COUNTY OF RIVERSIDE
TRANSPORTATION DEPARTMENT

PAVEMENT MANAGEMENT REPORT
2022/2023

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EXECUTIVE SUMMARY

The County of Riverside Transportation Department (County) strives to provide a safe, efficient, and sustainable transportation system to its users. The County has implemented a Pavement Management System (PMS) to assist in determining pavement needs and priorities. The PMS supplements decision-making by helping the County implement cost effective solutions to pavement problems and improve the overall condition of roads. The PMS also allows the County to maximize the use of limited funding for pavement improvements by taking a comprehensive approach using best management practices instead of a "worst-first" pavement strategy. The PMS considers pavement life cycle costs in determining what work should be completed. This involves applying the right treatment to the right pavement at the right time to maximize the pavement's service life at the lowest cost. An example would be to spend limited funding on applying preservation treatment to good roads instead of completing a costly reconstruction of one severely deteriorated and relatively low use section of a road.

PAVEMENT CONDITION ASSESSMENT

The Pavement Condition Index (PCI) method was used in assessing the condition of the County's pave roads. The PCI method is an objective and repetitive method for assessing pavement condition and is widely used in industry. Pavement conditions were categorized based on PCI values using the criteria shown in Figure ES–1.

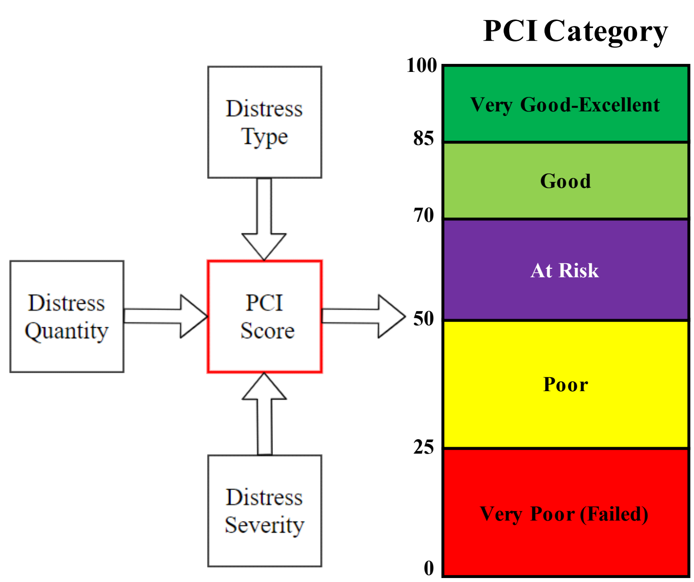


Figure ES–1 Pavement Condition Index Process and Categories

At the end of FY 2022/23, the overall PCI weighted average of the County's road network was 73. About 29 percent of the total maintained miles throughout the County were found to be in need of resurfacing or replacement and considered to be At Risk, Poor, or Very Poor condition. The estimated cost to reduce this value from 30 percent to 25 percent is $294 million; however, this is not a stagnant value. It grows as maintenance and repairs are delayed while roads continue to age and deteriorate. In fact, delayed maintenance accelerates pavement deterioration and the type of maintenance or repair required changes from relatively low-cost surface treatment to medium cost surface rehabilitation to high-cost complete reconstruction.

From FY 2018/19 to FY 2019/20 the overall PCI score increased from 72 to 74 due to a change in road inspection using a semi-automated laser inspection system instead of a manual inspection. The use of a semi-automated system provided an accurate and consistent inspection rating for all County maintained roads. The overall PCI for FY 2022/23 is 73, which is one point lower from FY 2021/22 PCI. The reduction was likely due to delay on completing projects within this fiscal year.

SB1 FUNDING

The State legislature passed SB1 in April 2017. It established the Road Maintenance and Rehabilitation Program (RMRP) to fund road maintenance, rehabilitation, and critical safety improvements on both the state highway system and local streets and roads. SB1 augments existing budgets for road maintenance and rehabilitation projects by infusing funds based on local needs and priorities. It is expected that SB1 funding will provide approximately $91 million over the next two years (FY 2023/24 and FY 2024/25) to fund road maintenance and rehabilitation improvements on local streets and roads. The purpose of the PMS is to use this funding as efficiently as possible to improve overall road conditions.

In order to provide a transportation system that is safe, cost-effective, sustainable, and efficient, environmental considerations and complete streets concepts will be incorporated into future SB1 projects. These considerations include:

- Using materials that reduce the life cycle cost and minimize greenhouse gas (GHG) through recycling, such as in-place Portland cement concrete pulverization, cold in-place asphalt recycling, and the use of crumb rubber from scrap tires in asphalt.
- Incorporating features resilient to climate change risks, such as flooding, by using Portland cement concrete (PCC) pavement in flood-prone areas.
- Incorporating complete streets elements to improve and increase mobility for pedestrians and bicyclists by installing curb ramps and sidewalks and widening the roadway, where feasible and practicable.

SUPERVISORY REDISTRICTING

This report takes into account the adjusted boundaries of any or all of the County supervisorial districts as a result of the county’s population changes and following the 2020 decennial federal census count. The established new supervisorial district boundaries are reflected in this FY 2022/23 Pavement Management Report.

CURRENT TOTAL MAINTAINED MILES

The County of Riverside Transportation Department is responsible for the operation and maintenance of 2,258 centerline miles of road, as of the end of FY 2022/23 (2,088 paved and 170 unpaved). The table below shows the breakdown of the roadway network grouped by functional classification with the average network Pavement Condition Index (PCI).

Table ES–1. Total Maintained Miles (Countywide)

FUNCTIONAL CLASSIFICATION[1]	CENTERLINE MILES[2]	LANE MILES[3]	PCI[5]
Arterial	421	962	71
Collector	686	1,402	72
Residential/Local	981	1,949	74
Gravel/Dirt[4]	170	341	--
TOTAL	2,258	4,654	
Overall PCI[5,6] [FY 2022/23]	**73**		

1) Functional classification is the grouping of roads based on traffic and degree of land access they provide.
2) Centerline mile represents the total length of a road from its starting point to its end point regardless of the pavement width or the number of lanes.
3) Lane miles represent the total length and the lane count of a road from its starting point to its endpoint. Lane miles take into account the number of lanes of a road maintained by the County.
4) PCI is not calculated for gravel and dirt roads.
5) The PCI shown is the area weighted PCI (i.e. larger areas impact the average PCI more than smaller areas)
6) The average PCI in FY 2022/23 was 73 whereas the desirable goal is 80 or higher. Roads with a PCI less than 70 are considered to be at risk of rapid deterioration.

CURRENT ROAD NETWORK CONDITION

Figure ES–2 through ES–4 show the County's existing pavement condition categorized by functional classification and condition category. The total percentage of distressed roads, which includes the At Risk, Poor, and Very Poor road categories, is shown in Figure ES–2 at 29.6%. Over the last 5 years, the percentage of distressed roads have been declining gradually through the implementation of pavement preservation and effective pavement treatment solutions.

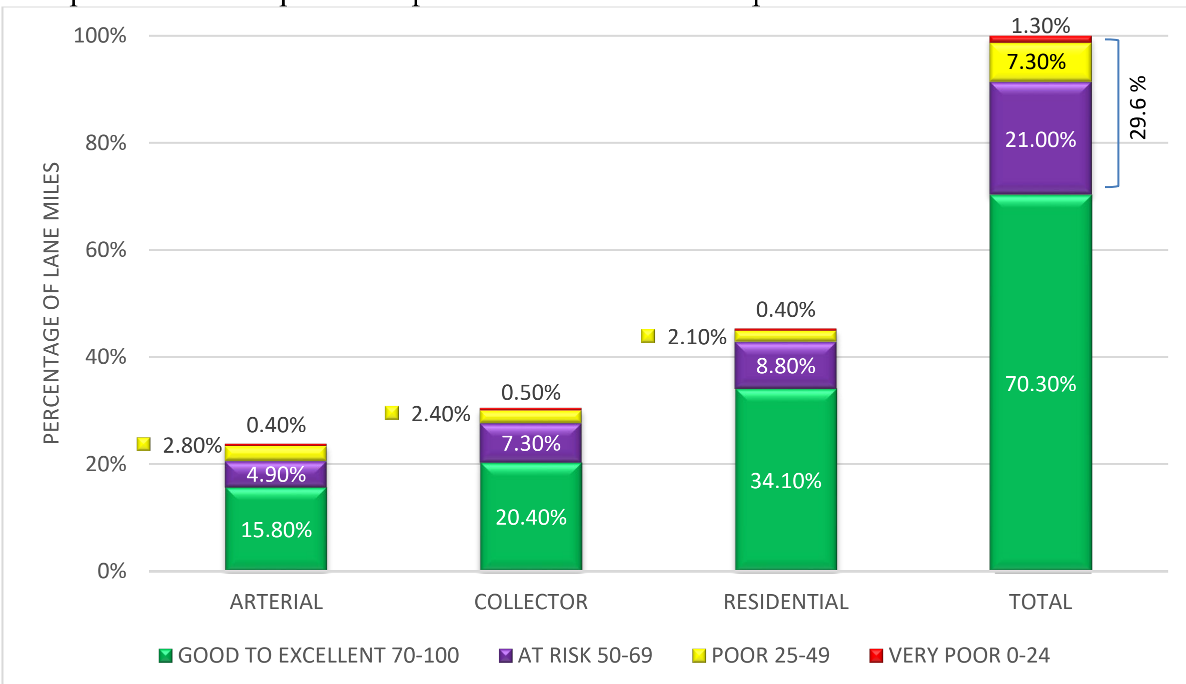


Figure ES–2. Pavement Condition by Category (FY 2022/23) – Countywide

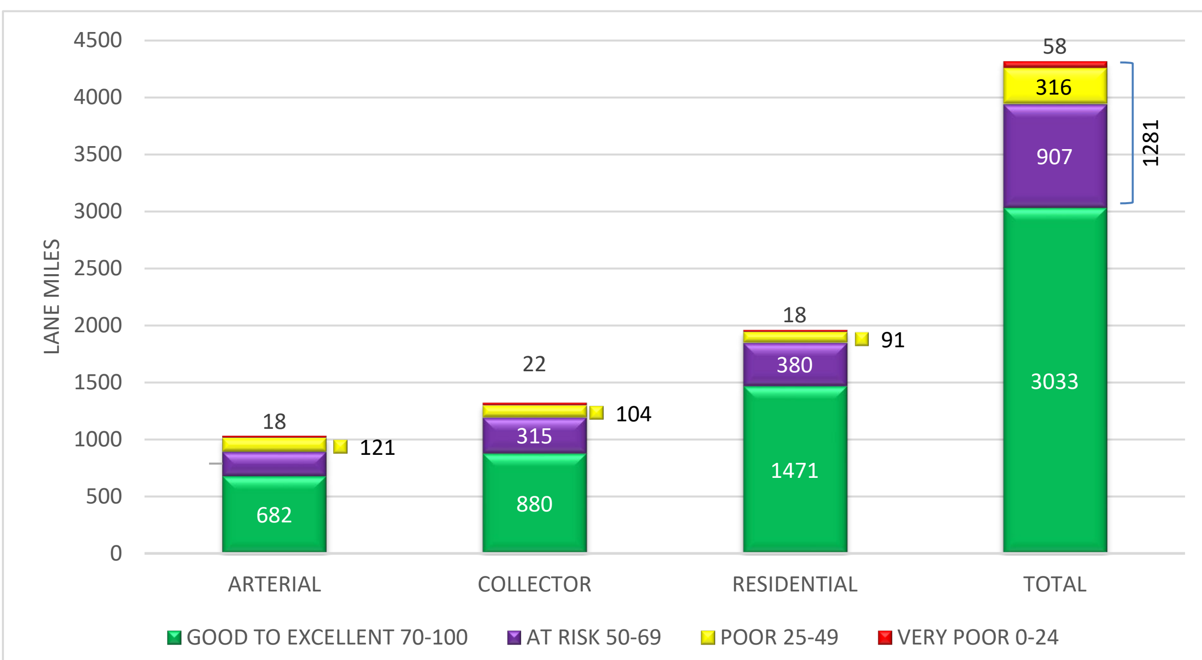


Figure ES–3. Pavement Condition by Category (FY 2022/23) – Countywide

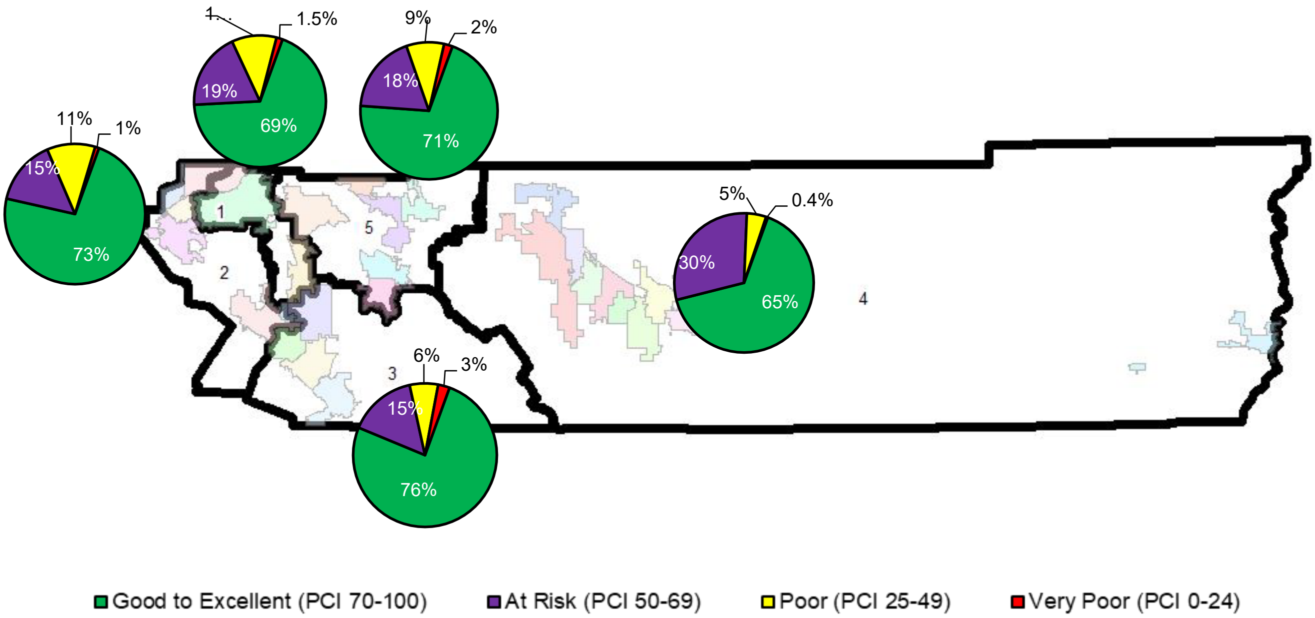


Figure ES–4 CURRENT ROAD CONDITION BY DISTRICT (FY 2022/23)

SUSTAINABLE PAVEMENT PRACTICES

As part of the County's effort to reduce greenhouse gas emissions, from FY 2004/05 to FY 2022/23, the County has:

- Used approximately 232,000 tons of reclaimed asphalt, which translate to a reduction of 1,160,000 pounds of carbon emission or the equivalent of about 1,960 passenger cars removed from the County roads.
- Used about scrap/used tires for pavement overlays and rehabilitation, resulting in less tires at the landfill, greater longevity of pavement life, and reduced pavement/tire noise from vehicles.

CALIFORNIA STATEWIDE NEEDS ASSESSMENT

In 2008, the first California Statewide Needs Assessment report was published. This report provides a detailed analysis of California's local roads. It includes the current condition, cost to repair, and funding shortfall for local streets and roads. In April 2017, the Road Repair and Accountability Act (also known as SB1) passed with the goal to provide over $5 billion annually for fixing roads, bridges, and improving safety across California.

It is anticipated that SB1 will distribute approximately $2.43 billion in critical funding annually to help cities and counties maintain their local streets and roads and slow the deterioration that has occurred to local transportation infrastructure during the past decade. However, the 2022 "California Statewide Needs Assessment" report estimated that an additional $8.54 billion is needed annually for the next 10 years "…to bring local street and road pavement into a state of good repair."

The average PCI in the State of California of all counties is 65, which has decreased by one point since 2020 due to the COVID-19 pandemic in early 2020. The pandemic resulted in significant revenue reductions and uncertainties especially with construction. The pandemic also impacted transportation project delivery from 2020 through 2022. The PCI ranges from a high of 79 in Orange County to a low of 24 in Tuolumne County. The reported PCI for Riverside County with cities included showed 69. As of FY 2022/23, the PCI for Riverside County itself is 73.

The "California Statewide Local Streets and Roads Needs Assessment 2022" can be found at www.savecaliforniastreets.org.

PROJECT LISTS FOR FISCAL YEAR 2023-24

The County list of projects for rehabilitation and pavement preservation including slurry seal, chip seal, overlay, and reconstruction for FY 2023/24 are available on the County's website at:

https://trans.rctlma.org/projects/transportation-improvement-program

INTRODUCTION

The objectives of this Pavement Management Report are as follows:

1. Describe the results of the FY 2022/23 network-level pavement condition survey in the County;
2. Describe the County's StreetSaver pavement management program to use best pavement management practices;
3. Discuss the pavement management analysis used to estimate the future maintenance and rehabilitation (M&R) funding requirements of the County's pavements; and describe how the County is using recycling to reduce landfill waste and greenhouse gas emissions while improving the County's roads.

PAVEMENT MANAGEMENT PROGRAM

A Pavement Management Program (PMP) is a tool that assists the County in making cost-effective decisions related to the maintenance and rehabilitation of roadway pavements. It provides an objective decision-making process or system for rating pavement condition, establishing a consistent maintenance and repair schedule, and evaluating the effectiveness of maintenance treatment strategies. A PMP is also an optimization tool that facilitates the prioritization of current and future needs to make the best use of available funds. The goal of a pavement management program is to strategize cost effective treatments to pavement sections that will deliver the best performance for the funds allocated. Simply put, a pavement management program provides the most cost-effective approach to optimize available funds for maintaining and rehabilitating public roadways.

Through a PMP, the County is able to employ a strategic and systematic process on how to spend limited funds to preserve and maintain roads in good condition as opposed to using the more costly "worst-first" approach. That process involves a structured sequence of maintenance and preservation actions where monitoring the condition of the pavement network and forecasting its performance are crucial to predict the appropriate treatments and achieve a desired level of service at the minimum practicable cost. The cost is generally based on achieving a roadway pavement condition level called best management practices (BMPs) whereby less costly preventive maintenance treatments such as, slurry seals, chip seals, and overlays are applied.

The PMP used by the County of Riverside Transportation Department is called "StreetSaver." This program was developed by the Metropolitan Transportation Commission (MTC), which is the transportation planning, coordinating, and financing agency for the nine San Francisco Bay Area counties - Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano and Sonoma. Other users of the PMP from outside the bay region are cities, counties, universities, and consulting firms in Southern California.

PAVEMENT CONDITION INDEX

The MTC StreetSaver software combines the pavement condition assessment data from the visual inspection of the pavement frames to calculate the PCI. The PCI is based on the type, quantity, and severity of distresses from each segment of pavement. The PCI is a numerical index from 0 and 100. If properly designed and constructed, new pavements begin their service life with a PCI of 100. Due to the effects of loading and aging, the pavement deteriorates over time. For each combination of distress type, severity level, and quantity observed, points are deducted from 100, and the PCI decreases. Pavement management software, including StreetSaver, calculate the PCI scores for each pavement section based on a combination of distress types, severities, and quantities. Figure 1 shows the relationship between the PCI and pavement condition.

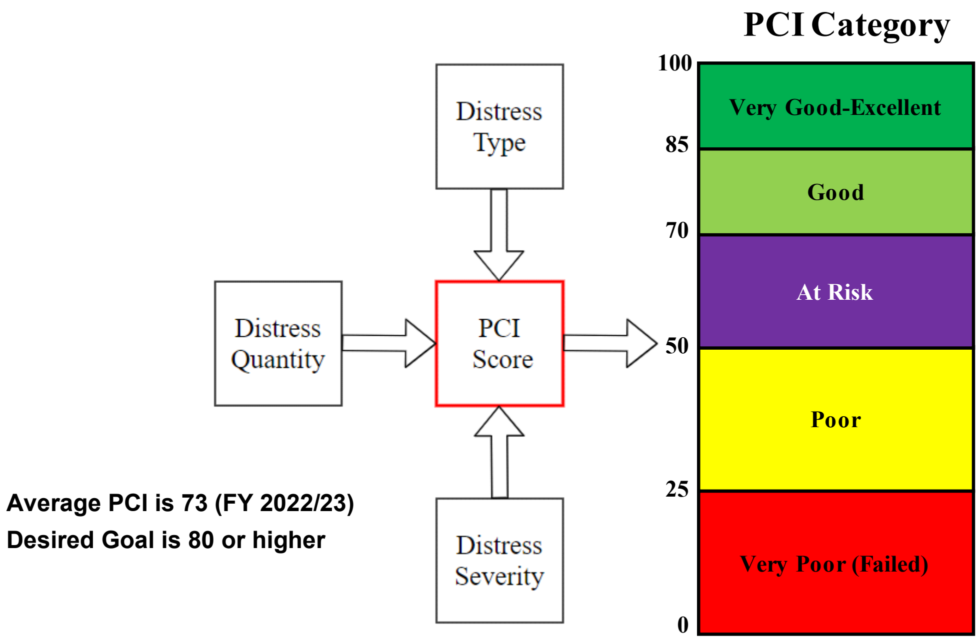


Figure 1. Relationship Between PCI and Pavement Condition

An example of Street-Saver output showing road data and a deterioration curve is shown in Figure 2 below.

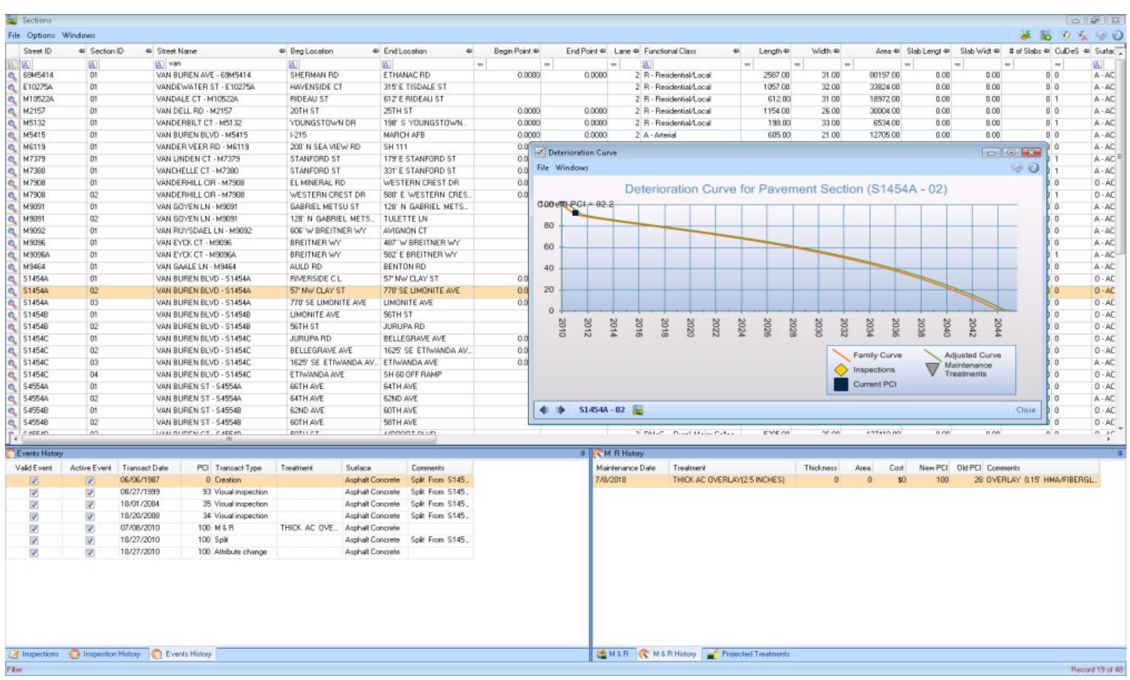


Figure 2. Pavement Management Program – StreetSaver

Additionally, the integration of the PMP with Geographic Information Systems (GIS) has provided the County with a snapshot of the roadway network to better organize the road segments, and data collected and improves the decision-making in selecting roads to be included for treatment/repair in the County's annual Transportation Improvement Program. An example of the PMP/GIS integration is shown in Figure 3.

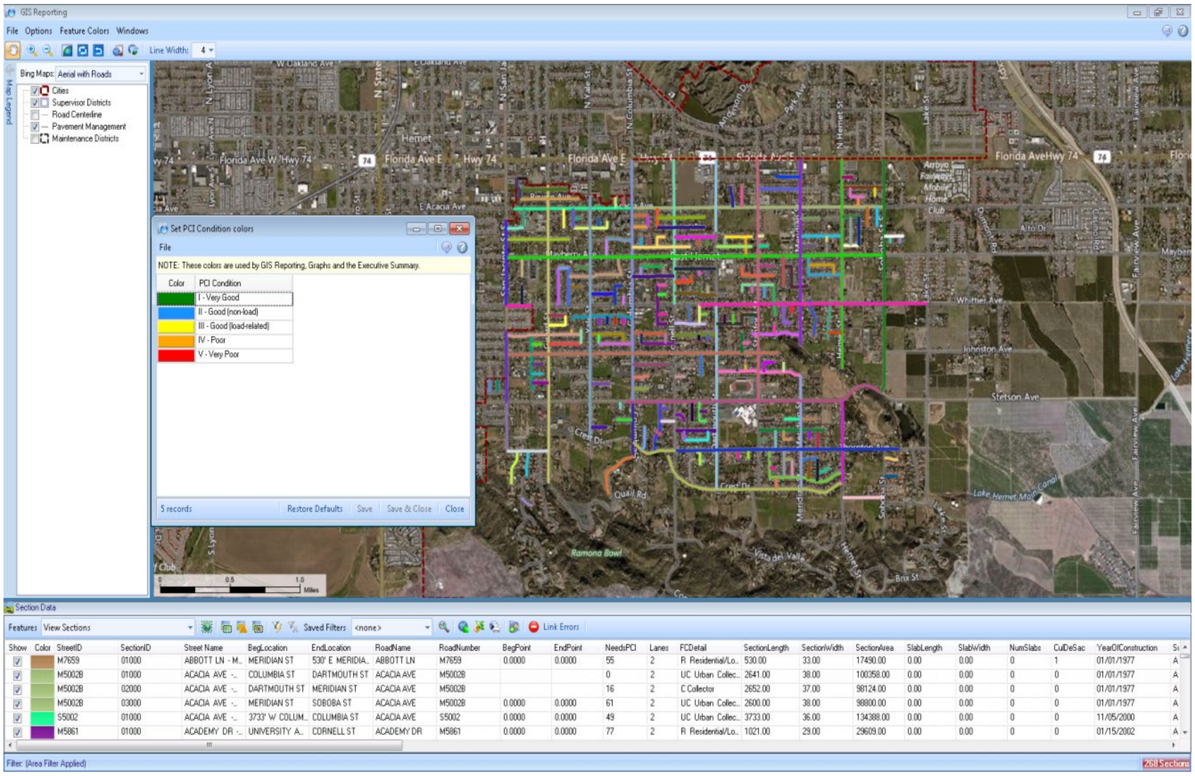


Figure 3. PMP PCI results on GIS map

PAVEMENT DISTRESS DATA COLLECTION

The pavement survey method changed from manual surveying to a semi-automated survey in 2020. While the same distresses and severities are identified, there are differences between the two collection methods.

Automated Data Collection

The County transitioned to the vehicle mounted automatic data collection system for 2020. The inspection involved collecting Right of Way (ROW) images and Downward Laser Crack Measurement System (LCMS) images. The images are rated by certified pavement inspectors on computers on a frame-by-frame basis and the distresses found in each frame are then imported into StreetSaver to calculate the PCI.

Table 1 examines the differences and the benefits of using the vehicle mounted system for the pavement inspection.

Table 1. Comparison of Manual and Semi-Automated Surveys

Manual Survey		Semi-Automated Survey
Visual survey is performed from the side of the road		Vehicle based laser downward images and Right of Way images
Manual survey exposes raters to traffic and environmental hazards		Vehicle travels at traffic speed, limiting hazards to inspectors
Areas and lengths of cracks are estimated		Measures crack lengths, widths, and depths
Small sample sizes, inspect complete road width but not complete length		All images collected are rated
Pavement roughness is not measured		Measure's pavement roughness
Rutting is estimated		Includes accurate rutting measurements
2-4 images per sample		Laser Pavement and ROW images every 20ft
No road geometry measurements		Road geometrics possible
No additional asset condition evaluation possible		Additional asset condition evaluation possible, signs, guard rails, manholes, railroad crossings

Survey Equipment

The data collection equipment as shown in Figure 5 includes:

- LCMS Cameras: high-resolution laser scan, 13 ft wide pavement images
- High-Speed Laser Profiler for measuring road roughness
- High-definition Right of Way (ROW) cameras
- GPS coordinate's location marker

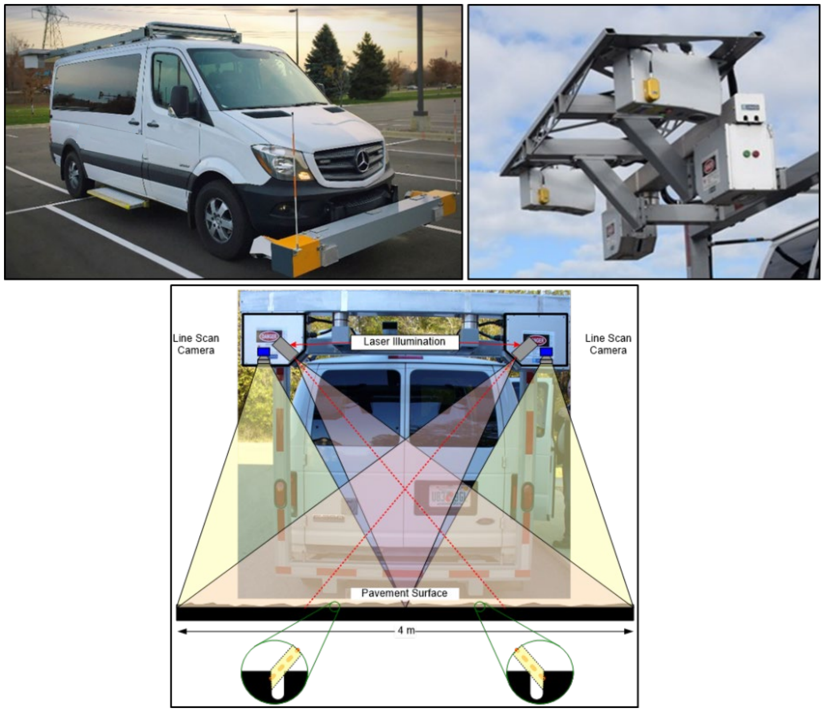


Figure 5. Vehicle mounted automated data collection equipment

Laser Crack Measurement System (LCMS)

The LCMS is composed of two lasers and high-resolution cameras designed to take an image scan of the pavement surface. Image frames are created every 20 ft with GPS coordinates attached. Figure 6 shows a diagram of the laser data collection and a downward image of the pavement.

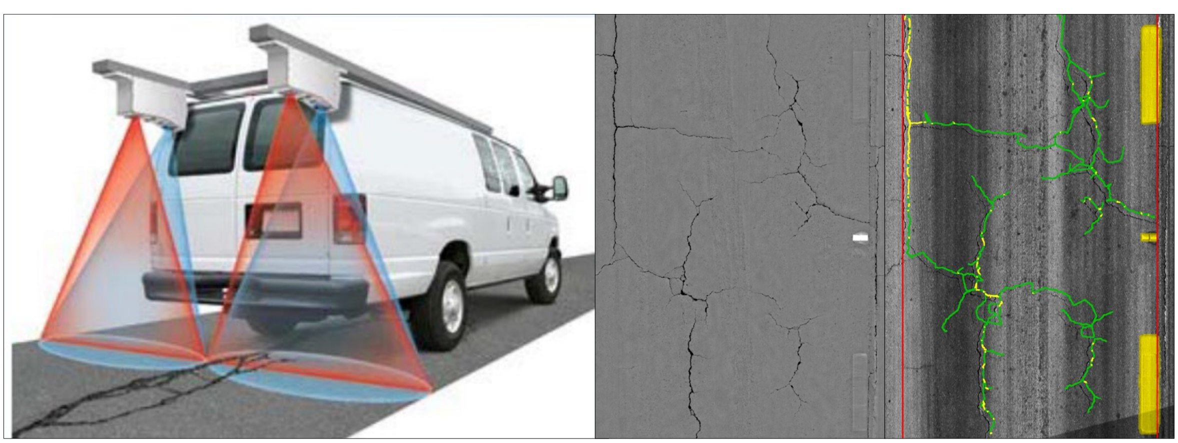


Figure 6. Schematic of LCMS Operation – Collection, 3D Range Image, and Crack Detection with Low and Medium Severity Cracks Identified

Right of Way (ROW) Images

Four high-definition digital cameras are used for acquiring ROW images. The images are collected every 20 ft. As with the downward images, the ROW images are collected with GPS coordinates attached. Sample ROW images are shown in Figure 7 below.

Figure 7. ROW Images

Computer Based Pavement Condition Rating

Pavement condition is rated using a distress rating software where the road is divided into 20-ft pavement frames and each downward image is rated. The rating data is imported into StreetSaver and the PCI values are calculated automatically. A sample diagram of the rating process can be seen in Figure 8.

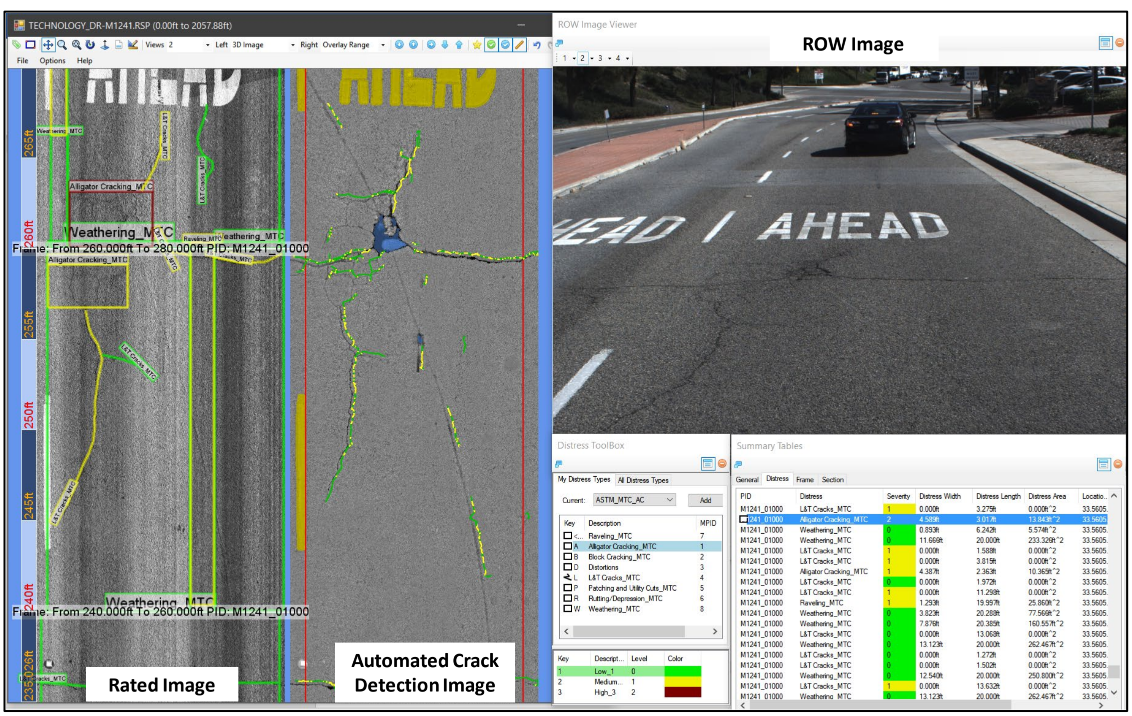


Figure 8. Distress Rating - PCI Distress Types and Pavement Frames

PAVEMENT STRUCTURAL DATA COLLECTION

The County invests millions of dollars each year in pavement maintenance activities. The Pavement Management Program (PMP) assists the County in determining the most cost-effective strategy for investing in pavement rehabilitation. In addition to the PMP tool, the County has invested in advanced structural data collection equipment including a Ground Penetrating Radar (GPR) and a Falling Weight Deflectometer (FWD). Figure 9 shows this advanced structural data collection equipment.

Figure 9. FWD and GPR Data Collection Equipment

The GPR is used to measure pavement layer thickness and detect groundwater and voids beneath the pavement. The FWD is used to measure and evaluate the physical properties of the pavement structure. The use of the StreetSaver PMP which has been populated with data from the PCI inspection and with data collected from this state of the art equipment, provides the County Pavement Engineer with adequate information to make informed decisions to best utilize available funding.

PAVEMENT CONDITION BASED ON PCI

Figures 10A to 10H show different pavement sections with decreasing PCI values. The images are the Right of Way (ROW) image, the 3D downward laser image with identified cracks highlighted, and the 3D range image that smooths surface texture to highlight crack details.

Data was collected on the No.1 lane of 2 lane roads and 2 lanes for roads with 4 or more lanes. Each side of a divided road was treated independently, and data was collected for both directions on divided roads.

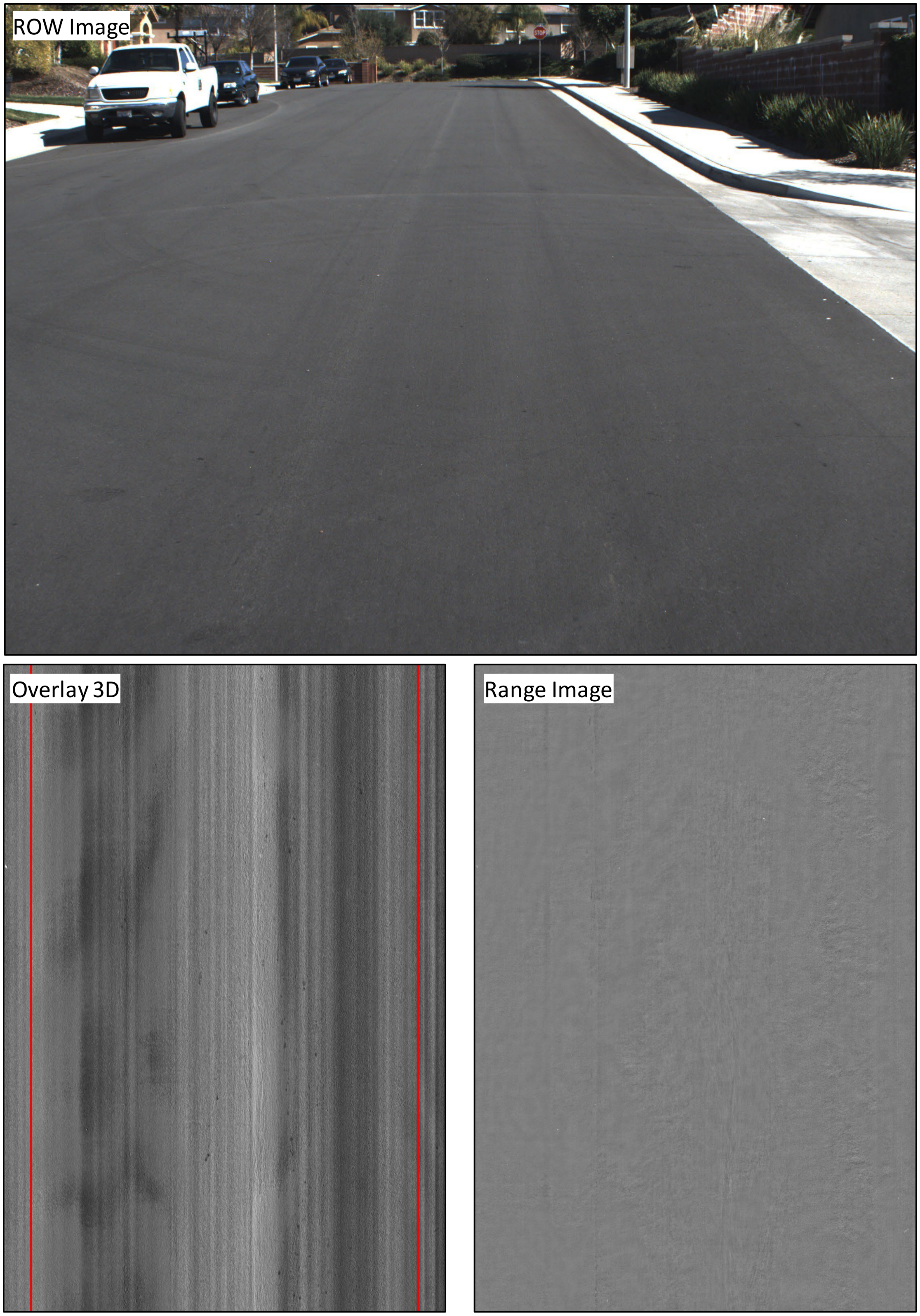


Figure 10A. PCI=99 (Excellent Condition)

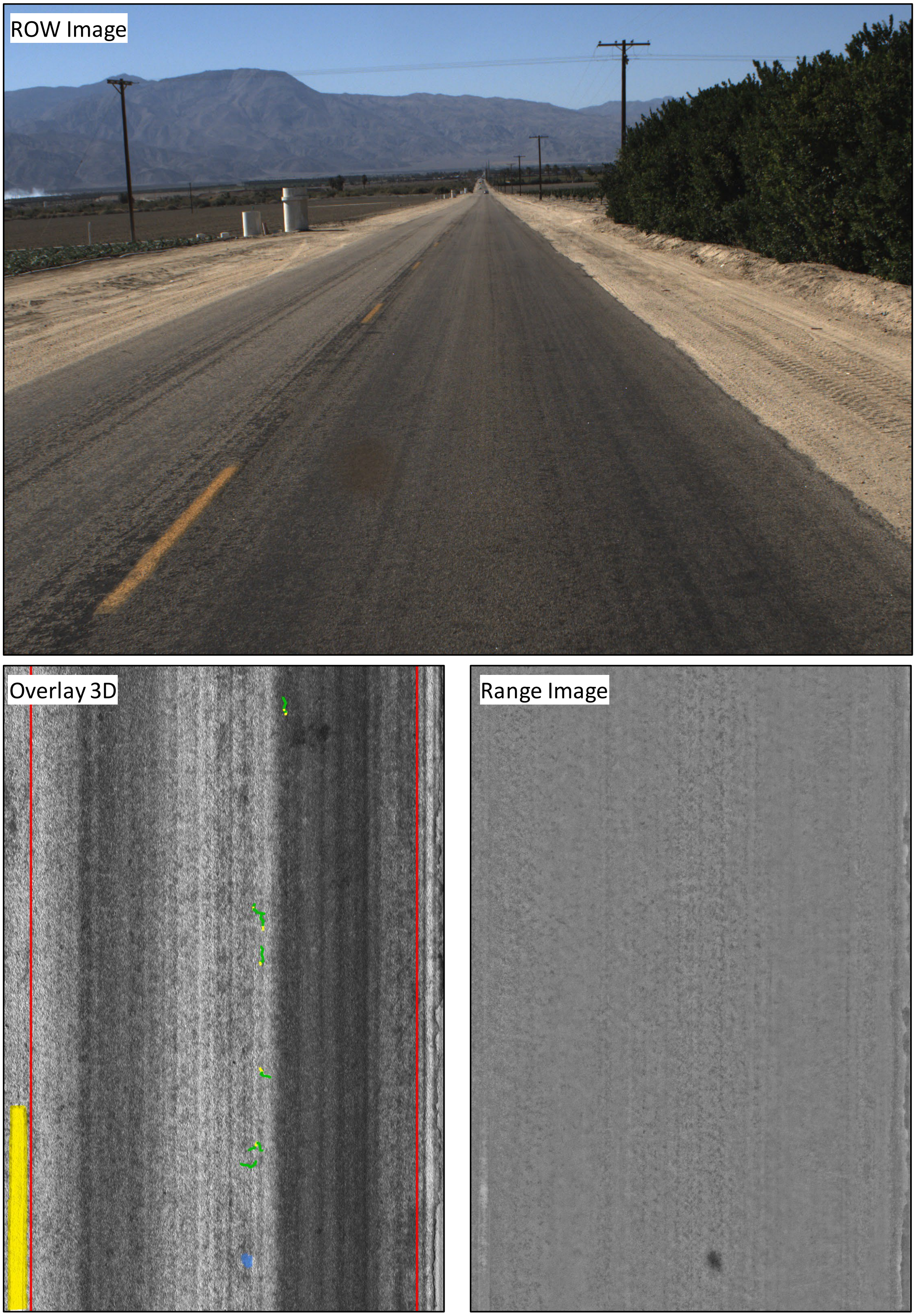


Figure 10B. PCI=85 (Very Good Condition)

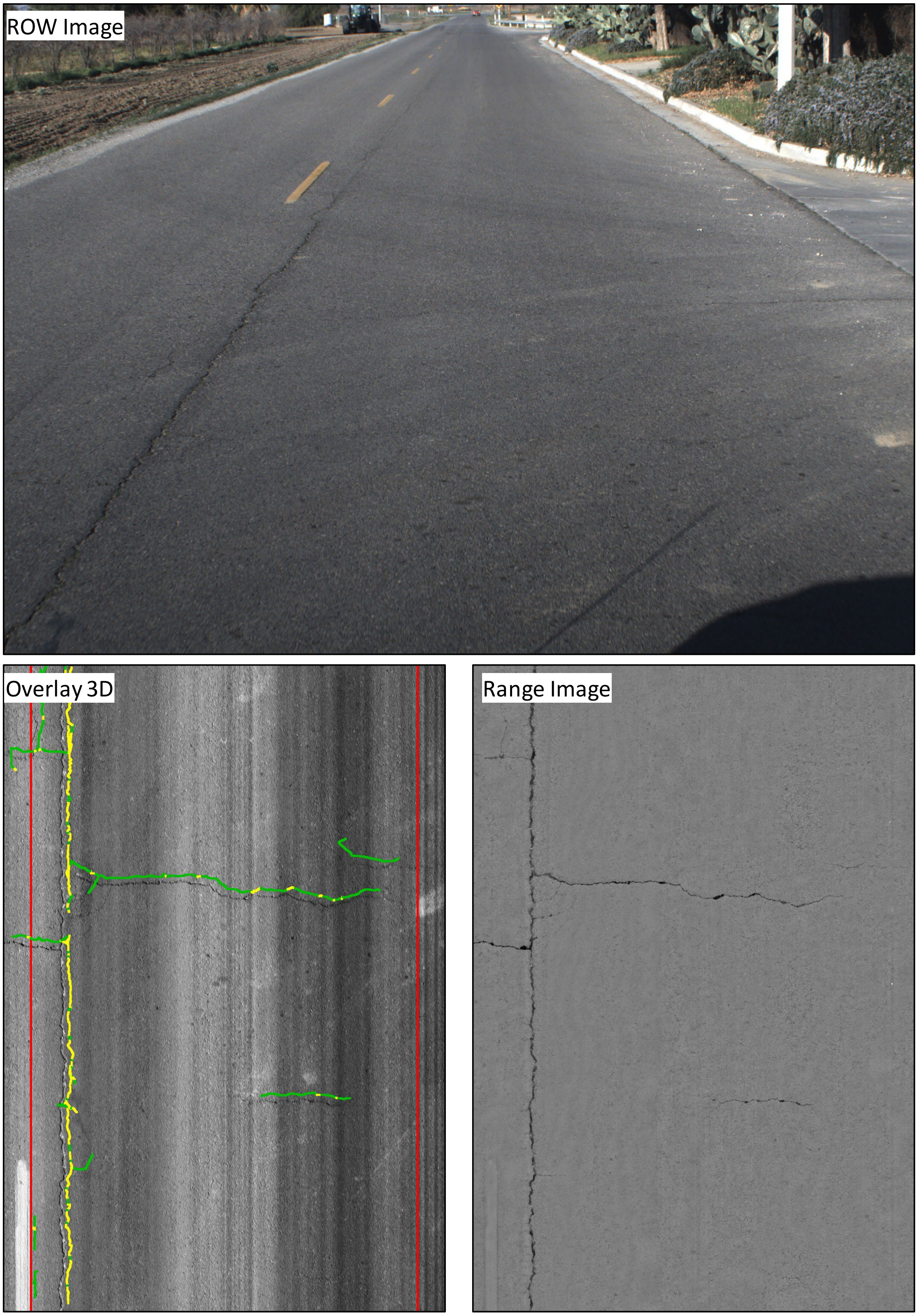


Figure 10C. PCI=73 (Good Condition)

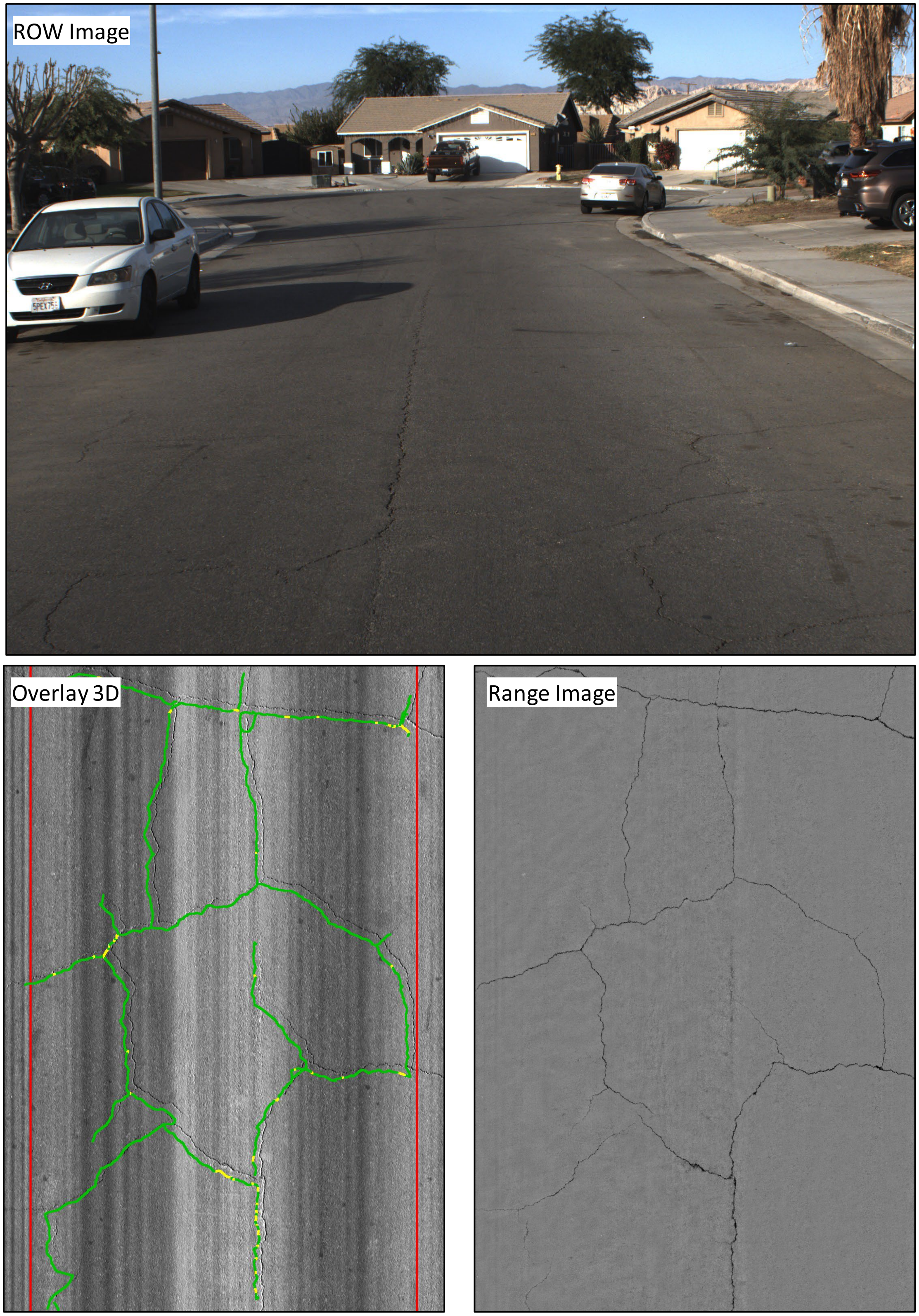


Figure 10D. PCI=68 (At Risk Condition)

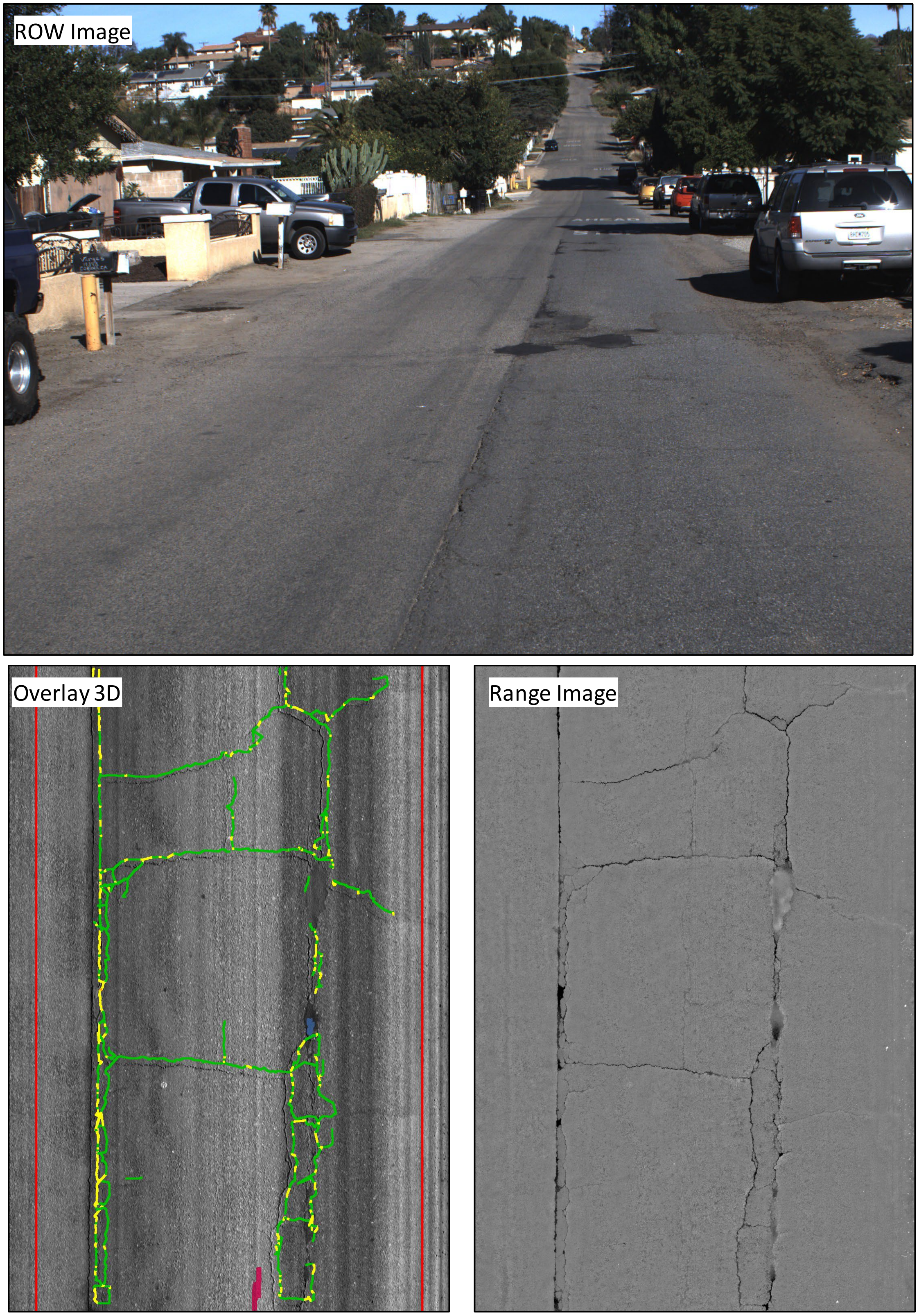


Figure 10E. PCI=54 (At Risk Condition)

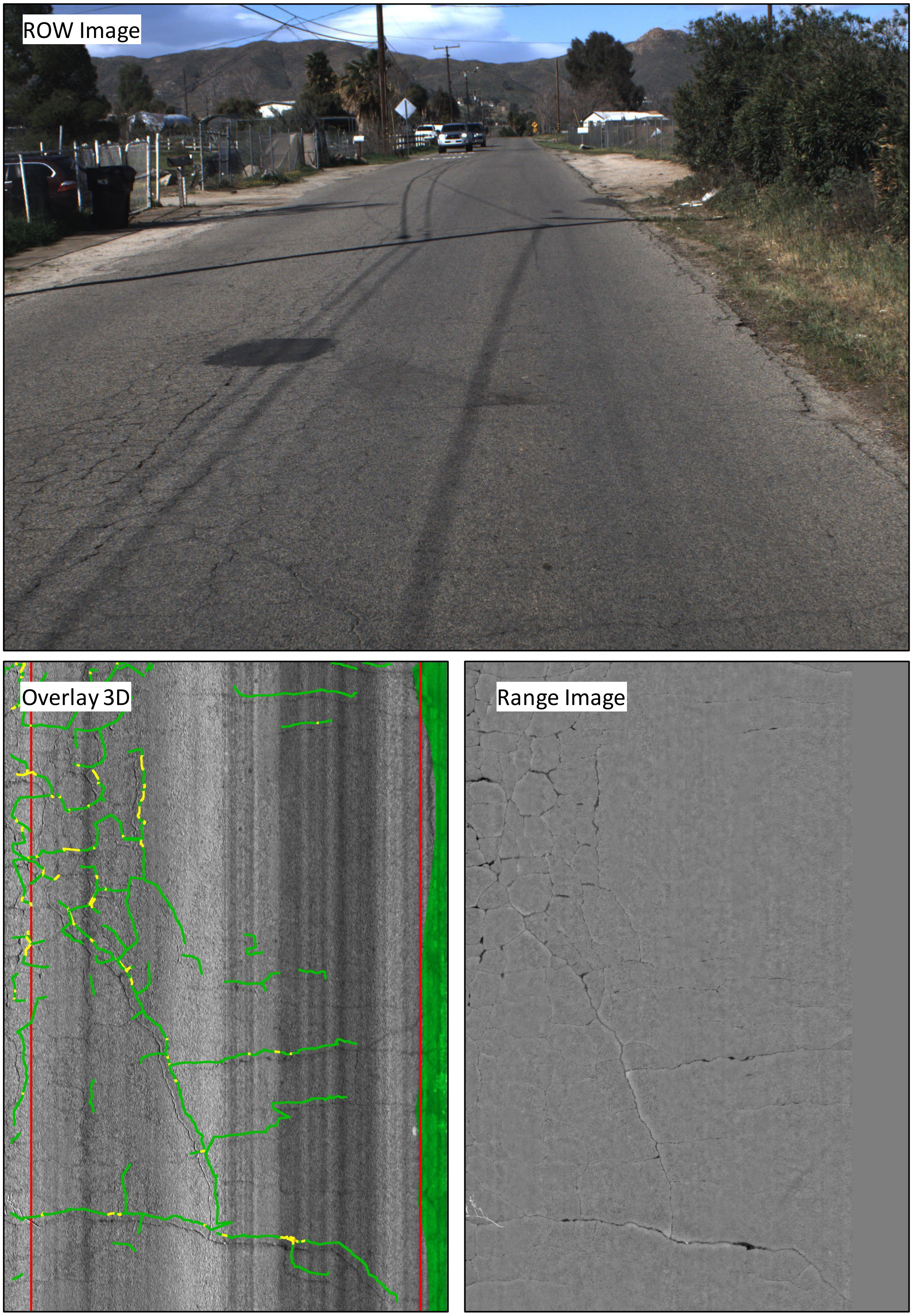


Figure 10F. PCI=38 (Poor Condition)

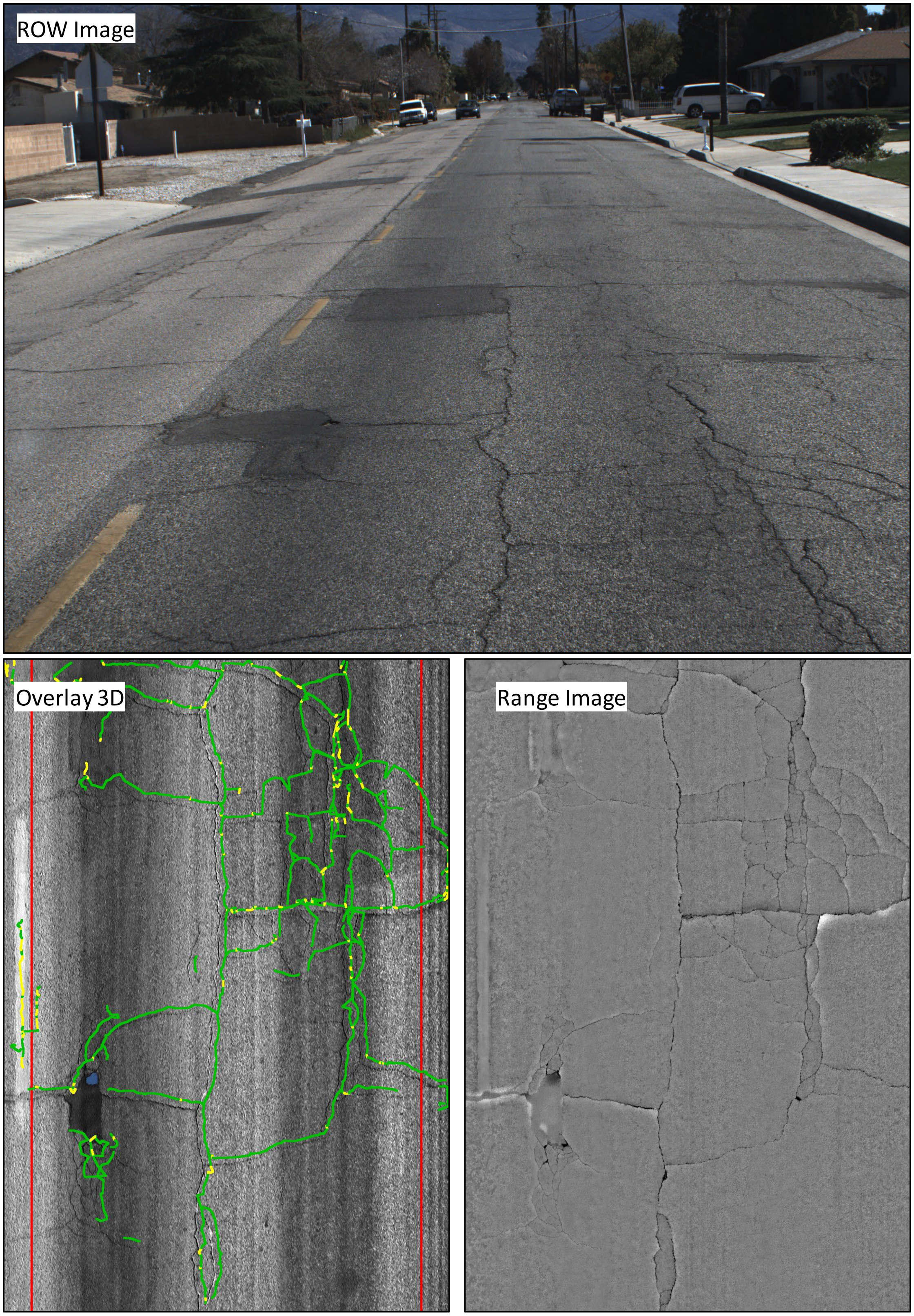


Figure 10G. PCI=26 (Poor Condition)

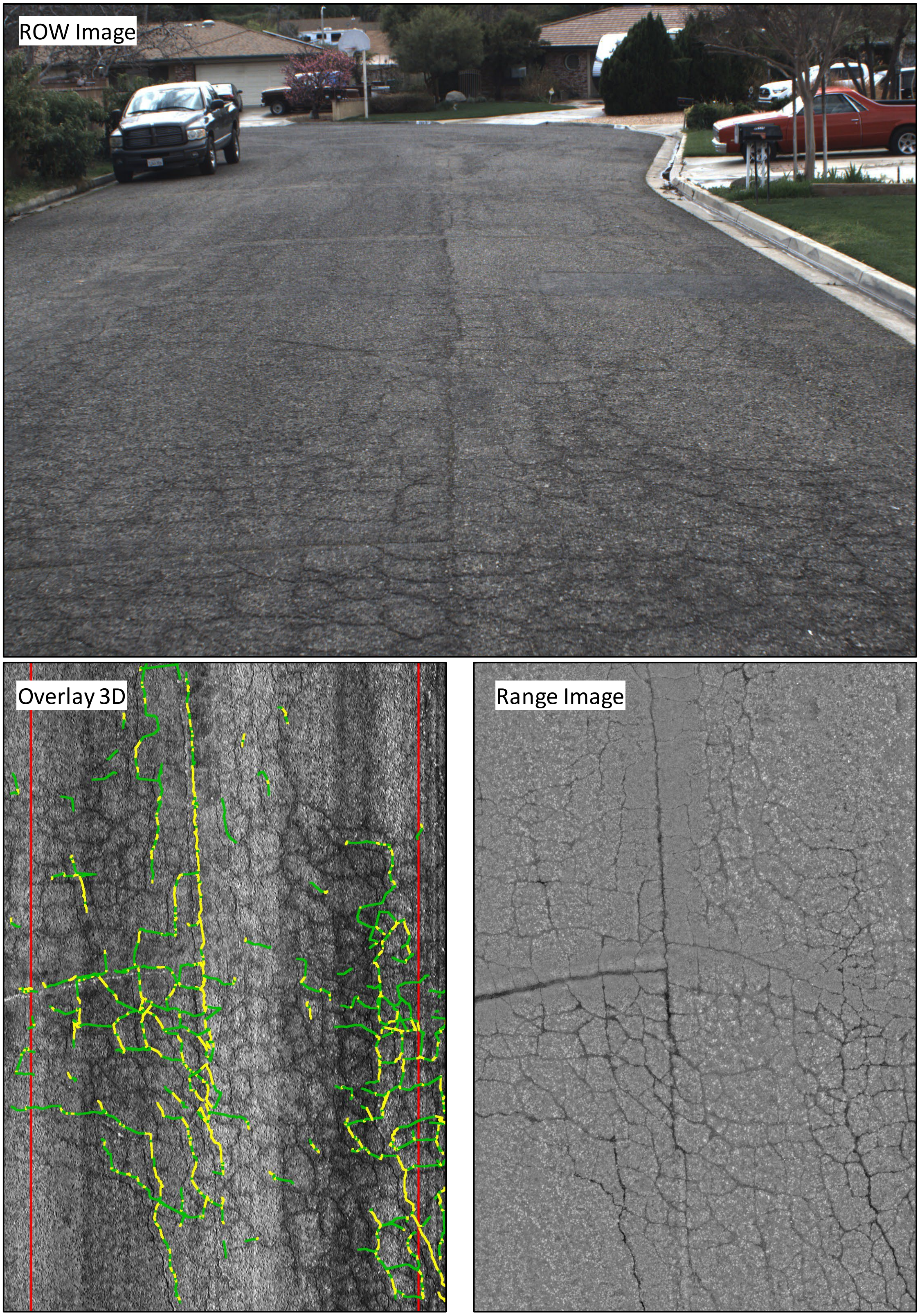


Figure 10H. PCI=8 (Very Poor Condition)

ROAD NETWORK

Road Condition

The percentage of mileage categorized by condition rating (good to excellent, at risk, poor, and very poor) over the last 5 years is summarized in Table 2. This table is also presented graphically showing the pavement condition trend in Figure 11 below.

Table 2. Condition Rating[1] (Countywide)

	GOOD TO EXCELLENT PCI 70-100	AT RISK PCI 50-69	POOR PCI 25-49	VERY POOR PCI 0-24	DISTRESSED ROADS[2]
FY 22/23	70%	21%	7%	2%	30%
FY 21/22	73%	19%	6%	2%	27%
FY 20/21	73%	19%	7%	1%	27%
FY 19/20	70%	21%	8%	1%	30%
FY 18/19	66%	22%	9%	3%	34%

1) Gravel or dirt roads are not included in the condition rating above.

2) Distressed roads include roads from the AT RISK, POOR, and VERY POOR categories. Over the last 5 years, the percentage of distressed roads has been gradually declining from 34% to 29%.

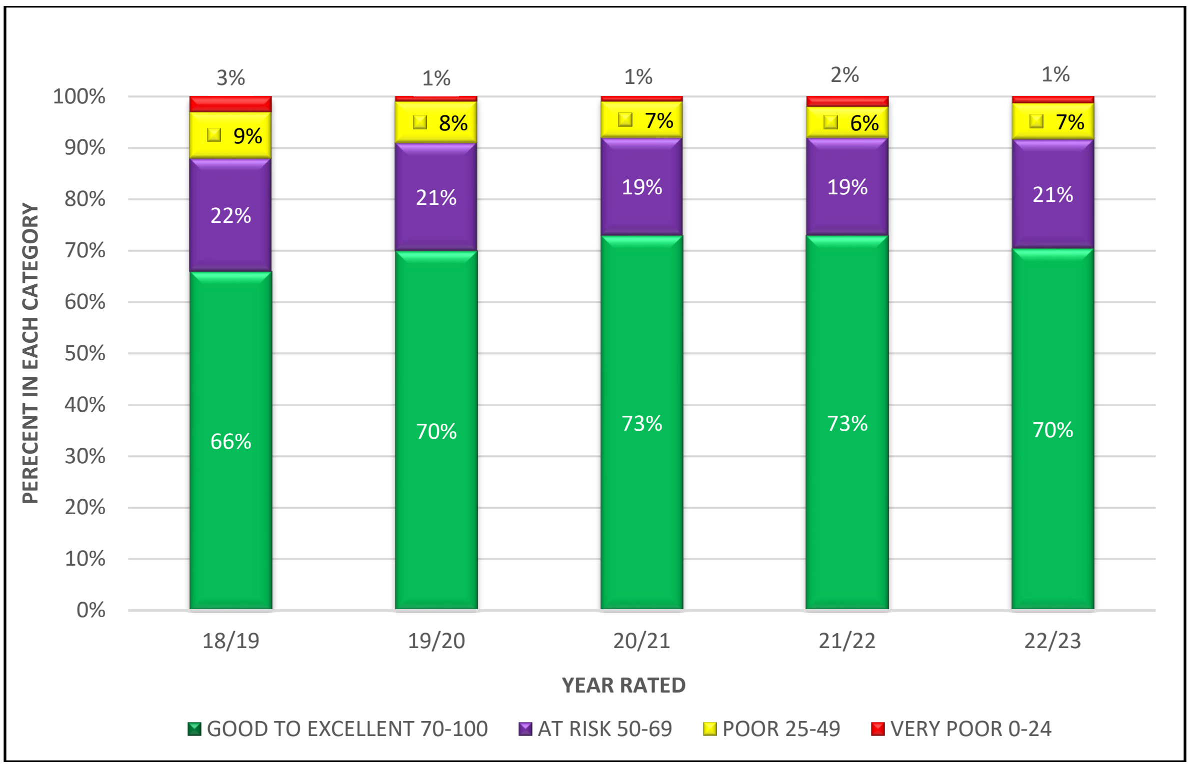
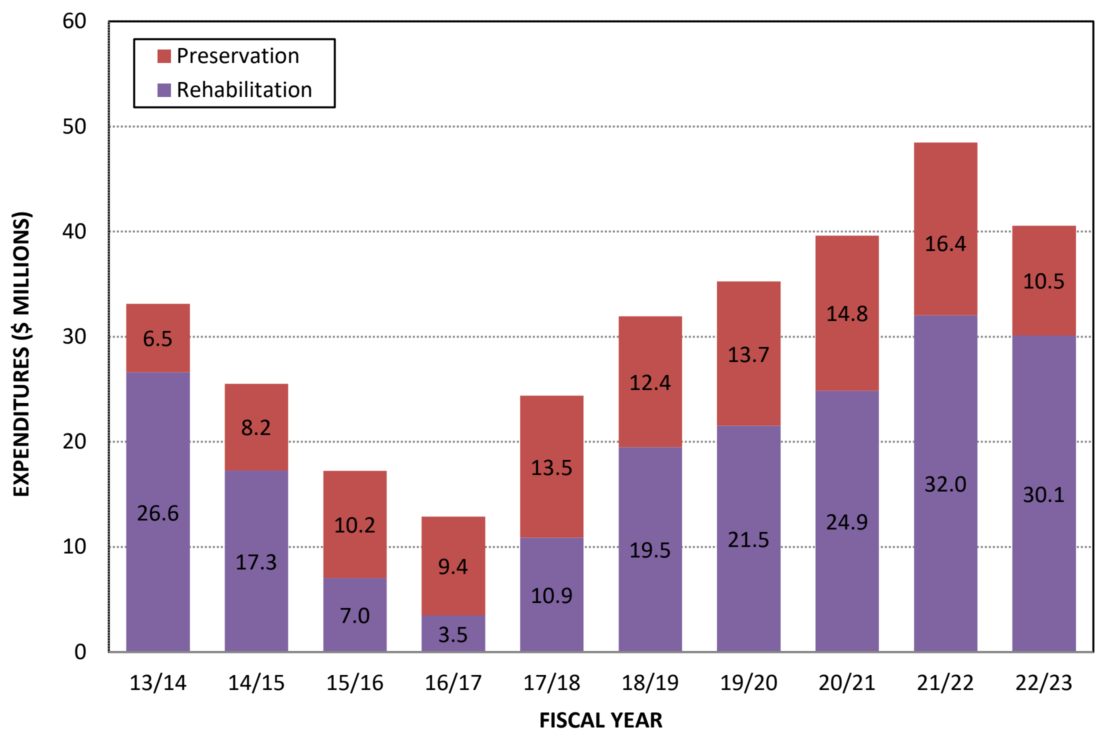


Figure 11. Pavement Condition Trend (Countywide)

Funding History & Miles Treated by Treatment Type

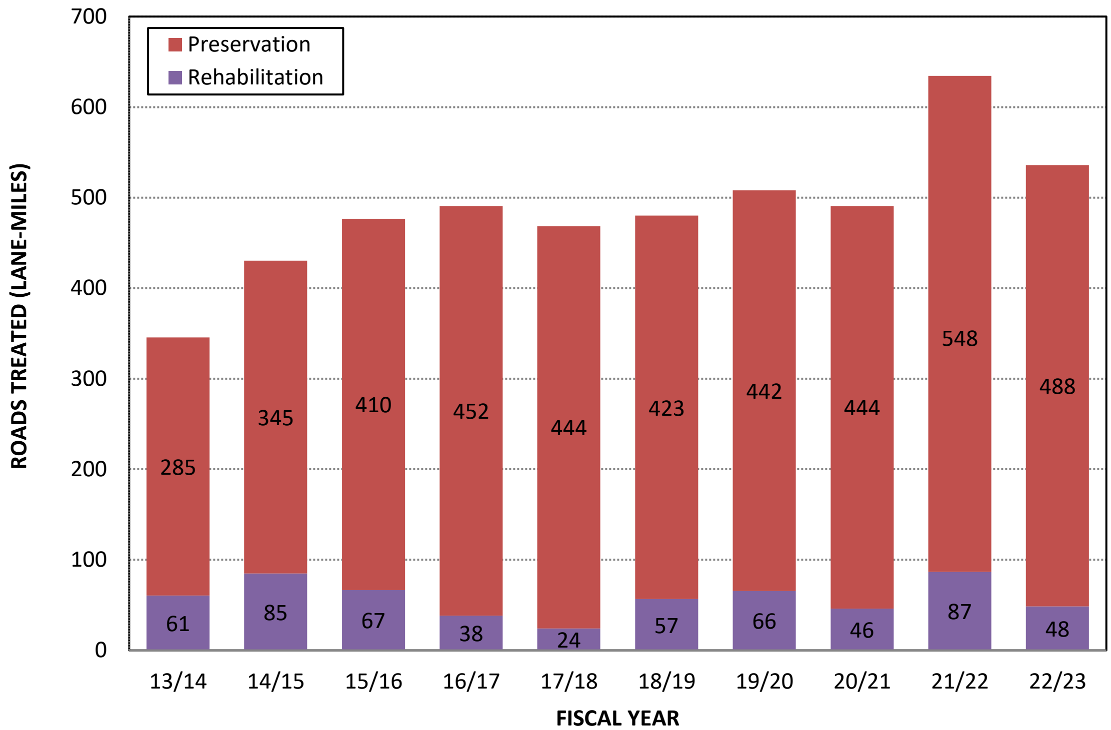
Roadway rehabilitation funding varies from year to year. With the passage of SB1, the County will be able to plan for improvement projects into the future due to the relative certainty of gas tax revenue. Over the last 10 years, the transportation department has invested approximately $309 million in pavement preservation and rehabilitation. Figure 12 and Figure 13 show the amount invested on preservation and rehabilitation and the associated total number of lane miles treated over the last 10 years.

In Figure 12, it is seen that the percentage of the budget spent on preservation and rehabilitation starting in FY 2017/18 have increased due to the additional SB 1 funding. The chart further illustrates an increase in expenditures of at least 40% on preservation and twice as much on rehabilitation from when the SB 1 was implemented in 2017. This indicates that the County continues to be cognizant of the need to preserve roads in good condition while addressing distressed roads needing rehabilitation.



Preservation includes Chip Seal, Slurry Seal, and Cape Seal.
Rehabilitation includes Overlays and Reconstruction. Spending spike in 2011 was caused by Prop 1B, Transportation Bonds for Local Roads. Increase in expenditures starting in 2018 was the result of the passage of SB 1.

Figure 12. Funding History



Preservation includes Chip Seal, Slurry Seal, and Cape Seal.
Rehabilitation includes Overlays and Reconstruction.

Figure 13. Road Miles Treated History

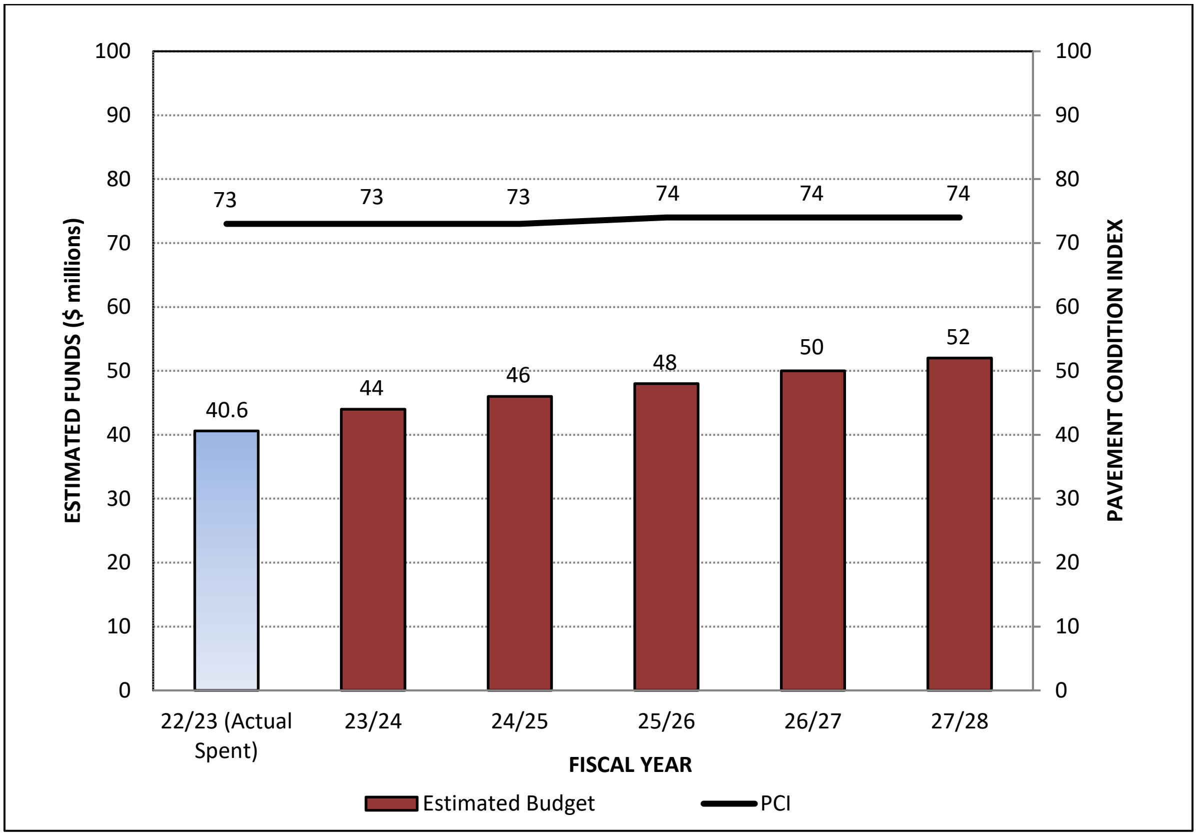
Needs Assessment

In determining the pavement needs to maintain the network condition at an acceptable level, a goal must first be defined. The goal for Riverside County unincorporated roads is as follows:

- Attain a PCI of 80 or higher where Best Management Practices (BMP) can be implemented. These BMP maximize the use of the most cost-effective preventive maintenance (pavement preservation) treatments such as, slurry seal, chip seal, and overlays.

For this goal to be effective, it should be attainable within a specific timeframe. Two funding scenarios were analyzed to determine the impact of various funding levels in terms of the overall change in PCI. These scenarios are:

1. Impact based on current funding projections (Figure 14)
2. Funding required to reach BMP at PCI of 80 (Figure 15)

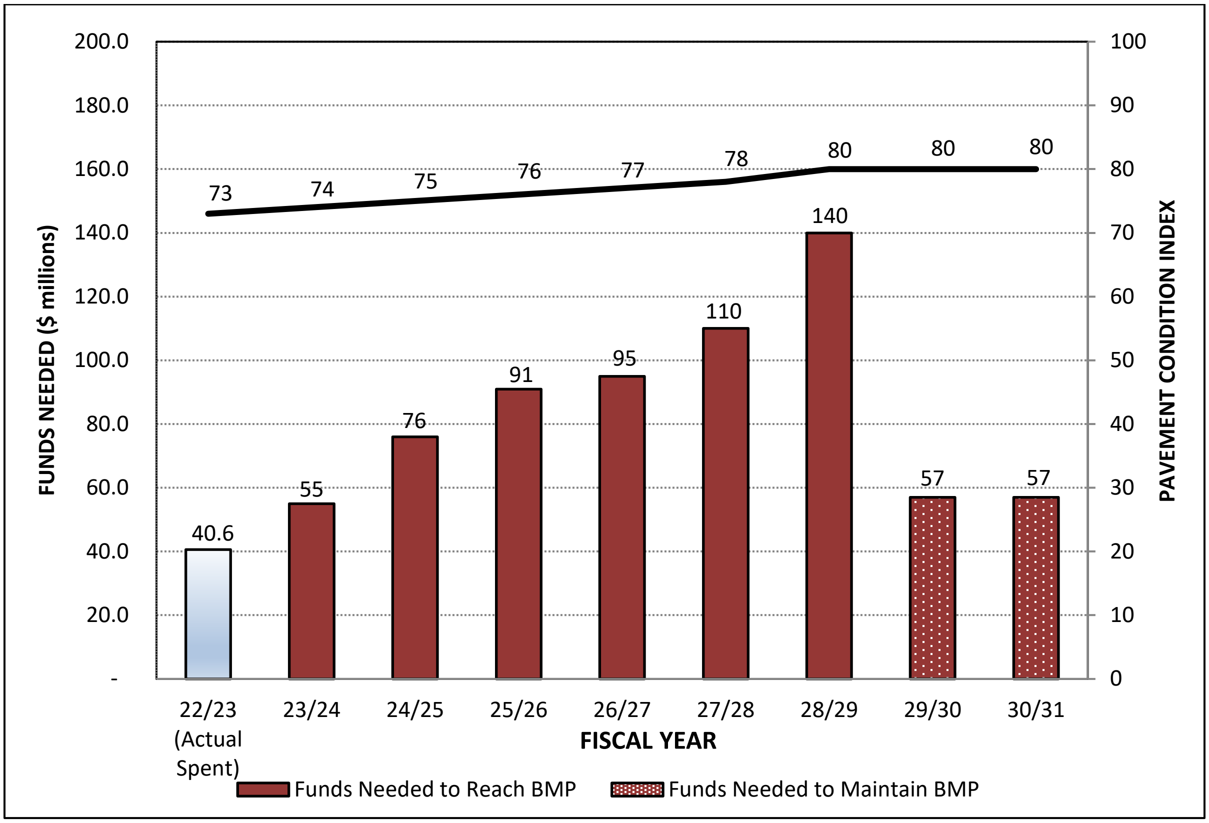


Note: The projected total budget is $240 million over the next 5 years. Estimated budget is derived from revenue sources – SB 1, Measure A, and Gas Tax/HUTA.

Figure 14. PCI based on Current Funding Projections

With the passage of SB1 in April 2017 combined with other revenue sources, the overall condition of the road network is expected to improve in the long term. As can be seen in Figure 14, the PCI is projected to improve from 73 in FY 2022/23 to 74 in FY 2027/28. As was shown in Table 2, approximately 29 percent of the total maintained road miles throughout the County were identified to be in need of resurfacing or replacement in FY 2022/23. In order to reduce the percentage of distressed roads (roads identified as AT RISK, POOR, and VERY POOR) from 30 percent to 25 percent, it is estimated that it will cost at least $294 million over a 5-year period. By attaining a PCI of 75, the distressed roads will decline to less than 25% of the road network. The desired goal is to have 20% or less distressed roads of the road network to maintain at a BMP level (PCI of 80 or greater).

Figure 15 shows the estimated funding required to reach a BMP level at PCI of 80 or greater. This budget scenario analyzed all roads to bring pavements into a state of good repair so that BMP can prevail. At this condition level, the distressed roads are reduced to 17% of the road network and cost-effective preventive maintenance treatments can be applied. Based on this analysis, it would take $567 million to reach the BMP level over the next 6 years. After that, approximately $57 million per year would be needed to maintain the road network at the BMP level.



Note: The projected total funding needed is $567 million over the next 6 years to reach BMP level.

Figure 15. Funding Needed to reach BMP Level (PCI ≥ 80)

Roadway Functional Classifications and Condition

Riverside County maintains approximately 2,088 centerline miles of paved road and 170 miles of unpaved road as of fiscal year 2023. Table 3 shows the breakdown of the countywide road network grouped by functional classification with the average network Pavement Condition Index (PCI).

Table 3. Total Maintained Miles (Countywide)

FUNCTIONAL CLASSIFICATION[1]	CENTERLINE MILES[2]	LANE MILES[3]	PCI[5]
Arterial	421	962	71
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5) The PCI shown is the area weighted PCI (i.e. larger areas impact the average PCI more than smaller areas)

[6] The average PCI in FY 2022/23 was 73 whereas the desirable goal is 80 or higher. Roads with a PCI less than 70 are considered to be at risk of rapid deterioration.

Figure 16 below shows the PCI trend for the County for the last 10 years.

Historical PCI

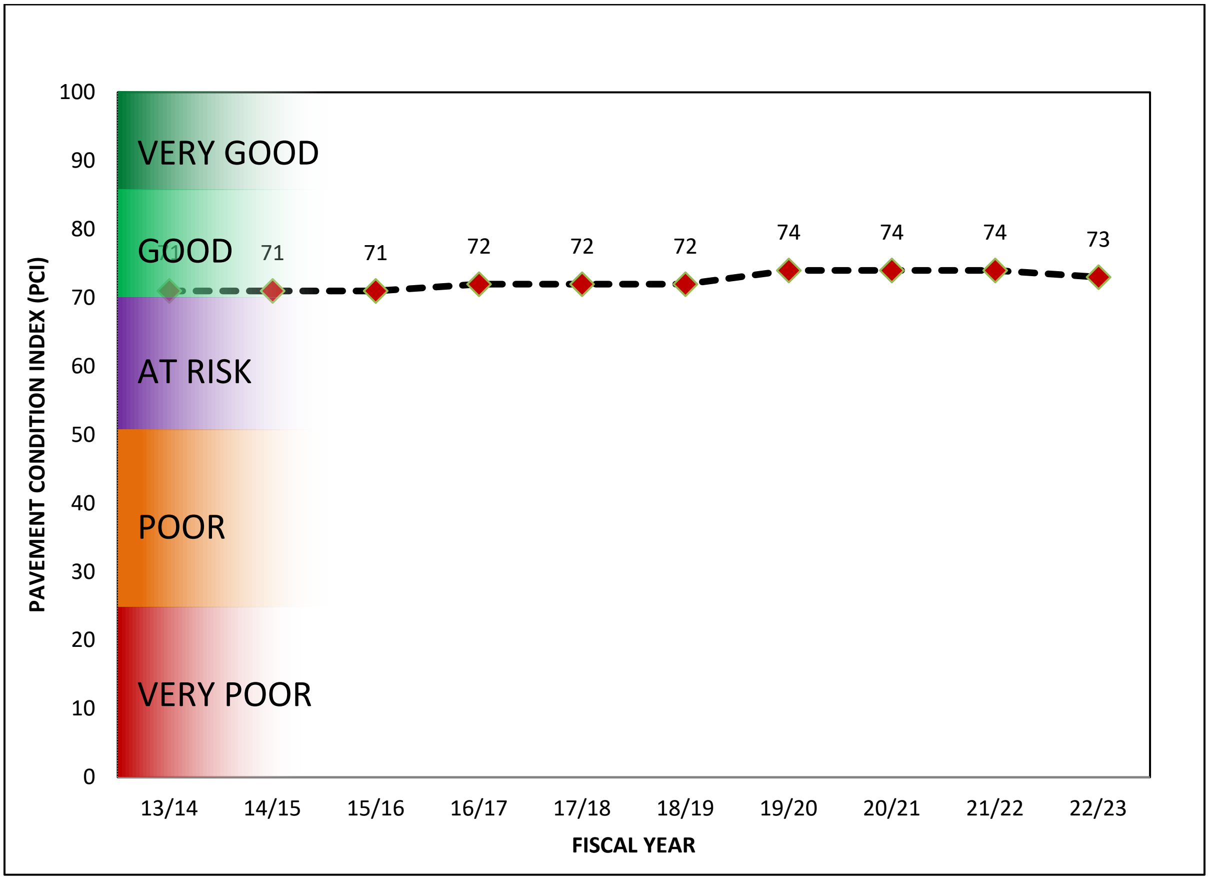


Figure 16. Pavement Condition Index Trend

Road Condition by Supervisorial District

Tables 4 and 5 depict the total number of centerline miles in each Supervisorial District by the functional classification of road and the associated area weighted average PCI.

Table 4. Supervisorial District Centerline Miles

	District Centerline Miles					
FUNCTIONAL CLASSIFICATION	**1**	**2**	**3**	**4**	**5**	**Total**
Arterial	40	64	100	160	56	421
Collector	55	60	150	350	72	686
Residential/Local	98	214	253	293	121	981
Gravel/Dirt	2	7	23	120	18	170
TOTAL	195	345	526	923	267	2,258

Table 5. Supervisorial District PCI

	District PCI[1]					
FUNCTIONAL CLASSIFICATION	**1**	**2**	**3**	**4**	**5**	**Overall**
Arterial	68	63	72	76	74	71
Collector	68	70	72	73	70	72
Residential/Local	73	77	77	71	74	74
Gravel/Dirt[2]	-	-	-	-	-	-
Average PCI	70	72	74	73	73	73

1) Calculated PCI shown is the area weighted average PCI
2) PCI is not calculated for gravel and dirt roads

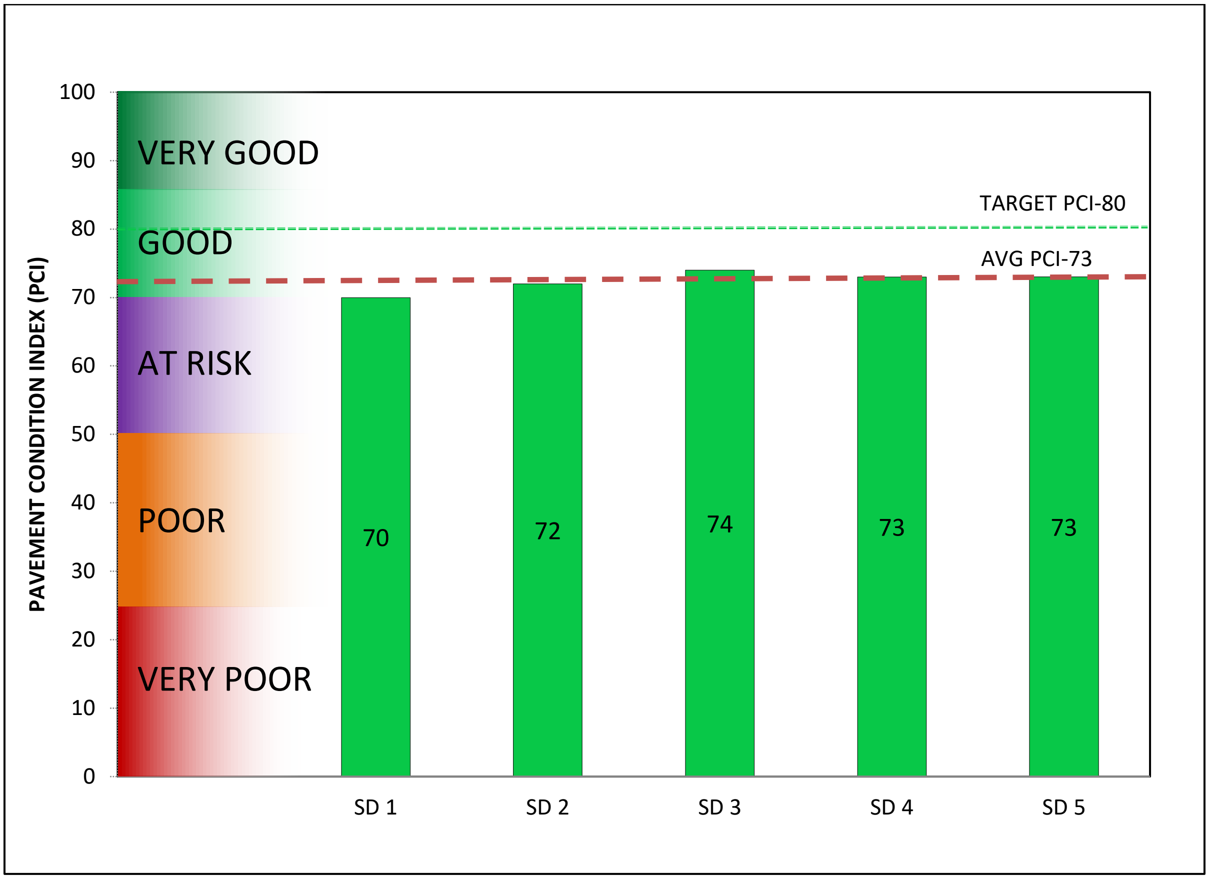


Figure 17. Pavement Condition Index by Supervisorial District

The Target PCI of 80 or higher, as shown in Figure 17, is based on a set goal that all pavements throughout the County road network system be in a condition where Best Management Practices (BMP) can occur. This means that the service life of roads can be extended by cost-effective pavement preservation treatments, such as, chip seal, slurry seal, cape seal, and thin overlay. Reaching and maintaining the target PCI of 80 offers other benefits to the public (other than cost):

- Fewer and shorter construction delays
- Reduced environmental impacts - less noise, dust, energy use, and greenhouse gas emissions
- Smoother roads (reducing accidents, fuel use, and vehicle maintenance and repair costs)

The average PCI of County roads is 73. A PCI of 73 is approaching the “At Risk” category and deterioration of a pavement can increase rapidly once the PCI falls below 70 (also called the “critical PCI”). If repairs are delayed by just a few years, the PCI drops quickly and the cost of repair could be up to ten times more than the preventive maintenance treatment.

PAVEMENT PRESERVATION

The desired goal of the County is to extend pavement life with the most effective treatment solution at the minimal life cycle cost. Over the useful life of a road, it is less expensive to "preserve" the pavement surface than to do nothing and have to reconstruct it.

Pavement Life Cycle

A pavement's life cycle is the relationship between its condition (PCI) and age. A newly constructed pavement is considered in perfect condition (PCI=100), but as it gets older, factors such as use, applied load, and climate cause its PCI to decrease. A properly designed pavement will usually have a slow deterioration rate during the first part of its life and at some PCI value and age combination, the pavement's deterioration rate will increase rapidly. The PCI value at this point in a pavement's life is called the "critical PCI". Figure 18 demonstrates this concept, at 75 percent of pavement design life (15yrs), the PCI drops by 40 percent (a rate of loss of ~2.7 PCI points/yr). If left untreated, it only takes another 15 percent of pavement life (3yrs) for the PCI to decline another 40 percent (a rate of loss of ~13.3 PCI points/yr). So, for this example, the "critical PCI" would be 70, at 15 years of in-service life. The work required to improve the road back to an acceptable PCI will cost 4 to 5 times as much at the 18-year point than if a preservation treatment had been applied at or before the 15-year point.

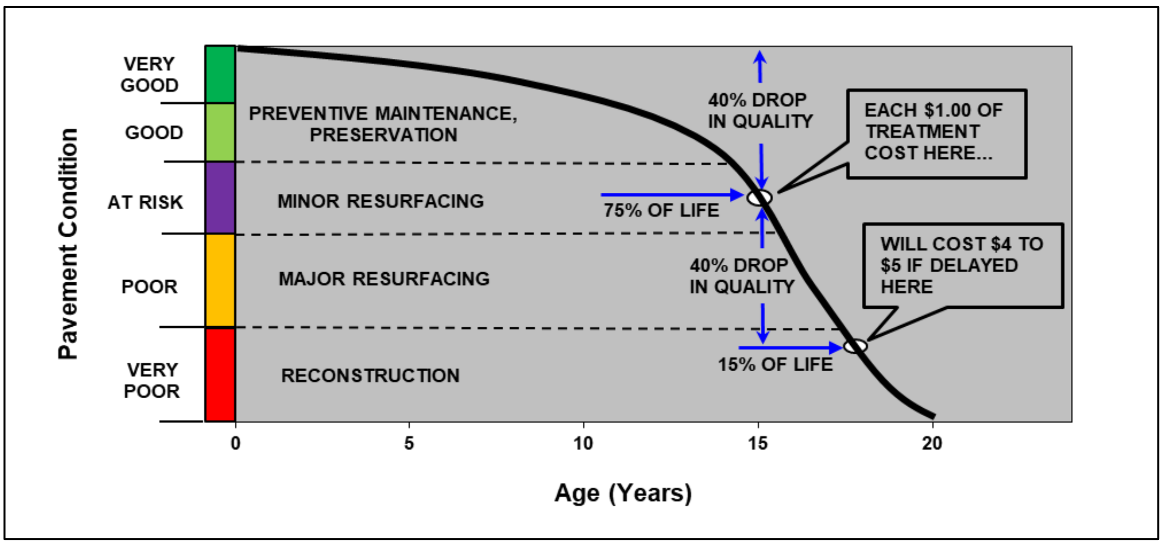


Figure 18. Pavement Life Cycle with No Maintenance and Repair

Life Cycle Cost Concept

A key concept in life cycle costing for pavement management is the timing of pavement preservation work; the work needs to be completed before the pavement reaches the critical PCI, this is a "proactive" approach to pavement management.

In "reactive" pavement management, projects are developed and funded in response to impending or critical failure and/or customer complaints. Reactive pavement management is both inconvenient and costly because large portions of a budget are consumed by small but expensive reconstruction projects or surface treatments are applied to deteriorated pavements which are doomed to premature failure requiring additional costly work and road closures. The overall poor condition of pavements from a reactive approach ultimately has a negative effect on both the local economy and the quality of life for users.

"Proactive" management determines what maintenance should be planned, when it should be budgeted, and what the consequences will be if the maintenance is not completed. A proactive approach uses a long-term, life-cycle cost perspective and takes advantage of sound, engineering-based procedures through the use of a network level pavement management program.

Pavement treatments include surface treatments such as slurry seals and cape seals, minor and major resurfacing, and reconstruction. The best treatment for a road is determined by pavement condition, location, and functional classification of the road. Proactive treatments are designed to bring the pavement up to an acceptable condition and extend the service life of the pavement.

Proactive pavement treatment actions can be effectively planned by monitoring the condition of the pavement network and conducting maintenance or repair on roads before the critical PCI is reached. This will increase the life of the pavement and reduce the "life cycle cost." Additionally, if a pavement PCI is too low, a choice may be made to forego a "preservation" treatment that would likely not extend the useful life of the pavement so that the funding can be used to preserve a road above the critical PCI point.

Figure 19 shows an example of life cycle costs for the life of an asphalt pavement for 60 years if proactive preservation is not applied to the pavement. The construction costs to keep the two lane road operational is estimated at $950k/mile of road and the road will be out of service for 70 days for each mile of road.

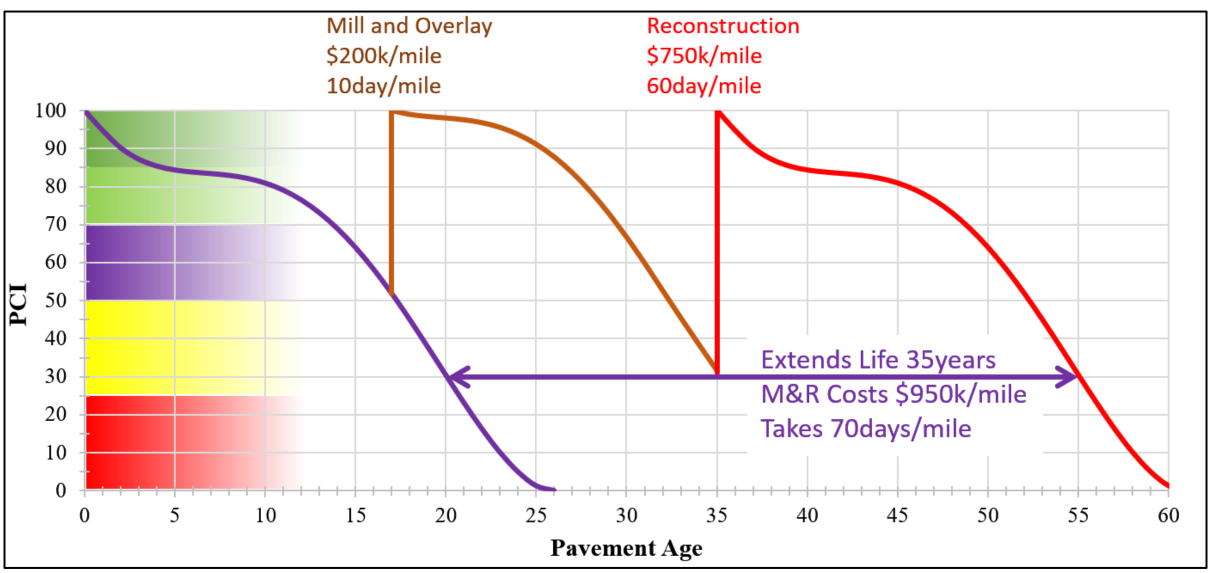


Figure 19. Life Cycle Cost Estimate with No Pavement Preservation

Using the wrong treatment on a road at the wrong time will increase the life cycle costs for that road. An effective pavement management program will extend the life of pavements through preventive maintenance and preservation. By applying a cost-effective treatment at the right time, the pavement is restored almost to its original condition. Figure 20 illustrates the concept of pavement preservation as it relates to enhancing pavement performance, extending pavement life, and ensuring taxpayer dollars are utilized wisely while providing improved safety and mobility to the public. Figure 20 also shows the cumulative effect of systematic, successive M&R treatments which result in the postponement of costly resurfacing and reconstruction. The life cycle cost to "maintain" the pavement for 60 years in this figure is \$233k/mile for the construction costs, 4 times cheaper than not using pavement preservation and causes 57.5 days less traffic disruption.

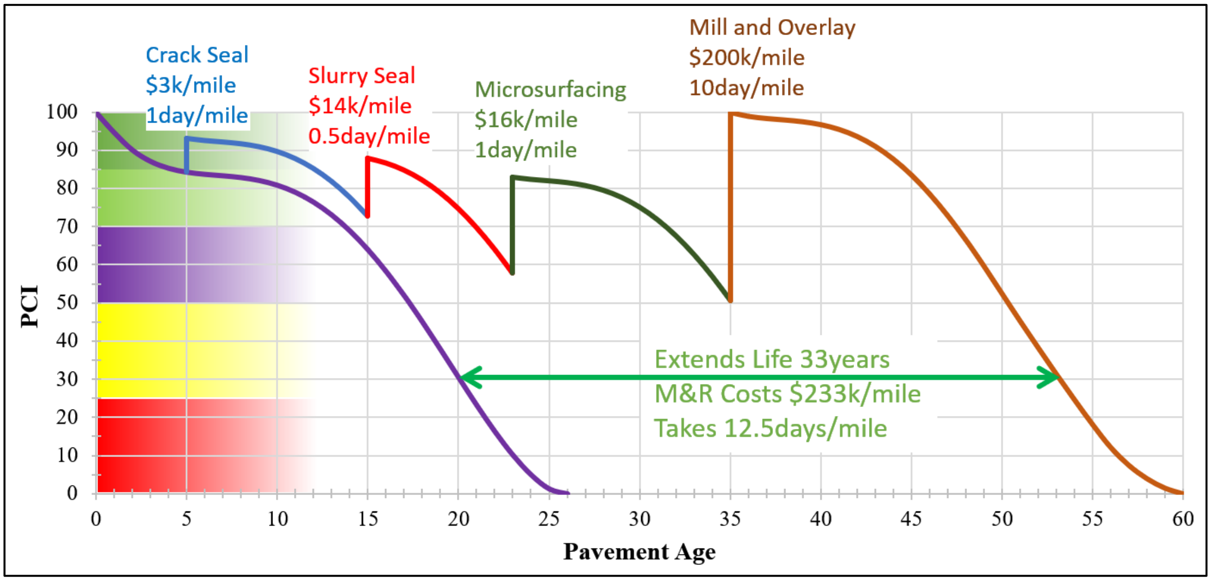


Figure 20. Treatment Zone Alternatives as a Function of Pavement Condition

IMPLEMENTATION OF PAVEMENT PRESERVATION USING BEST MANAGEMENT PRACTICES

Riverside County implements preventive maintenance treatments to preserve roads in good condition. In order to keep the good roads from deteriorating further, treatment strategies that can extend the life of roads at minimal costs are used. These treatment strategies include various surface treatments such as chip seals, scrub seals, slurry seals, and cape seals.

Pavement surface treatments are non-structural preventive maintenance applications that are classified as pavement preservation techniques. While these surface treatments do not increase the load carrying capacity of the road, if applied at the right time on the right pavement they do extend pavement life by keeping water out of the pavement layers and improve safety by decreasing road roughness and increasing surface friction.

Seal Coat (Preventive) Treatment

A seal coat treatment is a preventive measure designed to preserve a pavement in good condition and prolong its service life. Seal coats reduce further deterioration by sealing and rejuvenating the pavement surface. Sealing the pavement keeps water and debris from entering cracks and causing the pavement system to lose the capacity to carry loads without causing additional cracking. Sealing also prevents additional "weathering" or aging of the pavement surface. Weathering leads to a more brittle pavement surface which will crack due to temperature changes or load. Some seal coat treatments are as described below in more detail.

Chip / Scrub Seal

A chip seal is a surface treatment applied to pavement with minimal surface distress to provide a new wearing surface, extend pavement life, and delay major rehabilitation or reconstruction. It is a process in which an asphalt emulsion is sprayed on the pavement then immediately covered by small crushed aggregate particles, also known as "chips." Figure 21 illustrates the spreading of aggregate over the sprayed emulsion. When the asphalt emulsion is applied to the road surface in conjunction with a mechanized scrub broom (that forces the emulsion into the cracks), this process is called "scrub seal" (shown in Figure 22).

Figure 21. Chip Seal (slurry emulsion applied on right, chips applied on left)


Figure 22. Scrub Seal (brooms on left, in use on right)

Slurry Seal / Micro-surfacing

A slurry seal is a maintenance treatment applied to pavement to improve the functional characteristics of the pavement surface. It is a mixture of asphalt emulsion, aggregates, and mineral fillers. It is mixed and placed in a continuous basis using a truck mixer. A micro-surfacing is a maintenance treatment similar to slurry seal except it uses polymer modified and fast setting asphalt emulsion allowing thicker layers to be placed. The thick layer application allows the micro-surfacing slurry to fill in ruts commonly found on roads with light to moderate truck traffic. Prior to application, any surface distresses, such as cracks, are filled and sealed. After thoroughly mixing the emulsion, aggregates, and mineral fillers in the slurry truck's built-in pug mill, the slurry mixture is poured into a spreader box. As the truck moves forward, the slurry is extruded from the backside of the spreader box, see Figure 23. The box is capable of spreading the slurry over the width of a traffic lane in a single pass resulting in a uniform application. The slurry cures as the water evaporates and turns the freshly placed brown slurry into black slurry. Traffic can be returned once the slurry has cured, which is usually two to four hours.


Figure 23. Spreading of Micro-surface Slurry

Cape Seal

Cape seal treatment consists of a bottom course of a chip seal covered with a wearing course of slurry seal to lock the aggregate chips in place (Figure 24). Preventing the aggregate from the chip seal application from being dislodged is particularly useful for roads with curb and gutter where loose chips can fill the gutter. In addition, chip seals are also not popular with the public because of the rough ride and the loose chips that are picked up by vehicles.

Figure 24. Cape Seal

RECYCLING AND ENVIRONMENTAL CONSIDERATIONS OF PAVEMENT CONSTRUCTION AND PRESERVATION

The County maximizes the recycling and reuse of materials in construction projects whenever feasible. These materials include reuse of existing pavements as well as other recycled materials such as scrap tires. Consideration is given whenever such materials meet the minimum engineering standards and are economically feasible. It should be noted that the use of recycled materials is made on a case-by-case basis based on material properties, past performance of the recycled material, benefit/cost analysis, and engineering judgment.

With high-volume of industrial by-products, construction and demolition debris, and scrap tires being generated each year, hundreds of millions of waste materials are added to landfills and have a potential of being a threat to both the environment and public health and safety. Such materials can have beneficial uses, particularly in roadway construction. Pavement made with these materials can be stronger, more durable and less costly. Recycling and reusing these materials save energy, conserves natural resources, and reduces greenhouse gas emissions (carbon footprint).

Over the last few years, the highway construction industry has developed more options and better techniques on building "green." This has provided public agencies with tools to protect the environment and reduce greenhouse gas emissions. The use of Reclaimed Asphalt Pavement (RAP) in hot mix asphalt, base stabilization and subgrade treatment using the Full Depth Reclamation (FDR) process, warm mix asphalt, and rehabilitation/maintenance of existing roadways using Cold-in-place Recycling (CIR) method, are some of the recycling technologies being practiced in the County.

Reclaimed Asphalt Pavement (RAP)

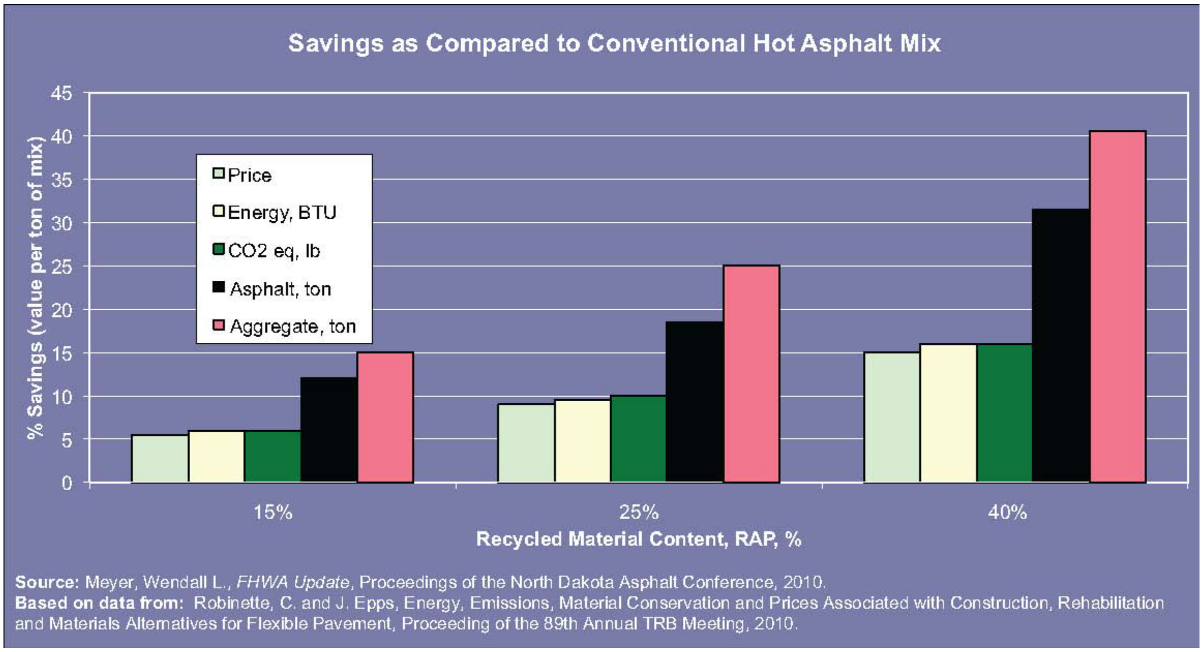
Reclaimed Asphalt Pavement (RAP) – removed/reprocessed asphalt concrete pavement – is a commonly recycled material incorporated in the production of new Hot-Mixed Asphalt (HMA). RAP can be generated from a number of different sources including cold milling, full-depth removal, and pulverize-in-place operations of existing pavements. The use of RAP in HMA is the most efficient use of this material as it provides a reduction in virgin asphalt binder and aggregate demand, thus conserving natural resources. RAP is also used as recycled aggregate base and helps reduce the pavement structural section due to its increased strength in comparison to conventional aggregate base.

The California Department of Transportation (Caltrans) goal is 40 percent RAP in HMA. In the recent report published by Caltrans in the "Specifications for the Use of Reclaimed Asphalt Pavement: A Status Report," dated 18 July 2016, up to 40 percent is allowed for the subsurface course in the asphalt pavement and up to 25 percent for the surface course. In the same report, concerns have been raised regarding premature cracking in relatively new asphalt pavements as a result of using high content of RAP. Caltrans is currently working with the asphalt industry to address the issue of premature cracking in asphalt pavements containing up to 40% of RAP. The status report on the reclaimed asphalt pavement can be found at the following address:
https://dot.ca.gov/SearchResults?q=reclaimed+asphalt+pavement

Recycling asphalt is simple in concept but complex in execution because the asphalt surface that is recycled will have variability in the asphalt chemistry, aggregate qualities, and contaminants in the mix. Developing an HMA mix design capable of accounting for this variability is extremely difficult and costly. The use of more than 15% RAP may potentially cause long-term durability and premature cracking issues with the asphalt because of stability, swell, and moisture vapor susceptibility of the RAP in the asphalt mix. Because of this, in Riverside County, the goal is 15% of RAP in HMA. The County will continue to allow up to 15% RAP until Caltrans and the asphalt industry come up with solutions to address durability and cracking.

From the chart illustrated in Figure 25, some environmental benefits and cost savings of using at least 15 percent RAP in conventional HMA will yield a reduction in asphalt by about 12%, a decrease of virgin aggregate by about 15%, and a reduction of greenhouse gas emissions at a rate of 5 pounds per ton of RAP used in the hot mix asphalt.

Figure 25. Benefits and Cost Savings of using RAP



Price corresponds to materials, construction, rehabilitation, and maintenance costs based on Life Cycle Cost Analysis (LCCA) with environmental impact assessment. Energy (BTU) represents the requirements for construction materials processing and construction material production. CO_2 eq (lb) is a measure of greenhouse emissions and it includes the production of raw materials, transportation, production, and laydown of materials. Asphalt and Aggregate in tons are considered the natural resources [Sources: Transportation Research Board and Federal Highway Administration (FHWA)].

Since 2005, the County has used over 232,000 tons of RAP in its pavement rehabilitation and reconstruction projects. This translates to approximately 203 lane miles of recycled County maintained roads and a reduction of 1,160,000 pounds of carbon emissions or the equivalent of about 1,960 passenger cars removed from the County roads.

Full-Depth Reclamation (FDR)

Full-Depth Reclamation (FDR) involves the pulverization of the asphalt layers of the pavement and a portion of the underlying materials in-place four to ten inches deep, removing any excess material, and then stabilizing the materials with cement, foam asphalt, or asphalt emulsion (Figure 26). The new material is shaped and compacted in preparation for a new wearing surface such as hot mix asphalt. The wearing surface is placed within one to three days of completing the FDR material.

Figure 26. Full Depth Reclamation (FDR)

Cold In-Place Recycling (CIR)

Another method that involves the reuse of pavement material is Cold In-Place Recycling (CIR). Pavement is removed by cold planning or milling 3 to 4 inches of material, leaving a small amount of pavement to support the equipment during the construction process (Figure 27). The material is crushed, sized, and mixed with an asphalt emulsion and other additives. Then the material is immediately placed and compacted. Within two to five days of placing the CIR material, a layer of hot mix asphalt is placed. Typically, a 3-piece "train" is used consisting of a cold planning machine, a screening/crushing/mixing unit, and conventional laydown and rolling equipment. This "train" occupies only one lane, thus maximizing traffic flow.

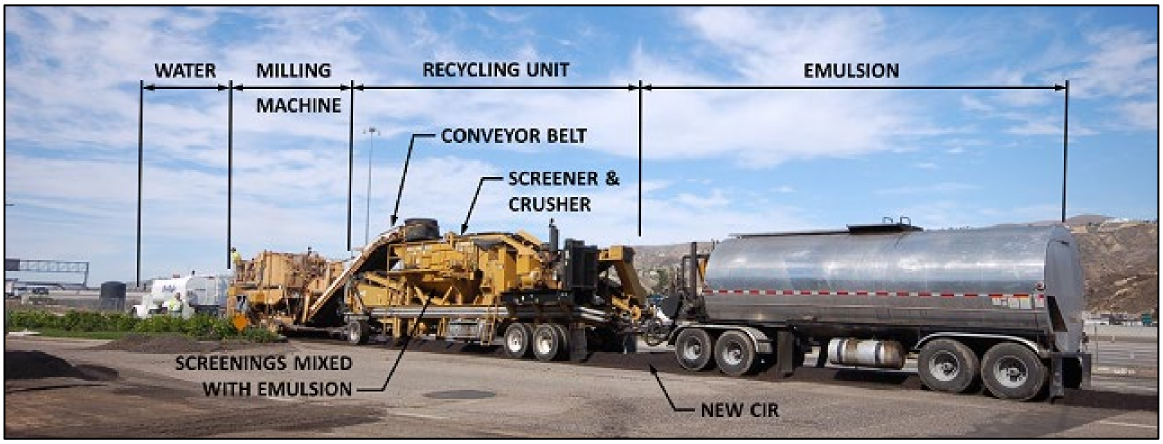


Figure 27. Cold In-Place Recycling (CIR)

Warm Mix Asphalt (WMA)

Warm Mix Asphalt (WMA) is the generic term for a variety of technologies that allow producers of Hot Mix Asphalt (HMA) pavement material to lower temperatures at which the material is mixed and placed on the road. WMA production methods use mix temperatures 30 to 120 degrees Fahrenheit lower than traditional hot-mix asphalt. Because less energy is needed to heat the asphalt mix, less fuel is needed to produce WMA. Fuel consumption during WMA manufacturing is typically reduced by 20 percent.

In paving projects, the greater the temperature difference between the asphalt mix and the outside temperature, the faster the mix cools. Since faster cooling effects durability, cold ambient temperatures adversely affect hot-mix asphalt. Relative to HMA, WMA cools more slowly allowing WMA to be successfully placed in lower temperatures. As a result, WMA extends the paving season. It also makes night paving more feasible.

Additionally, WMA saves time in production as well as in surfacing roads. Because WMA makes compaction easier, cost savings are achieved by reducing time and labor spent compacting the mix. Lower temperatures also permit larger haul volumes per vehicle, reducing transportation costs.

WMA technologies work by reducing the viscosity (thickness) of the asphalt binder so that asphalt aggregates can be coated at lower temperatures. The key is the addition of additives (water-based, organic, chemical, or hybrids) to the asphalt mix. The additives allow the asphalt binders and asphalt aggregates to be mixed at the lower temperatures. Reducing the viscosity also makes the mixture easier to manipulate and compact at the lower temperature saving time and money on compaction.

Because of the lower temperatures involved, warm mix also lowers emissions during placement, creating a better environment for workers and the public.

Rubberized Asphalt Concrete (RAC)

Rubberized asphalt concrete (RAC) is a road paving material made by blending and heating ground tire rubber with asphalt to produce a binder, which is then mixed with conventional aggregate materials (Figure 28). This mix is then placed and compacted into a road surface.

Figure 28. Rubberized Asphalt Concrete using Crumb Rubber

Benefits of using RAC are as follows:

<u>Cost-effective</u>
In most applications, RAC can be used at a reduced thickness compared to conventional asphalt overlays, in some cases at half the thickness of conventional material, which can result in significant material reduction and cost savings.

<u>Durable, Safe and Quiet</u>

RAC is long lasting. It resists cracking, which can reduce maintenance costs, it provides better skid resistance, it retains its darker color longer so that road markings are more clearly visible, and RAC can also reduce road noise.

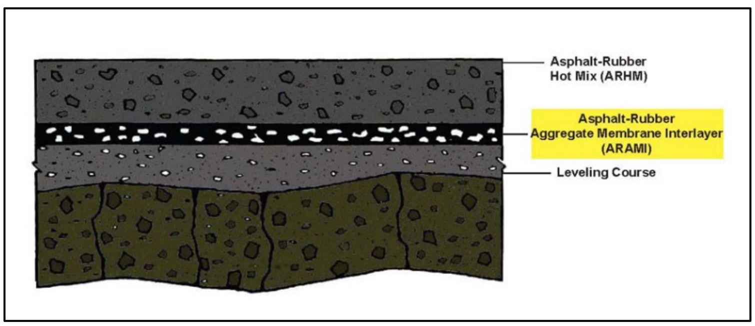
Environmentally Friendly

California produces more than 40 million waste tires annually, of which approximately 75 percent are diverted from landfill disposal. Over the past few years, California has used more than 10 million waste tires in RAC paving projects, diverting them from landfills or illegal disposal.

Asphalt-Rubber Aggregate Membrane (ARAM)

ARAM is a 3/8 to 1/2 inch rubberized membrane comprised of both California scrap tire rubber and tires with a high natural rubber content that can provide maintenance-free street surfaces for 10 to 15 (or more) years. ARAM recycles the equivalent of over 600 scrap tires in every lane mile. ARAM can be applied to both residential and arterial streets.

ARAM can be used as a final wearing surface, which is common practice for Caltrans on open, often rural, highways. ARAM can also be used as part of a composite layering system (ARAM Interlayers). In this instance, ARAM is "sandwiched" between layers, which may include a leveling course, slurry seal or final hot mix asphalt overlay (Figure 29). Arterial streets, highways and streets that are potentially targeted for reconstruction are usually the best candidates for these types of systems.



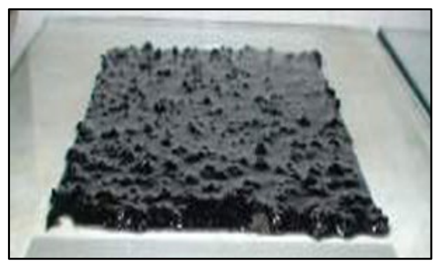


Figure 29. Asphalt Rubber Aggregate Membrane (ARAM)

Asphalt-Rubber Aggregate Membrane (ARAM) applications are different in comparison to other "rubberized" chip seals and products because it is the only product whose binder reacts with the rubber particles to form a hot, thick, viscous jellied composition for a significantly thicker binder application resulting in better crack mitigation and longer pavement life. (In contrast, other "rubberized" products digest or "dissolve" the rubber.) At less than 1/2 inch thick, the ARAM membrane is thin and flexible, expanding and contracting with the various weather cycles to mitigate reflective cracking and maintain the integrity of the subgrade and final wearing surface. It also acts as a barrier to water intrusion.

Use of RAC in Riverside County

The County of Riverside has been using RAC since 1995. The county typically uses a 2-inch thick overlay on all RAC resurfacing projects. A 2-inch thick RAC overlay uses over 1,200 scrap tires per lane mile. This means that for a one-mile section of a four-lane highway, over 4,800 scrap tires can be used in creating a safer, quieter, longer-lasting road. Since 2005, the County has used over 624,300 scrap tires in its pavement rehabilitation projects. This translates to at least 520 lane miles of rubber treated County maintained roadway.

Recycled Materials Usage Summary

A summary of the environmental benefits of recycling and reusing of roadway materials in road paving is as follows (as implemented by Riverside County) and as shown in Figure 30:

- 232,000 tons of RAP used in HMA which translate to a reduction of 1,160,000 pounds of carbon emissions or the equivalent of about 1,960 passenger cars removed from the County roads.
- 910,400 scrap tires diverted from the landfill by substituting RAC in HMA.

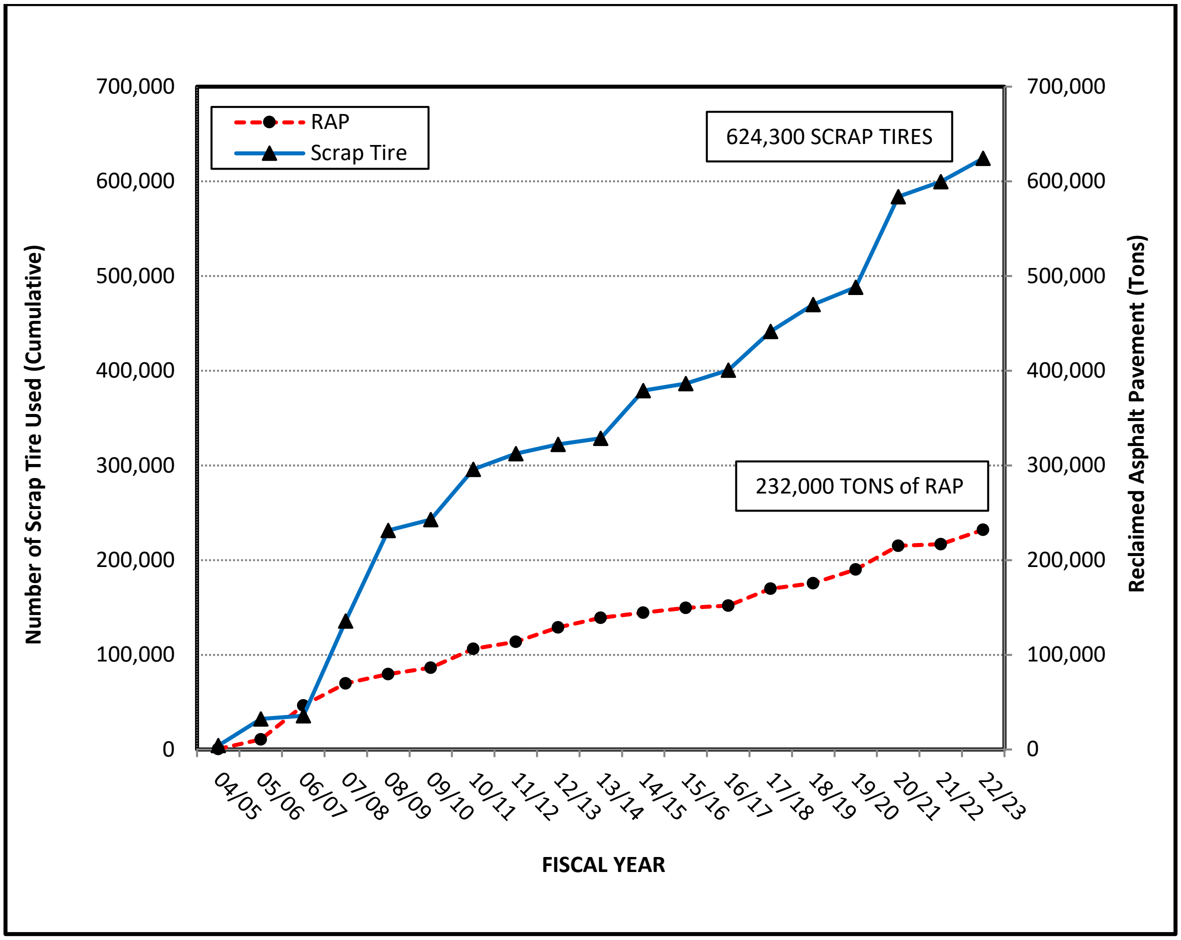


Figure 30. Benefits and Cost Savings of using RAP

SUMMARY

The County's StreetSaver database includes a total of 6,759 pavement section of which 6,382 are paved. At the time of the 2020 inspection, approximately 70% of the County's paved roads were found to be in good condition (i.e., PCI scores higher than 70), with an overall network area weighted average PCI of 73. The arterial roads were found to have an area weighted average PCI of 71, the collector roads had an average PCI of 72, and the residential roads had an area weighted average PCI of 74. The PCI has dropped by one point and is at 73 in FY 2022/23.

StreetSaver was used to analyze the impact of different funding scenarios on the condition of the County's pavement network. It is expected that if funding levels remain as expected, the County's PCI value will increase to 74 by FY 2027/28. This will also reduce the number of AT RISK, POOR, and VERY POOR roads from 30% down to 26%.