



CIVIL ENGINEERING STUDIES
Illinois Center for Transportation Series No. 15-011
UIIU-ENG-2015-2012
ISSN: 0197-9191

ENHANCEMENTS TO HIGHWAY CONSTRUCTION SCHEDULING EXPERT SYSTEM

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Research Report No. FHWA-ICT-15-011

A report of the findings of
ICT-R27-135
**Enhancements to Highway Construction
Scheduling Expert System**

Illinois Center for Transportation

May 2015

Technical Documentation Page

1. Report No. FHWA-ICT-15-011		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Enhancements to Highway Construction Scheduling Expert System				5. Report Date May 2015	
				6. Performing Organization Code	
7. Author(s) Dianne K. Slattery and Kerry T. Slattery				8. Performing Organization Report No. ICT-15-011 UILU-ENG-2015-2012	
9. Performing Organization Name and Address Department of Technology and Construction Management College of Business Administration Missouri State University 901 S. National Avenue Springfield, MO 65897				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. R27-135	
12. Sponsoring Agency Name and Address Illinois Department of Transportation Bureau of Materials and Physical Research 120 E. Ash St. Springfield, IL 62704				13. Type of Report and Period Covered	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract This research was performed to enhance the software tool (Illinois Construction Scheduling Expert System, ICSES) developed in Phase I of this project (ICT project R27-86) by mining data collected on IDOT construction projects and differentiating production rates based on project type and size, and training for IDOT engineers on effective use of the expert system tool. The researchers obtained Illinois CONstruction Record System (ICORS) data from each district and assembled a statewide database of more than 4,000 projects completed from 2003-2014. Rich production rate data was extracted from the ICORS files by analyzing the resident engineers' daily diaries and other historical records and processing this data for use in the ICSES software. The results of the data analysis give the scheduler templates of a variety of highway construction projects with the controlling items associated with those projects and the order in which the activities typically occur. The ICSES software was updated based on the results of the analysis of the ICORS data. Templates were modified and/or added in the existing Excel-based database. Production rates currently given in the Construction Daily Production Rate table (Bureau of Design and Environment Manual, Table 66-2.B) were updated based on analyses of data generated by the research. Users of ICSES are given information to assist in development of a schedule and engineers' estimate of time based on project parameters.					
17. Key Words construction scheduling, highway construction, estimate of time			18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 7 plus appendices	22. Price

ACKNOWLEDGMENTS

This publication is based on the results of ICT-R27-135, **Enhancements to Highway Construction Scheduling Expert System**. ICT-R27-135 was conducted in cooperation with the Illinois Center for Transportation (ICT) and the Illinois Department of Transportation (IDOT), Division of Highways.

The research was conducted by personnel from the Department of Technology and Construction Management at Missouri State University (MSU). Dianne K. Slattery, Ph.D., P.E., and Kerry T. Slattery, Ph.D., P.E. were co-principal investigators. MSU graduate students Jason Harmon and Rocky Bryant (Department of Technology and Construction Management) assisted in analyzing project templates, production rates, and in developing training materials.

IDOT personnel who served as the project Technical Review Panel (TRP) guided the research, provided meeting and training space, assisted in identifying projects for study, and made introductions for the researchers to gain access to needed information. The researchers wish to thank Ted Nemsy, P.E., Director of Construction, District 8, who chaired the TRP and assisted the researchers in many ways; Mike Ripka, Office of Quality Compliance and Review; John Negangard, District 6; Kensil Garnett, District 5; Mike Hine, Federal Highway Administration (FHWA); Al Mlacnik, IDOT Division of Aeronautics; Eric Therkildsen, District 4, and Tim Padgett, District 8.

A number of individuals assisted the researchers in gathering data from the Illinois COstruction Records System (ICORS) in each district office of the state. The researchers especially wish to thank Philip Coppennoll, Mike Berg, Jay Edwards, Vince Madonia, Frank Lowry, Charles Ragsdale and Tim Padgett for their comments on early versions of the software.

Directors of Construction in each district and at IDOT Aeronautics assisted in providing ICORS data for the project. The researchers wish to thank Ann Berube (District 1), Doug Happ (District 2), Herbert Jung (District 3), Eric Therkildsen (District 4), Kensil Garnett (District 5), Ronald Archambeau (District 6), Robert Utz (District 7), Ted Nemsy (District 8), Douglas Helfrich (District 9), and Al Mlacnik (Aeronautics) for putting us in contact with their personnel and making data available. The researchers also thank Ron Mescher, Malina Hoyle, Harold Fogarty, Kainon Murnan, Kathleen McConnell, Ben Ogle, Mike Mudra, Charles Miller, and Doug Helfrich for assistance in obtaining ICORS data. Finally, we thank the following for their assistance in providing facilities for training: Jose Rios and Jose Dominguez (District 1), Ahmad Masoud (District 2), Sal Madonia (District 6); and Ted Nemsy (District 8).

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Illinois Center for Transportation or the Illinois Department of Transportation. This report does not constitute a standard, specification, or regulation.

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EXECUTIVE SUMMARY

Objectives

The primary objective of this research was to enhance the software tool, Illinois Construction Scheduling Expert System (ICSES) developed in Phase I of this project (ICT project R27-086), by mining data collected on IDOT construction projects and differentiating production rates based on project type and size.

The secondary objective was to provide training for IDOT engineers on effective use of the expert system tool. Four training sessions were held across the state in October and November 2014, and the training materials were posted on the IDOT website for future use. The software tool and user manual are currently hosted on website of the Missouri State University Center for Project Innovation and Management Education.

Methodology

Phase II began with a series of meetings with the Technical Review Panel (TRP) to refine the functionality and design of the software system, discuss the research approach and the location of historical project data stored in the Illinois CONstruction Records System (ICORS), and arrange for training of IDOT design engineers on use of the ICSES software.

The researchers obtained ICORS data from each district and assembled a statewide database of more than 4,000 projects completed from 2003–2014. Rich production rate data were extracted from the ICORS files by analyzing the resident engineers' daily diaries and other historical records; these data were then processed for use in the ICSES software. The results of the data analysis give the scheduler templates of a variety of highway construction projects with the controlling items associated with those projects and the order in which the activities typically occur.

The ICSES software was updated based on the results of the analysis of the ICORS data. Templates were modified and/or added in the existing Excel-based database. Production rates currently given in the Construction Daily Production Rate table (*Bureau of Design and Environment Manual*, Table 66-2.B) were updated based on analyses of data generated by the research. Users of ICSES are given information to assist in development of a schedule and engineers' estimate of time.

A total of 85 key IDOT design personnel representing each of the nine districts were trained in the use of the ICSES software tool during day-long training sessions in the fall of 2014. The training materials will be disseminated to a wider audience through an audio-enhanced PowerPoint presentation to be hosted on the IDOT website.

Results

The final report documents the methodology of the research and provides a summary of findings and updated production rates. The report also includes the user manual and documentation for the ICSES software, developed using Visual Studio 2010, and scheduling templates in a format compatible with Microsoft Project to assist IDOT personnel in planning and scheduling highway construction projects. The software provides a baseline schedule for ten types of road construction projects. IDOT is given unrestricted license to use the software.

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CHAPTER 1: INTRODUCTION

A 1-year project funded by the Illinois Department of Transportation (IDOT), *An Expert Systems Approach to Highway Construction Scheduling*, was completed in June 2011 (ICT project R27-086). The goal of that project was to assist design engineers in developing construction schedules for a wide variety of IDOT projects. This goal was met by achieving three objectives.

- The research team conducted in-depth interviews with schedulers in highway construction firms, and reviewed the scholarly literature and published research on expert systems in highway construction scheduling and productivity rates for highway construction activities.
- The team analyzed historical weather records published by the Illinois State Water Survey (ISWS) and the National Oceanographic and Atmospheric Administration (NOAA) and used the resulting annual trends to determine the probable number of rain days per month and probable periods during which temperature-sensitive construction operations could be conducted.
- The research team synthesized the expert knowledge developed from all sources into the Illinois Construction Scheduling Expert System (ICSES) software tool to assist designers in developing schedules for a variety of typical highway construction activities.

During the course of the R27-086 project, the Technical Review Panel (TRP) emphasized the need for updating the productivity rates published in the *Bureau of Design and Environment Manual* (BDE Table 66-2.B). As a result, this Phase II project, R27-135, was initiated in May 2013. The research was focused on methods to compute productivity rates by extracting production rate information from the Illinois COstruction Record System (ICORS). Project data on more than 4,200 statewide projects completed from 2003–2014 were collected and analyzed to determine historical production rates, controlling items, and the typical order of activities. The resulting information was incorporated into ICSES to enhance the accuracy and functionality of the scheduling tool.

1.1 OBJECTIVES

The primary objective of this research was to enhance the expert system tool, Illinois Construction Scheduling Expert System (ICSES) developed in earlier research, by mining ICORS data collected on construction projects and differentiating production rates based on project type, size, and location. ICSES was updated to access this information in a useable format and to make improvements based on feedback obtained during TRP meetings and subsequent statewide training sessions.

The secondary objective was to provide training for IDOT engineers and consultants on effective use of ICSES. Eighty-five IDOT personnel attended training sessions that were held in Collinsville on October 8, 2014, for Districts 7,8, and 9; in Springfield on October 9, 2014, for Districts 4,5 and 6; in Dixon on October 10, 2014, for Districts 2 and 3; and in Schaumburg on November 21, 2014, for District 1.

CHAPTER 2: METHODOLOGY

One way of determining production rates for construction activities is field observation and measurement. This would require observing a large number of projects to see every activity being performed multiple times, a costly and time-intensive proposition. Instead, the researchers decided to use the results of years of observations already taken and recorded by IDOT resident engineers, recorded in project diaries, and stored in the ICORS database.

Algorithms were developed for extracting production rate data for construction activities and incorporating that information into ICSES, initially using ICORS data from a limited number of projects in District 8 and District 5. After the methodology had been proven workable, ICORS data on more than 4,200 projects completed since 2003 were obtained from every district in the state and analyzed. The data analysis was used to refine the templates of controlling items that are used in ICSES as the basis for scheduling project time.

Finally, productivity rates for activities listed in the Construction Daily Productivity Rate table (BDE, Table 66-2.B) were validated or updated based on the analysis of actual daily productivity rates achieved on these historical projects.

2.1 OVERVIEW

The Phase II project began with validation and improvement of the ICSES software developed in Phase I. The TRP invested considerable time in training on the software themselves and giving feedback to refine the project templates and improve the functionality prior to scheduling training for a general audience. Meetings and training sessions with the TRP were held in Springfield on May 21, 2013; July 12, 2013; October 4, 2013; and February 28, 2014. At the July 2013 and February 2014 meetings, additional personnel from Aeronautics, Districts 5 and 8, and the Bureau of Materials and Physical Research joined the TRP in training and using the software and giving feedback. After these changes were incorporated, statewide ICSES training was initially scheduled for June 2014 but was postponed to October and November 2014 because of demands on design engineers' time during the summer of 2014.

ICORS data from a small number of District 8 projects had been obtained during Phase I and used in developing algorithms for extraction of production rates, for developing project templates for common project types, and in identifying the construction activities that appeared in the project templates as controlling items. In Phase II, additional ICORS data from approximately 400 District 8 and District 5 projects were obtained and incorporated into ICSES. This allowed users to filter production rate data by district, by project type, and by project size.

Finally, in the fall of 2014, the researchers obtained comprehensive, statewide ICORS data on a total of more than 4,200 projects. The data were obtained electronically or manually copied from project files at the various district offices.

The archived letting information for these projects was obtained from the IDOT website, which yielded brief project descriptions, quantities, and awarded bid prices.

2.2 ASSEMBLE HISTORICAL DATA

A resident engineer's project diary and other project documentation entered into the ICORS database during a project is saved on CDs and kept with the project files at the district offices for 4 or more years after completion of the project. The ICORS database includes the daily controlling item, resident engineer's notes, working-day record, and schedule of quantities approved for pay throughout the job.

Archived letting information, containing brief project descriptions and bid tabulation data, is available on the IDOT website for projects going back more than 10 years. The researchers collected ICORS data and the corresponding letting information for more than 4,200 projects completed since 2003. The total number of projects collected from each district is given in Table 1.

ICORS data were obtained from each district in Microsoft Access format (*.mdb). A VB.NET program was developed to extract the required data from each project file and convert the information to text files for analysis. PDF files were downloaded from the IDOT website for each letting since 2003 to extract the project descriptions so they could be paired with the construction records. Bid tabulation data were also downloaded from the IDOT website, in Microsoft Excel format. Price data were extracted from these files to determine the “cost intensity” of work on each pay item throughout the project.

Table 1. ICORS Project Files Collected by District

District	Number of Projects
1	977
2	410
3	725
4	449
5	444
6	480
7	203
8	341
9	172
TOTAL	4,201

2.3 PROCESS/ANALYZE HISTORICAL DATA

Productivity rate is defined as quantity of work divided by unit of time. The current table of Construction Daily Productivity Rates (BDE Table 66-2.B) gives a range of possible productivity rates for about 150 activities. In some cases, this range is greater than one order of magnitude. The actual productivity rate for each activity will depend on the construction method selected by the contractor and the level of resources committed to the job. This information can't be known during the design phase, but one would expect that, in most cases, the productivity rate would be greater when there is a larger quantity of a given work item. The productivity rate may also depend on the type of project. For example, milling rates tend to be significantly higher on a rural interstate than on an urban reconstruction project. Additionally, productivity rates may vary by district depending on the resources of the local contractors. To provide better guidance to the engineer preparing the estimate of time for the project, the productivity rate data were analyzed to study the relationship between production rate and quantity, and to allow differences between districts to be seen.

To determine the expected project duration based on the duration of controlling activities, production rates for an activity were determined when that activity was a priority on the project. Because cost provides a common unit (dollars) for comparing the relative effort devoted to various activities, each project was initially analyzed to extract a schedule of priority activities based on the amount of money spent on each controlling item during a given time interval. The schedule of costs was reconstructed for each project from the pay quantities submitted by the resident engineer as recorded in ICORS and the unit bid prices recorded in the archived bid tabulations.

A Visual Basic for Applications program was developed in Microsoft Excel to analyze each of the 4,200 completed projects for which ICORS data were obtained. First, the schedule for each project was broken into discrete time intervals (e.g., 10 calendar days), and the bid item on which the most

money was spent during each time interval was determined. The key assumption was that, if several activities were happening concurrently during the time interval, the one on which the most money was spent would be considered the priority activity. The quantity of work on the priority activity was determined from the resident engineer’s pay item records, and the number of working days was determined by scanning the resident engineer’s notes for those days. If a working day (or fractional day) was charged and a key word (or fragment of a key word) relating to that activity was found in the notes for that day, the activity duration was increased. To account for priority activities whose duration didn’t coincide with the selected time interval, the record of work performed on days immediately before and after each time interval was also considered. Pay quantities and working days for each priority activity were then summed over the entire project, and the quantity was divided by the number of working days when the activity was a priority to determine the production rate.

This automatic data extraction and production rate calculation will not produce exact results in every case. The greatest uncertainty is in the number of working days because that depends on the interpretation of the resident engineer’s notes. Some unrealistically high production rates are calculated when the program finds only 1 working day recorded for an activity that has a large quantity. However, the large quantity of data available for most activities will minimize the impact of outliers on the relationship between production rate and quantity.

The impact of the duration chosen for the discrete time interval was studied. All jobs were processed using a 5-, 10-, 15-, and 30-day interval. While some difference in results was expected, the impact was minor—providing support for the robustness of this approach. The data reported used a 10-day interval.

2.4 ENHANCE TEMPLATES AND CALCULATORS

The methodology for developing project schedules in ICSES uses templates of controlling items for common project types to provide users a starting point. ICORS data were studied extensively to improve the project templates that had been developed in Phase I. Each project description was read and manually categorized by the researchers. The categories were refined and consolidated, and a total of 28 recurring project types were identified. Templates were developed for 11 of these and included in the ICSES scheduling software (Table 2). Templates were determined to be not warranted for project types that rarely occurred or that consisted of one or two tasks (Table 3).

Table 2. Project Templates Used in ICSES Software

Bridge New Construction	Roadway New Construction
Bridge Reconstruction	Roadway Reconstruction
Bridge Rehabilitation	Roadway Rehabilitation
Grading	Roadway Resurfacing
Intersection Reconstruction	Urban Reconstruction
Patching	

Table 3. Project Types Not Assigned Templates

Bridge Cleaning	Drainage	Marking
Bridge Deck Overlay	Guardrail	Seal Coat
Bridge Painting	Guardrail Repair	Signals
Bridge Patching	Intelligent Transportation System	Signs
Cable Guardrail	Landscaping	
Crack Seal	Lights	

The resident engineer’s project diary and record of controlling items was extracted from the ICORS data to develop a schedule for each job. In order to standardize the notation, the controlling item names were converted to the three-digit code indicating the corresponding article from the IDOT Standard Specification for Road and Bridge Construction. For example, Earth Excavation was coded 202. All schedules were analyzed to determine the start and finish times for each activity and to find the order in which each activity occurred in a working day schedule for the project.

The schedules for all projects classified as a given type were then studied to determine how frequently a given activity occurred and at what point in the schedule it occurred. The average of the start and finish time was calculated for the activity in each job and averaged over all occurrences.

The templates developed earlier in the research were re-evaluated in light of this data. An activity that occurred in at least 25% of projects was usually included in the template and the position in the schedule was adjusted in some cases based on the analysis.

2.5 INCORPORATE RESULTS INTO ICSES

The production rate data for more than 100 are is available through the ICSES software. During the initial template review, the user can input quantities for each activity and extract a production rate for the activity based on that quantity. The relevant data for each activity can also be viewed and filtered later in the process.

Figure 1 shows the ICSES Production Rate Data form for earth excavation, with production rate vs. quantity plotted. The maximum production rate and maximum quantity for all selected data are shown on the X and Y axes, and a vertical line indicates the input quantity for that activity. Two regression analyses are superimposed on the data—linear and power law. The value of each regression function for the input quantity is displayed on the plot.

Left-clicking a data point displays the description of that job on the form. A data point can be removed by right-clicking. All data points are restored when the plot is updated.

Four filters are also provided. The data are initially filtered for the district and job type input earlier in the ICSES session. The user can select other districts and/or job types. The user can also choose to view data from jobs for which the quantity or duration of work on that activity is more or is less than an input value.

The “expected” production rate based on the regression analyses through the selected data can be used, or another reasonable value can be input before closing the form. The user should be aware that this tool isn’t intended to provide an exact answer but rather to supplement other information.

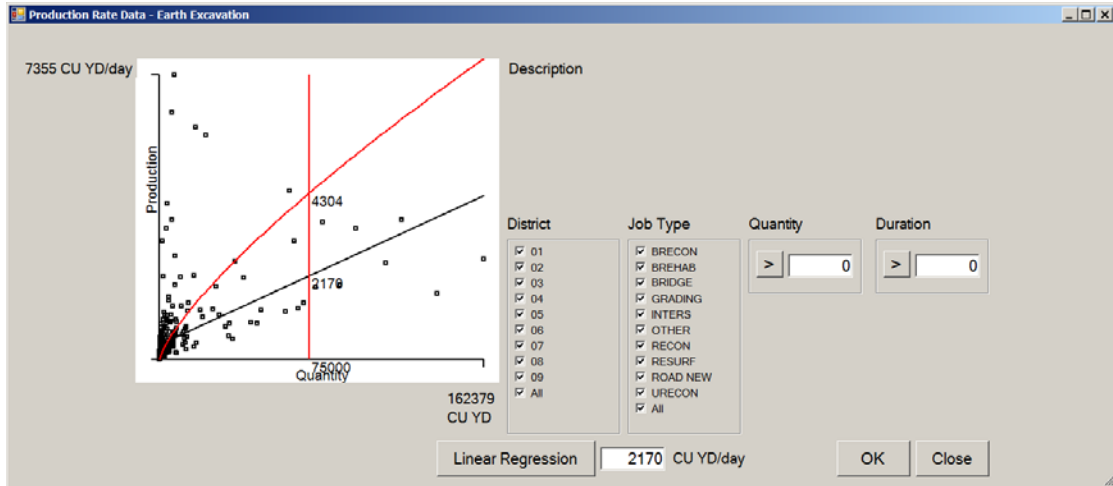


Figure 1. Production Rate Data form.

CHAPTER 3: SUMMARY AND CONCLUSIONS

The overall goal of the research (Phase I and II) was to create a tool to assist design engineers in developing construction schedules for a wide variety of IDOT projects. The Illinois Construction Scheduling Expert System (ICSES) software tool has captured highway construction scheduling knowledge from contractors, design engineers, resident engineers, consultants, and historical project records, and presents this knowledge in a format that allows users of the software to apply their own engineering judgment to prepare construction schedules.

The research approach was to focus on controlling items for typical highway construction projects. Scheduling templates were developed using only controlling items (based on examination of historical project records) and incorporating expert input as part of the final validation process for the software.





The Phase II project had an objective of updating production rates contained in Table 66-2.B of the *Bureau of Design and Environment Manual* (BDE). It was hypothesized that changes in technology and construction methods may have increased the productivity of some key activities (for example, bituminous concrete surface removal, or milling). Historical data from more than 4,200 projects were used to verify or update more than 100 of the 148 activities listed in BDE Table 66-2.B. The remaining items were not observed or occurred too infrequently to justify making a recommendation to change the rate. It should be noted that most of the rates published in BDE Table 66-2.B were verified by the research, and no changes were recommended. Of course, the results of the research are most relevant when the relationship between production rate and quantity is considered and when the data are filtered based on the type of job and the location of the project using the ICSES software rather than tabled values.

The recommended changes are summarized in a Table A.1 in Appendix 1. Plots of production rate data for those activities are also included. The plots show data points from all districts and job types, along with the regression curves. The current recommended range of production rates is indicated by solid horizontal lines, and the recommended change is indicated by dashed lines. The recommendations were based on the range of production rates that were observed over a wide range of quantities. Low rates for jobs with small quantities were not considered, and some high rates that were calculated when only 1 or 2 working days were found during the data analysis were also ignored.

In Phase II, the project templates developed in Phase I were updated and validated through the examination of historical data. The common controlling items and the order of activities were extracted from the historical data and incorporated into the ICSES software. This enhancement provides users with a baseline template for the 11 most common types of projects performed. The templates may be customized and saved by the user. It is recommended that a mechanism for sharing, commenting on, and accepting project templates department-wide be developed to continue to capture the knowledge and expertise of IDOT design engineers.

APPENDIX 1: SUMMARY TABLES

Table A.1. Updated Construction Daily Production Rates
(Bureau of Design and Environment Manual Table 66-2.B)

Key: cells shaded  increases over previous rate
 cells shaded  decreases over previous rate
 blank cells  insufficient data to make recommendation
 filled cells  no recommended change to previous rate

MAJOR WORKTYPE	SUB WORKTYPE	DESCRIPTION	UNIT	LOW	HIGH	LOW (NEW)	HIGH (NEW)
Bridge	Bridge	Bearing Assembly	each	5	10	5	10
Bridge	Bridge	Bridge Deck Concrete Overlay	square yard	200	500		
Bridge	Bridge	Bridge Deck Grooving	square yard	500	800	500	2000
Bridge	Bridge	Bridge Deck Scarification (Cold Milling)	square yard	350	1000	350	1000
Bridge	Bridge	Bridge Deck Scarification (Hydroblasting)	square yard	175	500	175	500
Bridge	Bridge	Concrete Structures	cubic yard	10	25	10	25
Bridge	Bridge	Concrete Superstructure	cubic yard	10	30	10	30
Bridge	Bridge	Clean & Paint Steel Bridge - SP 10	square foot	1000	2100		
Bridge	Bridge	Clean & Paint Steel Bridge - SP 6	square foot	800	1600		
Bridge	Bridge	Clean & Paint Steel Bridge - SP 3	square foot	250	550		
Bridge	Bridge	Cofferdam (Not for major river bridges)	each	0.20	0.50	0.2	0.5
Bridge	Bridge	Concrete Removal	cubic yard	5	20	5	20
Bridge	Bridge	Deck Slab Repair (Full Depth)	square yard	10	25		
Bridge	Bridge	Deck Slab Repair (Partial Depth)	square yard	25	50		
Bridge	Bridge	Driving Piles	foot	250	500	250	500
Bridge	Bridge	Cofferdam Excavation	cubic yard	75	150	75	300
Bridge	Bridge	Formed Concrete Repair	square foot	50	100		
Bridge	Bridge	Jacking & Cribbing (per beam)	each	5	10		
Bridge	Bridge	Precast Concrete Beam Erection	foot	150	325		
Bridge	Bridge	Precast Concrete Beams (Fab & Furnish)	calendar day	30	120		
Bridge	Bridge	Precast Concrete Bridge Deck	square foot	500	800	500	800
Bridge	Bridge	Precast Deck Beams	square foot	1000	3000		
Bridge	Bridge	Protective Shield	square yard	160	250	160	250
Bridge	Bridge	Reinforcement Bars (Substructure)	pounds	4000	6000	4000	6000
Bridge	Bridge	Reinforcement Bars (Superstructure)	pounds	10000	15000	10000	15000
Bridge	Bridge	Removal of Existing Concrete Deck	square yard	150	300	150	400
Bridge	Bridge	Removal of Existing Substructure	cubic yard	20	40	5	25
Bridge	Bridge	Removal of Existing Superstructure	square yard	100	250	100	250
Bridge	Bridge	Slope Wall	square yard	25	75	25	75
Bridge	Bridge	Structural Steel Erection	foot	150	250		
Bridge	Bridge	Structural Steel (Fabricate & Furnish)	calendar day	60	270	60	270
Bridge	Bridge	Stud Shear Connectors	each	1000	2500	1000	2500
Bridge	Bridge	Temporary Sheet Piling	square foot	300	1000		
Bridge	Bridge	Test Pile	Each	0.5	1	0.5	1
Bridge	Bridge	Waterproofing Membrane System	square yard	100	250	100	250
Electrical	Electrical	Conduit in Trench	foot	75	325	75	325
Electrical	Electrical	Conduit (Pushed)	foot	30	75		
Electrical	Electrical	Controller	each	0.5	1	0.5	1
Electrical	Electrical	Detector Loop	foot	150	300	150	500
Electrical	Electrical	Electric Cable	foot	1500	3000		

Electrical	Electrical	Electrical Conductors in Conduit	foot	750	1300	750	1300
Electrical	Electrical	Foundations – Controller, Signal	foot	2	5		
Electrical	Electrical	Foundations – Light Poles	foot	10	20	10	30
Electrical	Electrical	Foundations – Light Towers	foot	20	25		
Electrical	Electrical	Handholes	each	2	4	2	4
Electrical	Electrical	Junction Box	each	2	5	2	5
Electrical	Electrical	Light Pole	each	4	6	4	6
Electrical	Electrical	Light Tower	each	1	2	1	2
Electrical	Electrical	Luminaire	each	5	10	5	10
Electrical	Electrical	Mast Arm Assembly & Pole	each	2	4	2	4
Electrical	Electrical	Raceway for Magnetic Detectors	foot	100	200		
Electrical	Electrical	Relocate Existing Traffic Signal Posts	each	2	4	2	4
Electrical	Electrical	Service Installation	each	0.5	1	0.5	1
Electrical	Electrical	Signal Head	each	5	10	5	10
Electrical	Electrical	Signal Post (wood or metal)	each	4	8	1	4
Electrical	Electrical	Trench & Backfill	foot	75	350	75	350
Electrical	Electrical	Unit Duct	foot	550	700	550	700
Electrical	Electrical	Unit Duct/without Cable	foot	150	350	150	350
Landscape	Landscape	Evergreens	each	20	40		
Landscape	Landscape	Excelsior Blanket	square yard	1000	4000	1000	10000
Landscape	Landscape	Intermediate Trees	each	20	40		
Landscape	Landscape	Seeding	acre	5	10	2	10
Landscape	Landscape	Seedling Trees	each	2000	3000		
Landscape	Landscape	Shade Trees	each	20	40		
Landscape	Landscape	Shrubs	each	200	400		
Landscape	Landscape	Sodding	square yard	1000	1500	500	2000
Landscape	Landscape	Straw Mulch	ton	10	20		
Landscape	Landscape	Vines	each	1000	2000		
Landscape	Landscape	Weed Control Spraying	acre	50	100		
Roadway	Aggregate	Granular Backfill	cubic yard	300	600		
Roadway	Aggregate	Granular Embankment Special	ton	800	1500		
Roadway	Aggregate	Gravel or Crushed Stone Base Course	ton	700	1200	200	1200
Roadway	Aggregate	Gravel or Crushed Stone Shoulders	ton	500	1200	500	1200
Roadway	Aggregate	Gravel or Crushed Stone Surface Course	ton	700	1200	200	600
Roadway	Aggregate	Porous Granular Embankment	cubic yard	400	1000	400	1000
Roadway	Aggregate	Subbase Granular Materials	ton	700	2000	200	700
Roadway	Drainage	Adjust Frames & Grates	each	5	10		
Roadway	Drainage	Catch Basins	each	2	5	2	5
Roadway	Drainage	Concrete Box Culverts	cubic yard	8	15	5	15
Roadway	Drainage	Concrete Headwalls	cubic yard	3	8		
Roadway	Drainage	Concrete Gutter	foot	400	1400	400	1400
Roadway	Drainage	Curb & Gutter	foot	300	1200	300	1200
Roadway	Drainage	End Sections (Pipe Culvert & Storm Swr)	each	5	10	5	10
Roadway	Drainage	Inlets	each	2	5	2	5
Roadway	Drainage	Manholes	each	2	4	2	4
Roadway	Drainage	Paved Ditch	foot	200	400	200	400
Roadway	Drainage	Pipe Culverts (Depend on size & depth)	foot	100	300	100	300
Roadway	Drainage	Pipe Underdrains	foot	1500	7500	1500	7500
Roadway	Drainage	Precast Box Culverts	foot	75	250	50	150
Roadway	Drainage	Reinforcement Bars (Culverts)	pound	3000	5000	3000	5000
Roadway	Drainage	Riprap	square yard	100	200	50	200
Roadway	Drainage	Storm Sewers (Depend on size & depth)	foot	75	300	75	300
Roadway	Drainage	Trench Backfill	cubic yard	100	200	100	200
Roadway	Drainage	Exploration Trench	foot	250	1000	250	1000

Roadway	Excavation	Embankment	cubic yard	500	10000	500	6000
Roadway	Excavation	Borrow Excavation	cubic yard	1000	10000	1000	10000
Roadway	Excavation	Channel Excavation	cubic yard	200	500	200	500
Roadway	Excavation	Earth Excavation (Shoulders & Widening)	cubic yard	500	1000	500	1000
Roadway	Excavation	Earth Excavation	cubic yard	750	10000	750	6000
Roadway	Excavation	Rock Excavation (Ripping or Blasting)	cubic yard	500	2000		
Roadway	Excavation	Excavation (Special)	cubic yard	500	1000		
Roadway	Excavation	Excavation (Topsoil)	cubic yard	500	1000	200	500
Roadway	Excavation	Process Lime Modified Soil	square yard	2000	6500	2000	6500
Roadway	Excavation	Process Lime Stabilized Soil	square yard	2000	6500	2000	6500
Roadway	Excavation	Topsoil Placement	square yard	5000	25000	500	5000
Roadway	Misc.	Chain Link Fence	foot	300	500	300	500
Roadway	Misc.	Concrete Barrier	foot	200	400		
Roadway	Misc.	Delineators	each	75	150	75	150
Roadway	Misc.	Furnishing and Erecting Row Markers	each	10	30	10	30
Roadway	Misc.	Noise Abatement Wall	square foot	800	1000		
Roadway	Misc.	Steel Plate Beam Guardrail	foot	300	600	300	1000
Roadway	Misc.	Steel Plate Beam Guardrail Removal	foot	500	800	500	800
Roadway	Misc.	Temporary Concrete Barrier Wall	foot	500	1500		
Roadway	Misc.	Woven Wire Fence	foot	500	1000	500	1000
Roadway	Patching	Class A	square yard	50	100	100	400
Roadway	Patching	Class B	square yard	50	100	100	400
Roadway	Patching	Class C & D	square yard	100	150	100	400
Roadway	Paving	Bituminous Concrete Binder & Surface Course SuperPave	ton	500	1600		
Roadway	Paving	Bituminous Materials	gallon	3000	10000		
Roadway	Paving	Bituminous Pavement Removal & Replacement	square yard	50	100		
Roadway	Paving	Bridge Approach Pavement	square yard	50	100		
Roadway	Paving	Continuously Reinforced Concrete Pavement	square yard	2000	7000		
Roadway	Paving	Cracking and Sealing Pavement	square yard	5000	15000		
Roadway	Paving	HMA Base Course	square yard			500	1000
Roadway	Paving	HMA Base Course Widening	square yard	500	2000	500	2000
Roadway	Paving	HMA Shoulders	square yard	1500	4500	1500	4500
Roadway	Paving	HMA Pavement (Full depth)	square yard	1000	3500		
Roadway	Paving	HMA Surface Course	square yard			50	800
Roadway	Paving	Level Binder	ton	50	1600	50	1600
Roadway	Paving	Median Surface (Concrete)	square foot	750	2000	750	4000
Roadway	Paving	Micro-surfacing/Lane	Mile	1	3		
Roadway	Paving	Pavement Fabric	square yard	1200	6000	500	1500
Roadway	Paving	Pavement Reinforcement	square yard	1500	5000		
Roadway	Paving	PC Concrete Base Course	square yard	1500	6000		
Roadway	Paving	PC Concrete Base Course Widening	square yard	750	2500	250	750
Roadway	Paving	PC Concrete Driveways	square yard	100	150	50	100
Roadway	Paving	PC Concrete Pavement	square yard	1500	6000	500	1500
Roadway	Paving	PC Concrete Pavement (Hinge Joint)	square foot	1500	6000		
Roadway	Paving	PC Concrete Sidewalks	square yard	1000	1500		
Roadway	Paving	PCC Shoulders	square yard	1200	6000	200	1000
Roadway	Paving	Protective Coat	square yard	3000	7000	3000	7000
Roadway	Paving	Stabilized Subbase 4"	square yard	3000	10000	500	3000
Roadway	Paving	Strip Reflective Crack Control	foot	10000	20000	10000	20000
Roadway	Pvt Mk	Paint Pavement Marking (Hand)	foot	500	1000		
Roadway	Pvt Mk	Paint Pavement Marking (Truck)	foot		20000		

Roadway	Pvt Mk	Raised Reflective Pavement Markers	each	100	200	100	200
Roadway	Pvt Mk	Thermoplastic Pavement Marking Symbol	square foot	450	900	450	900
Roadway	Pvt Mk	Thermoplastic Pavement Marking (Hand)	foot	500	1000		
Roadway	Pvt Mk	Thermoplastic Pavement Marking (Truck)	foot	60000	180000		
Roadway	Removal	Bituminous Surface Removal	square yard	2000	10000	2000	10000
Roadway	Removal	Curb & Gutter Removal	foot	600	1400	600	1400
Roadway	Removal	HMA Surface Course Removal (1.5 in.)	square yard	10000	60000	10000	60000
Roadway	Removal	Pavement Grinding	square yard	1000	2000		
Roadway	Removal	Pavement Removal	square yard	1000	2000		
Roadway	Removal	Sidewalk Removal	square foot	1500	2500		
Roadway	Removal	Tree Removal	acre	2	4	2	4
Roadway	Removal	Tree Removal (6 to 15 Units Diameter)	units	150	400	150	400
Roadway	Removal	Tree Removal (Over 15 Units Diameter)	units	100	300	100	300
Signing	Signing	Metal Post	foot	250	400	250	400
Signing	Signing	Overhead Sign Foundation	cubic yard	5	16	5	16
Signing	Signing	Overhead Sign Structure	foot	25	50		
Signing	Signing	Sign Panel	square foot	500	2000	100	250
Signing	Signing	Structural Steel Sign Support Non-Breakaway	pound	1000	15000	1000	15000

APPENDIX 2: PRODUCTIVITY RATE CHARTS

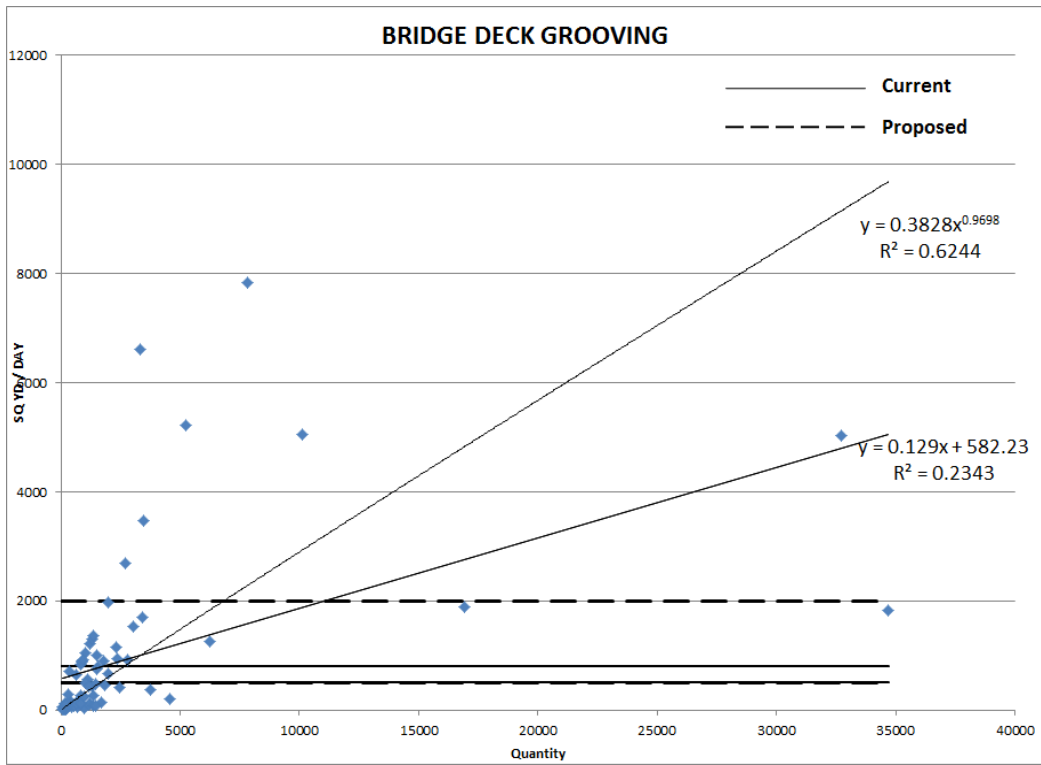


Figure A.2.1 Bridge deck grooving.

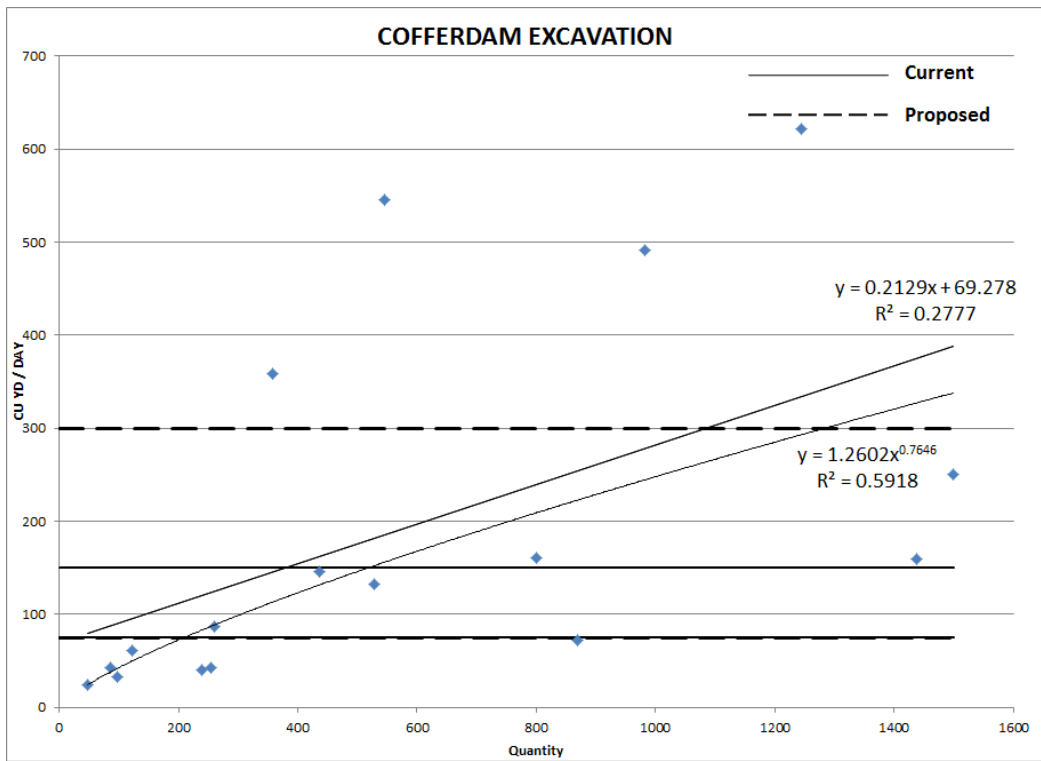


Figure A.2.2 Cofferdam excavation.

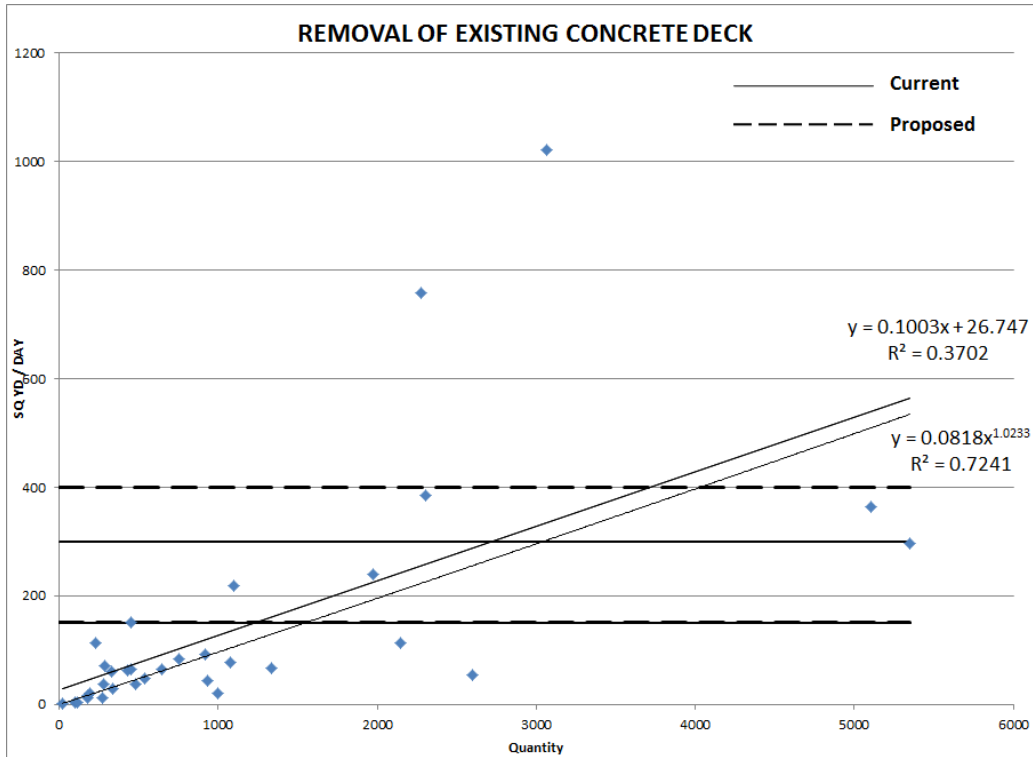


Figure A.2.3 Removal of existing concrete deck.

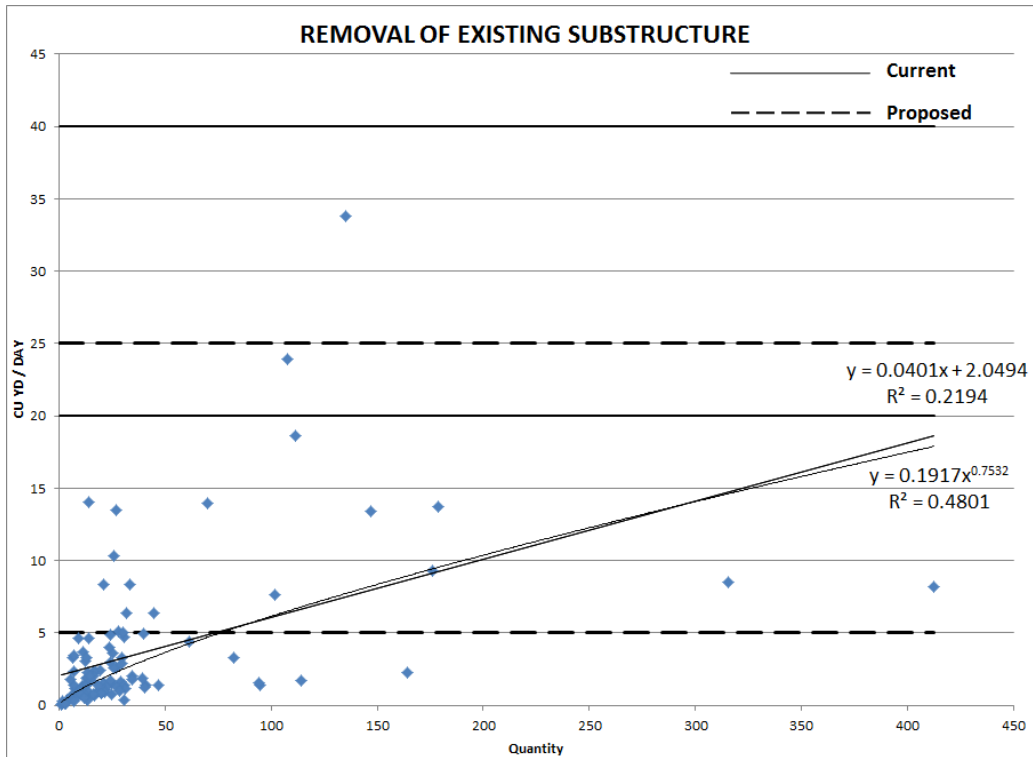


Figure A.2.4 Removal of existing substructure.

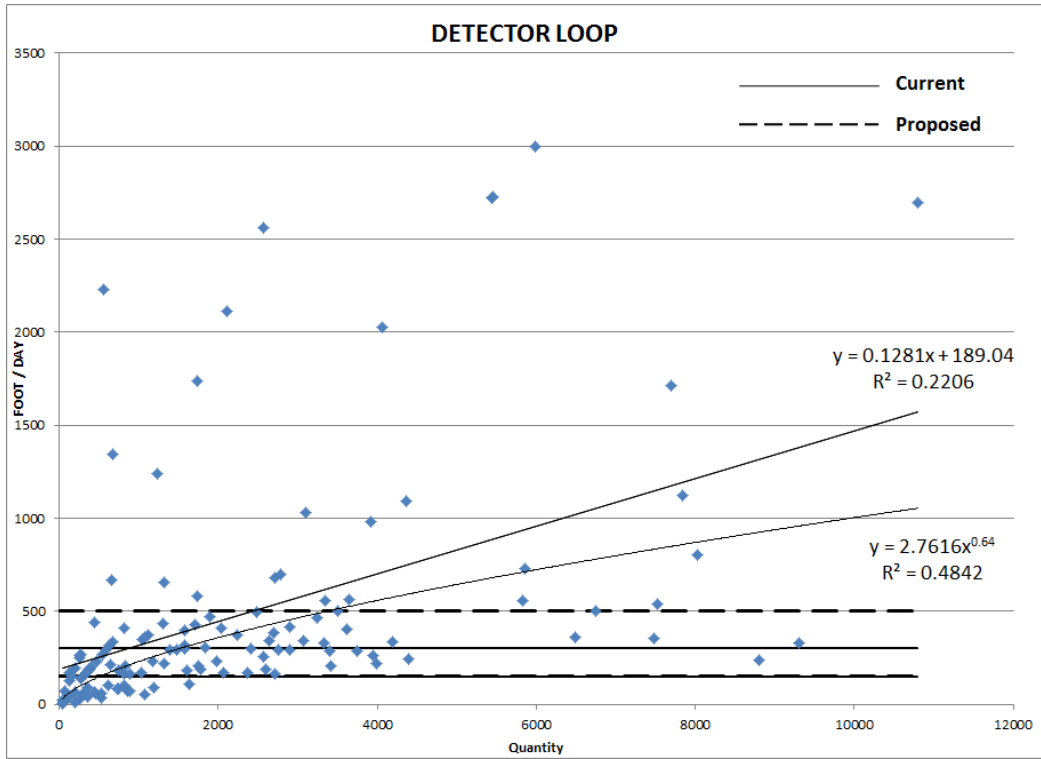


Figure A.2.5 Detector loop.

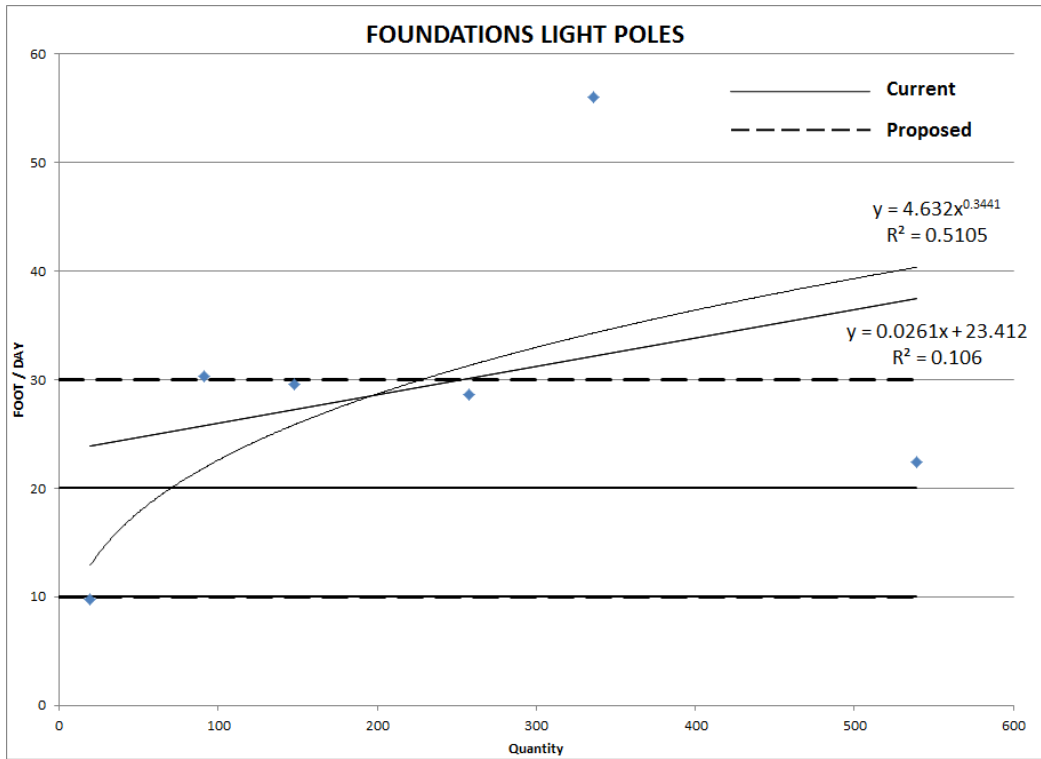


Figure A.2.6 Foundations light poles.

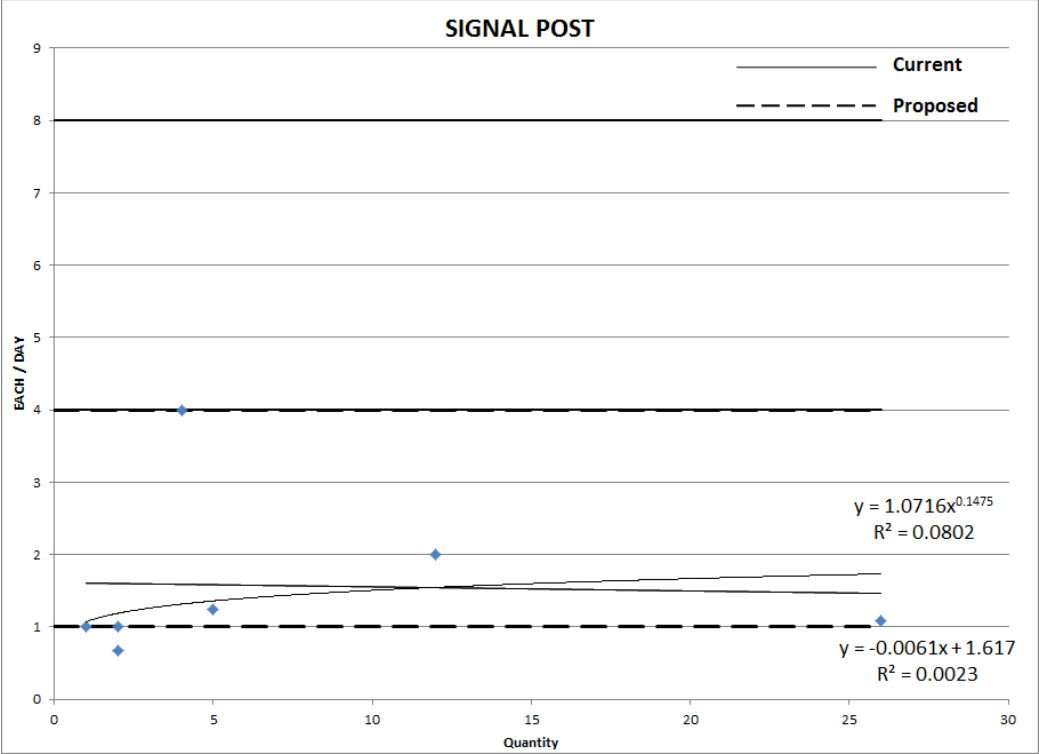


Figure A.2.7 Signal post.

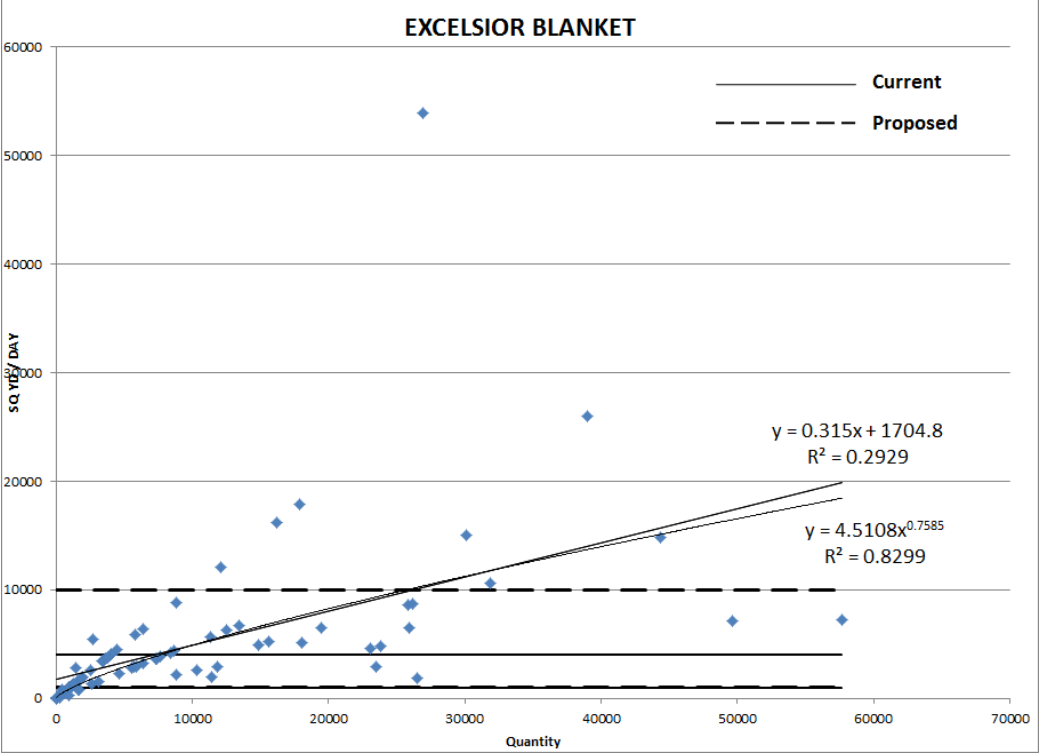


Figure A.2.8 Excelsior blanket.

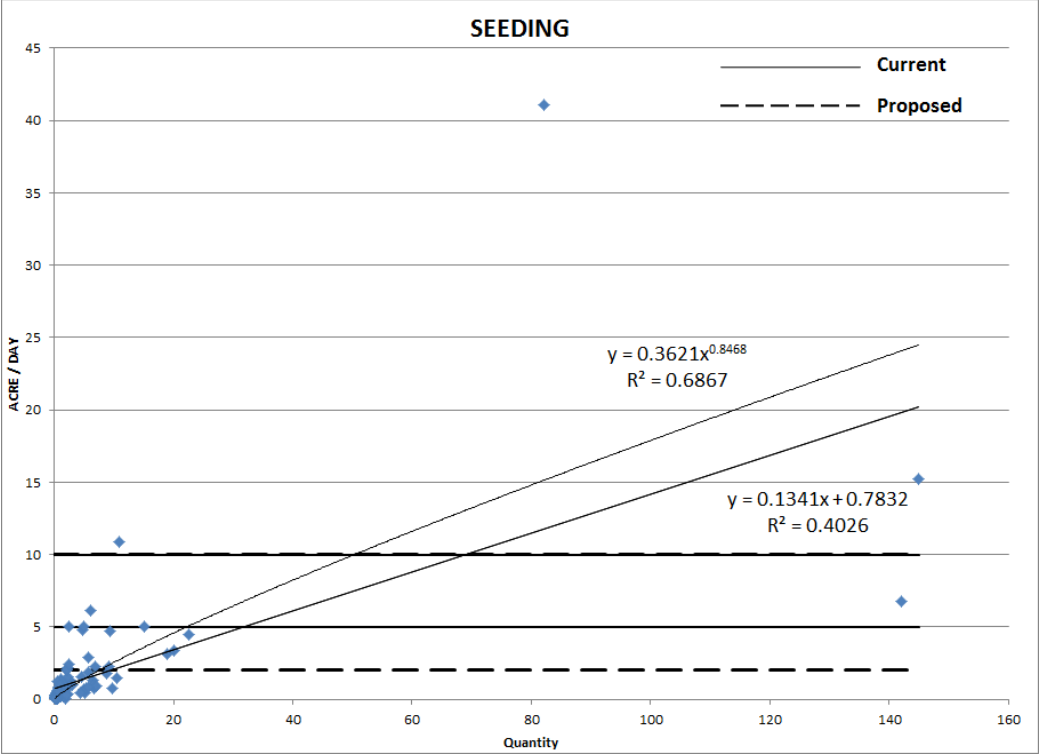


Figure A.2.9 Seeding.

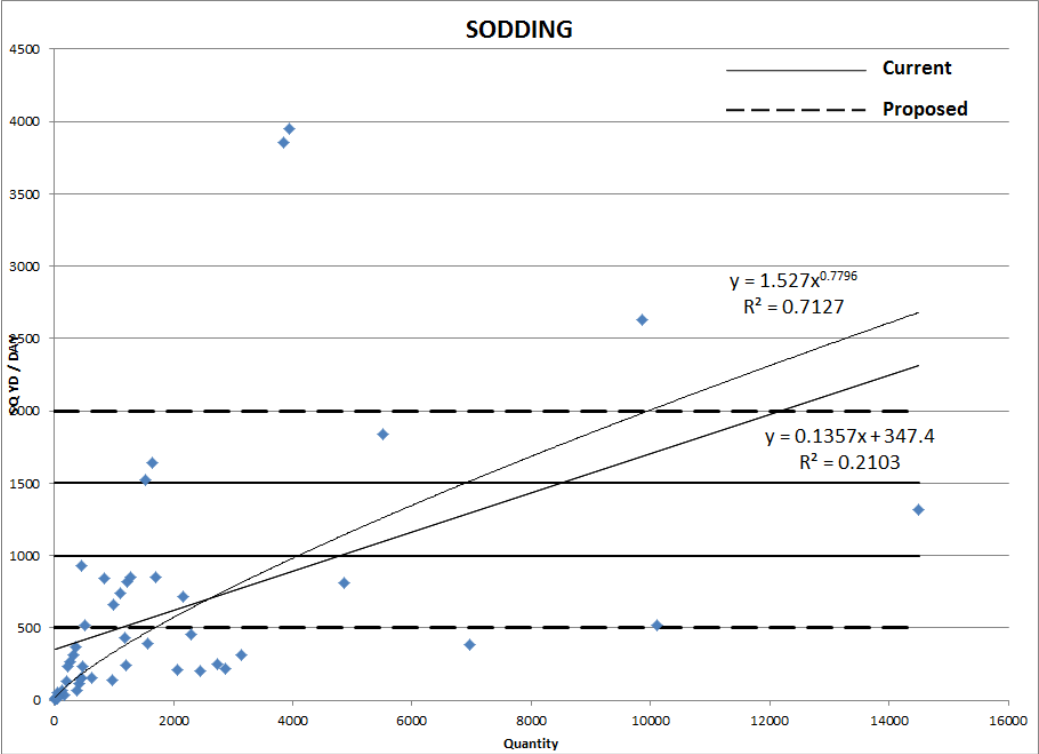


Figure A.2.10 Sodding.

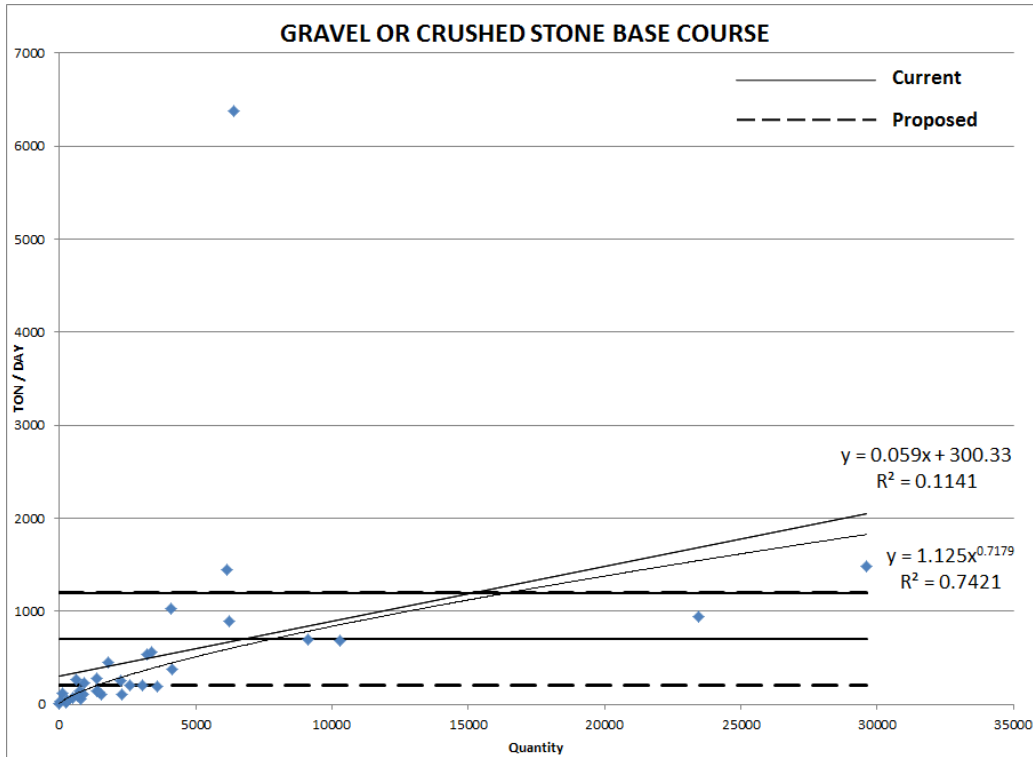


Figure A.2.11 Gravel or crushed stone base.

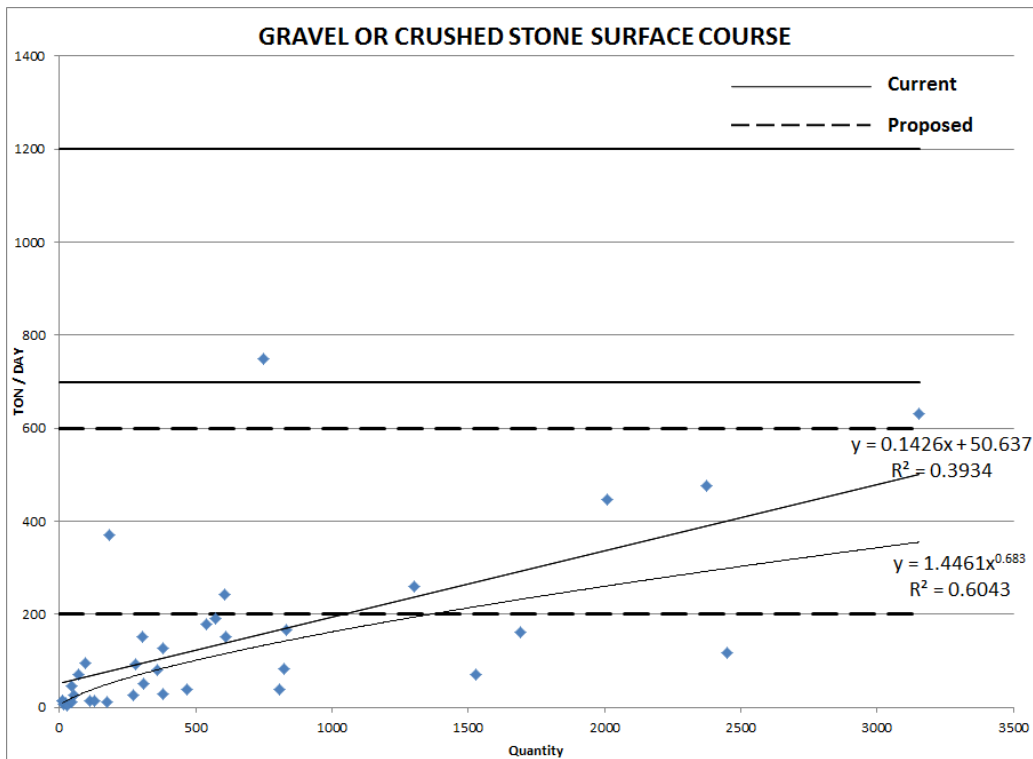


Figure A.2.12 Gravel or crushed stone surface course.

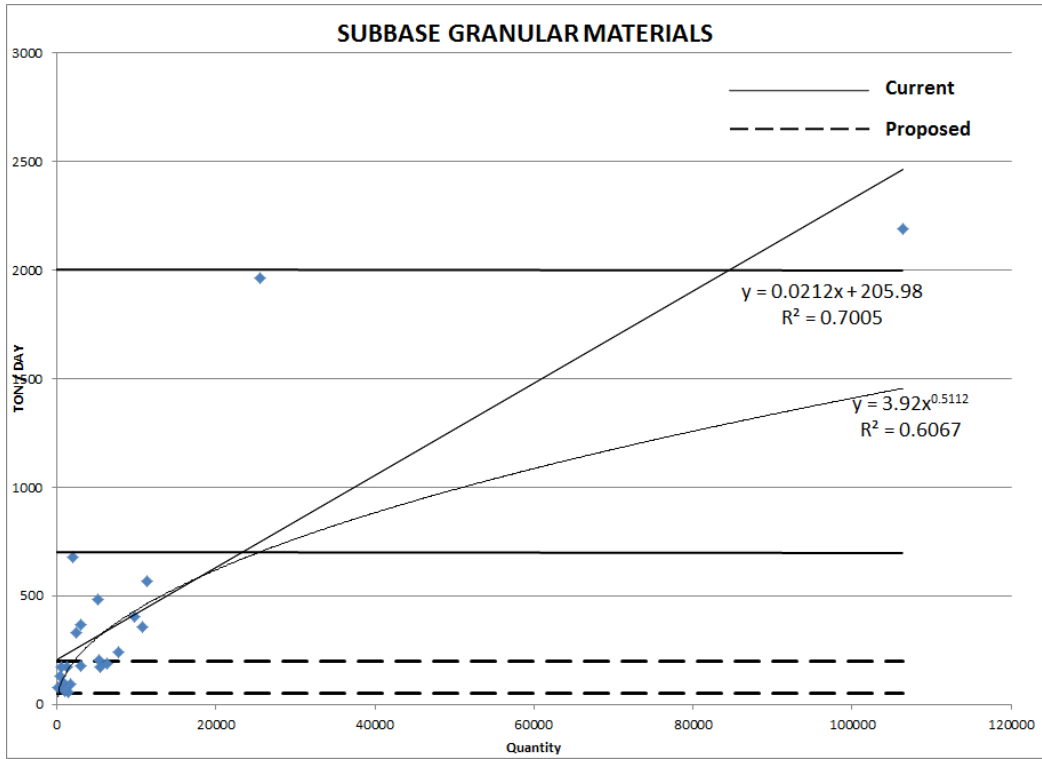


Figure A.2.13 Subbase granular materials.

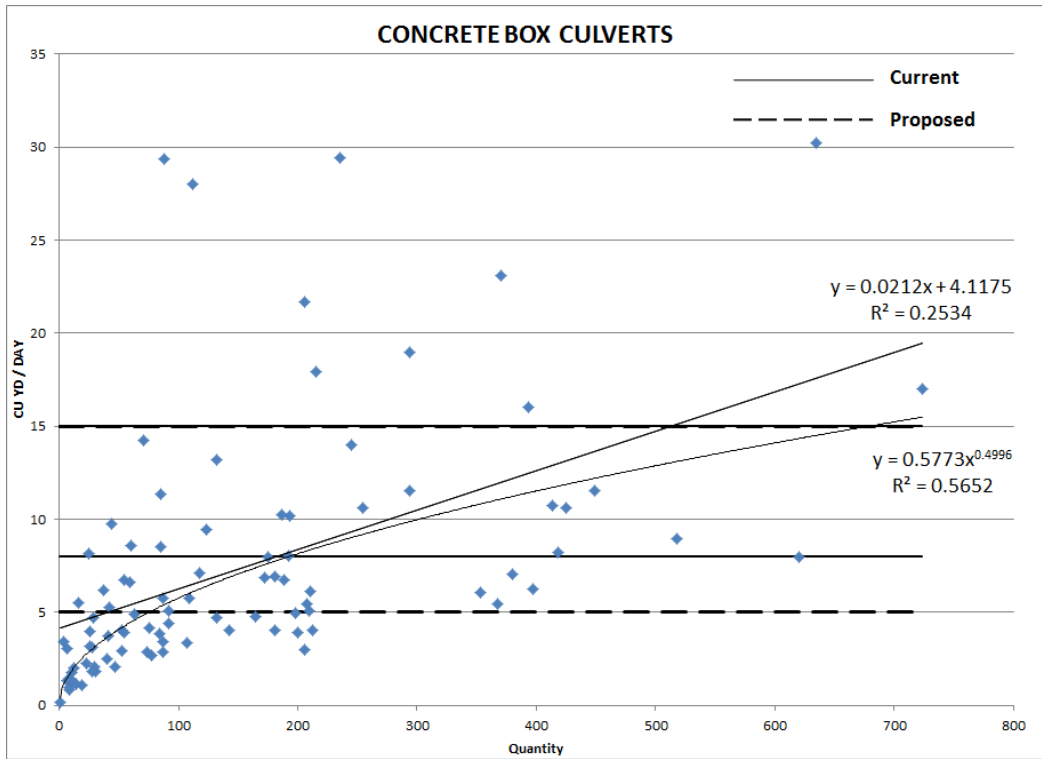


Figure A.2.14 Concrete box culverts.

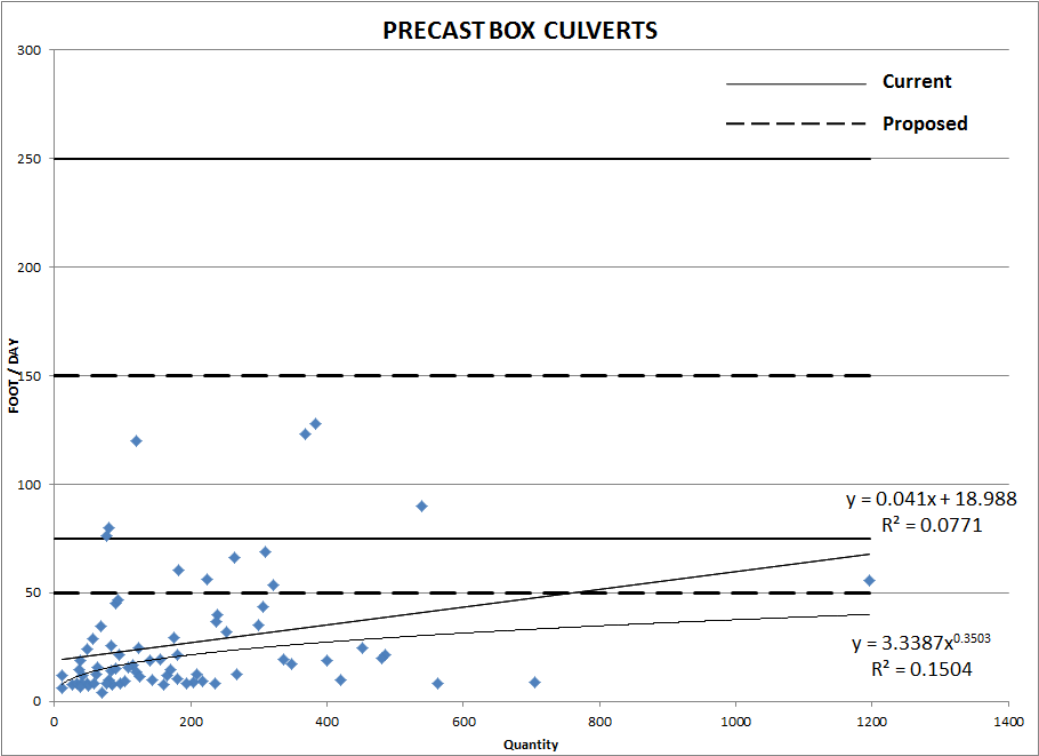


Figure A.2.15 Precast box culverts.

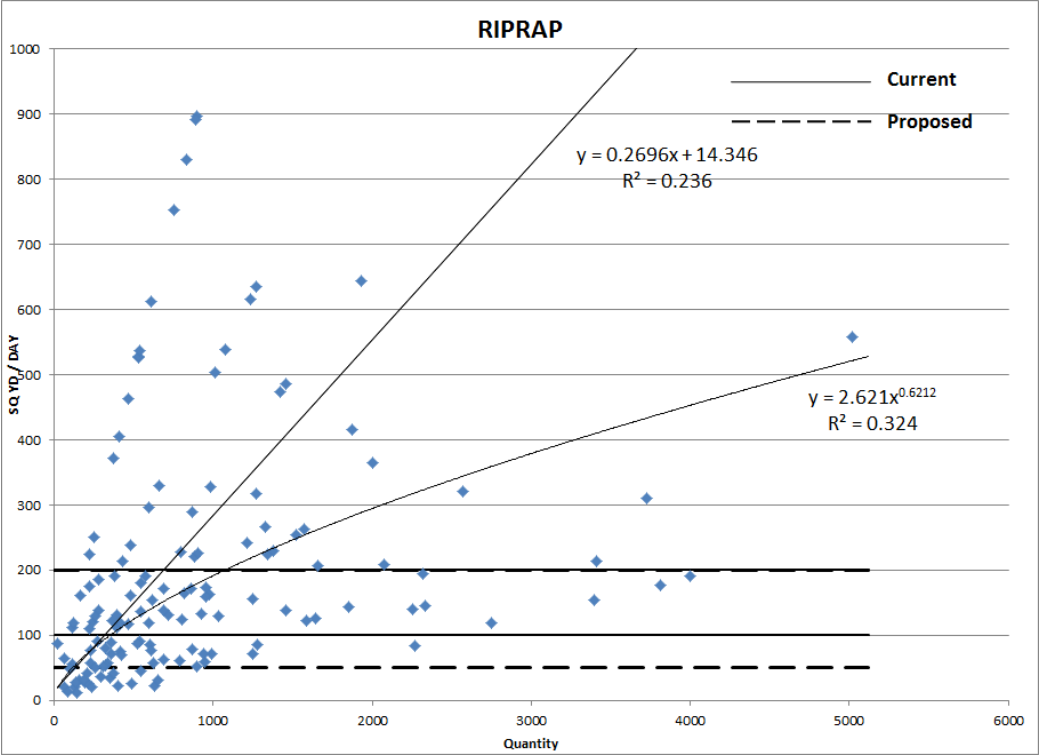


Figure A.2.16 Riprap.

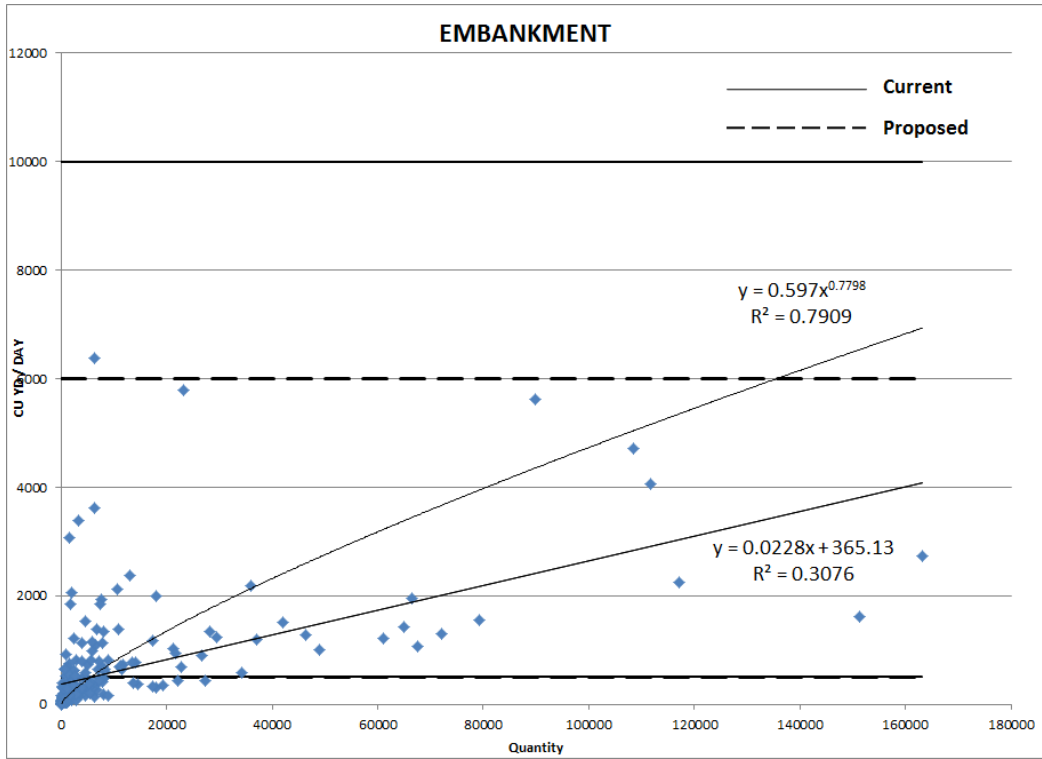


Figure A.2.17 Embankment.

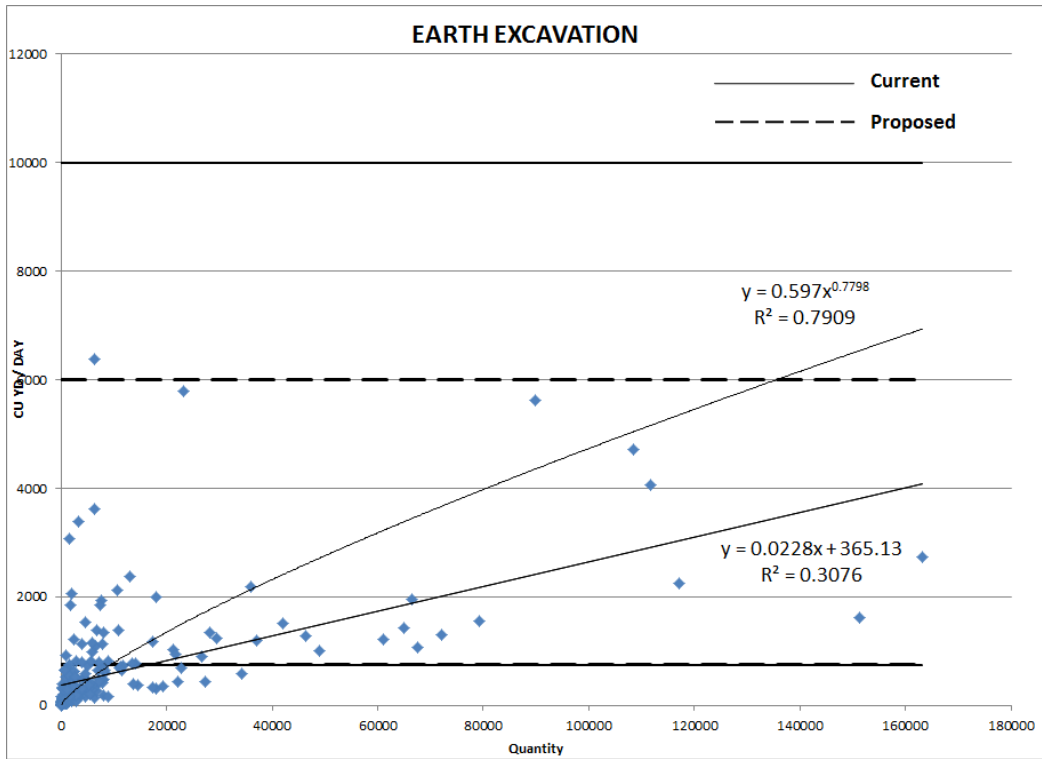


Figure A.2.18 Earth excavation.

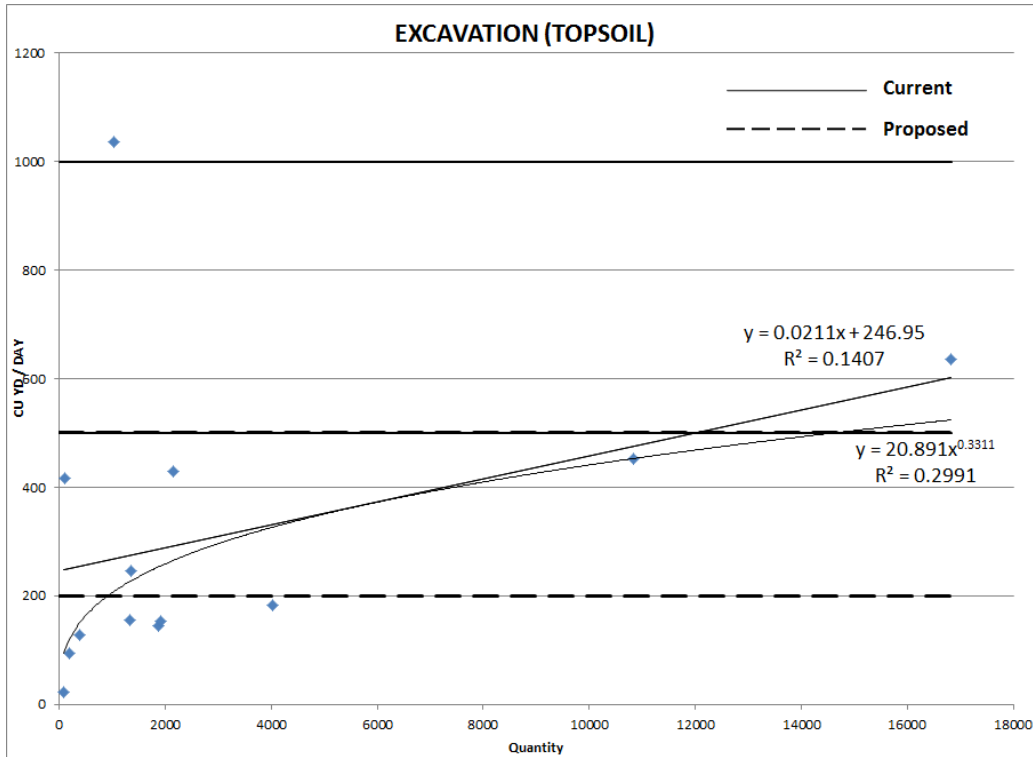


Figure A.2.19 Excavation (topsoil).

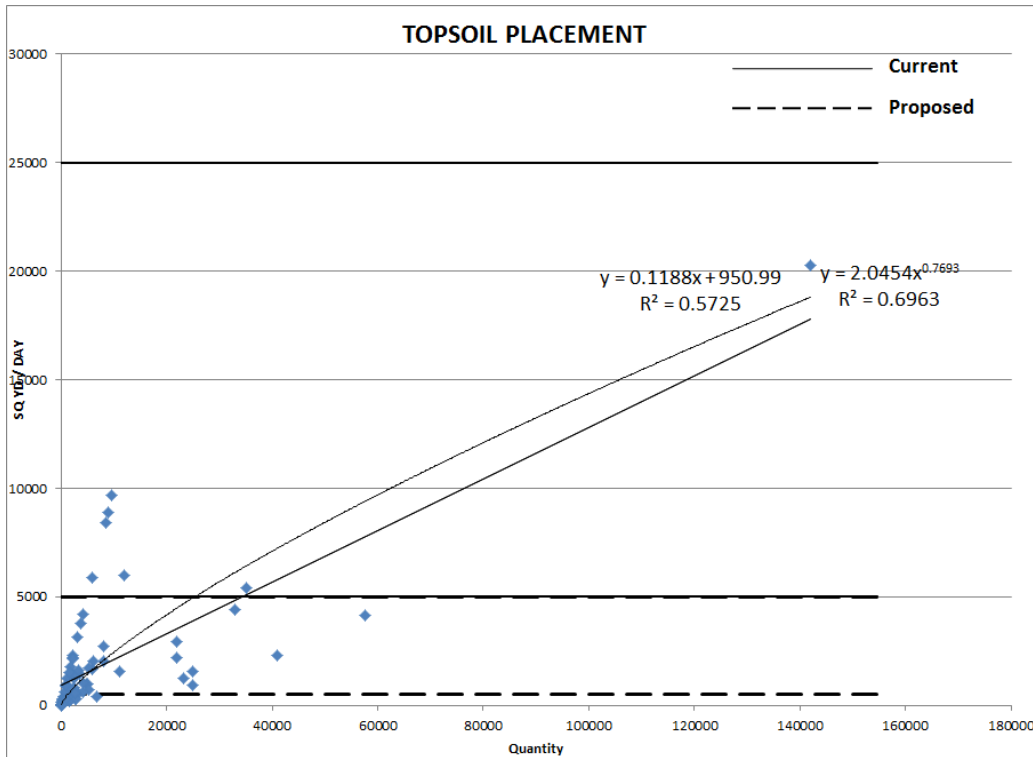


Figure A.2.20 Topsoil placement.

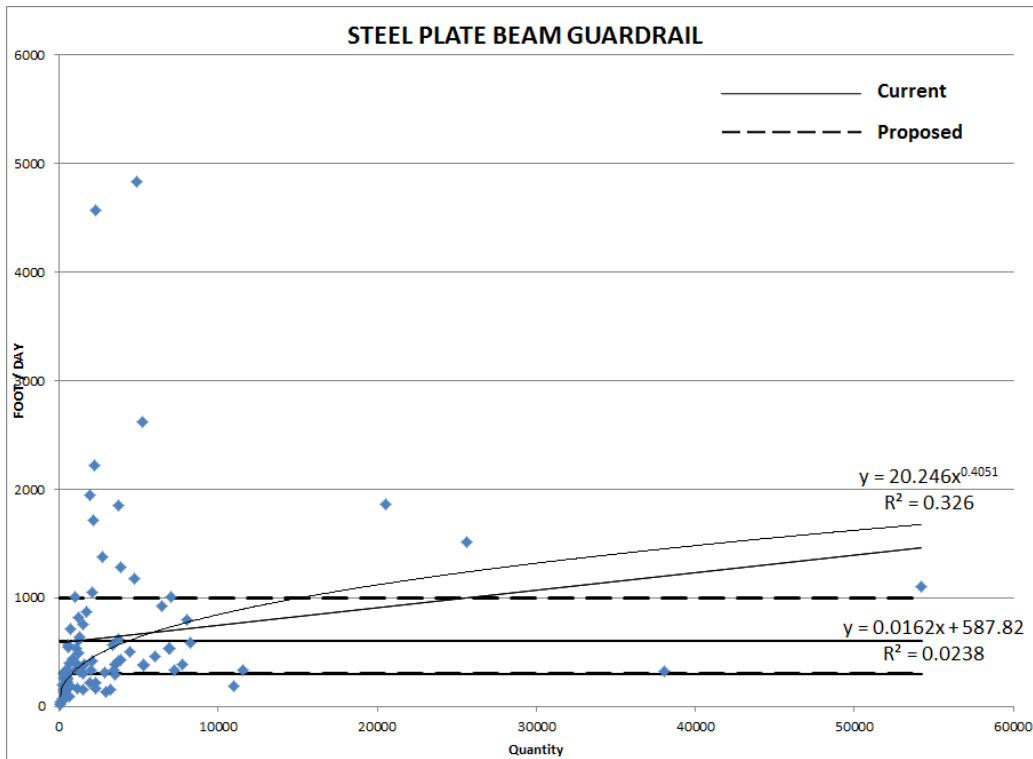


Figure A.2.21 Steel plate beam guardrail.

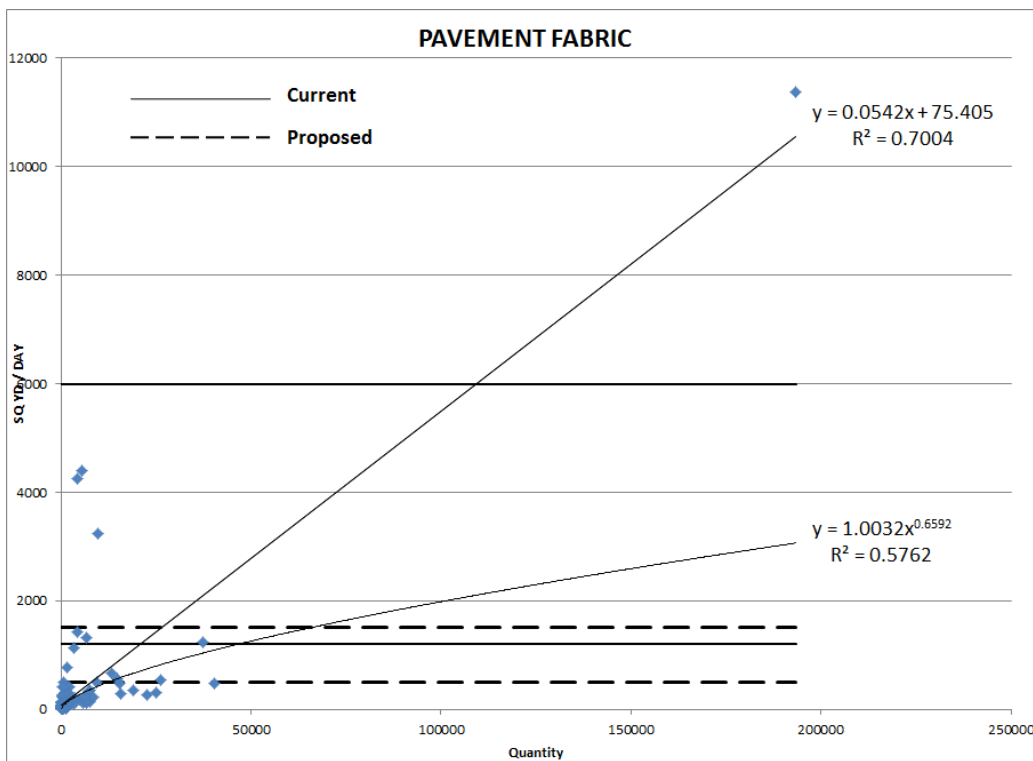


Figure A.2.22 Pavement fabric.

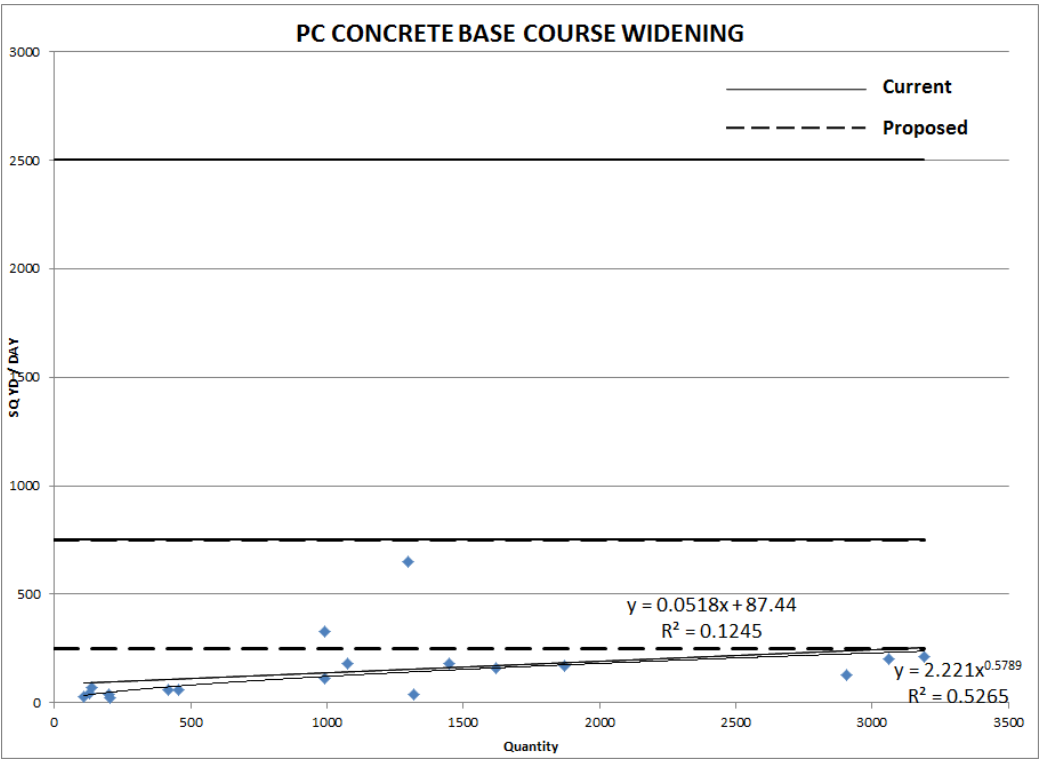


Figure A.2.23 PC concrete base course widening.

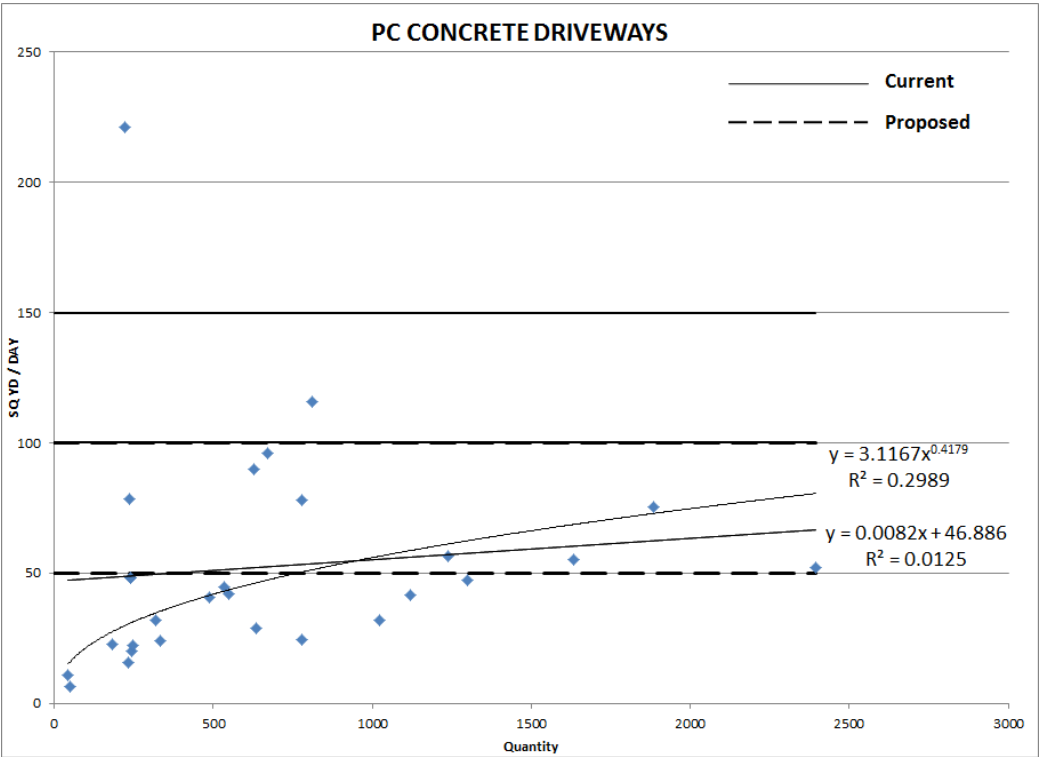


Figure A.2.24 PC concrete driveways.

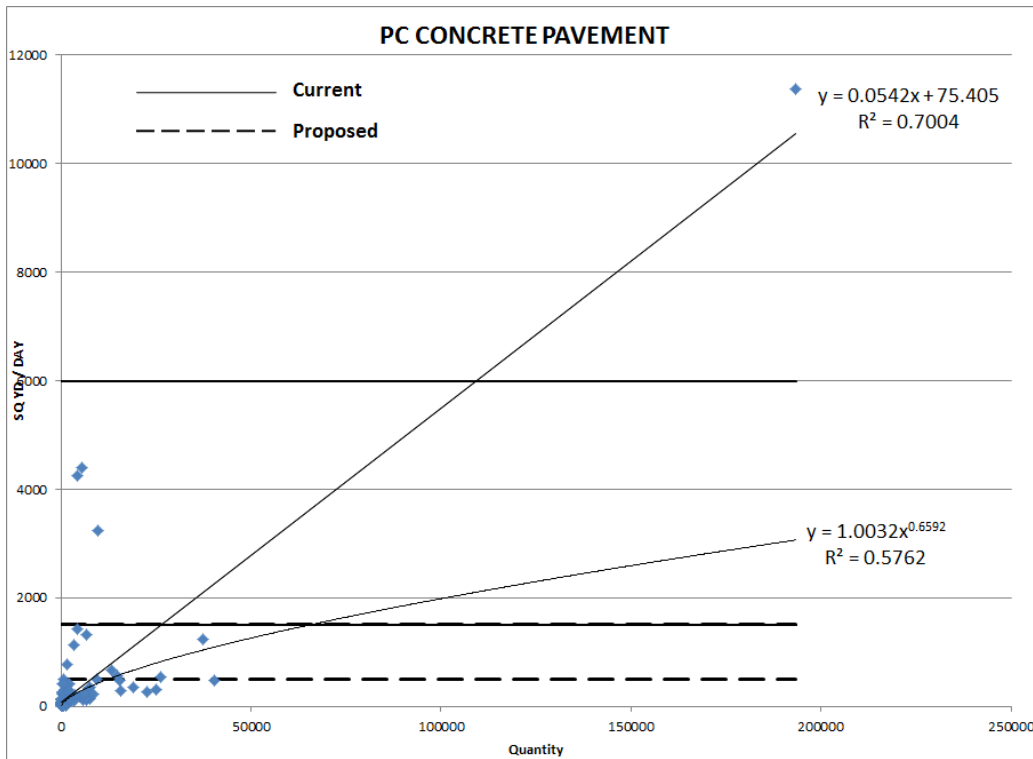


Figure A.2.25 PC concrete pavement.

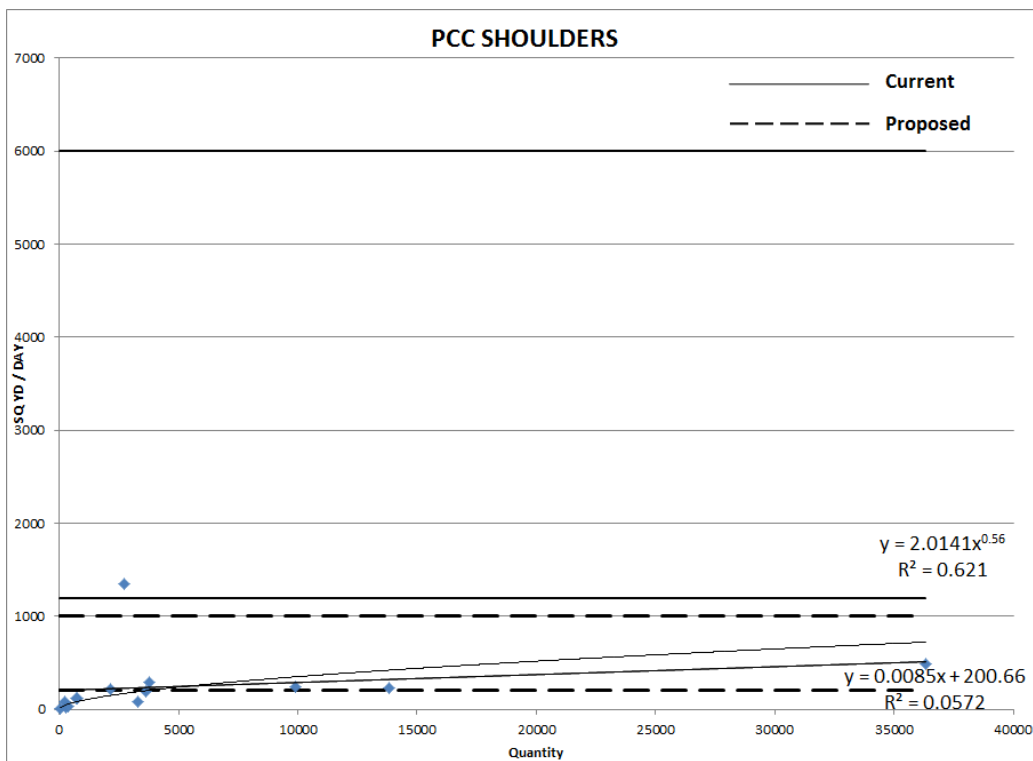


Figure A.2.26 PCC shoulders.

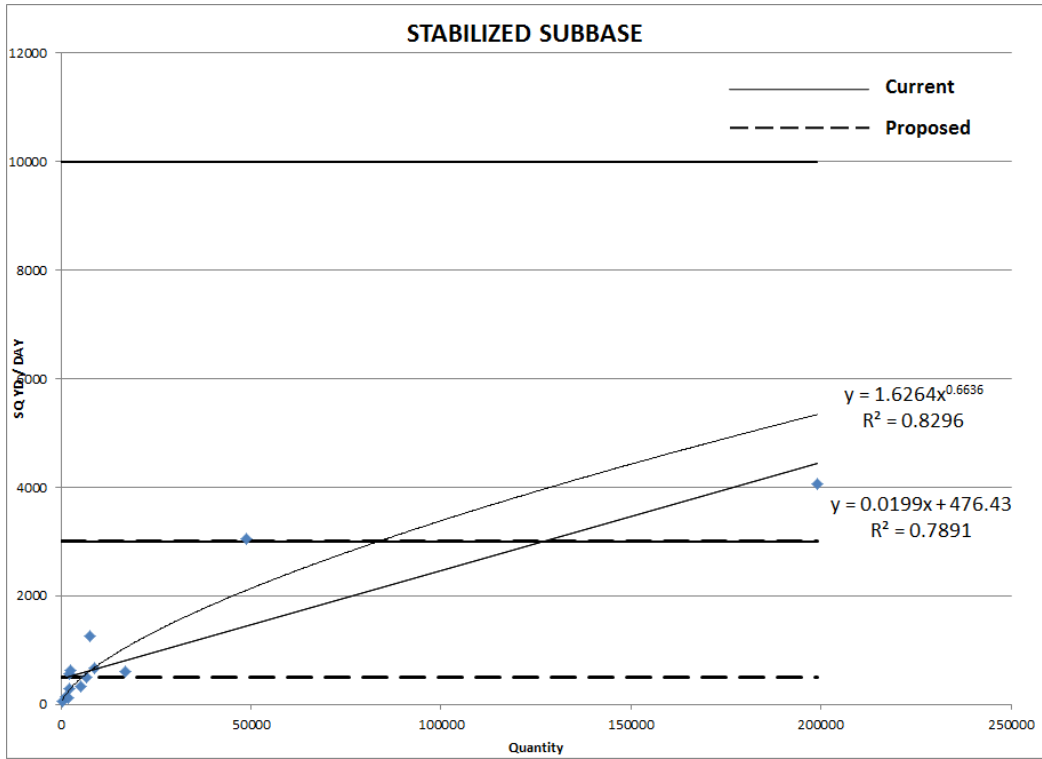


Figure A.2.27 Stabilized subbase.

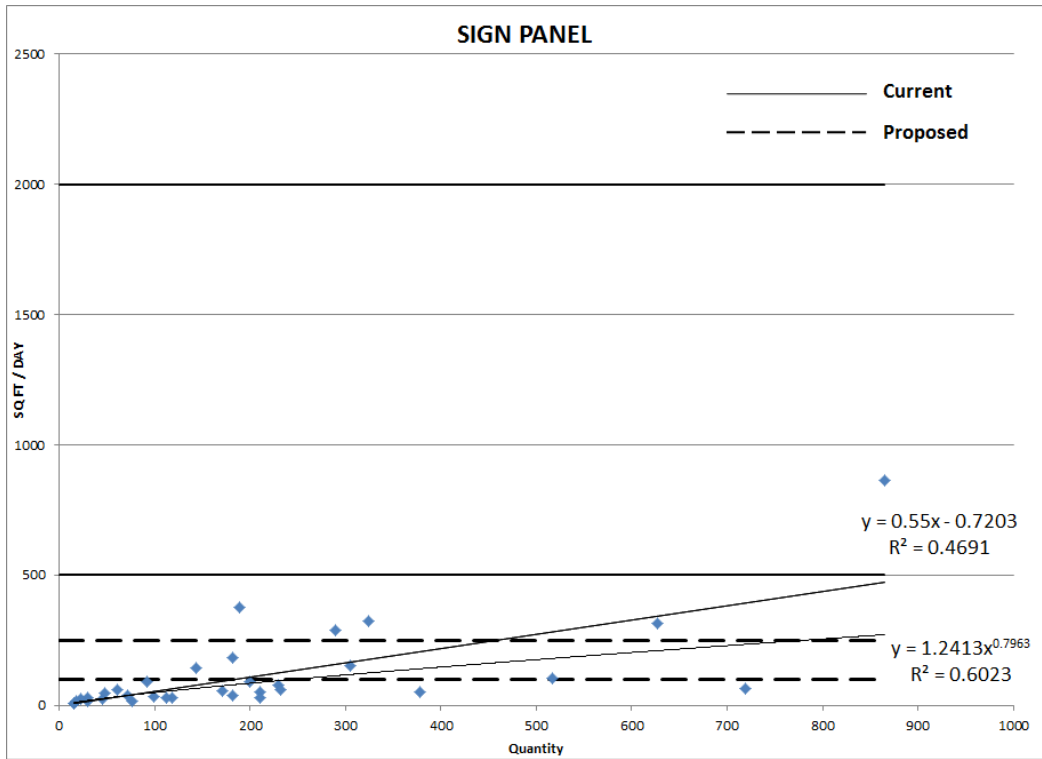
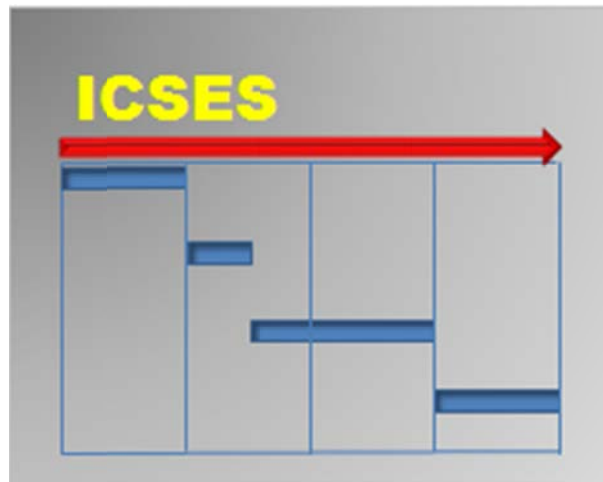


Figure A.2.28 Sign panel.

**APPENDIX 3: ILLINOIS CONSTRUCTION SCHEDULING EXPERT
SYSTEM USER MANUAL**



ILLINOIS CONSTRUCTION SCHEDULING EXPERT SYSTEM

User's Manual

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PREFACE

The Illinois Construction Scheduling Expert System (ICSES) is a Windows-based software program used for planning and scheduling road construction projects. The program is designed to allow users to develop an engineer's estimate of time required to complete road and bridge construction projects.

ICSES was developed by researchers at Missouri State University (MSU) in Springfield, Missouri. The program is the product of research sponsored in two phases by the Illinois Center for Transportation (ICT) and MSU. Principal researchers on the project were Dianne K. Slattery, Ph.D., P.E., Kerry T. Slattery, Ph.D., P.E., and Richard D. Bruce, Ph.D.

ICSES was designed and written by Kerry Slattery. Program documentation and this user manual were written by Kerry Slattery and Dianne Slattery. Project guidance was given by Technical Review Panels (TRPs) consisting of members from the Illinois Department of Transportation (IDOT) and the Federal Highway Administration (FHWA).

Special thanks go to Phase I TRP chairman Mike Ripka and members Jerry Cameron, Kensil Garnett, Michael Hine, Al Mlacnik, John Negangard, Ted Nemsky, and Dan Wilcox. Members of the Phase II TRP were Ted Nemsky (chair), Kensil Garnett, Mike Hine, Frank Lowry, Alan Mlacnik, John Negangard, Tim Padgett, Mike Ripka, and Eric Therkilden.

DEFINITIONS AND ACRONYMS

BDE — Bureau of Design and Environment

HMA — Hot-Mix Asphalt

ICSES — Illinois Construction Scheduling Expert System

ICORS — Illinois Construction Record System

ICT — Illinois Center for Transportation

IDOT — Illinois Department of Transportation

SSRBCI — Standard Specifications for Road and Bridge Construction in Illinois, adopted January 1, 2012

JOB TYPES

GRADING — Grading

ROAD NEW — Roadway New Alignment

RESURF — Resurfacing

RECON — Roadway Reconstruction

INTERS — Intersection Reconstruction

URECON — Urban Reconstruction

PRPCC — Patching and Resurfacing, Portland Cement Concrete

BRIDGE NEW — Bridge New Construction

BREHAB — Bridge Rehabilitation

BRECON — Bridge Reconstruction

MULTI — Multiple Stage

BACKGROUND INFORMATION

The Illinois Department of Transportation (IDOT) identified a need to improve engineers' estimates of time required to construct typical IDOT projects. A research team from Missouri State University (MSU) was selected to perform the work outlined in a Request for Proposal for Illinois Center for Transportation (ICT) project, "An Expert Systems Approach to Highway Construction Scheduling" (R27-86). The project began July 1, 2010, and was completed June 30, 2011.

The primary objective of this research was to develop a software tool to assist highway designers in developing more accurate estimates of the time required to complete highway construction projects in Illinois; and to examine the statewide winter exclusion period and evaluate which construction operations might be carried out in parts of the state during that time based on historical weather records.

Interviews with highway construction contractors, input from IDOT design and construction personnel, records from the Illinois Construction Record System (ICORS), and published reports from the other state DOTs and reference sources provided expert knowledge on how planning and scheduling of highway projects is carried out, the work activities that typically affect project duration (controlling items), and the production rates of those work activities.

Using these sources, the researchers developed project templates for 12 project types and guidance to assist designers in selecting the production rates for controlling items. Each template will present a bar chart project schedule showing only the controlling items. Concurrent activities that may be required to complete the project but are not likely to impact the project completion date are not shown.

Constraints on the project can be selected, including the current projected number of working days per month as specified in Figure 66-2C of the IDOT *Bureau of Design and Environment Manual* (BDE manual) and the winter exclusion period of December 1 through April 30. Historical temperature and rainfall records can be selected to allow users to study the impact of various start dates, the likely project-specific weather throughout the calendar year, and other project-specific constraints such as protection of bat habitat or restrictions on road closure dates.

Weather-related constraints on controlling items were referenced to the *Standard Specifications for Road and Bridge Construction in Illinois* (SSRBCI) adopted January 1, 2007. The researchers used the production rates for activities listed in Figure 66-2B of the BDE manual as the standard for naming controlling items, but they updated the term "bituminous" to "HMA" for consistency with the SSRBCI.

After the duration of each of the controlling activities for a project has been determined, the user is given the projected number of working days, the projected number of calendar days, and a completion date for the project.

GETTING STARTED

SYSTEM REQUIREMENTS

ICSES will work on computers running the Windows XP or Windows 7 operating system. Computers running Windows 8 must have .NET Framework 3.5.1 loaded. Display resolution should be at least 1280 × 800 pixels. Contact your systems administrator for questions regarding your computer's display properties.

INSTALLING ICSES

ICSES Version 2.0 is available for download at Build.MissouriState.edu/CPRIME.

USES FOR ICSES

ICSES was designed to develop an estimate of time required for typical highway construction project types for IDOT. The tool references the SSRBCI and Illinois climate data. The scheduling tool uses production rates from Chapter 66 of the IDOT BDE manual, supplemented with guidance derived from a variety of reference sources. Historical production rate data extracted from the ICORS data on hundreds of recent IDOT projects are also available through the software.

EXITING ICSES

To close ICSES, use the File function on the Menu bar and select Exit. You will be prompted to save the project before closing.

USER INTERFACE

The **Illinois Construction Scheduling Expert System (ICSES)** opens with a form that allows you to choose to begin a new project or open an existing project (Figure 1).

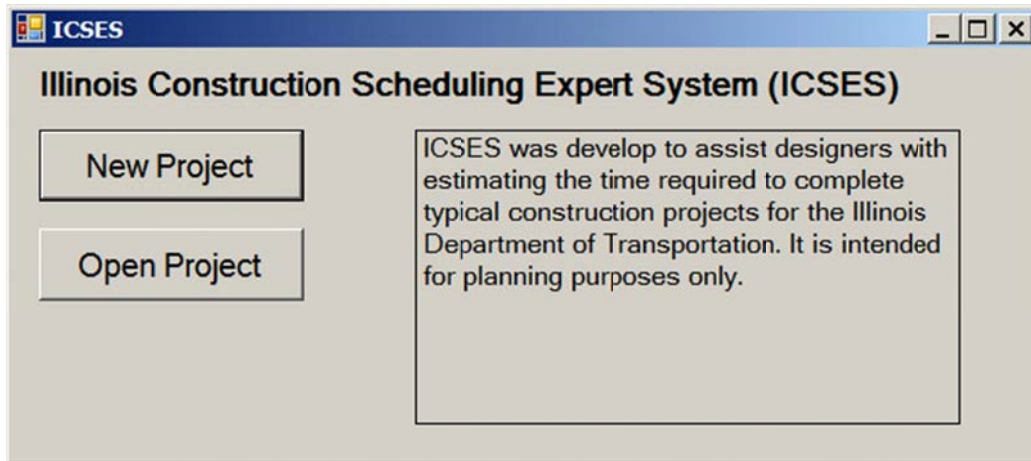


Figure 1. Illinois Construction Scheduling Expert System form.

NEW PROJECT

Click the New Project button to open the New Project form (Figure 2). This form allows the user to develop the project start date, enter project information, and select/review the project template.

Step 1: Choose a Project Start Date

ICSES opens with a default start date computed to be 45 days after the next IDOT letting after today's date. The project start date can be set in one of three ways: choose the anticipated letting date, enter the start date or select the date from a calendar. Expanding the Letting Date drop-down box displays standard IDOT letting dates for a 3-year period from the current date. When the letting date is selected, the program will calculate the start date based on the default number of days to award (30) and default number of days to start (15). These default values can be modified on the form.

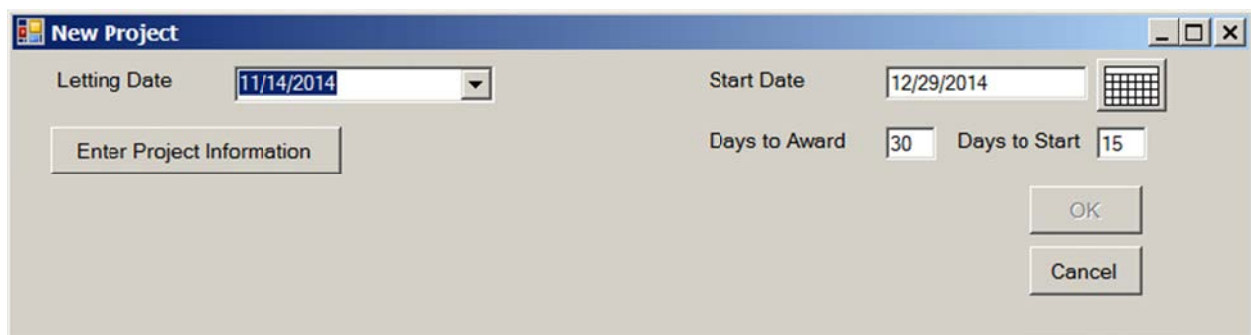


Figure 2. New Project form.

Step 2: Enter Project Information

Click the Enter Project Information button to open the Project Information form (Figure 3). Select the district and county from drop-down lists. You may enter appropriate identifying designations in the Project, Route, Section, and Description text boxes (optional). This information will be displayed in the BDE Form 220 that is generated at the end of the schedule development, and it may be added later if not completed here. The default project entry name is NewProject. A specific project name may be entered and will become the default name for project files.

Click OK to close the Project Information form and return to the New Project form.

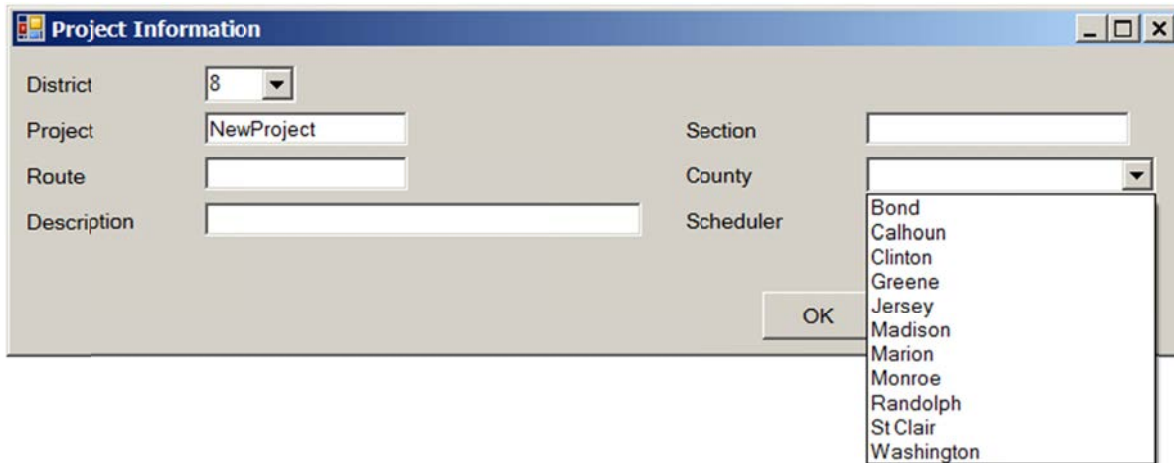


Figure 3. Project Information form.

Step 3: Select Project Type

Select the project type on the New Project form (Figure 4) from a drop-down list of standard templates for ten common project types: Grading, Roadway New Alignment, Resurfacing, Roadway Reconstruction, Intersection Reconstruction, Urban Reconstruction, Patching, Bridge New Construction, Bridge Rehabilitation, and Bridge Reconstruction. These templates represent a starting point for creating a project schedule and can be modified by adding, deleting, or renaming activities.

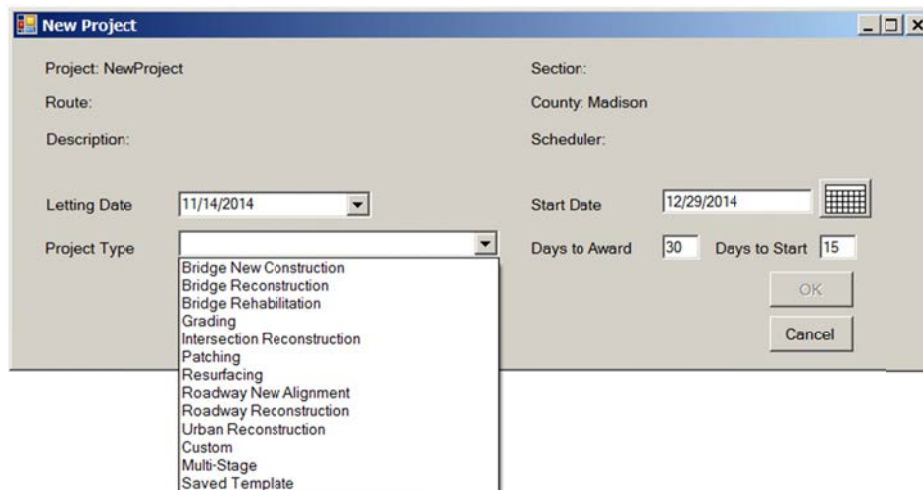


Figure 4. Select the template in the New Project form.

The Custom template consists of the first and last activities: mobilization and checkout/acceptance. You create the project template by adding relevant activities from a list of standard items. The Multi-Stage template option allows you to construct a project with multiple standard or custom templates in series. Selecting Saved Template prompts you to choose a template created previously by modifying a standard template. These are stored in *.est files and may be shared among users.

Each standard template represents the “critical path” for completing a project and lists only the construction activities that typically control the schedule for each project type. Construction activities are listed in the typical order of performance, and they occur sequentially. Activities that may be performed concurrently with the controlling items but would not affect the schedule do not appear in the template.

Step 4: Review Schedule

Click the Review button (Figure 5) to display the Template Review form (Figure 6). This form lists the template Activities with their Predecessors and Units. Figure 6 shows this form for the Roadway New Alignment template.

The 'New Project' dialog box contains the following fields and controls:

- Project: NewProject
- Route:
- Description:
- Section:
- County: Madison
- Scheduler:
- Letting Date: 11/14/2014
- Start Date: 12/29/2014
- Project Type: Roadway New Alignment
- Days to Award: 30
- Days to Start: 15
- Buttons: Review, OK, Cancel

Figure 5. New Project form; Review button displayed.

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Mobilization	0		C DAY	1
2	Tree Removal	1		UNIT	150
3	Earth Excavation	2		CU YD	5375
4	Process Lime Stabilized Soil	3		SQ YD	4250
5	Gravel or Crushed Stone Base Course	4		TON	950
6	HMA Pavement	5		SQ YD	1500
7	Pipe Underdrains	6		FOOT	4500
8	HMA Shoulders	7		SQ YD	3000
9	Paint Pavement Marking (Truck)	8		FOOT	15000
10	Thermoplastic Pavement Marking	9		SQ FT	675
11	Seeding	10		ACRE	7.5
12	Raised Reflective Pavement Markers	11		EACH	150
13	Checkout / Acceptance	12		C DAY	1

Buttons: Accept, Cancel, Save Revised Template, Calculate Production, BDE Average

Figure 6. Template Review form.

Combine quantities for similar items (e.g., HMA binder and surface course) as necessary. The default daily production rate is the numerical average of the low and high values from Figure 66-2B of the BDE manual. You may modify these rates by entering new values into the Daily Production box.

For more guidance on production rates, you can check the Calculate Production box in the lower right corner of the Template Review form. The production rates displayed will be modified according to one of three models: the BDE 66-2B average rate, a linear regression (straight-line fit), or a power law (curved-line fit) of historical data on quantities versus actual production rates on completed IDOT projects. Toggle the BDE Average button to select the linear regression or power law model.

The use of historical data is described in more detail in the Production Rate Data section of this manual. In most cases, you will further refine these preliminary production rate values during Step 6: Review Preliminary Schedule. Quantities can be entered for the first time or modified during the schedule review process.

Modifying Project Templates

You can accept the template as presented or modify it. Predecessors can be changed by modifying the numbers. The default precedence is finish-to-start; that is, if activity 2 is the predecessor for activity 3, activity 2 must be finished before activity 3 can be started.

A start-to-start precedence can be specified by adding SS+n after the preceding activity number, where *n* is the lag time between the start of the two activities. For example, if activity 3 may begin 4 working days after activity 2 begins, the predecessor for activity 3 is 2SS+4. The lag time can be modified as the schedule is developed and reviewed. Multiple predecessors can be assigned to one activity by adding predecessor activity numbers separated with commas in the text box (e.g., 3, 4, 7). Figure 7 shows examples of these predecessor options.

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Mobilization	0		C DAY	1
2	Tree Removal	1		UNIT	150
3	Earth Excavation	2SS+4		CU YD	5375
4	Process Lime Stabilized Soil	3		SQ YD	4250
5	Gravel or Crushed Stone Base Course	4		TON	950
6	HMA Pavement	5		SQ YD	1500
7	Pipe Underdrains	6		FOOT	4500
8	HMA Shoulders	3,4,7		SQ YD	3000
9	Paint Pavement Marking (Truck)	8		FOOT	15000
10	Thermoplastic Pavement Marking	9		SQ FT	675
11	Seeding	10		ACRE	7.5
12	Raised Reflective Pavement Markers	11		EACH	150
13	Checkout / Acceptance	12		C DAY	1

Buttons: Accept, Cancel, Save Revised Template, Calculate Production, BDE Average

Figure 7. Enter multiple or start-to-start predecessors.

To add or delete an activity in the template, left-click the activity name to display three options: Add Above, Delete, and Add Below (Figure 8). Click the activity name again to cancel those choices. Select Add Above or Add Below to add a new activity to the template. A drop-down list of available activities will open (Figure 9). Select the desired activity to add it to the template. The list of available activities is linked to production rate data from historical IDOT construction projects.

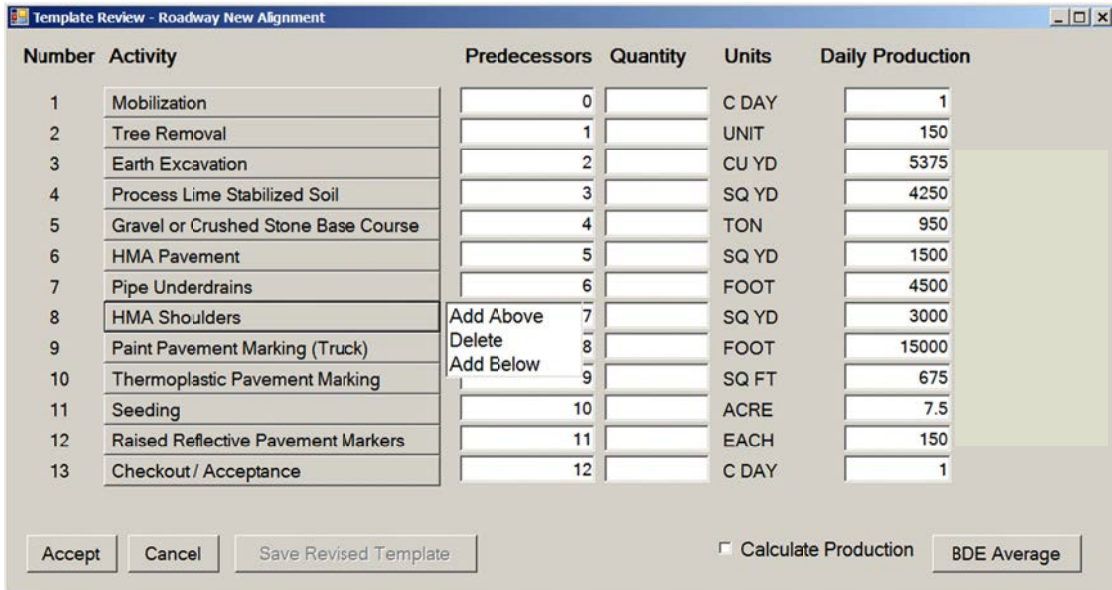


Figure 8. Add Above, Add Below, and Delete options for HMA Shoulders activity.

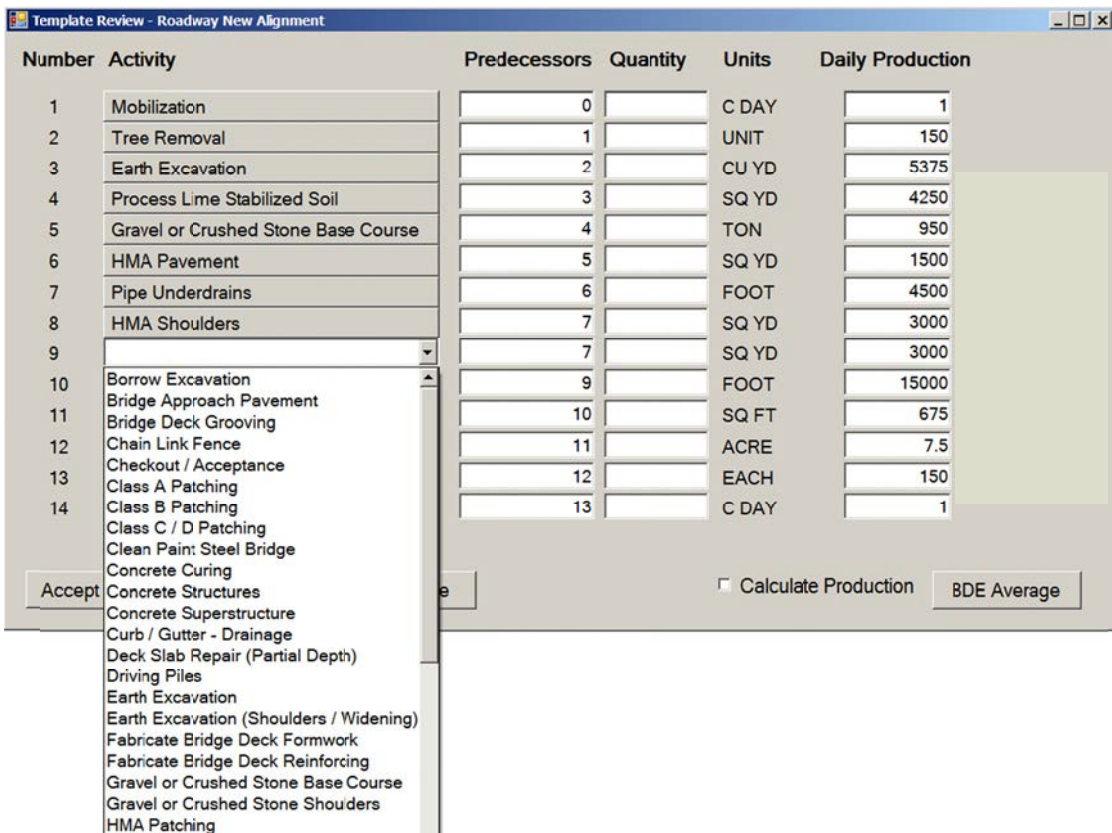


Figure 9. Select an activity to add after HMA Shoulders.

The Delete option removes a selected activity from the template. Predecessors for other tasks are automatically updated but should be reviewed and modified if required. Click the Save Template button to save the modified template to a *.est file for use on other projects.

To change an activity name to one that is more descriptive or helpful in differentiating between multiple instances of the activity, right-click the activity name in the standard template and type in a new name. For example, the first instance of an activity, HMA Binder/Surface Course, may be changed to HMA Binder Course, with the next instance named HMA Surface Course. The production rates will remain linked to the standard activity name.

Click Accept to use the modified template. Click Cancel to revert to the original, default template. Either choice returns you to the New Project form. The Template Review form stays open on the desktop to allow for further modification as the schedule is developed.

Select OK in the New Project form to create the project and proceed to the calendar.

Step 5: Review Calendar

The default calendar includes a 5-day work week, the winter exclusion period from December 1 through April 30, the projected working days per month from Figure 66-2C of the BDE manual (Table 1), and seven standard holidays per Article 107.09 of the SSRBCI.

Table 1. Working Days per Month, from BDE Manual Chapter 66, Figure 66-2C.

WORKING DAYS PER MONTH												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
WORKING DAYS	0	0	0	0	15	17	17	17	16	16	14	0
CALENDAR DAYS	31	28	31	30	31	30	31	31	30	31	30	31

Figure 10 shows the calendar with the four default constraints and their effective dates. The holidays constraint is selected. Days not affected by holidays are shown in **bold** type on the calendar, while days on which holiday restrictions are imposed are not bold (e.g., May 24–26, 2014, for Memorial Day). The current project start date is indicated with a box on the calendar (December 29 for this example).

Constraints

Type	Name	First Day	Last Day	Activity
Holidays	Standard	1/1	12/31	All
Weekends-2 day	Standard	1/1	12/31	All
Holidays	Standard	1/1	12/31	All
Rain-BDE 66-2C	BDE Working Days	1/1	12/31	All
Winter Exclusion	Standard	12/1	4/30	All

Buttons: All Years, Delete, Map/Temp

Calendar Grid (2014):

Month	Sun	Mon	Tue	Wed	Thu	Fri	Sat
January			1	2	3	4	
February		2	3	4	5	6	7
March		2	3	4	5	6	7
April		6	7	8	9	10	11
May		4	5	6	7	8	9
June		1	2	3	4	5	6
July		6	7	8	9	10	11
August		3	4	5	6	7	8
September		7	8	9	10	11	12
October		5	6	7	8	9	10
November		2	3	4	5	6	7
December		7	8	9	10	11	12

Buttons: Save, Close

Figure 10. Calendar form.

Additional constraints will be activated if the project template contains items that have date limitations. For example, the Tree Removal constraint activates an additional default constraint related to the Indiana Bats constraint. Similarly, the Seeding constraint activates a default constraint during summer months in accordance with SSRBCI Article 250.07 (check the specifications for the recommended dates for the project-specific seed mixtures). Both of these activity-specific constraints can be modified or deleted.

The default constraints can be modified to study the impact of

- Allowing work during the winter exclusion period (delete winter exclusion)
- Working 6-day weeks (add weekends-1 day, delete weekends-2 day)
- Expected rain days based on historical rainfall records

The Rain-BDE 66-2C constraint adds enough rain days throughout the month to ensure the number of working days specified in BDE 66-2C (Table 1). Historical rain days are scattered throughout the month and may fall on non-working days, such as weekends or holidays.

Adding Constraints

Figure 11 shows the list of available constraint types. The optional project-specific constraint types (last half of the constraint type drop-down list) are reminders of other constraints that may restrict road closures or impact the contractor's ability to perform work on the project. Examples are utility relocation, permits, long lead-time items such as structural steel, and local events such as grain harvest.

The screenshot displays the 'Constraints' dialog box in a software application. The window title is 'NewProject Start Date: 12/29/2014'. The dialog is divided into several sections:

- Constraint Entry Section:**
 - Type:** A dropdown menu currently showing 'Utility Relocations'.
 - Name:** A text box containing 'Standard'.
 - First Day:** A text box containing '12/29/2014'.
 - Last Day:** A text box containing '6/30/2015'.
 - Activity:** A dropdown menu currently showing 'HMA Patching'.
 - All Years:** A checkbox that is currently unchecked.
 - Add:** A button to confirm the constraint.
 - Map/Temp:** A button for additional options.
- Calendar Section:**
 - Buttons for months: February, 2015; March, 2015; April, 2015; June, 2015; July, 2015; August, 2015; September, 2015; October, 2015; November, 2015; December, 2015.
 - A calendar grid for June 2015 is shown, with the 30th highlighted in blue.
- Activity List Section:**
 - A scrollable list of activities including: Holidays, Weekends-1 day, Weekends-2 day, Rain-Historical, Rain-BDE 66-2C, Winter Exclusion, Indiana Bats, Seeding, Critical Habitats, Critical Land Use, Farm-to-Market Route, Load Limits, Long-Lead Items - Other, Long-Lead Items - Steel Fab, Permits, Public Events, Utility Relocations, and Other.
- Bottom Section:**
 - Save:** A button to save the constraint.
 - Close:** A button to close the dialog.

Figure 11. Select constraint type.

If you wish to consider project-specific constraints, select it from the Type drop-down list, enter a name and select the first day and last day that work is restricted. These dates may be selected by modifying the date in the text box, by dragging the mouse from the first day on the calendar to the last day, or by clicking the first and last days separately. The calendar can be advanced to the next year before clicking the last day, if necessary.

Designate which activity or activities in the schedule template are restricted by the constraint. Expand the Activity combo box to display all available activities. There is an option to select all activities. If a constraint affects more than one activity, but not all, enter different constraints for each affected activity. Check the All Years box if the constraint is identical for every year of the project. When All Years is checked, the date in the display does not include a year. The example in Figure 11 restricts the Earth Excavation activity during Utility Relocation in the first year (2015) of the project. Click Add to add the new constraint.

When a constraint is selected, the Add button changes to Delete. Click the Delete button to remove the selected constraint.

If changes are made to the selected constraint (e.g., dates are changed), the Delete button changes to Modify. Click Modify when changes are complete to save the modifications to the calendar.

Temperature-Based Constraints

Click the Map/Temp button to display a map of Illinois and a list of the activities in the project template that have temperature restrictions (Figure 12). Toggle the Calendar button to return to the calendar.

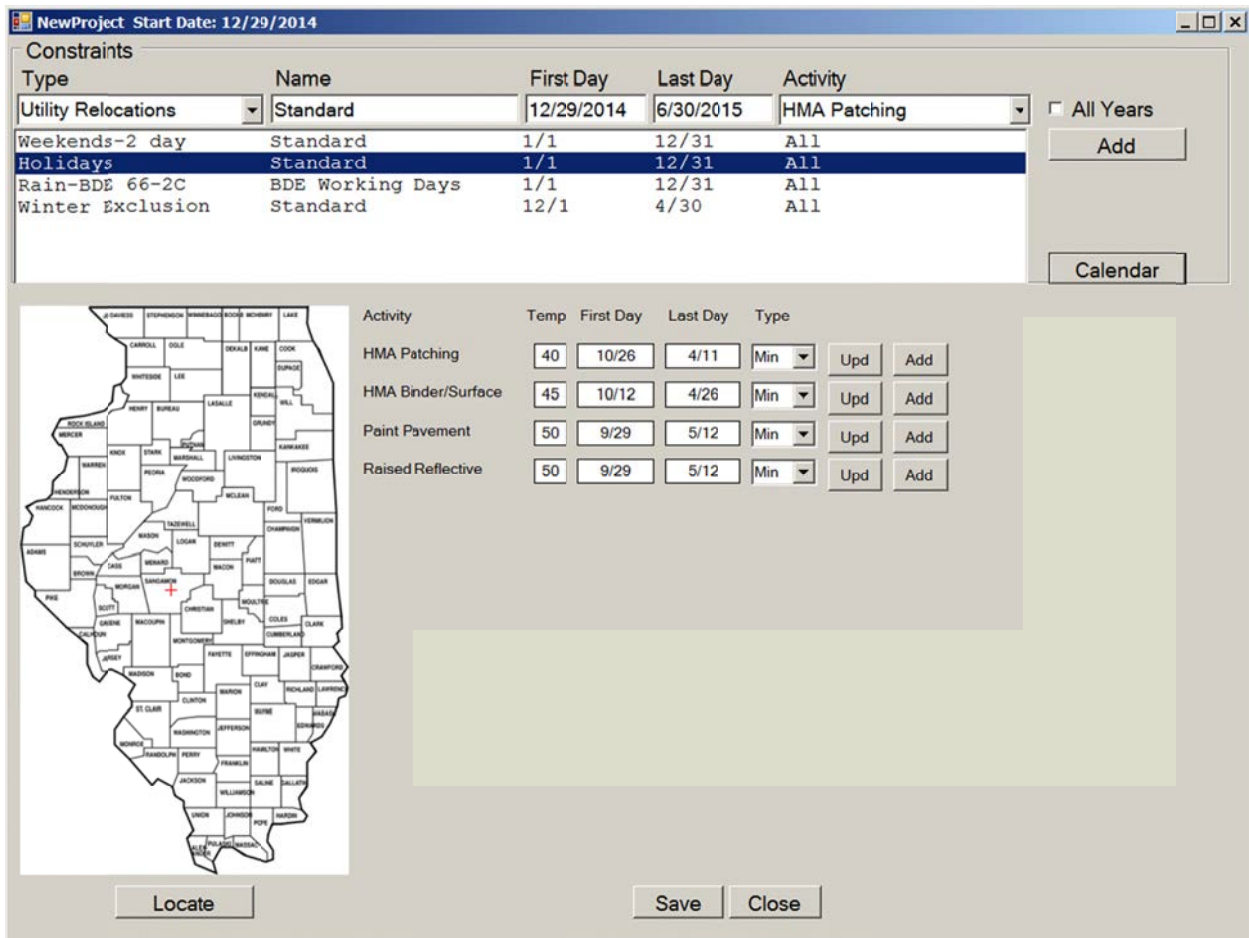


Figure 12. Temperature-based constraint utility.

The county in which the project is located (as entered on the Project Information form) will be marked with a red cross. The default location near the center of the county may be revised by clicking on the approximate project location, but doing so will not significantly affect the results. The program accesses historical temperature records and determines the first day and last day on which the average minimum temperature crosses the threshold for each temperature-limited activity. These dates are displayed as shown in Figure 13.

Three types of temperature data are available: average minimum, average mean, and average maximum daily temperature. The default type is the minimum temperature. You may change the threshold temperature, the first day and last day, and the type. The Upd (update) button must be clicked after changing the temperature or type to update the first and last days based on historical

temperature records. If the Upd button is clicked after the first day or last day has been manually changed, the values will revert to historically based dates.

Click the Add button next to each of the temperature-based constraints to add it to the list of constraints for the project. Only constraints shown in the Constraints box will be used in computing the schedule.

Click Save to save changes to the project constraints. Click Close to exit the calendar and display the preliminary project schedule.

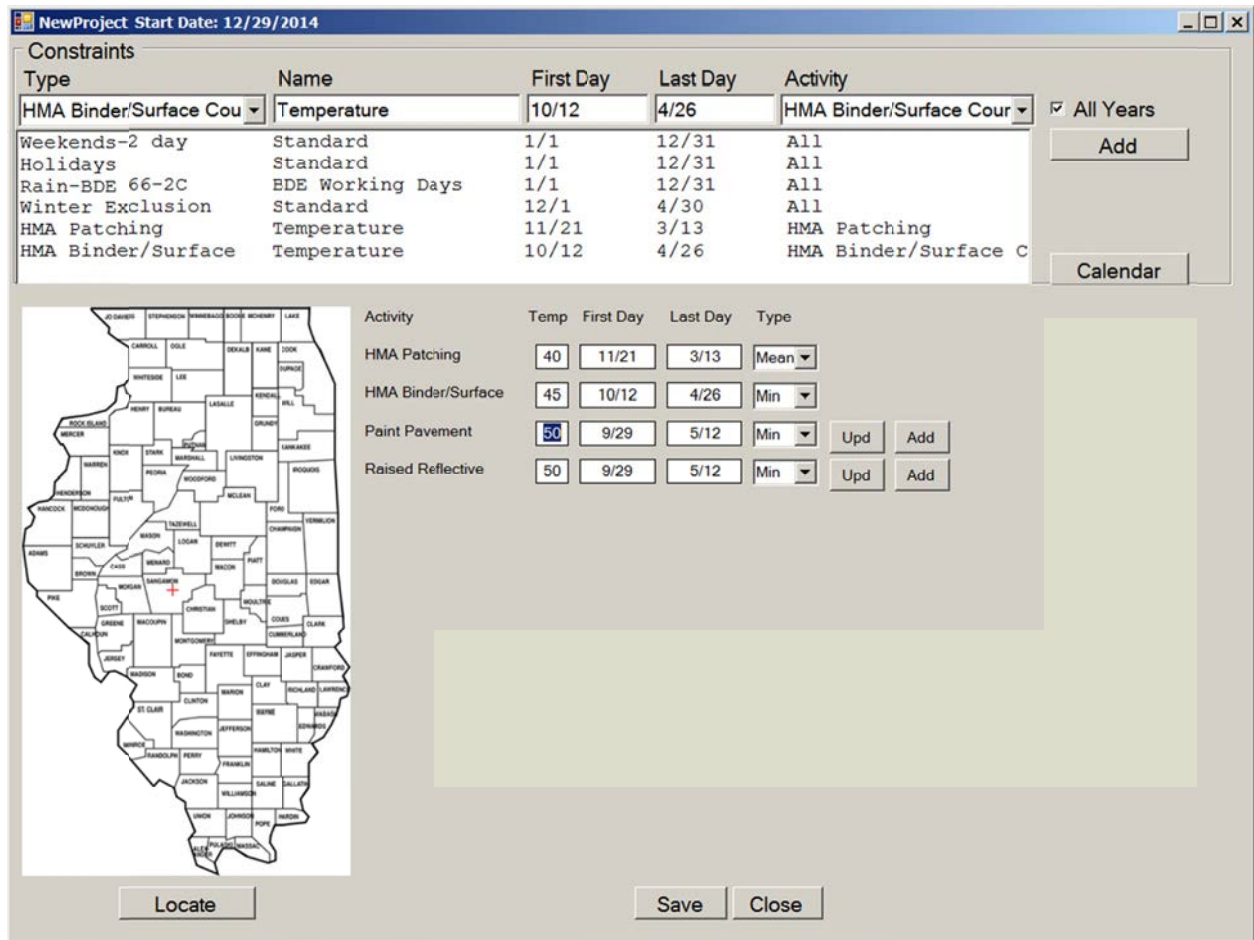


Figure 13. Location/activity-based temperature constraints defined.

Step 6: View Preliminary Schedule

A color-coded bar chart schedule is displayed, showing the name, order, duration, and predecessors for all activities in the project template. A key to the schedule colors, along with start date, completion date, number of working days, and number of calendar days, is displayed (Figure 14). The bar colors indicate which constraint is expected to prevent work on a given day. Yellow days are working days. The key for other bar colors is provided below the chart. Scroll bars on the right side and across the bottom of the schedule allow you to examine the entire schedule.

If no quantities were entered in the Template Review form, all activities are arbitrarily assigned a default duration of five working days. If quantities were entered in the Template Review form, activity durations will be based on the quantity and the production rate model selected (e.g., BDE average,

linear regression, or power law). The red background color on the Duration buttons (Figure 14) indicates that the preliminary durations have not been reviewed.

In Figure 14, the top bar chart shows the beginning of a project (Roadway New Alignment) that begins on 9/14/2015. The Tree Removal activity cannot begin until October 1 because of the Indiana bat roosting dates. The bottom bar chart, accessed by scrolling to the right, shows the first estimation of the end of the project on 6/20/2017.

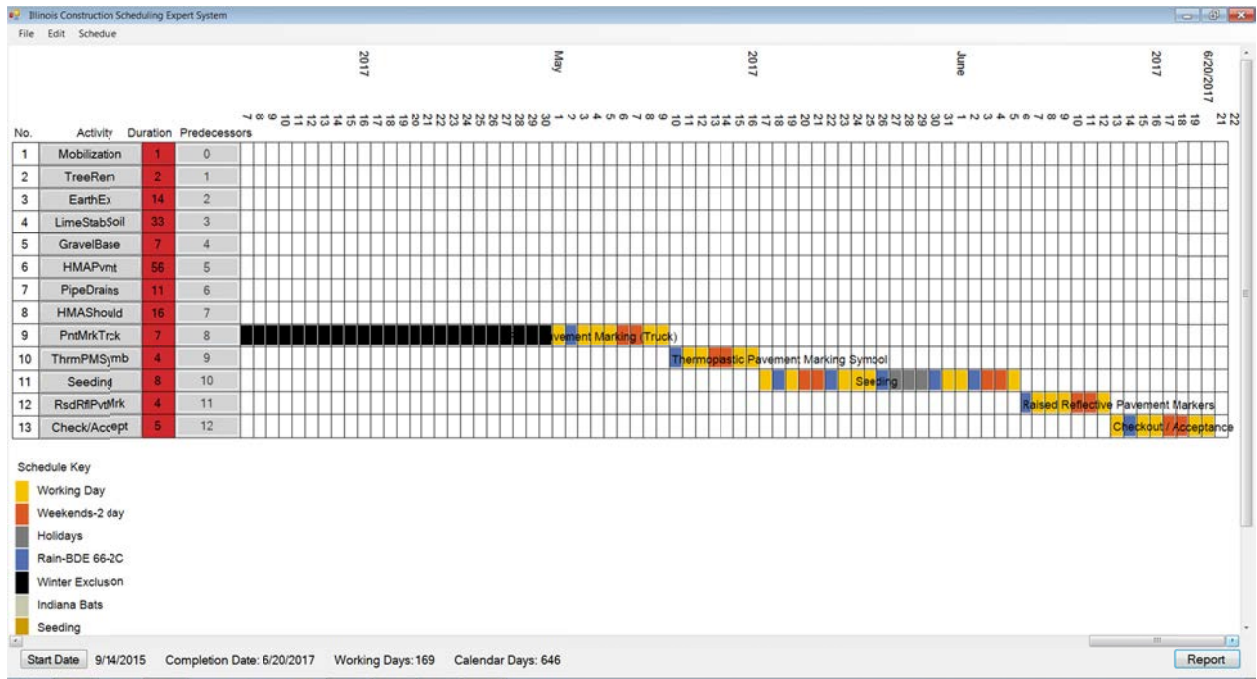
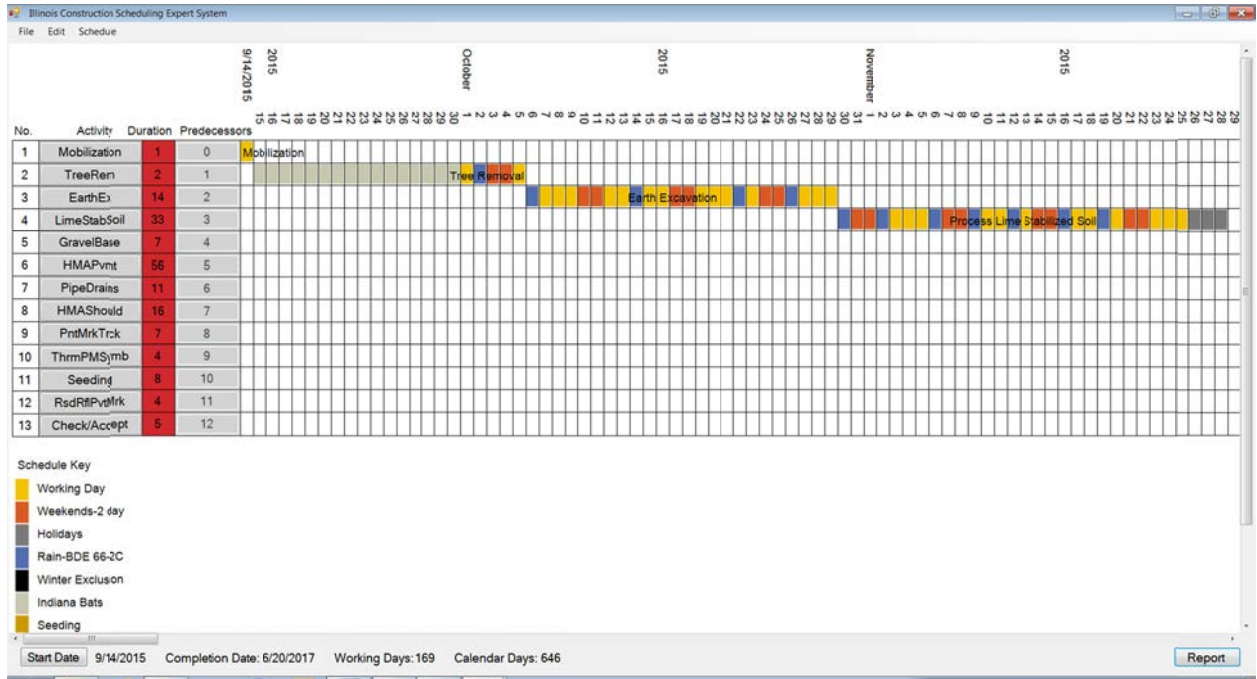


Figure 14. Preliminary bar chart schedule.

Step 7: Finalize the Schedule

Evaluate the start and end dates, and update the duration of all activities based on the project quantities and expected production rates for the controlling items listed in the project template.

Start Date

The start date for the project can be modified by clicking the Start Date button in the lower left corner of the Schedule form. Enter the new start date when prompted and click OK in the input box to update the entire schedule. This may take several seconds for some multi-stage schedules. The Start Date button is disabled when the update begins and will be enabled when the process is finished.

Review/Edit Activity Duration

Click on an activity in the left column to open the Activity Duration Estimation (ADE) form. Figure 15 shows the ADE form for the Earth Excavation activity. If a quantity for Earth Excavation was entered on the Template Review form, it will appear in the Quantity box. If no quantity was previously entered, or if the quantity needs to be modified, enter it in the Quantity box.

ADE forms provide guidance on how to estimate the production rate, based on a typical production rate for one crew. If you entered or calculated a production rate value in the Template Review form, this value will appear in the Crew Production box. Assign multiple crews to an activity by typing in the # Crew text box. A new duration is calculated and rounded up to the nearest integer. The Notes box in the lower right corner of the form allows you to document the assumptions made or reasons for selecting this duration, if desired.

Additional production rate data from various references are provided on the form when available. The current low and high productivity values from the BDE manual are shown, along with the calculated average value. The three references are Reference 1 (O'Connor et al. 2004), Reference 2 (Atreya 2007), and Reference 3 (IDOT District 5 Production Rate Data).

Reference	Min	Avg	Max	Unit
IDOT BDE: Earth Excavation	750	5375	10000	CU YD/day
Reference 1: Excavation	199	1163	3558	cy/crew day
Reference 2: Unclassified Roadway Excavation/Borrow	1800	2825	7000	cy/crew day

Figure 15. Activity Duration Estimation form.

Finally, historical production data from IDOT projects can be viewed graphically on the Production Rate Data (PRD) form. The production rate for an activity on any given project is likely to be influenced by the quantity of work for that particular activity. Contractors are expected to mobilize additional resources or use more efficient production methods on activities with large quantities. These data are available through ISCES for controlling activities.

The data and simple regression analyses of the data are intended to assist in determining an appropriate production rate. The values calculated from the regression analyses based on the quantity are not intended to be used as the *exact* production rate. These values were available in the Template Review form to be used as preliminary production rates, but the final production rate to be used in the schedule should be based on your experience and understanding of the project—*combined* with the results of the ICSES software.

Click Review Data on the ADE form to see a data plot of production rate versus quantity (Figure 16) for all currently available data. The project quantity for Earth Excavation (75,000 CY) is indicated with a vertical line. The values at which this quantity intercepts the linear regression fit through the production rate data (2170 CY/day) and the power law fit (4304 CY/day) are indicated on the graph. The maximum quantity (162,379 CY) and the maximum production rate in the data set (7355 CY/day) are indicated on the X and Y axes, respectively.

The data can be filtered by checking/unchecking boxes to view data by district, job type, quantity (greater than or less than a specified quantity), or duration (greater than or less than a specified number of days). Hover the mouse over any abbreviation shown in the Job Type list to display the full name. The named job types correspond to the ten templates available in the ICSES program. Several other job types in the database occur infrequently or have few activities (e.g., cable guardrail repair). Data from these job types are included in the Other category.

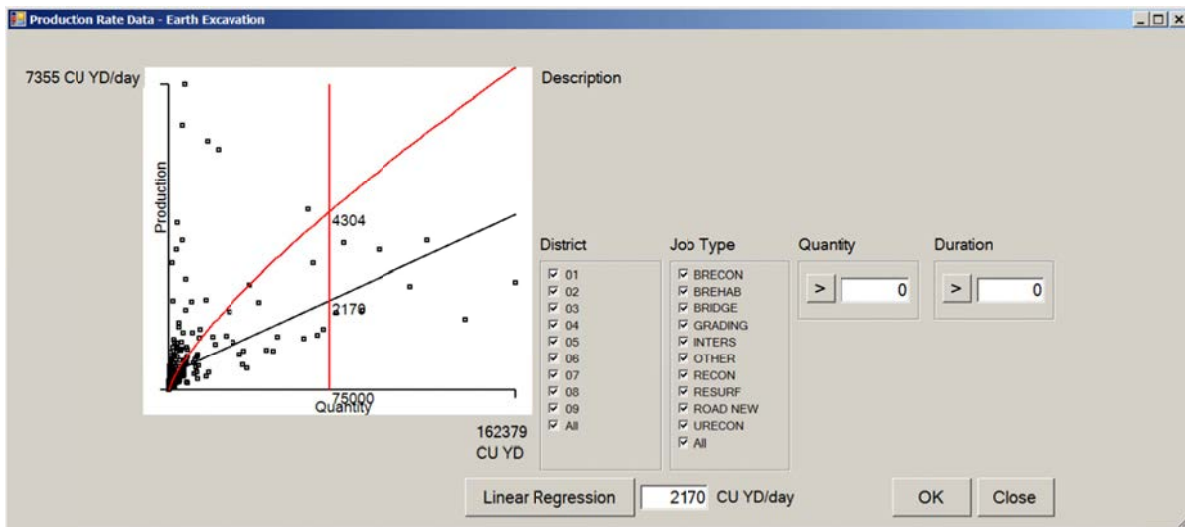


Figure 16. Production Rate Data form.

Right-click on any data point to delete that point from the displayed data and from the regression calculations. Data points that are obvious outliers can be removed this way. The regression analyses are automatically updated when the collection of data points is modified. All data points can be restored by closing the Production Rate Data form and reopening it by clicking Review Data in the ADE form.

Left-click on any data point in the plot to view information on the project from which it was derived (Figure 17). Here, clicking the data point indicated by the blue arrow gives information for a project reconstructing Ridge Road beneath Interstate 80 (District 3) in which 67,446 CY of Earth Excavation was completed at a production rate of 3065 CY/day. After considering all relevant guidance, you select a production rate or duration for the activity.

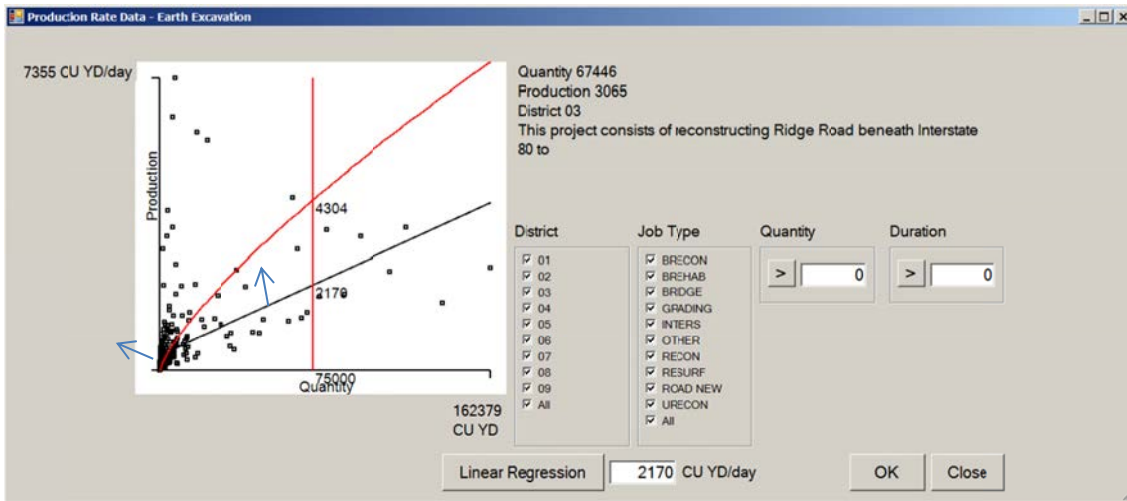


Figure 17. Historic production rate information.

The plot and regression analyses are updated after any change to the data pool. The value of the linear regression function at the activity quantity is shown next to the linear regression button. Toggling that button will show the production rate based on the power law regression. You can modify the production rate shown. For example, you may choose to manually round the value. Clicking OK closes the Production Rate Data form and transfers the production rate to the ADE form. Clicking Close just closes the Production Rate Data form without making changes to the ADE form.

Click OK to accept or click Close to reject the suggested production rate on the PRD form and return to the ADE form. If applicable, a new production rate appears in the Crew Production box, and the duration is modified.

Click OK on the ADE form to return to the project schedule. The duration of the earth excavation activity is now displayed in green, indicating that it has been reviewed and/or modified (Figure 18). Continue reviewing and modifying activity durations as applicable.

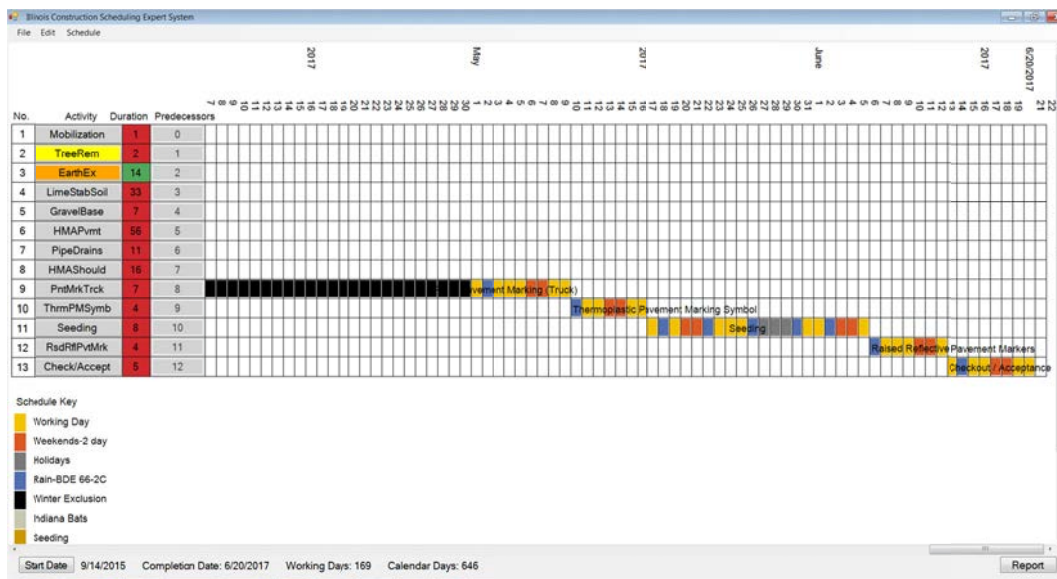


Figure 18. Schedule review process.

Calculators are provided on some ADE forms to assist with estimating. Figure 19 shows the HMA Pavement ADE form for full-depth HMA pavement. The production rate will generally be governed by the tons/hour supplied by the asphalt plant supporting the activity, while the bid quantity is usually given in square yards. The calculator allows you to input additional parameters for the paving job to convert the tons/hour available from the asphalt plant to sq. yd./day.

The production rate for continuous full depth paving is usually governed by the production rate of the asphalt plant supplying the job. Production rate in sq.yd./day will depend on pavement thickness. A typical rate is 200 tons/hour. The number of hours per day will depend on workzone restrictions and day or night work. Smaller areas of pavement will have lower production rates.

Input Parameters	Calculated Values
Thickness: 10 inches	Production: 2130 SQ YD/day
Density: 112.5 lb/sy-in	
Production: 200 tons/hour	
Hours/Day: 6 hours	

IDOT BDE: HMA Pavement	Min: 1000	Avg: 1500	Max: 2000	SQ YD/day
Reference 1: Dense graded hot mix asphalt (method)	Min: 158	Avg: 817	Max: 1460	ton/crew day
Reference 2: Asphalt_ Type A	Min: 440	Avg: 900	Max: 1600	tn/crew day
Reference 3: Bituminous Concrete Binder and Surface Course (Urban)	Min: 500	Avg: 1000	Max: 1500	ton/crew day
Reference 3: Bituminous Concrete Surface (Rural)	Min: 1500	Avg: 1650	Max: 1800	ton/crew day
Reference 3: Bituminous Concrete Binder Course (Rural)	Min: 1600	Avg: 1800	Max: 2000	ton/crew day
Reference 3: Level Binder (Urban)	Min: 1000	Avg: 1250	Max: 1500	ton/crew day
Reference 3: Leveling Binder (Rural)	Min: 1300	Avg: 1400	Max: 1500	ton/crew day

Figure 19. HMA Pavement ADE form.

Step 8: Generate Report

Click the Report button to generate a report of the results in Microsoft Excel (Figure 20). The file contains three worksheets: BDE Form 220, Working Day, and Calendar Day. The BDE 220 worksheet follows the format of the BDE220a.xls spreadsheet. The other sheets are bar charts of the schedule. These bar charts can be resized and formatted for printing as desired.

Illinois Department of Transportation							
					Estimate	of Time	Required
				Route			
				Section			
				County	Sangamon		
				Project			
Item	Unit (Check One) English Metric	Quantity	Rate Per Day	Days	Days Not Affecting Time	Total Days Required	
Mobilization	C DAY	1	1	1	0	1	
Tree Removal	UNIT	300	150	2	0	2	
Earth Excavation	CU YD	75000	9000	9	0	9	
Process Lime Stabilized Soil	SQ YD	140000	4250	33	0	33	
Gravel or Crushed Stone Base Cours	TON	6500	950	7	0	7	
HMA Pavement	SQ YD	84000	1500	56	0	56	
Pipe Underdrains	FOOT	47000	4500	11	0	11	
HMA Shoulders	SQ YD	47500	3000	16	0	16	
Paint Pavement Marking (Truck)	FOOT	100000	15000	7	0	7	
Thermoplastic Pavement Marking S	SQ FT	2500	675	4	0	4	
Seeding	ACRE	60	7.5	8	0	8	
Raised Reflective Pavement Marker	EACH	585	150	4	0	4	
Checkout / Acceptance	C DAY	5	1	5	0	5	
Total Actual Working Days Required						163	
Total Days from page one							
Total Days							
Made by		Date		Checked by		Date	
						Regional Engineer	

Figure 20. Report format.

Open Project

If Open Project was selected in the ICSES form, you are prompted to select the *.esp project file to open.

Schedule Options

ICSES Schedule Form

The ICSES Schedule form is displayed when an existing project is opened or after the Calendar form is saved and closed when creating a new project. The menu bar for the form displaying the ICSES Schedule has three options: File, Edit, and Schedule. A fourth option, Multi-Stage, is provided when this template option is used.

File Options

Save Project/Save Project As

The project can be saved at any time. The Save Project As option allows you to save the project under a new name. The previously saved version will be retained under the old name.

Exit

Select Exit to exit the program.

Edit Options

Calendar

You can edit the project calendar to characterize work restrictions due to weather and other constraints. Weekends, holidays, expected rain days, and days that are too cold to perform work on controlling items are identified. You can also enter other types of constraints related to local and job conditions that will restrict when work is allowed. In multi-stage projects, the calendar for the current stage is displayed for editing.

Project Information

Selecting Project Information opens the Project Information form (Figure 3) to edit these entries.

Schedule Option

Refresh

You can select Schedule | Refresh at any time; however, the schedule is automatically refreshed after any change, so this will rarely be necessary.

Multi-Stage Options

Stage n

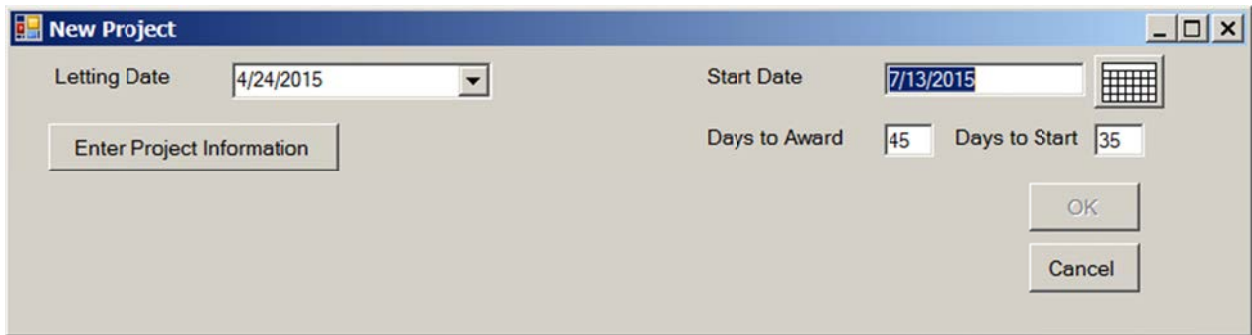
You can select the desired stage for editing. The appropriate bar chart schedule will be displayed. If Edit | Calendar is selected, the calendar for that stage will be shown to allow you to add or modify constraints.

EXAMPLES

EXAMPLE 1: RESURFACING PROJECT

This example is based on a project from Vermilion County completed in 2009. The example project will be planned in 2015 to take place during the same time of year.

Run ICSES and select New Project. Select the April 2015 letting date. Change the Days to Award field to 45 and Days to Start field to 35. Click the Enter Project Information button (Figure 21).

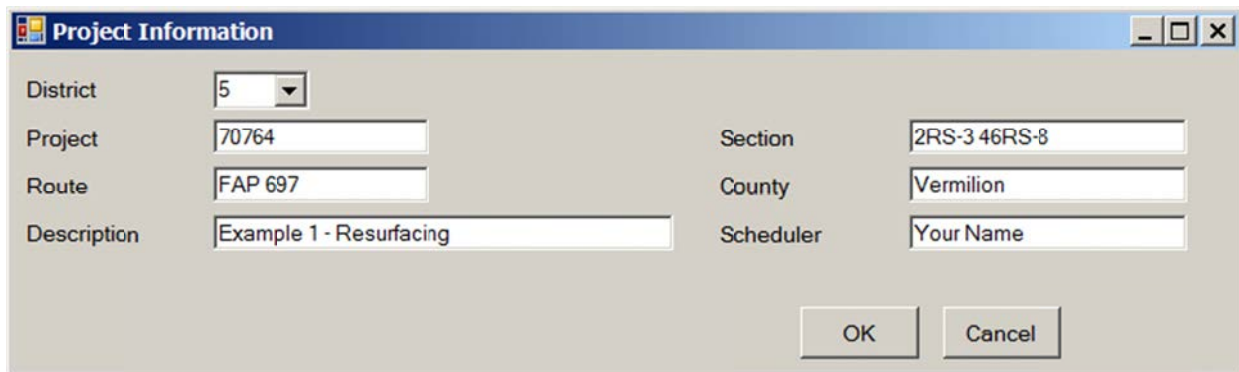


The screenshot shows a window titled "New Project". It contains the following fields and controls:

- Letting Date: 4/24/2015 (dropdown menu)
- Start Date: 7/13/2015 (text input with calendar icon)
- Days to Award: 45 (text input)
- Days to Start: 35 (text input)
- Buttons: "Enter Project Information", "OK", and "Cancel".

Figure 21. New Project form.

Select District 5 then Vermilion from the drop-down list of counties in District 5. Enter additional project information as shown in Figure 22. Click OK.



The screenshot shows a window titled "Project Information". It contains the following fields and controls:

- District: 5 (dropdown menu)
- Project: 70764 (text input)
- Route: FAP 697 (text input)
- Description: Example 1 - Resurfacing (text input)
- Section: 2RS-3 46RS-8 (text input)
- County: Vermilion (text input)
- Scheduler: Your Name (text input)
- Buttons: "OK" and "Cancel".

Figure 22. Enter project information.

Select Resurfacing from the Project Type drop-down list (Figure 23). Click Review to display the Review Template form.

Figure 23. Select the Resurfacing project type.

Figure 24 shows the Resurfacing template. Delete three activities: Curb/Gutter – Drainage; Gravel or Crushed Stone Shoulders; and Raised Reflective Pavement Markers by clicking the activity and selecting Delete from the pop-up menu (Figure 25).

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Mobilization	0		C DAY	1
2	Traffic Control	1		C DAY	1
3	HMA Patching	2		SQ YD	125
4	HMA Surface Removal	3		SQ YD	6000
5	Curb / Gutter - Drainage	4		FOOT	750
6	HMA Binder/Surface Course	5		TON	2250
7	Gravel or Crushed Stone Shoulders	6		TON	850
8	Paint Pavement Marking (Truck)	7		FOOT	15000
9	Raised Reflective Pavement Markers	8		EACH	150
10	Checkout / Acceptance	9		C DAY	1

Figure 24. Review the Resurfacing template.

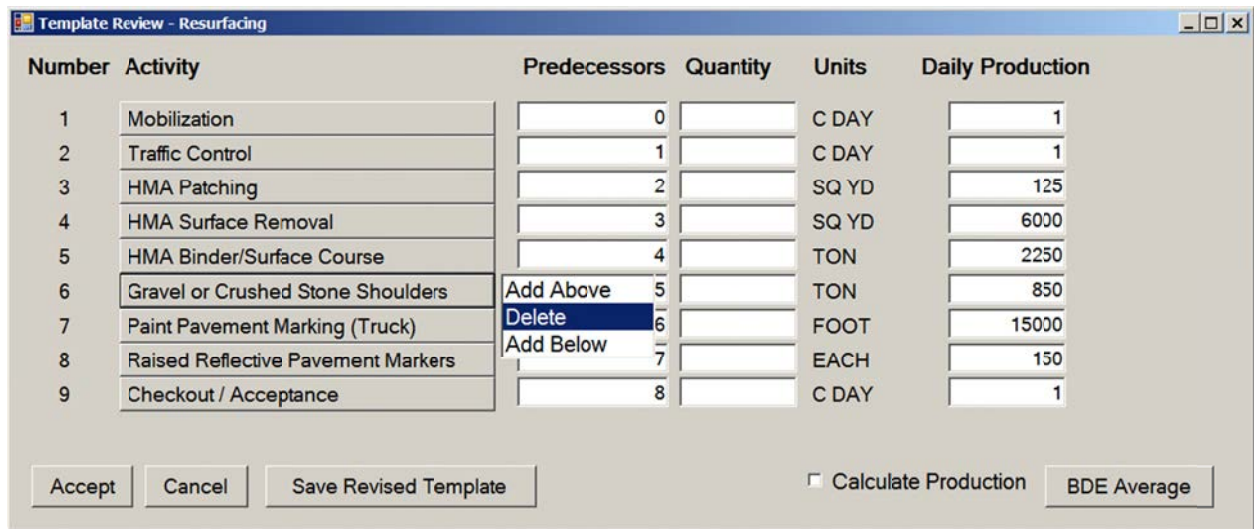


Figure 25. Delete unnecessary activities.

Add HMA Shoulders after HMA Binder/Surface Course by clicking HMA Binder/Surface Course and selecting Add Below from the drop-down menu. Select HMA Shoulders from the drop-down list as shown in Figure 26.

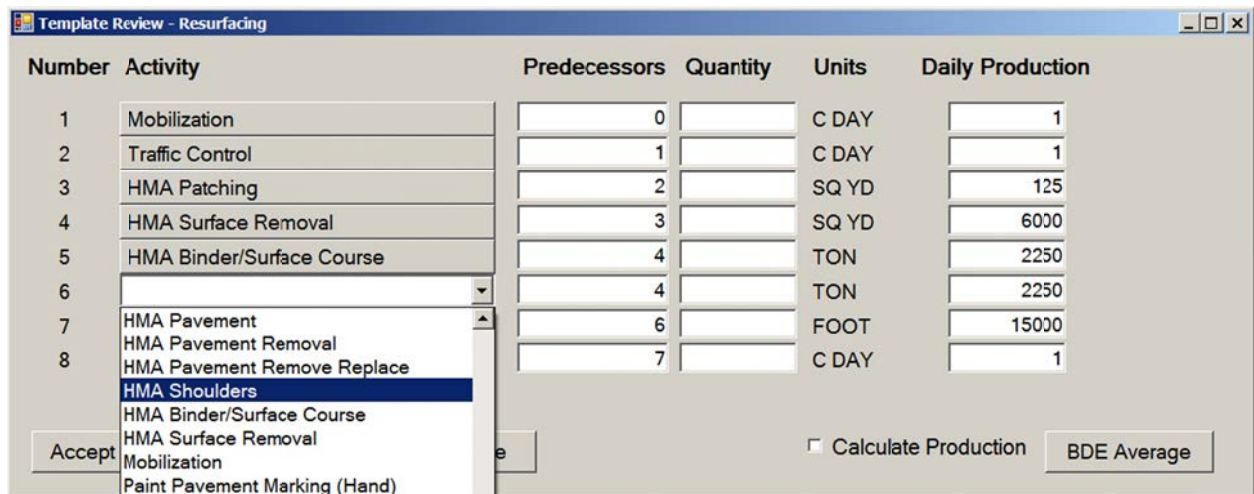


Figure 26. Add HMA Shoulders.

Enter quantities in the Template Review form as shown in Figure 27. The default daily production rates are the average of the low and high values from the BDE manual.

Check Calculate Production and click BDE Average to view production rates based on the input quantity and the linear regression fit to available production rate data (Figure 28).

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Mobilization	0	1	C DAY	1
2	Traffic Control	1	1	C DAY	1
3	HMA Patching	2	2728	SQ YD	125
4	HMA Surface Removal	3	220869	SQ YD	6000
5	HMA Binder/Surface Course	4	38250	TON	2250
6	HMA Shoulders	5	38400	SQ YD	3000
7	Paint Pavement Marking (Truck)	6	177004	FOOT	15000
8	Checkout / Acceptance	7	4	C DAY	1

Buttons: Accept, Cancel, Save Revised Template, Calculate Production, BDE Average

Figure 27. Enter quantities.

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Mobilization	0	1	C DAY	1
2	Traffic Control	1	1	C DAY	1
3	HMA Patching	2	2728	SQ YD	369
4	HMA Surface Removal	3	220869	SQ YD	16409
5	HMA Binder/Surface Course	4	38250	TON	3849
6	HMA Shoulders	5	38400	SQ YD	2520
7	Paint Pavement Marking (Truck)	6	177004	FOOT	59894
8	Checkout / Acceptance	7	4	C DAY	1

Buttons: Accept, Cancel, Save Revised Template, Calculate Production, Linear

Figure 28. View production rates based on linear regression analysis.

Click Linear to toggle the button to show the rate based on a power law fit (Figure 29). Click the button again to return to the BDE Average value.

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Mobilization	0	1	C DAY	1
2	Traffic Control	1	1	C DAY	1
3	HMA Patching	2	2728	SQ YD	340
4	HMA Surface Removal	3	220869	SQ YD	16753
5	HMA Binder/Surface Course	4	38250	TON	2603
6	HMA Shoulders	5	38400	SQ YD	2569
7	Paint Pavement Marking (Truck)	6	177004	FOOT	42681
8	Checkout / Acceptance	7	4	C DAY	1

Buttons: Accept, Cancel, Save Revised Template, Calculate Production, Power Law

Figure 29. View production rates based on power law regression analysis.

Click Accept to display the New Project form, then Click OK to display the Calendar form (Figure 30). Note that the production rates derived from regression analyses use all available data. You should consider refining these estimates on an activity-by-activity basis later in the process.

70764 FAP 697 Start Date: 7/13/2015

Constraints

Type	Name	First Day	Last Day	Activity
Winter Exclusion	Standard	12/1	4/30	All
Weekends-2 day	Standard	1/1	12/31	All
Holidays	Standard	1/1	12/31	All
Rain-BDE 66-2C	BDE Working Days	1/1	12/31	All
Winter Exclusion	Standard	12/1	4/30	All

Buttons: Add, Map/Temp

Calendar Grid (2015):

- January: 1, 2, 3
- February: 1-28
- March: 1-31
- April: 1-30
- May: 1-31
- June: 1-30
- July: 1-31
- August: 1-31
- September: 1-30
- October: 1-31
- November: 1-30
- December: 1-31

Buttons: Save, Close

Figure 30. Project calendar.

Click Save then click Close on the calendar to accept the defaults (options for editing the calendar are shown in greater detail in Example 2 of this manual). You will be prompted to save the project at this time.

The default schedule is displayed. Figure 31 shows the first couple of months. The durations for all activities, shown next to the activity name, were calculated from the quantity and the production rates selected on the Template Review form. All durations are highlighted in red to indicate that they were based on default production rates that should be reviewed individually.

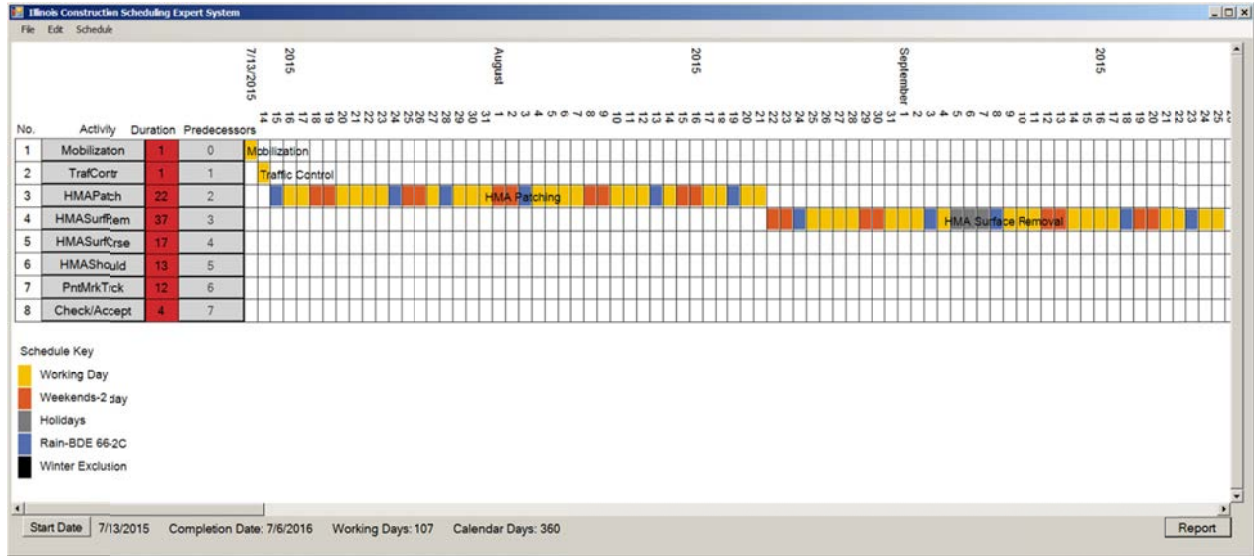


Figure 31. Default schedule.

Click HMAPatch to display the ADE form shown in Figure 32. Click Review Data to view production rates derived from ICORS data.

Quantity: 2728 SQ YD Patching rates will depend on the size and spacing of the areas to be patched. Lower rates will apply with smaller patches spaced far apart.

Crew Production: 125 SQ YD/day

Crew: 1

Duration: 22 days

Review Data

IDOT BDE: HMA Patching Min: 100 Avg: 125 Max: 150 SQ YD/day

Notes

Apply OK Cancel

Figure 32. HMA Patching ADE form.

Figure 33 shows production rate data for HMA Patching from District 5 for resurfacing projects. Left-click the data point from the data point with a quantity of 16,949 sq. yd. to show the project details. Right-click to eliminate it from the data. Click the Linear Regression button to display the production rate value from this function for the project quantity of 2728 sq. yd. (Figure 34). Click OK to close the form and use this value to determine the activity duration.

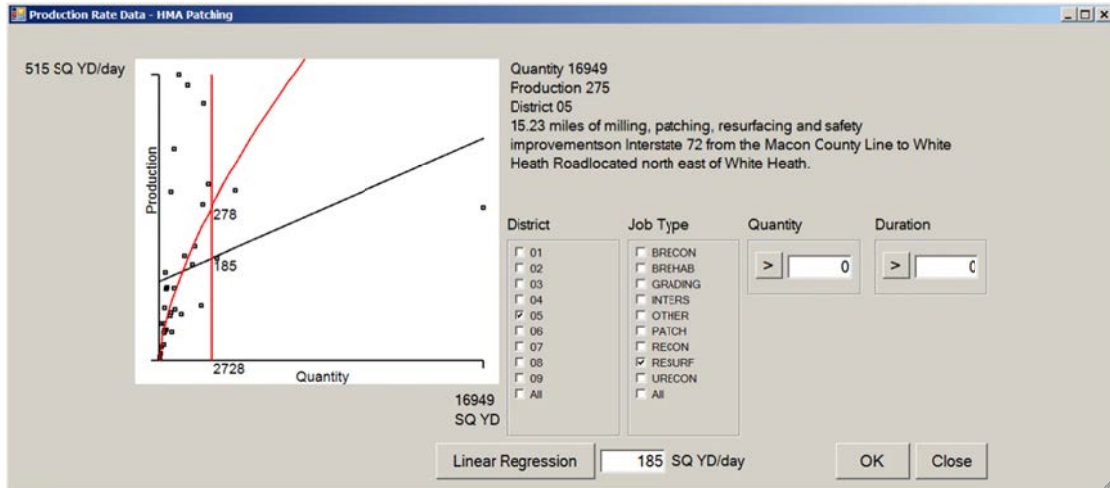


Figure 33. HMA Patching production rate data.

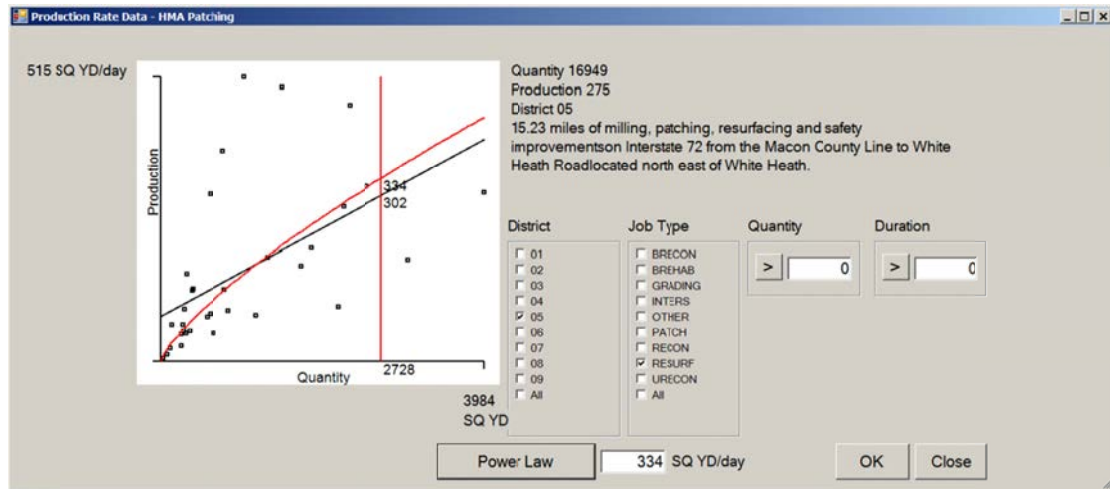


Figure 34. Filtered HMA Patching production rate data.

Figure 35 shows that this updated production rate has reduced the expected activity duration from 22 to 9 days. Click OK to update the schedule.

Quantity SQ YD

Crew Production SQ YD/day

Crew

Duration days

IDOT BDE: HMA Patching Min: 100 Avg: 125 Max: 150 SQ YD/day

Notes

Figure 35. HMA Patching production rate data.

Click HMASurfRem and enter a crew production rate of 37500 sq. yd./day based on Reference 3 (District 5) data for rural profile milling (Figure 36). Click OK to update the schedule.

Quantity SQ YD

Crew Production SQ YD/day

Crew

Duration days

Large areas of bituminous surface are removed by milling. Millers generally remove a 3-4 inch layer at a rate of 10000 sy/day. In urban areas with multiple obstructions such as utility covers and curb and gutter the production rate with the rotomill will be roughly half. Additional time may be required for hand removal but may be done concurrently.

IDOT BDE: HMA Surface Removal Min: 2000 Avg: 6000 Max: 10000 SQ YD/day

Reference 3: Bituminous Surface Removal (Urban) Min: 2000 Avg: 6000 Max: 10000 sq yd/crew day

Reference 3: Bituminous Surface Removal (Rural profile milling) Min: 30000 Avg: 37500 Max: 45000 sq yd/crew day

Notes

Figure 36. HMA Surface Removal ADE form.

Click HMA Shoulders to view the ADE form with a calculator to aid in converting a production rate based on tons/hour to sq. yd./day. Entering a thickness of 8 inches and assuming a plant production of 200 tons/hour for an 8-hour day yield a production rate of 3550 sq. yd./day (Figure 37). Click OK to apply this to the schedule.

The production rate for continuous full depth paving is usually governed by the production rate of the asphalt plant supplying the job. A typical rate is 200 tons/hour. You must convert tons to square yards based on the thickness and density of the asphalt. The number of hours per day will depend on workzone restrictions and day or nightwork. There may be contractual restrictions on the paving rate in linear feet per minute. Smaller areas of pavement will have lower production rates.

Input Parameters		Calculated Values		
Thickness	8 inches	Production	3550	SQ YD/day
Density	112.5 lb/sy-in			
Production	200 tons/hour			
Hours/Day	8 hours			

IDOT BDE: HMA Shoulders	Min: 1500	Avg: 3000	Max: 4500	SQ YD/day
Reference 1: Dense graded hot mix asphalt (method)	Min: 158	Avg: 817	Max: 1460	ton/crew day
Reference 2: Asphalt_Type B	Min: 400	Avg: 825	Max: 1560	tn/crew day
Reference 3: Bituminous Shoulders	Min: 10000	Avg: 12500	Max: 15000	sq yd/crew day

Notes

Apply OK Cancel

Figure 37. HMA Shoulder ADE form.

A review of the current schedule shows that the project duration is considerably less than the schedule based on default production rates. The duration of activities that have been studied in more detail are highlighted in green. You may continue to refine the schedule or click Report to generate the BDE 220 report in Excel (Figure 38).

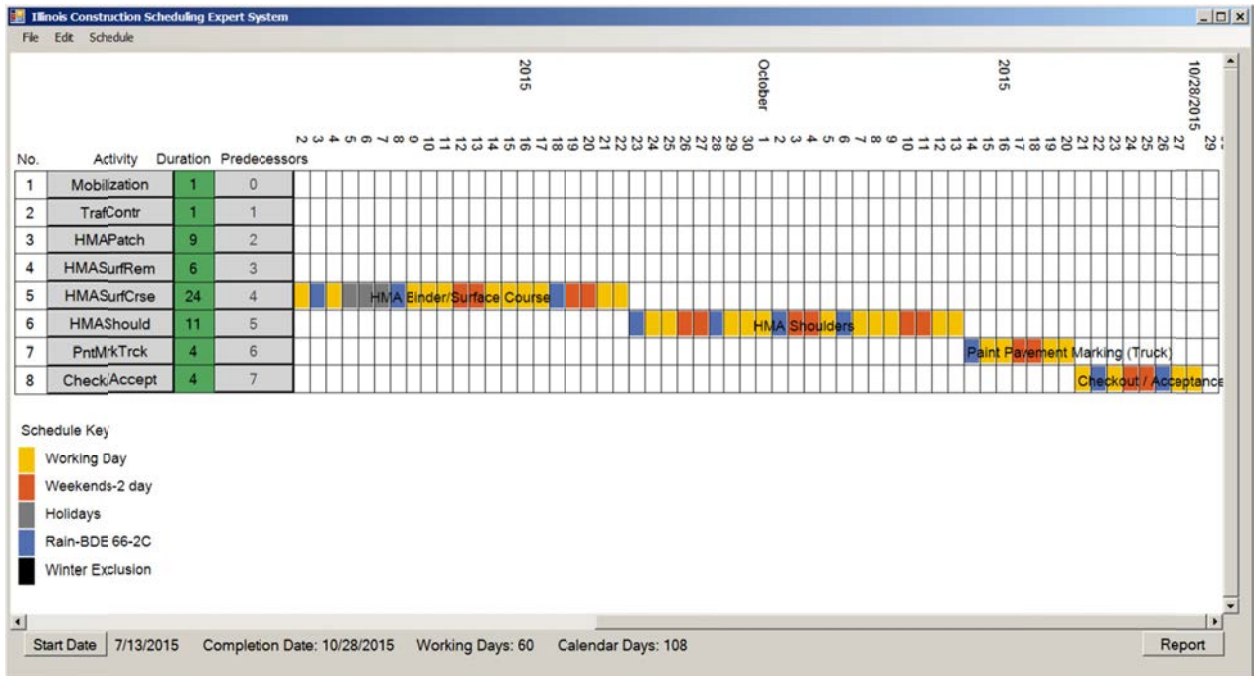
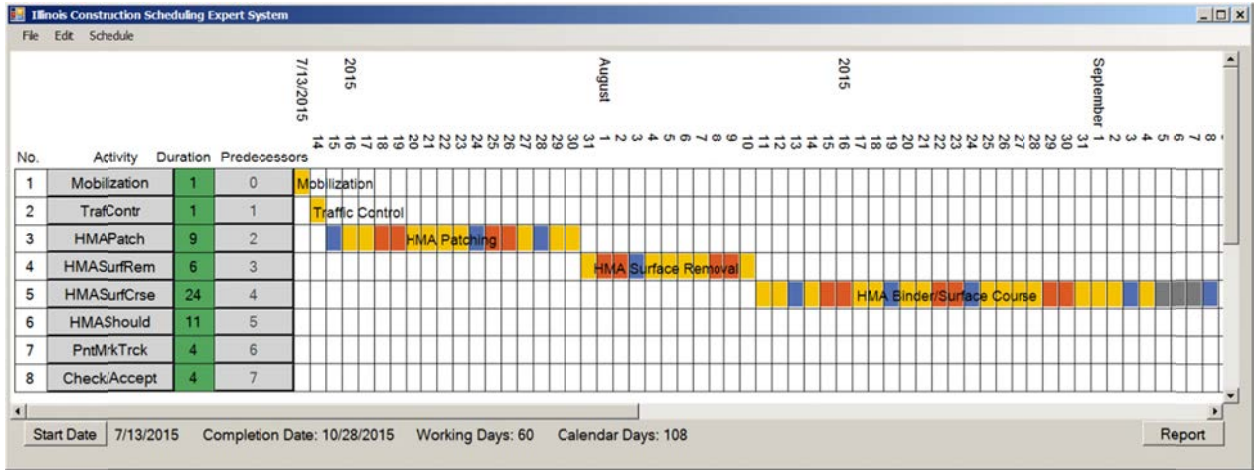


Figure 38. Refined schedule.

EXAMPLE 2: BRIDGE RECONSTRUCTION

This example demonstrates the use of the Multi-Stage scheduling template. It is based on a project from District 5 constructed in 2012. An existing two-lane overpass was removed and replaced in two stages. Production rate data are still being collected and analyzed at this time (for this user manual). Activities that are frequently bid as lump sum are broken down into unit quantities in this example. The first few steps in this example are presented in Figures 39 through 46.

Open a New Project

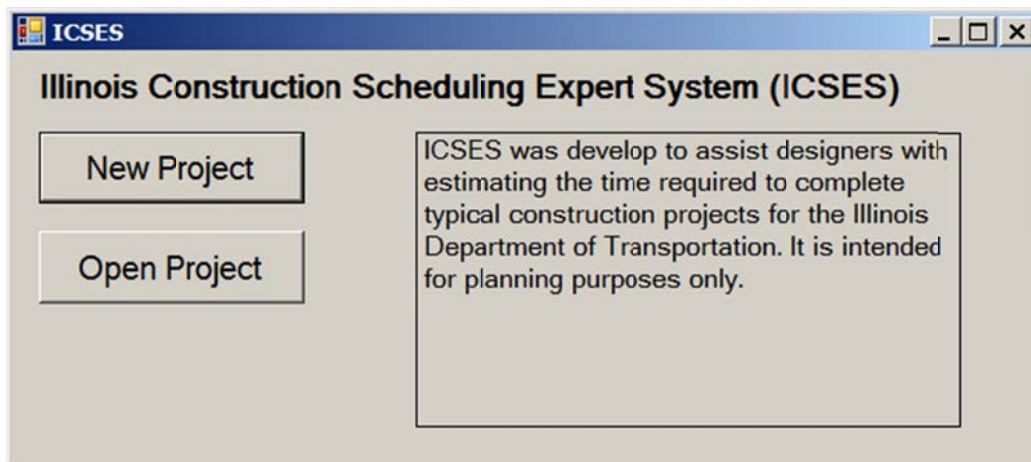


Figure 39. Click New Project.

Enter Project Information

Because this example was completed in the past, you may type in the actual letting date (11/18/2011) first. (It isn't necessary to do this to complete the example.) Enter the start date that was planned for this job, 3/25/2012. The start date is within the standard winter exclusion period, but the initial construction activities weren't expected to be constrained by the early spring start.

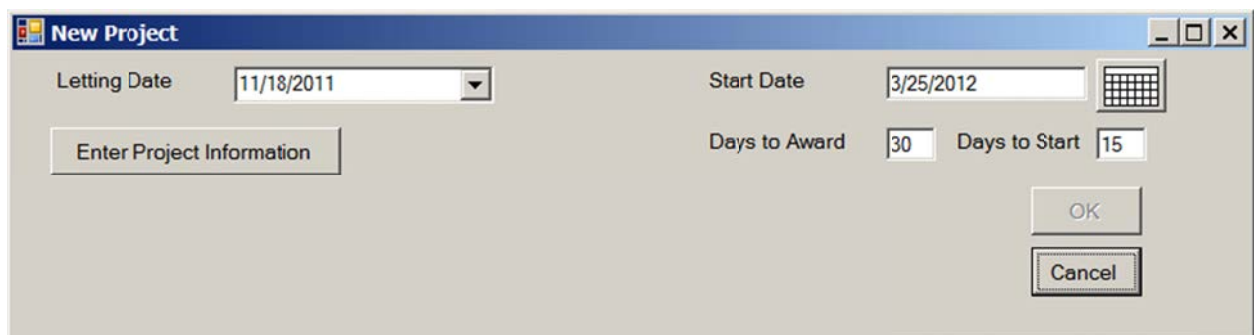


Figure 40. Enter start date; click Enter Project Information.

Select the district, then expand the County drop-down box to select the county that the project is located in.

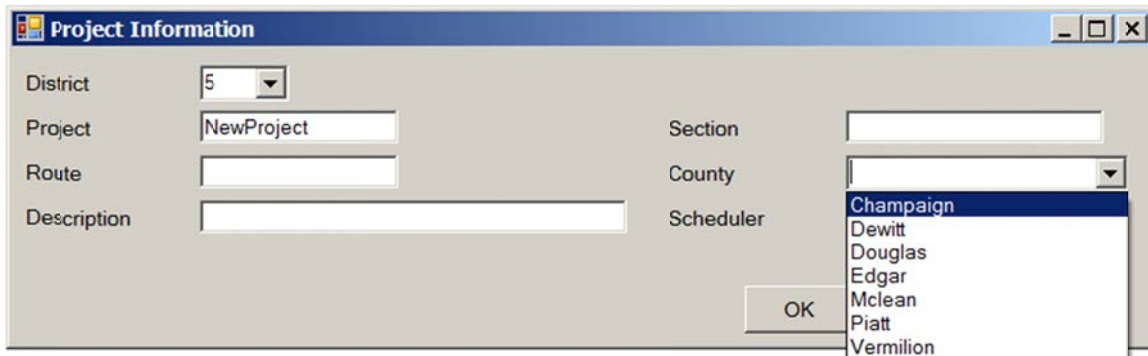


Figure 41. Select the district and county.

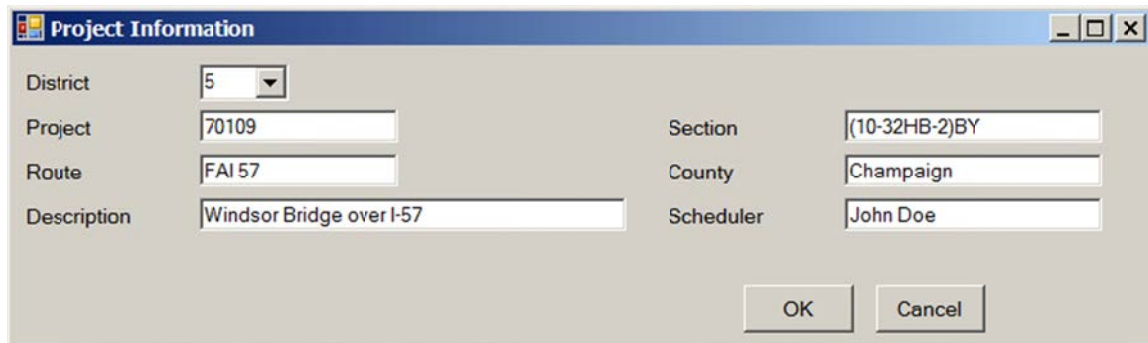


Figure 42. Enter other project information; click OK.

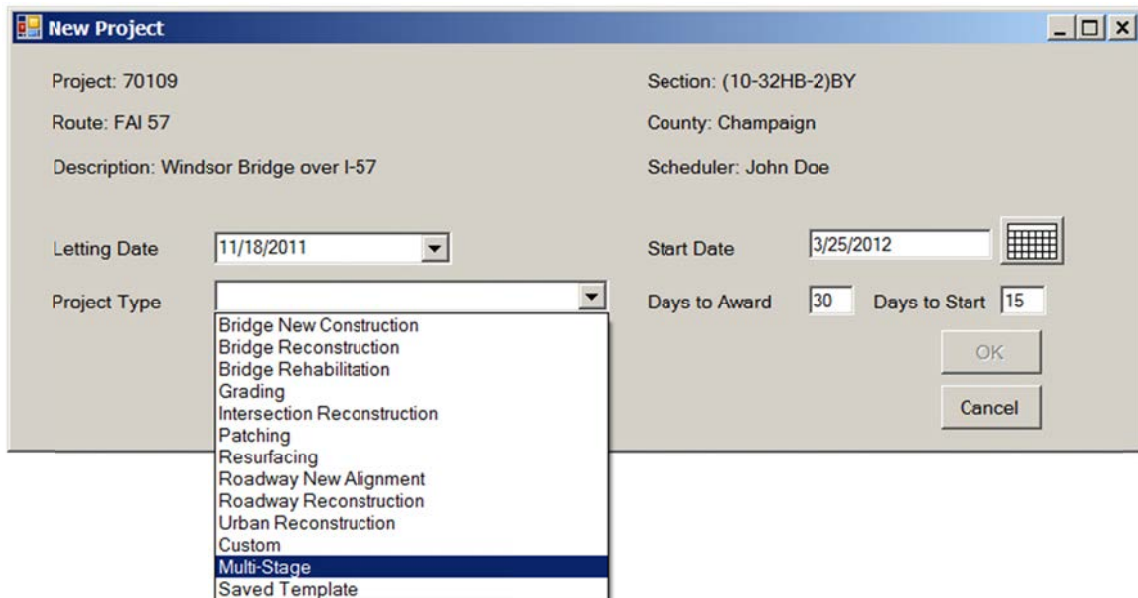


Figure 43. For project type, select Multi-Stage.

New Project

Project: 70109 Section: (10-32HB-2)BY
 Route: FAI 57 County: Champaign
 Description: Windsor Bridge over I-57 Scheduler: John Doe

Letting Date: 11/18/2011 Start Date: 3/25/2012
 Project Type: Multi-Stage Days to Award: 30 Days to Start: 15

Define Stages OK Cancel

Figure 44. Click Define Stages.

Number of Stages

How many stages to define?

2

OK Cancel

Figure 45. Enter 2; click OK.

New Project

Project: 70109 Section: (10-32HB-2)BY
 Route: FAI 57 County: Champaign
 Description: Windsor Bridge over I-57 Scheduler: John Doe

Letting Date: 11/18/2011 Start Date: 3/25/2012
 Project Type: Multi-Stage Days to Award: 30 Days to Start: 15

Stage 1: Bridge Reconstruction Review
 Stage 2: Bridge Reconstruction Review

OK Cancel

Figure 46. Select the Bridge Reconstruction template for both stages.

Click the Review button next to Stage 1 (shown in Figure 46) to review and edit the template for this stage. Change the name from Stage 1 to something more descriptive, as shown in Figure 47. The eastbound lane was reconstructed first.

Figure 47. Name Stage 1; Click OK.

The default Bridge Reconstruction template is displayed (Figure 48) for editing. The template contains activities that are likely to occur on this type of project. Many either do not occur in this stage or are not expected to be controlling items. Those should be deleted. Left-click the activity to be deleted, and select Delete in the pop-up menu.

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Mobilization	0		C DAY	1
2	Storm Sewers (Dependent on size and	1		FOOT	187.5
3	Traffic Control	2		C DAY	1
4	Removal of Existing Concrete Deck	3		SQ YD	225
5	Driving Piles	4		FOOT	375
6	Concrete Structures	5		CU YD	17.5
7	Earth Excavation (Shoulders /	6		CU YD	750
8	Structural Steel Erection	7		FOOT	200
9	Concrete Superstructure	8		CU YD	20
10	Bridge Deck Grooving	9		SQ YD	650
11	Steel Plate Beam Guardrail	10		FOOT	450
12	Bridge Approach Pavement	11		SQ YD	75
13	Gravel or Crushed Stone Shoulders	12		TON	850
14	HMA Binder/Surface Course	13		TON	2250
15	Clean Paint Steel Bridge	14		SQ FT	1550
16	Seeding	15		ACRE	7.5
17	Paint Pavement Marking (Truck)	16		FOOT	15000
18	Raised Reflective Pavement Markers	17		EACH	150
19	Checkout / Acceptance	18		C DAY	1

Figure 48. Edit the Bridge Reconstruction template for the eastbound lane.

Delete the following activities:

- Mobilization
- Storm Sewers
- Earth Excavation
- Bridge Deck Grooving
- Bridge Approach Pavement
- Gravel or Crushed Stone Shoulders
- HMA Binder/Surface Course
- Clean Paint Steel Bridge
- Seeding
- Paint Pavement Marking
- Raised Reflective Pavement Markers
- Checkout/Acceptance

The template should now look like Figure 49.

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Traffic Control	0		C DAY	1
2	Removal of Existing Concrete Deck	1		SQ YD	225
3	Driving Piles	2		FOOT	375
4	Concrete Structures	3		CU YD	17.5
5	Structural Steel Erection	4		FOOT	200
6	Concrete Superstructure	5		CU YD	20
7	Steel Plate Beam Guardrail	6		FOOT	450

Accept Cancel Save Revised Template Calculate Production BDE Average

Figure 49. Eastbound template after removing unneeded activities.

The schedule for this project lumped the removal of the existing structure into one activity. In this example, we will break it in to three activities. Add Removal of Existing Superstructure and Removal of Existing Substructure after Removal of Existing Concrete Deck. To do so, left-click the activity, select Add After, and select the new activity from the drop-down list. Figure 50 shows the addition of the second of these new activities.

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Traffic Control	0		C DAY	1
2	Removal of Existing Concrete Deck	1		SQ YD	225
3	Removal of Existing Superstructure	2		SQ YD	175
4	Driving Piles	3		FOOT	375
5	Concrete Structures	4		CU YD	17.5
6	Structural Steel Erection	5		FOOT	200
7	Concrete Superstructure	6		CU YD	20
8	Steel Plate Beam Guardrail	7		FOOT	450

Figure 50. Add Removal of Existing Substructure activity.

Quantities may be entered in the Template Review form, as shown in Figure 51. The quantity for the Traffic Control activity is the number of days expected to be needed for that activity. The 3 days allowed for erecting the temporary barrier were included in the total of 8 days for traffic control. Remove Existing Structure was one lump sum activity in the project, so estimates for the quantities for Activities 2, 3, and 4 were entered. The quantities for Activities 5, 6, 7, and 8 are one half of the total for the project. The actual quantities may not be exactly half for the two stages, but this approximation is adequate. The quantity for Steel Plate Beam Guardrail was greater in the first stage, so two thirds of the quantity is accounted for.

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Traffic Control	0	8	C DAY	1
2	Removal of Existing Concrete Deck	1	375	SQ YD	225
3	Removal of Existing Superstructure	2	375	SQ YD	175
4	Removal of Existing Substructure	3	120	CU YD	30
5	Driving Piles	4	923	FOOT	375
6	Concrete Structures	5	85	CU YD	17.5
7	Structural Steel Erection	6	968	FOOT	200
8	Concrete Superstructure	7	280	CU YD	20
9	Steel Plate Beam Guardrail	8	250	FOOT	450

Figure 51. Quantities entered in the Template Review form.

The daily production rates in the default template are the average of the low and high values in the BDE manual. Because there are not sufficient data for many of these activities at the time of writing this user manual, the BDE-based values will be used at this time. Data will be reviewed for individual activities. Click Accept when all values have been entered. Click Review on the New Project form for Stage 2, and enter Westbound as the name for this stage. The default Template Review form is displayed for the westbound stage (see Figure 48). Several activities that only occur once on the project or that may not have been controlling in the eastbound stage are included. Delete the following activities:

- Mobilization
- Storm Sewers
- Earth Excavation
- Bridge Deck Grooving
- Bridge Approach Pavement
- Gravel or Crushed Stone Shoulders
- Clean Paint Steel Bridge
- Raised Reflective Pavement Markers

Add the two removal activities, as was done in the eastbound stage. The Westbound template should look like Figure 52. Click Accept when this is complete. Then Click OK on the New Project form.

Number	Activity	Predecessors	Quantity	Units	Daily Production
1	Traffic Control	0	3	C DAY	1
2	Removal of Existing Concrete Deck	1	375	SQ YD	225
3	Removal of Existing Superstructure	2	375	SQ YD	175
4	Removal of Existing Substructure	3	120	CU YD	30
5	Driving Piles	4	923	FOOT	375
6	Concrete Structures	5	85	CU YD	17.5
7	Structural Steel Erection	6	968	FOOT	200
8	Concrete Superstructure	7	280	CU YD	20
9	Steel Plate Beam Guardrail	8	125	FOOT	450
10	HMA Binder/Surface Course	9	76	TON	2250
11	Seeding	10	0.5	ACRE	7.5
12	Paint Pavement Marking (Truck)	11	2852	FOOT	15000
13	Checkout / Acceptance	12	1	C DAY	1

Buttons: Accept, Cancel, Save Revised Template, Calculate Production, BDE Average

Figure 52. Quantities entered in the Template Review form.

The Calendar form for the eastbound stage opens after the New Project form closes. Because the project was planned to start before the end of the standard winter exclusion period, delete this constraint. The calendar should look like Figure 53 after deleting the constraint.

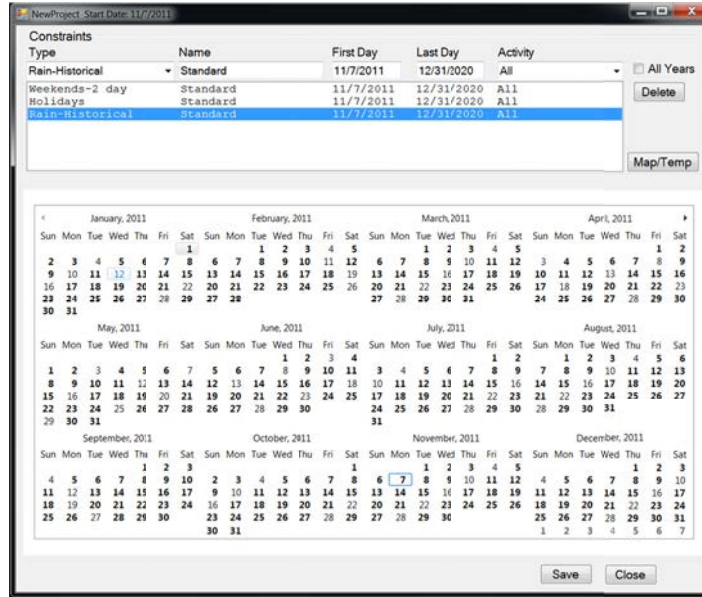


Figure 53. Delete winter exclusion; click Map/Temp.

Click the Map/Temp button to display the state map and temperature-based constraints for activities in the Eastbound template (Figure 54). A red cross is displayed near the center of Champaign County to indicate the project location. Dates at which the average minimum temperature crosses through the critical minimum temperature for the concrete activities are displayed. There is also a maximum temperature for concrete superstructure. The default is to base this on the average maximum temperature.

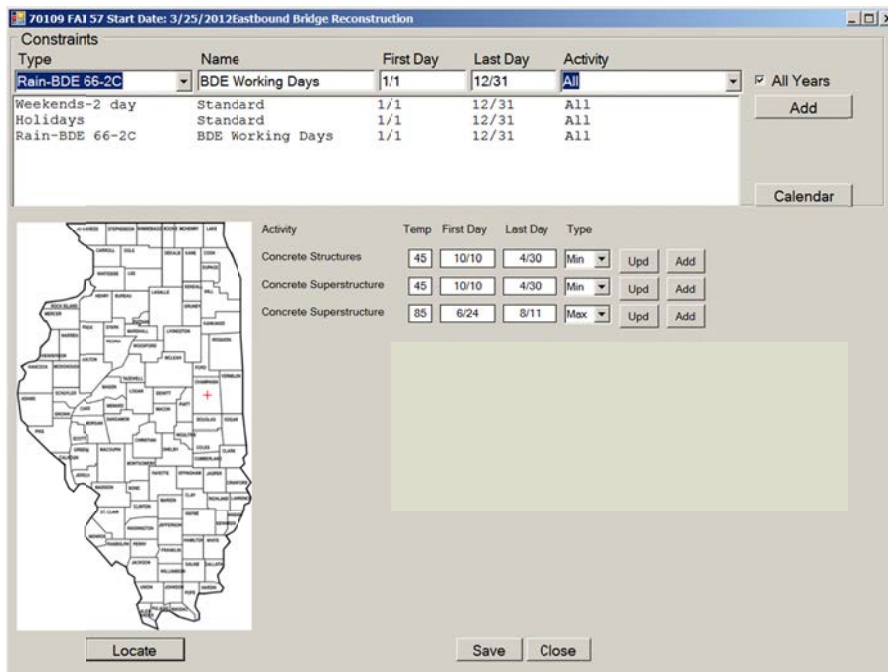


Figure 54. Evaluate temperature-based constraints.

Changing all of these types from min or max to mean is less conservative but probably realistic. After changing the type, click Upd (update) to change the first day and last day based on this choice. When the 85°F maximum temperature is changed to mean, there is no constraint. The average mean temperature is never above 85°F. Concrete work can probably be done early in the day any day of the year. Click Add for the two minimum temperature constraints to include them in the list (Figure 55). The Add button disappears after it has been clicked. If the constraint is deleted, the Upd and Add buttons reappear.

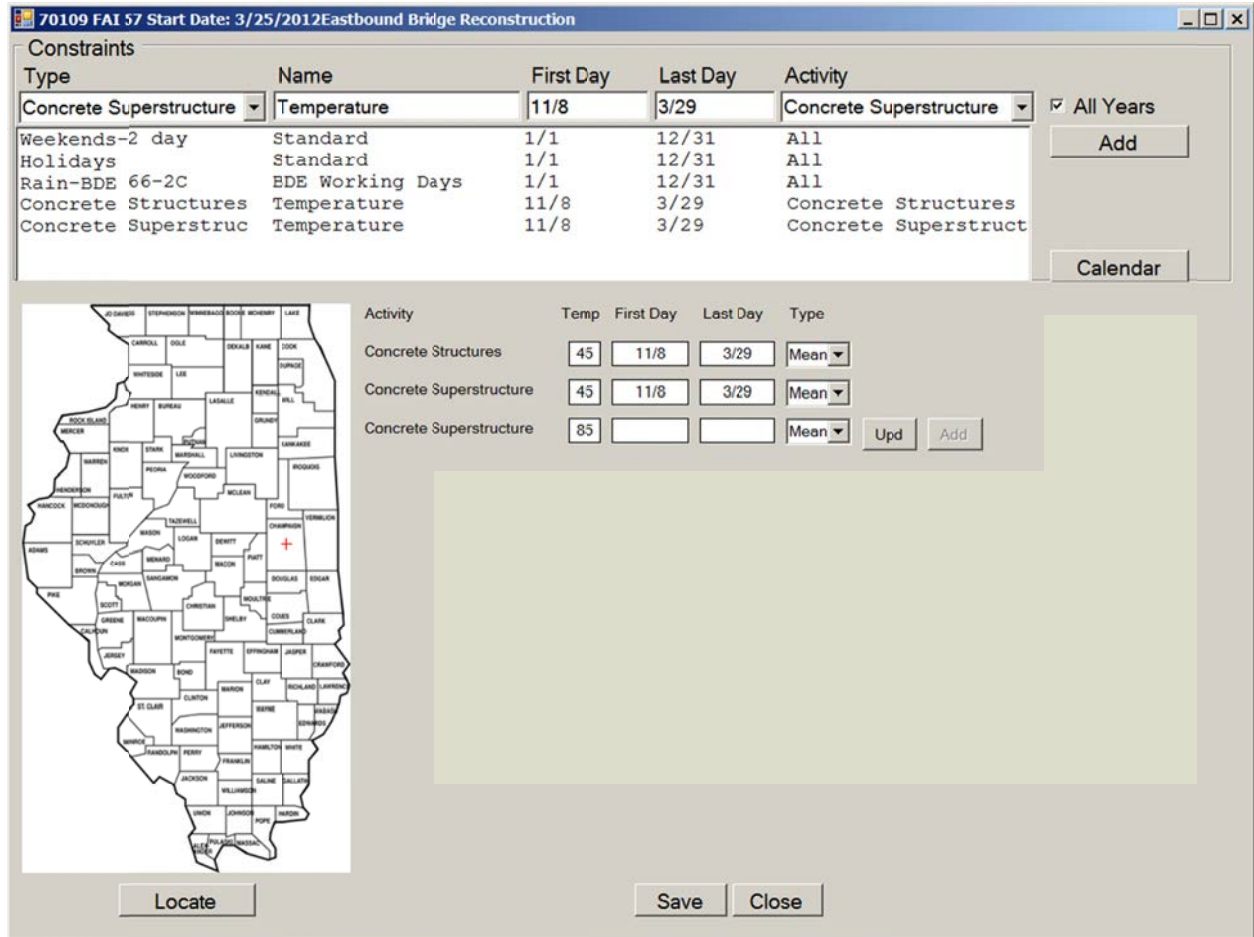


Figure 55. Evaluate temperature-based constraints.

On multi-stage projects, click Save and Close on the calendar for the first stage to automatically generate the calendars for the other stages. You can edit them when refining the schedule for each stage.

Figure 56 shows the beginning of the preliminary schedule for the eastbound stage of the project along with the schedule key. Figure 57 shows the end of the stage. Select MultiStage | Westbound to view the schedule for the second stage.

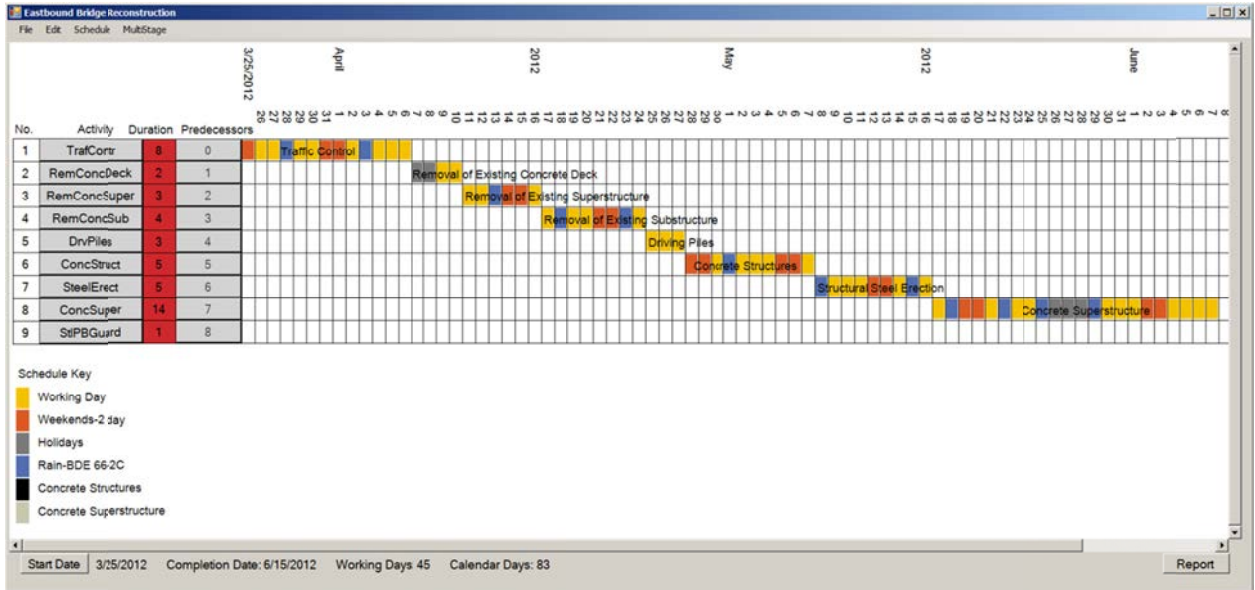


Figure 56. Preliminary eastbound stage schedule.

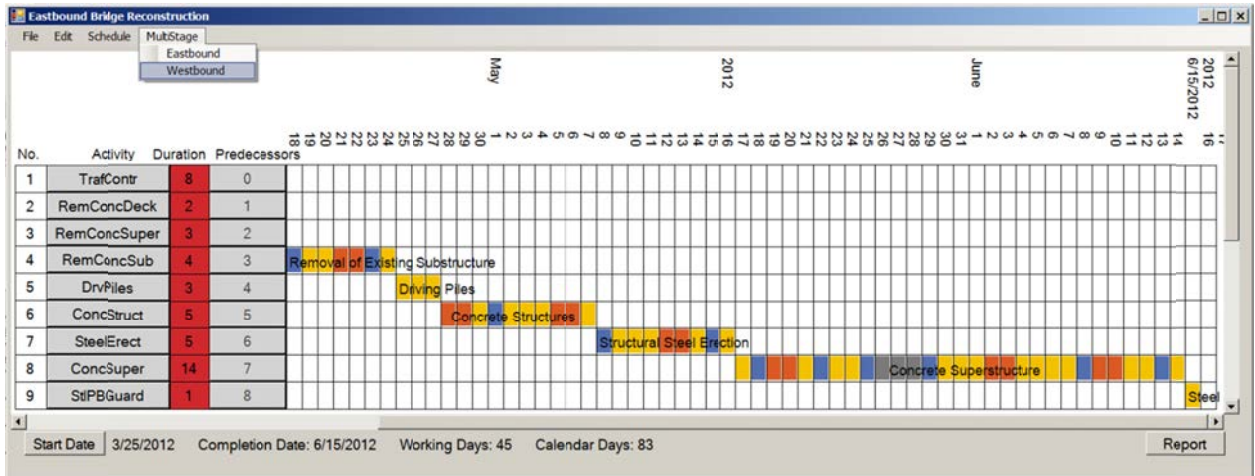


Figure 57. Select MultiStage | Westbound.

Select Edit | Calendar in the westbound bridge reconstruction schedule to edit the calendar for this stage. Figure 58 shows the default constraints. Because seeding is often restricted during the hotter months, a constraint is added that may be modified or deleted, as appropriate. Delete the winter exclusion constraint and click Map/Temp.

The temperature-constrained activities in this stage are shown with the range of days that work may be restricted because of temperature (Figure 59). Add all five to the constraints using the conservative, default types (min for low temperature, max for high temperature). The end of the project schedule (Figure 60) shows that seeding might be delayed by the default constraint.

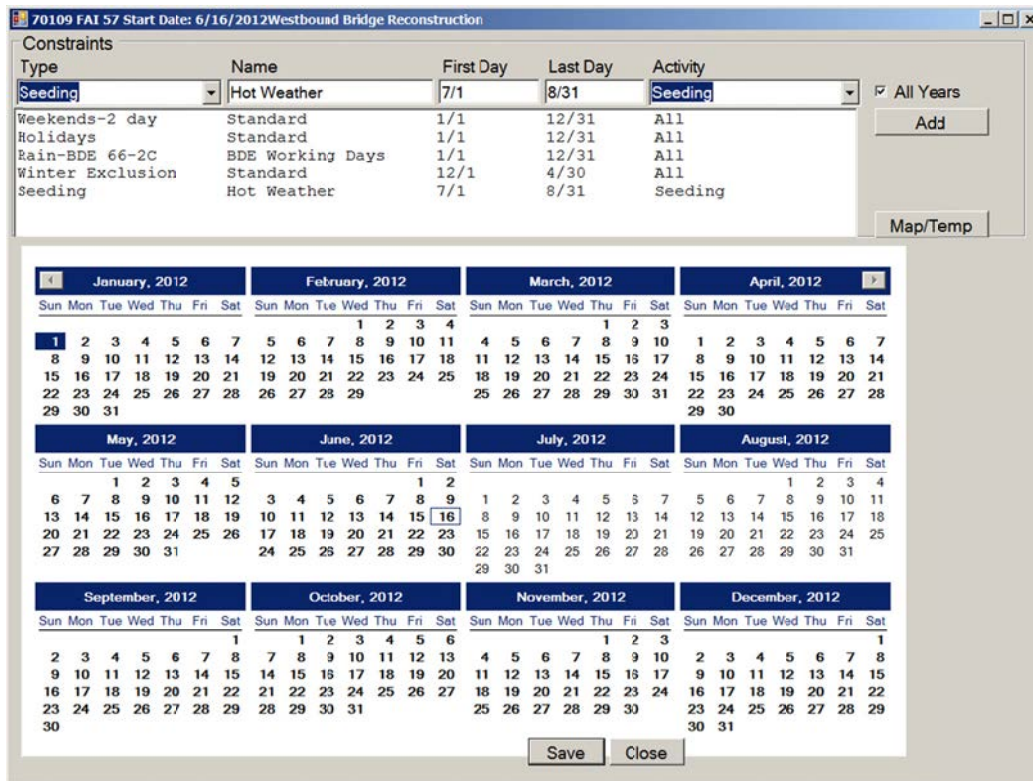


Figure 58. Westbound stage calendar.

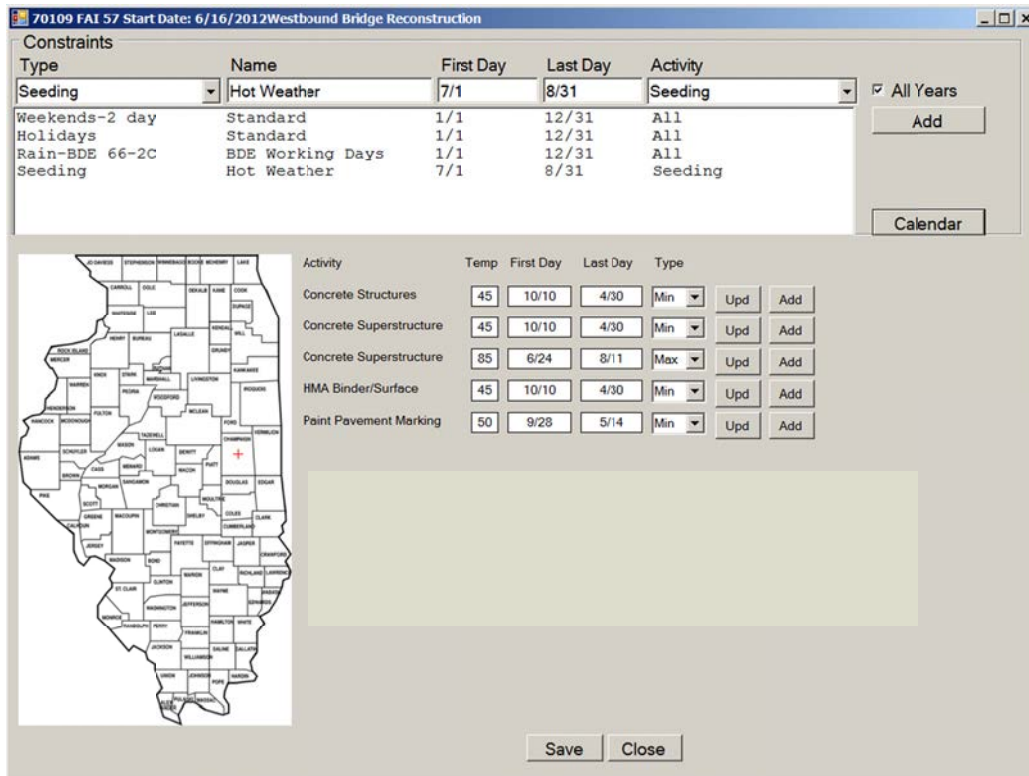


Figure 59. Temperature-constrained activities.

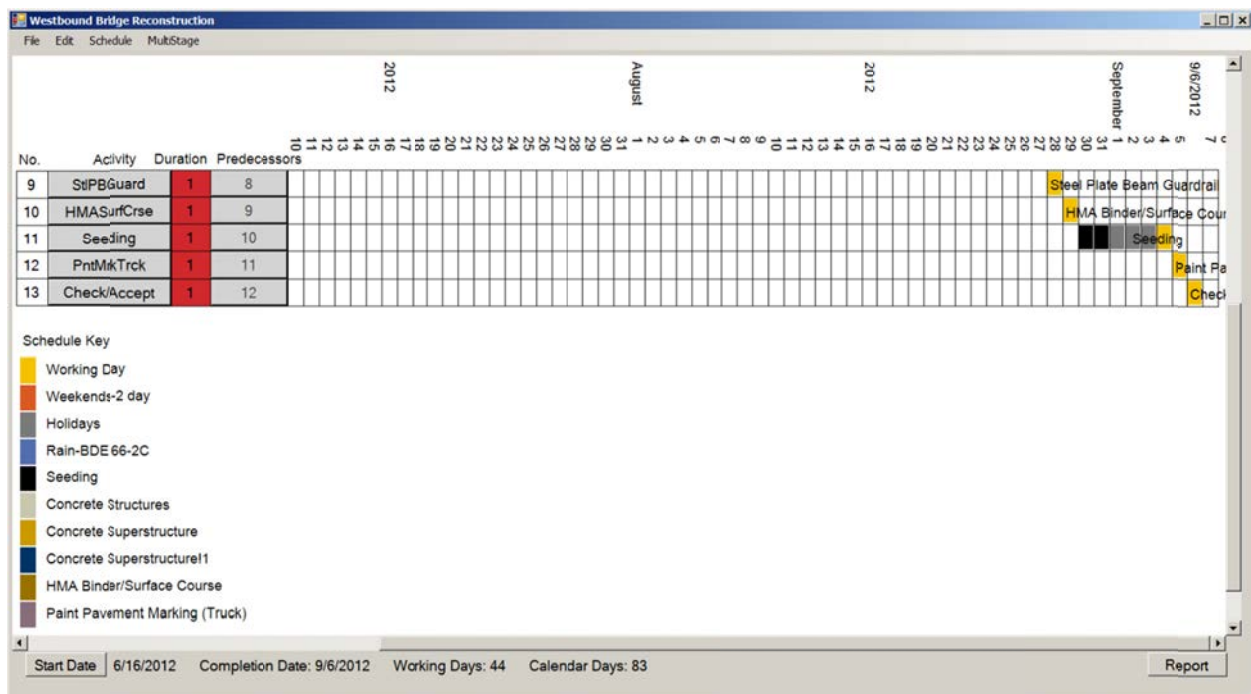


Figure 60. Seeding affected by constraint in preliminary schedule.

You should review each activity to refine the production rate estimates. The actual project schedule submitted by the contractor before construction required 103 working days in addition to work performed before May 1 (during the winter exclusion period). Production rates for many items tended to be lower because of the difficulty in working next to an active bridge.

Click the Report button to generate the BDE 220 form in Excel.

