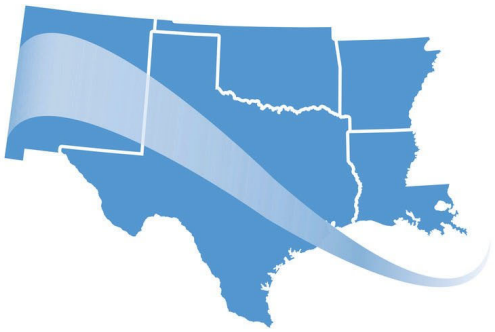
VISUALIZING THE IMPACT OF CONCURRENT SCHEDULE DELAYS USING LINEAR SCHEDULING METHOD

DOUGLAS D. GRANSBERG, PHD, PE



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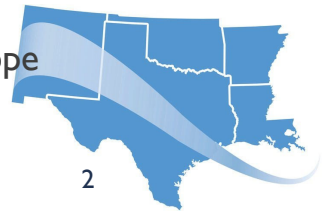
YOUR INSTRUCTOR

Transform I-285/SR-400
P3 Project – Atlanta, GA

- 20 years industry experience:
  - US Army Corps of Engineers
  - First DB project - 1985
  - > $200 million in USACE DB projects
  - Warranted Contracting Officer
- 23 years academic: Texas Tech; OU; ISU
- Consultant – Construction Management, Project Delivery, Cost Engineering
  - > $12 billion Alternative delivery projects: Highway, Bridges, Commuter Rail, Water Treatment.
  - Helped > 20 public agencies implement first alternative delivery projects
    - US Forest Service; BLM; DOE; DoD; FHWA; 16 State DOTs; City of Seattle; NYC Transit Authority; City of Sioux Falls, SD; San Antonio Water System; Santa Clara Valley Water District; Sarasota Cty, FL; Hennepin Cty, MN.
    - Canada; Curacao; Okinawa; Korea; New Zealand; Panama; Brazil; Turkey; Central Asia; Middle East; Europe

Panama Canal
Expansion Project

Sellwood Bridge –
Multnomah County, OR



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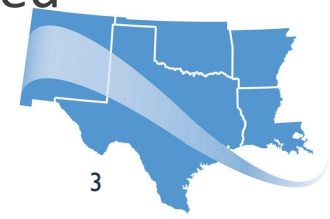
OBJECTIVE

- **Objective:**
  - Review the construction claims doctrine of concurrent delays
  - Demonstrate the use of the Linear Scheduling Method (LSM) as a data processing and visualization tool to improve decision making and evaluate delays in construction projects.
  - Disclaimer: I am not a lawyer. The following discussion of legal concepts is based solely on my interpretation of them developed during past experience with forensic schedule delay analysis.



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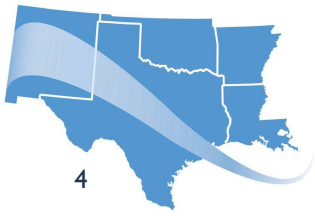
INTRODUCTION

- In most construction projects, data is collected periodically for production and quality control/assurance records.
- This data, which typically holds contractual validity, is often not utilized to its full potential.
- An opportunity exists to manage this information to improve decision making and use it effectively in case of a delay-related dispute.
- The Linear Scheduling Method (LSM) provides an alternative means to the Critical Path Method (CPM) use this information.



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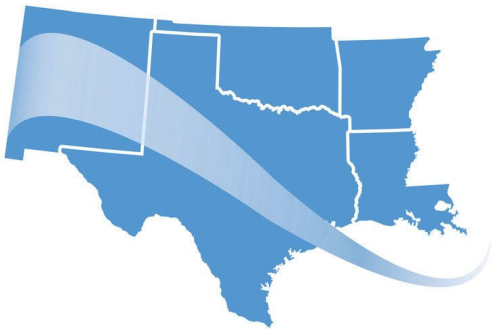
CONCURRENT DELAY PRINCIPLES

MODULE 1



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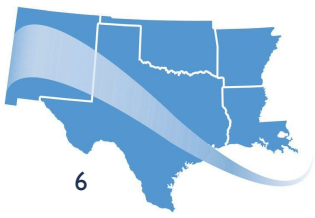
KEY POINTS ON PROVING A DELAY

- Three types of paths on the "official" baseline schedule:
  - Critical: Has no float
  - Non-Critical: Has float
  - Near-Critical: Has float but amount is small
- Only delays on the critical path can delay the project, i.e. justify an extension of the contract.
- Delay analysis requires an up-to-date as-built schedule to compare to the approved as-bid schedule.



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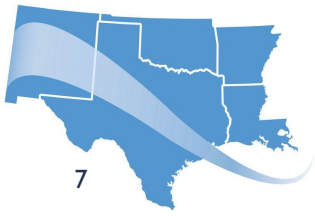
WHAT IS A CONCURRENT DELAY?

- Concurrent delays are independent sources of delay that occur at the same time.
- When a non-excusable delay is concurrent with an excusable delay, the Contractor is not entitled to an extension of Contract Time for the period the non-excusable delay is concurrent with the excusable delay.
- When a non-compensable delay is concurrent with a compensable delay, the Contractor is entitled to an extension of Contract Time, but not entitled to compensation for the period the non-compensable delay is concurrent with the compensable delay.



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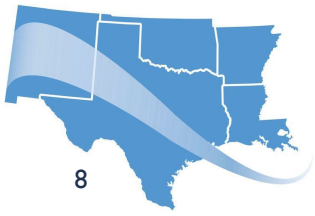
DEFINITIONS

- Non-excusable delay: Delays that are the contractor's responsibility and for which the contractor is not due any additional time or delay damage compensation.
- Excusable delay: Delays that are either the owner's responsibility or caused by some form of a *force majeure* event that was not the owner's or the contractor's responsibility



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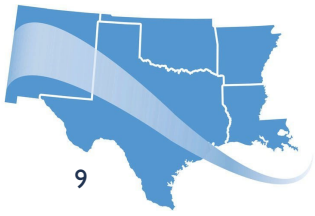
DEFINITIONS

- Excusable, compensable delay: Delay the is solely the responsibility of the owner and, as such, the contractor is entitled to recover its delay damages in addition to a time extension.
- Excusable non-compensable delay: Delay that is not the fault of either the owner or the contractor and generally are considered to be *force majeure-type* events for which the contractor is only due a time extension.



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CONCURRENCY ISSUES

- Both delays must be critical to qualify as concurrent.
- If one is not, "lack of an actual concurrent delay" is an owner's defense against time extension.
- Exception: if one of the delays is "near-critical," may qualify if impact of the near-critical delay could change the critical path.

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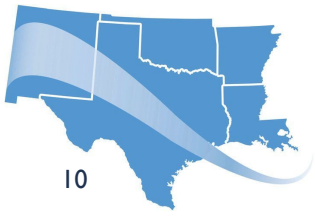

TYPES OF CONCURRENCY

- Literal: Delays that are "happening at the same time."
- Functional: Delays that "need to be occurring within the same analysis period."
  - Example: Analysis period is month; two delays
    - One occurred in first 5 days of the analysis month - One occurred in last 5 days of the analysis month
    - Functional concurrency is satisfied
- Dueling delays resolved using "primacy of delay" principle
  - Event that caused the delay first is primary
  - Sole driver of delay because it creates float in other paths

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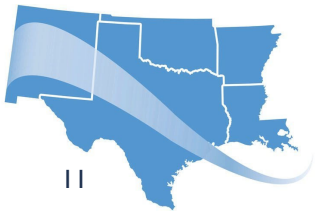
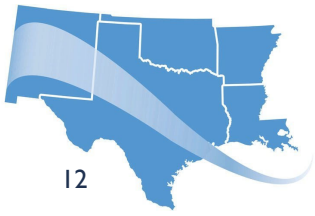


SIMPLE CONCURRENCY EXAMPLE

- Contractor fails to procure precast members in time to install as schedule and activity was critical – Non-excusable
- Later in the same analysis period, Owner issues a change order that alters the planned sequence of erection work - Excusable.
- Contractor argues functional concurrency
- Owner argues literal concurrency; i.e. lack of concurrency



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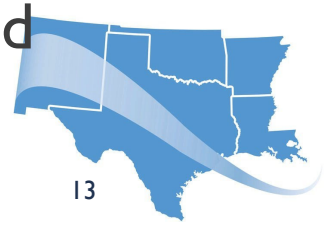
OVERVIEW

- The resolution of concurrent delays is complex and often confusing.
- When using CPM as the basis for forensic analysis of delays, it is difficult to visualize the actual impact of multiple delays because CPM is activity based and uses a network to display the relationships.
- Objective is to document what actually happened and what actually was impacted.
- Both parties need to be able to "see" multiple relationships.
- Achieve a mutually agreed "picture" of actual events and avoid litigation.



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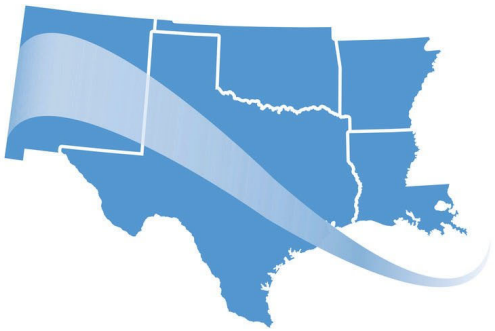
BRIEF INTRODUCTION TO LINEAR SCHEDULING METHOD

MODULE 2



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THE USE OF LSM IN CONSTRUCTION

- How is LSM used in Construction?
  - The method is best suited for projects that follow a linear path, such as: ports, bridges, pipelines, dams, roads and channels, among others.
  - It can be intuitively implemented in any project that involves repetitive production and follows an alignment. But it is flexible enough for other applications.

Amador Causeway, Panama City, Panama (Author: Ricardo M. Tapia)

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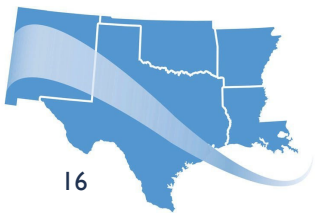
THE LSM CONCEPT

- What is a Linear Schedule?
  - Developed in the 50s. Also called Line of Balance, Time-Distance Diagram or March Chart.
  - It is a graphical scheduling method
    - Physical Alignment (stationing) in the X Axis
    - Time in the Y axis
  - Activities are modeled as lines, blocks or dots based production rates.
  - Physical, resource and logic constraints are easily identified.
  - The complete schedule can be represented in a single chart.



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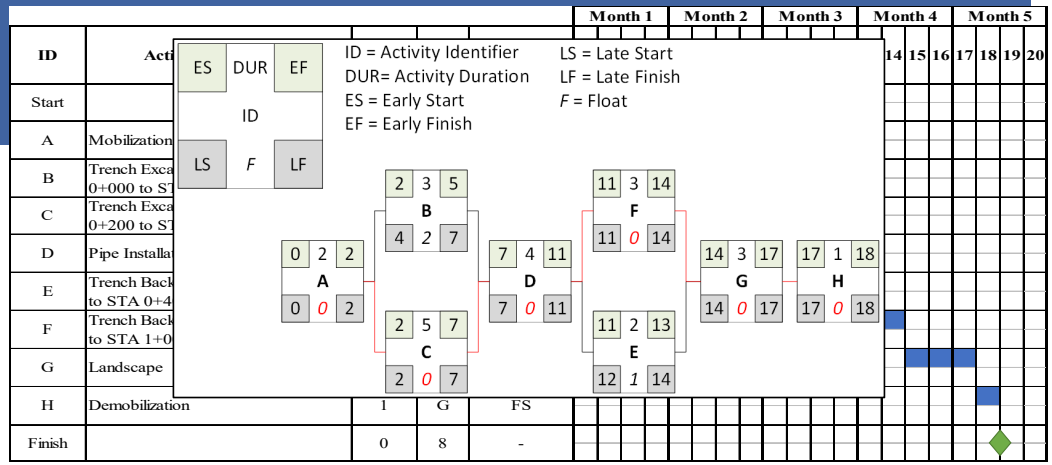
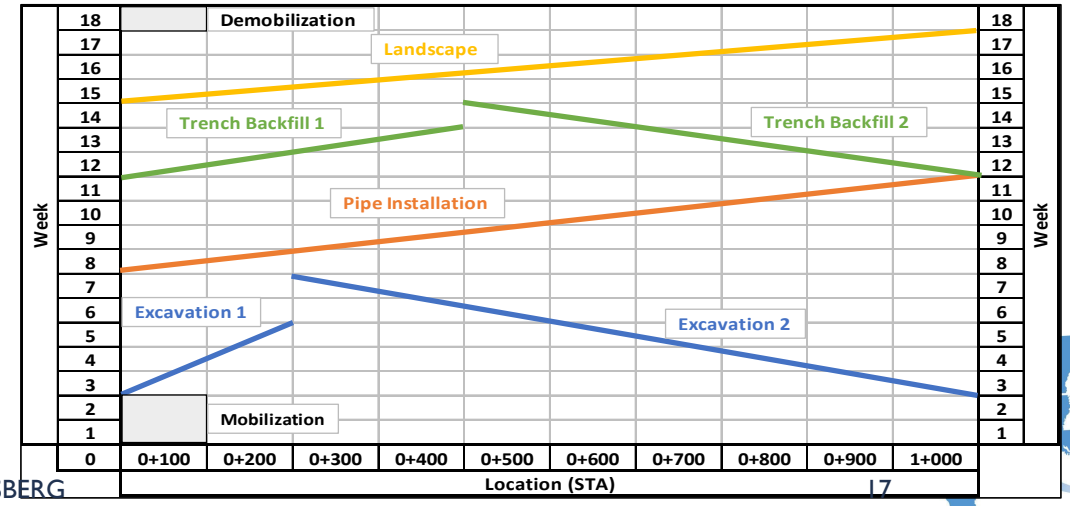
THE LSM CONCEPT

- Comparison with the Critical Path Method
  - Based on production rates, not activity durations.
  - The units of measure are time and distance
  - LSM was developed before, but it was replaced by CPM due to the manual fashion in which it was used at the time.





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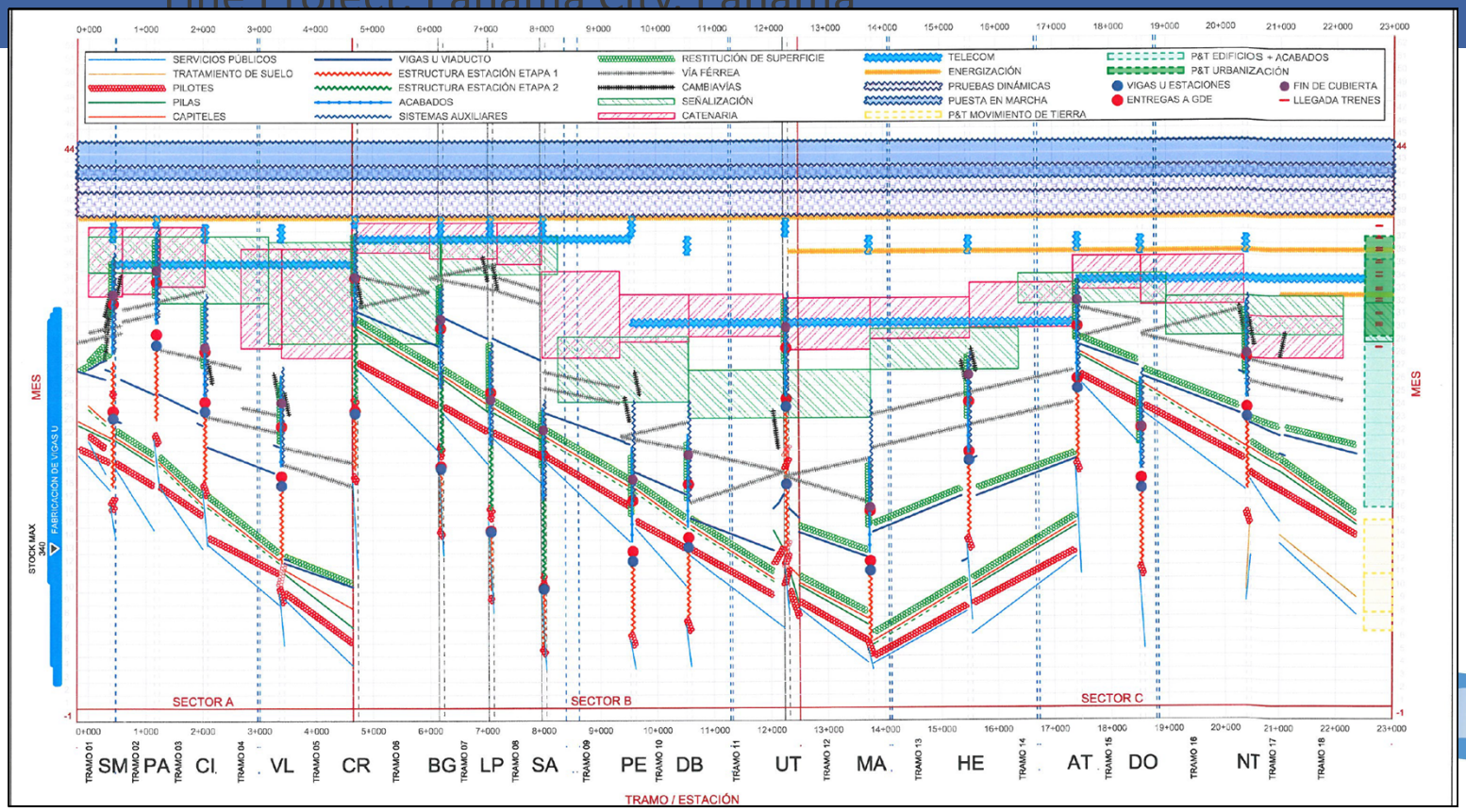
THE USE OF LSM IN CONSTRUCTION

- Example of the use of LSM for planning: Second Metro Line Project, Panama City, Panama



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FORENSIC CLAIM ANALYSIS MODEL

Use the linear scheduling format as a communication tool to explaining the events that either support or deny a contractual breach.

- Daily Reports as data source: Actual work performed between stations in a given date.
- Use the linear scheduling model: x-axis as physical alignment and y-axis as time.
- No activities or production rates, just actual data plotted as lines.
- Influential factors added graphically, such as underground conditions, rainfall data, production as volumes or any other physical unit within the time unit.

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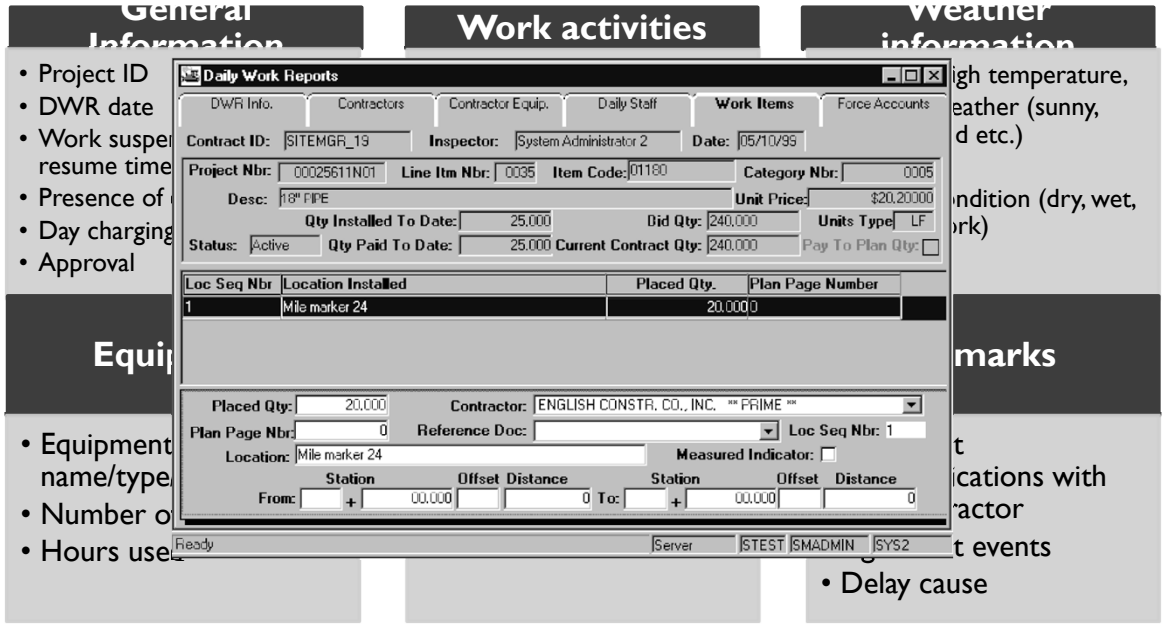
DEEP DATA ANALYTICS OF DAILY WORK REPORT DATA

- Digital Daily Work Report (DWR) Systems have been developed and used by US public agencies and private industry.



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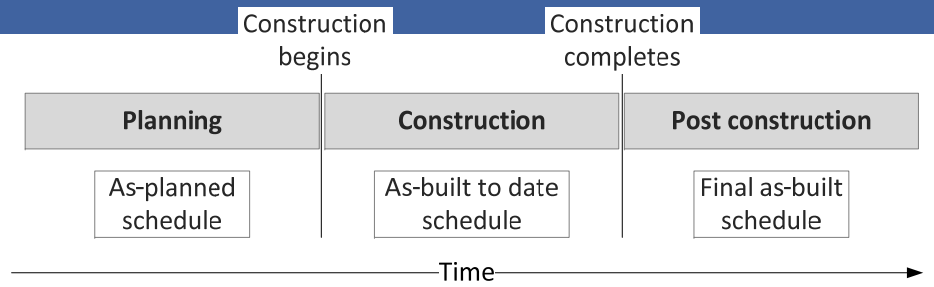
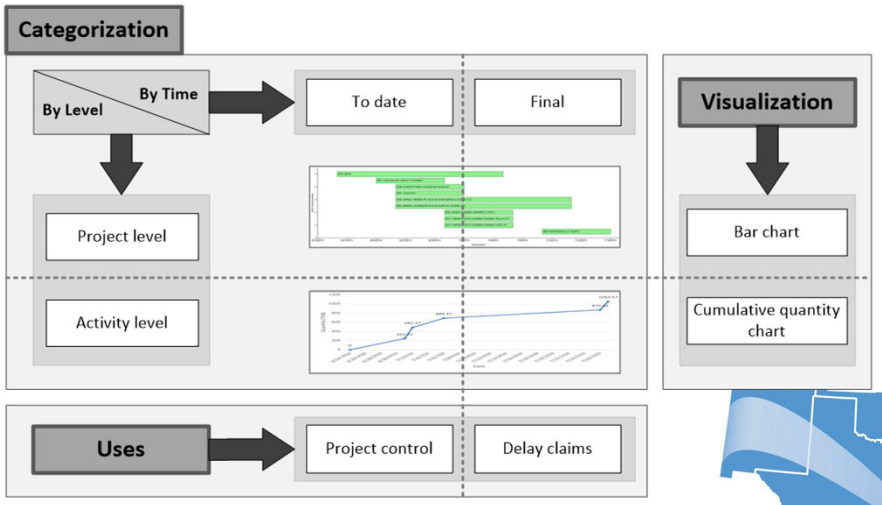
AUTOMATED AS-BUILT SCHEDULES

- Shows actual sequences and durations of construction activities
- Takes account of change orders and schedule changes from the originally planned schedule
- Project level vs activity level as-builts





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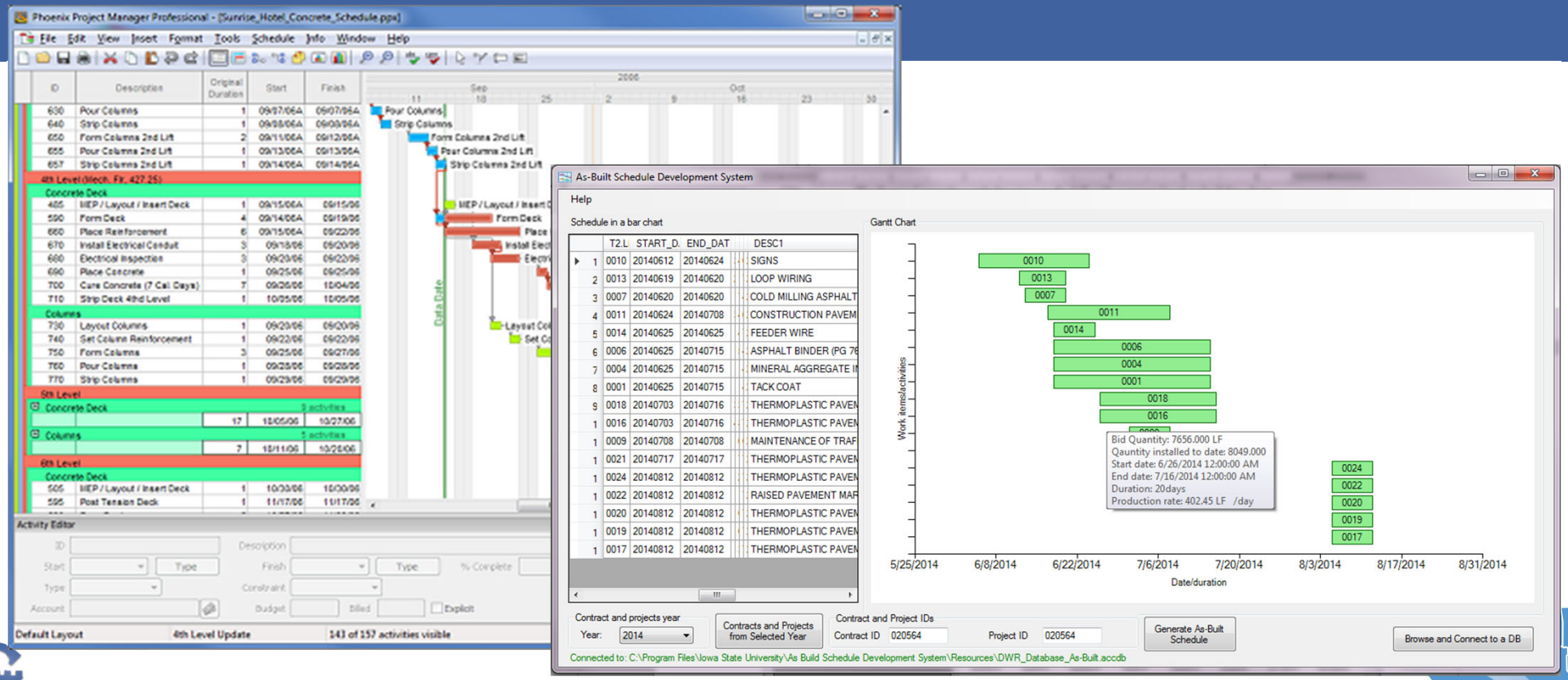
PLANNED VERSUS ACTUAL



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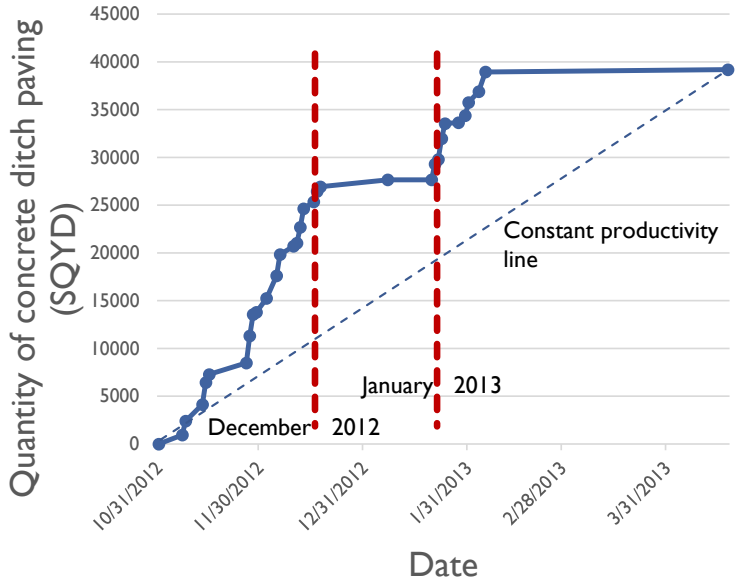
ACTIVITY LEVEL AS-BUILT ANALYSIS

- Detailed project control
- Identify dates when productivity was low
- Predict time to complete the task based on the current productivity
- Manage inspection resources



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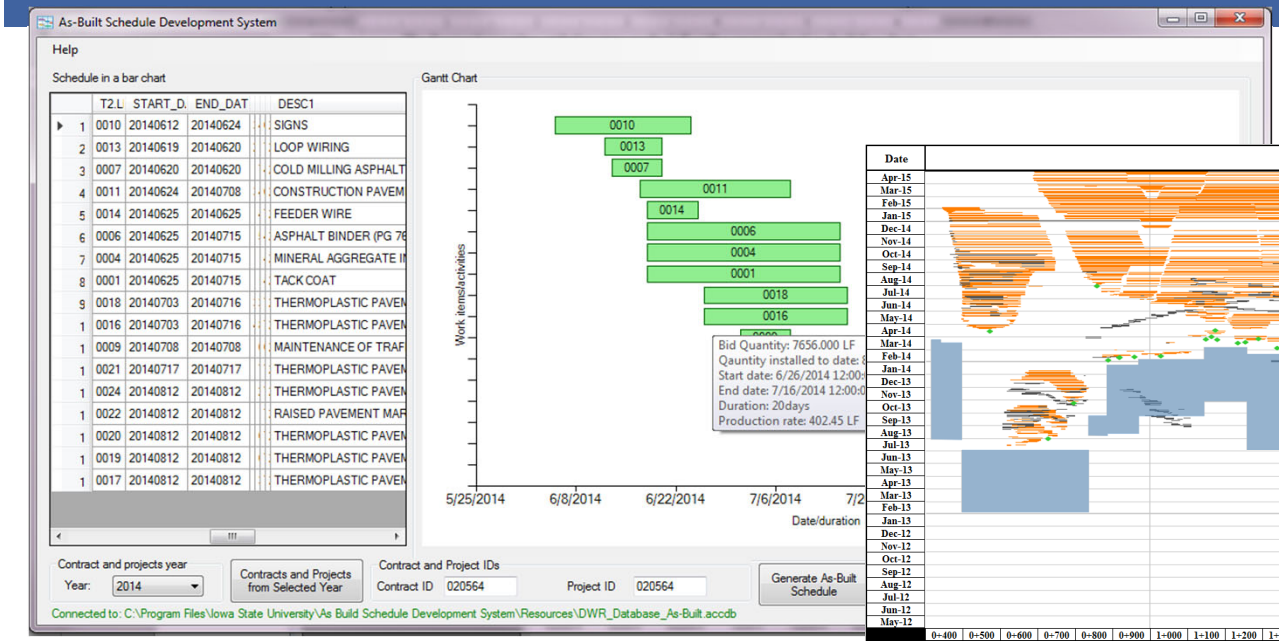
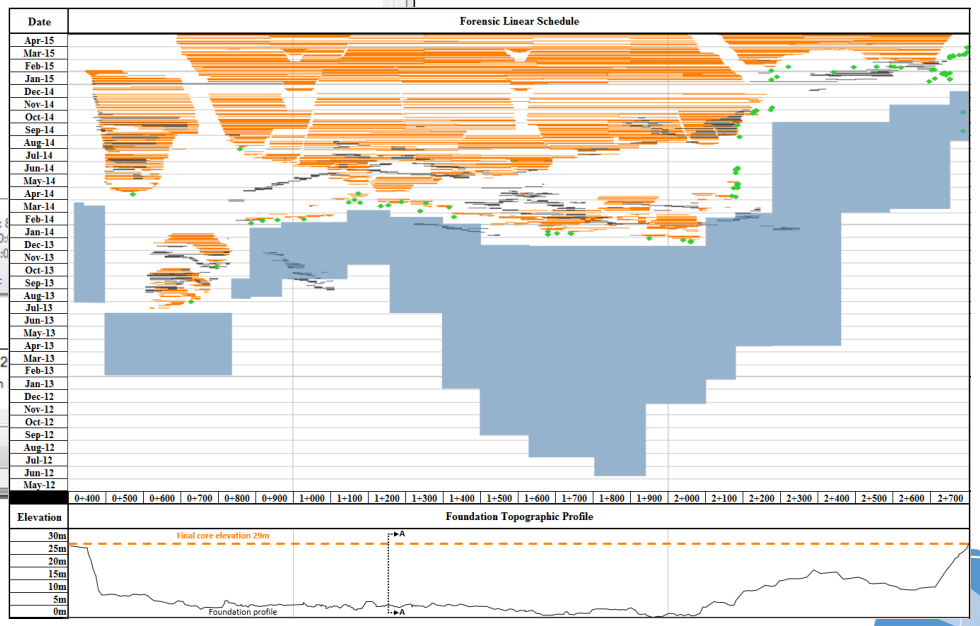
ACTUAL TO FORENSIC





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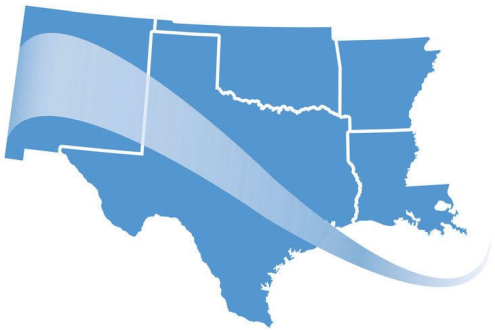
CONCURRENT DELAY PRINCIPLE CASE STUDY

MODULE 3



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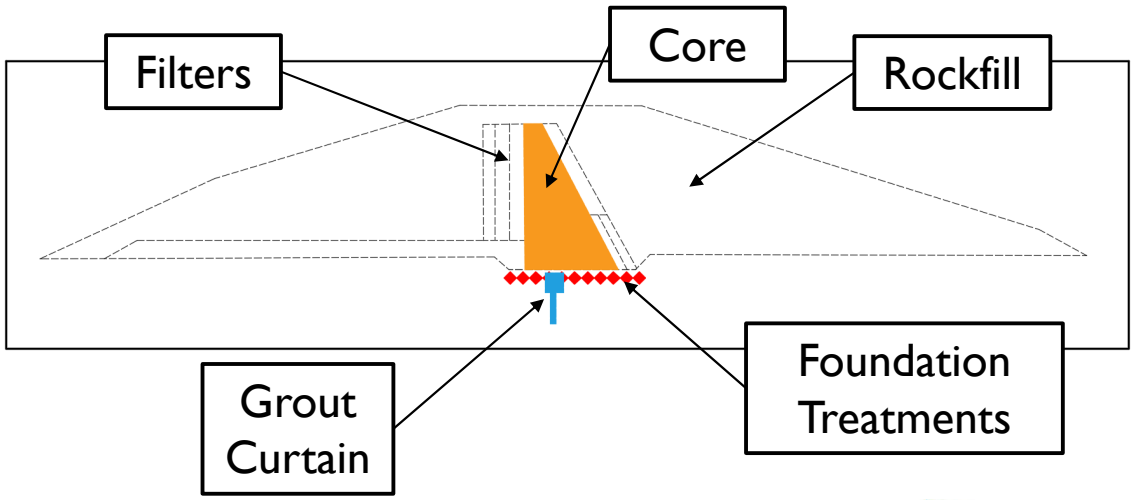
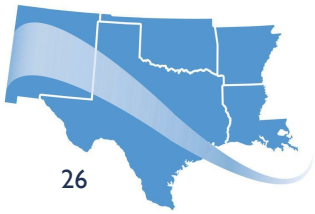
THE BORINQUEN DAM 1E – PANAMA CANAL EXPANSION PROJECT

- Length: 2.3 Kilometers (1.4 miles)
- Volume: 5 million cubic meters (6.54 million cubic yards)
- Embankment dam with an impervious residual soil core, multi-zone filters, rockfill body, rip-rap shell, treated foundation, and a pressure grouted curtain below it.





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THE PROJECT ON A NON-RAINY DAY

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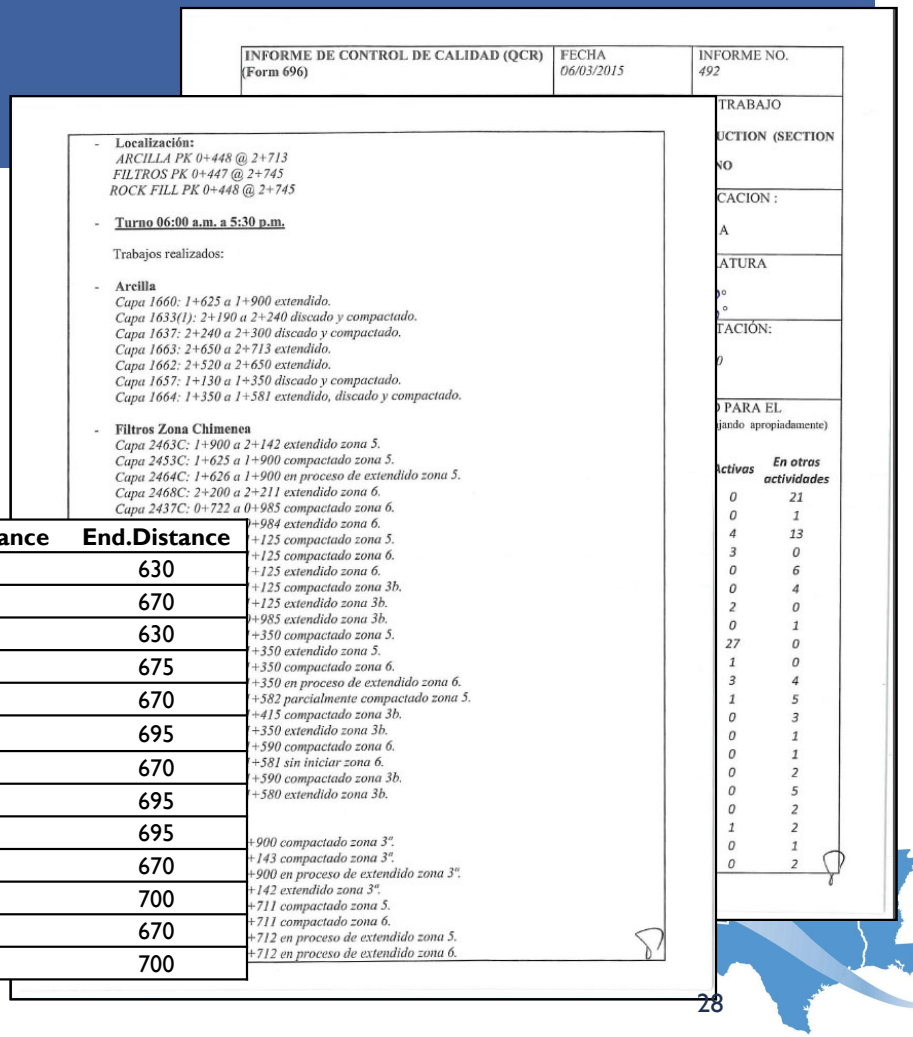
THE BORINQUEN DAM 1E – FORENSIC MODEL

- Borinquen Dam 1E Forensic Linear Schedule Model
  - Extract data from daily reports:
    - Activity Type
    - Initial Station
    - Final Station
    - Date

Task-ID	Name	Date	Start.Distance	End.Distance
A-00001	/ Capa 1	16-Jul-13	620	630
A-00002	/ Capa 2	17-Jul-13	645	670
A-00003	/ Capa 3	17-Jul-13	620	630
A-00004	/ Capa 4	23-Jul-13	645	675
A-00005	/ Capa 5	24-Jul-13	660	670
A-00006	/ Capa 6	24-Jul-13	675	695
A-00007	/ Capa 7	24-Jul-13	660	670
A-00008	/ Capa 8	25-Jul-13	675	695
A-00009	/ Capa 9	25-Jul-13	670	695
A-00010	/ Capa 10	25-Jul-13	660	670
A-00011	/ Capa 11	25-Jul-13	695	700
A-00012	/ Capa 12	25-Jul-13	660	670
A-00013	/ Capa 13	25-Jul-13	690	700



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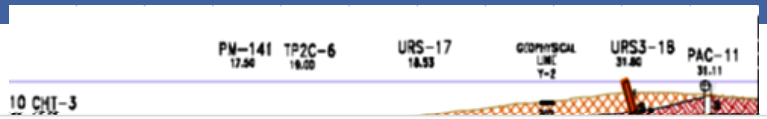
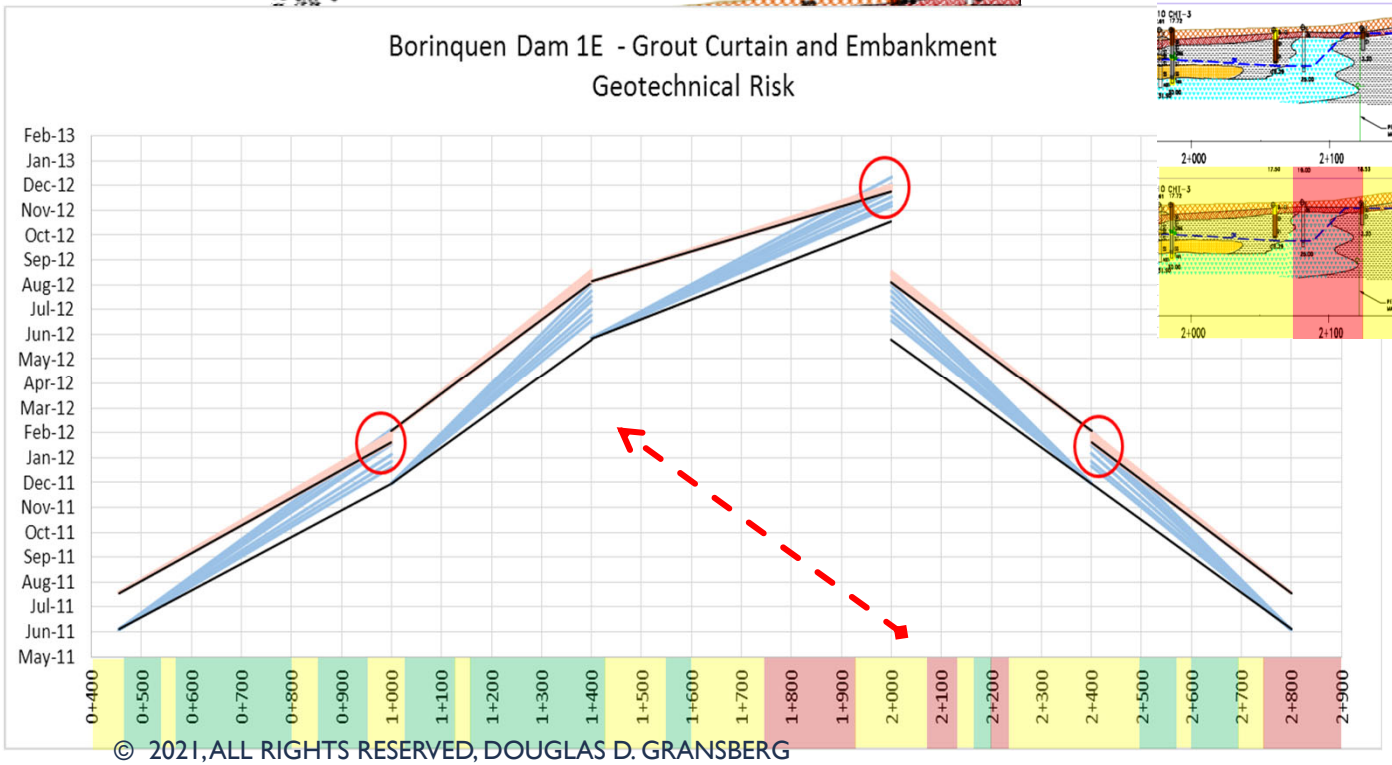
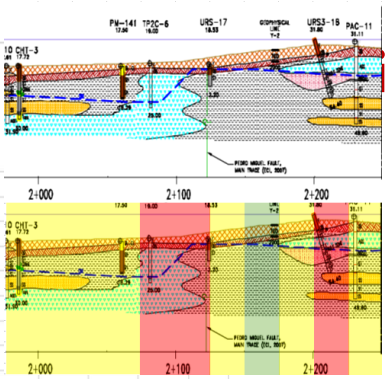
DESIGN TO CONSTRUCTION VISUALIZATION







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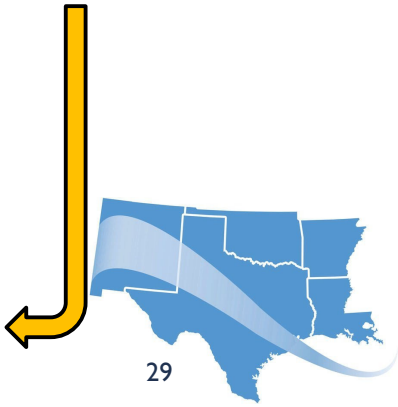

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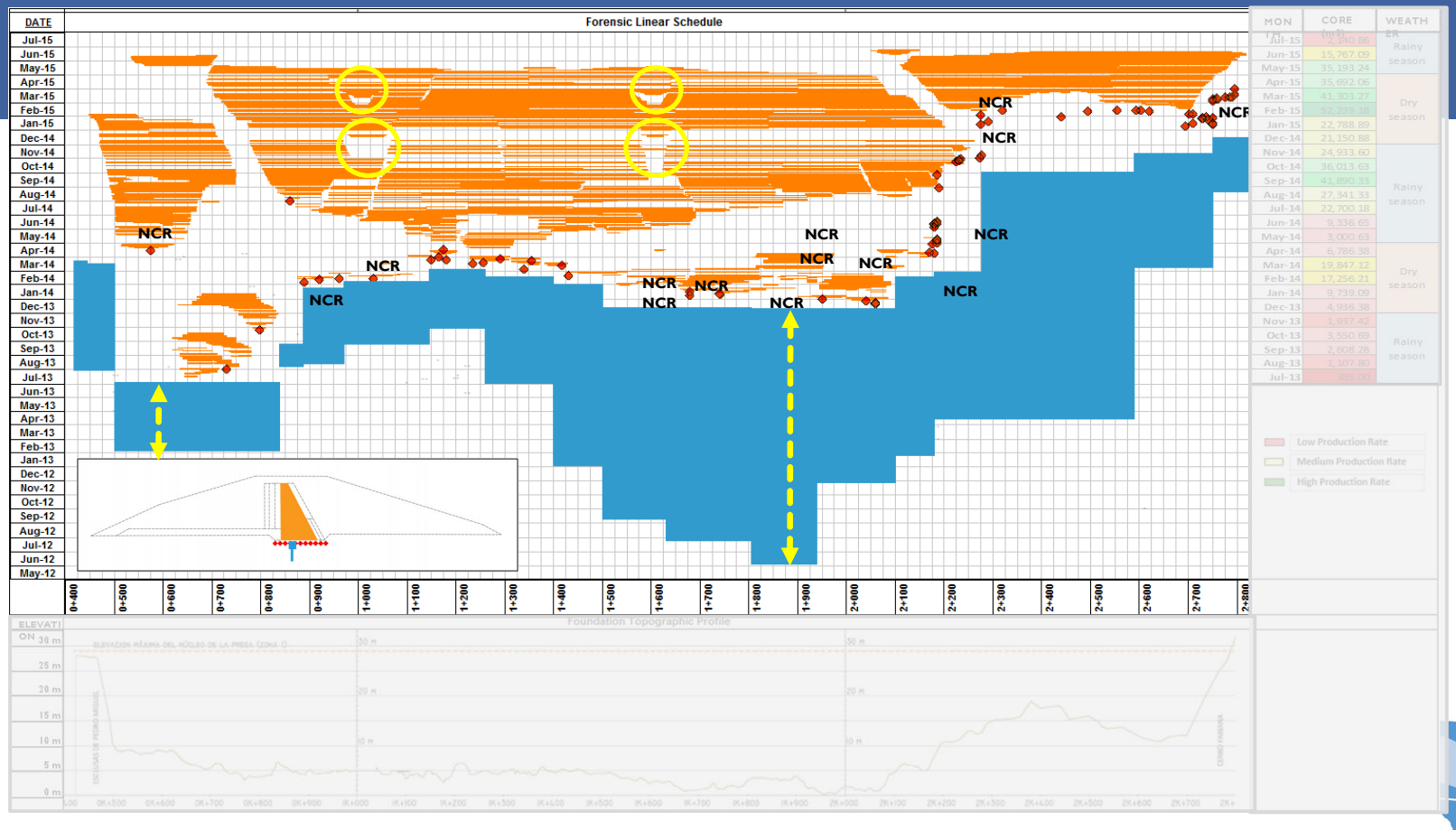

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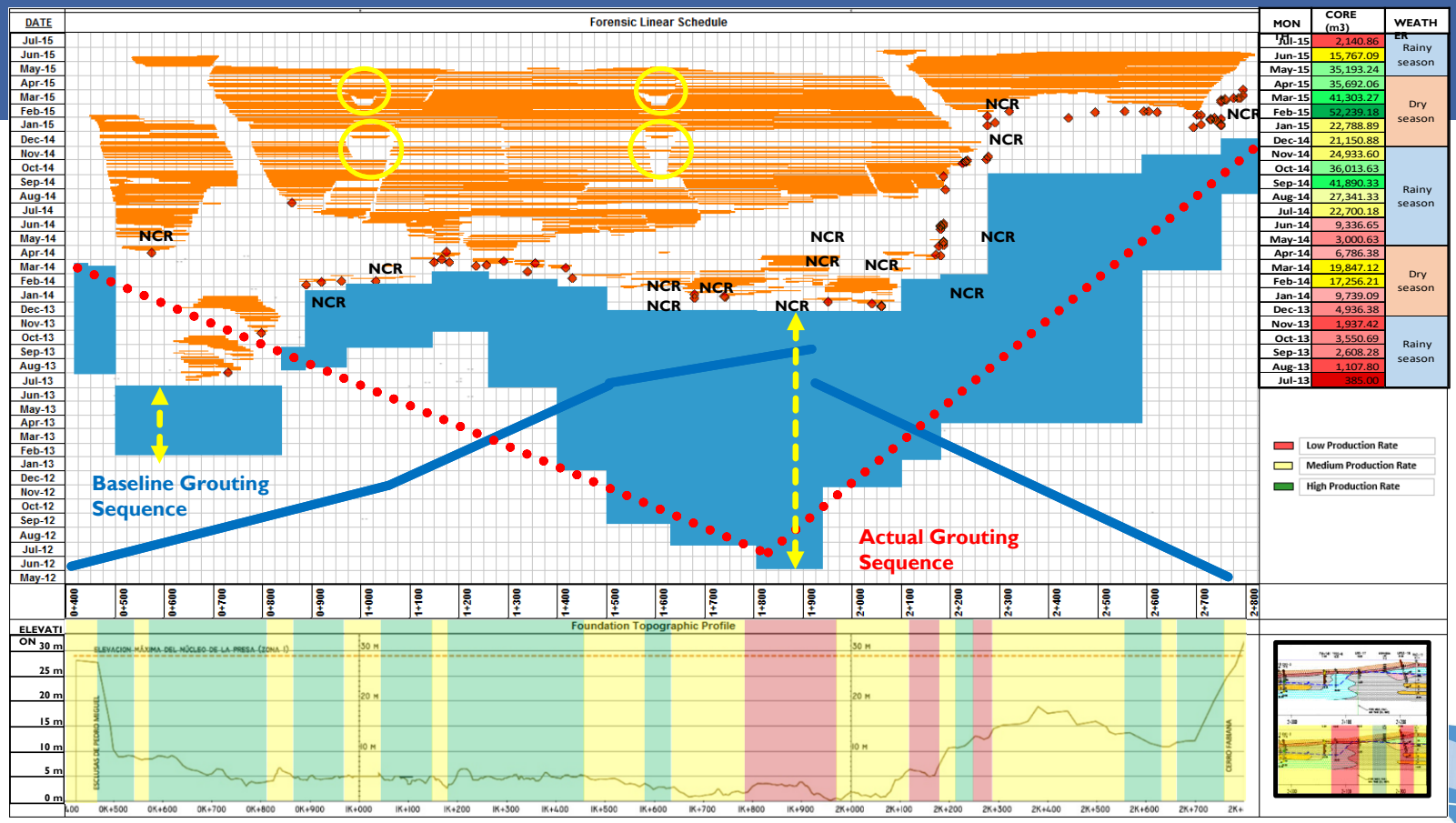

MON	CORE (m3)	WEATHER
Jul-15	2,140.86	Rainy season
Jun-15	15,767.09	
May-15	35,193.24	
Apr-15	35,692.06	Dry season
Mar-15	41,303.27	
Feb-15	52,239.18	
Jan-15	22,788.89	
Dec-14	21,150.88	
Nov-14	24,933.60	Rainy season
Oct-14	36,013.63	
Sep-14	41,890.33	
Aug-14	27,341.33	
Jul-14	22,700.18	
Jun-14	9,336.65	
May-14	3,000.63	
Apr-14	6,786.38	Dry season
Mar-14	19,847.12	
Feb-14	17,256.21	
Jan-14	9,739.09	
Dec-13	4,936.38	
Nov-13	1,937.42	Rainy season
Oct-13	3,550.69	
Sep-13	2,608.28	
Aug-13	1,107.80	
Jul-13	385.00	

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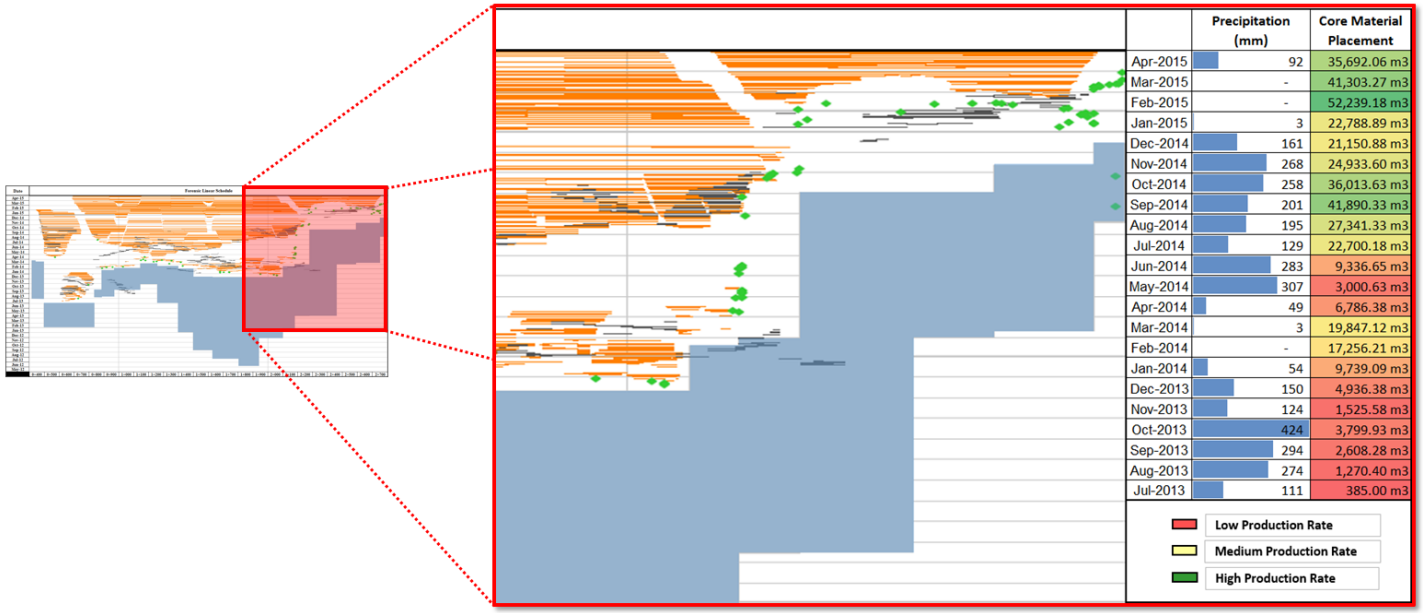
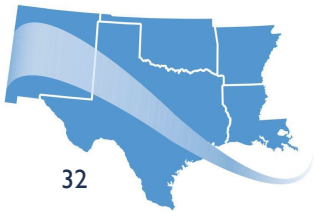
BORINQUEN DAM 1E MODEL – RAINFALL AND PRODUCTION



	Precipitation (mm)	Core Material Placement
Apr-2015	92	35,692.06 m3
Mar-2015	-	41,303.27 m3
Feb-2015	-	52,239.18 m3
Jan-2015	3	22,788.89 m3
Dec-2014	161	21,150.88 m3
Nov-2014	268	24,933.60 m3
Oct-2014	258	36,013.63 m3
Sep-2014	201	41,890.33 m3
Aug-2014	195	27,341.33 m3
Jul-2014	129	22,700.18 m3
Jun-2014	283	9,336.65 m3
May-2014	307	3,000.63 m3
Apr-2014	49	6,786.38 m3
Mar-2014	3	19,847.12 m3
Feb-2014	-	17,256.21 m3
Jan-2014	54	9,739.09 m3
Dec-2013	150	4,936.38 m3
Nov-2013	124	1,525.58 m3
Oct-2013	424	3,799.93 m3
Sep-2013	294	2,608.28 m3
Aug-2013	274	1,270.40 m3
Jul-2013	111	385.00 m3

Low Production Rate
Medium Production Rate
High Production Rate



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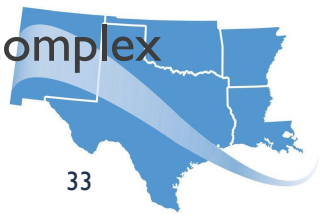
SUMMARY

- The proposed method is a new application of the LSM as a data visualization tool that previously did not exist in the literature.
  - Can be used for forensic analysis or as a project controls tool, providing accurate and objective results.
  - Uses data that is typically collected in a construction project (daily production reports).
- The correlation of information is the biggest advantage of this method, as the effect of influencing factors in way the activities were performed is sometimes not apparent in traditional scheduling tools.
- It is a great communication tool for explaining how events developed in a complex project. Saves time and conveys the message objectively.



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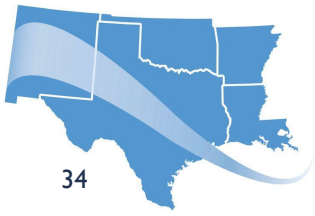
CURRENT APPLICATIONS

- COVID 19 is a *Force Majeure* event - Excusable non-compensable delay… time only.
- Concurrent delays that may have occurred
  - Owner stop work orders
  - Contractor supply chain issues
  - Weather events
  - Delayed permits
  - Reduced production due to PPE, virus testing, etc.
- Other factors
  - Decreased traffic volumes
  - Ability to accelerate production



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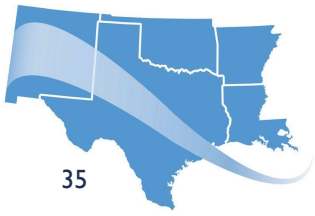
FUTURE APPLICATIONS

- LSM forensic analysis provides
  - Single picture of events based on
    - Documented production records
    - Quality assurance/quality control records
    - Actual weather data
    - Other objective information
- As the industry moves to post-COVID infrastructure projects, LSM provides a tool to achieve a fair and equitable resolution of the pandemic-related and other events.



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WRAP-UP

- Thank you for your participation
- Please fill out and hand in evaluation forms
- Let me know if I can ever be of service
  - dgransberg@gransberg.com

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