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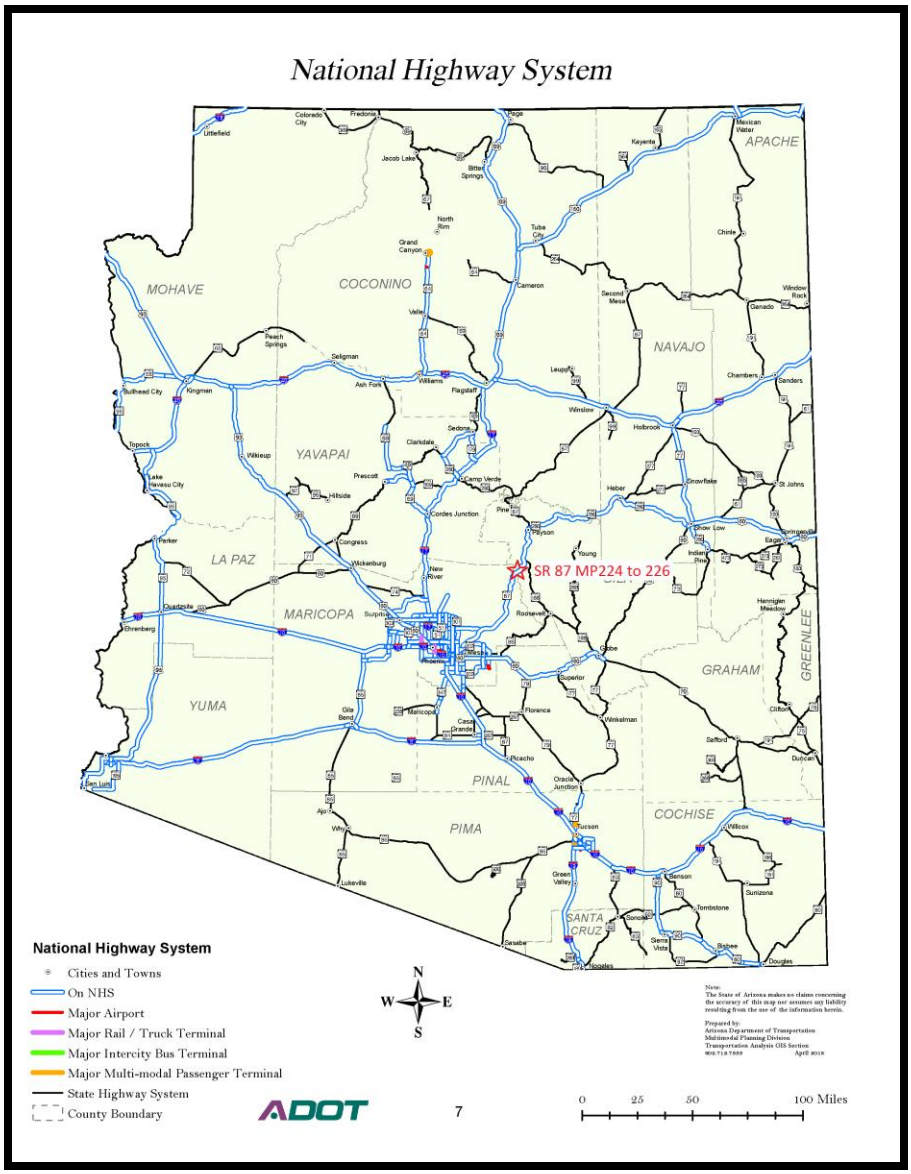
Subject: Recurring NHS Emergency Projects with Geotechnical Origins

A comprehensive review was conducted of ADOT's historical projects, from January 1, 1997 to Current, on the National Highway System (NHS) that have been designated as Emergency Repair (ER). The results of the review indicate a total of one location on the NHS has produced multiple ER projects since January 1, 1997.

PROJECT LOCATION



OVERVIEW

TABLE 1 – Summary of ER projects on SR 87 MP 224 to 226

Project No.	TRACS	Begin MP	End MP	Year	Construction Scope
ER-087-224	H6745 01C	224	226	2005	SLOPE STABILIZATION
ER-087-B-NFA	H7035 01C	224.02	224.92	2008	EMBANKMENT AND SLOPE REPAIR
ER-087-B(201)A	H7700 01C	223.92	224.96	2009	SLOPE STABILIZATION
ER-087-B(208)A	H8175 01C	224.21	224.42	2010	SLOPE UNLOADING
ER-087-B(207)A	H8072 01C	224	225	2011	SLOPE STABILIZATION

Heavy rains in 2004 and 2005 caused the cut slopes and soil nail walls between MP 224 and MP 226 began to experience localized failures. Project ER-087-224, TRACS No. H6745 01C ($2.4M) removed several of the failed soil nail walls and regraded the cut slopes to reduce the steepness of the slope grades. The excavated material was utilized to buttress an existing 100+ ft embankment with 1.5:1 (H:V) slope rate. This embankment was exhibiting signs of failure with tension cracking affecting the pavement.

Project ER-087-B-NFA, TRACS No. H7035 01C ($5.1M) began construction in March, 2008. The project removed additional soil nail walls that had failed, flattened the existing cut slopes, and continued the embankment buttress stabilization. During the early portion of the project, and after a period of heavy precipitation events, a landslide at MP 224.3 closed the highway for approximately 1 week. Additional excavation, soil-nail wall removal, and embankment construction was added to the project. A total of 89 soldier piles (30” diameter x 43’ deep) and 9 drilled shafts (48” diameter x 65’ deep) were also added to the project. A total of approximately 186,300 cubic yards (CY) of material was excavated, and utilized to improve stability of the 100+ ft embankment.

Project ER-087-B(201)A, TRACS No. H7700 01C ($1.8M), was constructed in 2009 as a result of the geotechnical investigation and monitoring. The drilled shafts and soldier piles previously installed in 2008 as emergency mitigation measures were being displaced and bent by a continued slow slide movement. A total of 26 drilled shaft shear piles (66” diameter x 73’ deep) were installed in the landslide, and approximately 75,000 CY of material was excavated and used to construct additional NB embankment buttress near MP 226 in anticipation of a possible alignment shift. A rock buttress was placed behind the SB barrier between MP 224.3 (STA 2816+00) and MP 224.4 (STA 2824+00) to aid in stabilizing the local slide at that location. A separate rock buttress was placed behind the SB barrier from MP 224.0 (STA 2803+00) to MP 224.1 (STA 2805+00) to stabilize a partially failed soil nail wall. The 12-foot diameter multiplate pipe in Slate Creek (MP 226) was extended.

Heavy rains in January 2010 resulted in a change in the slide conditions and the slide began to show an increase in the rate of movement due to increased pore water pressure heads in the perched groundwater trapped in the landslide near STA. 2820. To save the shear piles, Project ER-087-B(208)A,

TRACS No. 8175 01C, excavated approximately 62,000 CY above the shear piles, and installed a series of horizontal slope drains to reduce the groundwater in the slopes adjacent to the roadway..

Project ER-087-B(207)A, TRACS No. H8072 01C ($1.5M) was constructed in February of 2012. This project removed the Northbound (NB) upper tiered wall and a portion of the damaged NB lower wall near MP 224.2. An estimated 124,000 CY of material were excavated and used to construct additional NB embankment buttress near MP 226.

Figure 2 – Southbound Slope Failure

Figure 3 – Northbound Slope Failure

ROOT CAUSE ANALYSIS

Stability failure of the slopes is attributed to global stability failure due to low shear strength soil and periods of high rainfall. Saturation of the low plasticity silt and clay deposits behind and under the earth retaining structures creates lateral forces and weakens the shear strength of the soils. Saturation of the site soils is increased due to the fractured, inconsistent depositional history of the site soils due to historic landslides. Fissures and soil physical property changes within the soil mass creates zones of water infiltration and retention. Retention of water within the soil mass creates excessive lateral forces which have caused catastrophic failure of the slopes during and after periods of heavy precipitation.

Heavy rainfall and catastrophic failure of the slopes have shown a strong cause and effect relationship. Piezometer instrumentation has documented significant increases in groundwater elevation following periods of heavy rainfall. Loss of shear strength of the saturated soil combined with lateral forces due to saturation is the root cause of the slope failures.

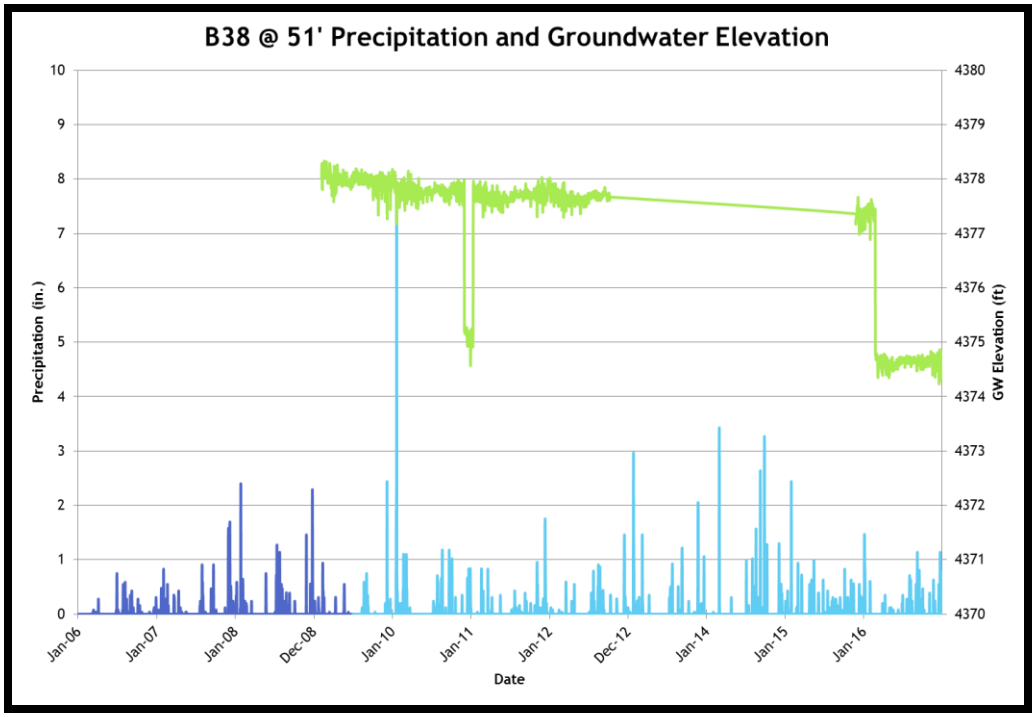


Figure 4 – Piezometer measurement of groundwater elevation

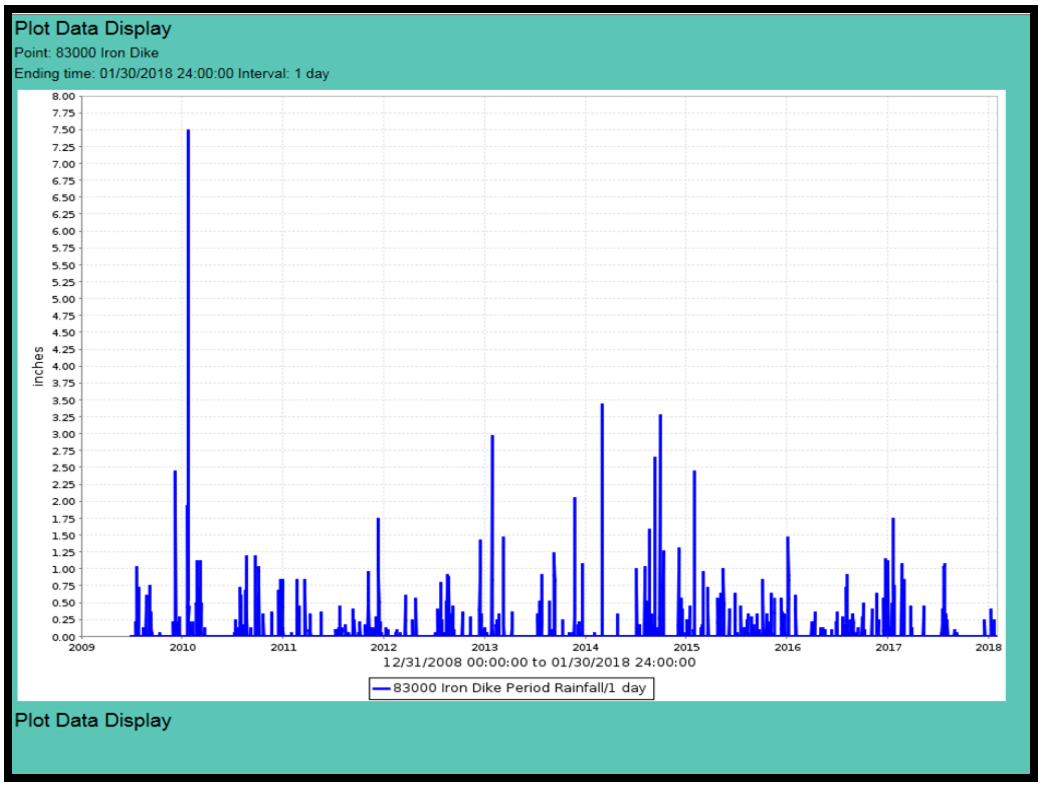


Figure 5 – Rainfall history from Iron Dike rain gauge

RISK ASSESSMENT

The fractured, inconsistent deposition of site soils during historic landslide events combined with low plasticity silts and clays physical properties of site soils creates high risk for future slope instability. The low plasticity silts and clays readily absorb water and exhibit low to no shear strength when saturated. The landslide depositional history has created fissures and high permeability zones which allow a high rate of permeability. Saturation of site soils must be mitigated to limit risk of future slope stability failures.

Mobility impacts to SR 87 are probable if slope stability failures occur. SR 87 is a major commerce corridor between Phoenix and Payson. In March of 2008, slope failure closed SR 87 for approximately 1 week resulting in loss of commerce and monetary impacts to the travelling public.

Continued monitoring is recommended to identify slope movement and other indications of instability. Increased frequency of monitoring is recommended following periods of rainfall.

ALTERNATIVE SOLUTIONS

Mitigation measures to date have included slope flattening, shear piles, lateral drains, rock buttresses, and drainage channeling. Installation of shear piles has proven ineffective due to inability to control large lateral forces due to saturated soils. Control and removal of the subsurface water with lateral drains has been an effective mitigation strategy. Slope flattening has also proven to be an effective mitigation strategy. Rock buttressing has also proven to be an effective strategy.

Table 2 – Mitigation Strategy Alternative Evaluation

MITIGATION STRATEGY	COST	EFFECTIVENESS
Slope Flattening	HIgh	High
Shear Piles	HIgh	Low
Lateral Drains	Low	High
Rock Buttressing	Medium	High
Surface Drainage Control	Low	Medium

PREFERRED ALTERNATIVES

Control of the subsurface water content through lateral drains is the most cost effective mitigation strategy. Additional strategies to stabilize the near surface with native plant vegetation should be investigated. Initial layback of slopes where wall failures have occurred are necessary to provide a slope angle that is suitable for vegetation establishment and erosion control. Slope flattening should be minimized to limit impacts to right of way.

Rock buttressing provides stability and a highly permeable pathway to remove water from the toe of slope. Importation of angular rock and disposal of displaced soil is expensive. Surface drainage control provides low cost and benefits the management of slope erosion. Control of surface water also reduces the volume of water that may infiltrate the site soils. Lining of drainage channels with an impermeable barrier may be an effective strategy.

NEXT STEPS

Continued monitoring of the area is recommended. Installed instrumentation and lateral drainage systems should be maintained. The following two slopes have been identified for immediate mitigation:

Northbound slope from station 2804+00 to station 2810+00 has developed surficial indications of a slope failure following heavy rains from the remnants of hurricane Rosa. The fissure is located approximately 70 feet in elevation above SR 87 and extends laterally for 200+ feet. Depth of the fissure is approximately 12 feet deep. Width is approximately 12 inches. Continued rainfall will produce additional movement toward SR 87. A mitigation project should be immediately planned.

Figure 6 – North Bound Slope Failure at Station 2807+00

The South Bound slope from station 2801+00 to 2806+00 upper tier was removed in a previous project. Since the upper tier removal, the lower tier has begun failing. Heavy erosion is also occurring above the lower tier. The slope is in excess of 100 feet tall and will continue to erode and additional sections of the lower wall tier will continue to fail.

Figure 7 – South Bound wall failure and erosion at station 2803+00