QuickZone Case Studies

"The Application of QuickZone in Eight Common Construction Projects"

October 2004

FHWA-HOP-09-054

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16. Abstract

QuickZone is a spreadsheet-based analytic tool that allows for quick estimation of work zone delay and can be used to support decisionmaking during all phases of the project development process (policy, planning, design and operations). FHWA commissioned a series of QuickZone case studies to capture the uses and impact of the tool. The case studies contained herein are a few examples of the many applications of QuickZone. The eight highway construction project sites presented in the case studies are intended to showcase a range of applications, plus to highlight innovative modeling approaches using QuickZone. The case studies are located throughout the United States and Canada and include urban and rural applications. The roadway facilities include both high-volume, freeway applications with recurring congestion and low-volume, rural road applications where congestion is rarely a problem.

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1.0 Introduction

In all but a few high-visibility roadway construction and refurbishment projects, the “soft cost” of traveler delay is typically not considered when key decisions about project staging and duration are made. The 1998 Federal Highway Administration (FHWA) report “Meeting the Customer’s Needs for Mobility and Safety During Construction and Maintenance Operations” identifies this issue and recommends the development of an analytical tool to estimate and quantify work zone delays. To this end, the FHWA sponsored the development of QuickZone, an easy-to-master analytic tool that allows for quick and flexible estimation of work zone delay supporting all four phases of the project development process (policy, planning, design and operations).

The overall goal in terms of ease-of-use for QuickZone is less than one hour to input and check a QuickZone network, and less than three minutes to analyze the data and produce delay profiles over the project duration. Target users of QuickZone include state and local traffic construction, operations, and planning staff as well as construction contractors. QuickZone allows these users to:

- Quantify corridor delay resulting from capacity decreases in work zones;
- Identify delay impacts of alternative project phasing plans; and
- Support tradeoff analyses between construction costs and delay costs.

1.1 QuickZone 1.0

QuickZone development began in April 2000 using a rapid prototyping approach. This implies that a series of prototypes with limited capability be released to a set of beta testers for evaluation. The QuickZone Tool Review Committee, a sub-group of the FHWA Strategic Work Zone Analysis Team, was formed and drew from a user base of contractors, DOT planners and local agency personnel. The tool review committee was to help guide and evaluate the development of QuickZone Version 1.0 as well as beta test early versions of the software. The tool review committee responded not only in terms of look and feel of the product, but in terms of how they imagined using the tool.

For example, during feedback regarding Version 0.91 (February 2001), all of the respondents indicated that they would be a potential user of QuickZone and believed that QuickZone will address critical needs in their organization. They also indicated they would eventually use QuickZone for construction planning and work zone staging to evaluate highway design alternatives analysis for transportation management plans in life-cycle costing, and to select proper mitigation strategies and determine traffic control strategies. With this feedback provided in the early stages of development, the tool development effort reduced the risk of developing a tool that did not fit the needs of the target user.

The rapid prototyping approach enabled QuickZone to be developed in a relatively short time-frame. The total time from project inception to the wide release of QuickZone 1.0 was 24 months. However, beta versions were being actively used on projects by many users even before the final version was released. The following was the QuickZone Version 1.0 development schedule:

- **Version 0.5 Beta—**Distributed in July 2000 to the QuickZone Tool Review Committee members. Members are provided comments on look, feel and usefulness of QuickZone.
- **Version 0.9 Beta—**Distributed in October 2000 to the QuickZone Tool Review Committee members. Version 0.9 incorporated comments from Beta 0.5 and allowed members to input their own networks.
- **Version 0.99 Beta—**Widely distributed in June 2001 via the internet. Still receiving comments on this version.
- **Version 1.0—**Public release of QuickZone in June 2002 McTrans and PCTrans.

QuickZone Version 1.0 was made generally available in June 2002. Since that time approximately 109 licenses have been sold at a cost of $199. Sales of QuickZone have occurred across the United States to contractors, universities, and various state and local DOTs. QuickZone has also been purchased by users in foreign countries including Canada, South Africa and Japan. In addition, numerous training classes and seminars have been sponsored by FHWA and state DOTs to further promote the use of QuickZone. Figure 1.1 shows the geographic distribution of QuickZone sales throughout the United States.

1.2 QuickZone Partnership Program

Early in the development of QuickZone, it was clear that the varied needs of transportation agencies in modeling and assessing work zones could not be addressed by a single federal version of QuickZone. In order to develop QuickZone using the rapid-prototyping approach, QuickZone was written as a program within Microsoft Excel using the Visual Basic for Applications (VBA) programming language. This approach enabled QuickZone to be an open-source computer program. Therefore, to take advantage of QuickZone's open source code, and to encourage individual states to modify the underlying core code to create state-specific versions of QuickZone, the QuickZone Partnership Program was established.

The QuickZone Partnership Program takes advantage of QuickZone's open source code to both further improve the software and to provide state and local transportation agencies with a tool that best meets their needs. Under the QuickZone Partnership Program, the FHWA builds, maintains and distributes new Federal versions of QuickZone periodically as needed. Partner transportation agencies receive free versions of QuickZone to develop and support customized versions of QuickZone for use throughout their agency. Under the partnership program, the FHWA can include modifications made by individual partners into future version that are determined to be valuable to everyone.

The QuickZone Partnership Program includes seven state agencies and one division of FHWA, the Central Federal Lands Highway Division (CFLHD), as indicated in Figure 1.1. Two examples of the success of the QuickZone Partnership Program include MD-QuickZone and CFLHD-QuickZone. MD-QuickZone was developed in partnership with the Maryland State Highway Administration (MDSHA) and University of Maryland in 2001. The MDSHA had an ongoing project with the University of Maryland looking at capacity in work zones and trying to come up with a tool for estimating queues and delays. When MDSHA found out about QuickZone, they decided to combine the two efforts. MD-QuickZone included a state specific method to calculate capacity reductions in work zones and a work zone scheduler to further assist engineers in work zone traffic control plans. CFLHD-QuickZone was developed to specifically address the unique needs of the FHWA Central Federal Lands Highway Division. Many of the modifications made to develop these two partnership versions of QuickZone are included in Version 2.0.

1.3 Case Study Overview

QuickZone is a widely recognized and utilized tool. However, the success of QuickZone cannot measured only by the number of licenses sold, but rather by its impact on work zone planning, design and operations. In order to examine whether or not QuickZone was meeting the original goal, FHWA commissioned a series of QuickZone Case Studies to capture the uses and impact of the tool. In this document, eight highway construction projects are presented. The case studies selected here are just a few of the many applications of QuickZone. The eight sites selected to be a case study are intended to showcase the range of applications plus to highlight innovative modeling approaches using QuickZone. These case studies used various versions of QuickZone (V 0.99 Beta, V 1.0, MD-QuickZone and CFLHD-QuickZone) in a wide range of roadway locations. The case study locations are presented in Figure 1.1 marked with a triangle.

The case studies are located throughout the United States and Canada and include urban and rural applications. The roadway facilities include both high-volume, freeway applications with recurring congestion and low-volume, rural road applications where congestion is rarely a problem. In order to better organize the applications of QuickZone, each case study has been categorized into one of four areas described below. In each case study area there are two case studies.

- **Urban Freeway—**Road work planned or in-construction on higher volume roadways where recurring congestion is a problem and lane closures, if permissible, are severely restricted.

    1. **Knoxville, TN: I-40—**High volume roadway with major reconstruction scheduled. Current concepts include a full-closure of the mainline.

2. **Maryland/Virginia Woodrow Wilson Bridge: I-95—**High volume roadway with peak periods lasting for five hours or more during the morning and evening. Limited time availability partial lane closures given the consistently high traffic volume through the work zone.

- **Urban Arterial—**Medium to high volume roads with signals and at-grade intersections. Recurring congestion may be a problem in which case lane closures are restricted depending upon traffic volume and time-of-day.

3. **Little Bras d'Or Bridge: Nova Scotia, Canada**—Medium volume two-lane road. Major structural repairs to bridge required flagging operations.
4. **Reeves Street: Nova Scotia, Canada—**Medium volume two-lane road. Intersection reconstruction required periodic lane closures on major route through Nova Scotia province.

- **Rural High AADT—**Higher volume rural roads (AADT greater than 1000) where congestion may be a concern if lane closure and flagging operations are conducted during peak periods.

5. **Yosemite National Park—**High volume rural road through a major National Park destination. Roadway reconstruction may require periodic lane closures that coincide with peak demand.
6. **Zion National Park—**High volume road through major National Park. Roadway milling/paving operations required closure of 1 of 2 entrance booth lanes during peak visitor hours.

- **Rural Low AADT—**Lower volume rural roads (AADT less than 1000) where recurring congestion is not a problem. Here, partial lane closures are permissible throughout the day, but impacts of periodic full closures or flagging operations on road users is poorly known.

7. **Beartooth Highway**—Low volume two-lane rural road. Major reconstruction of entire facility requires full closure and flagging operations through day. Detour route is not feasible.

8. **Louis Lake Road**—Low volume two-lane rural road. Major reconstruction of entire facility requires full closure for long durations. Possible detour route exists.

Table 1.1 provides a summary of work zone characteristics of each case study. The case studies include a range of high, medium and low volume roads in both urban/suburban settings as well as rural locations. Traffic control options include partial closure, full closure, flagging and detours. Full closures include both long duration (1 or more days) and periodic (0 – 6 hours). Network types range from large and complex to small and simple. Finally, the case studies include examples of QuickZone being used for planning purposes—where the work zone and construction schedule are still being developed—and operations—where QuickZone is used to further refine a predetermined construction schedule.

The case study summaries provide an analysis of how QuickZone was utilized for the eight case studies presented above. The analysis includes a listing of key observations that are important to how QuickZone was used for each project; an overview, which includes a description of the project location, to better orient the reader and provide context; a discussion on network design for each case study; an analysis of the results and how they were used; and finally, contact information. In addition to the eight case studies, a summary of other selected projects where QuickZone has been used is also provided.

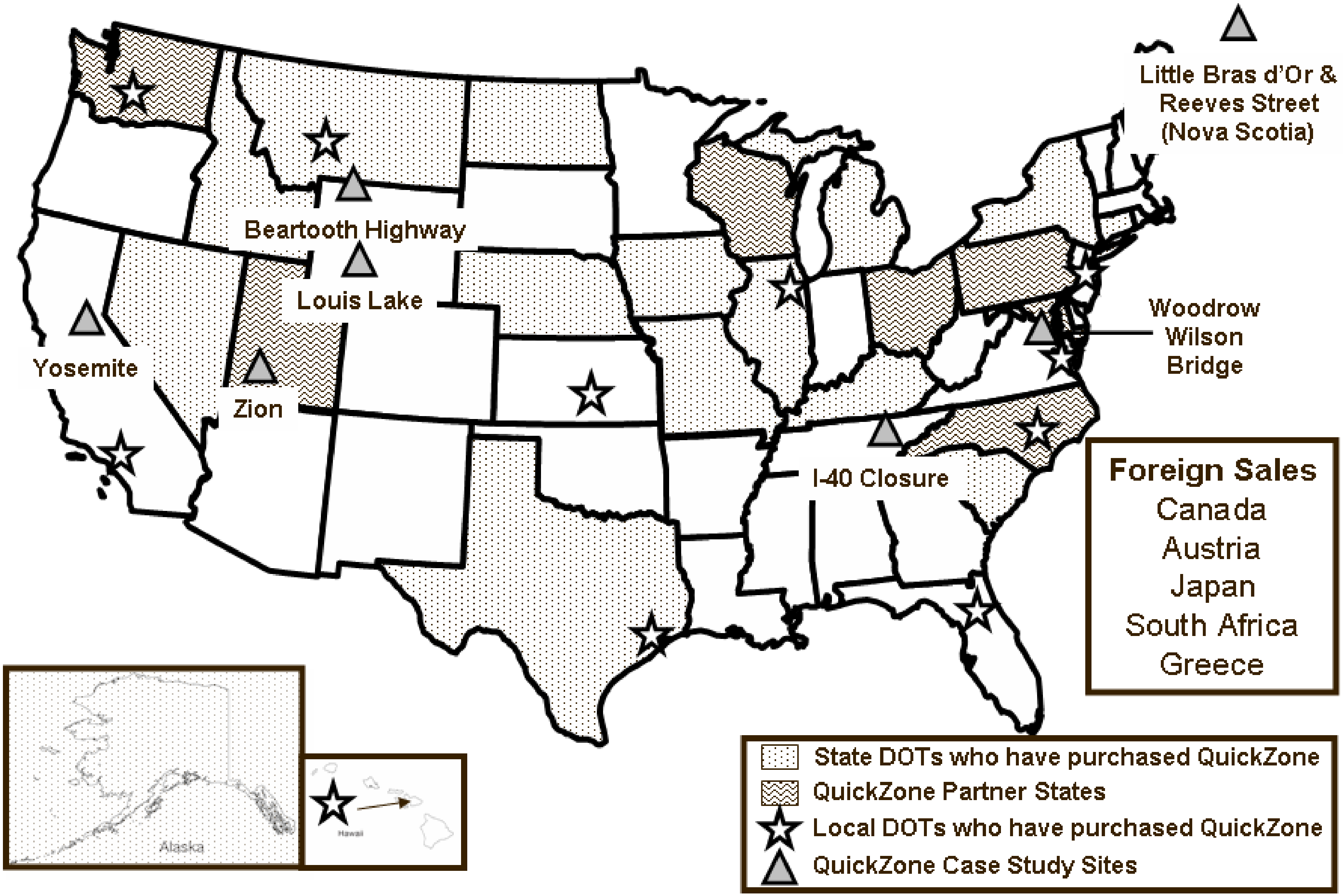

Figure 1.1 Geographic Distribution of QuickZone Sales and Case Study Location

Table 1.1 Case Study Comparison Matrix

	AADT	Traffic Control Elements				QuickZone Network Model	Purpose		Objective (for use of QuickZone)	QuickZone Version
		Partial Closure	Full Closure	Flagging	Detour		Planning	Operations		
Urban Freeway										
Knoxville, TN: I-40	High	X	Long Duration		X	Large, Complex	X		Determine feasibility of full closures option for a congested urban freeway.	V 1.0 Summer 2004
Maryland/Virginia Woodrow Wilson Bridge: I-95	High	X				Medium, Complex		X Results of QuickZone verified in field.	Analyze additional construction staging strategies to maximize time for contractor in work zone without impacting motorists.	MD-QuickZone Fall 2001
Urban Arterial										
Little Bras d'Or Bridge: Nova Scotia, Canada	Medium			X		Small, Simple		X Results of QuickZone verified in field.	Determine feasible construction times to limit impact on motorists.	V 0.99 Beta Summer 2001
Reeves Street: Nova Scotia, Canada	Medium			X		Small, Simple		X Results of QuickZone verified in field.	Justify additional cost of night work by quantifying delays expected from planned daytime roadwork.	V 1.0 Winter 2002
Rural High AADT										
Yosemite National Park	High	X	Long Duration	X		Medium, Complex	X		Alternatives analysis comparing one-season and two-season construction phasing.	QuickZone-CFLHD Spring 2004
Zion National Park	High	X				Small, Simple	X		Analyze various construction staging scenarios.	QuickZone-CFLHD Spring 2004
Rural Low AADT										
Beartooth Highway	Low		Periodic	X		Large, Complex	X		Analyze overall construction impact on motorists resulting from multiple work zones.	QuickZone-CFLHD 2003 - 2004
Louis Lake Road	Low		Periodic	X	X	Large, Simple	X		Estimate economic loss and delays from a work zone with a lengthy detour.	QuickZone-CFLHD 2004

2.0 Urban Freeway

2.1 Knoxville, Tennessee: I-40

Key Observations

- **QuickZone can be utilized to predict likely delay impacts from a proposed full closure on a major interstate.**
- **The predicted delays brought to light the potential for extensive delays and helped Tennessee DOT to mobilize resources for demand management and public outreach prior to construction.**
- **A tiered modeling approach is a cost-effective strategy for using QuickZone. First, less detailed data is used to scope potential delays – then, enhanced travel demand and more detailed network models are employed to provide more refined estimates if necessary.**

2.1.1 Overview

Connecting the mid-Atlantic region to the Midwest and central Southern states, Interstate 40 is a key east-west connection for a variety of road users ranging from freight operators to cross-country motorists. West of a key junction with I-81, I-40 carries interstate traffic to and through Knoxville Tennessee, including a series of major interchanges in the downtown area. In and around Knoxville on both I-40 and the half-beltway formed with I-640 (Figure 2.1.1), the combination of interstate and local travel demand produces recurrent delay in several locations in both morning and afternoon peak periods. In addition, summer travel demand to tourist locations to the east of Knoxville can result in near-capacity or congested conditions on various weekday and weekend afternoon and early evenings.

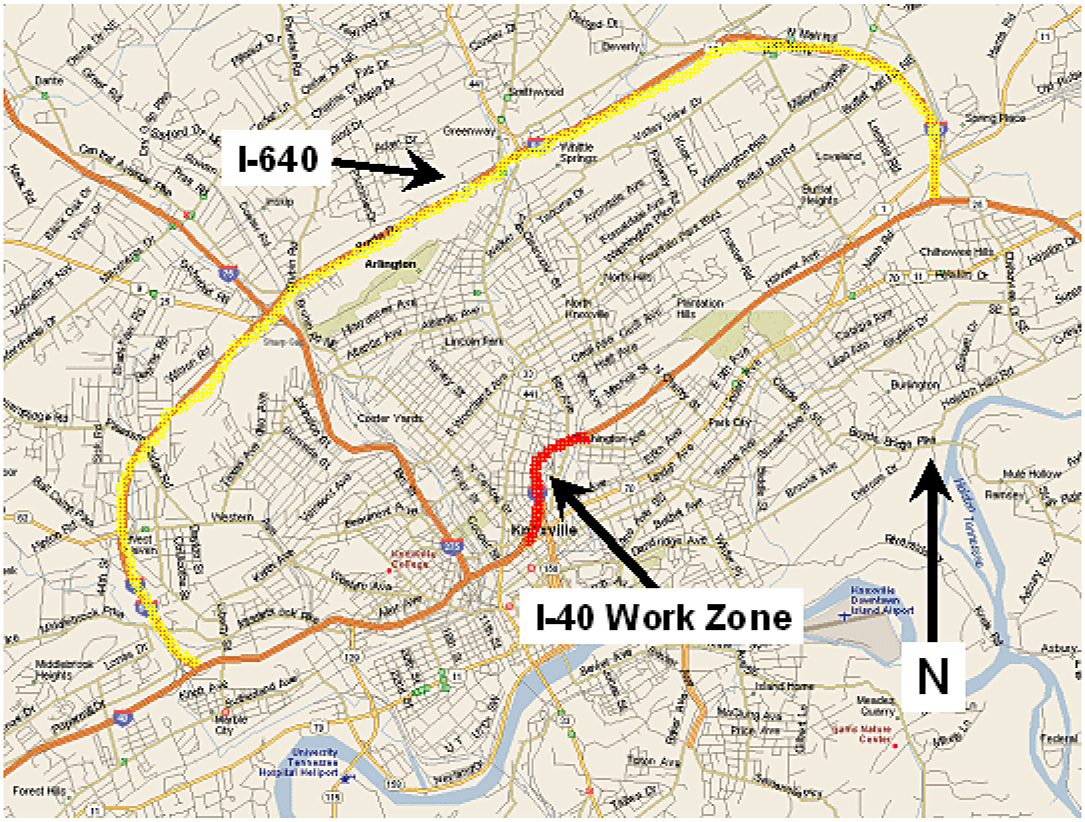

Figure 2.1.1 Knoxville, TN

Tennessee DOT (TNDOT) identified a section of I-40 just east of downtown Knoxville as a candidate for major rehabilitation, and in 2004 began to consider various strategies to perform the needed roadwork considering construction costs, project duration and potential impact to road users. One option of interest for TNDOT was the use of a full closure to complete complex work on freeway interchanges without the maintenance of through traffic on I-40. This option had the advantage of reduced project duration, improved worker safety and potential cost savings over more traditional approaches. However, the impact on road users throughout the closure period was not clearly understood. In this case, TNDOT turned to the use of QuickZone to scope the potential delays to motorists in and around Knoxville during the periods when I-40 would essentially be shut down for through travel to both the east and west.

From the road network geometry in the metropolitan area, it was clear that the brunt of the diverted travel demand would have to be borne by I-640. This facility, like I-40 was already experiencing some recurrent congestion in 2004 with I-40 open at full capacity. TNDOT commissioned a traffic study to predict traffic volumes on I-640 for a prospective 2008 full closure on I-40. The study, performed by a consultant from the Knoxville area, used vehicle-matching technologies to identify through and local traffic volumes collecting field data in the first half of 2004. The results of this study, in combination with existing TNDOT data describing seasonal, day-of-week, and time-of-day distributions of travel demand were used by analysts to sharpen a picture of predicted travel demands on the I-640 facility during the construction season.

The role of QuickZone in this case study was to first perform a quick prediction based on current traffic volumes to identify if significant congestion was likely under the proposed full closure option. When it became clear that congestion was likely to be significant, more refined travel demand data and more detailed network geometry in QuickZone was applied to scope the likely delay impacts and to identify targets for the management of local and interstate travel demand to prevent lengthy delays on I-640 and at the I-40/I-640 interchanges. TNDOT is using the results of the study as they consider approaches to this major project and a potential public awareness campaign to prepare the community, freight operators and other stakeholders in advance of the actual construction activity.

2.1.2 Network Design

In this case study, two networks were constructed in QuickZone to model the I-40 closure. The first included both I-40 and I-640 and was used for the initial delay screening activity. A second more detailed model was constructed of just the I-640 detour including key bottlenecks at interchanges along its length in both east and west directions (Figure 2.1.2). Modeling the details of the bottleneck areas was important in identifying the capability of I-640 to effectively absorb diverted travel volume from I-40 during the proposed full closure period. For example, capacity of the off-ramp from westbound I-40 onto I-640 was estimated with consideration for features of the proposed travel movement, e.g., number of lanes, grade, ramp curvature and merge area length. Likewise, a capacity reduction was modeled at the intersection of I-640 and I-275 because of a narrowing of the I-640 as it passes beneath I-275.

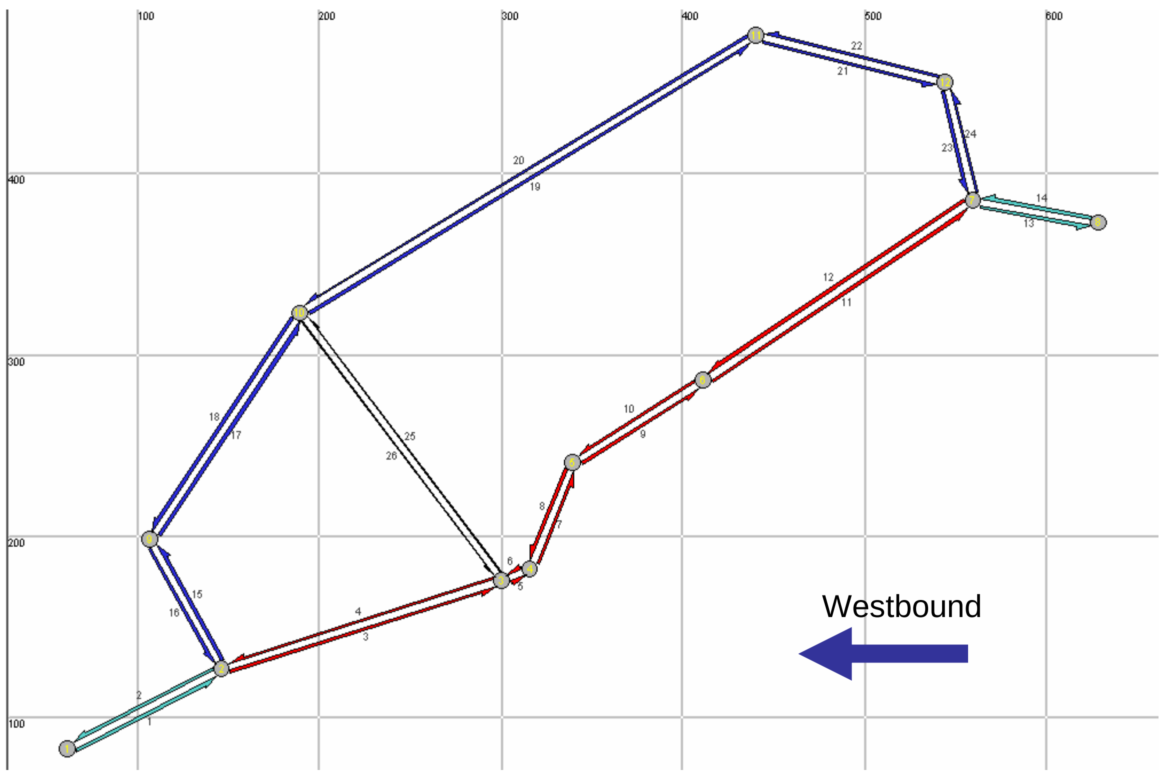

Figure 2.1.2 Knoxville, TN QuickZone Network

Given the potential disruption a full closure might have on the distribution of travel demand throughout the Knoxville area, TNDOT commissioned a traffic study to identify likely travel demand for I-640 given a full closure on I-40. Vehicle-matching technology was utilized to identify the current volume of through traffic traversing the length of I-40 in the Knoxville area in both eastbound and westbound directions. This characterization of current traffic patterns was combined with projected demand increases over the period 2004-2008 to arrive at average daily travel demand for I-640 given the full closure condition on I-40. QuickZone analysts utilized these average travel demand figures to determine likely hour-by-hour travel demand taking into consideration current prevailing distributions of travel demand on I-640 by time-of-day, day-of-week and month of the year (obtained from TNDOT permanent count stations as well as periodic count activities). These refined travel demand estimates were then applied with the detailed model of the I-640 diversion route in QuickZone to predict queue length and delay throughout the proposed full closure period.

2.1.3 Results

In the initial screening analysis performed with QuickZone, it became clear that I-640 would be unlikely to absorb a significant share of I-40 volume given expected 2008 travel demand conditions without serious congestion conditions developing during peak periods and on high-volume weekend conditions associated with the summer travel season. The predicted severity of congestion prompted TNDOT to consider a more detailed model of the I-640 detour route in QuickZone along with bringing into QuickZone the results of the more detailed I-40 closure traffic study completed in mid-2004.

The analysis of the more detailed detour model in QuickZone indicated that several key bottlenecks along the proposed diversion route would not support the combination of current travel demand and diverted travel demand from I-40. Queuing at these bottlenecks are predicted to generate significant congestion during morning and afternoon peak travel demand periods that would persist without dissipation in the mid-day period for most weekdays. In addition, heavy travel demand on the weekends in the summer would generate backups at some of the same bottlenecks with significant delays that would build and dissipate over a period of 6-8 hours.

Because of the severity and duration of the predicted delays, the QuickZone analysis was extended to consider the improvement of I-640 to reduce bottleneck effects at key intersections (like the one with I-275). Even with these improvements, it was clear that significant and potentially unacceptable delays would be likely unless travel demand management strategies could shift local and interstate road users away from weekday peak periods and summer weekend afternoons. Using QuickZone, the effectiveness of strategies aimed at reducing through truck travel as well as local and interstate passenger car values were analyzed. A range of target values for demand management were explored to realize some of the reductions in travel demand required to reduce delay to minimal levels. TNDOT is considering these targets as well as potential public outreach on the project as a result of the QuickZone analysis.

2.1.4 Contact Information

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2.2 Maryland/Virginia Woodrow Wilson Bridge: I-95

Key Observations

- **QuickZone can be used to estimate delay and queuing on large construction project with high volumes.**
- **Impact to the traveling public was reduced since total duration of the construction project was reduced from an estimated 6 months to 2 months.**
- **Creation of an efficient dialog between the construction contractor and the Woodrow Wilson Bridge management team.**

2.2.1 Overview

The replacement of the Woodrow Wilson Bridge, along Interstate 95 in the Metropolitan Washington, DC area, is an extremely large and complex construction project requiring the close coordination of numerous contractors and various state and local government agencies. The Woodrow Wilson Bridge carries upwards of 100,000 vehicles per day along Interstate 95 which spans the Potomac River. The current 6-lane bridge is being replaced with a dual-span bridge that will more than double the number of traffic lanes. The management of the construction project primarily involves the Maryland State Highway Administration (MD-SHA) and the Virginia Department of Transportation (VDOT) who are responsible for overseeing daily operations of the construction site including scheduled lane closures.

An important aspect to the replacement of the Woodrow Wilson Bridge is to maintain current roadway capacity during peak periods while construction takes place. This requires limited, if any, lane closures during peak periods and daylight hours. In general, any necessary lane closures were conducted at night to minimize the impact on drivers. In Fall 2001, a contractor for the Maryland State Highway Administration was in the process of constructing one of many new bridges as part of the replacement and refurbishment of the Woodrow Wilson Bridge at the MD 210/I-295/I-95 interchange just east of the Potomac River shoreline (see Figure 2.2.1 below). The construction involved the demolition of existing bridges and the construction of new bridges. The plan included closing lanes during the overnight hours (12:00pm to 4:00am) and two temporary openings in the median barrier in order to divert traffic safely around the construction area while construction was taking place. This work zone plan configuration was scheduled to take between 4 and 6 months to complete.

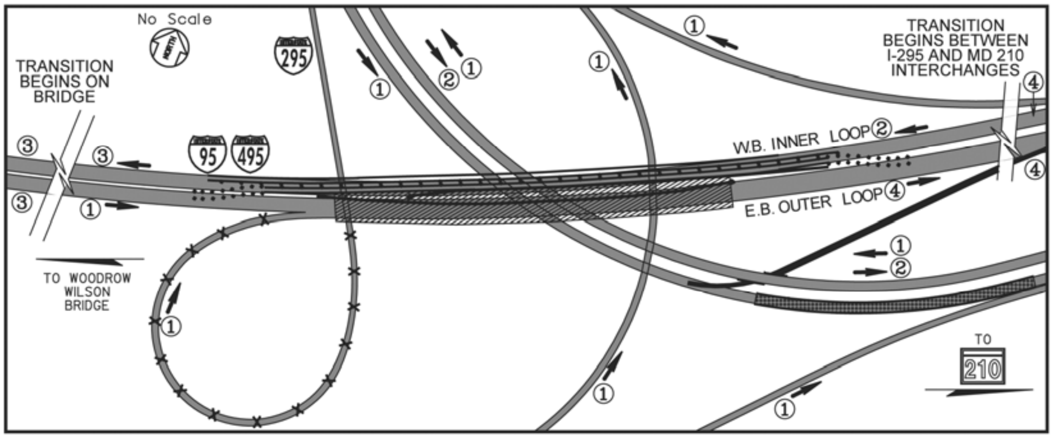

Figure 2.2.1 Woodrow Wilson Bridge Construction Diagram

The need for QuickZone arose when the contractor determined that to more efficiently utilize available resources, a four-hour window of construction would not be sufficient. The original work zone plan had lane closures occurring between 12:00pm and 4:00pm and the contractor estimated it would take 1.5 hours for work zone set up and take down, leaving 2.5 hours of actual production time. The contractor went to the Woodrow Wilson Bridge management team requesting more hours of production time to better utilize available resources. The request for more production time essentially meant that lane closure durations would have to increase. The request was sent to the Maryland State Highway Administration to analyze and make/provide feedback to the Woodrow Wilson Bridge management team.

The analysis required a quick analysis of multiple scenarios of when lane closures could take place without severely impacting motorists. The consultant chosen to conduct the analysis utilized MD-QuickZone for a number of reasons.

- QuickZone had the ability to analyze multiple scenarios very quickly.

- Maryland State Highway Administration had a customized version of QuickZone available that they were encouraging traffic engineers across to use for analyze work zone impacts.
- Results, namely delay and queue, were exactly the measures they needed to make a decision regarding the extension of the lane closure duration.

2.2.2 Network Design

The QuickZone network for the Woodrow Wilson Bridge was complex in design due to the complex nature of the roadway geometry. The location of the construction included multiple roads coming together to form a complex interchange. In order to account for the total demand on the roads, the Woodrow Wilson Bridge QuickZone network includes 35 nodes and 53 links. Many of the links were the individual entrance and exit ramps along with the primary travel lanes of the outer and inner loops of the capital beltway. The network is shown in figure 2.2.2 below.

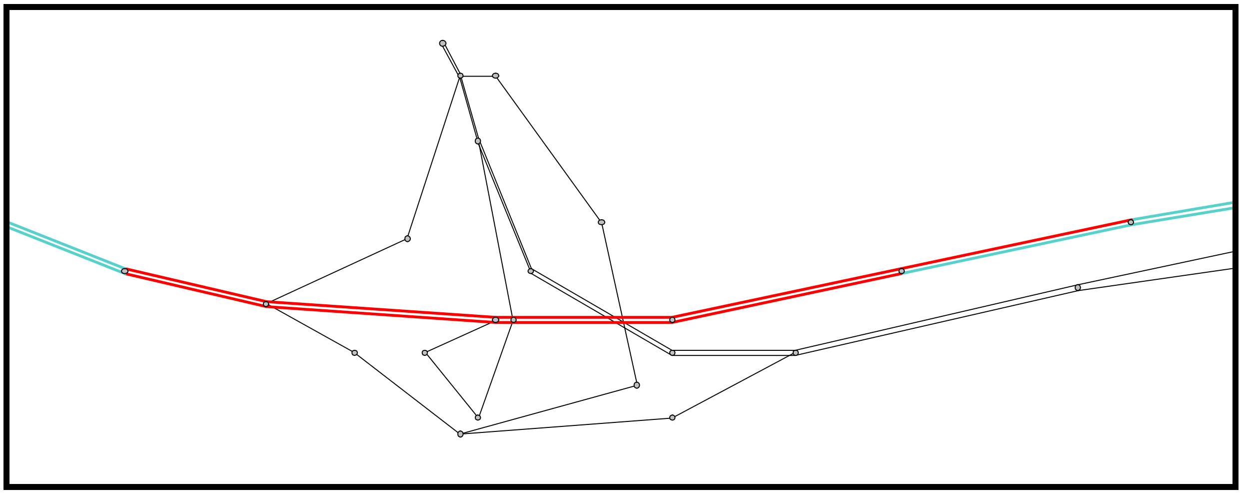

Figure 2.2.2 Woodrow Wilson Bridge QuickZone Network

Traffic volumes and demand data were available from both the Maryland State Highway Administration and the Virginia Department of Transportation. Demand data for the inner-loop was acquired from the various MD-SHA permanent traffic count stations set up prior to the construction site. The data is available to anyone interested via the Maryland Roads web site (www.marylandroads.com). Demand data for the outer-loop was made available through special traffic counts conducted by the VDOT on the Virginia approach to the Woodrow Wilson Bridge. Lane capacities, lengths, and free-flow speeds were gathered from historical data.

2.2.3 Results

The QuickZone analysis included multiple scenarios for extending the lane closure duration time and the number of lanes closed. These scenarios included beginning lane closures at 9 PM, 10 PM, 11 PM and 12 midnight and removing the work zone at 4 AM and 5 AM. The results of the analysis showed that there was very little impact to drivers if the lane closures began at 9 PM or 12 midnight and that opening all lanes up by 5 AM would be sufficient. These results were presented to the Woodrow Wilson Bridge management team, Federal Highway Administration and MD-SHA. As a result of this analysis, the contractor was given permission to begin lane closures at 9 PM and remove the lane closures by 5 AM.

At the time of the analysis, MD-QuickZone was a fairly new software program and had not been extensively used. An important aspect of trusting the results of QuickZone was to insure that the actual queue and delay that developed in the field were similar to the results generated by QuickZone. The Woodrow Wilson Bridge management team made the decision to monitor the queue and delay for the first week of construction. The results generated by QuickZone were very similar to those seen in the field.

The impact of the change in the work zone plan had very positive results. Overall, the impact to the traveling public was reduced since total duration of the construction project was reduced from an estimated 6 months to 2 months. The increase in production time to the contractor more than doubled (2.5 hours to 6 hours) resulting in better use of available resources and ultimately saving money on the overall construction project. Another important impact of using QuickZone was the creation of a dialog between the construction contractor and the Woodrow Wilson Bridge management team. The management team was in the position of weighing the interests of the construction contractor, who needed more production time, against that of the traveling public, who did not want unnecessary queuing and delay. QuickZone was a tool the management team could easily use to test out various work zone plan scenarios and determine the best compromise between the interests of the construction contractor and the public.

2.2.4 Contact Information

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Virginia Department of Transportation
SHA State Highway Administration
District Department of Transportation

3.0 Urban Arterial

3.1 Little Bras d'Or Bridge: Nova Scotia, Canada

Key Observations

- **QuickZone enabled the quick testing of a number of alternate phasing plans in order to balance the need for the construction with the political pressure to reduce the overall impact on motorists.**
- **QuickZone results helped to insure that a work zone with unacceptable delays was avoided.**
- **Queue lengths and delays estimated by QuickZone were consistent with field observations lending more credibility to the results of various alternate phasing plans.**

3.1.1 Overview

Nova Scotia is one of Canada's smaller provinces and is located on the east coast. The provincial population is just under 1 million. Cape Breton Island is on the north-east tip of Nova Scotia and is connected to the mainland by a man-made causeway. The main road through Nova Scotia is the Trans-Canada Highway that runs through Cape Breton Island and over to the port of North Sydney which provides the ferry link to the province of Newfoundland. The Trans-Canada Highway, along with the port of North Sydney, is the primary link for the movement of people and goods to and from that province.

Access to North Sydney from the Trans-Canada highway is only available via two bridges: the Great Bras d'Or and Little Bras d'Or bridges. The Little Bras d'Or bridge provides the only crossing over the Bras d'Or gut which connects Bras d'Or Lake with the Atlantic Ocean. Currents in the gut are very strong as the tides move in and out of an inland lake. In the spring of 2001 a major structural rehabilitation project was started on the Little Bras d'Or bridge which consists of 4 x 100' steel girder spans and was built in 1959.

The bridge carries a two lane, two way highway. It was necessary to close one lane to carry out repairs. Traffic flow was controlled by signals, and later during peak traffic flow hours by flaggers. As the project progressed into late spring, traffic volumes increased and motorists began to experience significant delays. Local residents, businesses, politicians and emergency services were very vocal about the delays which resulted. Political pressure forced the work to be rescheduled for November. In anticipation of the November bridge work, the provincial transportation engineer started to look for tools which would help him predict the impact of the proposed closure so that he could make objective decisions on when work could take place. He discovered the QuickZone V 0.99 beta software on the internet and realized the value it could have on testing various approaches to work zone staging for the Little Bras d'Or project.

3.1.2 Network Design

The network for the Little Bras d'Or bridge is simple in design and consists of six links and four nodes as shown in Figure 3.1.1. The only complication with the Little Bras d'Or network is the existence of two-way one lane operations which QuickZone V 0.99 Beta (and Version 1.0 as well) cannot explicitly handle. Only link 2 of the Little Bras d'Or network was designated as a work zone. Cleary, links 2 and 5 will both be affected by the construction. However, since QuickZone V 0.99 Beta is limited with analyzing flagging operations, each direction of traffic flow had to be analyzed separately. Therefore, only the inbound direction was analyzed since this had the highest demand and would result in the maximum queue and delay for the entire network. QuickZone 2.0 now includes features to directly analyze two way, one-lane operation.

Traffic data was made available through the Nova Scotia Department of Transportation. Hourly traffic volume data was obtained from the Department's Traffic Census Team. The traffic census data is not available on-line so specific requests were made to the Traffic Census Team for information on each site studied. Turn around time for data was usually within 24 hours. This data was only been available in "raw" counts, so some re-calculation was required in order to develop the necessary daily and hourly demand factors which QuickZone uses for its demand inputs. Seasonality factors were also available for each highway section from the Traffic Census Team. Most traffic data is unclassified so assumptions were made for percent of heavy vehicles.

A critical factor to provide accurate predictions is to accurately estimate the work zone capacity. While QuickZone does not directly estimate capacity loss due to a work zone (some guidelines based upon the Highway Capacity Manual are included), there is a fair amount of research available on multi-lane highways, but very little on two lane two-way highways under a full lane closure. Estimates of capacity loss were based upon observations made on various types of sites over the past few years.

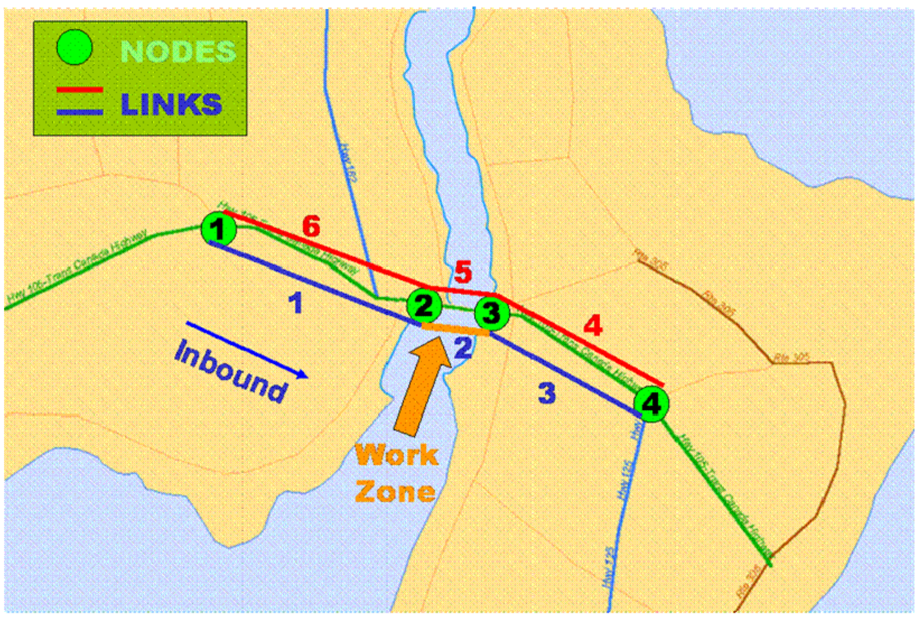

Figure 3.1.1 Little Bras d'Or Bridge QuickZone Network

3.1.3 Results

Due to political pressure, the initial construction project was stopped and basic repairs were made in order to keep the bridge safely open until a better solution could be found so as to not impact motorists as much. In 2004, the initial analysis performed at this site was updated for a milling and repaving project on the same section of highway. QuickZone was used to support the decision to do the work at night and also to define the nighttime work hours, which would have to be followed by the contractor. It is anticipated that the structural repairs started in 2001 will re-start and be finished in 2005.

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3.2 *Reeves Street: Nova Scotia, Canada*

Key Observations

- **Simple intersection analysis can be conducted with QuickZone to identify possible queuing and delay.**
- **QuickZone provided the analytical backup to effectively demonstrate the advantages of night-time construction.**
- **Queue length and delays predicted by QuickZone were consistent with field observations.**

3.2.1 Overview

Nova Scotia is one of Canada's Atlantic maritime provinces located on the east coast with a provincial population just under 1 million. Nova Scotia is composed of several islands and peninsulas with key commercial and population centers connected by the Trans Canada Highway. Port Hawkesbury is a key commercial location on Cape Breton Island just south of the Trans Canada Highway. The town of Port Hawkesbury includes a number of major industrial facilities representing companies such as Georgia-Pacific, Statia Terminals, USG, and the Sable Offshore Oil Company. The town also includes a number of residential communities.

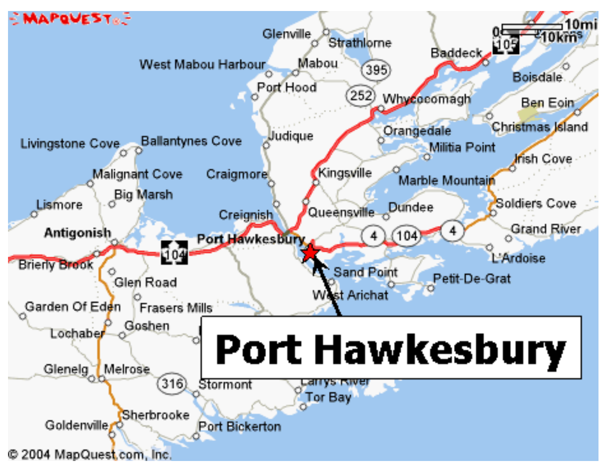

Figure 3.2.1 Port Hawkesbury, NS

In 2001, the intersection of Reeves Street and Trunk 4 in Port Hawkesbury, a location along a key access route to the Trans Canada Highway, was slated to be upgraded. Both Reeves Street and Trunk 4 are generally 2-lane highways with certain sections upgraded to include designated turn lanes in built-up areas. Average Annual Daily Traffic (AADT) was on the order of 8,000 vehicles per day with approximately 10% of those being trucks. Truck traffic is concentrated during the daytime on weekdays, while trucks make up fewer than 5% of traffic volume on weekends. Most of the traffic volume at this location in Port Hawkesbury is through traffic continuing on to some of the industrial centers near the town or to points further north.

The reconstruction involved a major upgrade of the intersection including additional dedicated turn lanes to accommodate higher traffic volumes and to improve safety. In order for construction to take place, overall capacity of the intersection would be reduced due to narrow lanes widths and periodic lane closures. Construction was slated to take place only during daylight hours because of cost and safety concerns. However, it was also evident that any construction taking place during the day would have an impact on motorists, since the Reeves Street/Trunk 4 intersection carries a large amount of traffic. Therefore, in order to reduce the impact to motorists as much as possible, QuickZone Version 1.0 was used to test various construction phasing alternatives, including analyzing the possibility of a detour route, and to also provide the necessary data to justify the additional expense of night work.

3.2.2 Network Design

The network for the signalized Reeves Street intersection is a fairly basic design and consists of 12 links and 6 nodes including a detour route as shown in figure 3.2.2 below. As shown in figure 3.2.3 below, Reeves Street ends at a “T” intersection with roads Trunk 4 and Trunk 4a. The left turning movement continues on to Trunk 4 and carries most of the traffic volume. The right turning movement continues on to Trunk 4a and terminates shortly thereafter in large industrial area. In order for QuickZone to analyze the intersection, only the left turning movement headed north-east and the right turn movement headed south-west were modeled. This can be considered a corridor unto itself with the capacity limited primarily by the left turning movement lanes and signal phasing. The detour route consisted of Sydney Road which cut through a mostly residential section.

Detailed traffic data was available for this intersection from a traffic study which was carried out in 2000. The demand data, along with the signal timing plans, helped to determine the capacity of the intersection. Thus, the capacities of the various turning movements helped to determine the capacity of each link. Capacities under work zone conditions were estimated by the engineer from prior experience with flagging operations. The capacity and demand along the detour route was measured during the peak periods and on weekends by hand.

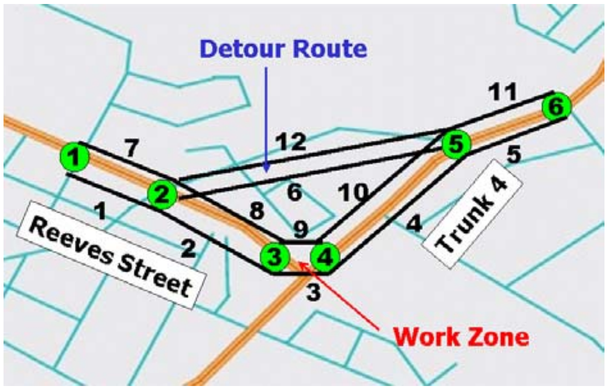

Figure 3.2.2 Reeves Street QuickZone Network

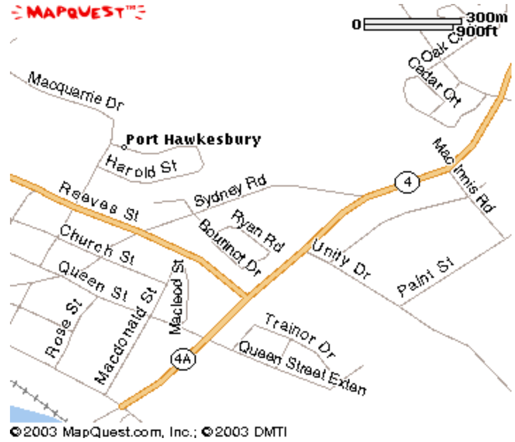

Figure 3.2.3 Reeves Street Intersection

3.2.3 Results

The local engineers suspected that the reconstruction of the Reeves Street intersection would result in significant queuing and delay and that doing the construction at night could potentially mitigate many of these impacts. Initial results from QuickZone proved these suspicions and showed an estimated maximum queue of 4.1 miles resulting in a 70 minute delay occurring on Friday evenings. Queuing and delay were also seen on Monday, Tuesday, Wednesday and Thursday but were approximately half the length and duration as seen on Friday evenings. Detour traffic was estimated at 10,000 vehicles per week. Knowing that the queuing, delay and detour volumes through the residential areas would be contentious issues with residents, the local engineers tested various construction phasing scenarios with QuickZone.

The first QuickZone analysis had the work zone in place and operating with reduced capacity 24 hours a day, 7 days a week. Queuing during the day on Friday and Saturday were predicted to be especially severe. The engineers noted that queuing and delay did not form during the overnight hours on any day and tested a scenario that eliminated construction during daylight hours on Friday and Saturday (essentially shifting work to night). The results of this scenario cut in half the queuing and delay associated with the construction to 2.19 miles and 36.4 minutes respectively. In addition, the number of weekly vehicles on the detour route was reduced to 6,000, a 40% reduction.

Additional refinements in the work zone design, including tweaking the hours and days of operation, enabled the engineers to better schedule the construction activities so as to not impact motorists. Also, the Nova Scotia Department of Transportation & Public Works did not have a night-time construction policy and did not routinely approve projects for night work due to cost and safety concerns. Because of the results generated by QuickZone, the decision was made to carry out some of the most disruptive phases of construction at the Reeves Street intersection at night.

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4.0 Rural High AADT

4.1 Yosemite National Park

Key Observations:

- **Complex geometric changes and traffic control by phase can be effectively modeled in QuickZone, including full closures and a variety of one-way and two-way traffic patterns on the same facility throughout the project.**
- **QuickZone helped to identify a feasible single-season construction schedule – reducing impacts to park visitors and reducing total project duration and costs.**
- **Development of an analytical traffic operations model early in the project life cycle motivates use and refinement in following project phases.**

4.1.1 Overview

Yosemite National Park in California is one of the most popular national park destinations in the nation, averaging more than 40,000 visitors through its entrance gates each day throughout the year. One of the primary entrance destinations for park visitors is Yosemite Village, the primary hub of activity within the park and home to the Valley Visitors Center, a wide variety of lodging and dining options, trail heads, and other visitor services.

The shape of Yosemite Valley (Figure 4.1.1) makes access to Yosemite Village scenic for the park visitor but quite limiting for a traffic manager. Given the steep terrain around the valley, the only roadways into and out of Yosemite Village are Northside and Southside Drives running along the Merced River which flows through the center of the valley. Both facilities are two-lane, one-way facilities with stop-controlled intersections along their length at two bridge crossings.

These two key valley roadways are scheduled for a significant repaving and rehabilitation project starting in 2006-2008. The Central Federal Lands Highway Division (CFLHD) of the FHWA is responsible for the planning, design and construction phases of the project, working in conjunction with the National Park Service to minimize impact on park visitors and the environment while cost-effectively conducting the needed roadwork.

Figure 4.1.1 Yosemite Case Study Area

Concern regarding significant delays in the construction phase led CFLHD staff and NPS personnel to consider a range of phasing and staging alternatives. This concern is nontrivial given current (no roadwork) traffic conditions, where weekend congestion and delays are already a recurring event during peak travel months.

One alternative considered was an alternating full closure plan where work on Southside Drive could be conducted quickly while all inbound/outbound traffic would be directed onto Northside Drive (temporarily configured to support 2-way traffic). In a second phase, Northside Drive would be closed and all traffic diverted onto Southside Drive. The advantage of this alternative was that the project could be completed faster (one season) and more efficiently at a lower cost. The disadvantage of such an approach was that capacity reductions from the roadwork had to be in place around the clock, and could not be timed to avoid weekly and daily peaks in travel demand.

A second alternative was to pursue project planning under a more traditional approach where one lane of each facility would be repaved while the other remained open to traffic. This approach would allow for work to be suspended during peak demand hours but would be less efficient to conduct, lengthening the project duration to two seasons and incurring additional costs.

The original role of QuickZone in the Yosemite project was to identify the likely travel delays expected under the two alternatives, allowing CFLHD and NPS staff to make an informed choice between the two, trading off road user delay against project cost. As the case study progressed, however, QuickZone became integral in the incremental refinement of a phasing and staging plan combining advantageous aspects of both alternatives.

4.1.2 Network Design

Network design for each alternative was different given the significant changes in geometry and traffic flow associated with the full closure components of the single-season alternative. The first alternative was coded using two networks (Figure 2). In the first phase, links representing Southside Drive are removed from the network and new links representing inbound operations on Northside Drive are added. The reverse is true for phase 2, where links representing Northside Drive are removed from the network and new links added to Southside Drive for outbound operations. These networks were run as separate files in QuickZone and results arecombined external to the model. The second alternative was coded using a single network for all project phases.

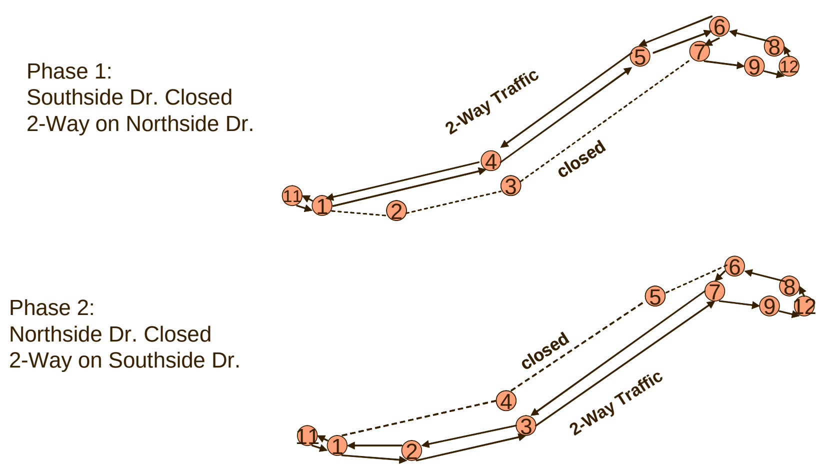

Figure 4.1.2 Yosemite QuickZone Network

Travel demand data were assembled from a number of sources and then refined through two short-term data collection activities. A first-cut distribution of hourly and daily travel demand factors were obtained from a 1998 traffic study. Monthly variations in travel demand were obtained from park entrance station data. Finally, two-short term (one two-week collection activity in June 2004 and one one-week collection activity in August 2004) were conducted to refine hourly and daily distributions and to establish a rate of travel demand growth from 1998-2004. Given that recurrent weekend congestion had worsened over the period, data were collected to identify when and by how much visitors had shifted departure or arrival times to avoid congested periods since 1998 (Figure 3). The supplementary data collection effort in 2004 was conducted using NuMetrics Hi-Star portable traffic counters, a commonley utilized technology within CFLHD.

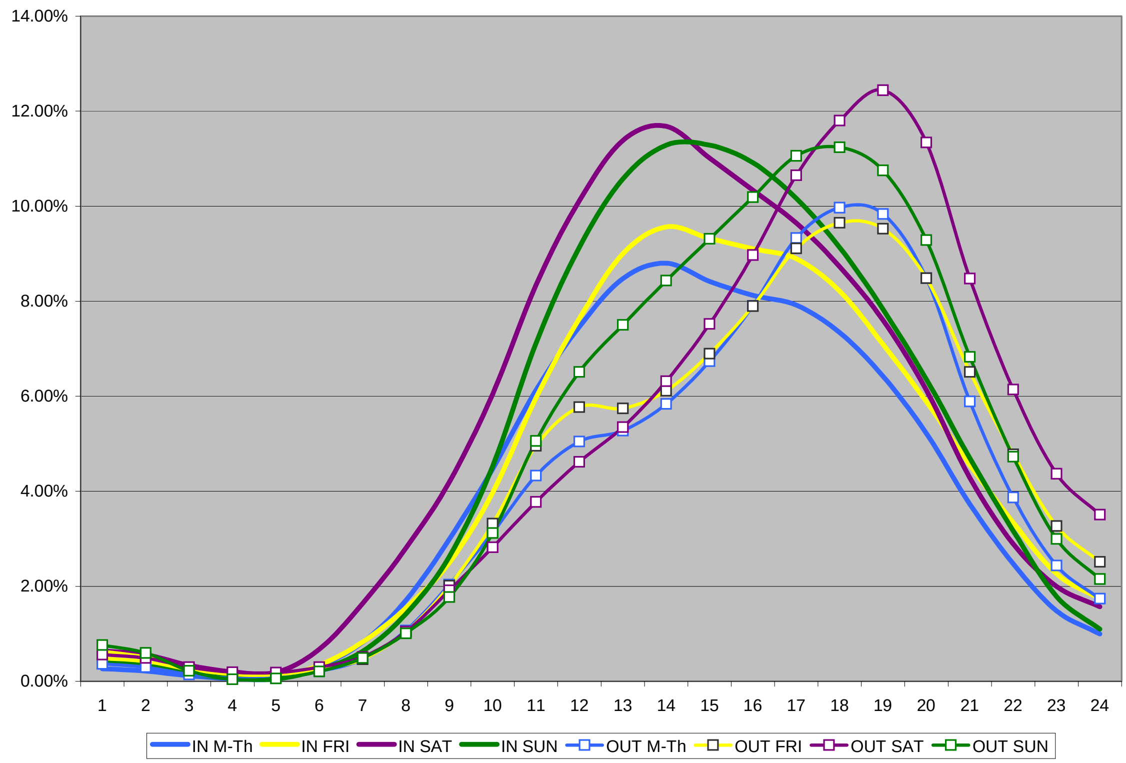

Figure 4.1.3 2004 Hourly Demand Pattern By Day of Week (from HI-STAR)

Traffic control operations modeled in QuickZone 1.0 included lane closures, flagger operations, and full closures. Capacity of flagger operations were estimated externally to the model and then input for affected links. The Yosemite case study was also used to test QuickZone Version 2.0, where the capacities of flagger operations are internally calculated.

4.1.3 Results

The single-season alternative, although cost-saving and shorter in total duration, was predicted to generate long and unacceptable delays for park visitors, particularly on weekend afternoons during summer months. The two-season alternative, when no-work hours had been refined by additional QuickZone analysis, produced no more than 10 minutes of additional visitor delay. The differential in road user delay between the single-season and two-season alternative was too large to justify the reduced cost of the single-season alternative.

In discussing the results, however, it became clear that the full-closure elements of the single-season alternative could be viable if the delay during the peak months of July, August and September could be avoided. In response, CFLHD staff developed a hybrid third alternative plan that combined full closure activity during relatively low-demand months (March-June, October-November), and traditional one-lane paving operations in the peak summer months.

This third alternative plan had the advantage of recouping most of the cost savings of the single-season approach with significantly lower travel delays. Delay was not eliminated, however. In June, outbound delays were predicted to approach 30 minutes for outbound traffic on Sunday afternoons. Likewise, in October, inbound delays on weekends could approach 60 minutes.

No final decision about the timing or phasing of the work has been made at this time (August 2004), since the project is still in development. However, the time and effort invested in data collection and QuickZone analysis have already had a marked impact in helping to shape the planned work to minimize impacts to park visitors while finding effective ways to reduce project duration and costs. CFLHD staff plan to continue utilizing the QuickZone model for the Yosemite case study throughout the project life cycle, including the actual construction phase.

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4.2 Zion National Park

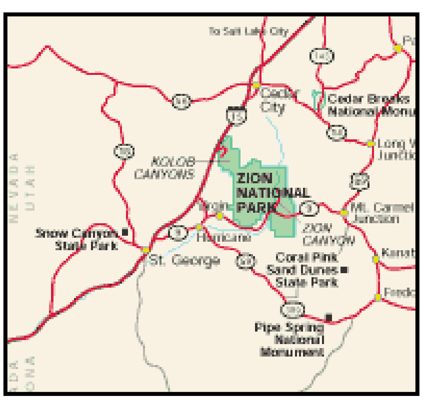
Key Observations

- **QuickZone can analyze queuing on roadways that include entrances booths/stations.**
- **The results of the QuickZone analysis provided quantitative estimates of impacts to both the park (reduction in entrance fees) and visitors (increase in delay).**
- **The results of the analysis motivated project staff to seek alternatives to the original traffic control plan.**

4.2.1 Overview

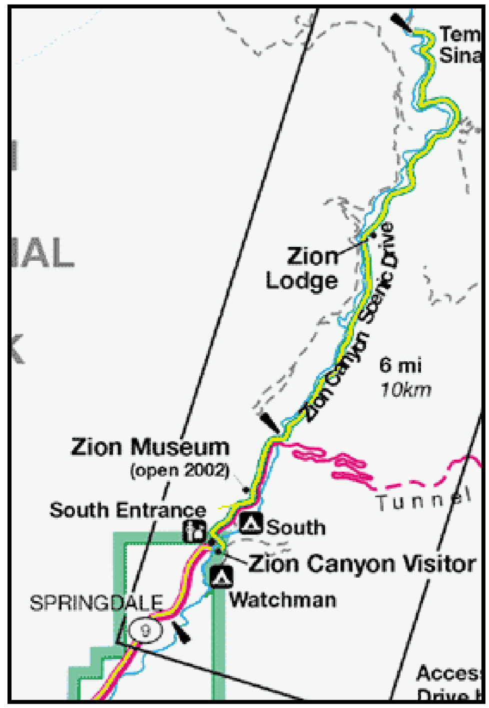
Designated a National Park in 1919, Zion National Park is Utah's oldest national park. Zion canyon features soaring towers and monoliths that suggest a quiet grandeur. Zion is also known for its incredible slot canyons, including "The Narrows," which attract hikers from around the world. With nearly three million visitors per year, Zion is Utah's most popular National park. Entrance fees are $20 per vehicle and $10 per person arriving on foot.

There are two major entrances two Zion National Park, a south and an east entrance. A third entrance, located on the west side of the park, provides access only to Zion's Kolob Canyon. The South Entrance is the larger and most frequently-used of the three entrances. The South Entrance is on Utah Route 9 about 60 miles south from Cedar City, via I-15 and Utah Route 17. The East Entrance is on Utah Route 9, 12 miles east of Mt. Carmel Junction, at U.S. Route 89. The park contains over 12 miles of road. To ease traffic congestion within the park, a shuttle system is available to take visitors to the most popular areas. A shuttle bus service is also available from the town of Springdale, just outside of the park. Shuttles operate from April through October; during that period private automobiles are not allowed on the 6.5 mile stretch of road in Zion Canyon. The shuttles provide the only access to marquee



attractions like the Great White Throne, the Watchman, the Grotto, Angels Landing, Weeping Rock and the Temple of Sinawava. Automobiles are allowed on other park roads, including all of Hwy 9, which provides access to the lower part of the park, the Tunnel and the East Entrance/Checkerboard Mesa area.

Currently, approximately 90% of park visitors utilize the south visitors entrance. The entrance includes 2 visitor lanes and 1 employee lane, controlled by an radio-frequency tag system. Employees are able to process approximately 240 visitor vehicles an hour of which 50% are cash transactions, 40% credit card and 10% National Park Pass. 75% of the vehicles entering the park are passenger cars/trucks and 25% are RVs. During the peak season, recurring queue can extend as much as ¼ mile from the entrance.



In 2004, a major rehabilitation of the main road through Zion, beginning at the south visitors entrance and extending into Zion Canyon was scheduled to take place. This includes widening and structural repairs of certain sections of the existing road and milling/paving of the entire 7 mile stretch. A major concern of the National Park Service was the impact to visitors coming to Zion National Park through the town of Springdale. Traffic congestion on roads inside the park was not a concern since visitors are required to use the free shuttle bus service.

Significant queuing and delay at the south visitors entrance, where recurrent queues were already present, was of major concern to park administrators. The original work zone plan called for shutting down one visitor entrance lane at a time for construction. The National Park Service did not want construction to cause a queue to form that extended into the town of Springdale, approximately 1/2 mile from the south visitors entrance. A queue of this length would not only impact traffic in the town, but employees getting to the park and the operation of the shuttle bus service from the town to the park. QuickZone was primarily used to estimate the length of queue and number of vehicles in queue if one of the two visitor entrance lanes were to be closed for construction. This was conducted for the peak tourist months of June, July, August, September and October.

4.2.2 Network Design

The Zion National Park QuickZone network is simple in design and includes 4 nodes and 6 links. Only the south visitors entrance was modeled since there was no concern about queuing or delay along the seven mile stretch of road within the park. The network is shown in figure 4.2.1 below. The work zone link (the middle of the three links) is the visitors entrance area which consists of four lanes: one exit lane, two visitor entrance lanes and one employee entrance lane. The far left line is Utah Route 9 which terminates at the town of Springdale. The far right line is inside the park. Queues will form to the left of the work zone link as the capacity is reduced due to construction.

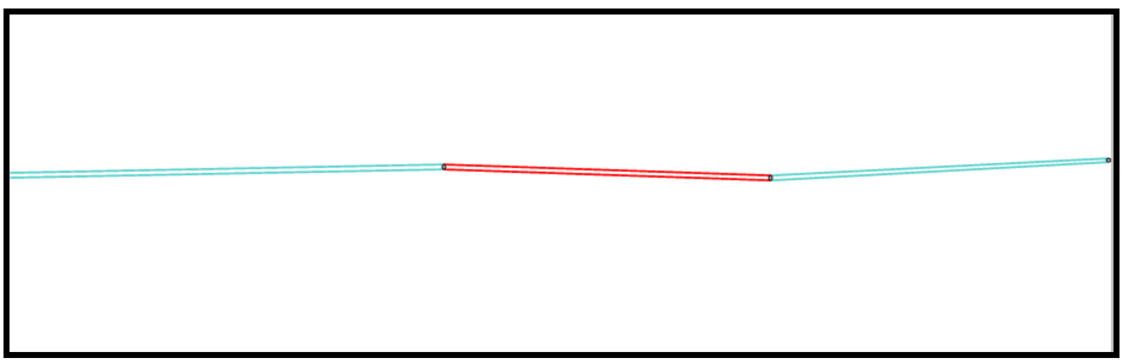


Figure 4.2.1 Zion National Park QuickZone Network

The network was created using the QuickZone Network Editor and a paper map. The capacity of the south visitors entrance (or the number of vehicles that can be processed in an hour) was calculated using average transaction time per vehicle and a breakdown of average transaction types per day. It was also

calibrated against historical queuing data to arrive at an overall facility capacity. Hourly counts were generated from a simple traffic study conducted in April for an average day both during the week and on the weekend. Seasonality was taken into account by using April as a baseline point and scaling up demand based upon historical knowledge for the months of June, July, August, September and October.

Construction at the south visitors entrance was just one component of the overall construction project and was estimated to take between two to three weeks. QuickZone was being used to estimate the impact if construction were to occur during the months of June, July, August, September or October and to determine which month would cause the least amount of impact. To conduct this type of analysis, the QuickZone network was setup to analyze the months of June, July, August, September and October separately. This resulted in five individual work zone plans with the only difference being the start and end date.

4.2.3 Results

The roadway construction at Zion National Park was planned to only occur Monday through Friday and during daylight hours. This was done to avoid impacting the larger crowds visiting on the weekends and disturbing those visitors camping during the evening and overnight hours. As a result, the QuickZone analysis focused upon the weekdays. Baseline queuing was calibrated against actual demand seen in the field during the month of April. Once the calibration was complete, the QuickZone model was run where capacity of the south visitors entrance was reduced by 50%.

The results of the QuickZone analysis indicate that the queue will impact the town of Springdale in each of the five months analyzed:

- June: .58 mile queue, 463 vehicles in queue
- July: .66 mile queue, 513 vehicles in queue
- August: .66 mile queue, 513 vehicles in queue
- September: .58 mile queue, 461 vehicles in queue
- October: .45 mile queue, 361 vehicles in queue

The order of magnitude for delay was around 300 minutes or 5 hours with the queue beginning to form around 9 AM, peaking at 3 PM and dissipating by 9 PM. Clearly, people will not wait 5 hours to get into the park. The key data point for this analysis was the estimated number of vehicles in queue and whether that queue will impact the town of Springdale.

Results of the Zion QuickZone analysis have given CFLHD engineers the necessary data to reevaluate the construction phasing. After seeing the results in QuickZone, CFLHD engineers knew that the current construction phasing could not take place as originally designed and began to brainstorm on various alternatives including opening up temporary entrance booths and shifting construction to the early evening hours to not coincide with the peak demand. Currently, CFLHD engineers are continuing to discuss possible alternate construction phasing with park rangers. As these new ideas are developed, CFLHD engineers will analyze them in QuickZone to determine which will have the least impact on park visitors and employees.

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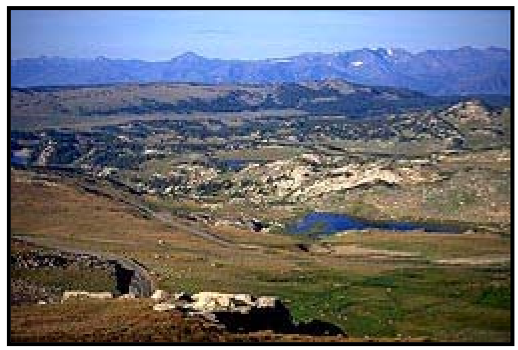
5.0 Rural Low AADT

5.1 Beartooth Highway

Key Observations

- **CFLHD used QuickZone's capabilities to help inform the local community of possible future delays through a series of concurrent flagging operations.**
- **CFLHD was able to see that no one flagging operation would cause major delay problems but the combination of all four did produce potentially unacceptable delay.**
- **CFLHD was able to quickly evaluate a series of work zones and their interactions with each other without having to use more complex simulation models.**

5.1.1 Overview



Beartooth highway, or US-212, begins in the northeast entrance of Yellowstone Park and continues along the Montana-Wyoming state border. This 64 mile highway is known for its spectacular views of many different ecosystems including lush forest and alpine tundra. The Beartooth Mountains, for which the highway is named, boast one of the highest elevations and most rugged regions in the county.

In addition to the traditional use for automobile travel, the highway is also used for cross-country skiing, hiking to view the wildlife and views, guided horseback riding tours, and snowmobiling in the off season when the road is closed to automobiles. Other attractions for the highway include fishing in the adjacent steams and lakes, and camping in the twelve National Forest campgrounds located along the highway. Beartooth Highway is unique compared to the other case studies in that the road itself is the destination rather than the road leading a destination or point of interest.

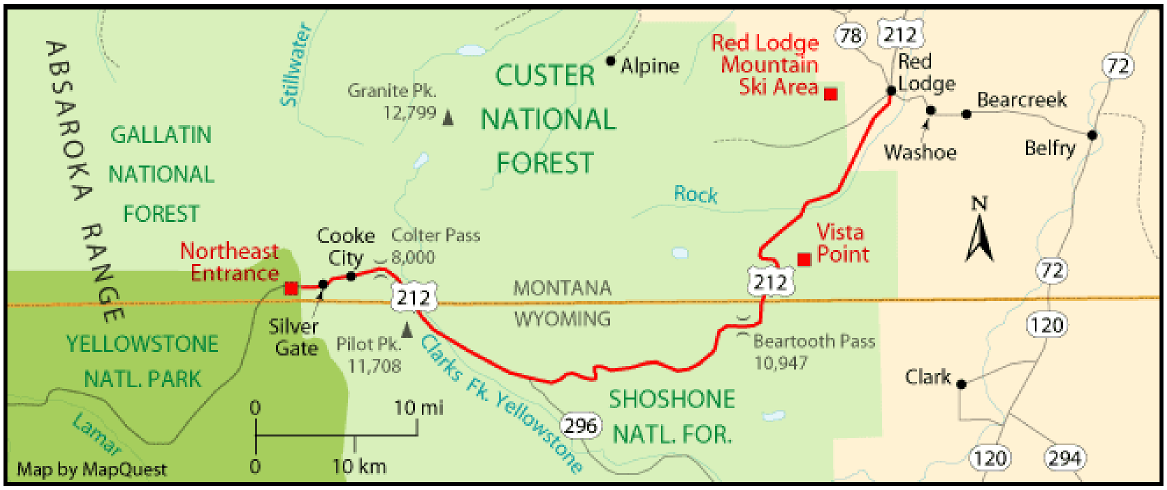


Figure 5.1.1 Beartooth Highway Location

FHWA CFLHD has been working with the US Forest Service and the Yellowstone Park Service to reconstruct an 18.6 mile section of the Beartooth Highway. This section has not been rebuilt since the original construction in 1936. The highway can no longer support the types of vehicles driving on it today nor the increased volumes anticipated in future years. The reconstruction project will consist of upgrading the current roadway with improvements to the alignment, grade, and width of the road to meet current FHWA guidelines. The two following pictures show the extent of the construction with the left hand picture showing the current condition of the highway and right hand picture showing the new proposed construction.

Current Highway

Proposed Highway

The construction season for the Beartooth Highway is very limited because the highway is closed from October – March each year due to heavy snowfall. CFLHD is concerned that this type of construction, on this generally peaceful 2-lane highway, would cause major delays for the local public and vacationers so they decided to use the FHWA's QuickZone software.

The QuickZone software was used to evaluate a series of four different flagging operations near the Beartooth Ravine which is part of the proposed 18.6 mile section. QuickZone allowed CFLHD to account for delays on each work zone and also delays incurred by all work zones in conjunction with each other. QuickZone could also handle the detailed seasonality demand information. Some of the key information CFLHD was seeking to gather from the QuickZone Software was the delay during under saturated and saturated conditions and queue information for all of the work zones.

5.1.2 Network Design

The network for the Beartooth project was designed using the QuickZone network editor. A copy of the whole 18.6 mile construction layout was scanned in from the environmental impact statement created for the Beartooth Project and was imposed into the QuickZone network editor. With the construction layout in the QuickZone network editor, software nodes and links were quickly added to create the new QuickZone network.

The design of the Beartooth network is very simplistic with no exits, detours, or complex intersections. All of the 18.6 mile highway section was created for QuickZone with work zone links added only around the section that contained the Beartooth Ravine. This allowed for future QuickZone studies to be conducted along the section without having to recreate a network. Below is a close up picture showing the Beartooth Ravine section of the QuickZone Network:

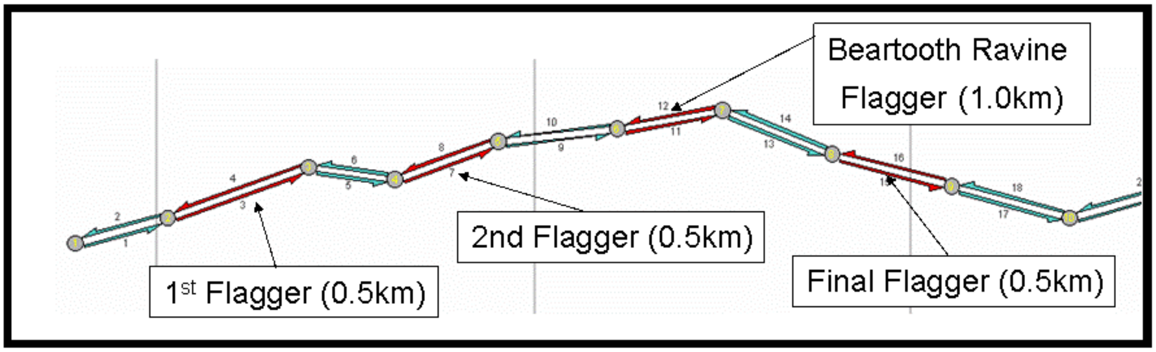


Figure 5.1.2 Beartooth Highway QuickZone Network

Each of the four flagging operations were added as work zones with 1 kilometer distances between each work zone which was based on the project engineer estimates. All flagging operations were 0.5 kilometers in length except for the Beartooth Ravine flagging operation that had a length of 1.0 kilometer.

5.1.3 Results

The first results returned from QuickZone for the four flagging operations produced substantial amounts of saturated delay caused by the switchover time of the flagging operations. A switchover time of 5 minutes was used to start, based on more urban flagging operations. Upon further investigation of the project it was determined that CFLHD can have switchover times as high as 15 minutes because of the low volumes and long flagging operations. With this new higher switchover value we found that the four work zones only produced unsaturated delay from the flagging operations. Using QuickZone's fast calculation time a trial and error method was used to determine the optimal switchover time for the flagging operations that would not produce any saturated delay and a value of 7 minutes was found.

Using a switchover time of 7 minutes and the same speed throughout all of the work zones, QuickZone produced identical results for all work zones except the Beartooth Ravine flagging operation. These results are the same because the demand, switchover time, speed, and work zone length are the same for all 3 work zones. However, the values on the Beartooth Ravine were higher which was caused by the longer work zone length. Below are the values produced for each of the work zones.

Beartooth Delays in the Inbound and Outbound Direction

Work Zone	Max User Delay (Minutes)	Average User Delay (Minutes)	Max Queue (vehicles)	Average Queue (vehicles)
1st,2nd, and Final	3.0	2.8	3	1.4
Beartooth Ravine	5.7	5.3	6	2.3

Each work zone produces marginal delays but by combining all the work zones together we get a maximum user delay of 14.7 minutes and 15 vehicles in queue in the inbound and outbound directions. This maximum delay occurs on Sunday between the hours of 1:00PM – 2:00PM during July which matches up with the high demand on the weekends and seasonality values in July.

The average delay of 13.7 minutes, with 6 to 7 vehicles in queue, may cause concern among the local public and businesses who are used to free flow conditions. CFLHD is considering these concerns and may run the work zones only during the week to avoid the high weekend demand, reduce the length of the work zones where possible, or run an effective media campaign to inform the local public and businesses of the delays.

5.1.4 Contact Information

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5.2 Louis Lake Road

Key Observations

- **QuickZone can identify a range of user cost including motorist delay and vehicle operating costs.**
- **Potentially problematic public relations around work zones can be effectively mitigated when quantified estimates of delay are presented.**
- **QuickZone is suitable for assessing impacts in projects with a mix of traffic control strategies including flaggers, periodic full closures, and detour projects.**

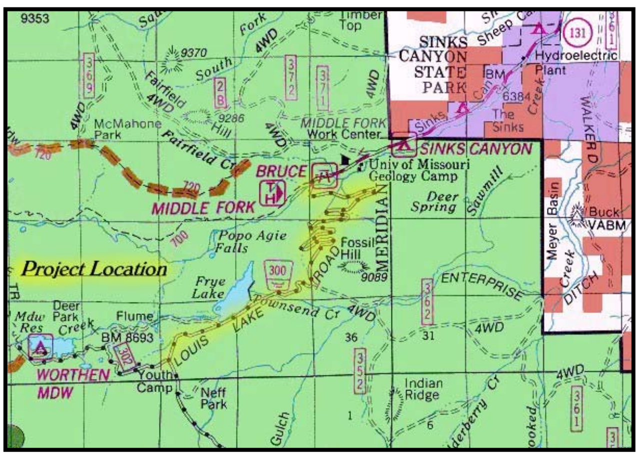
5.2.1 Overview

Wyoming Forest Highway 23 (WY FH 23) / Louis Lake Road is located in Fremont County, Wyoming, and links the town of Lander, Wyoming, and the Shoshone National Forest. It is a narrow gravel road with turnouts to better facilitate two vehicles passing at once. The current road design is unsafe and inadequate for expected traffic volume increase as more visitors are drawn to the area.

Louis Lake Road provides direct roadside access to an abundance of recreational opportunities, including driving for pleasure, viewing scenery and wildlife, camping, picnicking, lake and stream fishing, hunting, hiking, nature trails, backpacking, rock climbing, cross-country biking, snowmobiling, and cross-country skiing. There are areas of historic significance, including the CCC-constructed facilities, mining sites, and Blue Ridge Historic Lookout. WY FH 23 contributes to the economies of Fremont County and Lander, Wyoming, as it is the primary local access from Lander to the Forest. Increasing interest in the recreational opportunities provided along WY FH 23 indicates a potential for local economic growth in the form of lodging, restaurants, outfitters, and other recreational related businesses and services.

Louis Lake Road also provides access to non-recreational resources of the Forest, which contribute to the local economy. These resources include a managed timber harvest program, pole fencing materials harvest, commercial and residential firewood harvest, community watershed management, and livestock management.

CFLHD administers the surveying, designing and constructing of forest highway system roads, parkways and park roads, bridges, and other Federal Lands roads. CFLHD was interested in using QuickZone for this project primarily because of the public's concern over the economic impacts on the area during construction. Because the road is such a vital link to the Forest, residents of Lander in particular were concerned that real and perceived construction delays would deter vacationers and local businesses would lose revenue. QuickZone was needed to assure the public that the construction schedule chosen was the best of the available options. Further, it allowed CFLHD to give travelers an idea of what delays to expect at different times to help them better plan their trips.



This was primarily a flagger application of QuickZone, a new feature available in Version 2.0 as well as CFLHD-QuickZone. Being a rural area, the traffic volumes were low and saturated delays were not a concern. The primary means of traffic control were flaggers when the narrow two-lane road was reduced to one-lane, two-way operation, and full closures during rock blasting and other dangerous operations. When full closures do take place, a detour route is available. The diversion point is at the town of Lander which is 15 km from the work zone area. QuickZone estimated the delay a traveler would face at flagging operations of different lengths and capacities, as well as the amount of traffic that might have to take the detour during road closures.

The primary traffic control decisions faced by CFLHD regarding construction phasing were:

- At what times of day and day of the week can the road be closed while minimizing the impact to the traveling public?
- What maximum delay stipulations can reasonably be imposed on the construction contractors?

The construction specification drawn up by CFLHD gives specific allowances for the frequency and times of day the road can be closed and the maximum allowable delay for a traveler traversing the project area. In order to balance the needs of the public with the needs of the contractor, QuickZone was needed to determine reasonable restrictions on construction activity to keep the project on time while still allowing reasonable access to travelers.

5.2.2 Network Design

The project area was 11.5 kilometers in length and was broken down into six work zones as shown in the figure below. The type of work required in each of these areas varied and included blasting rock and building retaining walls, upgrading switchbacks, building culverts, and realigning. Since work at different work zones overlapped, QuickZone was needed to estimate delays at each flagging operation to know whether a traveler could face a proposed series of flaggers and still not exceed the maximum allowable delay. Not only was this important to derive the initial specification, but for CFLHD to intelligently respond to modification requests from the contractor as well.

The network design was straightforward, and included the six work zone links through the project area and a detour which added approximately 50 kilometers to a trip. Since the existing road was narrow and gravel, the capacity was assumed to be a low 600 vehicles per hour. Demand data came from 1997 traffic counts, projected to 2003 at an assumed 2.5% growth rate per year, drawn from the environmental impact statement. Monthly average daily traffic figures ranged from a low of 157 in October to a high of 421 in July. The road would close in October and reopen in May. Required QuickZone data included how traffic volume varied by time of day and day of the week. Since this level of detail was not available for this project, distributions from the Beartooth Highway project were used since the demand characteristics—primarily recreational travel—were sufficiently similar.

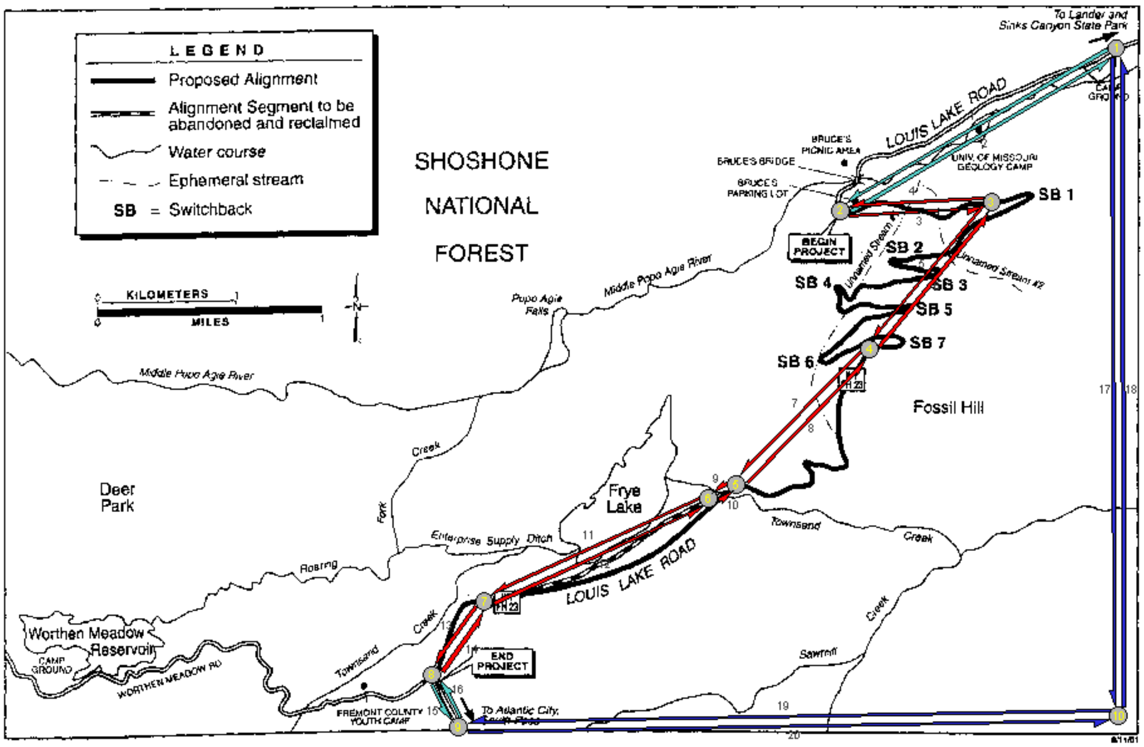


Figure 5.2.1 Louis Lake Road QuickZone Network

5.2.3 Results

Due to the low volumes in the project area, the only delays were caused by the flagger operations. The delays to be expected at a flagger zone are affected by its length because the entire length has to be cleared in one direction before the other direction can be allowed to proceed. At the time of highest demand, at 2pm on Saturdays in July, the demand on Louis Lake Road is 57 vehicles per hour. For a work zone of 3 km and with a clearance time of 13.4 minutes, the maximum user delay is 27.5 minutes. That is, the delay experienced by the vehicle that arrives just as his direction is halted. He would have to wait for the vehicle ahead of him to clear the work zone and wait for the traffic in the other direction to proceed and clear. As the construction specification stipulates that the longest a traveler may be delayed through one work zone is 30 minutes, the longest work zone may be 3 km. if there is only a single work zone in place at a time. If multiple work zones are in place at the same time, each one would clearly have to be shorter. QuickZone can determine the maximum user delays for any combination of multiple work zones.

A major concern of both CFLHD and local residents was the economic impact of the construction. In order to address this issue, CFLHD-QuickZone includes a robust economic impact analysis module, which can estimate the amount of revenue lost by reduced travel, the additional cost to freight traffic, the cost of lost time by delayed travelers, and the additional vehicle operating costs from the additional miles traveled on the detour. The economic analysis will be used by CFLHD to help determine when flagging operations and full closures will be allowed and to assure the public that delay costs and economic impacts to the town of Lander were considered in construction plans.

Currently, CFLHD is in the process of refining the current Louis Lake Road model to determine the effects of potential construction phasing plans. The QuickZone results could be used by CFLHD to adjust their construction specification to either relax or tighten the limits set on the contractor. Further, they could be used to evaluate modification requests to the specification by the contractor. With regard to full closures, simply based on the time of day and day of week demand data, CFLHD could determine how many vehicles would be affected by full closures at all times of day for each day of the week. By setting a cap on the number of vehicles that could be turned back or detoured, CFLHD could control the impact to road users and intelligently direct the construction contractor to when the road may or may not be closed.

5.2.4 Contact Information

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6.0 Other Applications

6.1 Pennsylvania I-80

In the Summer of 2002, motorists on Interstate 80 in Clarion County, Pennsylvania experienced significant delays and frustrations caused by traffic back-ups in highway work zones. As a result, some complaints and concerns were conveyed to PENNDOT. Expecting similar public reaction regarding future construction activities, PENNDOT looked for tools and methods to eliminate these complaints and concerns. In Summer 2003, before beginning a resurfacing project on Interstate 80 in Butler and Clarion counties, PennDOT District 10 used QuickZone to create highway work zones that minimize impacts on the traveling public.

Applying QuickZone to the I-80 project, PENNDOT engineers were able to select work zone configurations and construction schedules that met project needs while minimizing impacts to the traveling public. Based on the reduced number of complaints and the length of time motorists have been delayed in the work zone, PENNDOT feels the effort was successful. "We are very pleased with the results of QuickZone modeling," said Richard H. Hogg, P.E., District Executive. "Based on what we saw occur on the Interstate last year compared to this year, the improvements for our customers, the traveling public, are significant."

6.2 Virginia Calibration Sites

Two construction sites in Northern Virginia were chosen to validate and verify the results of QuickZone 1.0. In August and September 2001, detailed data collection was conducted at a site in Purcelville, VA and McLean, VA. The sites are located approximately 60 and 10 miles, respectively, west of Washington, DC. The construction for both sites was similar and included two-way one lane operations on a bridge where the bridge deck was being replaced. Both sites include the use of a temporary traffic control signal that include a fixed signal timing plan that changed by time-of-day.

Data collection was conducted over a two week period at both sites and included volume counts, travel time and incident logs. For each site a QuickZone network was developed and all necessary data was entered. The results that were generated by QuickZone were reflected in the field in terms of queue and delay. The Purcelville site saw no queue or delay during the baseline conditions (no construction) and slight queueing, less than .10 miles, during construction. The delay was under 5 minutes. The McLean site saw a larger queue, .25 miles, with delay also being less than 5 minutes.

6.3 ITS Technology Assessment

At the 2004 TRB Annual Meeting, Rob Bushman (Rob.Bushman@usask.ca) presented a paper entitled "*Estimating The Benefits Of Deploying Intelligent Transportation Systems In Work Zones*" where QuickZone was used to help estimate the benefits of deploying ITS in work zones. An evaluation was made of the expected benefits of the application of ITS technology to a construction project on I-95 in North Carolina. QuickZone was used to model two situations, a base case without the use of a traffic management system and the alternate case of a traffic management system applied. Estimations were also made of the expected reduction in emissions and the expected reduction in injuries and fatalities. The analysis demonstrated the application of analysis methods that can be applied generally to work zone ITS projects of this type and a favorable benefit/cost ratio expected for the specific project studied. User delay has the potential to provide significant benefits in relation to costs and other benefits, and therefore should be one of the initial decision making criteria. A user delay graph was presented which estimates the amount of delay based on traffic volume and composition.

6.4 Other Nova Scotia Projects

In addition to the two case studies presented in this document, QuickZone has been widely used throughout the Nova Scotia Province. Two other examples include:

- **Highway 125 – Re-paving Projects**
  QuickZone was used to make the case for night work and to define working hours on two projects on Highway 125, which is the main arterial highway for the city of Sydney and surrounding communities.
- **Highway 104 – Canso Causeway – Repaving, Bridge Repair and Rotary Upgrade**
  QuickZone was used to make the case for night work and to define working hours on three projects at the Canso Causeway, which connects Cape Breton Island with the mainland.

7.0 Summary

The QuickZone case study document is intended to provide potential users with an introduction to the use of QuickZone and different examples of how it has already been used in the field by planners and engineers. Clearly, the utilization of QuickZone is not relegated to just one type of roadway facility or location and the case studies presented in this document highlight this. QuickZone can be used for multiple applications including:

- **Rural or Urban—**Four of the projects were rural applications and four were urban applications. The Beartooth Highway project highlights the need for work zone analysis even on roads with little to no demand while the Woodrow Wilson Bridge demonstrated the effectiveness of using QuickZone on high demand projects.
- **Big Projects/Small Projects**—The Woodrow Wilson Bridge project shows that QuickZone can be effectively used for large projects to establish a dialog among stakeholders to create a win-win situation. The Zion project, though a fraction of the size, had the same results.
- **Operations and Planning—**Three of the eight projects were used for operations while five were used for planning purposes. The Knoxville, TN project is one of the planning projects where the results have had a clear impact on the direction of the project and prompted state personnel to consider a more detailed analysis of the proposed detour route.
- **Freeway and Arterial—**Two of the eight projects were classified as freeway and two as arterial. With regards to the Reeves Street project, without the results of QuickZone, the decision to perform construction at night could not have been made and the impact to motorists would have been more severe. In addition, the use of QuickZone helped Nova Scotia DOT avoid public outcry and complaints as was seen in the Little Bras d'Or project.
- **Single Work Zones to Projects with Multiple, Interacting Work Zones—**All of the projects included at least one work zone while some had five or more interacting work zones.. The Beartooth Highway, in particular, demonstrated the need for QuickZone to analyze multiple work zones that impact each other.
- **Full and Partial Lane Closures, Flagging Operations, Periodic Full Closure—** Modeling each of these traffic control elements was necessary in QuickZone. The Little Bras d'Or Bridge project highlighted the need for more direct analysis of

flagging operations, in QuickZone Version 0.99 Beta, a feature incorporated into Version 2.0 and CFLHD-QuickZone

- **Projects with Good Detour Routes—**Two of the projects included detours. The Knoxville, TN project showed the need for the QuickZone user to fully analyze and understand a proposed detour route; while the Louis Lake Road project demonstrated the need of QuickZone to take into account detour travel times and additional travel distances.
- **Projects with No Detour Routes—**Most of the projects did not include detour routes. While there are no detour routes through Yosemite National Park, the project did demonstrate the effectiveness of QuickZone in its ability to test various construction scenarios to determine which construction phasing plan is best.

In 2003, an update to QuickZone 1.0 began based upon the needs and concerns of current QuickZone users, some of which were documented in the case study analysis. The development of QuickZone 2.0 has been a direct result of the needs and feedback generated by previous versions of QuickZone and the partnership program. The feedback from QuickZone users included three major requests for enhancements. The first concern was generating and inputting networks into QuickZone. Version 1.0 did not include a network editing program and all networks had to be developed using pen-and-paper or Microsoft PowerPoint and then carefully entered into QuickZone. This was a time consuming and tedious task that was seen as a barrier to the success of QuickZone. To solve this problem, the network editor for the TSIS simulation program was adapted for use in QuickZone. The QuickZone Network Editor now provides an easy-to-use graphical user interface to easily create and modify QuickZone networks.

The second most frequent request of QuickZone users was the modeling of two way one-lane operations, including flagging operations. Version 1.0 did not include a direct method to analyze these types of work zones. In response, Version 2.0 has been enhanced to calculate capacities and directly model various types of two way one-lane operations including signal controlled (both fixed and optimized) and flagging operations.

The third requested enhancement of QuickZone users was improved user cost estimation. Version 1.0 has a simple cost estimator based upon a delay cost per hour for passenger cars and trucks. CFLHD, in particular, saw a need for QuickZone but wanted a more robust method to analyze the user cost. Therefore, a major focus area for CHLHD-QuickZone was a detailed analysis of user cost estimation and the development of a more detailed user cost estimation module for QuickZone. The efforts applied to CFLHD-QuickZone will be incorporated into Version 2.0.

In addition to these three improvements, other features included in QuickZone 2.0 are:

- MDSHA's work zone capacity estimator;
- Ability to model more complex work zone configurations;
- Improved data entry including a re-designed work zone project information interface and the ability to copy construction phasing and work zone plans;
- More comprehensive outputs that can be modified by the user; and
- Packaging of the QuickZone and QZEdit (network editor) together.

After the release of QuickZone 2.0, planned for release in January 2005, additional case studies will be documented in order to continue to highlight its use in various roadway constitution projects as well as other unique applications. These new case studies will aid in the further refinement of QuickZone 2.0 and the development and addition of new features. For more information regarding QuickZone, please visit the QuickZone web site at http://www.ops.fhwa.dot.gov/wz/traffic_analysis/quickzone/index.htm.

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