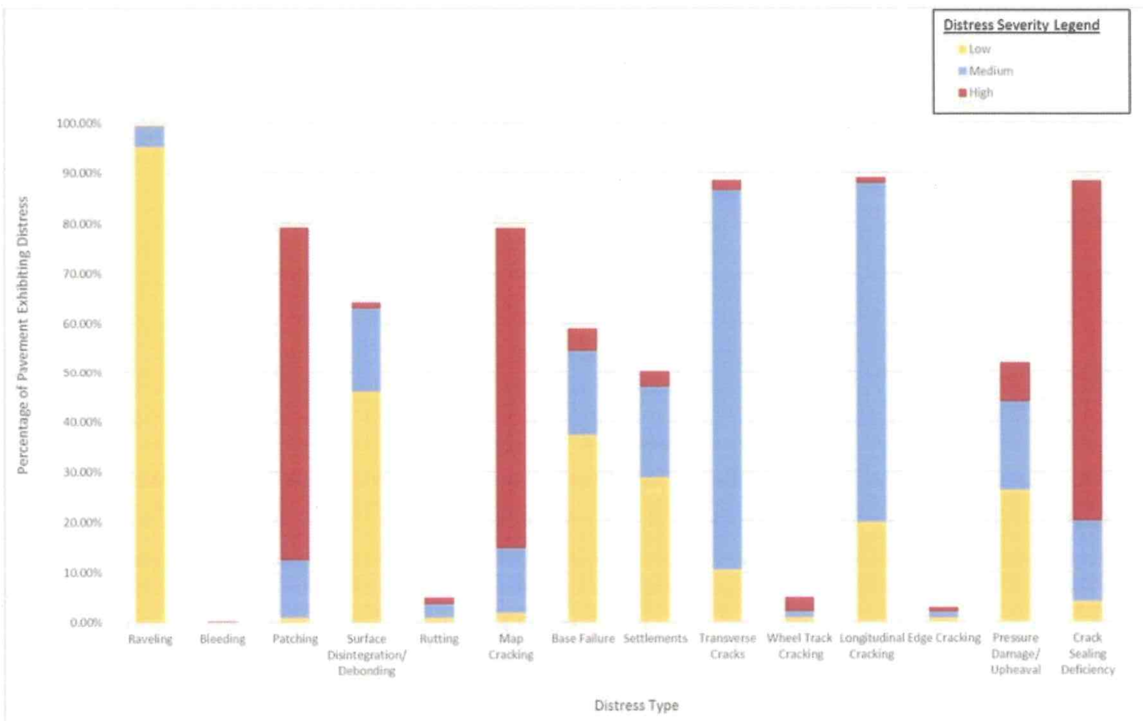
Beyond the snapshot of the current condition rating, an analysis of distresses and their causes can provide the managers and maintainers with insight into ways to better manage their pavement system. Distresses are generally caused by three factors: environment, load, and materials/construction practices. Analysis of the common distresses can help identify areas in which processes or practices could be changed in order to extend service life, creating a more cost effective system to operate and maintain. Recommendations for changes in practices that could reduce distress occurrence and extend pavement life have been provided. (See Appendix E)

4.4.1 LOCAL Pavement

LOCAL pavement (as defined by ODOT for rating purposes) includes all asphalt-surfaced roads in the City. Almost 85% of the City pavement by surface area includes an asphalt concrete surface. The LOCAL classification of street is rated in such a way that it identifies asphalt related distresses in the same way that FLEX or COMP pavement would be rated, but includes additional factors (base failure, pressure damage - upheaval) that are indicative of structural deficiencies, and which have an impact on ride quality. Typical distresses observed in asphalt include raveling, patching, debonding, crack seal deficiency, transverse cracking and longitudinal cracking. Raveling, debonding and block/transverse cracking are distresses typically related to environmental and age deterioration of the pavement. However, these distresses could also be an indication of poor construction practices if they are occurring in the pavement at an early age. Longitudinal cracking is directly related to construction and typically occurs along the paving joints between lanes. These are typically the weakest portion of the pavement and will open up over time as the pavement becomes more brittle. While this cannot be fully prevented, their formation can be delayed by ensuring proper construction practices. Patching and crack sealing deficiencies are directly related to maintenance. Patches are often related to utility cuts and other maintenance actions, which require removal of the existing pavement and replacement with a patch. Typically a patched pavement is not going to perform as well as the original pavement and the patch can deteriorate quickly causing major distress. Crack sealing deficiency is the failure to seal cracks after they have formed. Sealing cracks is a low-cost maintenance process that has been proven to significantly extend the life of a pavement. Sealed cracks will retard deterioration and prevent moisture from infiltrating the underlying pavement layers.

Changes in construction and maintenance processes and procedures can help reduce the occurrence of many of the common asphalt pavement distresses. Changes in mix design procedures and better quality control during paving can help reduce many of these distresses. Ensuring that a dense graded asphalt mat is produced is key to preventing premature raveling and debonding. Proper use of tack coats between asphalt lifts can also inhibit debonding of the surface layer. Many agencies have begun to require density testing on paving joints to ensure that they meet minimum requirements to inhibit premature opening of the paving lane joints. Changes in maintenance practices could include implementing a comprehensive crack sealing program will help maintain cracks when they do form and extend the life of the pavement. Periodic surface treatment application can also rejuvenate and retard aging. Surface treatments are a relatively low-cost treatment method that will prevent the need for more major rehabilitation such as a resurfacing project. (See Appendix F) While it is difficult to prevent patching requirements on city streets, ensuring any patches are properly placed and compacted is critical to ensure the patches will perform similarly to the existing pavement and minimize the loss in service life resulting from the patches. The chart in Figure 4.5 provides a summary of the distresses in LOCAL pavement.

Figure 4.5: Local Pavement Distress Rates



Note: For Crack Seal, the colors shown indicate the extent with which crack seal was present with yellow being <50%, blue >50% and red indicating that there were cracks but no sealant was present.

The figure clearly shows a pattern of distress in this category of pavement that can be characterized by:

- More than 50% of the streets exhibit at least 10 of the 14 possible distress features
- Almost 80% show serious distress due to patching

- Map cracking, a feature of old asphalt pavements that are subjected to thermal stress is prevalent in almost 80% of segments, and is severe in more than 65% of them.
- Serious crack sealing deficiencies are noted in more than 70% of segments.

Given the dominance of this pavement type throughout the City, maintenance needs are clearly present on a very large scale.

4.4.2 Concrete Pavement

There are two types of concrete pavement in the network, jointed concrete pavement (JCP) and continuously reinforced concrete pavement (CRC). For the surveyed roads, JCP pavement makes up approximately 9% of the total by surface area while CRC makes up less than 1% of them. Common distresses found in JCP include surface deterioration, joint spalls, patching, pumping and transverse and longitudinal cracking. Common distresses observed in CRC include popouts, patching and pressure damage. Pressure damage and longitudinal and transverse cracks are typically load and age related distresses but could occur at an early age if the pavement was inadequately designed or constructed. They may also occur if the operational traffic load exceeds the design value. Popouts, surface deterioration and joint spalling are all typically caused by poor quality construction materials or practices. They can also occur through operation of the pavement by foreign material being introduced into the joints preventing thermal movement or abrasion of the pavement due to traffic and environment. Patching can be used to correct many different distresses. For patching to be identified as a scored pavement distress, it must either be made with asphalt or have deteriorated. These identified patches can be a hazard to traffic and cause further deterioration of the pavement. Pumping typically occurs along paving joints when there is a loss of, or lack of, load transfer. Pumping can also occur at cracks due to the crack not having load transfer devices.

Many of the common distresses identified in JCP and CRC pavement can be reduced through changes in design and construction requirements. Ensuring a pavement is adequately designed for the anticipated load is critical to ensuring load related distresses do not occur early in the life of the pavement. Ensuring high quality materials are used in the pavement production and proper construction techniques are used can help reduce material related distresses. Aggregate quality is critical to prevent surface deterioration and popouts in pavement. In severe winter weather aggregates can be susceptible to deterioration under freeze-thaw cycles. Performing aggregate soundness testing and ensuring aggregates are not reactive can help prevent these material related distresses. Maintaining proper load transfer can not only prevent pumping, but can extend the structural life of JCP. Maintaining joints and resealing them will help prevent incompressible materials and moisture from infiltrating the joints preventing spalling, pumping and loss of load transfer. Performing dowel bar retrofits in pavement where load transfer is lost is a cost-effective maintenance method to help restore load transfer and extend pavement life. When cracks do form in the transverse direction dowel bar retrofits can be used to create load transfer in the crack and prevent faulting and pumping of the cracks. These maintenance methods are effective at extending the life of the pavement without major rehabilitation costs. Figures 4.6 and 4.7 summarize the distresses found in the two types of concrete pavement.

Figure 4.6: Jointed Concrete Pavement (JCP) Distress Rates

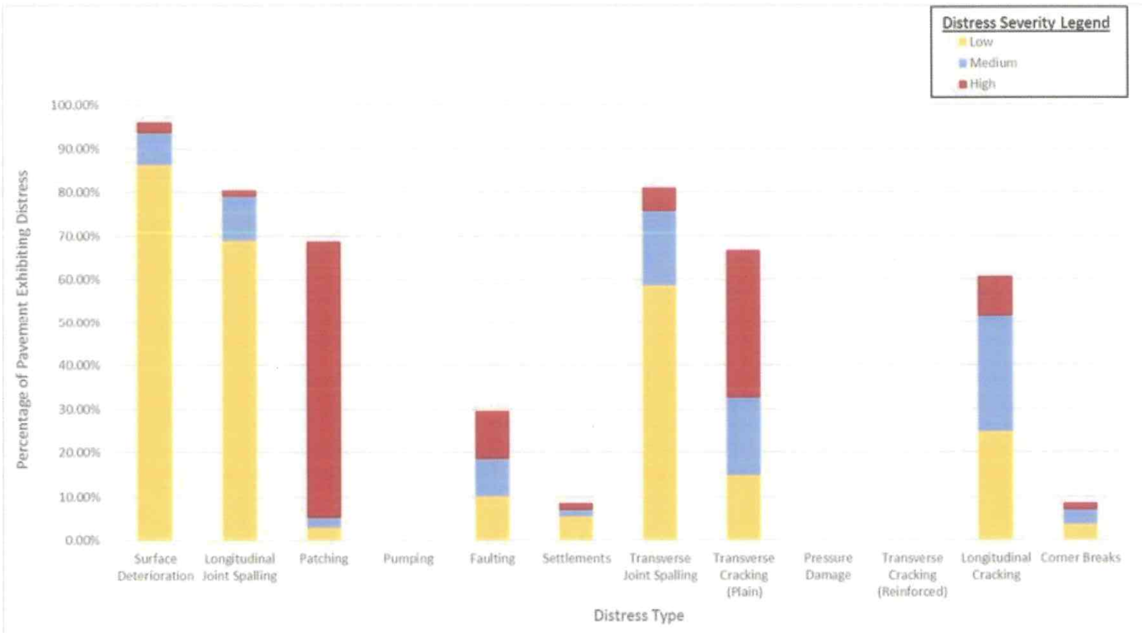
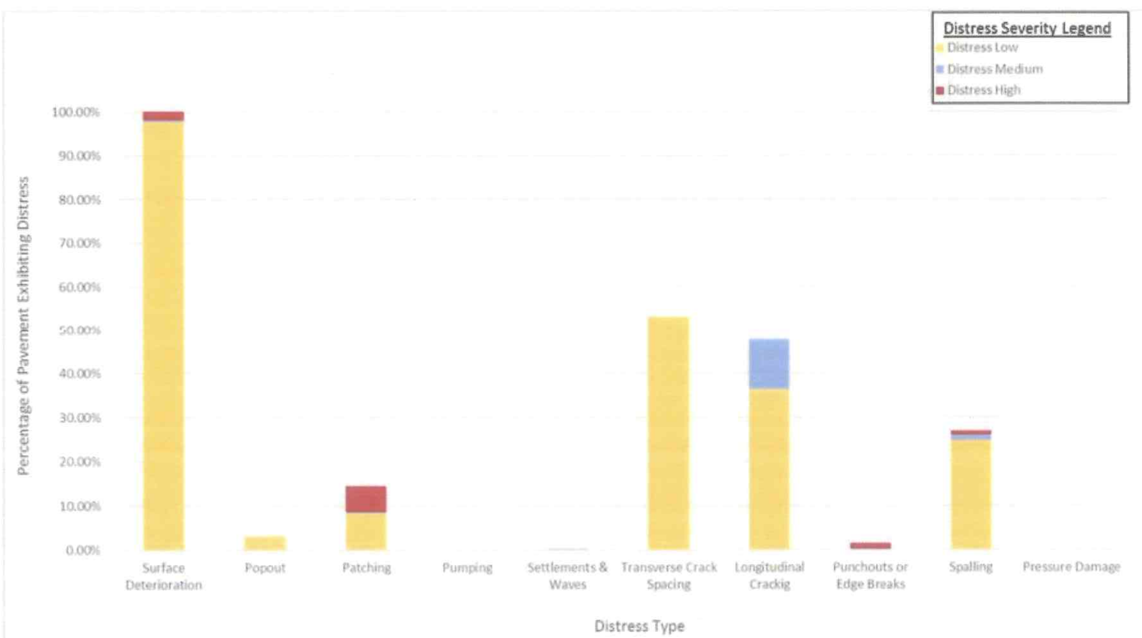


Figure 4.7: Continuous Concrete (CRC) Pavement Distress Rates



These figures show the relatively good performance of CRC pavement (see also Figures 4.2(c) and 4.3(d)). However, the older JCP is fairing slightly less well and is experiencing problems associated with patching (65% - severe) and various forms of cracking - generally of low to moderate severity. Surface deterioration is widespread (95%) but of low severity.

4.4.3 Brick and Gravel Pavement

Brick paver surfaces make up approximately 6% of the surveyed system. The common distresses observed in brick pavers include brick deterioration, pumping, joint erosion and brick settlement. Most of the brick pavements in the system are very old and difficult to maintain. The major distresses are generally related to loss of structural support and deterioration of the pavers themselves. Most new construction no longer uses true brick pavers, but rather has an underlying structural system with a brick surface. Maintaining brick pavers is difficult. If repairs are needed, removal and replacement of the underlying materials will help to stabilize the area being repaired and preventing deterioration of the replacement bricks. Ensuring new bricks are sound is also critical to prevent joint erosion and brick deterioration.

Two gravel pavements were rated; surface deterioration and poor drainage are noted as primary distresses. Figures 4.8 and 4.9 provide charts summarizing the distresses found in brick and gravel pavement.

Figure 4.8: Brick Pavement Distress Rates

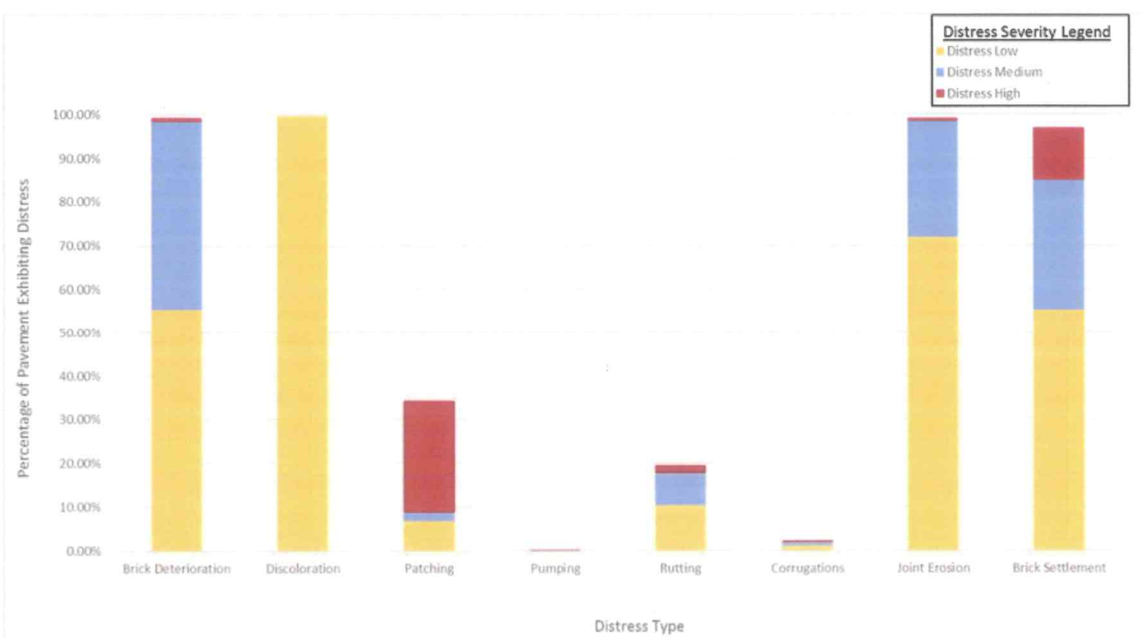
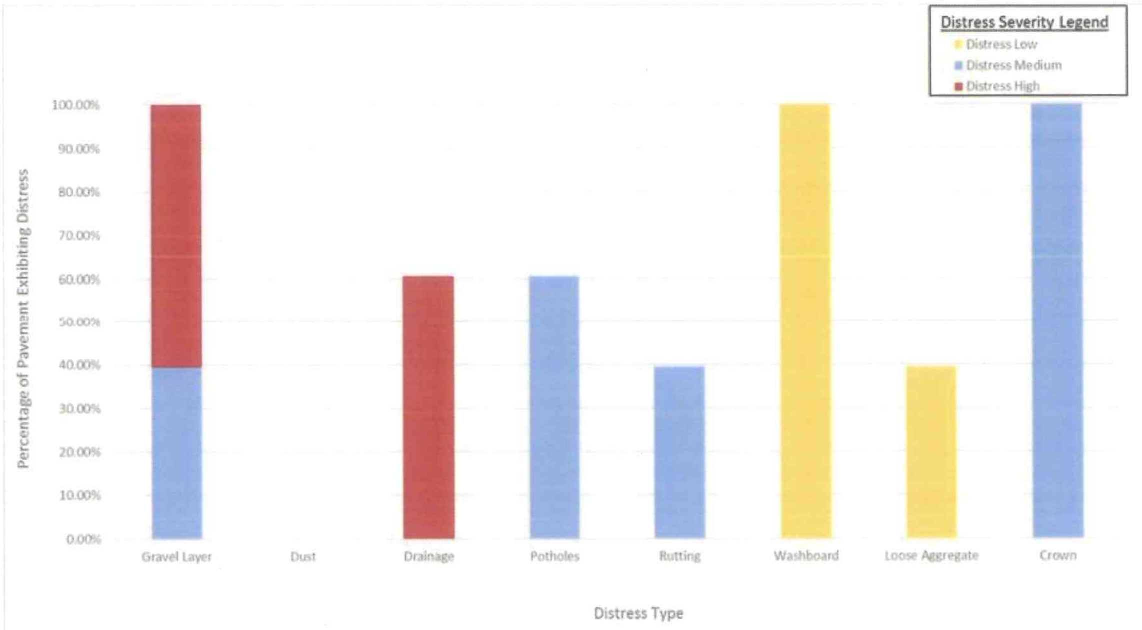


Figure 4.9: Gravel Pavement Distress Rates



5. TRAINING

The City is incorporating pavement condition assessment into its overall pavement management program using internal and external resources. Michael Baker provided training for City staff that covered: Pavement Condition Rating (consisting of both classroom and field instruction), ODOT's LPAT and data transfer with RoadManager. The rating sessions were conducted on November 16-17, 2015 and again on May 3-4, 2016.

5.1 Pavement Condition Rating Training

The Pavement Condition Rating (PCR) system was developed by the ODOT for inspecting and managing roadway network pavements at both state and local levels. The goal of this course was to give participants an overview of Pavement Management, and the ODOT PCR system. Attendees were instructed on how to identify and quantify distresses according to the PCR methodology. The course included both classroom training and field surveys. Field surveys were instructor led inspections of pavement to apply the material learned in the classroom.

Details of the training including: Instructor, References, Course Objectives, and Sign-In Sheets are presented in Appendix D.

5.2 ODOT Local Pavement Assessment Tool (LPAT) Training

This training provided instruction on the use of ODOT's software program LPAT and while covered in the first two training sessions, was again presented on July 8, 2016 when three tablets loaded with the software were delivered to the City Staff. LPAT operating procedures are outlined in Appendix D.

5.3 Data Transfer with RoadManager

Training was provided regarding the process to upload survey data into the City's RoadManager database. The upload and training took place on December 20-21, 2016 with documentation provided. This allows the City to update the pavement data annually as well as connecting to NOACA's latest maps.

6. PAVEMENT MANAGEMENT

6.1 Causes of Pavement Degradation

Individual distresses experienced by a pavement system can have a variety of causes, but usually depend on one of three primary mechanisms, sometimes acting together in concert: age related material deterioration, excess loading beyond design expectations, and direct destruction caused by utility cuts. Each is inevitable given passage of sufficient time, but pavements can be protected against all three, extending the service life for many when maintenance is managed carefully and funded adequately.

Asphalt paving, which covers ~85% of the city streets,begins a slow process of decomposition through oxidation starting the moment it is laid. As it ages, the flexible component in the asphalt oxidizes leaving a brittle skeleton of asphaltenes and aggregate that is increasingly susceptible to cracking.

All pavement types are designed to resist the vehicle loading that traffic that will impose, as characterized by repetitions of heavy truck axle loads. Once this design value is exceeded, fatigue is likely, resulting in such structural deterioration as base failure.

Utility cuts are an essential aspect of urban development, but often create localized zones of pavement that are susceptible to accelerated deterioration. Multiple openings along high traffic routes can soon lead to high distress levels.

6.2 Comparison of Pavement Management Programs

This section discusses the current City of Cleveland pavement management program and comparable features in ODOT's own programs for management of the State's highway infrastructure. Overall, the City's program is capable of providing appropriate planning information to managers to assist them in the effective use of resources. However, given the passage of time since it was last updated, there may be opportunities for improvement based on the new survey, current technology and management practices.

6.2.1 City of Cleveland

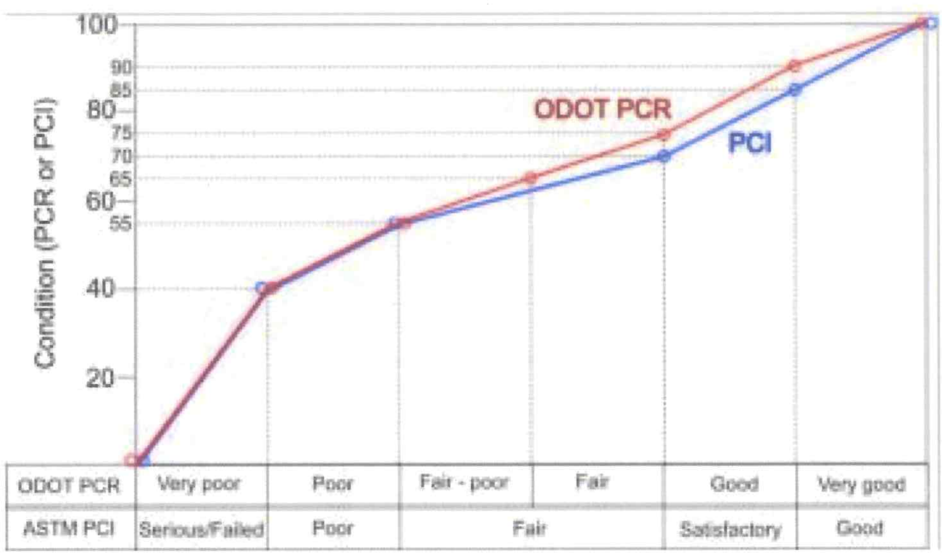
The City is keenly aware of the need for systematic and cost effective improvements to its transportation infrastructure. Its roadways (excluding Interstate Routes) include approximately 1,200 miles of scored Minor and Major streets, constructed with brick, jointed concrete, continuous reinforced concrete, or asphalt paving overlaid on concrete or brick (composite).

A pavement management program was developed in 2009 based on a detailed condition assessment performed in 2008. The program includes a custom GIS-based management system (RoadManager) that runs as a plug-in to ArcGIS, a geographic information system. Sixty-five fields of geo-referenced data may be captured by RoadManager including locational information, traffic counts, segment geometry, pavement type, and general pavement, curb and sidewalk condition. The specific nature of observed deterioration is not captured and would be a useful addition to support future diagnostic or forensic evaluations.

The results of baseline condition assessments and subsequent updates are input and the system is then able to generate annual planning scenarios for maintenance and rehabilitation activities, subject to overall budgetary constraints and compensating for the tendency of ongoing roadway network deterioration over time. It is unknown if any planning scenarios were generated from the 2009 program.

It should be noted that RoadManager database appears to be configured to accept a Pavement Condition Index (PCI) input (ASTM D6433) rather than the widely used (in Ohio) ODOT pavement condition rating (PCR). The current (2015) condition assessment uses the ODOT PCR, although this is stored in the 'PCI' field of the RoadManager database. This was used to permit proper upload to the City database. There is no distinct correlation between PCR and PCI - both are used to create subjective condition descriptions ('good', 'fair', A, B, C etc,) and associated thresholds for the various levels of maintenance or rehabilitation. (See Figure 6.1 below)

Figure 6.1: Approximate PCI/PCR Correlation



6.2.2 Cuyahoga County

Cuyahoga County does not currently have a formal pavement management program. In the past, they have used a combination of excel spreadsheets, inspectors, and ODOT data to determine roads that need repair. They currently rely on the municipalities to provide this information.

6.2.3 ODOT

Due to the size and complexity of the ODOT roadway network, a variety of management tools have been developed over the years to assist in the development and implementation of maintenance and rehabilitation plans. These tools provide input to ODOT's implementation of the Deighton Total Infrastructure Management System (dTIMS), a proprietary system now in use at 14 US state transportation agencies. Inputs to the system include programmed projects (from ELLIS), PCRs, budgets, project unit costs, project histories, traffic projections and decision trees. This state of the art system effectively addresses the data and analytical needs of all participants in the agency's pavement management program.

6.3 Pavement Options

The City currently classifies its roadway maintenance / rehabilitation activities for budgeting purposes based on their application to either Major streets (excluding Interstate Routes) or Minor streets. The current suite of options considered by the City for planning purposes is shown in Table 6.1:

Table 6.1: Options for Planning Purposes

Major	Minor
Routine Maintenance	Routine Maintenance
Mill and Fill	Mill and Fill
Mill and Fill w/ full curb	Mill and Fill w/ full curb
Mill and Fill w/ full curb and sidewalk	Mill and Fill w/ full curb and sidewalk
Reconstruction	Reconstruction
Slab Replacement	Slab Replacement
	Spot Repair - Brick

6.3.1 "Fix-It-First"

"Fix-It-First" is a relatively new concept for maintaining asphalt surfaces whereby the mechanisms that contribute strongly to natural deterioration of the asphalt itself are recognized and addresses by the application of surface treatments before the pavement starts to develop distress symptoms. This may mean that pavement with a PCR in the 90 - 100 range could receive treatment and thus extend the period where it scores in this range from 4 - 6 years to 8 - 12 years at very modest cost. Surface treatments include micro-surfacing using polymer modified asphalts that are applied as thin lifts (approximately 1.5 inches) and contain additives to improve their strength, permeability, crack resistance or temperature tolerance, depending on the needs. The financial benefits of "Fix-It-First" are high. With a given budget the additional coverage and associated maintenance of elevated PCR scores creates a high value alternative to a 'Fix it When it Breaks' or a "Worst First" approach.

6.3.2 Maintenance

Routine, or preventative maintenance activities can include treatments such as crack sealing, chip sealing, fog sealing, rut filling, and thin overlays. They can also include relatively new technologies such as ultra-thin wearing courses, very thin overlays, and micro-surfacing applications. Aside from crack treatments, all of these treatments leave the pavement with a new wearing surface. A fog seal provides a new wearing surface, although it generally has a lower friction number than the original surface.

For concrete pavement, patching, joint sealing, and crack sealing are the only measures being used right now. As concrete roadways are still widely constructed, it is known that additional or more efficient preventative measures would be beneficial in increasing the lifespan of concrete pavement.

Brick pavement currently undergoes reactionary maintenance. As rating brick roads is still a relatively new process and there are not many new brick roadways being constructed, this research is not as high of a priority as the other types of pavement maintenance.

Corrective maintenance activities for asphalt roadways include structural overlays, targeted mill and fill, pothole repair, patching, and crack repair. Whereas preventive maintenance is performed when the pavement is still in good condition, corrective maintenance is performed when it is in need of repair, and is therefore more costly. It is performed to correct a specific pavement problem or area of distress. Delays in maintenance increase pavement distresses so that, when corrected, the cost is much greater and life cycle costs are considerably increased.

6.3.3 Overlay with or without Milling

At some point in the life of an asphalt pavement, deterioration may become so severe that surface treatments and crack repairs are inadequate and no longer cost effective. At this point, it is typical to apply an overlay that may be on the order of 1.5 inches – 3 inches in thickness on roads. In most urban locations, curbs and gutters are set for pavement storm drainage, and it is not feasible to raise the street elevation by the thickness of additional pavement; milling and disposal of an equivalent amount of existing asphalt is required.

It should be noted that, where the distressed pavement is composed of asphalt on a concrete or brick base (composite), milling is limited to the thickness of the asphalt. In the case of a brick base, a thin layer of asphalt should be left in place to prevent damage to or dislocation of the bricks.

Overlays are suitable for situations where deterioration of the pavement has resulted from asphalt degradation. If the problems are subgrade related, replacement of one layer of asphalt with another is unlikely to be effective, and full depth reconstruction should be considered. This decision should be made at the outset based on specific knowledge of the soil conditions, design, and buildup of the existing pavement in the project area. If this is not available, exploration using subgrade borings and / or pavement cores should be undertaken so that the resulting design is sufficient for the anticipated traffic loading given the local subgrade conditions. This is particularly relevant in the study area where subgrade conditions are variable and may include extensive amounts of frost susceptible silty soils.

6.3.4 Reconstruction

Reconstruction is the most extreme response to the problem of pavement maintenance. Not only is it the most costly approach by a significant margin, but it also tends to be the most disruptive to the traveling public and will take the longest amount of time for construction.

A design should be prepared as described above and decisions made on the type and extent of subgrade stabilization that is required and the choice of concrete or asphalt pavement - bearing in mind the City's preference in many cases for a composite section consisting of a concrete base with an asphalt wearing surface. This design provides optimum structural capacity while offering good resistance to the deleterious effects of de-icing materials.

6.3.5 Cost Considerations

The cost of pavement maintenance increases in a near exponential manner as the degree of pavement deterioration becomes greater. However, providing reliable cost data for activities that will be contracted for multiple years in the future is challenging because many of the factors that control those costs (e.g. oil prices, changes in regulation, pavement deterioration rate, inflation, size of the project) cannot be predicted with any degree of certainty.

Table 6.2 shows typical reconstruction and repair costs for three recent (2015/2016) road rehabilitation projects in the Cleveland area. Three categories of cost are presented: total project cost, preparatory work such as base repair, driveway adjustment and sidewalks ('Roadway'), and direct paving costs ('Pavement') for the actual pavement build-up bid items. They do not consider project specific factors such as MOT and ancillary works (drainage improvements or manhole adjustments, for example). As such, they should only be used for budgeting purposes after being factored up to full project costs. For mill and fill projects with minor amounts of full depth repair, the roadway and pavement components of the projects are likely to represent only 60 - 70% of the total project costs. The percentages for the pavement and roadway as indicated generally fall within the range indicated above. For less intrusive projects, the percentage is somewhat higher.

Table 6.2: Maintenance/Rehabilitation Cost

Category	Description	Project Component	Cost $/SY	Percent of Total Project
Structural Improvement	28,000 SY 9 inches NRC Pavement, Asphalt Wearing Surface (2015)	Total Project	241	100.0
		Pavement	76	31.5
		Roadway	44	18.3
Resurface	320,000 SY AC Overlay (2013)	Total Project	32	100.0
		Pavement	15	47.0
		Roadway	5	16.2
Resurface	60,000 SY Mill and Fill (2016)	Total Project	41	100.0
		Pavement	23	55.0
		Roadway	5	12.4
City of Cleveland Planning for Asphalt Surfaces	Class	Criteria	2009 $/SY	2017 (MBI est. average cost) $/SY
Routine Maintenance	Local and Arterial	as needed	2	3
Resurface	Local	PCR < 70	15-50	30
Resurface	Arterial	PCR < 75	27-60	50
Structural Improvement	Local	PCR < 50	170	200
Structural Improvement	Arterial	PCR < 55	170	200

Almost 100% of routine maintenance costs are typically in the $1 - $5 / SY range with the higher values representing costs for micro-surfacing and the lower end of the range for crack sealing and pothole filling.

6.4 Findings and Recommendations - Management and Maintenance Practices

6.4.1 Ongoing Pavement Management

In the description of distresses it is frequently noted that a particular feature may be caused by aging of the asphalt, inappropriate design or poor construction. In a study of this type the latter two causes are not typically amenable to quantification - yet they are factors that must be acknowledged. The potential for poor long-term performance begins with the design and is then extremely sensitive to construction techniques and materials.

Recommendation: Continue to undertake an engineering review of the 2015/2016 data to evaluate the role of design in those pavements that are badly deteriorated. The review may be conducted on a sub-set of the data for efficiency. This review is likely to result in recommendations for modifications to current design methods.

Recommendation: Continue to emphasize the role of subgrade exploration where pavement deterioration is sufficiently severe to warrant reconstruction or major repair. Use subgrade borings and pavement cores along with current ADT estimates to validate the pavement design.

Recommendation: Review construction practices to pursue continuous improvement in methods of construction activities, together with regular feedback to designers.

This is not to suggest that there are any known or systemic problems with the design and construction processes; merely to suggest that a structured continuous improvement program will inevitably lead to better results.

The City's pavement management system is based on a block-by-block inventory of pavement type, condition and assessment of ancillary features such as curb and sidewalk. This amounts to about ~10,000 discrete roadway segments that provide a wealth of information for use in the maintenance planning process. The City is also located within two larger networks; one being NOACA, covering a wider area of NE Ohio than just the City limits and the other by ODOT, which is statewide in scope. At present it is not a clean comparison between PCR results obtained by

NOACA and ODOT with those from the City's surveys because the regional programs utilize longer segments for their survey and, for example, show only about 1,300 segments within the city limits.

Recommendation: Create a GIS layer that consolidates the City data into similar segment lengths to the NOACA system, so that direct comparisons can be made with data collected over different time periods. PCR values would be averaged for the larger segment using a lane-mile weighted average.

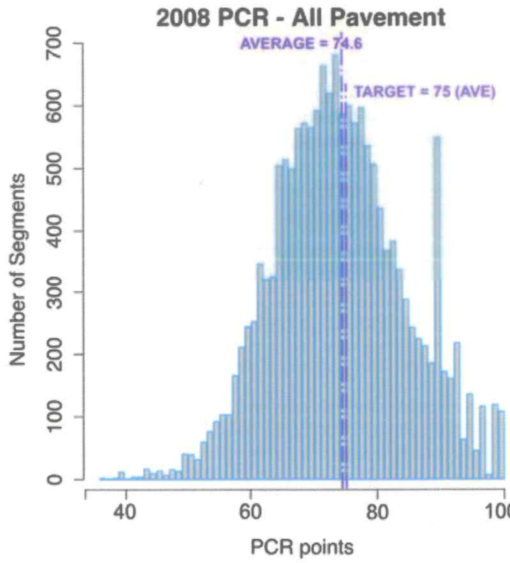
Recently, it has become increasingly common to document site conditions photographically. The advent of GPS equipped digital cameras and inexpensive cloud storage greatly facilitates the process of documenting site conditions, geo-referencing the digital imagery and placing it in a secure archive. Further, the imagery files can be linked to the GIS so that available pictures of a given segment can be displayed at the click of a mouse.

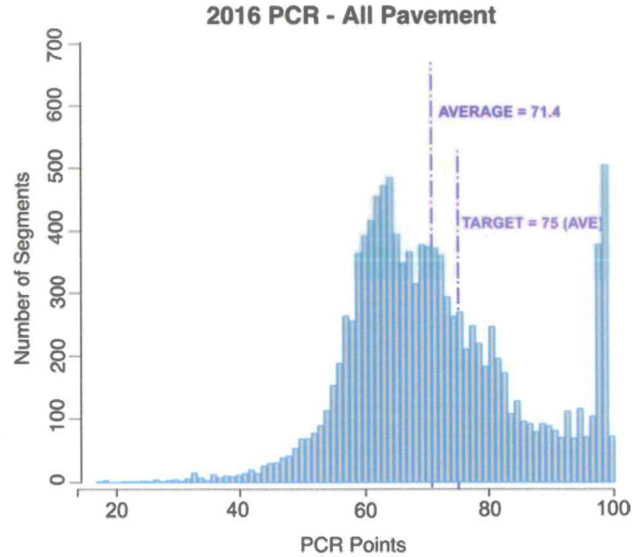
Recommendation: Enhance the data management system by including geo-referenced imagery in subsequent surveys.

When analyzing the results of a conditions survey it would be helpful to have a list of all known new roads (created since the last survey) and a list of those that have been resurfaced within the interval since the last survey. These are essentially the population of PCR=99+ roads and are the starting point for future analysis of historical performance.

Recommendation: Add an attribute to the GIS that identifies new roads and those resurfaced since the last survey.

Figure 6.2: Asphalt PCR Histograms





Note: This is no direct correlation between surveys. It illustrates the recent trend towards the higher PCR average

6.4.2 Asphalt Pavement Management

Asphalt concrete pavement is the dominant surfacing material in the City's roadway network. The condition of the pavement for the current year and the 2008 PCR values are provided in Figure 6.2.

The figures show the frequency with which roadway segments exhibit a given PCR. For example in 2016 there were about 1,100 instances where the PCR was >= 95. In 2008 the pattern is that of a fairly traditional bell curve, slightly skewed to the right. The average PCR presented in 2008 of 74.6 indicating work to be done to reach a target minimum average PCR of 75.

In 2016, there are now two distinct distributions - one centered around PCR = 65 and a new skewed pattern in the PCR = 95 -100 range. This second portion is assumed to represent a population of newly paved streets. The overall average decreased to a PCR = 71.4, well below the target minimum average PCR = 75.

Very little information was available regarding the methods of collection and pavement condition rating/index used for the 2008 Pavement Management Program. Thus, no direct comparisons should be drawn in comparison of the two data sets.

The challenge moving forward will shift from upgrading the PCR of roadway segments to preserving it at minimum cost. The performance of asphalt cement (AC) as a binder in hot mixed asphalt is dependent on its physical properties as determined by chemical composition. This is dominated by asphaltenes that provide body and color, are brittle, but not susceptible to oxidation and maltenes that provide adhesion and which are highly susceptible to oxidation. Over time, the maltenes break down and the asphalt naturally becomes more brittle because of the increased proportion of asphaltenes. Brittleness makes the pavement susceptible to various forms of distress including raveling, and block and transverse cracking. Over time these distress features devolve into potholes and areas requiring patching. Routine maintenance must include consideration of preserving the asphalt quality so that its deterioration and associated distresses are delayed as long as possible.

Degradation rates for asphalt pavement are difficult to predict; there is some data to show that it occurs at a rate of 3-4 PCR points per year. At that rate, a new pavement could move from a PCR of 99 to 75 in 6 - 8 years. ODOT anticipates major maintenance events at years 14, 24 and 34 on new pavement, suggesting that the decay rate may be as low as 2 PCR points per year. In any event there is a decay process that will cause future deterioration unless measures are taken to prevent / retard it. Some of this is traffic related, but much is caused by the effects described above. See Section 7.1.2 for published compared to empirical degradation rates.

As discussed in preceding sections, a currently popular strategy among some DOT's is for pavement life extension known as "Fix-It-First". This emphasizes the preservation of asphalt's physical properties through the application of surface treatments based purely on elapsed time and before significant distress is observed. Periodic application of surface treatment and minor crack sealing at a cost on the order of $3-5 / SY will pay dividends compared to major repairs costing $50 / SY or more at a later date.

<u>Recommendation:</u> Transition the flexible pavement maintenance plan to a balanced "Fix-It-First" program in parallel with the remaining "Worst First" Strategy. This plan will be discussed thoroughly in Section 7.

6.4.3 Concrete & Brick Pavement

Concrete pavement represents about 8% of the City's paved roadway surface. The average PCR has decreased from 76 to 73 from 2008 to the present on the Minor streets, which remain above 80 on the Majors. The concrete segments collectively exhibit high numbers of defects; more than

90% show surface deterioration. Five additional distress types are present at more than 50% of the locations.

Few maintenance options are available. Remediation of concrete surface defects or irregularities can be accomplished through diamond grinding. Dowel and tie-bar retrofitting together with joint re-sealing are additional corrective measures that may be called for. For brick joint erosion, reestablishing the joints can slow the segment PCR deterioration.

Recommendation: Establish a pool of funds for the rehabilitation of Minor Concrete and Brick streets. Section 7 discusses the efforts required to establish the PCR deterioration rate. For planning purposes - $70/SY for concrete; $90/SY for brick.

6.5 Evaluation of Permits and Construction Standards

In addition to the PCR scoring and analysis, Michael Baker also reviewed the City's Division of Engineering and Construction Standard Construction Drawings, Detail Specifications, and Street Opening Permit. A summary of the recommended revisions of each document follows while the commented versions of the complete documents can be found in Appendix E.

6.5.1 City of Cleveland Division of Engineering and Construction Standard Construction Drawings

The City of Cleveland Division of Engineering and Construction Standard Construction Drawings contain typical details for pavement construction and repair including bus pad construction and repair of street openings such as utility cuts; for construction of curbs, curb ramps, sidewalk, and driveways; for common drainage structures including manholes and catch basins; for survey references in the form of monument boxes; and for landscape details including sidewalk bump outs for trees and tree pits. The Standard Construction Drawing set was last issued in 2008 with select sheets reissued in 2009.

The details contained in the Standard Construction Drawings set were reviewed with emphasis on constructability, level of detail to ensure a quality product, and alignment with other standard documents published by other transportation facility engineering and construction agencies such as ODOT. Appendix E contains additional information, but a summary of the following revisions are recommended:

- "Asphalt Resurfacing and Asphalt Surface on Reinforced Concrete Base" detail on ASPH-1, additional dimensions were suggested to provide clarity and consistency between paving operations.
- "Sandstone Curb" detail on CONC-1, necessary compaction of material surrounding the curb may not be achieved and should be clarified.
- "Butt Joint" detail on CONC-1, the addition of dowel bars should be considered with notes as to minimum thickness for usage.
- Curb detail to be used on all curved sections on CR-1, clarification as to timing of placement of the concrete bedding within the construction sequence and the addition of #5 dowel bars at 24 to 30 inch spacing intervals should be considered.
- "Detail for Concrete Wall and Sidewalk," revision of the drainage material details should be considered to better convey water behind the wall.
- "Standard Trench for Pipe Sewers," minimum trench width should be specified to ensure that trench width allows for compaction under the haunch of the pipe and along the side of the pipe.

6.5.2 City of Cleveland Part D – Detail Specifications

The City of Cleveland Part D – Detail Specifications contains City of Cleveland construction specifications to provide clarification, additional information or revision to the State of Ohio, Department of Transportation, Construction and Material Specifications for pavement, roadway, drainage, erosion control, utility, traffic control, and landscaping transportation facility construction items. The City of Cleveland Part D – Detail Specifications were last issued on January 1, 2014.

The City of Cleveland Part D – Detail Specifications were reviewed with respect to verification that requires quality construction materials and procedures. In addition, they were compared with other standard documents published by other transportation facility engineering and construction agencies such as ODOT. The following revisions are recommended:

- Section D-2 "Construction and Material Specifications", the addition of Supplemental Specification 800 is recommended to assure all current revisions to the ODOT Construction and Material Specifications are included.

- Section D-22 “Erosion Control (SWPP), the addition of mid-project updates to the SWPP are recommended to capture changing conditions particularly with regard to needed Best Management Practices (BMPs) and at each new phase of work.
- Section D-23 “Construction of Concrete Base, Pavement, Sidewalks, Driveways and Curb,” a requirement of minimum 24-hour notice by the Contractor prior to concrete placement is recommended.
- Section D-34 “Catch Basins (ODOT Item 611),” additional clarification regarding requirements of submittals, inspection forms, performance reports, and installation plans that may or may not be specified under the ODOT Item 611 should be considered.
- Section D-73 “Testing of Construction Materials (Item Special),” consideration of revision of the Asphalt Extraction Test should be made to the AC Gauge (Nuclear) test as it reduces the effluent waste stream and is currently utilized by ODOT.
- Section D-77 “As-Built Record Plan Set,” addition of allowance of or requirement of a digital set of as-built drawings particularly for drainage systems should be considered.

6.5.3 City of Cleveland Street Opening Permit

Street Opening Permit provisions have been tightened in recent years. The current rules appear to be generally protective of the City's pavements, requiring that:

- All streets constructed or reconstructed within the past five years (known as moratorium streets) require restoration 'full depth from joint to joint and from curb to curb from beginning of project to end project........performed to exactly match the original materials .... '. These restorations to be the subject of 'stamped plans and specifications to confirm that the work conforms to the original material construction'.
- Any street that has been rehabilitated, reconstructed or resurfaced within the past seven years must be 'resurfaced from curb to curb from beginning of project to end project.......The street must also be ground to accept 2-inch asphalt overlay'.
- All other streets are to be restored in accordance with standard drawings provided by the City that require pavement reinstatement to extend 2 ft beyond the edge of the street opening in all directions.

A 2006 study from the University of North Carolina identified why utility cuts degrade pavement (Ogunro, et al, 2006). It found that degradation was unrelated to workmanship, materials used, age of pavement or age of cut. Rather, a utility cut creates a weakened zone in the soil supporting the pavement around the cut. This weakened zone is where pavement degradation generally occurs. The study proposes that pavement should be replaced and patched 5 ft beyond the cut on all sides, thereby re-compacting the weakened soil zone supporting the pavement. Consideration should be given to revising the 'all other streets' provision to require full depth reinstatement for a distance of 5 ft from the cut, rather than the 2 ft currently specified in the standard drawings.

Recommendation: All City Departments (City of Cleveland Water, Cleveland Public Power, Water Pollution Control, etc.) should apply for and adhere to the Street Opening Permit. This would enable all the utility cuts within the City to be inspected by the Division of Engineering and Construction for consistency and to ensure proper restoration. See Appendix E-3 for additional comments.

7. CAPITAL IMPROVEMENT PLAN

The Capital Improvement Plan proposed in this report can roughly be divided into three ideas. Firstly, we present an understanding of the assumptions made for modeling purposes as well as a baseline look at the City's inventory today. Secondly, we present several long term planning models that will help the City compare maintenance approaches and funding at the network level. Finally, a list of 2017-2018 eligible Minor streets was presented to the City on October 14, 2016 as the starting point for determining which Minor streets should be programmed for resurfacing. The PCR scores were compiled by street and segment, worst first, then manually organized to group the segments by street into 'right-sized' lengths. These are intended to represent individual projects for inclusion in a Minor street resurfacing program, currently at $4.4 million, targeted at approximate $10 million with an optional $1 million additional for each of the 2017-2018 construction seasons.

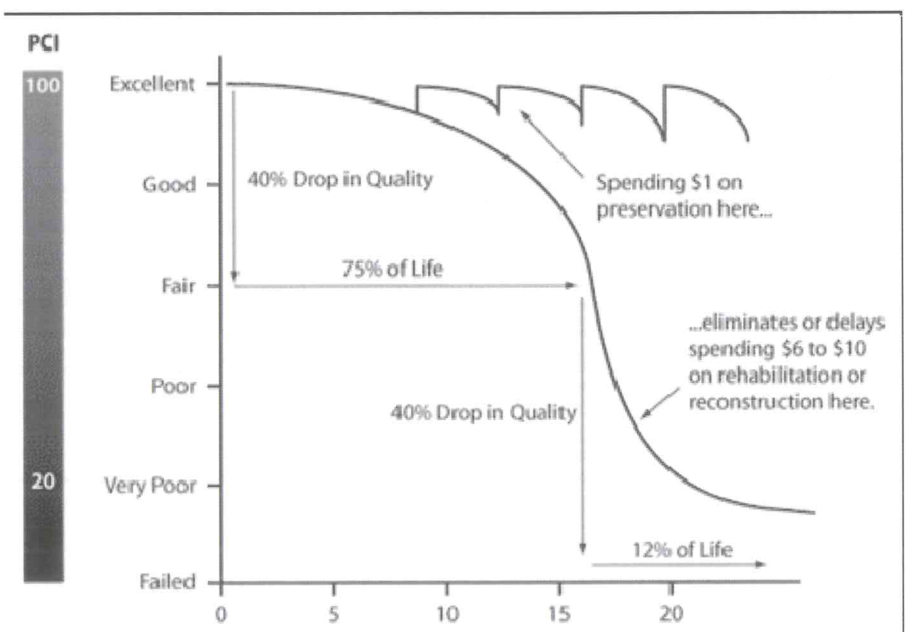
The City expressed a desire to have Minor streets and Major streets split into separate inventories to reflect the management structure within the Department. Michael Baker is providing electronically with this report, separate lists of Minor segment PCR scores and Major segment PCR scores.

7.1 Overview

Transportation access to local destinations and interstate infrastructure supports the social and economic viability of the City. Therefore, the roadway network maintained by the City of Cleveland is a vital asset that should be thoughtfully managed. Development of a pavement management plan is described in ODOT's publication *Pavement Management for Locals Manual* (see Appendix F). A series of flow charts provides guidance on using PCR values as a metric for pavement management decisions. The data collected and analyzed as part of this project will be used by the City in its comprehensive Pavement Management Program.

A graphical illustration of a typical pavement deterioration curve is provided in Figure 7.1. The use of PCI as the rating metric is considered roughly analogous to ODOT's PCR for purposes of this discussion. See Section 6.2.1 for a discussion of PCI and PCR.

Figure 7.1: Typical Pavement Degradation Curve (Source: FHWA)



7.1.1 Methodology of Long Term Planning Models

It is important to understand that the long term planning models may not be fully representative of future conditions. However, an understanding of the methodology of these models should assist the City in interpreting the results and appreciating their limitations. The analysis contains two overarching scenarios: a "Worst First" approach and a "Fix-It-First" approach. Every model was run for 20 years and applied to both Minor and Major streets.

The City's LOCAL inventory was analyzed in the models (See Section 2). In the beginning, streets with the lowest PCR are always addressed first in the model. In all scenarios funds can be spent between three different repair categories: Resurfacing, Routine Maintenance, and Ancillary Items. Resurfacing restores a street's PCR score to 97. Routine Maintenance also restores a street's PCR to 97 but can only be used when several conditions are met:

- Street has already been resurfaced in the model
- Street has ≥92 PCR
- Street can only receive 3 routine maintenance repairs between resurfacings

Ancillary Items represent repairs that do not increase a street's PCR but are necessary, such as ADA ramps, base repair and castings. Previous spending trends from the City of Cleveland's "2015 Resurfacing Analysis" indicated that 55% of the budget was allocated to resurfacing and 45% was allocated to ancillary items. Therefore it was assumed that every 55 cents spent on resurfacing requires 45 cents to be spent on ancillary items.

Using these assumptions two budget scenarios were defined that represent long-term maintenance approaches. The "Worst First" scenario focuses spending on resurfacing and ancillary items only.

"Worst First" Budget for Resurfacing = 55% * Yearly Budget

"Worst First" Budget for Ancillary Items = 45% * Yearly Budget

The "Fix-It-First" scenario allows for spending on routine maintenance. The amount allowed for routine maintenance in "Fix-It-First" strategically changes over time and is represented by a percentage, rmMult (a variable used in the forecast model).

Table 7.1: % of Annual Budget for Routine Maintenance under "Fix-It-First" (rmMult)

Year	1 to 4	5 to 8	9 to 12	13 to 16	17 to 20
rmMult	0%	5%	10%	15%	20%

We recognize the City desire to show immediate progress, and all of our "Fix-it-First" models include addressing the worst streets in years 1 to 4 spending no budget on routine maintenance, whereas years 17 to 20 allow for 20% of the budget to be spent on routine maintenance.

Since ancillary item spending is related only to resurfacing, the "Fix-It-First" budget becomes:

"Fix-It-First" Budget for Routine Maint. = rmMult * Yearly Budget

"Fix-It-First" Budget for Resurfacing = (1 – rmMult) * 55% * Yearly Budget

"Fix-It-First" Budget for Ancillary Items = "Fix-It-First" Budget for Resurfacing * (45%/55%)

With the scenario budget breakdowns established, total budgets and cost of repairs are assigned.

Table 7.2: Budget and Cost of Repair by Model (2016 Dollars)

Model	Base Yearly Budget	Total Cost of Resurfacing + Ancillary Items	Cost of Resurfacing	Cost of Routine Maintenance
Minor	$10 Million	30$/SY	16.50$/SY	2$/SY
Major	$30 Million	30$/SY	16.50$/SY	4$/SY

The cost of resurfacing comes from a base number of $30/SY for programmed resurfacing. Since 45% of that unit cost goes to ancillary items, the remaining 55% is assumed to be the cost for solely resurfacing, resulting in $16.50/SY.

After each scenario has run, the PCR grade scale follows the rest of the report:

- A > 90
- 90 ≥ B > 75
- 75 ≥ C > 65
- 65 ≥ D > 55
- F ≤ 55

Both percentage of streets within a grade and average ratings are weighted by area not number of streets thereby better representing the inventory as a whole.

The intent of the scenarios is twofold. The first is to show if a certain level of funding can maintain or improve the overall health of the inventory. The second is to compare how different maintenance approaches affect the inventory over a long term.

7.1.2 Pavement Deterioration Rates

A key variable in the analysis of rehabilitation effectiveness is the annual pavement deterioration rate measured in PCR points per year. ODOT has estimated that it may be as high as 3.8 points/yr, but an analysis of pavement performance in the Cleveland area suggests that this may be excessively high. Consider a newly constructed road rated at a perfect 100 PCR. A degradation rate of 3.8 points/yr would reduce this new road to a 24 after twenty years if left untouched. This may be conservative.

Without other surveys of the City's inventory, it is difficult to assign an accurate deterioration rate. However Michael Baker has gone to great lengths to bound the problem and provide the city two rates for consideration. This range can be reduced as more information is gathered through annual resurvey of the City inventory.

The first analysis uses the deterioration rate that was proposed by ODOT in their publication *Pavement Management for Locals Manual* (see Appendix F).

Table 7.3: ODOT Pavement Deterioration Rates

90 - 100	80 – 89	70 – 79	60 – 69	50 – 59	< 50
3	4	3	2.5	3.0	2

Table 7.3's first row represents a segment's current PCR. The second row represents that segments degradation rate for the year. A segment rated at 95 will drop to 92 over a year, while a street rated 85 will drop to 81. This deterioration rate should be considered a realistic, though **pessimistic** model for the City's inventory. It is questionable whether this model is accurate at lower PCR levels.

To address this question, Michael Baker looked at a significant sample of the City's inventory. By graphing this sample's PCR against when it was last resurfaced, an empirical deterioration rate was determined. The behavior seen in this deterioration rate tended to agree with the ODOT deterioration rate at higher PCRs. However, this empirical analysis showed that at the network level, streets stabilized in PCR around 65. This stabilization at the network level (as opposed to a specific segment) could possibly be explained by other city maintenance programs outside of capital improvement that prevent many streets from falling under 65. This isn't to say that a specific segment won't fall to a rating under 65. The data sets provided show quite the opposite. Rather this is to say the network currently stabilizes around 65 on average.

Figure 7.2: Empirical Deterioration Rate

Pavement Age (Years) vs PCR Averages with Linear Regression

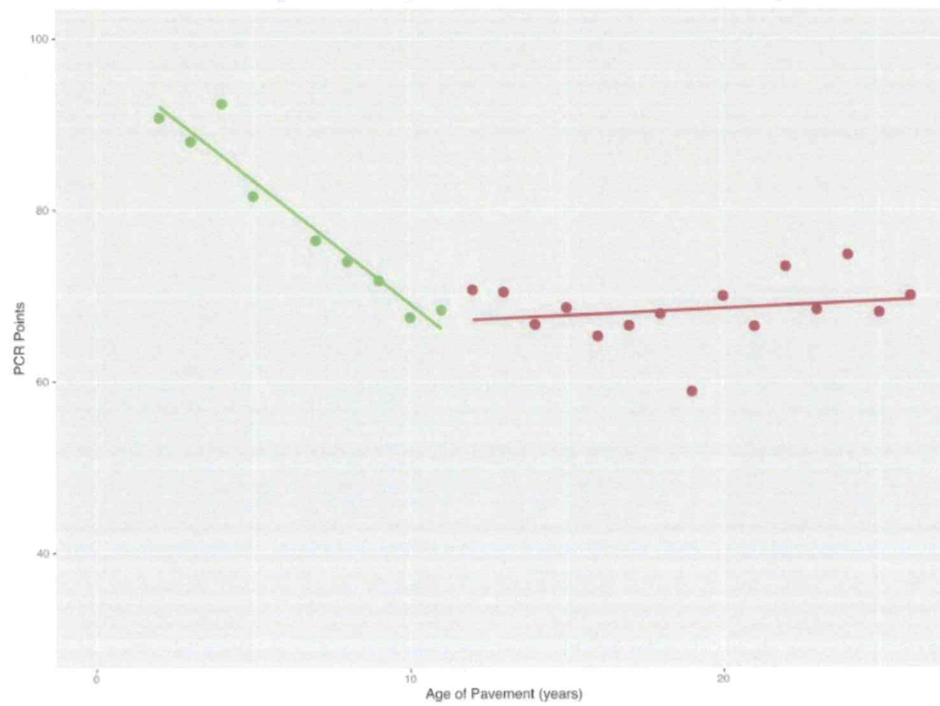


Figure 7.2 shows the actual Empirical Deterioration Rate. Dots of both red and green represent the average PCR of all segments that have pavement of a given age. For example, this graph shows that all pavements that were resurfaced 5 years ago have an average PCR of just above 80. The green regression line on the left side of the figure shows that pavements 11 years or newer degrade at approximately 3 points/yr. The red regression line to the right shows that at year 12, we begin to see a stabilization in average PCRs at around 65. This is the network level

stabilization discussed in the previous paragraph. Therefore the proposed Empirical Deterioration Rate is 3 points/yr until PCRs reach 65, where they remain until repaired.

This empirical deterioration rate should be considered an **optimistic** model for the City's inventory. Michael Baker believes that the true deterioration rate lies between the ODOT and Empirical models. While this report realistically bounds the problem, future pavement surveys will narrow the range of the forecast.

7.1.3 Long Term Budgeting Assumptions

Budgeting far into the future - in this case 20 years contains risks - costs may change significantly, inflation may become much higher than it is today, and funding sources may not remain constant. All can have a profound effect on the outcome and usefulness of a budget. For purposes of this study, the decision was made to maintain a simple set of assumptions - namely, that funding sources would remain available at current level and inflation would occur at **3.5%** annually.

7.1.4 Existing Conditions

The overall PCR for the City as rated in 2015-2016 is 71. Pavement condition distributed by Cleveland City Council Ward is shown in Figures 7.3 and 7.4 and Tables 7.4 and 7.5.

Figure 7.3: Existing (2015/2016, Local & Major) Average PCR by City Council Ward

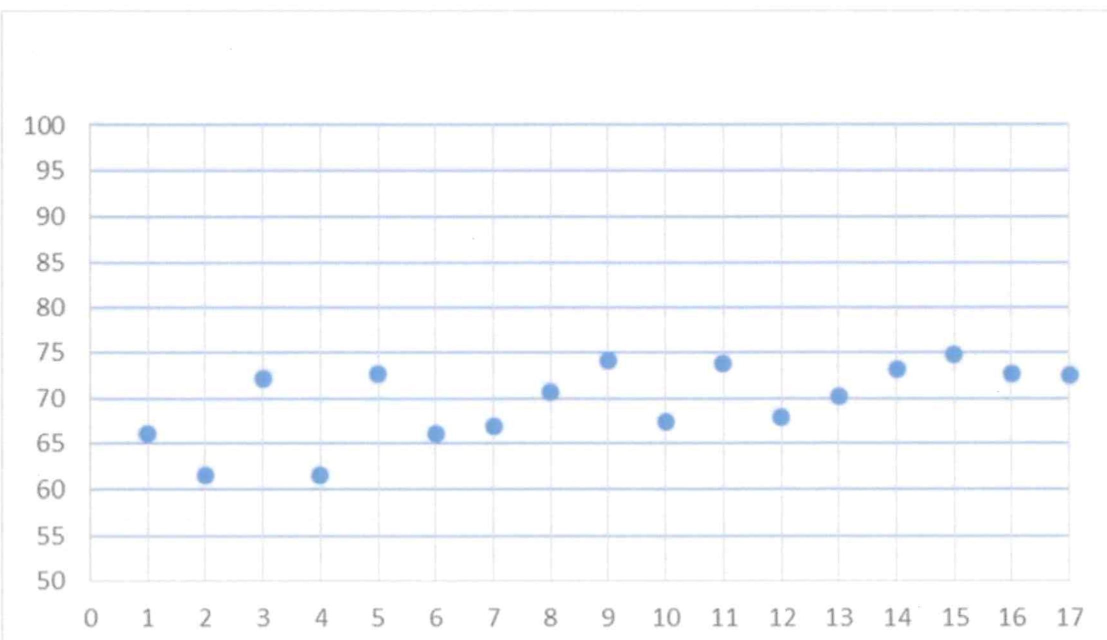


Table 7.4: Existing (2015/2016) PCR by City Council Ward

Ward	Lowest PCR	Highest PCR
1	26.58	97.58
2	15.31	94.81
3	31.36	98.36
4	28.59	94.09
5	24.00	97.50
6	15.90	96.90
7	25.96	96.60
8	43.24	95.74
9	38.80	95.80
10	38.82	94.32
11	49.22	98.50
12	31.04	99.04
13	39.91	94.21
14	27.49	99.24
15	39.25	99.75
16	29.32	97.82
17	30.79	96.29

Figure 7.4: Existing Average PCR by Pavement Type (Minor & Major) and Ward

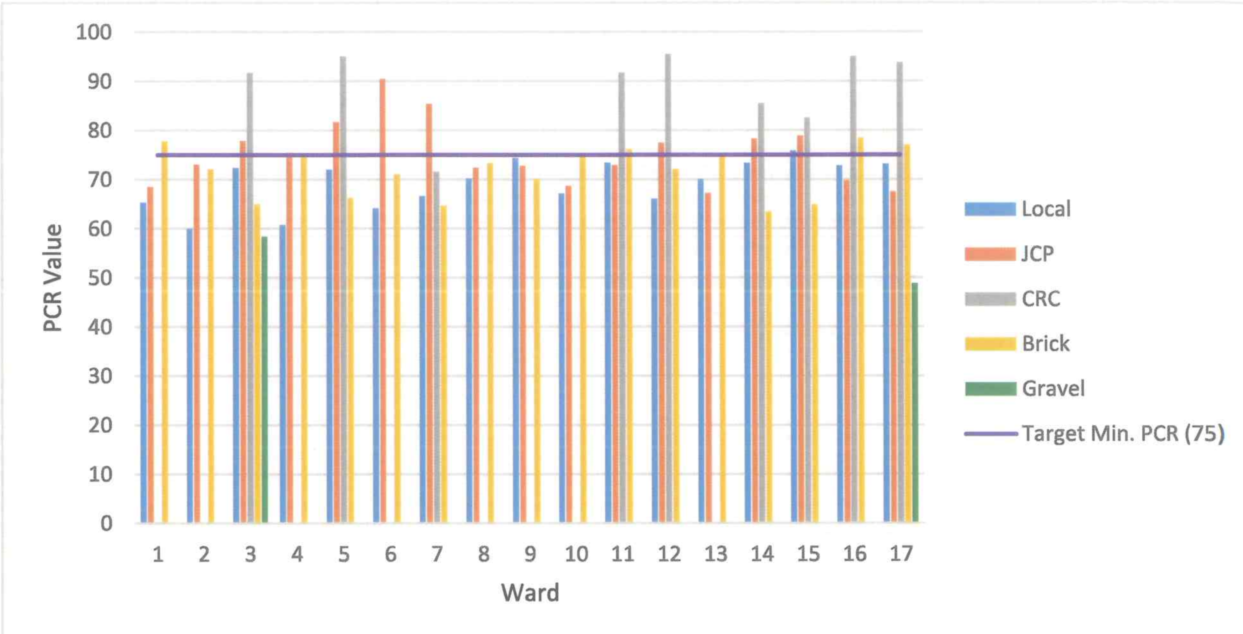


Table 7.5: Existing Average PCR by Pavement Type and Ward

Pavement Type/Ward	Local	JCP	CRC	Brick	Gravel
1	65.28	68.50	-	77.76	-
2	59.97	73.02	-	72.07	-
3	72.30	77.82	91.69	64.94	58.36
4	60.77	75.42	-	75.33	-
5	72.00	81.66	95.00	66.19	-
6	64.14	90.46	-	70.99	-
7	66.61	85.36	71.56	64.66	-
8	70.15	72.35	-	73.26	-
9	74.35	72.78	-	69.99	-
10	67.11	68.64	-	74.97	-
11	73.36	72.92	91.66	76.06	-
12	66.03	77.45	95.44	72.07	-
13	70.04	67.22	-	75.08	-
14	73.28	78.33	85.42	63.43	-
15	75.82	78.85	82.51	64.86	-
16	72.76	69.78	95.02	78.40	-
17	73.07	67.47	93.79	76.98	48.79

7.2 Minor LOCAL Streets - Long Term Planning Models

7.2.1 Overview of Models

The starting point for funding for the Minor Inventory was considered to be $10 million per year, adjusted for inflation over 20 years. For both "Worst First" and "Fix-It-First" scenarios, Tables 7.6 and 7.7 below show that this starting point of funding was inadequate to meet the City's goal of an average PCR of 75 in 20 years. Table 7.6 represents the models using the ODOT deterioration rate while Table 7.7 represents the models using the Empirical deterioration rate.

Table 7.6: Summary of Minor Long Term Planning Models (w/ ODOT Deterioration Rate)

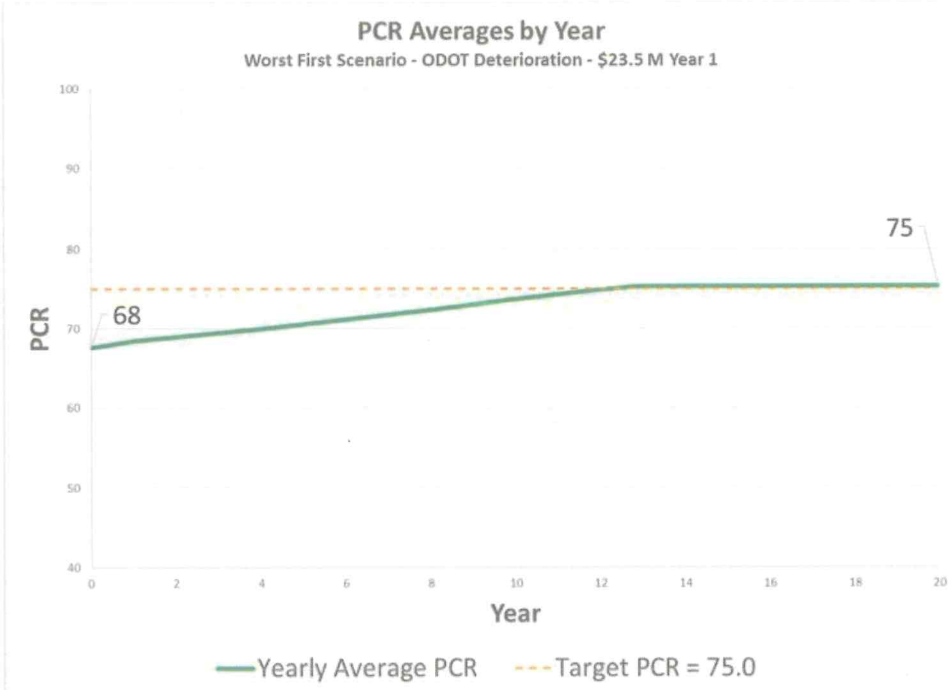
Scenario	Year 1 Budget	Year 20 Budget	Start PCR		End PCR	Year PCR Reaches Goal	% of Segments Resurfaced @ 20 yrs
Minor *Worst First*	$10.0 M	$19.2 M	68	to	52	Does not meet	55%
	$23.5 M	$45.2 M	68	to	75	12	100% (Year 16)
Minor *Fix-It-First*	$10.0 M	$19.2 M	68	to	54	Does not meet	49%
	$18.5 M	**$35.6 M**	**68**	**to**	**75**	**20**	**98%**
	$22.0 M	$42.3 M	68	to	81	12	100% (Year 18)

Table 7.7: Summary of Minor Long Term Planning Models (w/ Empirical Deterioration Rate)

Scenario	Year 1 Budget	Year 20 Budget	Start PCR		End PCR	Year PCR Reaches Goal	% of Segments Resurfaced @ 20 yrs
Minor *Worst-First*	$10.0 M	$19.2 M	68	to	70	Does not meet	55%
	$18.5 M	$35.6 M	68	to	75	9	84%
Minor *Fix-It-First*	$10.0 M	$19.2 M	68	to	73	Does not meet	49%
	$12.0 M	**$23.1 M**	**68**	**to**	**75**	**20**	**59%**
	$17.0 M	$32.7 M	68	to	79	9	79%

Since the starting point of funding was found to be inadequate, Michael Baker investigated scenarios with greater budgets that allow the City to reach its goal. These additional scenarios populate the remainder of Tables 7.6 and 7.7. For example, under "Worst First" and using the ODOT deterioration rate, our model predicted it will take $23.5 M annually ($45.2 M in year 20 due to inflation) to meet the City's goal. At first glance, it may be asked why this "Worst First" model aggressively reaches its goal in 12 years, when the City's goal is 20. It could be questioned that for a lesser budget, the goal could still be met under the same conditions. Figure 7.5 below helps explain the issue.

Figure 7.5



This figure shows the average PCR over time for this "Worst First" scenario. It shows a steady increase in PCR from 68 to 75 where it reaches a plateau. This plateau is a feature seen in all of the "Worst First" models. For a given budget, there is a PCR plateau that is not exceeded. To increase the plateau, the budget must be increased. From the figure above, a lesser funding amount would lower the plateau and the model would never reach the City's goal of 75. Therefore reaching the goal within 12 years, opposed to 20, was necessary for this model.

Our "Fix-It-First" models did not feature such plateaus (See Appendix G). For comparison to the "Worst First" scenarios, Michael Baker provided comparable "Fix-It-First" scenarios that reach the City's goal in 20 years as well as 12 years, assuming an ODOT Deterioration Rate (See Table 7.6). For the same comparison using the Empirical Deterioration Rate, see Table 7.7.

The bold lines in Tables 7.6 and 7.7 highlight Michael Baker's recommendation to city, which has two parts:

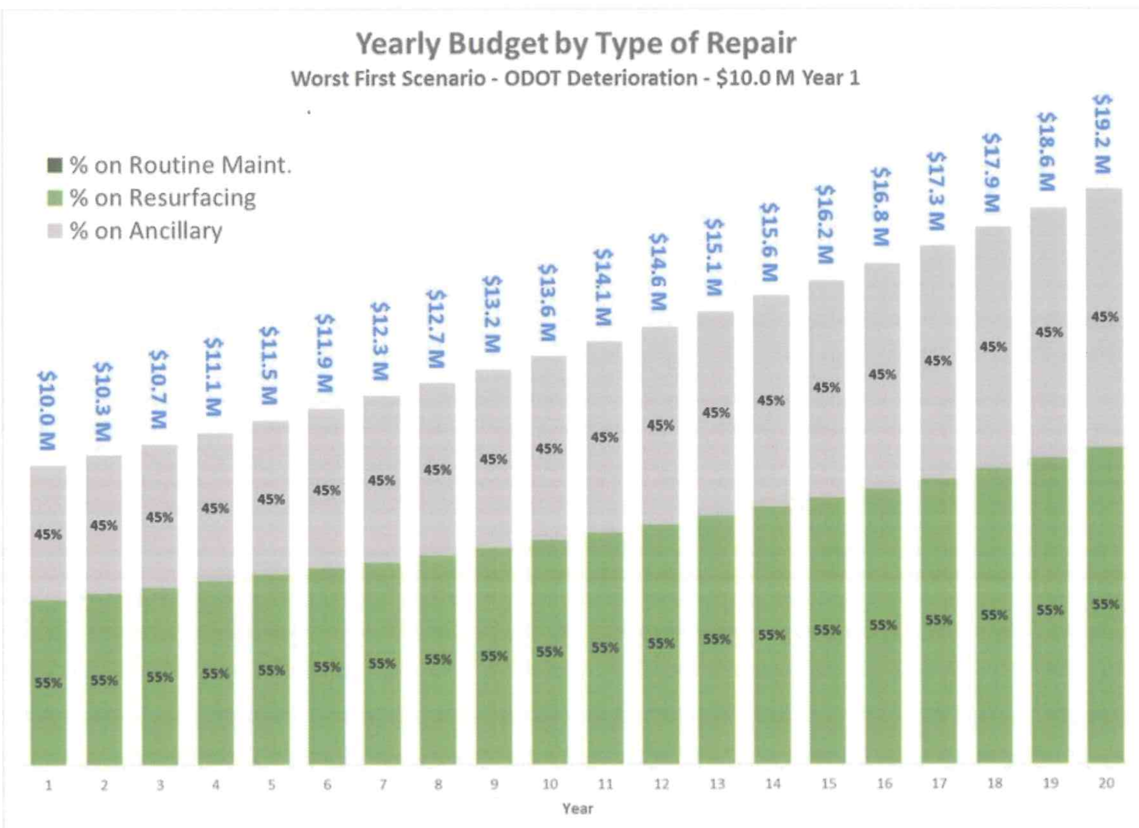
1) Use a "Fix-it-First" approach
2) Provide an annual budget between $12-18.5M for the Minor Inventory, adjusted yearly for inflation

Again, the boundaries on the recommended annual budget can be tightened when more resurveys are completed and more is understood about the City's actual degradation rate.

7.2.2 Model Budget Discussion

The following figures give visual meaning to the different scenarios from a budget standpoint. First, Figure 7.6 shows a typical "Worst First" funding scenario over 20 years.

Figure 7.6



In Figure 7.6, Year 1 shows the starting point budget of $10.0 M. Each year's budget grows due to inflation, where in year 20 the budget is $19.2 M. The green represents the portion of the budget that is spent on resurfacing, which is 55% each year. The grey represents the portion of the budget that is spent on ancillary items, which is the remaining 45% each year. The green portions of each year also represent money that improves PCR, while grey portions show money that does not improve PCR.

Next, Figure 7.7 shows a typical "Fix-It-First" funding scenario over 20 years.

Figure 7.7

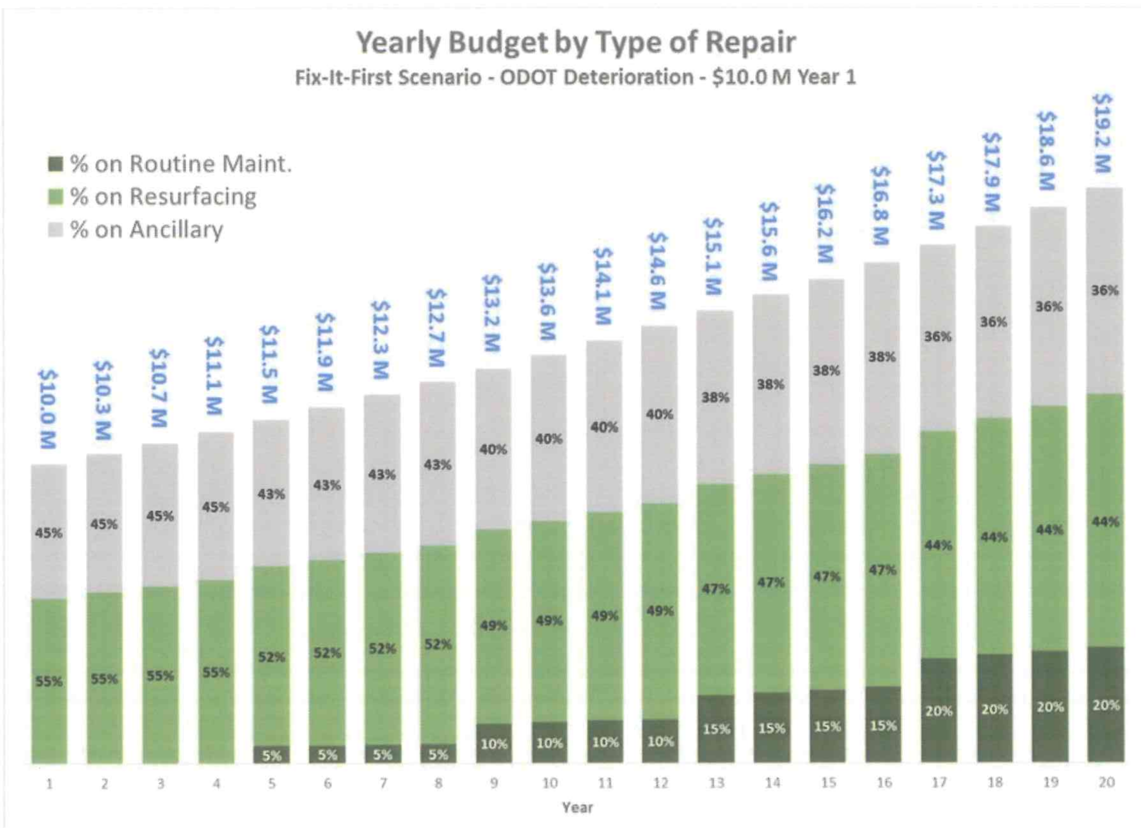


Figure 7.7 has the same Year 1 through Year 20 budget as Figure 7.5. The difference can be seen starting in Year 5 when some of the annual budget is allocated towards routine maintenance (dark green). Again, green portions of each year represent money improving PCR whereas grey portions do not. This distinction is important because in Year 20 of Figure 7.6, only 55% of the budget is going towards improving PCR. In Year 20 of Figure 7.7, 64% of the budget is going towards improving PCR. The levels of funding towards routine maintenance can

be found in Table 7.1.

The final key takeaway from Figures 7.6 and 7.7 is that a vast majority of the budget in either scenario goes towards addressing the worst roads in the system. The slow introduction of funds for routine maintenance simply represents a low cost protection of the City's investment, ensuring past repair work is maintained for as long as possible.

7.2.3 2017/2018 Recommended Pavement Rehabilitation Program (Minor)

A proposed list of eligible Minor Street resurfacing for years 2017 and 2018 is provided electronically with this report. This list complies with either the "Worst First" or "Fix-It-First" scenarios, as they do not diverge until after Year 4.

The list serves as a starting point for the City. Moving beyond the first two years, it is this report's opinion that decisions must be made at the network level (budget and maintenance approach) prior to the planning of future projects. Also given the high variability of pavement management, any rehabilitation program identifying specific projects beyond two years is believed to be of little value to the City at this point. This variability serves to highlight the importance of a resurvey program in the future (See Section 8). Such a program would allow the City to dynamically address its inventory as it changes, opposed to dogmatically following a potentially out-of-date and out-of-touch, long-term list of eligible projects.

7.3 Major LOCAL Streets - Long Term Planning Models

7.3.1 Overview of Models

The starting point for funding levels for the Major Inventory was considered to be $30 million per year, adjusted for inflation over 20 years. Recognizing that with external funding sources – applying the "Fix-it-First" approach might not be entirely feasible - maintaining the system where possible will yield higher PCR averages. For both scenarios, Tables 7.8 and 7.9 show that this starting point of funding was adequate to maintain the City's goal of an average PCR of 75 over

20 years. Table 7.8 represents the models using the ODOT deterioration rate while Table 7.9 represents the models using the Empirical deterioration rate.

Table 7.8: Summary of Major Long Term Planning Models (w/ ODOT Deterioration Rate)

Scenario	Year 1 Budget	Year 20 Budget	Start PCR		End PCR	Year PCR Reaches Goal	% of Segments Resurfaced @ 20 yrs
Major	**$30.0 M**	**$57.7 M**	**73**	**to**	**85**	**1**	**100% (Year 13)**

Table 7.9: Summary of Major Long Term Planning Models (w/ Empirical Deterioration Rate)

Scenario	Year 1 Budget	Year 20 Budget	Start PCR		End PCR	Year PCR Reaches Goal	% of Segments Resurfaced @ 20 yrs
Major	**$30.0 M**	**$57.7 M**	**73**	**to**	**86**	**1**	**100% (Year 12)**

Tables 7.8 and 7.9 show similar budget requirements, and what the final PCR average is anticipated to be. Since $30.0 M was found to be adequate, no other funding levels were investigated.

The bold lines in Tables 7.8 and 7.9 highlight Michael Baker's recommendation to the City, which has two parts:

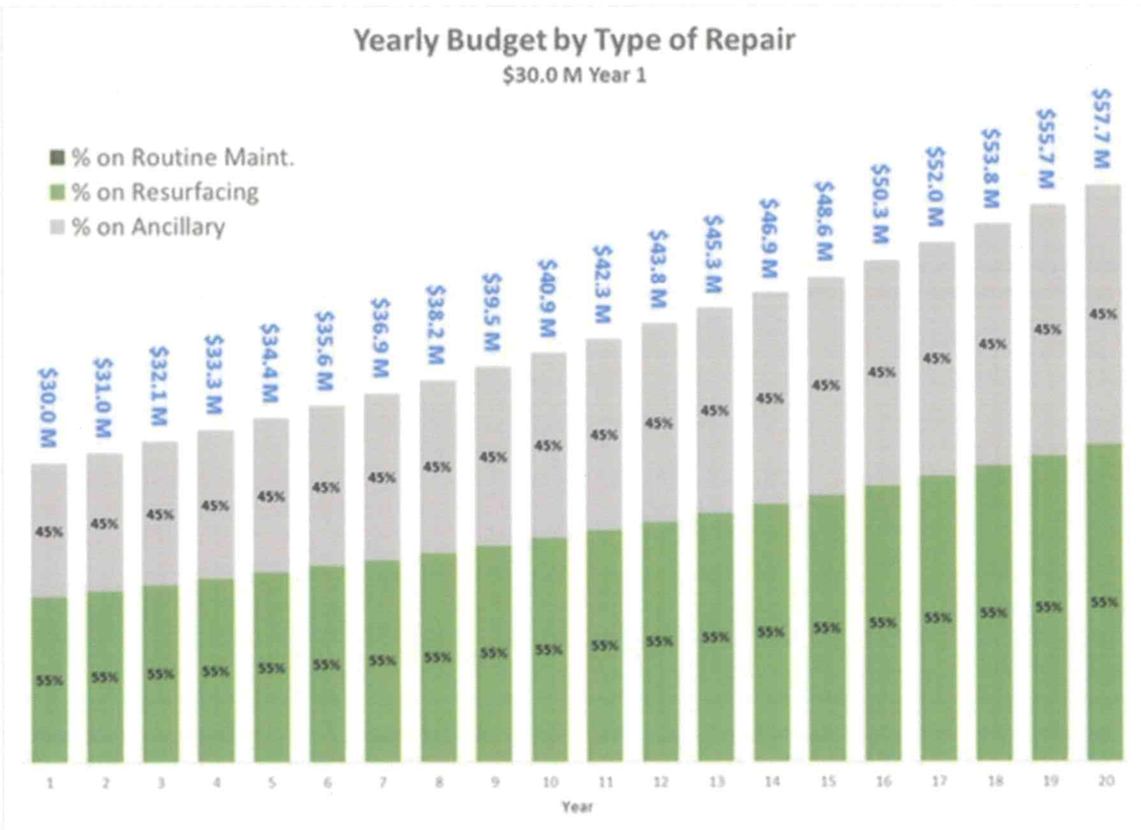
1) Use a "Fix-It-First" approach where possible.
2) Allocate / Plan for an annual budget of $30.0 M for the Major Inventory, adjusted yearly for inflation

Since the different deterioration rates are more comparable at higher PCRs, the models are closer in results as they remain within the higher PCR region. This is due to adequate funding and a higher initial average PCR. Note that the City Major planning has a variety of funding sources (Federal, State, County matching) with different scoring criteria.

7.3.2 Model Budget Discussion

The following figures give visual meaning to the different scenarios from a budget standpoint. First, Figure 7.8 shows the funding scenario over 20 years using.

Figure 7.8



In Figure 7.8, Year 1 shows the starting point budget of $30.0 M. Each year's budget grows due to inflation, where in year 20 the budget is $57.7 M. The green represents the portion of the budget that is spent on resurfacing, which is 55% each year. The grey represents the portion of the budget that is spent on ancillary items, which is the remaining 45% each year. The green portions of each year also represent money that improves PCR, while grey portions show money that does not improve PCR.

Next, Figure 7.9 shows a typical funding scenario over 20 years, with routine maintenance included, if it is available.

Figure 7.9

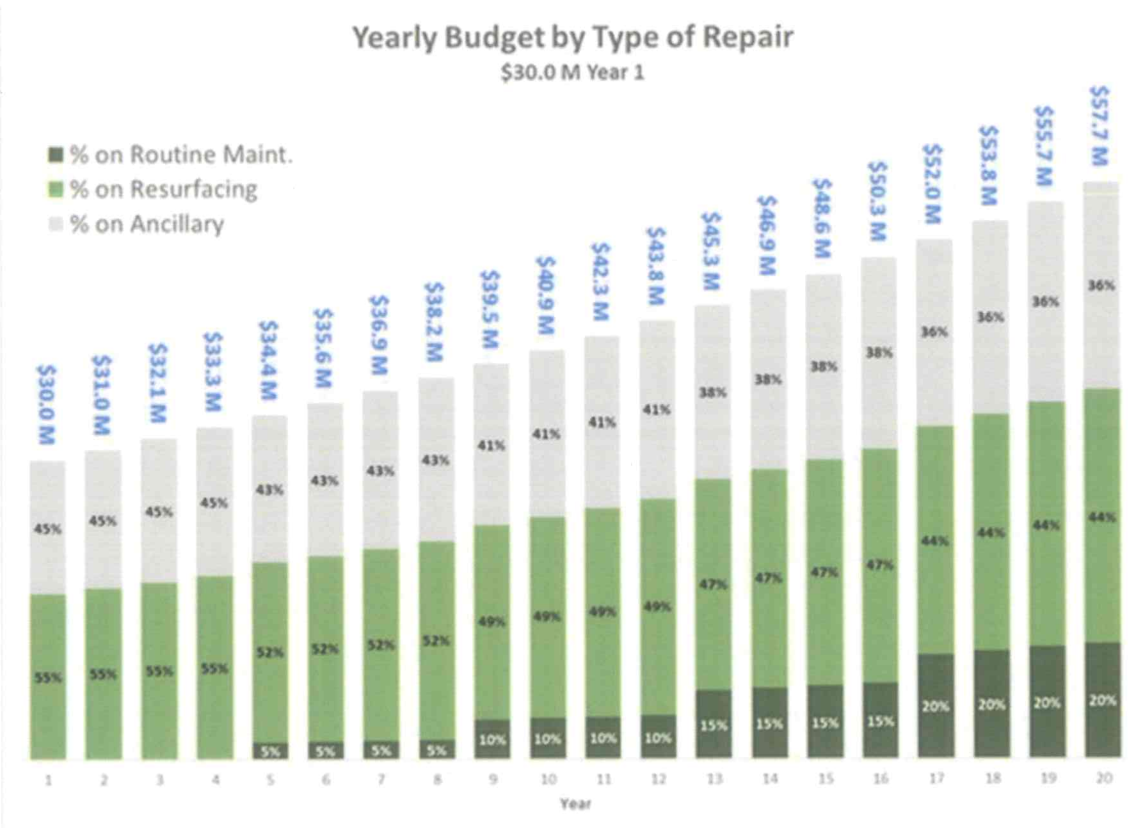


Figure 7.9 has the same Year 1 through Year 20 budget as Figure 7.8. The difference can be seen starting in Year 5 when some of the annual budget is potentially allocated towards routine maintenance (dark green). Again, green portions of each year represent money improving PCR whereas grey portions do not.

The final key takeaway from Figures 7.8 and 7.9 is that a vast majority of the budget in either scenario goes towards addressing the worst roads in the system. The slow introduction of funds for routine maintenance, if possible based upon available funding, simply represents a low cost protection of the City's investment, ensuring past repair work is maintained for as long as possible.

7.4 Summary

The following are selected key ideas from the Capital Improvement Plan which should help the City move forward in the most effective way possible.

- A "Fix-it-First" approach will help meet the City's goals more effectively. However, the report recognizes the critical need to address the worst roads in the inventory. Therefore it is important to note that for the first four years, each approach is identical to the other. Furthermore, even when funds are introduced for routine maintenance, the majority of funding still goes to addressing the worst streets in the inventory under a "Fix-It-First" policy.
- A Minor LOCAL Streets budget of $10 M per year will not allow the City to reach its goal of an average PCR of 75 within 20 years. This report recommends that $12 - 18.5 M per year, adjusted for inflation annually, will be required to meet the City's goal.
- A Major LOCAL Streets budget of $ 30 M per year, adjusted for inflation annually, will allow the City to maintain its goal of an average PCR of 75.
- A two year list of eligible Minor Streets has been provided to the City, focusing entirely on the need to fix the worst streets first. To move beyond two years, the City will need to make network level decisions such as funding levels and maintenance approaches. It is also this report's recommendation that the City develop a resurvey program to address the dynamic needs of its pavement inventory.
- A set of graphics for all scenarios listed in Tables 7.6-7.7, Minor Streets can be found in Appendices G.

8. RESURVEY

Progress towards meeting the City's goals for average pavement condition ratings can only be measured through periodic and systematic collection and analysis of field data. Similarly, planning for elimination of the worst performing pavements requires current, accurate data on the health of the system as a whole. Michael Baker recommends that the City develop a long-term pavement condition monitoring program that will ensure that the data is collected and updated regularly. Such a program would involve City personnel re-rating the entire pavement system on a frequency of once every three years. Our recommendation is a staggered basis where 1/3 of the streets are scored each year. It is recommended that a quality assurance function be established using an outside agency to ensure independence. This work would get uploaded into the City inventory annually, developing a specific deterioration rate, and allowing for more accurate future programming.

The resources necessary to support this program are estimated on the basis of a production rate of 8 minutes per segment (or ~5 miles/day with an average segment length of 470'). With a city-wide survey (following our recommendation to utilize minor and major ratings provided by NOACA) of 956 miles and 10,775 segments, this requires 1,437 hours, or 2,874 total person hours for a 2 person crew. The re-rating would be complete in 180 days, which is a significant effort to accomplish in a year, or 60 days/year for 3 years with one crew. The quality assurance program could be implemented with approximately 10% of the total survey time. This results in 288 hours, requiring 6 days/year following each annual survey for the QA program.

9. REFERENCES

Ogunro, V., J. Gergely and C. Ficken, 2006. *Utility Pavement Degradation Study.* Charlotte Department of Transportation Research Project. Department of Civil Engineering. University of North Carolina. June 2, 2006.

Ohio Department of Transportation, 2006. *Pavement Condition Rating System.* Office of Pavement Engineering. April 2006.

2015. *PCR Distress Codes.* http://www.dot.state.oh.us/Divisions/Engineering/Pavement/Additional%20Information/PCR_Distress_Codes.pdf

2016[1]. *Transportation Information Mapping System (TIMS).* http://gis.dot.state.oh.us/tims

2016[2]. *Pavement Management for Locals Manual.* Pavement Engineering Office. www.ltap.org/login/resource/entryupload/uploads/PMS**manual**.doc

Pierce, L.M., McGovern, G., Zimmerman, K.A. *Practical Guide for Quality Management of Pavement Condition Data Collection, Applied Pavement Technology, February 2013.* FHWA DTFH61-07-D-00028.

10. SUMMARY OF RECOMMENDATIONS

Section 6
Continue an engineering review of the 2015/2016 data to evaluate the role of design in those pavements that are badly deteriorated.
Continue to emphasize the role of subgrade exploration where pavement deterioration is sufficiently severe to warrant reconstruction or major repair. Use subgrade borings and pavement cores along with current ADT estimates to validate the pavement design.
Review construction practices to pursue continuous improvement in methods of construction activities, together with regular feedback to designers.
Create a GIS layer that consolidates the City data into similar segment lengths to the NOACA system, so that direct comparisons can be made.
Enhance the data management system by including geo-referenced imagery in subsequent surveys.
Add an attribute to the GIS that identifies new roads and those resurfaced since the last survey.
Adopt a balanced "Fix-It-First" program
Establish a pool of funds for the rehabilitation of Minor Concrete and Brick streets.
All City Departments (City of Cleveland Water, Cleveland Public Power, Water Pollution Control, etc.) should apply for and adhere to the Street Opening Permit.
Review and adopt changes in the City Standard Drawings, D-specifications and Street Opening Permit. (See Appendix E)
Section 7
For the **Minor** Inventory 1) Use a "Fix-it-First" approach 2) Provide an annual budget between $12-18.5M, adjusted yearly for inflation
For the **Major** Inventory 1) Use a "Fix-It-First" approach ***where possible***. 2) Provide an annual budget of $30.0 M for the Major Inventory, adjusted yearly for inflation

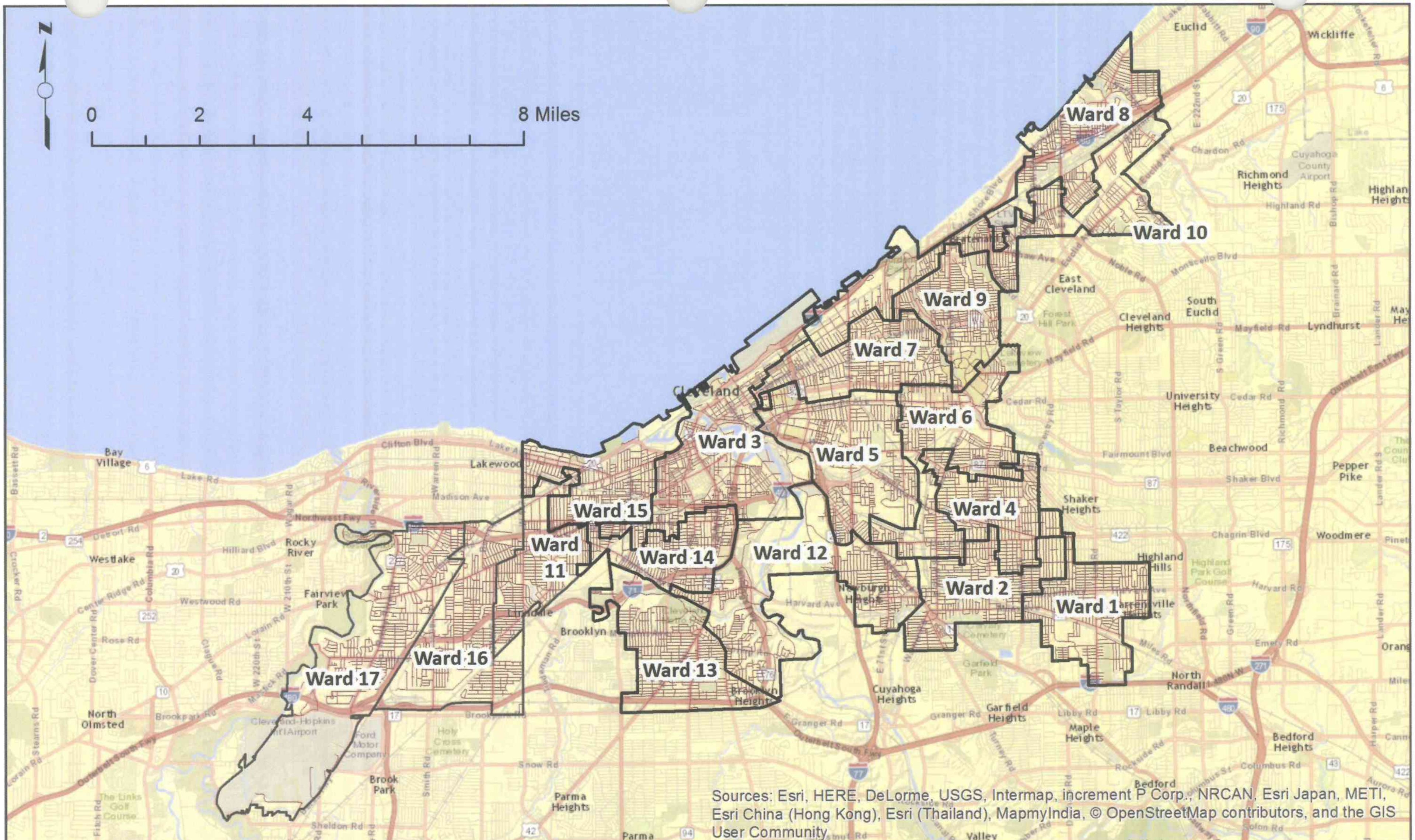
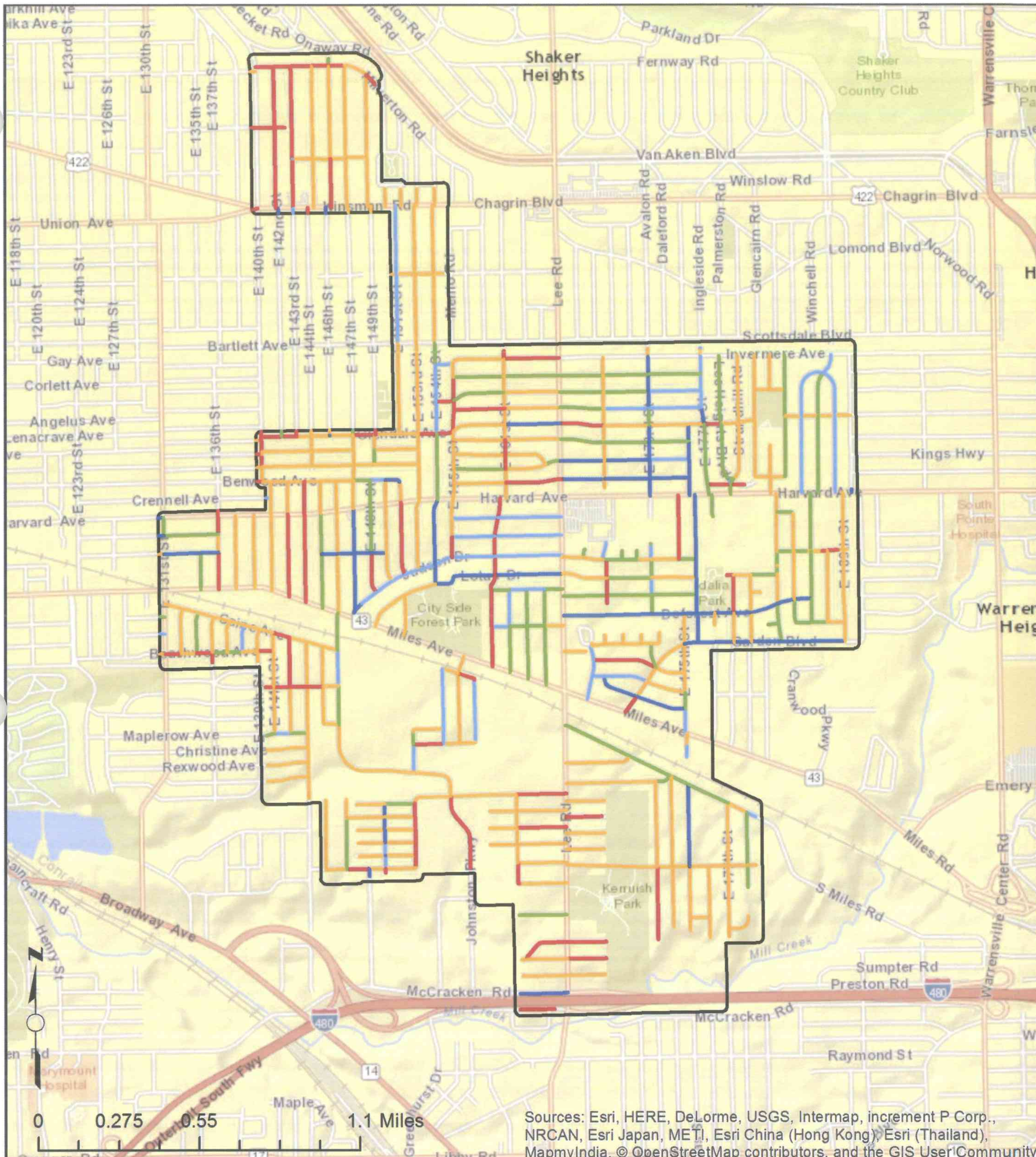


Exhibit 1

Michael Baker INTERNATIONAL

Cleveland City Council Wards

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
026.6-55.0	F

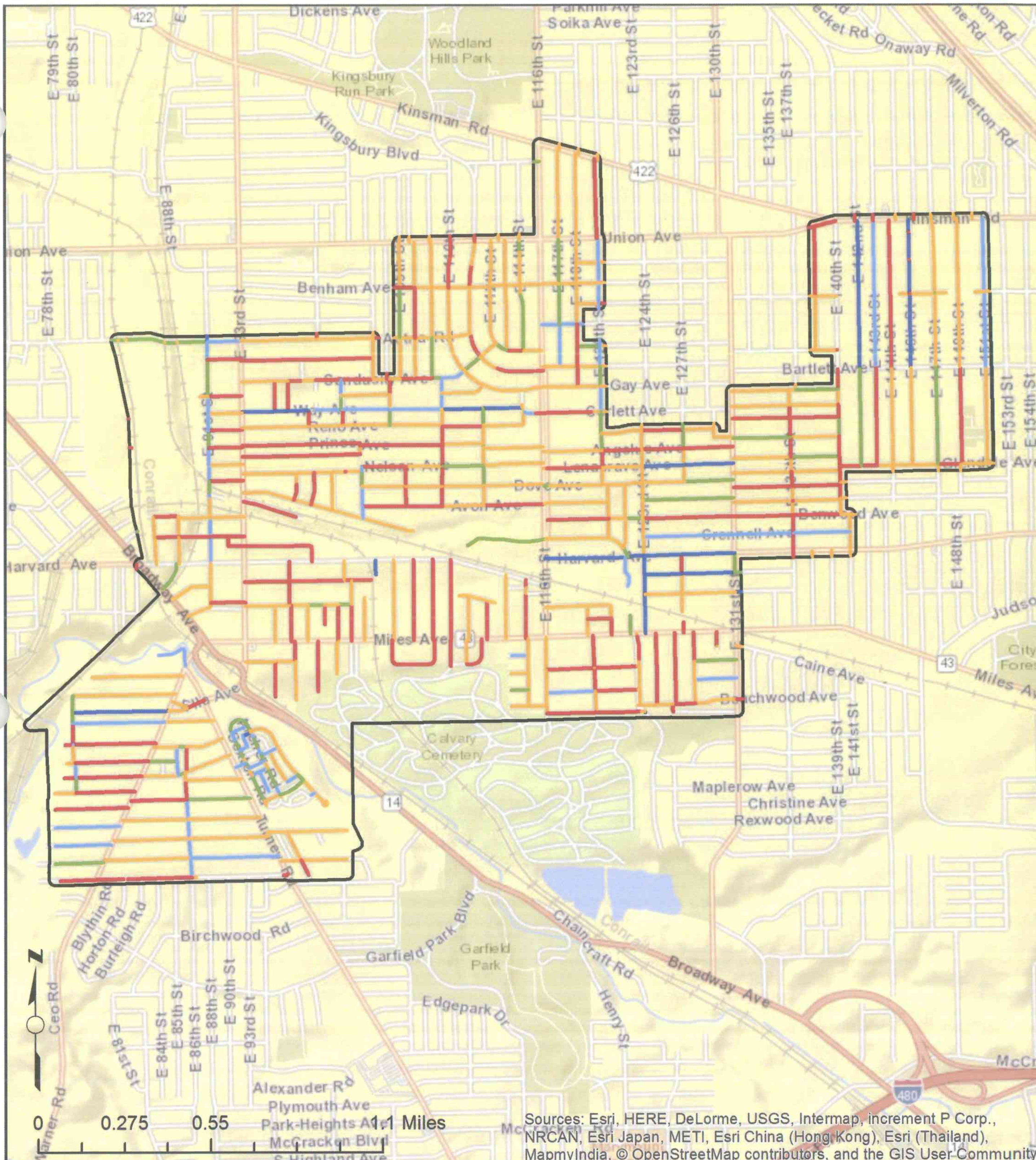
Ward 1 Boundary

Exhibit 2

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR)
Ward 1 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
015.3-55.0	F

Ward 2 Boundary

Exhibit 3

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 2 Minor Streets

Cleveland Pavement Survey 2015/2016

PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
026.0-55.0	F

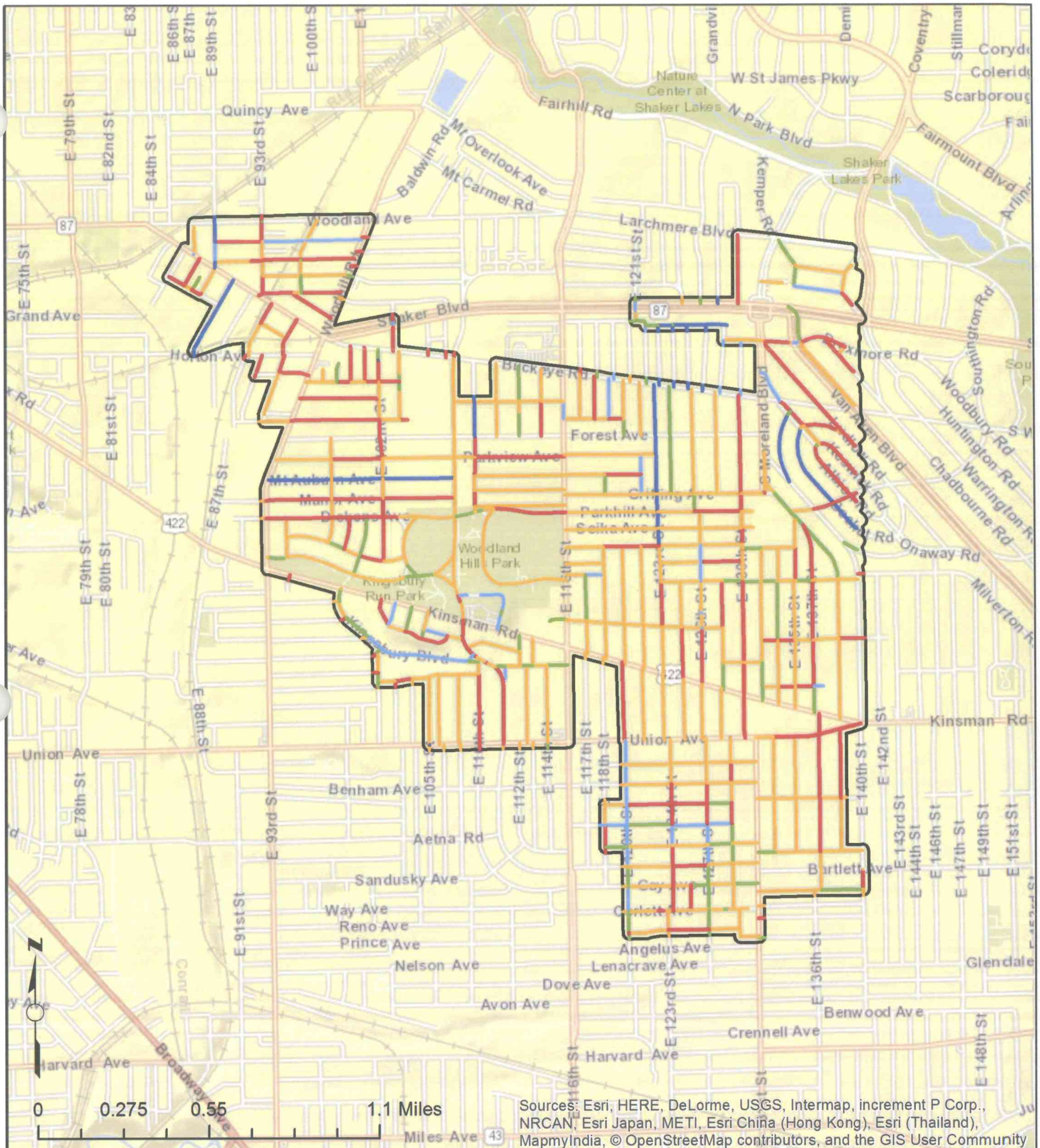
Ward 3 Boundary

Exhibit 4

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR)
Ward 3 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
028.6-55.0	F

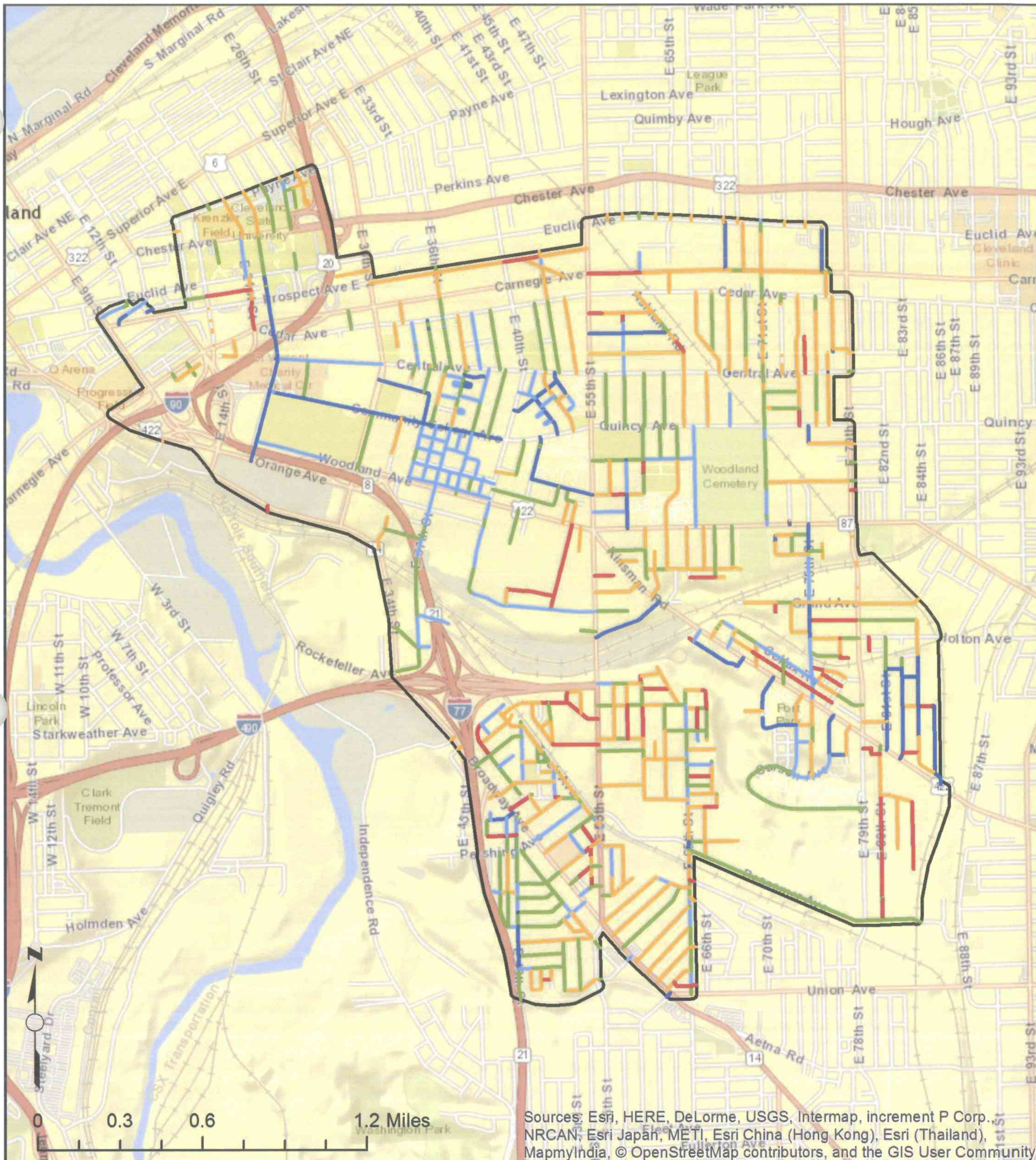
Ward 4 Boundary

Exhibit 5

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 4 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
024.0-55.0	F

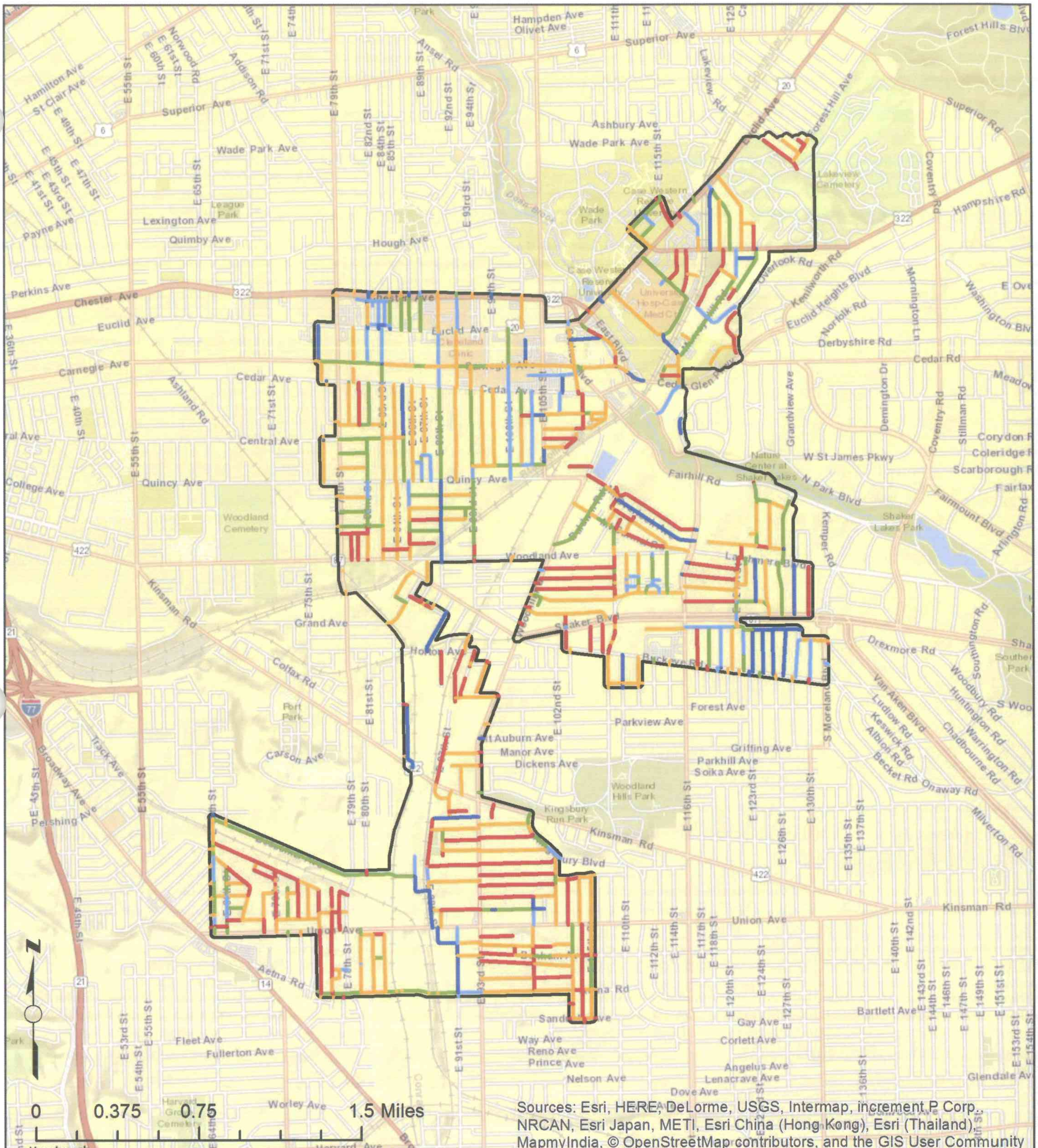
Ward 5 Boundary

Exhibit 6

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 5 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
015.9-55.0	F

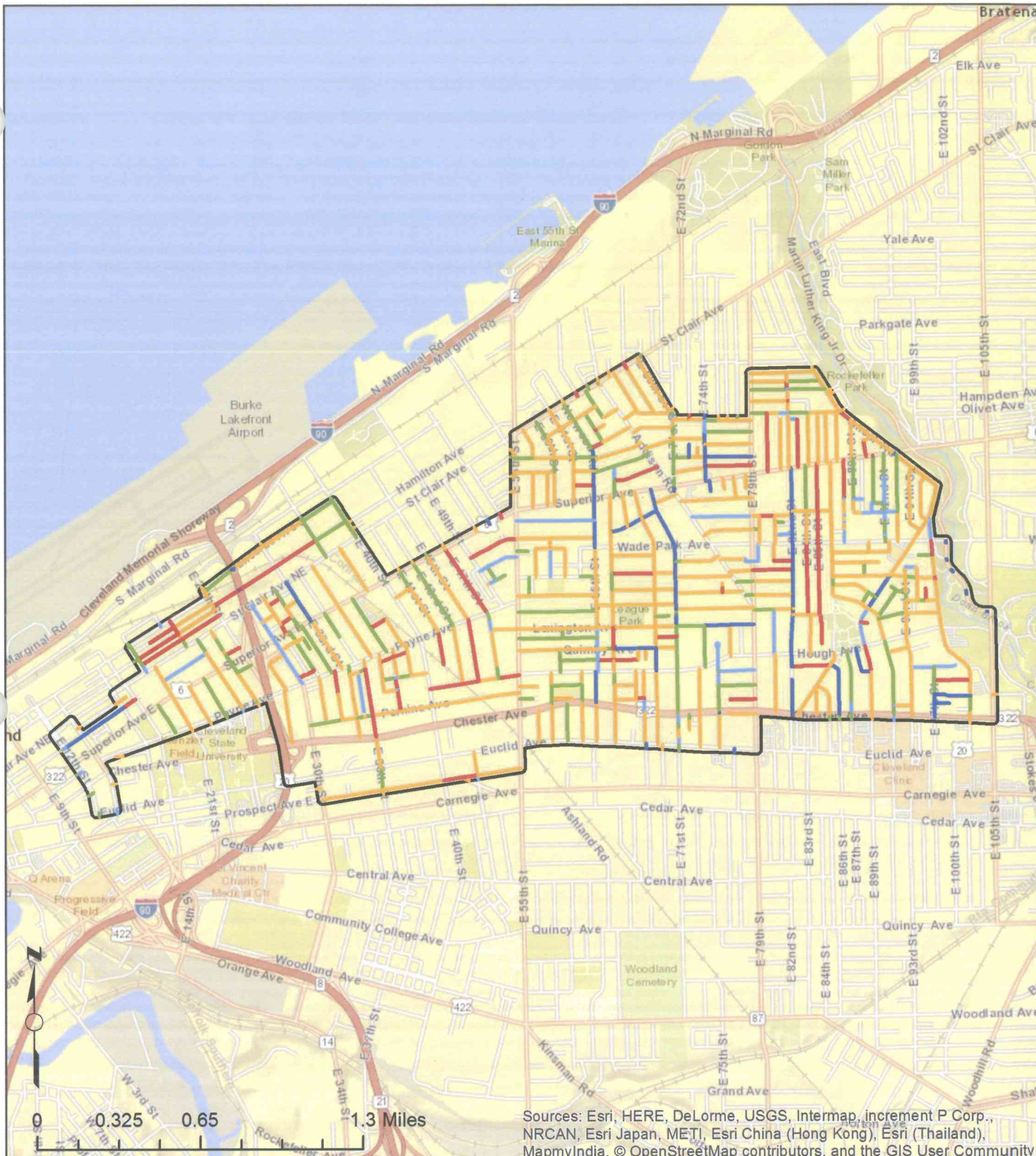
Ward 6 Boundary

Exhibit 7

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR)
Ward 6 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
026.0-55.0	F

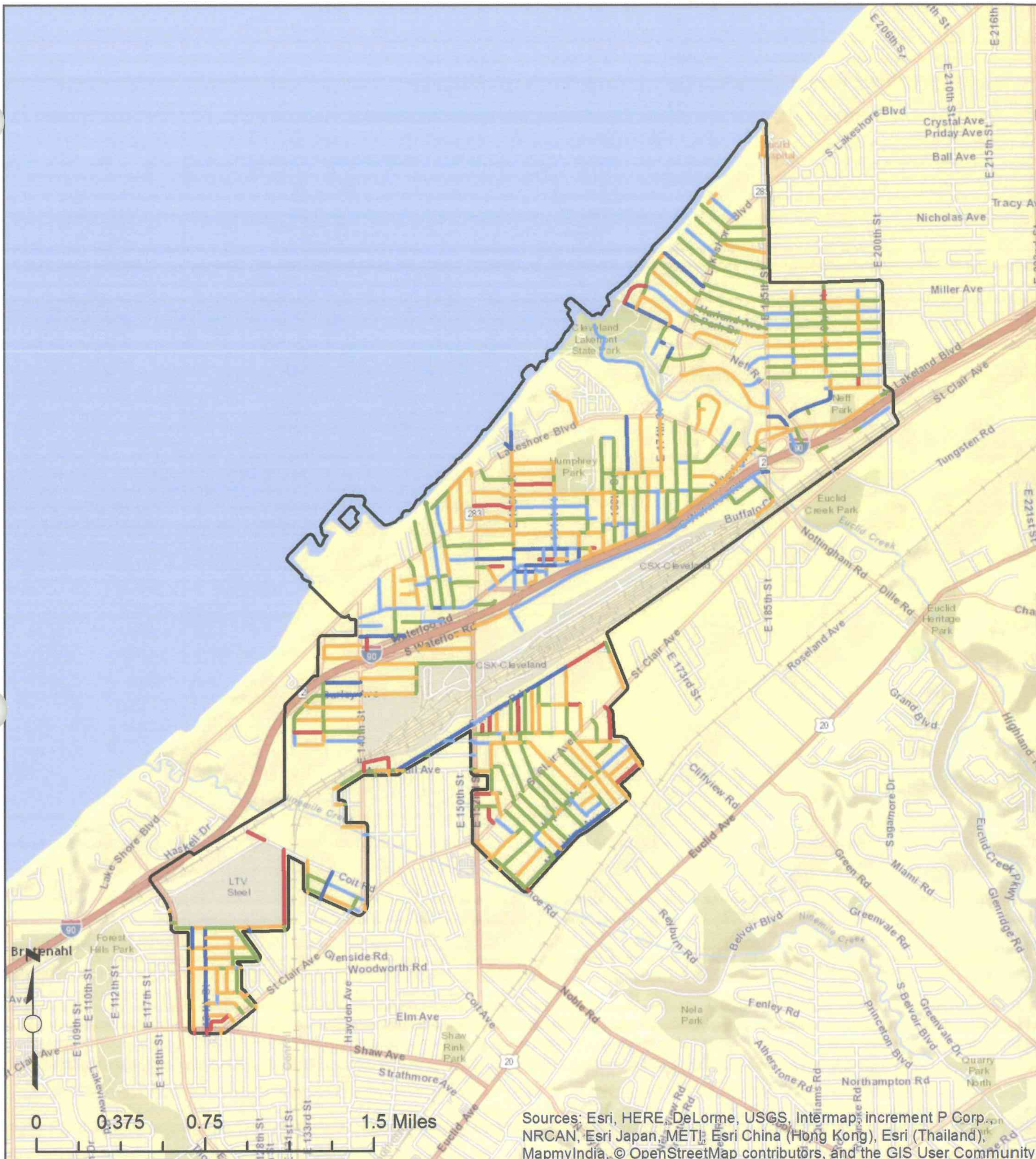
Ward 7 Boundary

Exhibit 8

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 7 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
043.2-55.0	F

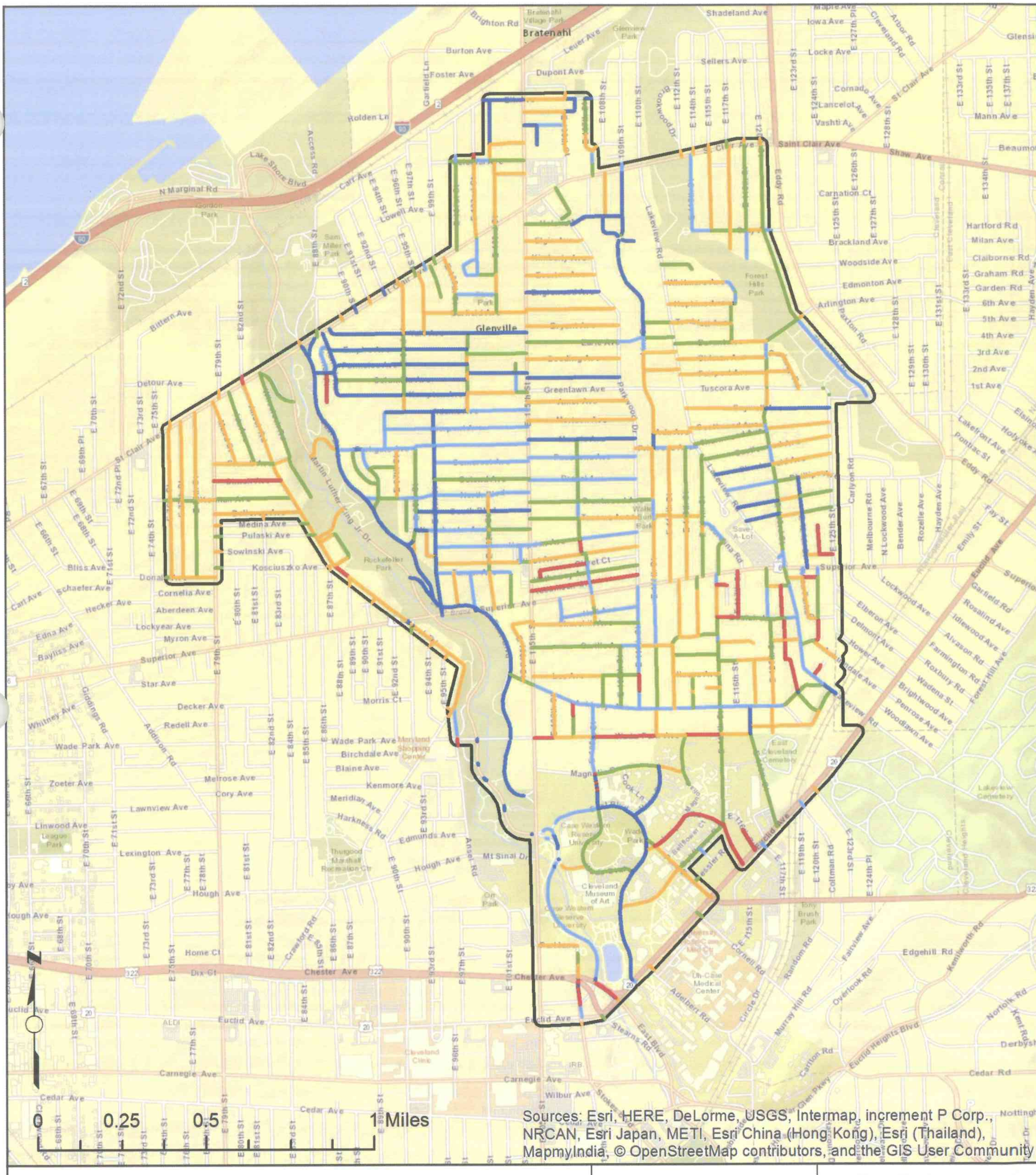
Ward 8 Boundary

Exhibit 9

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 8 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
038.8-55.0	F

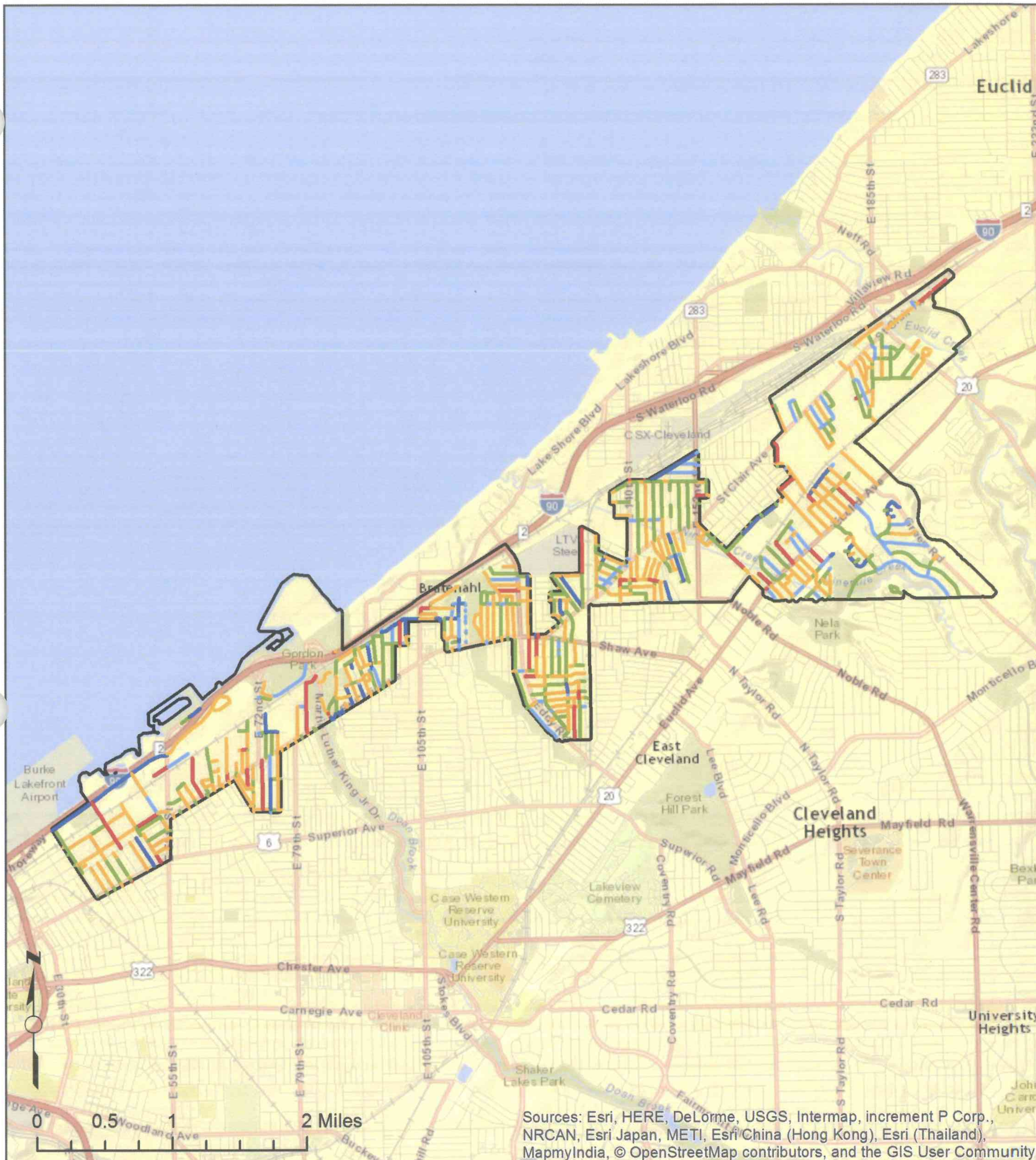
Ward 9 Boundary

Exhibit 10

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 9 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
038.8-55.0	F

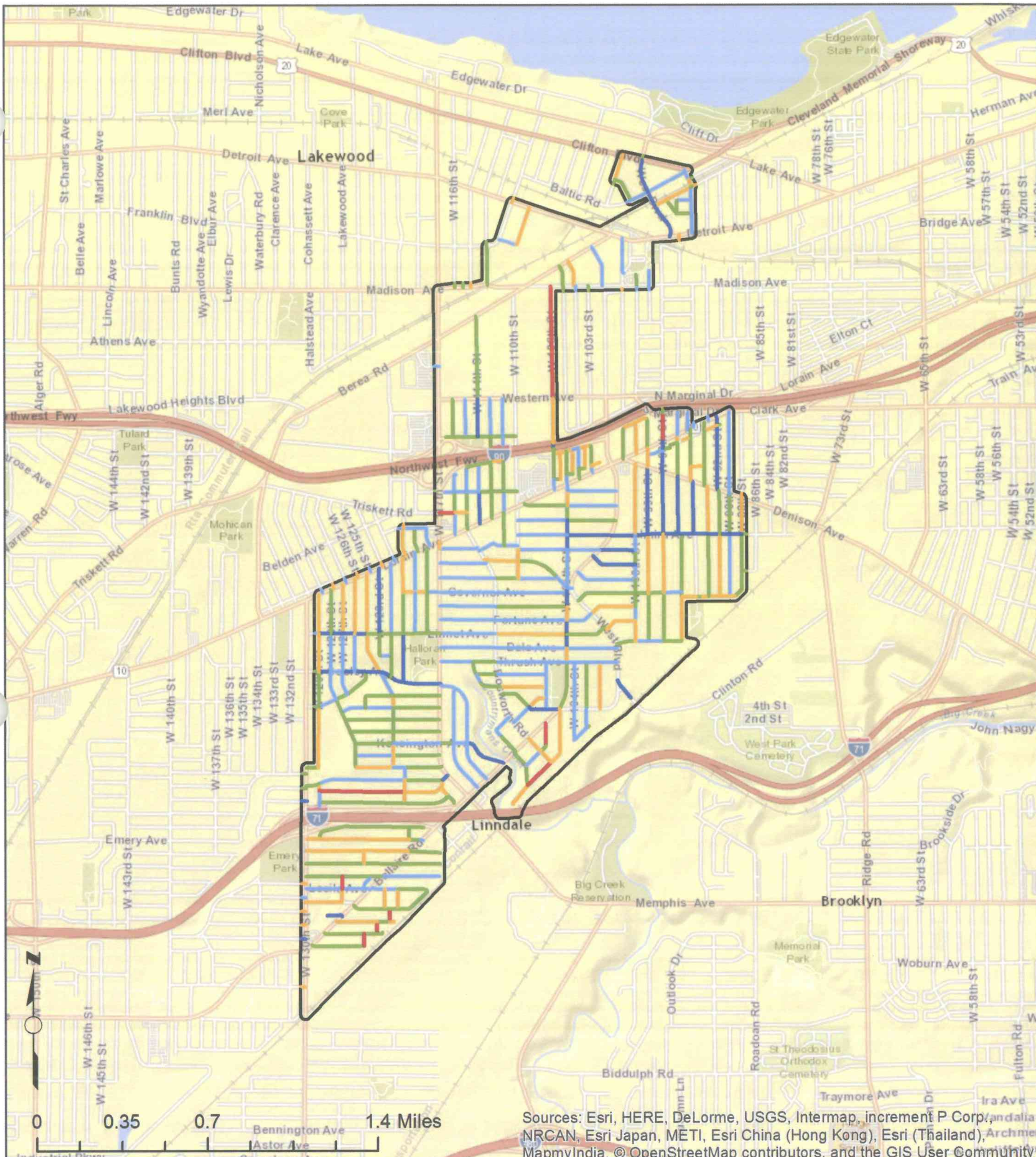
Ward 10 Boundary

Exhibit 11

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 10 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
049.2-55.0	F

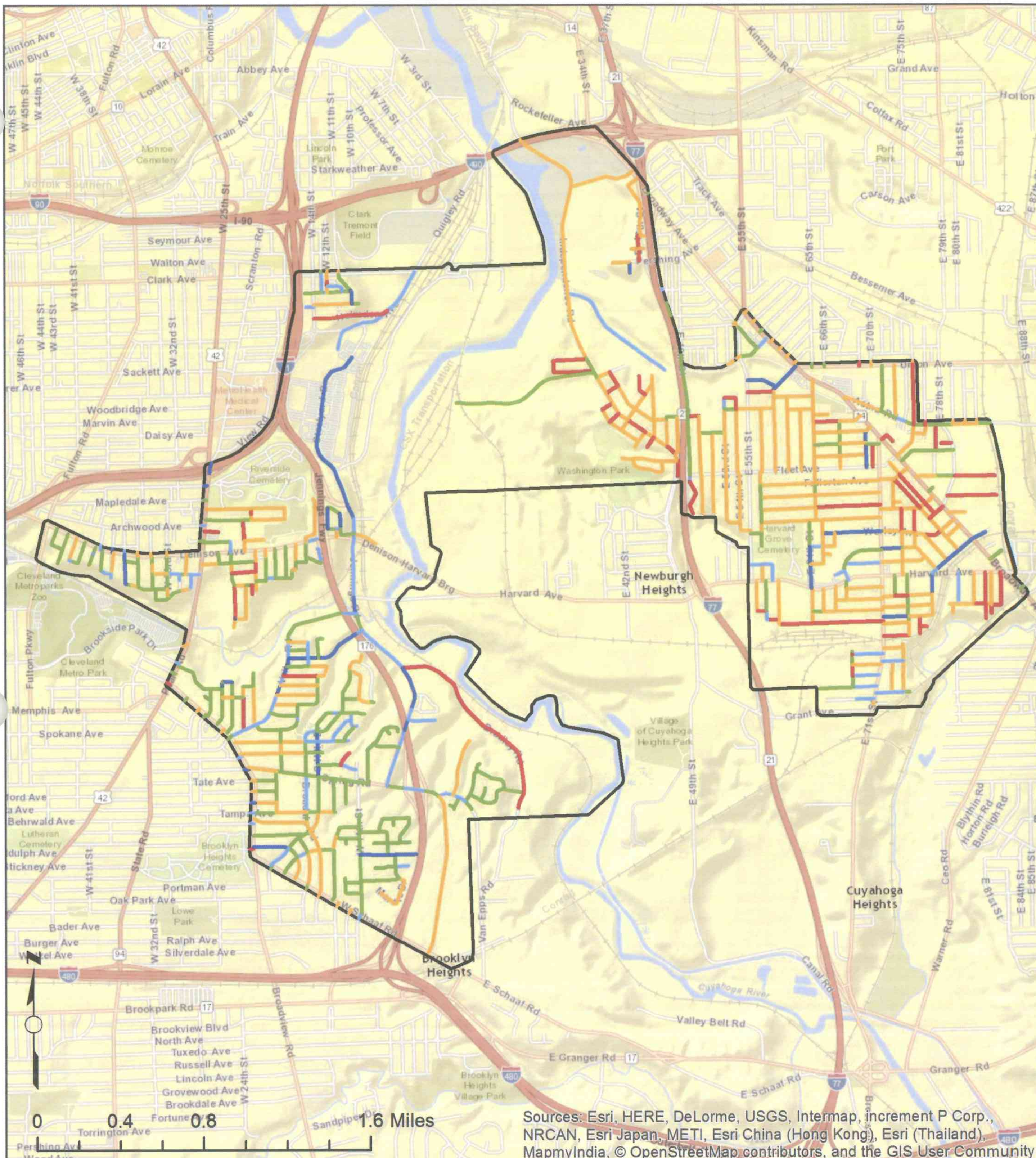
Ward 11 Boundary

Exhibit 12

Michael Baker
INTERNATIONAL

Pavement Condition Rating (PCR)
Ward 11 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
031.0-55.0	F

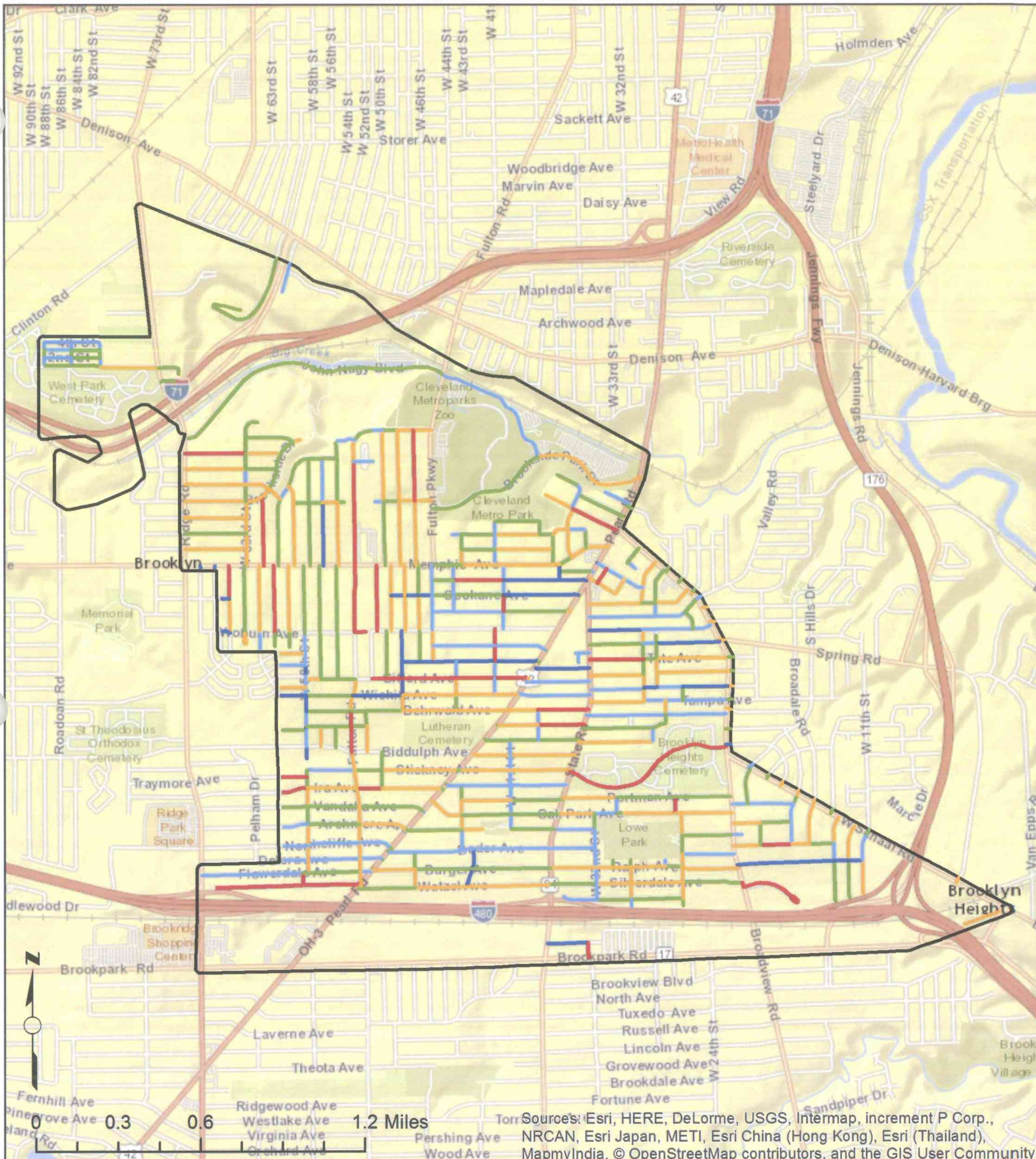
Ward 12 Boundary

Exhibit 13

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 12 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
039.9-55.0	F

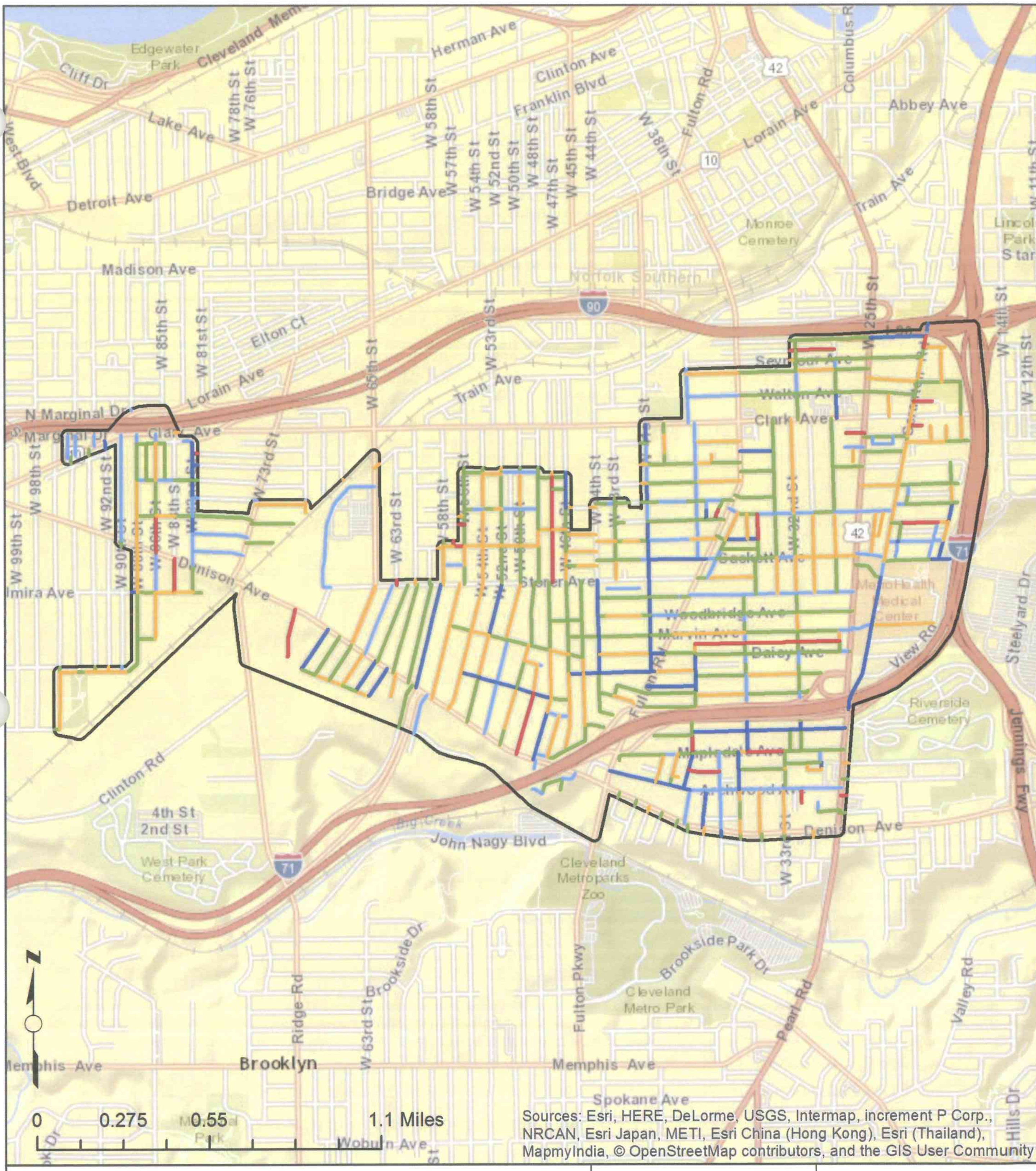
Ward 13 Boundary

Exhibit 14

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 13 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
027.5-55.0	F

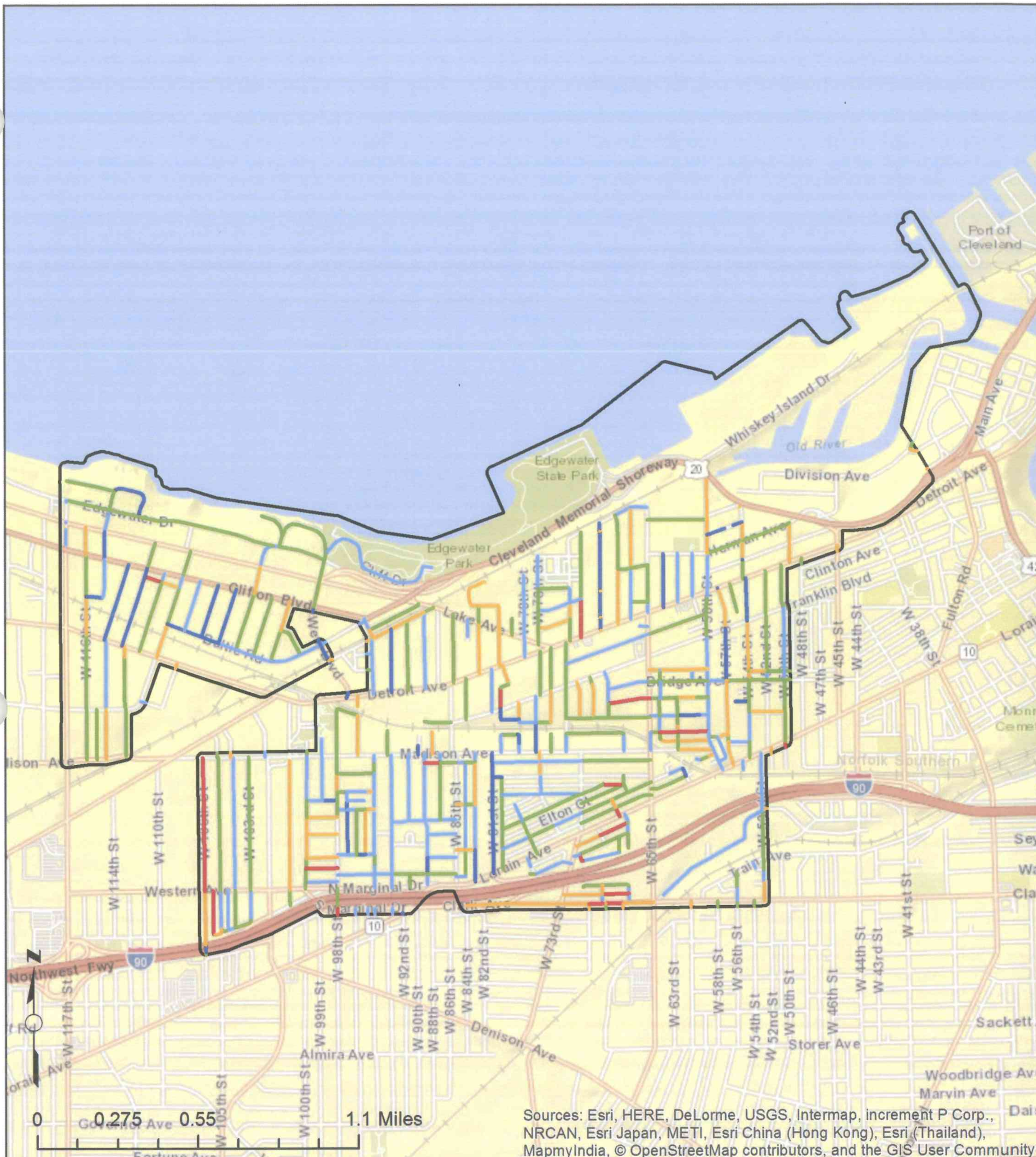
Ward 14 Boundary

Exhibit 15

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 14 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
039.3-55.0	F

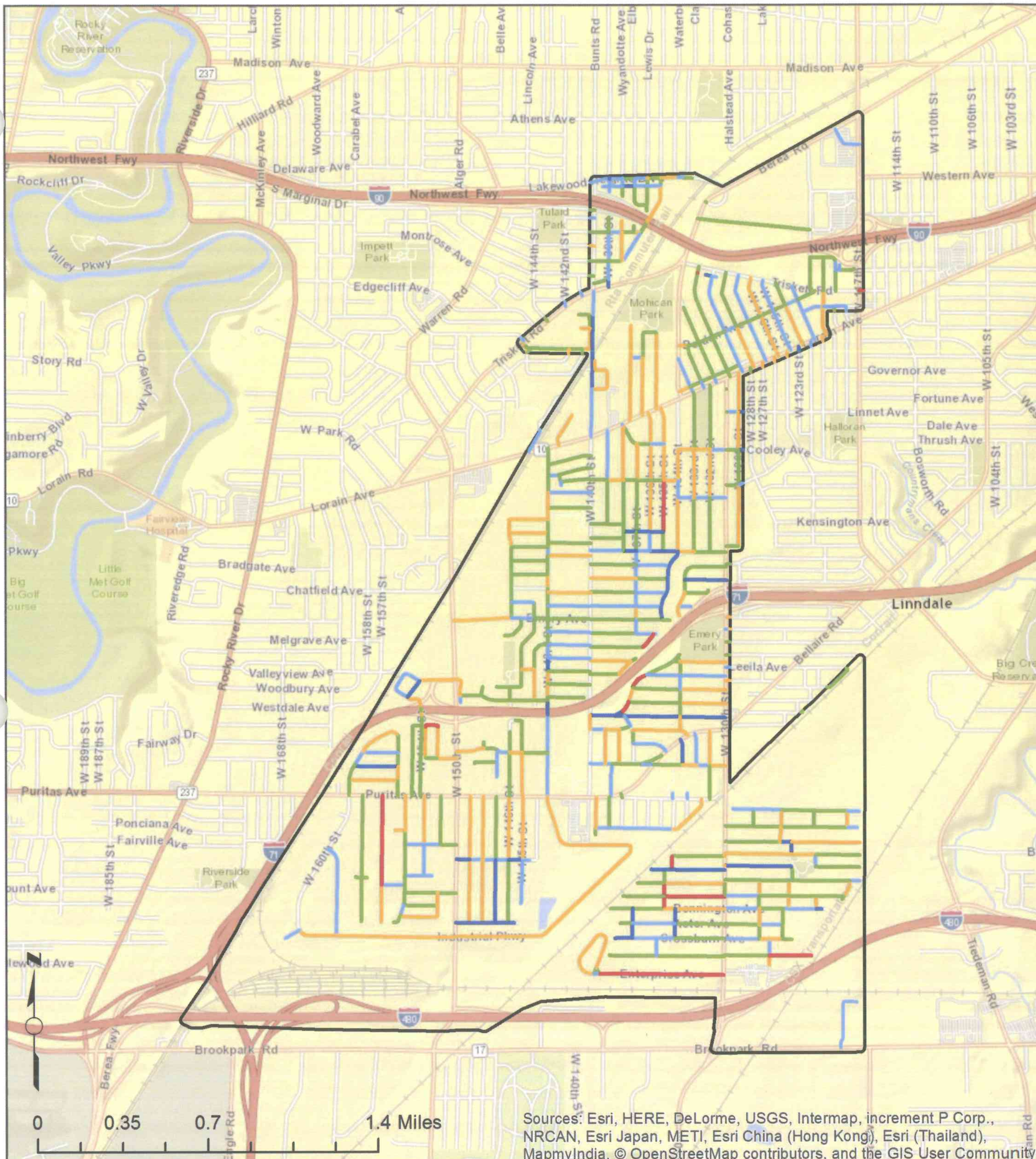
Ward 15 Boundary

Exhibit 16

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR)
Ward 15 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
029.3-55.0	F

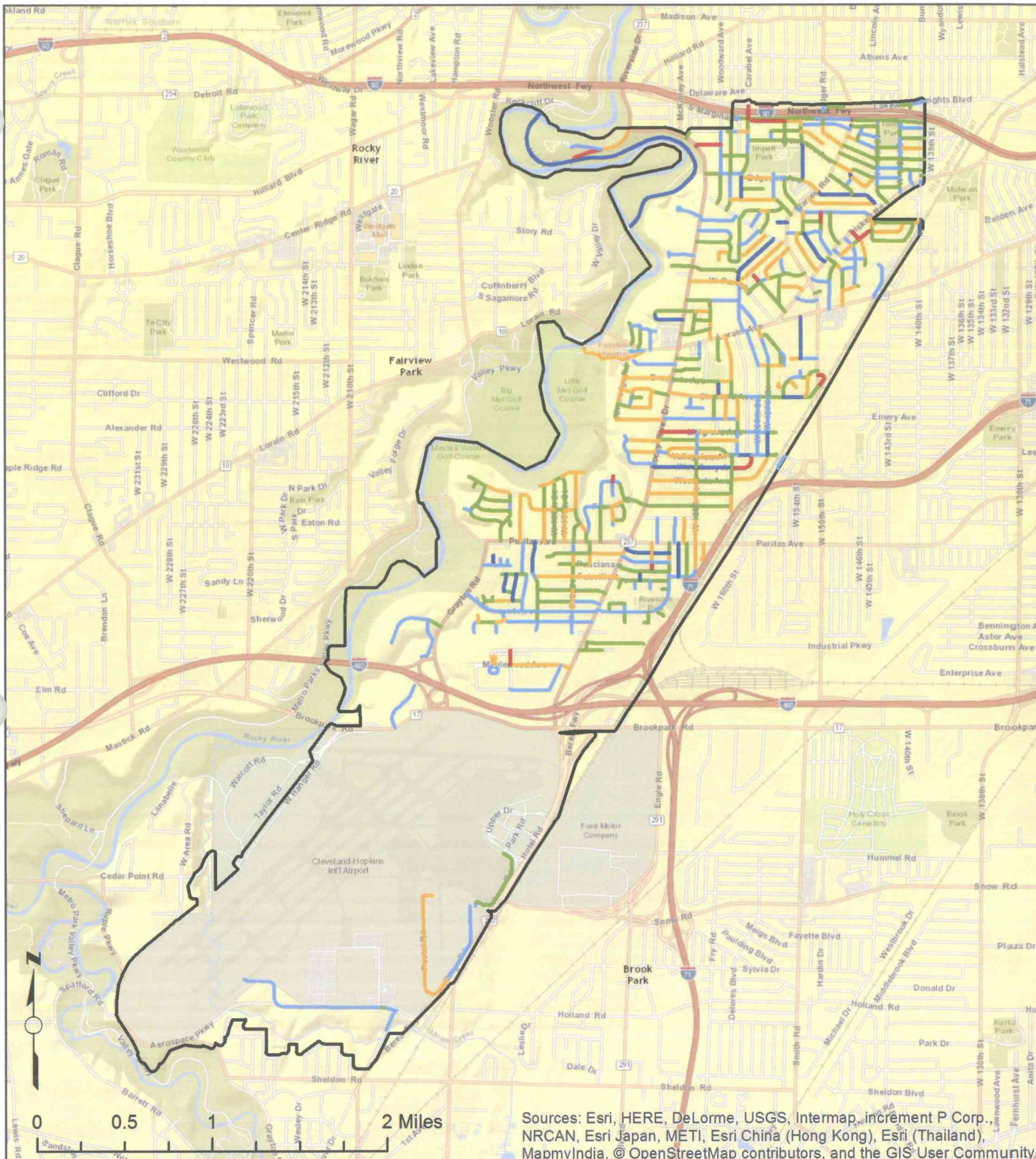
Ward 16 Boundary

Exhibit 17

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Ward 16 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
030.8-55.0	F

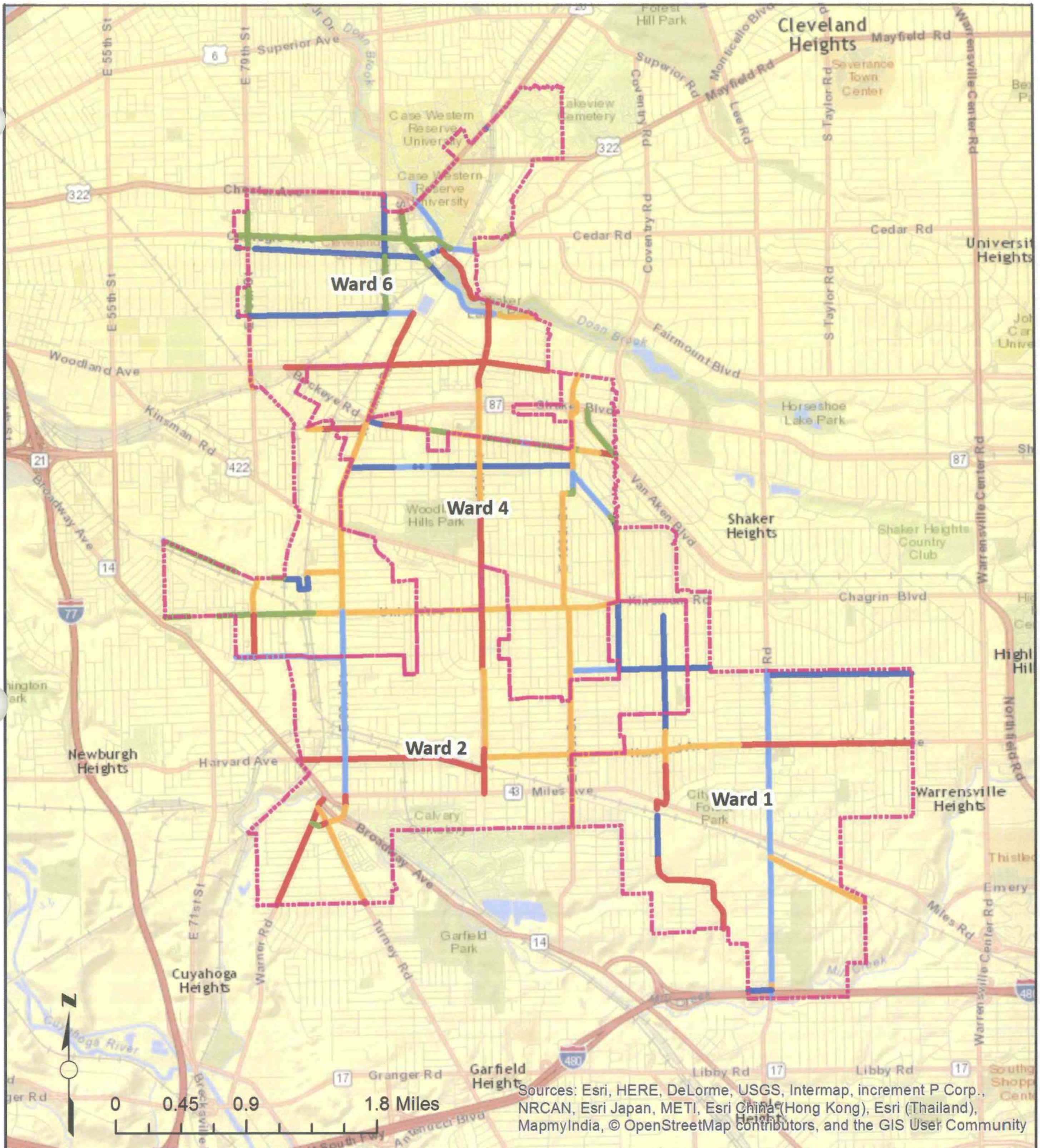
Ward 17 Boundary

Exhibit 18

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR)
Ward 17 Minor Streets

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
029.3-55.0	F

Ward Boundary

Exhibit 19

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Wards 1, 2, 4 & 6 Major Roads

Cleveland Pavement Survey 2015/2016

PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
039.3-55.0	F

Ward Boundary

Exhibit 20

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Wards 7, 8, 9 & 10 Major Roads

Cleveland Pavement Survey 2015/2016

PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
027.5-55.0	F

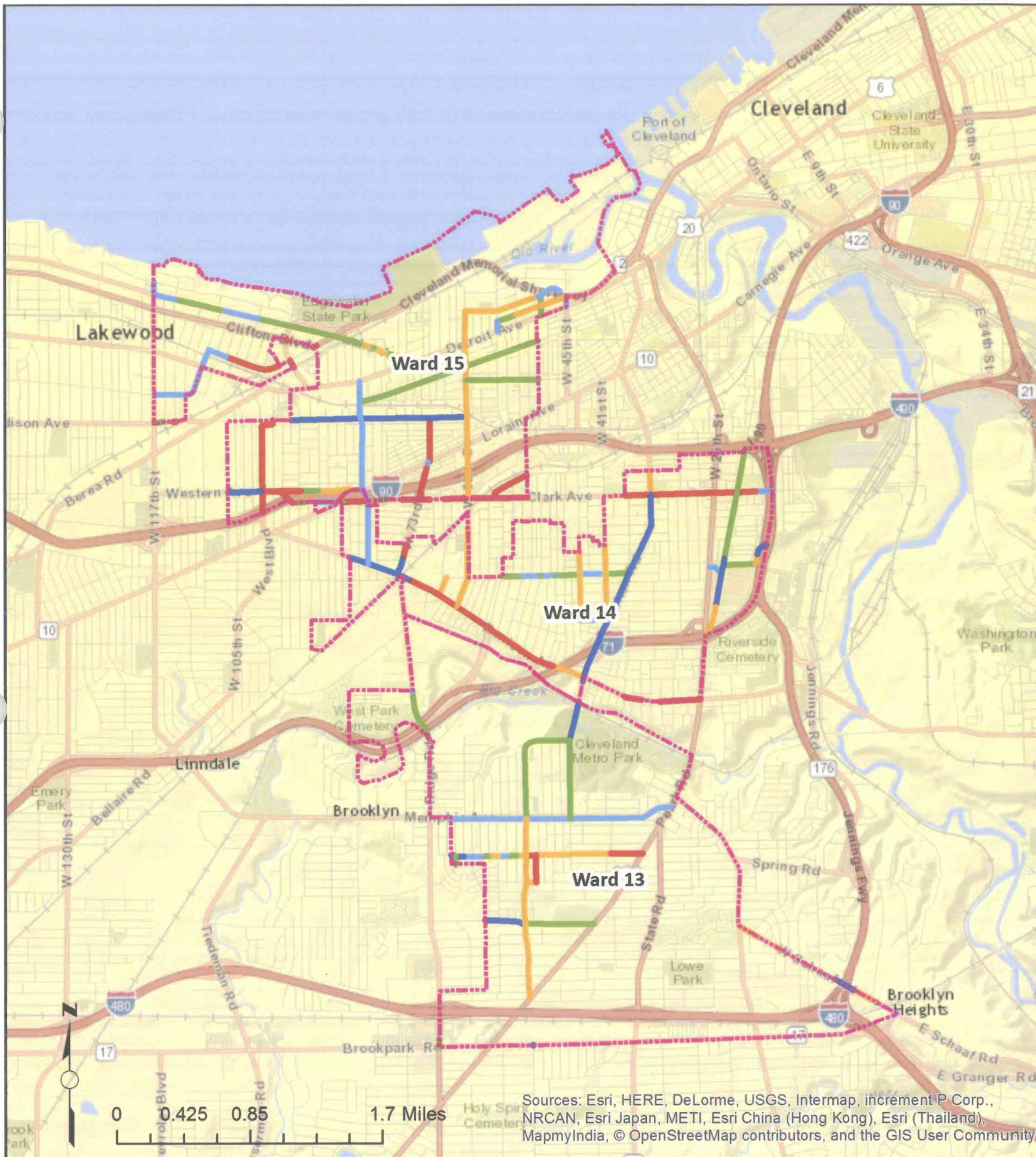
Ward Boundary

Exhibit 21

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Wards 3, 5 & 12 Major Roads

Cleveland Pavement Survey 2015/2016



PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
039.9-55.0	F

Ward Boundary

Exhibit 22

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Wards 13, 14 & 15 Major Roads

Cleveland Pavement Survey 2015/2016

PCR Values	Grade
090.1-100.0	A
075.1-90.0	B
065.1-75.0	C
055.1-65.0	D
031.0-55.0	F

Ward Boundary

Exhibit 23

Michael Baker INTERNATIONAL

Pavement Condition Rating (PCR) Wards 11, 16 & 17 Major Roads

Cleveland Pavement Survey 2015/2016