



Utilization of Terrestrial LiDAR in Reliability-Based Levee Operation and Maintenance

Rune Storesund, P.E.

Department of Civil & Environmental Engineering & Center for Catastrophic Risk Management
University of California, Berkeley Email: rstoresund@earthlink.net



LiDAR OVERVIEW

Light Detection And Ranging



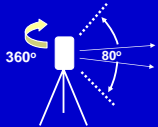
LiDAR is a technology that determines distance to an object or surface using laser pulses. The range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal

- Time of flight pulsed rangefinder
- 905 nm wavelength laser
- 1.4m radians Beam divergence
- Measures 4400 points per second
- Minimum angular separation of points at 0.108°
- Range: 80° Vertical and 360° Horizontal



Approximate Point Density per m²

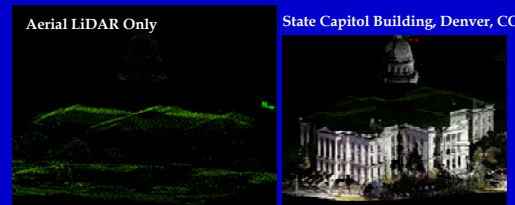
Scan Resol.	Horizontal Distance			
	10 m	50 m	100 m	300 m
High	2770	625	28	3
Med	156	7	2	0.2
Low	11	0.4	0.1	0.01



Scan Resolution Angular Separation: High (0.108°); Med (0.432°); Low (1.178°)

Benefits of Terrestrial LiDAR Technology

- Rapid data collection (4,000 to 50,000 pts/second)
- Captured detail & features
- Georeferenced "point cloud"
- Remote sensing - no access
- Light & transportable
- Ease of post-processing
- Merge with aerial LiDAR data
- Incorporate Traditional Surveys
- Photodocumentation & Overlay



This comparison shows the augmentation of terrestrial LiDAR to aerial LiDAR. The figure on the right is a point cloud from a terrestrial LiDAR survey that has been superimposed on the aerial-based LiDAR point cloud. As can be noted, the terrestrial LiDAR has significantly more detail than the aerial LiDAR survey.

RELIABILITY CONCEPTS

Reliability - The probability (likelihood) that a given level of quality will be achieved during the primary life-cycle associated with an engineered system (Bea, 1990).

Performance Levels as defined by USACE (ETL 1110-2-556)

Expected Performance Level	Beta (β)	Probability of Unsatisfactory Performance	Approximate Median Factor of Safety (F.S.)
High	5.0	0.000003	2.5
Good	4.0	0.00003	2.1
Above average	3.0	0.001	1.7
Below average	2.5	0.006	1.6
Poor	2.0	0.023	1.4
Unsatisfactory	1.5	0.07	1.3
Hazardous	1.0	0.16	1.2

The reliability of engineered systems are impacted by uncertainties associated with the demands and capacities of these systems. Four primary types of uncertainties have been identified.

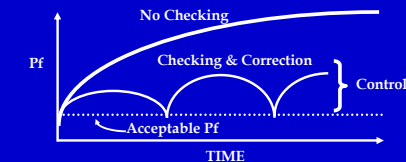
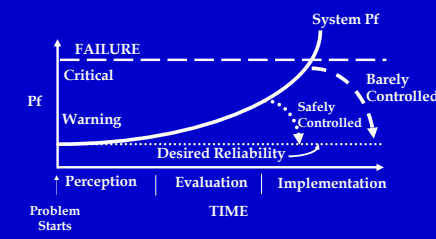
Uncertainties (Bea, 2005)

- Type I - Natural Variation (aleatory)
- Type II - Model Uncertainty (epistemic)
- Type III - Human & Organizational
- Type IV - Information & Knowledge

Reliability Approaches:

- Proactive - Completed before activities are carried out
- Interactive - Completed during (real-time) activities
- Reactive - Implemented after the activity has been carried out

INTERACTIVE APPROACHES (Operations & Maintenance)



RELIABILITY CHARACTERIZATION

Incorporation of Terrestrial LiDAR in Reliability Characterization:

- Proactive** - System Condition, Asset & Geometry Mapping, Hydrologic Modeling Surface Creation
- Interactive** - Levee Deformations (slumps, slides, etc.), Erosion Rates
- Reactive** - Seismic Deformations, Subsidence, Emergency Repair

COMPOSITE HYDRODYNAMIC MODELING:

Aerial LiDAR + Terrestrial LiDAR + Conventional Surveys + Bathymetry

**Georeferenced surveys can be integrated to create large coverage areas with the required level of detail in the form of Composite Models.

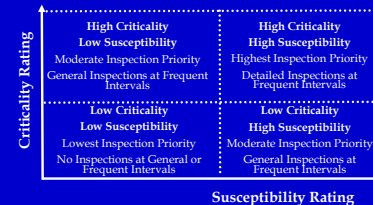
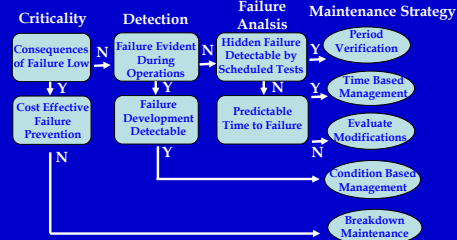
Levee "Capacity" Determination

The ability for levee systems to resist loads (demand) is a function of the levee's capacity against an identified failure mechanism. Actual system-wide levee geometry and erosion potential have been traditionally difficult to ascertain. New tools such as Terrestrial LiDAR is making this much easier, thereby improving system reliability evaluations.

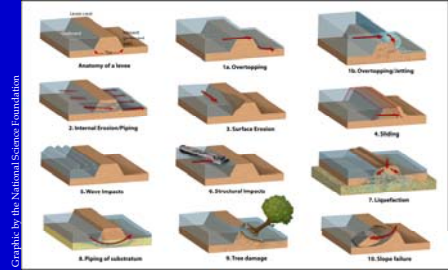
CAPACITY DETERMINATION

- Geometry: LiDAR
- Erosion Potential: EFA
- Foundation Conditions: Soil Borings & CPT

DECISION RULES (Operations & Maintenance)



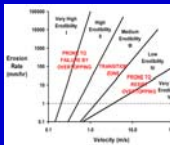
LEVEE PERFORMANCE



Graphic by the National Science Foundation

Examples of common levee failure modes. This is not a comprehensive summary of failure modes and it is not uncommon for multiple failure modes to occur in conjunction with each other.

Failure Mechanism	USACE Guidelines	FEMA Guidelines	Observed in Greater New Orleans Area
Overtopping	Not allowed	Not allowed	Yes
Sliding	Not allowed	Not allowed	Yes
Internal Erosion and Piping	Design criteria provided	Analysis required	Yes
Lateral Surface Erosion	Protection required	Protection required	Possibly
Wave Impacts	Protection required	Protection required	Yes
Structural Impacts	Not addressed	Not addressed	Yes
Slope Failures	Design criteria provided	Analysis required	Yes
Sliding	Design criteria provided	Analysis required	Yes
Underseepage	Design criteria provided	Analysis required	Yes
Liquefaction	Not directly addressed	Not directly addressed	Possibly
Human Errors/Blunders	Not directly addressed	Not directly addressed	Yes



Hurricanes Katrina and Rita demonstrated that our current design and evaluation approaches are not exclusive/exhaustive in their treatment of failure mechanisms associated with levee performance. Incorporation of new tools and techniques such as the Erosion Function Apparatus testing (developed by Dr. Briard, Texas A&M University) are vital to evaluating levee performance when subjected to surface scour.

Prioritizing Projects to Achieve Desired Performance

