# Potential Projects for Flood Mitigation

## Kardon Park

Water Diversion Options when the Thomas Moore Dam was Removed – Gannett Fleming 2013

Brownfield

Wetlands

Millrace/Basins – Christopher Reitman Analysis

Gannett Fleming
100 Years of Excellence Delivered As Promised

TECHNICAL MEMORANDUM

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**DATE:** February 24, 2015

**TO:** Jan Bowers, Chester County Water Resources Authority (CCWRA)

**BY:** Paul G. Schweiger, P.E., CFM, Andrzej Kulik, E.I.T, CDT

**RE:** Canal Investigation Summary

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The purpose of this memorandum is to provide CCWRA with a written summary of observations made by Paul Schweiger, P.E. and Andrzej Kulik, E.I.T. during their assessment of the remnants of the old mill canal beginning at the left abutment of Brandywine Dam, to the shallow lake system in Kardon Park, and ending at the point where the flow returns to East Branch Brandywine Creek.

**Description of Canal and Lakes:**

When the paper mills in Downingtown were in operation, Brandywine Dam was used to divert water from the East Branch Brandywine Creek and from Ludwig's Run into a canal through two intakes (inlets) at the left (east) concrete dam abutment wall. The original canal conveyed water by gravity into a series of four man-made lakes in Kardon Park, and then into a bypass canal around the southern lake (most downstream lake). From the bypass canal, the flow is discharged through a buried conduit through the Borough of Downingtown and outlets at the left bank of the East Branch Brandywine Creek below Business Route 30 (across the stream from the Borough Hall parking lot). The paper mills reportedly used the water from the lakes and the canal to support paper milling operations. An aerial map of the canal accompanied by inspection photographs and survey elevations taken during the June 24, 2014 assessment is provided in ***Appendix A***. No as-built or record drawings of the original canal system are available.

**Inspection Overview:**

*Note: Photos are located in* ***Appendix B***.

On May 31, 2013 and June 24, 2014 Gannett Fleming performed two separate walkthrough inspections of the canal, starting at the Brandywine Dam left abutment wall (canal intake) and ending at the confluence of the canal with the East Branch Brandywine Creek. The total length of the canal, from intake to outlet, is approximately 2 miles, with 0.5 miles from intake to the northernmost lake in Kardon Park, identified as Lake 5. Approximately 75% of the total path of the canal was traversed by foot. The 25% of the canal not traversed included locations of dense vegetation and the buried conduit through the Borough of Downingtown.

During the May 31, 2013 inspection, flow was observed entering the canal through the two square openings in the intake headwall ***(Photo 3)***. USGS Stream Gauge 01480700 upstream of Brandywine Dam located on the East Branch Brandywine Creek registered an average discharge

of approximately 95 CFS for the day. During the June 24, 2014 inspection, the bottom of the sediment filled intakes of the canal, as surveyed on June 24, 2014, were at approximately elevation 250.22 feet NGVD 1988. The same USGS stream gauge registered a flow of 80 CFS. No flow was observed entering the canal through the intake structure ***(Photo 4)***. A survey of the canal immediately downstream of the intake structure identified an approximately 6 inch deep deposit of newly accumulated sediment and gravel as comparison to the survey performed in July 2013 ***(Photo 5)***. The accumulated sediment and gravel appears to have been transported from a scour hole observed immediately downstream of the concrete slab beneath the Struble Trail bridge crossing over Ludwig's Run. On May 31, 2013 when flow was observed entering the canal, discharge in the canal was estimated by Gannett Fleming using approximate methods at the Struble Trail bridge, approximately 950 feet downstream of the intake, to be 0.30 CFS ***(Photo 10)***.

Approximately 170 feet downstream of the canal intake, the top of a concrete sill was identified along the right side of the canal channel, looking downstream ***(Photo 8 and 9)***. Flow was observed overtopping the concrete sill and returning to the East Branch Brandywine Creek on May 31, 2013. The top of the concrete sill was surveyed and determined to be at elevation 250.37 feet NGVD 1988. It is important to note that the concrete sill limits the amount of flow conveyed by the canal. Per the June 24, 2014 survey, the top of the concrete sill is only 0.15 feet (250.37 feet minus 250.22 feet) higher than the bottom of the canal intakes.

On May 31, 2013 flow in the canal was observed from the intakes to the upstream side of the Struble Trail bridge. Downstream of the bridge, and before the Route 30 crossing, two stormwater culverts were observed to have their discharges located within the bounds of the canal. One of the culverts is shown in ***Photo 14.*** Four corrugated metal pipe culverts that transport canal flow beneath Route 30 were noted to have approximately 50% of their cross-section areas filled with sediment deposits ***(Photos 12 and 13)***. Water was observed ponded in the forebay of the four culverts, but no concentrated flow was observed entering or emerging from the culverts beneath Route 30.

Standing water was observed in the canal from Route 30 downstream to the crossing at Norwood Road, on May 31, 2013 and June 24, 2014. A stormwater discharge ditch located adjacent to Norwood Road discharges into the canal immediately upstream of Norwood Road ***(Photo 15)***. Two concrete culverts that convey canal flow beneath Norwood Road were observed to have approximately 75% of their cross-sectional areas filled with sediment deposits ***(Photos 16 and 17).*** On May 31, 2014 flow was observed to be trickling into one of the conduits beneath Norwood Road (no flow was seen entering on June 24, 2014); no flow was observed exiting the conduits downstream of Norwood Road. Water was observed in the stretch of the canal from downstream of Norwood Road to Lake 5 on May 31, 2013 and June 24, 2014, however this water could not be distinguished from standing water or backwater from Lake 5.

A partially submerged conduit appears to transport water from Lake 5 into Lake 4. A well-defined canal with standing water as observed on May 31, 2013 and June 24, 2014 conveys water between Lake 4 and Lake 3. The banks along this portion of the canal are densely vegetated. Wood debris was observed within the canal. The bottom of the canal is comprised of soft mud and organic matter (i.e. leaves, branches). A narrowing of the lake shoreline occurs

between Lake 3 and Lake 2. Lake 3 and Lake 2 may be viewed as a single lake with a contraction in the middle, instead of two lakes being connected by a canal. Water feeding Lake 3 and Lake 2 may include water from the canal, springs, surface runoff and groundwater interflow. Water from Lake 2 exits through a concrete weir ***(Photo 19)*** and continues downstream through two concrete culverts beneath East Pennsylvania Avenue ***(Photo 20)***.

On the downstream side of East Pennsylvania Avenue, water ponds in the bypass canal which conveys water around the southern lake (Lake 1) and into a conduit that passes under the Borough of Downingtown before discharging into the East Brandywine Creek. The depth of water in the bypass canal is controlled by a small concrete spillway structure (crest at Elevation 247.08 feet) near the intersection of Green Street and Mill Road, immediately upstream of the inlet to the buried culvert. Water from the bypass canal enters Lake 1 through a pipe that passes through the earthen berm just downstream of the culverts beneath East Pennsylvania Avenue. Type and size of pipe is unknown as it was almost fully submerged and covered with debris during both site assessments ***(Photo 21)***. Overflow from Lake 1 discharges into the bypass canal at the south end of the lake through two high density polyethylene (HDPE) pipes ***(Photos 22 and 23).*** During the May 31, 2013 inspection, when flow from East Branch Brandywine Creek was observed to be entering the canal, ponded water was observed in the bypass canal only at the north end of the lake. The bypass channel did not have any ponded or flowing water along the southeast and south ends of the lake. During this inspection, the discharge from the downstream HDPE pipe was measured at 0.03 CFS. The upstream HDPE pipe had no flow. During the June 24, 2014 inspection, with no flow from East Branch Brandywine Creek entering the canal, water in the bypass canal was observed along the entire length of the bypass canal to the top of the concrete spillway crest at Elevation 247.08 feet ***(Photo 25).*** Discharge from the two HDPE pipes could not be measured as they were partially submerged ***(Photo 24).*** This suggests that alternative sources such as springs, surface runoff and groundwater interflow, instead of flow from East Branch Brandywine Creek are contributing flow to Lake 3 and Lake 2, which feed the bypass canal, which in turn feeds Lake 1.

**Summary of Observations and Conclusions:**

Based on the observations made during the two field assessments, the following is concluded:

1. Due to natural processes associated with stormwater, flooding, river overflows and road construction (e.g. Route 30 bypass, Norwood Road and other borough streets), the canal has lost significant conveyance capacity and function. The current condition of the canal does not provide reliable or effective conveyance of flows from East Branch Brandywine Creek into the manmade lakes at Kardon Park. The canal's current function appears to be a drainage channel for local stormwater drainage.
2. Bedload deposits (i.e. sediments and gravels) have accumulated throughout the canal resulting in: (1) near total blockage of the inlet openings to the canal from the East Branch Brandywine Creek, (2) loss of gradient through the canal to promote positive flow, (3) partial to total blockage of culverts under Route 30 and Norwood Road and, (4) continued bedload deposition, particularly at the inlet structure and in the canal channel immediately downstream of the inlet. Even if blockage is removed from the culverts, accumulated sediment along the canal and other features will restrict the capacity of the canal.
3. Accumulation of a significant volume of sediment and gravel deposits at the entrance to the canal and in the canal channel immediately downstream of the intake structure was observed to have occurred within the period between the two site visits. These deposits restrict the flow from entering into and flowing through the canal. It appears that sediment deposits will continue to be diverted into the canal from Ludwig's Run and East Branch Brandywine Creek during high flows while the dam remains.
4. The canal gradient from the intake headwall at the dam to the southernmost Lake 1 is very small (i.e. nearly flat). Survey elevations of 250.22-feet, 248.39-feet, and 244.60-feet, were measured at the canal entrance invert, culvert invert beneath Route 30, and culvert invert beneath East Pennsylvania Avenue respectively, indicating a gradient of only 0.13%.
5. A shallow concrete sill located on the right bank of the canal approximately 170 feet downstream of the canal creates a low point along the canal sidewall that limits the flow conveyed by the canal by allowing overflow to discharge back into East Branch Brandywine Creek. Therefore, increasing the flow into the canal through the upstream intake would not materially increase the flow conveyed in the canal to the downstream lakes unless the concrete sill was raised or the channel was deepened along the entire length of the canal.
6. The culverts (four at the Route 30 road crossing and two at the Norwood Road crossing) that convey canal flow were observed to be partially to completely obstructed with sediment deposits.
7. Sections of the canal are overgrown with dense briers and woody vegetation. Wetlands appear to have developed along portions of the channel.
8. Stormwater runoff entering the canal downstream of the Struble Trail bridge appears to be the primary source of flow carried by the canal into Lake 5. Little flow, if any, from the East Branch Brandywine Creek and Ludwig's Run appears to be reaching the downstream lakes during normal flow conditions.

9. When the flow in East Branch Brandywine Creek was 80 cfs, no flow was observed entering the canal through the intake structure at the dam. CCWRA observations indicate that higher flows can result in inflow through the inlet into the canal, but remain insufficient to convey flow beyond the Struble Trail bridge culvert. Flows conveyed from the East Branch Brandywine during high flows (that do not spill over the concrete sill) are augmented by stormwater flows from the culverts upstream of Route 30 and upstream of Norwood Road. These intervening flows provide intermittent flow to Lake 5, but also carry nutrients and other stormwater pollutants into the lake.
10. Returning the canal to its original as-built condition does not appear to be possible without substantial redesign and modification of the inlet, dredging along the canal and modifications to the downstream culverts.
    - Road crossings, channel relocations, weirs and other structures appear to have been installed or modified along the canal since it was constructed. The invert of the culverts under road crossings appear to be higher than the original design invert of the canal. These structures appear to control the conveyance capacity of the canal during low flow conditions.
    - Removal of the dense vegetation and sediment deposits throughout the canal would require a permit as the canal would likely be classified as a wetland feature.
    - Modification of the canal would require ensuring that adjacent properties would not be negatively impacted by flood flows.
    - Underground utilities located within the underground conduit in the Borough of Downingtown would need to be evaluated to determine their integrity to handle more flows, if modifications were made to the canal.

# APPENDIX A

Aerial Map of Canal

# BRANDYWINE DAM
# GANNETT FLEMING SITE INVESTIGATION

Gannett Fleming 6/24/2014 Survey (Point No.)

Canal Path

Underground Section of Canal

Source: GF
Note: Not all survey points shown, refer to July 2014 Encroachment Survey
Coordinates are displayed in NAD83 Pennsylvania State Plane South Feet

N

1 Inch = 500 Feet

0 125 250 500 Feet

Gannett Fleming

Vertical Datum: NAVD 88 FT

2/23/2015

Point No 1543: Concrete sill in canal @ EL. 250.37

LEFT PHOTO: Point No. 1537 - Silt Accumulation @ EL. 250.63; RIGHT PHOTO: Point No. 1535 - Bottom of Scour @ EL. 247.73

Point No. 1536: Invert @ Canal Entrance @ EL. 250.22

Point No. 1545: Invert of canal at pipe entrance below Route 30 @ EL. 248.39

Point No. 1544: Canal invert at pipe entrance under Struble Trail @ EL. 248.93

Canal invert at pipe discharge beneath Norwood Road @ EL. 248.48 (survey shot taken during July 2013 survey)

Point No. 1547: Invert of pipe @ EL. 244.60

Point No. 1546: Weir Invert @ EL. 247.63

Point No. 1550: HDPE Invert @ EL. 245.86

Point No. 1553: Canal discharge into East Branch Brandywine Creek @ EL. 225.09

Point Nos. 1551 & 1552: Top of Crest @ EL. 247.08, Bottom of

Point No. 1548: Pump House Invert @ EL. 244.46

Struble Trail

Ludwig's Run

Brandywine Dam

Canal Intake

Lake 5

Lake 4

East Branch Brandywine Creek

Lake 3

Lake 2

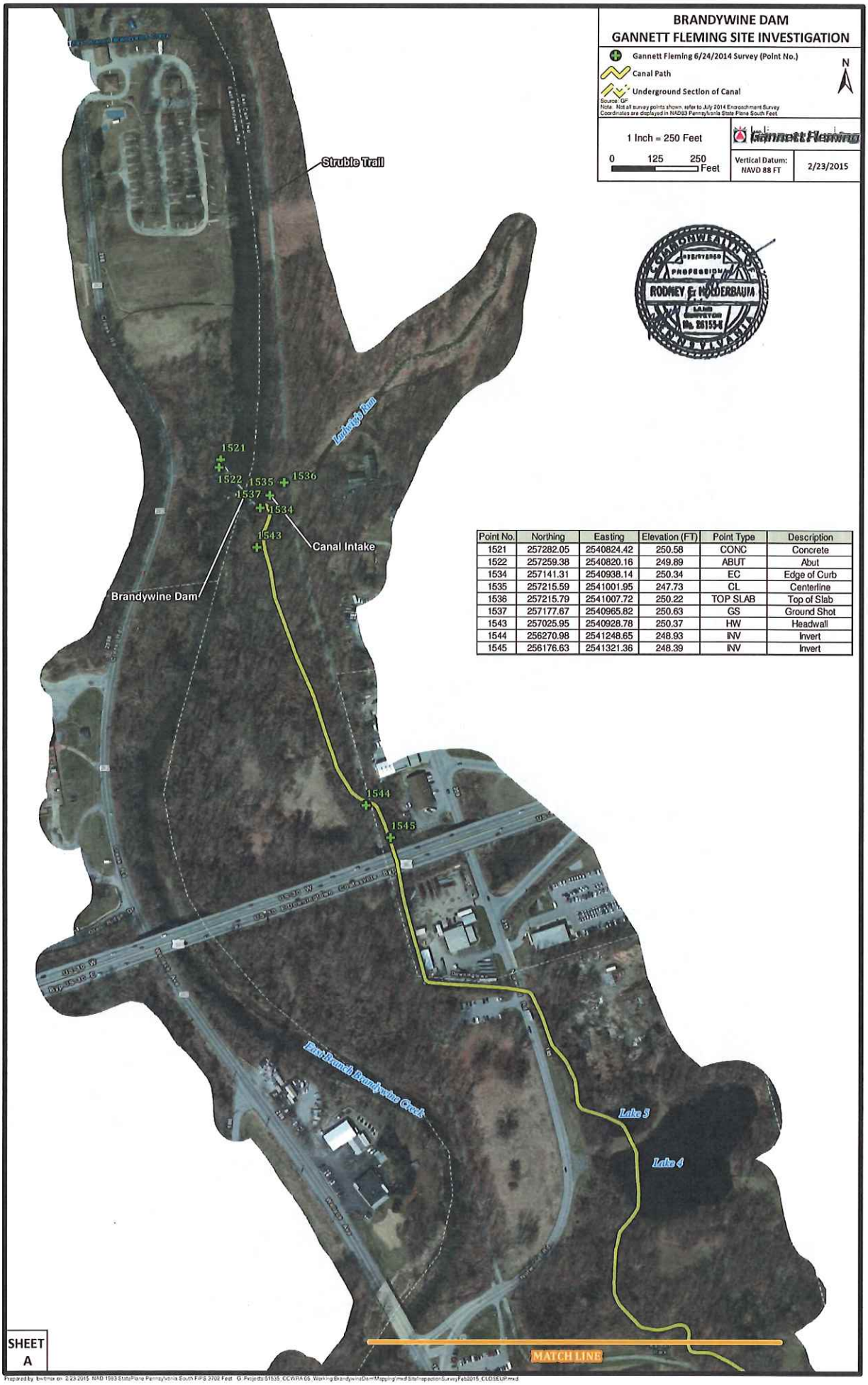
Lake 1

DOWNINGTOWN

NOTE: PATH OF BURIED CULVERT BENEATH DOWNINGTOWN IS UNKNOWN.

| Point No. | Northing | Easting | Elevation (FT) | Point Type | Description |
|---|---|---|---|---|---|
| 1521 | 257282.05 | 2540824.42 | 250.58 | CONC | Concrete |
| 1522 | 257259.38 | 2540820.16 | 249.89 | ABUT | Abut |
| 1523 | 257283.23 | 2540826.01 | 250.46 | EC ST | Start of Edge of Curb |
| 1524 | 257273.65 | 2540833.45 | 250.46 | EC | Edge of Curb |
| 1525 | 257265.94 | 2540839.54 | 250.37 | EC | Edge of Curb |
| 1526 | 257264.41 | 2540837.92 | 250.06 | CONC | Concrete |
| 1527 | 257250.20 | 2540852.15 | 250.37 | EC | Edge of Curb |
| 1528 | 257233.38 | 2540865.50 | 250.33 | EC | Edge of Curb |
| 1529 | 257215.84 | 2540879.39 | 250.26 | EC | Edge of Curb |
| 1530 | 257195.03 | 2540895.94 | 250.18 | EC | Edge of Curb |
| 1531 | 257172.25 | 2540913.64 | 250.24 | EC | Edge of Curb |
| 1532 | 257163.50 | 2540920.72 | 249.84 | EC | Edge of Curb |
| 1533 | 257158.18 | 2540924.55 | 250.31 | EC | Edge of Curb |
| 1534 | 257141.31 | 2540938.14 | 250.34 | EC | Edge of Curb |
| 1535 | 257215.59 | 2541001.95 | 247.73 | CL | Centerline |
| 1536 | 257215.79 | 2541007.72 | 250.22 | TOP SLAB | Top of Slab |
| 1537 | 257177.67 | 2540965.82 | 250.63 | GS | Ground Shot |
| 1538 | 257154.95 | 2540955.70 | 250.22 | GS | Ground Shot |
| 1539 | 257151.07 | 2540950.86 | 250.16 | GS | Ground Shot |
| 1540 | 257153.82 | 2540967.29 | 252.59 | TOP CONC | Top of Concrete |
| 1541 | 257146.90 | 2540957.88 | 251.13 | GS | Ground Shot |
| 1542 | 257123.74 | 2540971.83 | 250.95 | GS | Ground Shot |
| 1543 | 257025.95 | 2540928.78 | 250.37 | HW | Headwall |
| 1544 | 256270.98 | 2541248.65 | 248.93 | INV | Invert |
| 1545 | 256176.63 | 2541321.36 | 248.39 | INV | Invert |
| 1546 | 253456.19 | 2542584.43 | 247.63 | WEIR | Culvert |
| 1547 | 253313.99 | 2542524.60 | 244.60 | INV | Invert |
| 1548 | 252676.17 | 2542696.36 | 244.46 | INV | Invert |
| 1549 | 252674.35 | 2542718.35 | 246.04 | INV | Invert |
| 1550 | 252654.89 | 2542726.60 | 245.86 | INV | Invert |
| 1551 | 252563.83 | 2542600.21 | 243.32 | BOTTOM GATE | Bottom of Gate |
| 1552 | 252564.08 | 2542601.41 | 247.08 | TOP GATE | Top of Gate |
| 1553 | 251590.11 | 2541562.84 | 225.09 | INV | Invert |

Prepared by: bwitmer on 2/23/2015 NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet G:\Projects\51535_CCWRA 05 Working\BrandywineDam\Mapping\mxd\SiteInspectionSurveyFeb2015.mxd

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| 1544 | 256270.98 | 2541248.65 | 248.93 | INV | Invert |
| 1545 | 256176.63 | 2541321.36 | 248.39 | INV | Invert |

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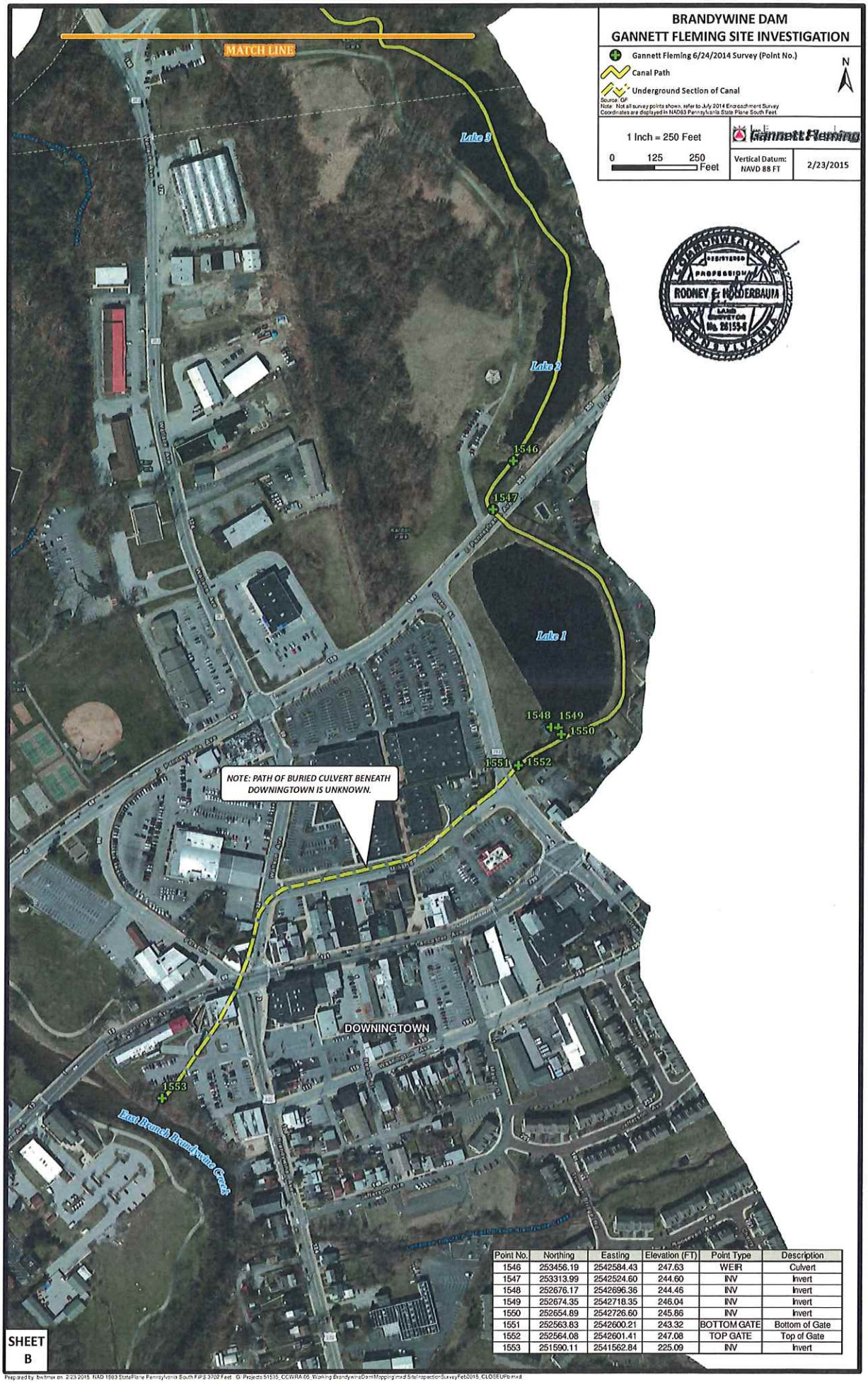


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Canal Path

Underground Section of Canal

Source: GF

Note: Not all survey points shown, refer to July 2014 Encroachment Survey

Coordinates are displayed in NAD83 Pennsylvania State Plane South Feet

N

1 Inch = 250 Feet

0 125 250 Feet

Gannett Fleming

Vertical Datum: NAVD 88 FT

2/23/2015

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSION
RODNEY E. HOLDERBAUM
LAND SURVEYOR
No. SU159-E

| Point No. | Northing | Easting | Elevation (FT) | Point Type | Description |
|---|---|---|---|---|---|
| 1546 | 253456.19 | 2542584.43 | 247.63 | WEIR | Culvert |
| 1547 | 253313.99 | 2542524.60 | 244.60 | INV | Invert |
| 1548 | 252676.17 | 2542696.36 | 244.46 | INV | Invert |
| 1549 | 252674.35 | 2542718.35 | 246.04 | INV | Invert |
| 1550 | 252654.89 | 2542726.60 | 245.86 | INV | Invert |
| 1551 | 252563.83 | 2542600.21 | 243.32 | BOTTOM GATE | Bottom of Gate |
| 1552 | 252564.08 | 2542601.41 | 247.08 | TOP GATE | Top of Gate |
| 1553 | 251590.11 | 2541562.84 | 225.09 | INV | Invert |

SHEET B

Prepared by bwimer on 2/23/2015. NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet. G:\Projects\51535_CCWRA\05_Working\BrandywineDam\Mapping\mxd\SiteInspectionSurveyFeb2015_CLOSEUP.mxd

# APPENDIX B

Photographs

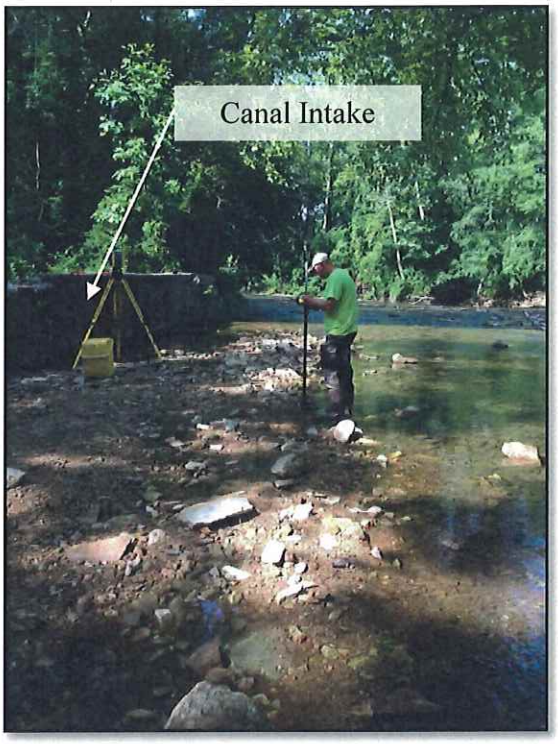



Photo 1 (06/24/14): Ludwig's Run and East Branch Brandywine Creek Confluence (Looking Downstream)

Photo 2 (06/24/14): Two Intakes into Canal

Photo 3 (05/31/13): Downstream End of Canal Intake (Looking Upstream)

Photo 4 (06/24/14): Downstream End of Canal Intake (Looking Upstream)
(Note Change in Silt Accumulation from 05/31/13)

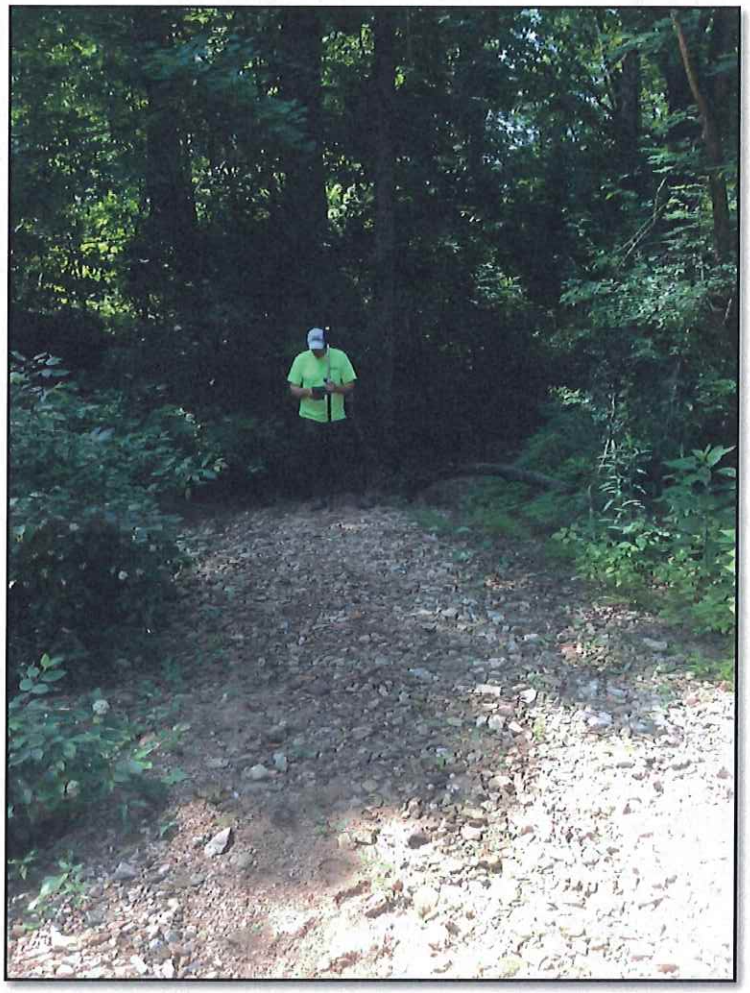


Photo 5 (06/24/14): Immediately Downstream of Canal Intake (Looking Downstream)
(Note Silt Accumulation)

Photo 6 (05/31/13): Canal ~50-FT Downstream of Canal Intake (Looking Downstream)

Photo 7 (06/24/14): Canal ~50-FT Downstream of Canal Intake (Looking Downstream)

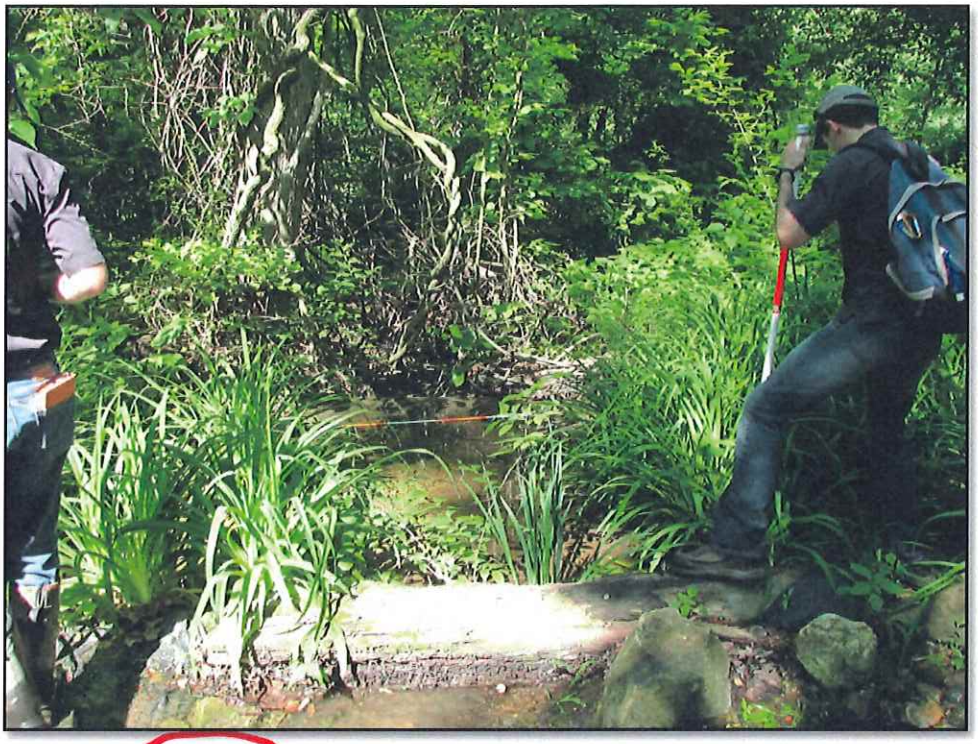


Photo 8 (05/31/14): Concrete Sill ~170-FT Downstream of Canal Intake

Photo 9 (05/31/13): Close-up of Concrete Sill


Photo 10 (05/31/13): Struble Trail Crossing Over Canal (North of Route 30)

Photo 11 (06/24/14): Struble Trail Crossing Over Canal (North of Route 30)

Photo 12 (05/31/13): Corrugated Metal Pipe Culverts Beneath Route 30

Photo 13 (06/24/14): Corrugated Metal Pipe Culverts Beneath Route 30

Photo 14 (05/31/13): Example of Stormwater Discharge into Canal

Photo 15 (05/31/13): Example of Stormwater Discharge into Canal

Photo 16 (06/24/14): Intake Side of Concrete Culverts Beneath Norwood Rd.

Photo 17 (06/24/14): Discharge End of Concrete Culverts Beneath Norwood Rd.

Photo 18 (06/24/14): Footbridge Over Canal Between Lake 4 and Lake 3

Photo 19 (05/31/13): Weir Discharge at Lake 2

Photo 20 (06/24/14): Culverts Beneath E. Pennsylvania Ave.

Photo 21 (06/24/14): Pipe Feeding Lake 1 (Downstream of E. Pennsylvania Ave.)

Photo 22 (05/31/13): Upstream HDPE Pipe from Lake 1 to Bypass Canal


Photo 23 (05/31/13): Downstream HDPE Pipe from Lake 1 to Bypass Canal


Photo 24 (06/24/14): Downstream HDPE Pipe from Lake 1 to Bypass Canal

Photo 25 (06/24/14): Bypass Canal Spillway Leading to Underground Canal

# Kardon Park Ponds and Mill Race

# Ponds

# Available Open Space

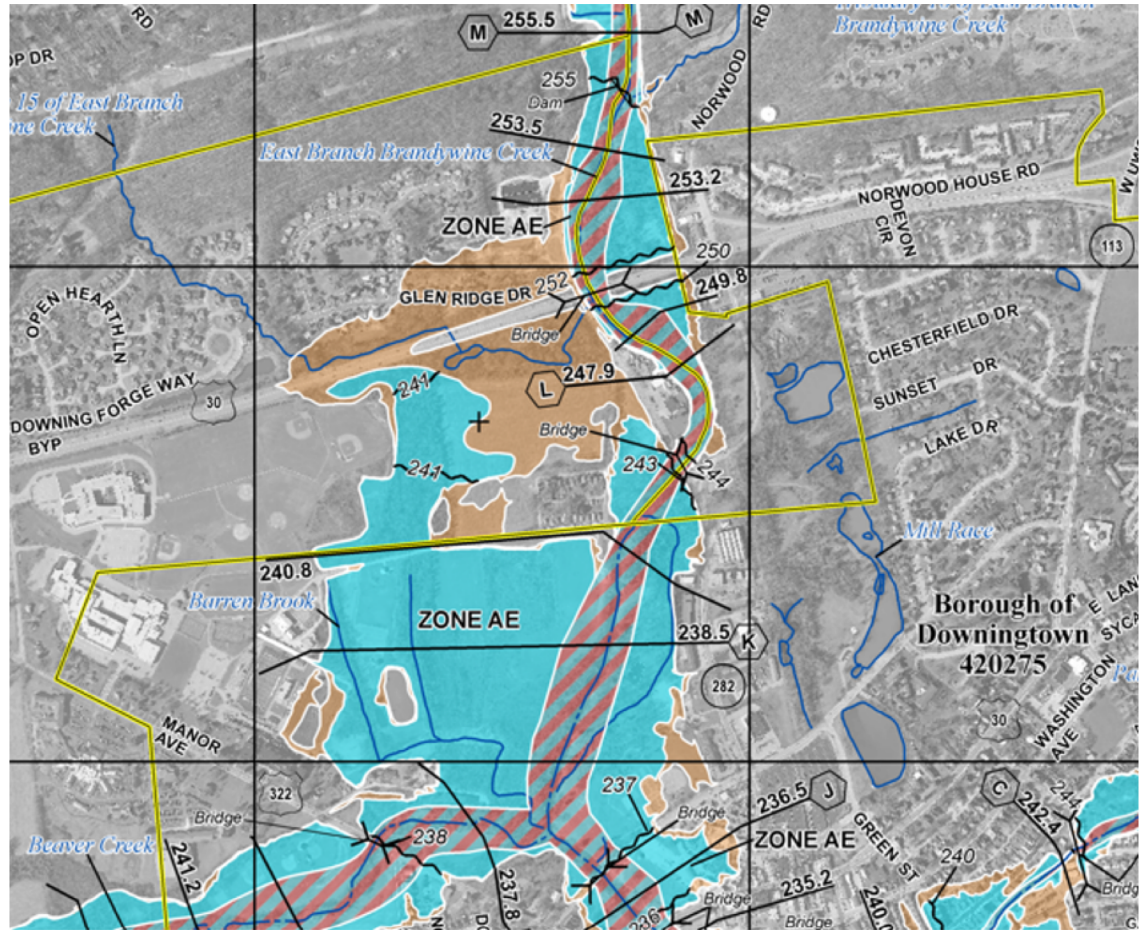
# Chris Reitman Analysis
# Works for firm borough used for Progressive Housing Project

- Barry,  I did a little bit more research on the flood storage concept at Kardon Park.  A snip from the FEMA map is provided below (Next Slide).  This snip is from before the dam was removed, so I suspect the flooding may be a little worse.

- Most of the storage at the park is between 247 and 250 and the adjacent flood elevation of Brandywine Creek is 238.5 to 244.  Although the set up is nice with Mill Race, I do not think the hydraulics work for the concept we discussed because Kardon Park is too high and water would want to flow downstream within the existing flood zone where there would be more flood capacity/water storage space. .  As we discussed when we were there, I do not think you can remove soils to create more air space at Kardon Park either, because of the high groundwater table.  Given this new information, I do not think this approach has merit for any further evaluation.

- I do like the idea, and if you have any other thoughts or suggestions which should be considered I would be happy to talk them over with you.

- As a side note, the flood map does show how isolated the Kardon Park ponds are.  The ponds don't seem to be fed by much overland flow.  It may be possible to divert Ludwigs run and direct it through the ponds using the mill race, which would take a little bit of pressure off the Brandywine and help make the isolated Kardon Park ponds healthier.  If this is something you are interested in let me know and we could talk about it, but it may not have a significant impact on the flooding.


M
255.5
M
255
Dam
253.5
East Branch Brandywine Creek
253.2
ZONE AE
250
252
249.8
GLEN RIDGE DR
Bridge
L
247.9
241
Bridge
243
244
241
240.8
Barren Brook
ZONE AE
238.5
K
Borough of
Downingtown
420275
MANOR AVE
322
Bridge
238
Beaver Creek
241.2
237
Bridge
236.5
J
ZONE AE
GREEN ST
C
242.4
240
235.2
Bridge
Bridge
NORWOOD RD
NORWOOD HOUSE RD
DEVON CIR
CHESTERFIELD DR
SUNSET DR
LAKE DR
Mill Race
WASHINGTON AVE
OPEN HEARTH LN
DOWNING FORGE WAY BYP
30
282
113
Brandywine Creek