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I. Executive Summary

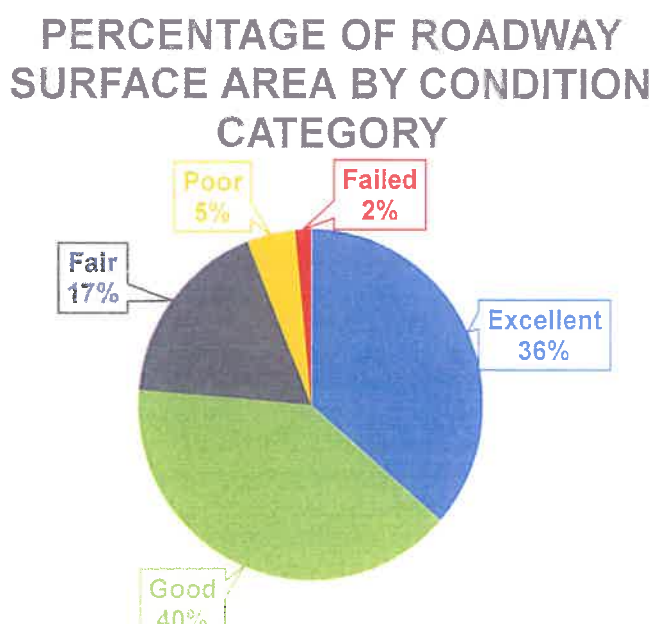
This report summarizes the findings of the pavement inspection of the road segments in Princeton performed by WSB & Associates and completed in May 2022. The report gives an overview of the condition of roads in the city but is not intended to be a final document on public policy or city planning and is subjected to change upon review by City Council. Additionally, pavement analysis was performed using the PAVER program to project the future condition of the City's pavement and make maintenance recommendations. Several scenarios were tested to determine the best maintenance strategy. These recommendations and the budgets needed to achieve them are included as part of the provided 5-year Capital Improvements Program (CIP). Segments the city did not want included in the analysis are not covered in this document.

A summary of the pavement condition report is listed below:

- 29.2 miles of City road were evaluated in Princeton.
- The current weighted average Pavement Condition Index (PCI) for bituminous roads in Princeton is 80.0. PCI is based on a 0 to 100 scale, with higher PCI values corresponding to better road conditions. This weighted average is calculated from the PCI values generated on each segment of roadway. A road's PCI is based on the quantity and severity of pavement distresses identified in the field. Any type of road maintenance (i.e. patching or crack sealing) done prior to inspections is accounted for in the PCI value.

Each segment of bituminous roadway was sorted into one of five broad categories based on their PCI value. Figure I.1. shows the percentage of bituminous roadways in each condition category in terms of surface area.

Figure I.1. Percent of System in Each Pavement Condition Category.



Most roadways qualified for the Excellent or Good categories. However, 24% of the City's roads are in Fair, Poor, or Failed condition. The analysis included aims to protect the investment already made in the network's better sections by establishing maintenance standards and prioritizing maintenance treatments. It also seeks to recommend the most cost-effective ways to improve the segments that need major repairs.

Four different scenarios were tested to show potential impacts to the CIP. Each version of the model examined different budgets or goals that could possibly get implemented over the next five years. A summary of the results is displayed in Table I.1.

Table I.1. 5-Year CIP Scenario Comparison

Scenario	Total 5-Year Budget	2027 Average PCI
1: No Maintenance	$0	69.2
2: Every Segment PCI > 80	$15,558,000	87.8
3: Maintain Average PCI Over 80	$3,676,000	81.2
4: Proposed Budget	$,$$$,$$$	XX.X

Comments on budget recommendation and reference any trends/what is needed after all scenarios are finished.

II. Introduction

A pavement management program includes a systematic method of conducting a detailed distress survey to evaluate the condition of roads in a network, followed by performing a cost-effective analysis of various maintenance and rehabilitation strategies. This assists decision makers in making the best decision on the use of available resources. The pavement management ideology, if successfully implemented, can result in improvement of the life cycle costs, performance, and service life of roads. The main objectives of a pavement management program are to maintain a high-level network, evaluate the effectiveness of different alternatives, and optimize timing of maintenance and rehabilitation activities. These objectives can be met by routinely conducting inspections and determining the condition of a system of roads. The data is typically managed within a pavement management software which can manage, sort, and store the collected information. Through this software, various models can be generated that allows the user to customize maintenance protocols, run different budget scenarios, and evaluate the outcomes of each scenario.

By conducting a pavement management analysis, the City is showing their willingness to continue looking for ways to improve their network of roads and extend the life of their pavement. On top of that, the benefits of a pavement management program extend beyond helping a City improve the average condition of its pavement. Better pavement results in less wear and damage to vehicles that travel the roads. Extending the life of a road reduces the frequency of major reconstruction projects that require lengthy detours and delays to travelers. Safety is improved by giving drivers a surface that allows them to stop quickly and predictably. Achieving the maximum service life of a road is also more sustainable for the environment by reducing the amount of material and fuel that is needed when pavement needs to be completely replaced.

Overall, a pavement management plan should improve the safety for a road network's users and the sustainability of its pavement maintenance while minimizing the costs to taxpayers. This document is designed to act as a guide to help the City manage its pavement. However, it is not the only source of information decision makers should use. It is important to also consult with maintenance staff and review other factors that cannot be accurately included a model. Circumstances unique to a specific City are hard to capture in a scientific analysis and may take precedent over the recommendations provided.

III. Pavement Condition Report Update

Pavement Lifecycle

Pavement is constructed to meet the demands of traffic and the environment for a certain design period. The Pavement Condition Index (PCI) of the roadway declines as traffic and time slowly take their toll on newly constructed pavement. Figure III.1. shows the typical life expectancy of pavement based on data obtained from the Army Corps of Engineers.

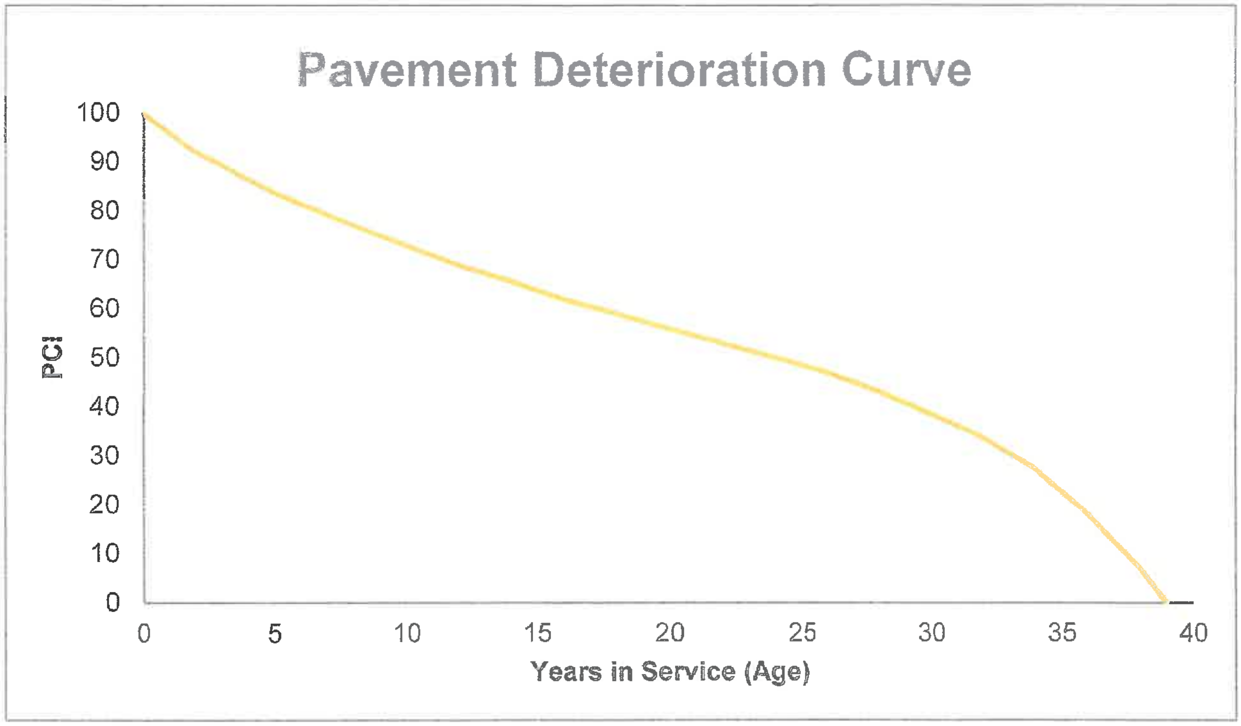


Figure III.1. Typical Pavement Deterioration Curve

This curve exhibits standard behavior when no maintenance is implemented. Each repair or preservation technique applied increases the PCI of a segment and increases its expected life by delaying degradation. The PCI values used in this report are based on a surface inspection of the City's streets. Surface inspections provide a good indication of the pavement and what riders experience when driving the road. However, they do not capture the sub-surface of a pavement structure. Pavement forensics such as pavement coring are required to analyze the entire depth of the road. Some repairs such as patching often improve the PCI of a road but fail to address underlying issues that will continue to cause deterioration. The recommendations in this report seek to keep PCI values high but also maintain the underlying layers of pavement for each segment.

Existing Pavement Conditions

PCI values are used to evaluate pavement condition on a scale from 0 to 100 with 100 being a perfect roadway that exhibits no distress. Table III.1. displays the PCI categories that the engineering staff at WSB use to describe the condition of bituminous roadways along with the maintenance strategy typically implemented on roads in that condition.

Table III.1. Pavement Condition Categories Based on PCI Values

Category	Pavement Condition Index (PCI)	Recommended Strategy
Excellent	85.01 – 100.00	Corrective Maintenance
Good	75.01 – 85.00	Preventative Maintenance
Fair	58.01 – 75.00	Mill/Overlay
Poor	40.01 – 58.00	Reclamation
Failed	0.00 – 40.00	Reconstruction

PAVER, an asset management software, was used to record and estimate the condition of each road segment. The software calculates PCI using deduct values that are based on the type, severity, and quantity of the visible pavement distresses on each road. Examples of asphalt pavement distresses include alligator cracking, longitudinal/transverse cracking, and potholes. Distress severity is classified as either low, moderate, or high. Depending on the type of distress, quantity is measured as the number of occurrences, length, or area.

The PCI values generated were based on a visual inspection and the corresponding recommended maintenance strategies should only be used as a guideline. In some cases, pavement forensics such as coring may be needed to supplement visual inspections and provide more information regarding roadway condition.

This report shows updated pavement conditions for all road segments requested by the City. Most bituminous roadways at the time of inspection were in Excellent or Good condition, but some have reached the point of failure. Table III.2. shows how much of the City's pavement is in each condition category.

Table III.2. City Roads by Condition Category

Pavement Condition Index	Mileage	Percent of System by Area
Excellent Category (85.01 – 100.00)	10.4	36.4 %
Good Category (75.01 – 85.00)	11.2	40.0 %
Fair Category (58.01 – 75.00)	5.3	17.5 %
Poor Category (40.01 – 58.00)	1.6	4.6 %
Failed Category (0.00 – 40.00	0.7	1.5 %

Appendix A includes maps of all the inspected road segments in the City with their PCI condition categories. Appendix B displays the PCI values of every inspected segment.

Pavement Rating Examples

PCI Rating = 14: Failed

14th Ave S (Segment ID: 286)

When a road's PCI rating is 40 or below, the pavement shows high severity distresses at multiple locations or extensive moderate and low severity distresses. The street has deteriorated to the point where the structural integrity has diminished along with the driving surface. Drivers using segments of this condition experience bumpy and rough rides. Typically, streets of this category require reconstruction. Reconstruction involves removing the pavement at full depth, through the surface layers of asphalt and into the gravel base, and constructing the street to its original state. Reconstruction is very costly, so every effort should be made to keep streets from entering this category.

Detailed Distresses on Segment Shown:

- Alligator Cracking, High Severity, 1.16%
- Alligator Cracking, Moderate Severity, 11.61%
- Potholes, High Severity, 0.05%
- Raveling, High Severity, 0.58%
- Weathering, High Severity, 100.00%

PCI Rating = 47: Poor

4th St (Segment ID: 24)

Roads in the Poor category are at the point where the number and severity of distresses dramatically worsen. Moderate and high severity distresses become common. Drivers experience many bumps while using these streets. Maintenance tactics such as crack sealing and seal coating are not effective, as the pavement has deteriorated beyond the point of repair. If the damage has not yet reached the base of the road, reclamation is recommended. Reclamation is an in-place recycling method for reconstruction of flexible pavements using the existing pavement section material as the base for a new roadway-wearing surface. While reclamation projects are much cheaper than reconstructions, it is still a costly procedure.

Detailed Distresses on Segment Shown:

- Alligator Cracking, High Severity, 0.54%
- Edge Cracking, High Severity, 0.67%
- Longitudinal & Transverse Cracking, High Severity, 1.66%
- Longitudinal & Transverse Cracking, Moderate Severity, 0.42%
- Longitudinal & Transverse Cracking, Low Severity, 0.56%
- Potholes, Moderate Severity, 0.08%
- Weathering, Low Severity, 100.00%

PCI Rating = 68: Fair

4th Ave S (Segment ID: 83)

Segments rated as Fair may have a few moderate and severe distresses but usually only have mild widespread distresses. The road shows wear but it is still structurally sound. Drivers may experience some bumps while using these segments, but the driving surface is mostly smooth. Typically, streets in this category can be rehabilitated with a mill and overlay. This method involves milling off the top part of the pavement and replacing it with a new lift of fresh asphalt. Milling eliminates most of the distresses since they are usually mild and still only on the surface. The overlay provides a new driving surface while utilizing the existing base which is still in adequate condition. This strategy prevents the pavement from deteriorating past the point where repairing it is no longer cost-effective.

Detailed Distresses on Segment Shown:

- Alligator Cracking, Moderate Severity, 0.03%
- Edge Cracking, Moderate Severity, 0.06%
- Longitudinal & Transverse Cracking, Moderate Severity, 0.21%
- Longitudinal & Transverse Cracking, Low Severity, 0.34%
- Potholes, High Severity, 0.01%
- Potholes, Moderate Severity, 0.01%
- Shoving, Moderate Severity, 0.08%
- Weathering, Low Severity, 100.00%

PCI Rating = 80: Good

13^{th} Ave N (Segment ID: 33)

Streets with a rating of Good have experienced enough freeze thaw cycles to show signs of distress. These distresses are usually mild with some moderate distresses also present. Drivers on these segments encounter mostly smooth rides with few bumps. While the distresses may still be relatively minor, they are prime candidates for preventative maintenance techniques. It is recommended that the City use a combination of crack sealing, chip sealing, and fog sealing to restore segments in the Good category. These strategies are relatively cheap and extremely cost-effective ways to extend the life of the pavement.

Detailed Distresses on Segment Shown:

- Alligator Cracking, Low Severity, 0.19%
- Block Cracking, Moderate Severity, 4.67%
- Block Cracking, Low Severity, 1.95%
- Longitudinal & Transverse Cracking, Moderate Severity, 0.44%
- Longitudinal & Transverse Cracking, Low Severity, 1.30%
- Weathering, Low Severity, 100.00%

PCI Rating = 93: Excellent

Old Airport (Segment ID: 86)

If a pavement section is categorized as Excellent, it will have been recently resurfaced or constructed. Distresses can be present but they are usually mild in severity. Drivers will experience few if any bumps while traveling the segment. In most cases no maintenance is required on Excellent pavement. However, the City should be proactive by crack sealing seams and any early cracks to prevent seepage into the base of the road.

Detailed Distresses on Segment Shown:

- Bumps and Sags, Low Severity, 0.02%
- Edge Cracking, Low Severity, 0.04%
- Longitudinal and Transverse Cracking, Moderate Severity, 0.20%
- Longitudinal and Transverse Cracking, Low Severity, 0.39%
- Weathering, Low Severity, 100.00%

IV. Pavement Management Report

The information provided in this pavement management report is based on a systematic method of inspecting and rating the pavement condition of roads in the City's network, followed by an analysis of various cost-effective maintenance and rehabilitation strategies which can aid in making the best decisions on the use of available resources. It can also be used to provide updated data regarding the current pavement management plan.

Recommended Maintenance Action

Princeton has many options at their disposal for pavement rehabilitation and preventative maintenance including reconstruction, reclamation, mill and overlays, and seal coats that extend the life of a roadway. Each of these treatments should last several years and be cost-effective if correctly implemented at the right time.

Corrective Maintenance

Corrective maintenance is used to fix a road segment that is not performing as expected. This may be the result of improper construction or unforeseen conditions. This typically involves crack sealing or patching. Corrective maintenance is recommended for roads in Excellent condition because these segments should not need any major maintenance other than minor crack sealing unless the pavement behaves unpredictably.

Preventative Maintenance

Preventative maintenance is defined as treatment to an existing road that will help preserve and protect the pavement, while also slowing future deterioration. This type of maintenance improves the condition of the system without increasing its structural capacity.

Implementing a preventative maintenance strategy is cost-effective and important since maintenance costs increase with pavement age. Preventative maintenance actions can be done at a much lower cost than preservation actions such as mill and overlays. By applying appropriate preventative maintenance before a road deteriorates, the pavement can be kept in good condition at a much lower cost. With proper preventative maintenance techniques, the life of an average paved road increases from 20 years to 60 years.

Preventative maintenance is best performed on newer pavements prior to the appearance of significant and/or severe distresses. There are many preventative maintenance applications that seek to protect pavement from deterioration. These treatments vary in effectiveness and price. Common preventative maintenance techniques include crack sealing, fog sealing, chip sealing, chip sealing followed by fog sealing, rejuvenating, micro-surfacing, and slurry sealing. WSB would be happy to provide additional guidance on what types of preventative maintenance would work best for Princeton if needed. Patching can also be considered preventative maintenance, but it is usually implemented on small areas of severe distress. Additionally, patching a road to increase its PCI does not provide long term structural improvement. Patching may be necessary to keep roads in serviceable condition but it should not be considered routine maintenance for every road.

Crack Seal

Crack sealing is done to prevent the intrusion of water and incompressible materials into cracks. When water enters cracks in pavement, it can soften the sub-base and base layers. This leads to the development of more severe distresses and ultimately the formation of potholes. In Minnesota where extensive freeze/thaw cycles exist, the water that enters the pavement structure through cracks can also lead to frost heaving issues. Crack sealing should be completed early in the life of a new pavement or overlay. For the most effective results, it should be performed 2 to 4 years after a new surface is constructed and periodically after that as deemed necessary. This technique will not improve the structural capacity of the pavement, but it will slow down future structural deterioration. In general, crack sealing should be done in coordination with other pavement preservation and rehabilitation treatments to enhance their performance. It may also be conducted as a stand-alone practice to increase pavement life through minimizing water and incompressible ingress and damage. Best practice is to seal cracks prior to fog seals, chip seals, overlays, and any other surface treatment. All moderate to high severity longitudinal, transverse, and block cracks between ¼ inch and ½ inch wide should be sealed. Cracks less than ¼ inch wide may be difficult to seal and should be filled with a surface treatment. Cracks wider than 3/4 inch will require a mastic fill material. To mitigate roughness issues, overbanding or buildup of seal material on the surface of the pavement should be avoided. Finally, alligator cracks should be addressed through base repair or patching methods and should be largely removed prior to crack sealing. Crack sealing is an important first step to mitigating future pavement damage but adding a seal coat layer on top of sealed cracks provides significantly more protection from distresses. WSB recommends the City reference MnDOT Spec 3719, 3723, or 3725 for more information on crack sealing guidelines

Fog Seal

Fog sealing is another type of preventative maintenance in which asphalt emulsion is applied to the roadway to protect the surface from environmental aging, moisture damage, and oxidation. This preventative maintenance technique will not add any strength to the pavement. Fog sealing is typically completed one year after crack sealing. Typically, a fog seal will last 3 to 5 years. It is important to note that while the color of a fog seal may fade as early as a year after its application, a fog seal remains effective for as many as 2 to 4 years. WSB recommends the City reference MnDOT Spec 2355 for more information on fog sealing guidelines.

Chip Seal

Like a fog seal, the chip sealing process involves an application of a uniform layer of emulsified asphalt. However, chip sealing includes immediately applying by a layer of cover aggregate across the pavement surface. Pre-sweeping and filling of cracks should be done prior to the chip seal application. Chip sealing creates a waterproof surface membrane to the existing membrane, which helps to slow down the deterioration of the pavement from oxidation as well as to prevent the intrusion of water. Chip sealing is typically completed one year after crack sealing. Normally, a chip seal placed on a newer road will last 5 to 10 years. This assumes the chip seal is protected during placement to allow proper curing time. Other factors that affect the performance of a chip seal include the type of binder that is used, the condition of the underlying road, and external factors such as plow damage. It is the responsibility of the owner to ensure that these external factors do not contribute to premature failure of a chip seal. Field surveys should assist in determining which roads are candidates for a chip seal. WSB recommends the City reference MnDOT Spec 2356 when considering chip sealing.

Chip Seal Followed by Fog Seal

A newer preventative maintenance strategy that has already proven cost-effective for cities includes combining the benefits of a chip seal and a fog seal. Applying a chip seal immediately followed by a fog seal extends the life of a traditional standalone chip seal project with some additional benefits. The fog seal over a chip seal provides for better chip retention resulting in a more durable surface and reducing the complaints from the public of chipped windows and rocks being tracked off the project. The public has been found to have a more positive opinion of the fog sealed chip seal projects because they appear as if the road was just overlaid at a reduced price and far less impact to roadway users.

The construction of this type of fix is the same as for the chip seal section in this report with the addition of a fog seal once the chip seal rock has been compacted. WSB would recommend applying CSS-1H emulsion at a rate of 0.10 gallons per square yard as a starting point. The application rate can depend on the rate of emulsion applied under the chip seal and the rock used so adjust as needed to the project conditions.

The City has reported having problems with standard chip seals in the past. Adding a fog seal on top of a chip seal is a way to reduce many of the issues experienced in the past. Engineers at WSB recently completed a statewide study on chip seals followed by fog seals and found they performed much better, were well-received by the public, and provided the cost-effective solution that seal coats are designed to deliver. For these reasons, chip seal followed by fog seal is recommended as the main preventative maintenance solution for the City.

Overlay/Mill and Overlay

An overlay involves placing a new layer of bituminous material on top of an existing asphalt surface. A mill and overlay requires grinding all or a portion of the in-place asphalt surface and topping the ground surface with a bituminous wearing course. This rehabilitation strategy provides a structural improvement to the roadway. We recommend conducting more investigation such as pavement coring to evaluate the subsurface conditions before implementing an overlay project. Information such as depths of pavement layers, signs of debonding, and distresses that are not visible from the road surface can be obtained through pavement coring. Applying an overlay to a pavement structure with inadequate subsurface conditions will cause the new surface to fail prematurely.

Reclamation

The most common types of reclamation are full-depth reclamations (FDR) and stabilized full-depth reclamations (SFDR). FDR involves pulverizing the full depth of bituminous and a portion of the underlying materials. That material then gets blended together and placed as a sound base for new pavement. Typically, FDR reclaim depth is 12 inches, although it can be as deep as 18 inches. Excess FDR mixture may be removed to allow 6-inch lifts compaction. Additional rock may need to be provided if the mixture is expected to be deficient in crushing or gradation.

The reclaimed mixture can be topped with different types of surface course, depending on the structural requirements and anticipated traffic level. A layer of tack coat needs to be applied prior to surface treatment to provide good bonding between the FDR mixture and surface course. SFDR involves the same process but includes mechanical, chemical, or bituminous stabilization. The typical minimum depth of stabilization is 4 inches, but it can go as deep as 6 inches. Mechanical stabilization involves the addition of new aggregate or recycled materials. Chemical stabilization includes the addition of lime, cement, fly ash, calcium chloride, or other proprietary products. The asphalt additives can be foamed asphalt or asphalt emulsion. These stabilizing agents if combined with additives, can help optimizing the FDR performance.

Reconstruction

Reconstruction includes the complete replacement of the road's driving surface and pavement structure. The pavement along with its base layers are then replaced with new material. Asphalt mix type, ride specification, lift thicknesses, and compaction requirements must be in accordance to the specified standard. Selecting the specific appropriate reconstruction plan for a road requires more detailed investigation such as pavement coring. Each road segment requires a specific pavement design that considers existing subgrade materials and traffic loading to create the most effective pavement structure. Subsurface water management is a significant component of a reconstruction project. Thus, addressing roadway drainage is included in roadway reconstruction projects. When performing a reconstruction, it is important to consider the entire pavement structure that includes the base and subbase. A larger initial investment in thicker base and subbase layers along with edge drains provides the pavement with a stronger foundation that reduces damage from moisture under the surface. This produces pavement that is less susceptible to damage and has a longer expected life. WSB can provide specific reconstruction design recommendations if requested.

Pavement Forensics

The final decision on implementing a reconstruction or reclamation project should come after a pavement forensic study. Pavement forensics studies the pavement structure and condition of the base underneath the visible layer of pavement. Important information results from this analysis. Examining pavement cores can determine the depths of pavement layers, signs of bonding or de-bonding, and distresses that might not be visible from the surface. Soil borings along the roadway can be used to identify aggregate depths and soil classifications to provide a better understanding of the roadway section. This information is crucial when determining what type of rehabilitation is needed and what it will cost. Several factors should be considered when deciding the number of cores to be taken such as the pavement condition and the variability in the pavement depth as cores are being taken. A pavement forensic study should be conducted less than two years before a major maintenance project to ensure the results of the study accurately reflect the road's condition. The findings of pavement forensic studies have been proven to lead to cost savings and more appropriate maintenance strategies. WSB can perform pavement forensics for Princeton if requested.

5-Year Capital Improvements Program (CIP)

To develop recommendations for the City regarding their 5-year CIP, a model was created using the PAVER software. PAVER uses construction, inspection, and maintenance records along with a degradation curve to predict how each segment of pavement in the City's system will perform over time. This analysis utilized the Army Corps of Engineer's standard pavement degradation curve. Different scenarios and maintenance budgets can then be tested to see how they would perform and determine the best plan moving forward. Leveraging PAVER's ability to optimize the cost-effectiveness makes sure the City's resources have the biggest impact on the roadway system.

To build an accurate model of in PAVER, unit pricing for the maintenance activities were developed as follows. The unit pricing of chip sealing followed by fog sealing was selected as the representative cost for the preventative maintenance activity since it has shown to be one of the most cost-effective forms of preventative maintenance. The cost of corrective maintenance on roads in Excellent condition was considered too minimal to include.

- Preventative Maintenance - $2/square yard
- Mill and Overlay - $30/square yard
- Reclamation - $54/square yard
- Reconstruction - $240/square yard

These cost estimates are based on historical project costs for similar work in the area. Estimates include other costs that accompany pavement maintenance such as adjusting casings, adjusting valve boxes, and replacing curb and gutter. Contingency and indirect costs are also included to provide accurate cost projections. Figure IV.1. demonstrates how the cost of restoring pavement increases as pavement deteriorates. This shows the importance of implementing preventative maintenance because it is exponentially cheaper. It also shows the importance of repairing roads before they reach the level where a reconstruction is needed since the cost jumps significantly. Once roads reach this level, the cost no longer increases and urgency to repair the road is driven solely by the need to keep roads serviceable for the traveling public. This data is reflected in the results of each scenario modeled in PAVER.

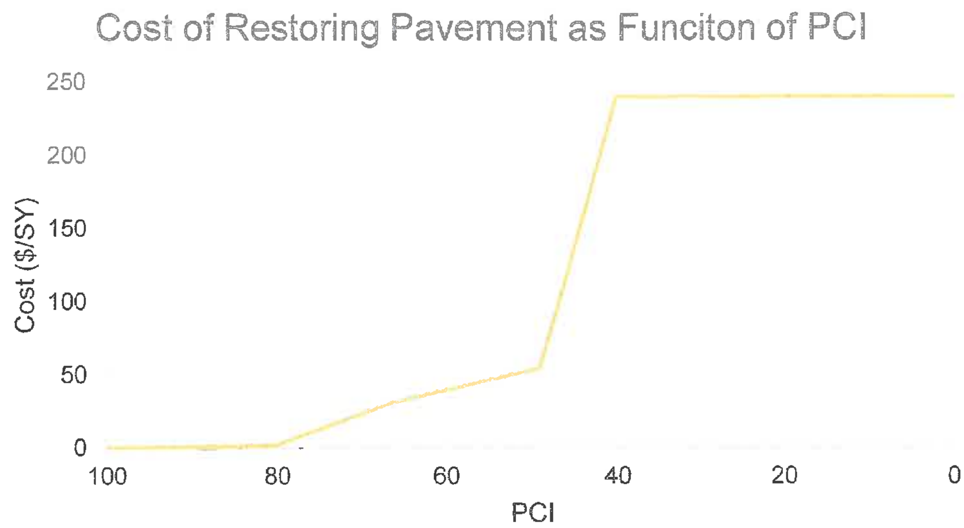


Figure IV.1. Increasing Cost of Restoring Pavement

A main goal of this pavement management report is to determine how much funding is necessary to maintain the City's streets over the next five years and how that budget should be spent. To best determine this, four scenarios were tested and the associated impacts on the overall PCI rating of the City were recorded.

Scenario 1: No Maintenance

The No Maintenance scenario is a good starting point when comparing various funding alternatives because it shows the rate of deterioration that the City must overcome through its maintenance and rehabilitation programs. Given no pavement maintenance funding over the next 5 years, the City pavement condition would deteriorate at a rate of approximately 2-3 PCI points per year, going from a PCI of 80.0 in 2022, to 69.2 in 2027. The goal of the other scenarios tested is to find the best way to offset this natural deterioration rate. The summary of results from Scenario 1 can be found in Table IV.1. and Figure IV.2.

Table IV.1. Summary Results for Scenario 1

Year	2023	2024	2025	2026	2027	Totals
Total Spent ($ thousand)	0.0	0.0	0.0	0.0	0.0	0.0
Average PCI	77.6	75.4	73.3	71.2	69.2	-

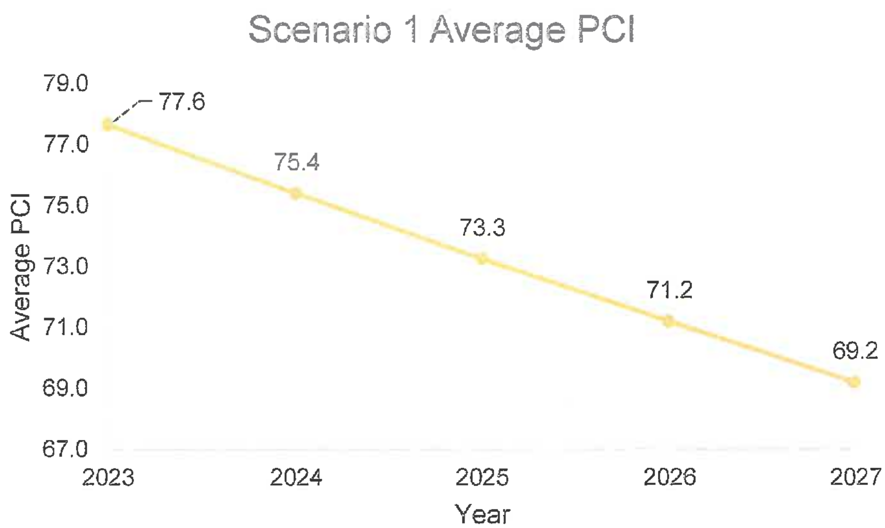


Figure IV.2. Average PCI in Scenario 1

Scenario 2: Minimum PCI of 80 on Every Segment

The second scenario was tested with the goal of getting every road in the city to have pavement in good condition by the end of the five-year plan. Under this scenario, the model increases the minimum PCI threshold each year until a target PCI of 80 is achieved at the end of year five on all segments. This scenario involves implementing many major rehabilitation projects on the roads currently in bad condition. To achieve this ambitious goal, an annual budget of $3,200,000 is required for each of the next five years. This large increase in spending would allow every segment to be firmly in the Good category and result in average PCI of 87.8 by the end of the CIP.

The results show how money is initially directed towards the worst roads resulting in many reconstruction projects. Funds then shift towards reclamation projects and the mill & overlay projects as the worst roads get repaired. Consequently, the average PCI increases dramatically. This scenario is much more costly than the others tested and is also the least cost-effective since all resources are allocated towards improving the worst roads and few are dedicated to preventative maintenance on the better segments. The summary of results from Scenario 2 can be found in Table IV.2. and Figure IV.3.

Table IV.2. Summary Results for Scenario 2

Year	2023	2024	2025	2026	2027	Totals
Spent on PM ($ thousand)	0	0	0	800	494	1,294
Spent on M/O ($ thousand)	0	1,417	3,252	2,348	2,671	9,687
Spent on Reclaim ($ thousand)	0	1,256	0	0	0	1,256
Spent on Recon ($ thousand)	3,047	274	0	0	0	3,321
Total Spent ($ thousand)	3,047	2,947	3,252	3,148	3,165	15,558
Average PCI	78.5	79.6	82.7	85.4	87.8	-

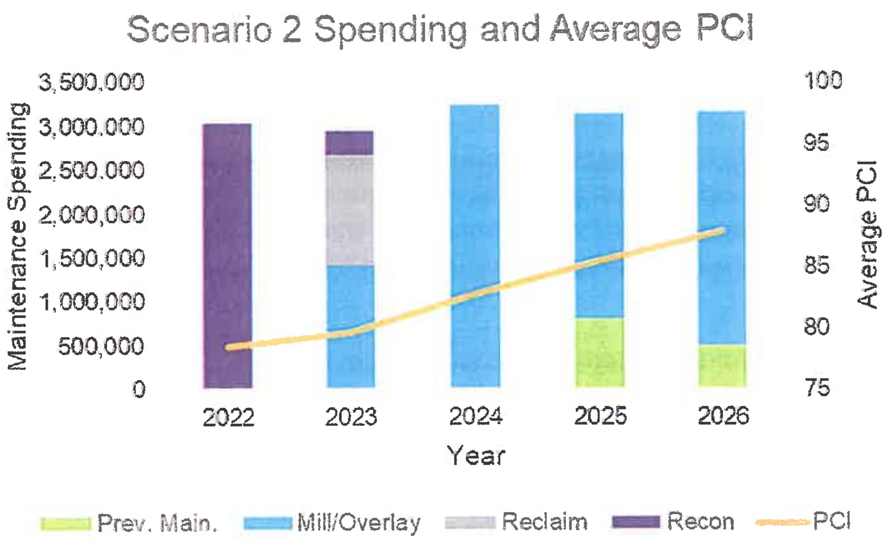


Figure IV.3. PCI vs Maintenance Budget for Scenario 2

Scenario 3: Maintain Average PCI Over 80

The third scenario tested examined what budget would be needed to maintain an average PCI of 80 over the life of the CIP. The City's average PCI value is currently 80.0 so this scenario identifies the budget needed to maintain the current average quality of pavement the City's residents are accustomed to. It is important to note that the PAVER simulation only seeks to maximize the average PCI while minimizing the budget. This means that reconstruction and reclamation projects receive last priority since they are the most expensive and least cost-effective way to improve the PCI of a segment. While this approach does keep average PCI values high, it lets some roads degrade beyond an unacceptable condition. To help offset this, roads rated as Poor or worse were designated as being in critical condition. Segments in critical condition are given a higher priority in the model. This helps make scenarios more realistic by ensuring the entire budget does not get allocated to maintaining the best roadways. However, no model is perfect and the decision between implementing more cost-effective maintenance projects on segments in better condition and implementing more costly repairs on roads in unacceptable condition is one City officials will need to make.

The model also does not account for important factors such as keeping heavily trafficked roads in better condition than lesser trafficked routes or public opinion about which roads should be repaired. The judgement of the City is needed to decide when a road has reached the end of its serviceable life and should receive a reconstruction or reclamation. When these additional variables are included, resources need to get spent in less cost-effective ways which means the weighted average PCI will likely perform worse than projected.

The results from Scenario 3 show most of the budget initially being allocated towards preventative maintenance projects. The city has many roads in Excellent and Good condition so PAVER is trying to implement cost-effective maintenance to preserve these segments and maximize the budget. In later years, the model was forced to spend more on reclamation and reconstruction projects to keep the average PCI level high. The model showed that an average annual budget of $740,000 is needed to ensure an average PCI of 80 is achieved each year until 2027. The final PCI value projected in this scenario is 81.2. This number is higher than the target score of 80.0 but accounts for the fact that after maintenance is completed in the summer and the score is raised, it will spend the rest of the year degrading back to the target score of 80.0.

The summary of results from Scenario 3 can be found in Table IV.3. and Figure IV.4.

Table IV.3. Summary Results for Scenario 3

Year	2023	2024	2025	2026	2027	Totals
Spent on PM ($ thousand)	535	188	73	8	0	804
Spent on M/O ($ thousand)	0	0	0	0	0	0
Spent on Reclaim ($ thousand)	236	572	64	117	622	1,612
Spent on Recon ($ thousand)	0	0	618	642	0	1,260
Total Spent ($ thousand)	771	760	755	768	622	3,676
Average PCI	82.4	85.8	85.2	83.2	81.2	-

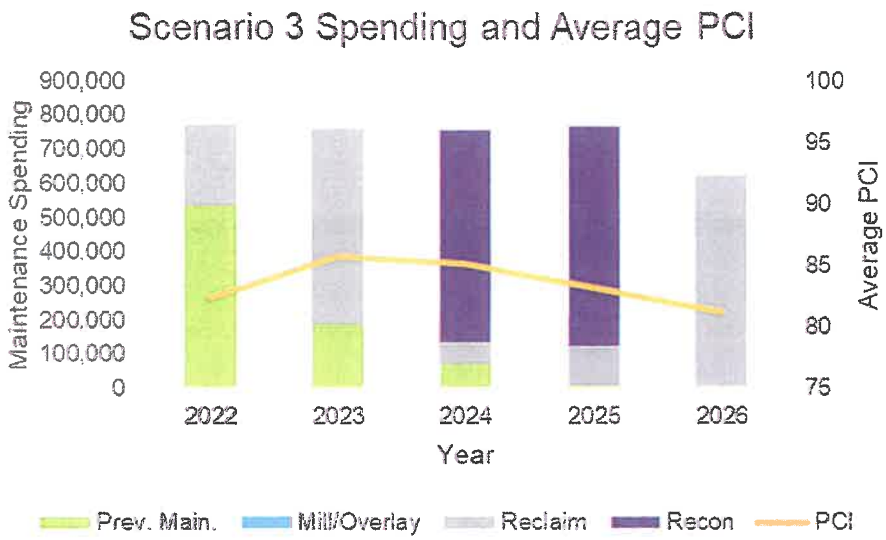


Figure IV.4. PCI vs Maintenance Budget for Scenario 3

Scenario 4: City's Current Proposed Budget

The fourth scenario tested the city's current proposed budget. This budget is shown in Table IV.4.

Table IV.4. Anticipated Maintenance Budget

Year	Budget
Year1	$123,456
Year2	$123,456
Year3	$123,456
Year4	$123,456
Year5	$123,456
Total CIP Budget	**$123,456**

If the expected funds are spent in the optimal way, the average PCI is projected to.......

The summary of results from Scenario 4 can be found in Table IV.5. and Figure IV.5.

Table IV.5. Summary Results for Scenario 4

Year	2023	2024	2025	2026	2027	Totals
Spent on PM ($ thousand)						
Spent on M/O ($ thousand)						
Spent on Reclaim ($ thousand)						

Spent on Recon ($ thousand)						
Total Spent ($ thousand)						
Average PCI						-

Figure IV.5. PCI vs Maintenance Budget for Scenario 4

Spending and Maintenance Recommendations

Figure IV.6. compares the four scenarios tested in PAVER. The results were used to notice trends and develop recommendations for the City.

Figure IV.6. Scenario Summary Comparison

Budget Recommendations

Recommendations to follow after all scenarios have been completed

Maintenance Recommendations

While the maintenance repair recommended for a segment typically aligns with its PCI score and the corresponding condition category noted above, there are a few other factors to consider when deciding which roads should receive a specific treatment. Anytime a major rehabilitation projects is needed (PCI less than 75), it is wise to do more investigation before moving ahead with a project. Spending resources investigating the pavement and base condition adds value by making sure the most cost-effective solution is applied. This is especially true when deciding between a reclamation or a reconstruction. The cost difference between these alternatives is substantial enough that pavement coring should always be implemented before moving forward with a project that has a PCI score lower than 58.

As mentioned earlier, the actual performance of the roads in the City's system will depend on how cost-effective its maintenance is. There are several strategies that can be used to protect the roads in good condition and to stretch the impact of the City's resources. To maximize the effectiveness of the available funding, we recommend prioritizing preventative maintenance. While it seems counterintuitive to focus on roads in the best condition, their preventative maintenance is relatively cheap and retaining segments with high PCI values is necessary to avoid high maintenance costs in the future. While roads will inevitably need more expensive repairs at some point, delaying those expenses and keeping roads in good condition is a best practice. Figure IV.7. illustrates this point.

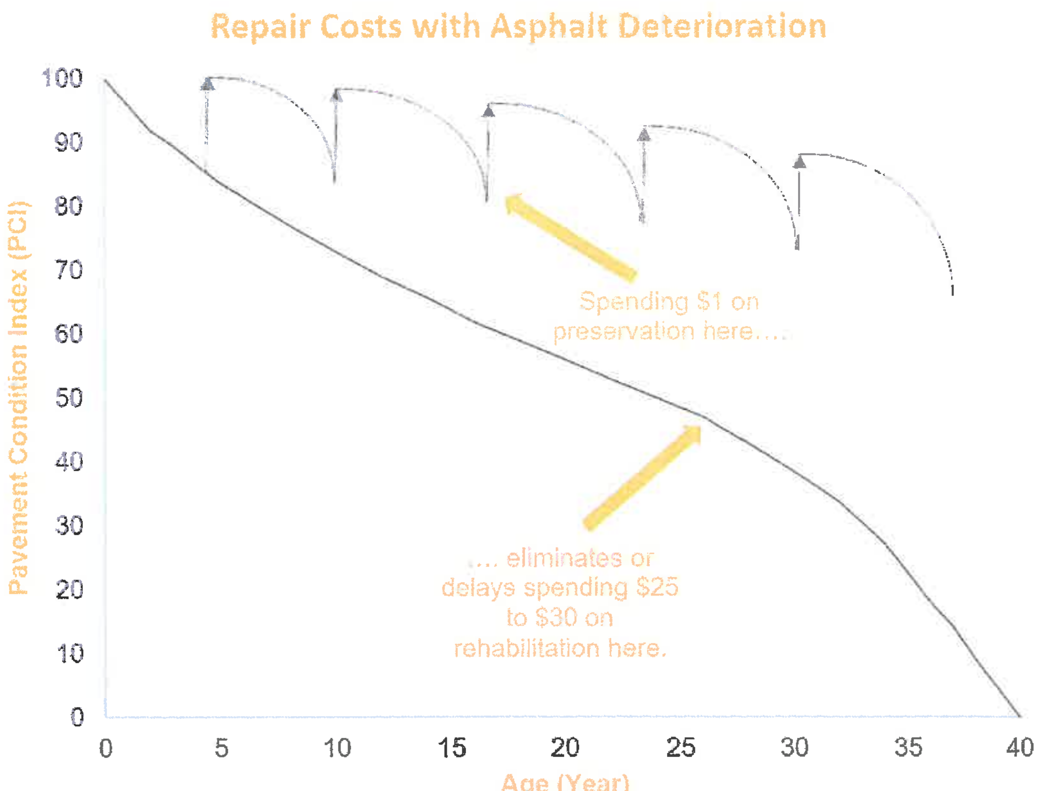


Figure IV.7. Cost-Effectiveness of Preventative Maintenance Example

Similarly, taking advantage of the lower cost of mill and overlay projects compared to other major rehabilitation projects allows the budget to improve more road segments in the city. This same logic applies to not letting a road deteriorate to the point where it will need to be reconstructed. Reconstructions consume many resources which is why most of the PAVER scenarios tested tried to implement reclamation projects before reconstruction would be necessary. When reconstruction is cannot be avoided, we recommend investing in base and subbase layers with adequate thickness. Paying extra to make sure the new road is built on a sturdy and dry foundation will extend the life of the pavement and reduce the amount of resources needed for maintenance. When constructed properly, aggregate bases and subbases should not need to be replaced, even when the pavement fails.

Another important methodology to adopt is to not implement a less expensive repair on a road that requires a more expensive fix. It is tempting to try and apply cheaper fixes when facing expensive cost estimates. However, this will result in wasting precious funds. For example, applying a chip seal as preventative maintenance on a road that is in Fair, Poor, or Bad condition is not effective. Instead of providing years or protection as intended, it will deteriorate quickly and not result in long-term results.

With all these factors in mind, a recommended maintenance schedule was created. This schedule is meant to serve as a guide for typical segments and will not apply to every road in the system. However, it does implement many best practices that cost-effectively keep the pavement in good condition. Table IV.5. shows this recommendation.

Table IV.5. Recommended Typical Maintenance Schedule

Typical Maintenance Schedule				
Cumulative Pavement Age (Years)	Time Between Maintenance	Maintenance	Predicted PCI	
			Initial	Improved
0	0	New Construction	100	
2	2 Years After New Construction	Initial Crack Seal	92	100
4	2 Years After Crack Seal	Crack Seal	92	100
5	1 Year After Crack Seal	Chip & Fog Seal	96	100
8-11	Every 3 to 6 Years	Crack Seal	85-90	98
12	1 Year After Final Crack Seal	Chip & Fog Seal	85	98
18-22	6-10 Years After Chip & Fog Seal	Mill and Overlay	60	95
20-24	2 Years After Overlay	Initial Crack Seal	86	93
21-25	1 Year After Crack Seal	Chip & Fog Seal	83	95
24-34	Every 3 to 6 Years	Crack Seal & Patch	80	92
27-35	1 Year After Final Crack Seal	Chip & Fog Seal	78	95
33-45	6-10 Years After Chip & Fog Seal	Mill and Overlay	59	90
35-47	2 Years After Overlay	Initial Crack Seal	86	90
36-48	1 Year After Crack Seal	Chip & Fog Seal	84	90
39-56	Every 3 to 6 Years	Crack Seal & Patch	85	90
42-57	1 Year After Final Crack Seal	Chip & Fog Seal	76	88
52-75	10-20 Years After Chip & Fog Seal	Reclamation	50	100

Finally, we recommend keeping a detailed log of all street maintenance implemented in the City. Recording information such as the type of maintenance activity, when it was implemented, how much it cost, the materials used, the age of the road during implementation, and any other testing results on that segment can prove helpful in the future. Maintenance logs can help determine what is working well for a City and what is not. Similarly, if a recommended maintenance strategy is not working well, reviewing details of the activity can help reveal why. This detailed information can also be used to improve the assumptions used by the PAVER model. This will ensure future recommendations will be based on accurate scenarios.

Appendices