

# GRAND AND MORLEY TUNNELS IN AMBOS NOGALES DRAINAGE FEATURES AND FLOOD MAGNITUDES

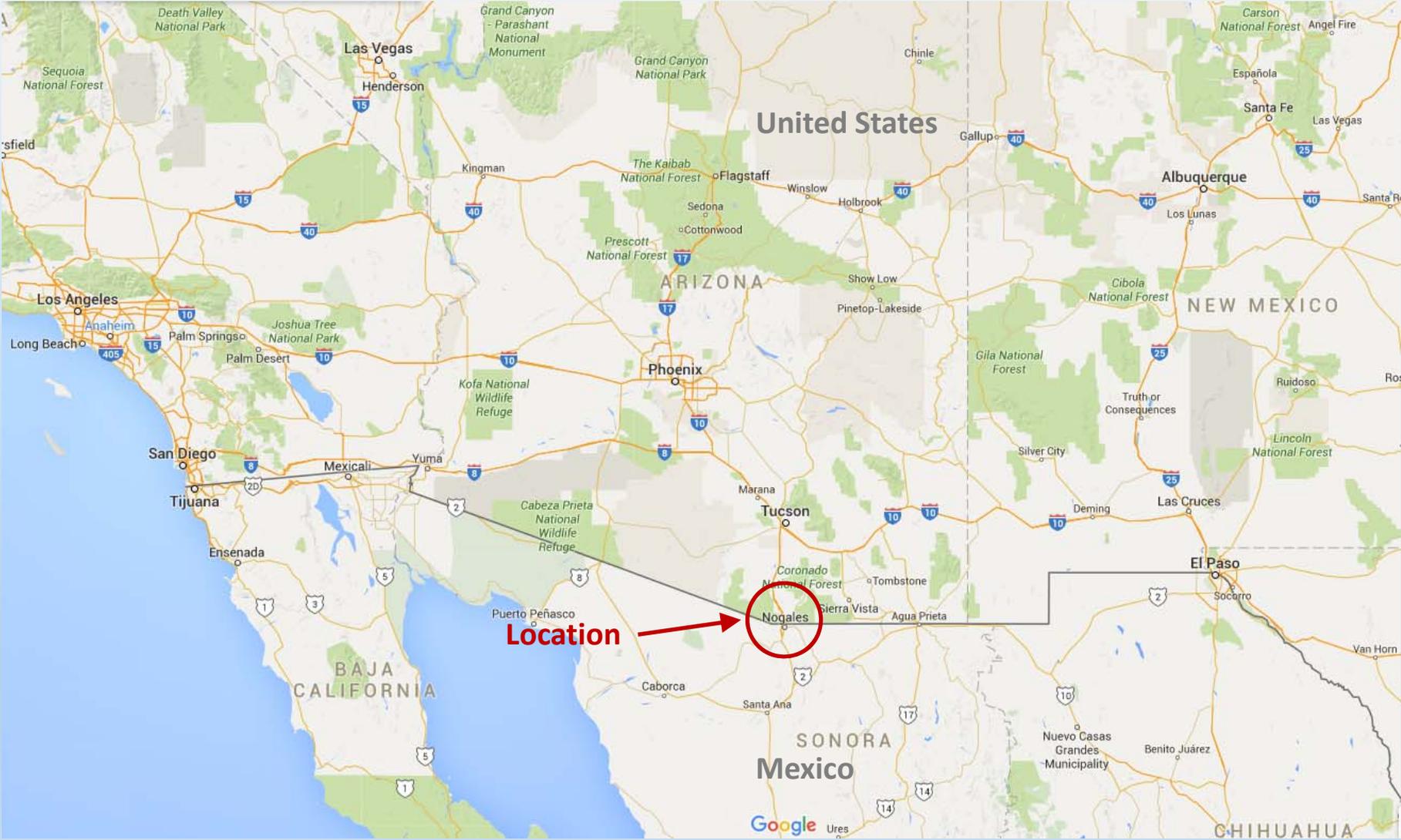
by Padinare Unnikrishna, Ph.D., P.E., CFM

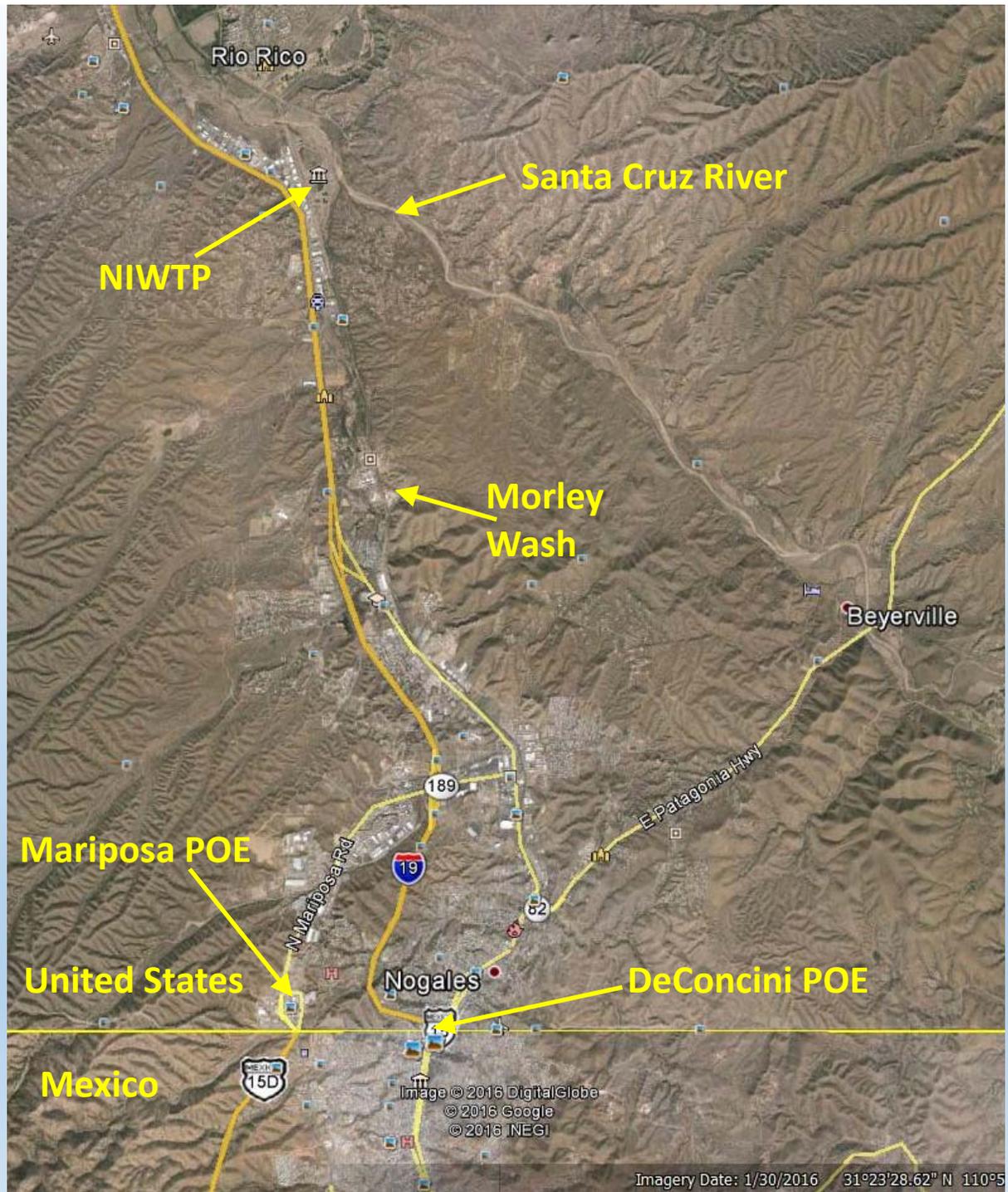


International Boundary and Water Commission  
United States Section

For U.S. Department of State Meeting on April 28, 2016

# Nogales Vicinity Map





# Nogales Watershed

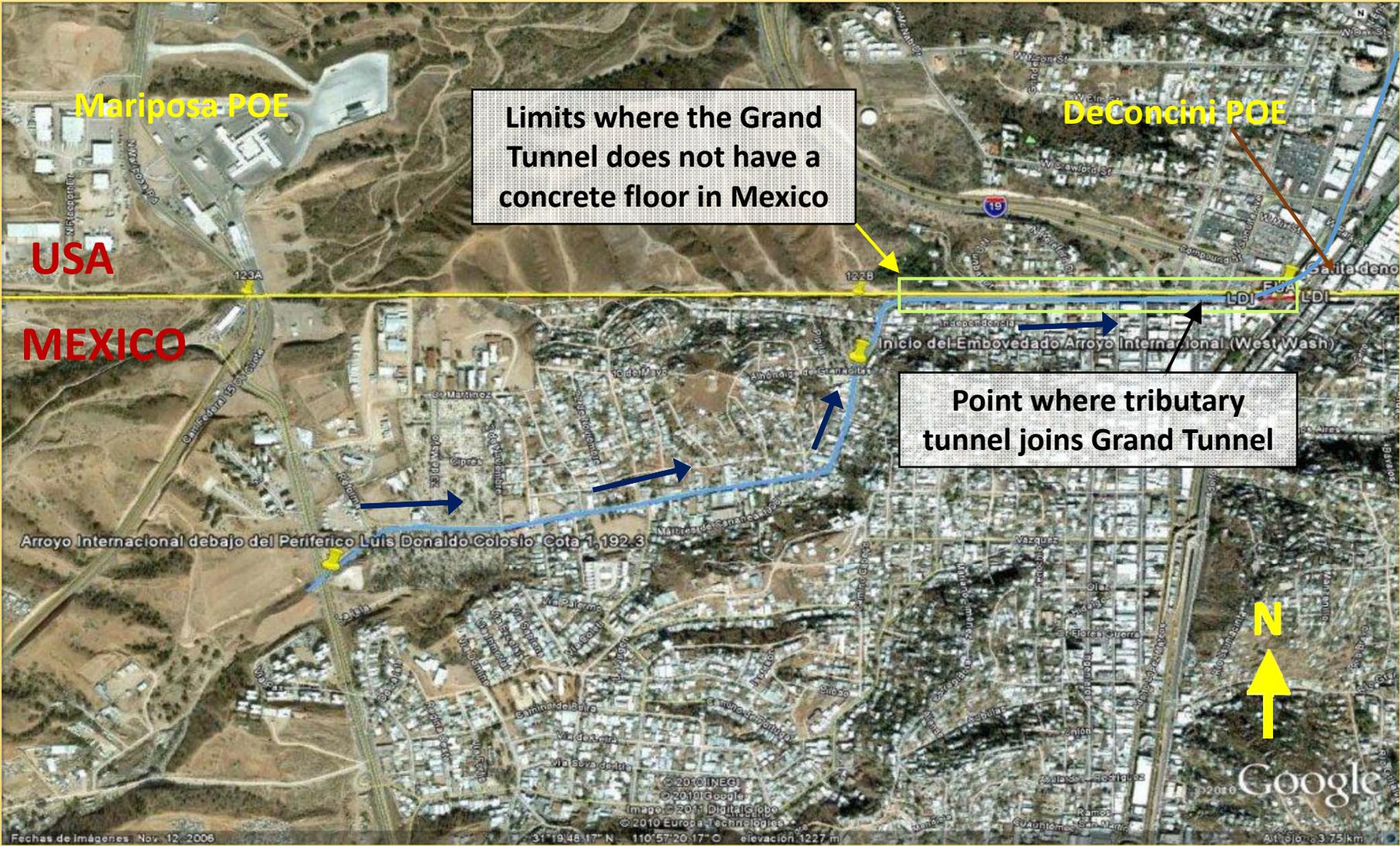


View of the terrain of the Nogales Watershed in Mexico





# Grand Tunnel in Mexico



Alignment of the Grand Tunnel (Arroyo Internacional) in Mexico



USA

MEXICO

12 July 2008 Flood – Approximately 1,000 Feet of the Morley Tunnel collapsed in Nogales, Sonora adjacent to the pedestrian POE.

# MORLEY TUNNEL COLLAPSE 12 JULY 2008 NOGALES, SONORA, MEXICO



## July 12, 2008 (Day 1) Morley Tunnel Collapse in Mexico





Morley Ave in Nogales, AZ



Morley Ave in Nogales, AZ



Morley Ave in Nogales, AZ

## Flooding along Nogales Wash in Nogales, AZ



## Flooding along Nogales Wash in Nogales, AZ



## Flooding from Manhole Pressure Flow in Nogales, AZ



# Damage from September 18, 2014 Flooding in Nogales, AZ



# Damage from September 18, 2014 Flooding in Nogales, AZ



# Nogales Flooding

## Flow Capacities of Tunnels

- Discharge or flow is expressed in cubic feet per second (cfs)
- 1 cfs  $\approx$  7.5 gallons per second [Fluid, U.S.]

The Baker (2011) report estimates capacities for maximum gravity flow throughout the tunnel.

Higher discharges cause pressure flow at tunnel entrance. Pressure flows can be higher, depending on the hydraulic head.

Maximum Gravity Flows:

- Morley Tunnel (East Tunnel) = 1925 cfs
- Grand Tunnel (West Tunnel) = 775 cfs

# Nogales Flooding

## Flow Capacities of Tunnels vs Existing Condition Discharges

The Tetra Tech (2005) report Table 1 cites the following underground channel capacities:

- Nogales Wash (Morley)  
= 5,297 cfs
- Cemetery Wash (Grand)  
= 1,589 cfs

### Nogales Watershed Existing Condition Discharges at International Boundary (Tetra Tech, 2005)

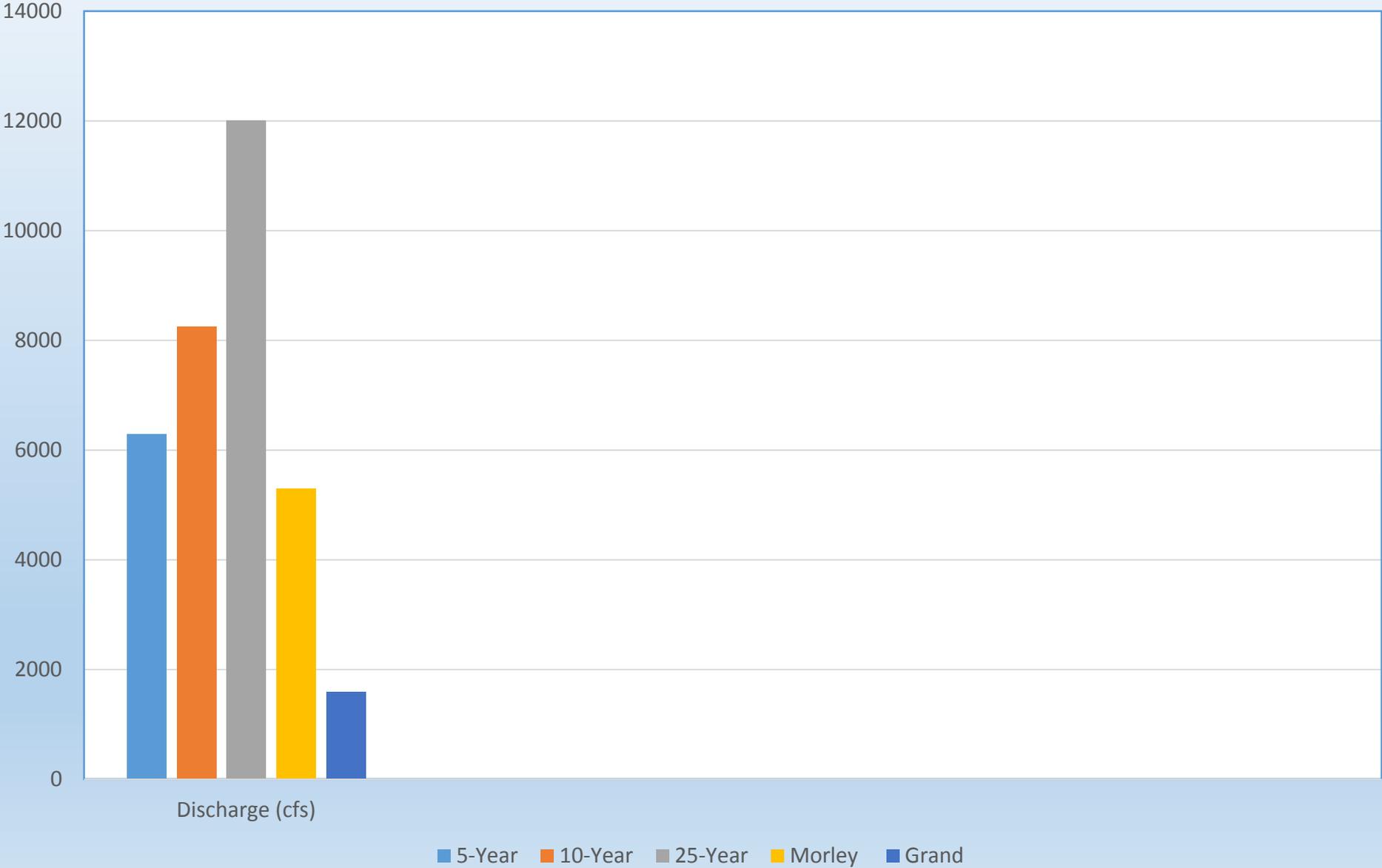
Frequency	Discharge (cfs)
5-Year	6,286
10-Year	8,250
25-Year	12,011

## One Hour Discharge Volume Equivalent

The 5-year discharge would inundate 520 acres under 1 foot of water. Similarly, the 10-year and 25-year discharges would respectively inundate 682 and 993 acres under 1 foot of water.

# Nogales Flooding

## Comparison of Existing Condition Discharges and Flow Capacities of Tunnels



# Nogales Flooding

## Flow Capacities of Tunnels vs Future Condition Discharges

The Tetra Tech (2005) report Table 1 cites the following underground channel capacities.

- Nogales Wash (Morley)  
= 5297 cfs

- Cemetery Wash (Grand)  
= 1589 cfs

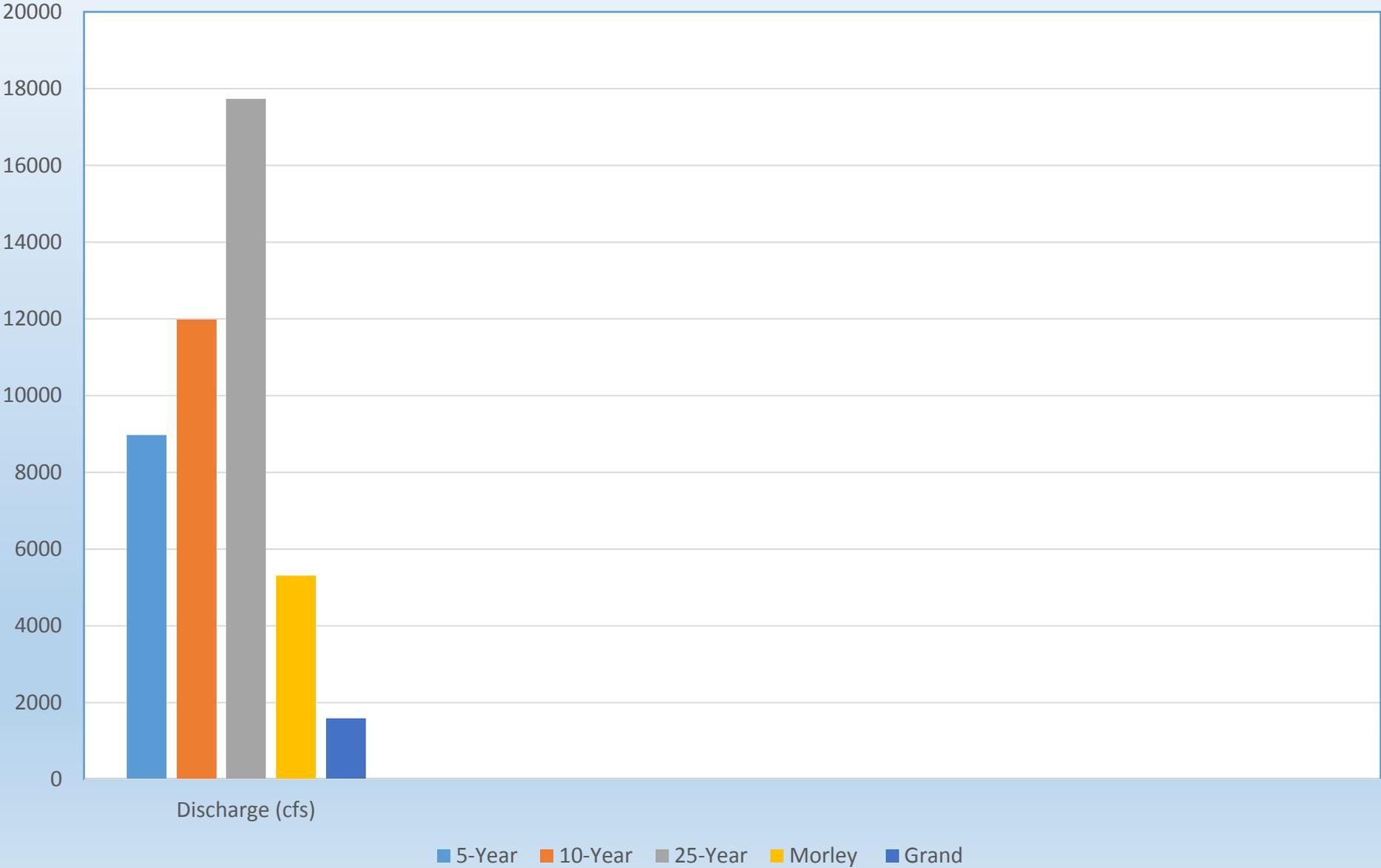
### Nogales Watershed Future Condition Discharges at International Boundary (Tetra Tech, 2005)

Frequency	Discharge (cfs)
5-Year	8,963
10-Year	11,968
25-Year	17,732

**Future conditions** are without mitigation. They represent development as occurring at a rate similar to past decades and **assuming that full build-out of the watershed occurs.**

# Nogales Flooding

## Comparison of Future Condition Discharges and Flow Capacities of Tunnels



**QUESTIONS?**



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# GRAND AND MORLEY TUNNELS IN AMBOS NOGALES

## STRUCTURAL CONCERNS

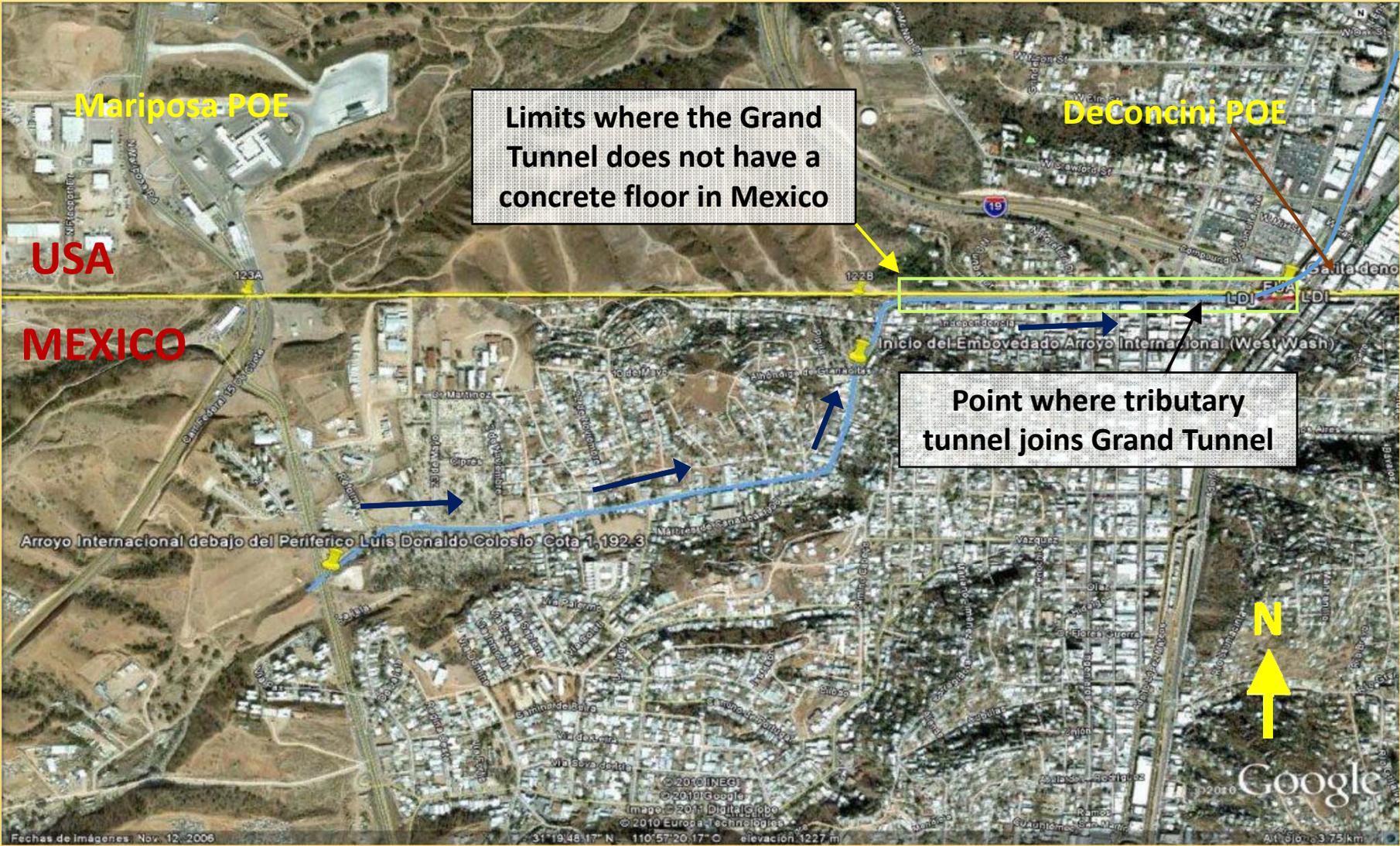
by Jose A. Nuñez, P.E.



International Boundary and Water Commission  
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# Grand Tunnel in Mexico



Alignment of the Grand Tunnel (Arroyo Internacional) in Mexico

# Grand Tunnel in Mexico



Looking west from under the Bus Depot located in Mexico

# Grand Tunnel in Mexico

North wall of channel paralleling international boundary in Mexico



# Grand Tunnel in Mexico

South wall of channel paralleling international boundary in Mexico



# Grand Tunnel in Mexico



12-inch Gap Below South Wall on July 6, 2014

# Grand Tunnel in Mexico



Looking west on July 6, 2014. Floor is now significantly deeper on August 7, 2014. It appears that a waterfall effect is eroding the support for the walls along the channel.

# Grand Tunnel in Mexico



Immediately adjacent to border. (see reflectors)

# Grand Tunnel in Mexico



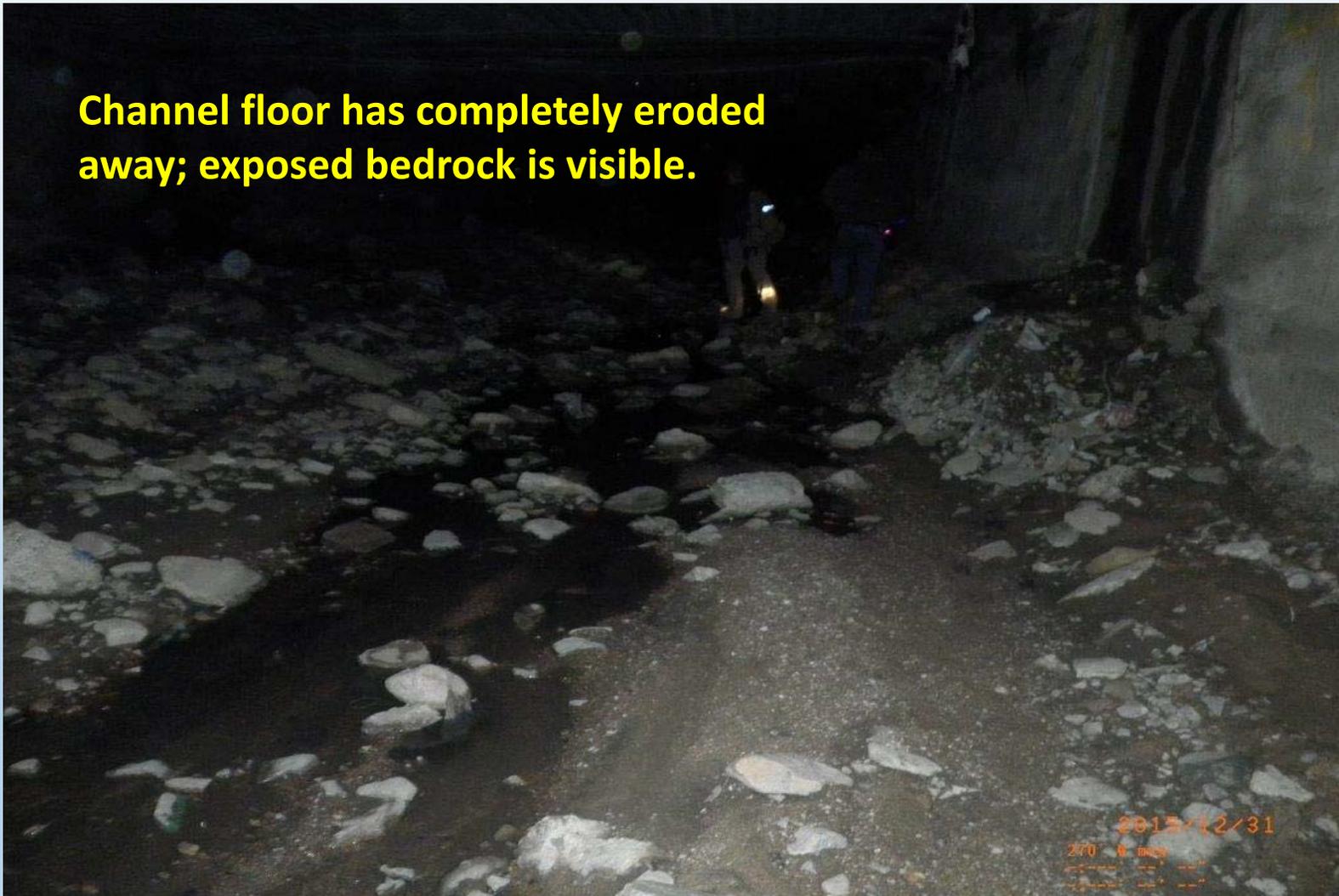
Immediately adjacent to border. (see reflectors)

# Grand Tunnel in Mexico



Within first 50 feet from international border.

# Grand Tunnel in Mexico



**Channel floor has completely eroded away; exposed bedrock is visible.**

Within first 50 feet from international border.



# Morley Tunnel in United States

Deck of the box culvert, which is used as access road between East International Street and East Park Street.



Traffic wear and tear to concrete deck, resulting in exposed rebar on the right side corner.



Close-up view of exposed rebar on the right side corner of the culvert deck.

# Morley Tunnel in United States

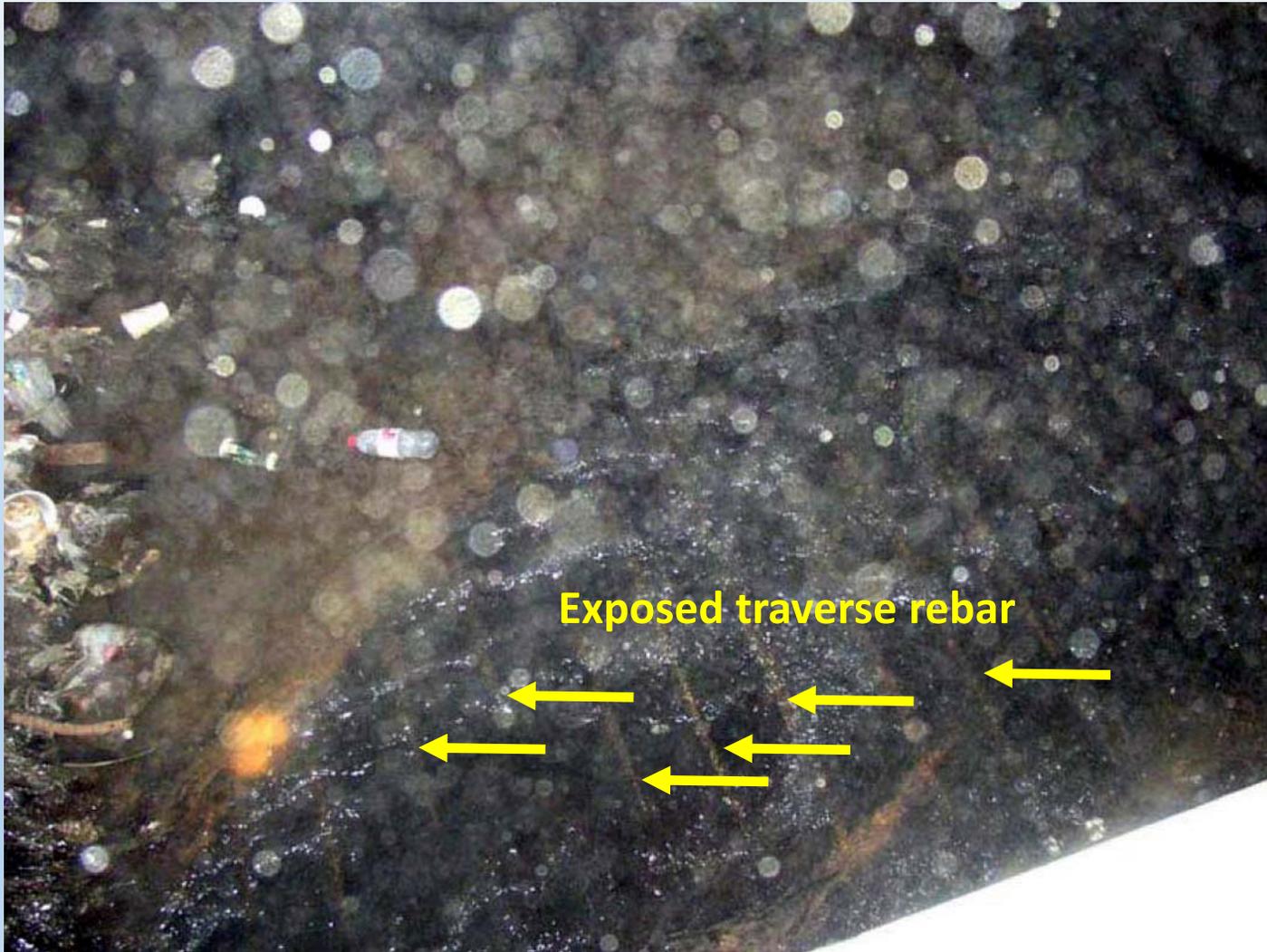
## Floor of the Box Culvert



**Abrasive particles have scoured away concrete and exposed transverse rebar.**

# Morley Tunnel in United States

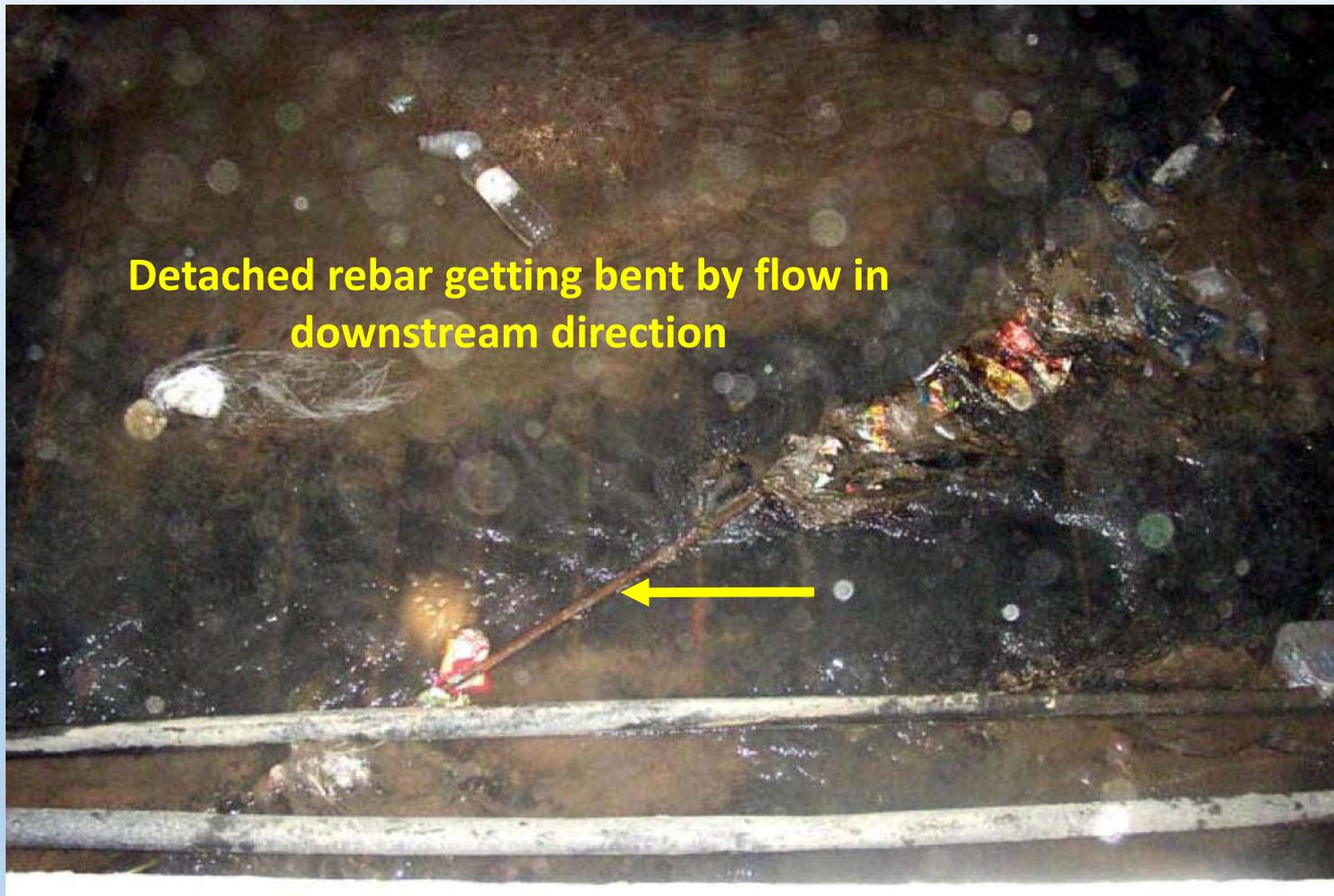
## Floor of the Box Culvert



Scour has worn away concrete and exposed transverse rebar.

# Morley Tunnel in United States

## Floor of the Box Culvert



Abrasive particles eroded concrete and exposed transverse rebar.

# Morley Tunnel in United States

## Ceiling of the Box Culvert

**Ceiling deck penetrated for installation of plumbing fixtures.**



**QUESTIONS?**



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