On October 3, 2018 the “Diversion” pipe located northwest of the southern end of the dam washed out during a rain event. This report summarizes the history of the diversion pipe, the observations made after the event and likely causes of the failure.

HISTORY OF THE DIVERSION PIPE AT THE SUCKER BROOK FLOOD CONTROL PROJECT.

The original design of the “Diversion” pipe is found in a 1965 hydraulics report prepared by the US Army Corps of Engineers (USACOE) and was incorporated into the design plans for the flood control project. It was determined that with minimal effort an additional 0.34 SM of drainage area could be re-routed into the flood control dam. From the original design reports, the original 48 inch Asphalt Coated Corrugated Metal Pipe (ACCMP) was designed to pass a 25 year flood without causing the auxiliary spillway weir to spill. The flows associated with this 25-year design event was stated in the report to be 200 cfs. The design flood frequency for this entire structure was not specifically noted, but during the design event, the auxiliary spillway weir would be flowing at a depth of 4 feet for a flow of 500 cfs and the 48 inch pipe would be flowing at a rate of 250 cfs. (this higher flow in the 48” pipe was generated by increasing the depth of flow over the 48” pipe entrance by an additional 4.5 feet above the 25-year flow conditions.)

The 48 inch ACCMP was constructed in 1967-68 by the USACOE and remained in place until it was replaced with a 42 inch N-12 HDDP pipe in 2016.

The datum for all of the pipe elevations, including the weir elevation, are taken from the 6-1-15 design plans, which were also marked “As-Built” and dated September 2016. The inlet to the pipe structure consists of an 18 foot weir at elevation 1014 (assumed elevation in feet) and the opening of a 42 inch Corrugated Plastic N-12 Pipe with an invert at 1007.5. (The lining of this N-12 Pipe is smooth by design, the exterior of the pipe is corrugated.)

On October 3, 2018 2-2.5 inches of rain was reported in Winsted with localized areas of 2.5-3 inches (with the majority of this rainfall falling in a relatively short amount of time) scattered in the Highland Lake watershed. It should be noted that upwards of 8 inches of rain fell in September in the general area resulting in ground saturation prior to the October event. This rainfall although not otherwise
noteworthy created flow conditions that were likely the highest experienced at the site since the completion of the construction work on the pipe system. If there were higher peak flows in this piping system between the pipe completion date of September 2016 and October 2018, it is my contention that a similar catastrophic event would have occurred.
POST EVENT OBSERVATIONS AS OF DECEMBER 2018:

The maximum water level in the concrete headwall/side channel weir structure at the site was 2 inches below the side channel weir. Estimates of flow related to this water surface elevation are discussed under the “Engineering Deductions” section of the report.

The top three sections of the upper manhole appear to have been displaced from their original location through an overturning process. The top two sections are located approximately 50 feet and 90 feet downslope from their original location, whereas the lower manhole piece might still be touching the remainder of the manhole. The concrete cap of the manhole is upside down and laying about 5 feet from the lower manhole piece. The actual manhole cover has not been recovered at this time. There was also one section of 20 foot pipe missing between the manhole and the downstream end of the 42 inch pipe.

10/5/2018 this upper manhole section is located close to its original position. Note: concrete cap nearby.

There was evidence that water had flowed down the slope starting at about the uppermost manhole location. The grass was laid down in an arc pattern starting at the original location of the upper manhole. The flow volume could not be considered insignificant since this flow leaving this original central location quickly developed rivulets and these deepened into gullies quickly. (Since I only got to look at the portion of the site that didn’t wash away, my photos and observations were on the outside edges of this arc of flow.)
10/5/18 Photo of grass laid down due to concentrated flow on left (looking downstream)

10/5/18 photo of sheet and rill erosion forming on left of washout
10/5/18 View of grass laid down by concentrated flow (note no evidence of water flow over the grass in the non-shaded portions of the upper left side of this photo.)

10/5/18 View of rill erosion starting to form due to concentrated flow. Right downstream of upper manhole.
I also noted that as the water flowed down the slope, there was evidence of more erosion. It was also observed that the larger rills occurred closer to the slope failure zone. This was most likely due to the higher concentration of flow in that area coupled with a greater depth of flow down the center.

The lower manhole had been tilted upon its base, but all the pieces of the manhole were still sitting on one another and had not been moved from their pre-rainfall location. The pipe on the upstream side of the manhole was still attached to the manhole through the mortared joint constructed in 2016. The manhole cover had been displaced, although the top of the manhole frame was only tilted at a 10-15 degree slope.

It was important to check if the connection between the upper 42 inch pipe and the upper manhole had failed due to ultimate movement of the upper manhole. However, no determination can be made as this connection was not found or observed.

Additional Observations Nov. 4-7 2019 (Removal of 42” pipe)

On November 4, 2019, the construction contractor NJR Construction LLC began excavation and removal of the manholes and pieces of 42” plastic pipe at the site. John Brochu P.E. of Macchi Engineers LLC was there on November 4th, and I was on site on November 5th and 6th. Most of the work on November 4th consisted of clearing the manhole structures and pieces of pipe from the scour area at the site. There was no removal of the approximately 240 feet of pipe that remained intact downstream of the culvert entrance.

On November 5, 2019, the excavator operator started to carefully uncover the sections of pipe from downstream to upstream. (one section at a time). Then he carefully pulled apart the freed pipe from the next pipe upstream. The purpose of this operation was to get an opportunity to carefully examine each pipe in place, including determining the condition of the bedding of select material that was placed around the pipe. This select material had three purposes, the first being to allow for drainage below the pipe, and the second being to allow for proper compaction and support around the pipe. And the third purpose was to prevent large stones being placed directly on the pipe and possibly deforming it or crushing it. This bedding was in place around the pipe in all locations observed.

Another purpose of taking the pipe apart one section at a time was to see if the gaskets required by the job specifications detailing the pipe installation were in place. All of the gaskets were in place except one. This gasket was at the joint 120 ‘downstream/downslope of the inlet structure was not present.

From the video report, a substantial flow of water (Approx. 5 GPM gallons per minute) entered the pipe at the pipe joint 119’ feet down from the pipe inlet. This was the same joint noted without the gasket.

There was a slight deformity in the downstream end of pipe 120-140, but the video did not note a large joint gap at joint 139’. Since there was about 5 GPM of flow flowing through the bedding of pipe 100-120, particular attention was paid to see if there were any voids under this section of pipe. There were not.

My conclusion is: there was one gasket missing from the pipes that were removed in front of us, and knowing from the video below that there were gaps in several joints of the pipe, and also knowing that construction was not consistent, I believe that there was not a great degree of care used in placing this 42 inch plastic pipe. These type of issues could lead to problems that would develop slowly over time, such as increased deflections in the pipe, and possibly the movement of some bedding materials leaving voids below the pipe could occur. However, I did not see anything that would lead me to believe that
the lack of care in placing this pipe, could have in itself caused this pipe system to fail only two years after it was constructed.

**Pipe video:**

Pipe conditions as reflected in the video inspection conducted on December 7, 2018 in order to see the conditions of the remaining pipe.

The video started at approximately 10:15am Friday 12/7/18. The video stationing started at 0.00 at the upstream entrance to the 42 inch pipe and continued upwards until the pipe became blocked with leaves and debris at station 228. The last 10-12 feet of the pipe was full of leaves and debris because the upper inlet chamber was full of leaves captured during the fall and flushed downstream during a trial run at dewatering the inlet chamber just a few days before the pipe video inspection. The video inspection showed that pipe joints at stations 1.50’, 20’, 59’, and 98’ had minimal gaps. The pipe joints at stations 79’, 139’, 197’ and 218’ had gaps with a maximum dimension of ½”. The gap at station 158’ was approximately 1”. The gaps at stations 39’, 119’, and 178’ were all approximately 2” in width. All of the gaps were located at the bottom of the pipe. All pipe tops were tight with a few pipe crests showing some signs of deformation that took place during the seating of the pipes.

A small seep of water was entering the pipe at station 79’. A substantial flow of water was entering the pipe at station 119’. This flow of water stayed in the pipe until it flowed out of the bottom of the pipe at station 178’. A small amount of water flowed back into the pipe at station 197’.

**ENGINEERING DEDUCTIONS:**

**NOTE:** Without the ability to test my deductions in a hydraulics laboratory, my opinions and deductions are based on my observations and calculations and insight from my 35 years of experience in the field of water resources engineering. With that in mind, here are my opinions and deductions.

It is my opinion that the pipe inspection showed that 4 joints out of the 12 within the pipe length inspected were not installed properly. Out of the remaining 8 joints only 4 joints could be considered typical. The joint gaskets on 2 of the pipe joints were ineffective, with the viability of the gaskets being questioned on 2 of the other joints.

There were definitely voids starting to develop around the pipe from water moving into and out of the pipe joints. This water movement would have been more severe during a rain event where the 42 inch pipe was flowing upwards of half full which are the suspected conditions of October 3, 2018.

This rainfall event resulted in a peak elevation at the diversion pipe inlet structure of 1013.8 which would result in flows between 150 cfs and 200 cfs. Although a 42” N-12 pipe at a 17% slope can carry over 200 cfs, the entrance conditions of the pipe most likely limit the amount of water that can enter the pipe to between 150 cfs and 200 cfs. There was some smoothing of the mortar that held the pipe in
place, but it was not specific to any rounded pipe entrance condition, meaning that there is a unique condition at the pipe face and the headwall and the 42” pipe entrance. This simply means there are no specific pre-existing charts to determine the entrance coefficients. To add another variable into the complex situation at the pipe entrance, the construction of a sump and tapered entrance within the concrete diversion pipe headwall structure would result in some initial velocity being maintained by the water flowing into the pipe. This would result in additional velocity head being available to drive more water into the pipe than would exist during a static water condition upstream of the pipe. Therefore, it is prudent to use a range of possible inflows into the pipe as for all future calculations on pipe and culvert flow.

Assuming the lower estimate of the flow range, the 150 cfs experienced on October 3rd 2018, water would have been flowing in the pipe at approximately 43% full (18” depth) and at a relatively steady velocity of 40.8 ft/sec as it entered the first manhole.

Assuming the upper estimate of the flow range, the 200 cfs experienced on October 3rd, 2018, water would have been flowing in the pipe at approximately 46% full (19” deep) and at a relatively steady velocity of 43.6 ft/sec as it entered the first manhole.

It is important at this point to calculate the amount of fall that the 18 inches of water exiting the 42 inch pipe would experience before it hit the other side of the 5 foot diameter manhole. Using the 40.8 ft/sec from above, the amount of fall would be 0.24 feet and this, added to the slope of the water leaving the pipe at 17% over 5 foot diameter of the manhole, would result in another 0.85 feet. This results in a total drop of 1.09 feet within the manhole. This would mean that a large percentage of the energy of the water would hit the other wall of the manhole. This would translate to some water and the energy of the water being directed downward into the bottom of the manhole and a smaller portion of the water and the energy from the water being directed upward into the top of the manhole and the manhole cover.
Manhole cover approx. elev. 971.0

PRECAST CONCRETE MANHOLE
INV. IN 964.46
INV. OUT 949.20

Upper Manhole
Upper Manhole
Assuming 150 cfs

- Elev. 972

18" of water in 42" pipe 40.8 ft/sec

Invert 964.46

Water dispersal limits = 25 vertical feet

Velocity head for water flowing at 40.8 ft/sec = 25 feet

0.85' drop due to slope
0.24' drop due to gravity
1.09' total drop

959.0 Depth of water needed to pass 150 cfs through 42" pipe at 949.2

42" N-12 pipe out of Manhole 1

Center of pipe 950.9

949.2
Although, the water exiting the 42 Inch pipe dropped 1.09' before it hit the other wall of the manhole, there was still a considerable component of the velocity head existing within the water that would act
perpendicular to the catch basin wall. Using the smaller flow volume of 150 cfs and therefore the smaller velocity of 40.8 ft/sec, I calculated the velocity head of 25.8 feet hitting the other side of the manhole using this slightly lower velocity.

Because the concrete cap of the upper manhole had been displaced, I couldn’t make any conclusions about the missing manhole cover of the upper manhole, but since the lower manhole cover was dislodged from its seat on top of the manhole, and knowing of the high velocities of the water in the piping system, I conclude that the lower manhole cover was moved by water forces acting from inside of the manhole.

It is my opinion that this build-up of head pressure was enough at the upper manhole to force the upper manhole cover from the manhole frame and distribute water in an arc formation in the area of the manhole. This water flowed down the hillside and concentrated in the center of the hill. The center of the hill had two issues. First, this area had been removed to place the pipe and manholes and disturbed material was more easily eroded than the surrounding natural ground. Secondly, the specification for this backfill material minimized the amount of larger stones that would have curtailed the erosion.

I also think that the lower manhole experienced the same effect to a smaller degree. But the distance for the water to run overland, and the assumption that some of the water flow volume would have been kept out of the piping system because it flowed overland from the upper manhole structure would have made the problems at the lower manhole structure less severe.

There were problems with the installation of the pipe as could be seen on the pipe inspection video. These problems would have gotten worse and given enough time, there may have been sink holes forming around the pipes and manholes. My opinion is that voids around the plastic pipe allow for the pipe to flex during periods of higher flow and at some point the pipe joints could be separated. This would result in a situation like the one that occurred in October of 2018. I don’t think that this happened during the October 3rd 2018 rainfall event, but I cannot rule this out as a cause of the failure of the piping system.

**Looking Forward:**

I suggest that when the remaining 200 + feet of this pipe gets dismantled that particular attention be paid to the efficacy of each of the gaskets. There was no full time inspection on this project, so there are very few photos and no reports on the process of connecting the pipes together.

I suggest that particular attention be given to locating the manhole section that contained the hole to accept the 42 inch upper pipe. This manhole section should be put aside and inspected to see if there is any relevant information that can be gleaned from the manhole and the condition of the mortared joint

12/31/18
In the future, I suggest that plastic pipe not be used in critical areas, such as through dams or on steep slopes.

Although construction inspection is a costly element of any project, I think that it is important to have a full time inspector for all but the simplest aspects of the repairs on dams. DEEP staff can act as this full time inspector, but it should be understood that although this staff person could continue to work on additional projects, their focus and “office” would need to be the construction site they are inspecting.

A better alternative would be to have an inspector/engineer consulting team undertake the inspection.