CITY OF RICHMOND
DEPARTMENT OF PUBLIC UTILITIES
Richmond, Virginia

Byrd Park Reservoir

Inspection Report

(Conducted November 2017)

May 2018

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Byrd Park Reservoir Inspection Report

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CITY OF RICHMOND, VIRGINIA
DEPARTMENT OF PUBLIC UTILITIES
BYRD PARK RESERVOIR

Reservoir Inspection Report

January 9, 2018

Executive Summary

This report provides the results of a structural condition assessment of the Byrd Park Reservoir conducted during the weeks of November 06 and 13, 2017 with the same methods used in the March 2013 inspection. The report also provides a comparison of the roof structure condition to previous inspections, an update to the recommended schedule for replacement, and a description of repairs to the reservoir roof system made by the City since the November 2011 inspection which was performed prior to the March 2013 inspection.

The existing roof, approximately eight acres in size, was constructed over the 55 million gallon Byrd Park Reservoir 46 years ago. [redacted] this was installed 35 years ago to replace the original roofing.

The 2017 internal reservoir roof inspection was conducted by using a boat with portable lights and by following established confined space entry procedures. The conditions noted in this report were based upon visual observations of the accessible portions of the reservoir structure. The field data sheets and photographs from the previous inspections were used to make qualitative comparisons of the conditions observed and the rate of deterioration. The established ranking system of the roof structure, consisting of three categories – “Good” (green), “Moderate” (yellow) and “Severe” (red), was used. The condition was assessed and plotted for each area of the roof grid and then was compared with plots from previous years.

[redacted]

[redacted] There were 12 new “Severe” (red) condition areas noted during the 2017 inspection, for a new total of 34 “Severe” areas.

It is recommended that the City plan for a total roof replacement within the next few years, starting with removing the West Reservoir from service, and then following with the East Reservoir. [redacted] It is also recommended that the City continue to monitor the reservoir roof condition periodically for ponding, deflections, and other condition changes which may occur along with restricting personnel access over or under the “Severe” condition areas.

CITY OF RICHMOND, VIRGINIA
DEPARTMENT OF PUBLIC UTILITIES
BYRD PARK RESERVOIR

Reservoir Inspection Report
January 9, 2018

1. Background:

The 2002 Byrd Park Reservoir Inspection Report (dated May 7, 2003) recommended that additional future reservoir roof inspections be conducted in order to monitor roof structure deterioration rates and to update the schedule for total roof replacement. Since then, the 2006, 2010, 2011 and 2013 Byrd Park Reservoir Inspection Reports (dated November 21, 2006, February 14, 2011, December 16, 2011, and May 17, 2013 respectively) provided an updated status of the roof structure condition and schedule for replacement.

This report summarizes the results of an inspection of the Byrd Park Reservoir conducted during the weeks of November 6 and 13 of 2017 with the same methods used in the March 2013 inspection. This report also includes a description of repairs to the reservoir roof system made by the City after the November 2011 inspection.

1.1. Existing Structure:

The 55 MG Byrd Park Reservoir was originally constructed as an open-air raw water reservoir from March 1874 to June 1876. [redacted]. For several years, the reservoir was operated as an open top treated water reservoir. In 1970 and 1971, the reservoir was covered with a roof. [redacted]

[redacted]

The roof over both Reservoirs covers a little over eight acres of surface area, as shown on Figure 1.

[redacted]

1.2. Summary of March to April 2002 Inspection:

Previous inspections of the reservoir were conducted in December 1992 to January 1993, December 2000, March to April 2002, October 2006, December 2010, November 2011, and March 2013. The 2002 inspection results are summarized in an inspection report dated May 7, 2003 which included a detailed inspection of the entire reservoir. This 2003 report included above water inspections, concrete sampling and testing, a corrosion survey, underwater inspections, a

roof structure condition survey, and concrete quality and durability evaluations. The 2003 inspection report also evaluated alternative roof repair and replacement options and concluded that the roof should be scheduled for total roof replacement and that additional roof condition inspections should be conducted in the future to monitor roof structure deterioration rates to update the schedule for roof replacement. In 2003, it was projected that the existing roof structure had a remaining effective life of at least 10 years before replacement would be needed.

Testing and expert analysis from the 2003 report concluded that [redacted] were the main factors causing deterioration of the concrete in the reservoir. The cracks and spalling caused by these chemical reactions with the concrete is continuing to allow moisture to reach the key elements of the [redacted].

The 2003 report included a roof condition evaluation based on the field inspection data with rankings of Good, Moderate or Severe. The roof area condition rankings included four areas in the "Severe" condition. The City consequently restricted personnel access to these four areas.

1.3. Summary of October 2006 Inspection:

In October 2006, an inspection was conducted to observe the current condition of the roof structure in comparison to findings from the March to April 2002 inspection. The results are summarized in an inspection report dated November 21, 2006. The evaluation of the roof condition in 2006 concluded that while conditions were not changing significantly, slow and steady deterioration was continuing. Areas identified under the ranking categories of the concrete roof structure of "Severe" and "Moderate" remained the same from the 2003 report, (as shown on Figure 2). In addition, other components of the roof were observed to be in poor condition. [redacted] The City noted, prior to the 2006 inspection that ponding on the roof [redacted] had been increasing. It was discovered during the inspection [redacted] deflected significantly more than adjacent members, thereby causing additional ponding.

1.4. Summary of December 2010 Inspection:

In December 2010, an inspection was conducted to observe the current condition of the roof structure in relation to findings from the October 2006 inspection. The results were summarized in an inspection report dated February 14, 2011 and are shown on Figure 3. The inspection showed that overall deterioration [redacted] was progressing at a faster rate than in previous inspection periods. It was estimated that [redacted] was close to the end of its effective remaining life (as of the December 2010 inspection) and that other roof maintenance type repairs were needed prior to roof replacement. The reservoir's [redacted] also appeared to be close to the end of its effective remaining life.

1.5. Summary of November 2011 Inspection:

In November 2011, an inspection was conducted to observe the current condition of the roof structure in relation to findings from the December 2010 inspection. The results were summarized in an inspection report dated December 16, 2011 and are shown on Figure 4. [redacted] It was estimated that the existing 41 year old roof structure was close to the end of its effective remaining life (as of the November 2011 inspection) and that other roof maintenance type repairs were needed prior to roof replacement. The reservoir's 30 year old [redacted] also appeared to be close to the end of its effective remaining life.

In addition to a survey of the existing condition of the Reservoir roofs, the 2011 inspection also included an underwater condition survey utilizing a remote operated vehicle. The underwater inspection surveyed the existing condition of the [redacted] Approximately one third of the support columns were inspected; none of these exhibited any significant signs of deterioration.

1.6. Summary of March 2013 Inspection:

In March 2013, an inspection was conducted to observe the current condition of the roof structure in relation to findings from the November 2011 inspection. The results were summarized in an inspection report dated May 17, 2013 and are shown on Figure 5. [redacted] It was estimated that the existing 43 year old roof structure was close to the end of its effective remaining life (as of the March 2013 inspection) and that other roof maintenance type repairs were needed prior to roof replacement. The reservoir's 32 year old [redacted] also appeared to be close to the end of its effective remaining life.

2. Reservoir Inspection Procedures (2017)

The scope of work for the current reservoir inspection (November 2017) is shown in Appendix A. The internal reservoir roof inspection was conducted by a two person team using a 14-foot, flat-bottom boat. The City managed reservoir levels for the inspection team to have access to the reservoir roof from the boat. Areas of the reservoir roof inspected are listed in Table 1. Condition observations of the roof structure were recorded on field data sheets (as shown in Appendix D) and photographs (as shown in Appendix C) were taken to document the condition of the structures. The field data sheets and photographs from the previous March to April 2002, October 2006, December 2010 and November 2011 inspections were used to make comparisons of the conditions. This allowed qualitative comparisons to be made for the rate of deterioration in the roof structure. This comparison in conjunction with the current age of the structure was used for evaluating the condition category. Condition categories were then updated for the East and West Reservoirs, as shown in Figure 6. The exterior of the reservoir roof was inspected and observed conditions were noted (as shown in Figure 7).

The Byrd Park Reservoir is classified by the City as a confined space. Therefore, the internal reservoir access and inspection followed the Notice of Operational Impact - 001 and Confined Space Entry procedures shown in Appendix B.

Limitations: The conditions presented herein are based upon visual inspection of accessible portions of the existing reservoir structure using portable lighting for visibility. Existing structure conditions were examined and evaluated visually from the boat at the nearest vantage point insofar as safely practical. At times, the water level of the reservoir during the inspection prevented direct views of the [redacted] No responsibility is assumed for the presence of any latent structural defects or conditions which could not be detected by such visual inspection.

In addition to a survey of the existing condition of the Reservoir roofs, the 2017 inspection also included an underwater condition survey utilizing divers with audio-video recording and relay equipment and a support team outside. The underwater inspection surveyed a portion of the existing condition of the [redacted]

3. Internal Reservoir Inspection Observations:

Representative reservoir inspection photographs are shown in Appendix C. Copies of the field data sheets completed during the internal reservoir inspection from the boat are shown in Appendix D. These data sheets follow the same format used for the 2002, 2006, 2010, 2011, and 2013 inspections. The reservoir roof system has been evaluated and the structural condition of the reservoir divided into the following three general classifications, as established in the 2003 report, based on the visible reservoir inspection:

Classification	Reservoir Condition
Good (Green)	Overall good structural condition without concrete cracks or spalls which can be expected to affect the performance of the structural support system.
Moderate (Yellow)	Areas of the reservoir roof support system which have visible concrete cracks and spalls that can be expected to affect the performance of the structural support system in the relative longer term.
Severe (Red)	Areas of the reservoir roof support system which can be expected to affect the performance of the structural support system in the short and long term. Areas of the roof support system with severe concrete cracks and spalls, exposed [redacted], visible deflection of support beams, and inadequate and/or unsound beam bearings, and severely cracked or sheared off cantilevered ends of [redacted]

The condition classification, in this instance, is unique in that any failure to one structural element will result in a suspension of the “clean-water” process. Therefore, structural elements are held to a higher standard and as a result, deemed severe, more so, because of its immediate potential to disrupt the integrity of the reservoir and its process.

Sections 3.1 – 3.5 describe typical Severe Condition Areas and show the progression of the deterioration over time. In addition, refer to Appendix C for a long term comparison of the

deterioration of the selected areas and for additional representative photographs of the conditions observed during the inspection.

3.1. 2006 Severe Condition Areas

A. [redacted]

(2010) (2011)

(2013) (2017)

(2011) (2013)

(2017) (2017)

B. [redacted]

(2010) (2011)

(2013) (2017)

(2011) (2011)

C.

(2011) (2017)

D. [redacted]

(2013)

(2017)

3.2. 2010 Severe Condition Areas:

A. [redacted]

(2011) (2013)

(2017) (2017)

B. [redacted]

(2011) (2013)

(2017) (2017)

C. [redacted]

(2011) (2011)

(2017) (2017)

D.

(2000) (2013)

(2017) (2017)

(2017) (2017)

3.3. 2011 Severe Condition Areas

A. [redacted]

(2011) (2013)

(2017) (2017)

B. [redacted]

(2011) (2013)

(2011) (2013)

C. [redacted]

(2011) (2013

(2017) (2017)

D. [redacted]

(2011)

(2013)

(2011)

(2017)

E. [redacted]

(2011)

(2011)

(2013)

(2017)

F. [redacted]

(2011) (2013)

(2017) (2017)

G. [redacted]

[redacted] 2013) (2017)

H. [redacted]:

(2011) (2011)

(2017) (2017)

I. [redacted]

(2011) (2011)

(2017) (2017)

3.4. 2013 Severe Condition Areas

A. [redacted]

(2013) (2013)

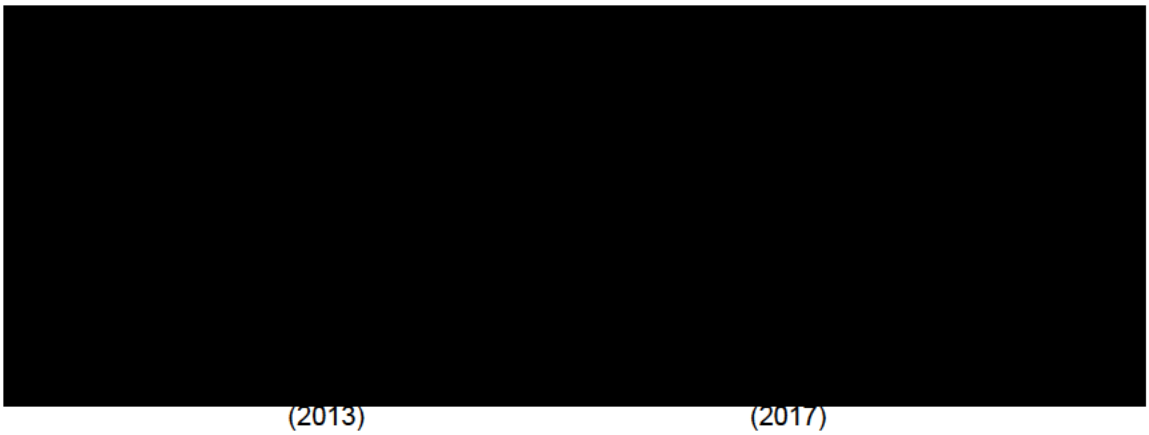
(2017) (2017)

B. [redacted]

(2013) (2013)

(2017) (2017)

C.



(2013) (2017)

D.

(2013) (2017)

E.

(2013) (2017)

3.5. (New) 2017 Severe Condition Areas:

A.

(2017)

B. [redacted]

(2017) (2017)

C. [redacted]

(2017) (2017)

(2017) (2017)

D. [redacted]

(2017)

(2017)

E. [redacted]

(2017) (2017)

(2017) (2017)

F. [redacted]

(2017) (2017)

(2017) (2017)

G. [redacted]

(2017) (2017)

(2017) (2017)

H. [redacted]

(2017)

(2017)

I. [redacted]

(2017)

(2017)

J. [redacted]

(2017)

(2017)

K. [redacted]

(2017)

(2017)

(2017)

(2017)

L. [redacted]

(2017) (2017)

(2017) (2017)

3.6. Moderate Condition Areas

A. 12 Moderate/Good condition areas changed to Severe Condition as noted above (Problem Areas 23 - 34). Additionally, there are many areas that changed from Good condition to Moderate condition throughout the reservoir, with more yellow areas observed in the East as compared to the West (7 areas in the West Reservoir, 9 areas in the East Reservoir). Changes of categories between 2013 and 2017 can be seen by comparing Figures 5 and 6. Since the last two inspections, it has been noticed that more Good (green) areas in the East basin are turning into Moderate (yellow) areas. This indicates that although the West basin deterioration had progressed earlier that the East basin in the past, that the deterioration is now accelerating in the East basin also.

1) [redacted] The loss of steel area results in a reduction in the load carrying capacity of the concrete beams. [redacted]

2) [redacted] The humid air and condensation in the reservoir have caused the concrete to become repeatedly wet (which can cause corrosion in the rebar, especially with chlorine present). Expansion of the rebar due to rust development can cause spalling of the concrete cover on the rebar.

3.7. Other Reservoir Roof Areas (Good Condition)

A total of 16 areas previously categorized as Good condition changed to Moderate condition as described above. Changes of categories between 2013 and 2017 can be seen by comparing Figures 5 and 6.

The East Reservoir is in overall better condition than the West Reservoir with many more Good Condition areas although the deterioration and hence turning of Good areas to Moderate appears to be accelerating in the East basin as seen in the past two inspections from the comparative number of green areas turning to yellow in the East v/s the West basin.

3.8. Reservoir Roof Slab Expansion Joints

[redacted] fair condition. Only one column bay was observed to have expansion joints seals either hanging down or missing. However, the [redacted]

[redacted] [redacted] Nearly 50% of the column bays were observed to have [redacted].

3.9. Reservoir Roof Side Wall Expansion Joints

During prior inspections, it was found that the [redacted] As a result, the perimeter of the reservoir was enclosed with a new [redacted] prevents surface water on the perimeter road from entering the reservoir and also keeps water draining

[redacted] is intended to 1) prevent surface water on the perimeter road from entering the reservoir and 2) keep water draining off the roof from saturating the perimeter wall and causing deterioration from freeze/thaw action. [redacted] appeared to be working well during a rainfall except at a few locations where rain water was observed to running down the [redacted]. Since [redacted], it is not expected that this water was running into the reservoir. During the inspection no water was observed running into the reservoir through the repaired side wall expansion joints.

3.10. [redacted]

It was observed during the inspection that the [redacted] are in good condition.

3.11. Underwater Video Inspections

Underwater video inspections were performed by Marine Technologies, Inc. under the guidance of Greeley and Hansen LLC. The underwater inspection involved a diver surveying the existing condition of the [redacted] within the [redacted]. The diver worked in coordination with an above ground team and the audio and video relay were recorded. The plan of the inspection was that the diver would select the column locations that were easiest to reach and would try to inspect at least 25% of the columns in each basin. Accordingly, [redacted] columns in the east basin and [redacted] columns in the west basin were inspected. None of the inspected underwater structures exhibited any significant signs of deterioration and although there was some minor spalling in a few locations, the inspection report rated these structures to be in good condition. The underwater inspection, however, revealed sedimentation at the basin floor ranging from ¾" to 2 ½" in thickness. The full report is included in Appendix F.

4. External Reservoir Inspection Observations

The exterior of the reservoir roof was observed from its perimeter as shown on Figure 7.

4.1 Roof Ponding near Perimeter Drains:

During the 2017 inspection, as during previous inspections, it was observed that during heavy rainfall, water ponding occurred atop the roof. This suggests that the roofing system may be inadequate for drainage [redacted] See the photos below:

(2011) (2013)

(2017) (2017)

4.2 [redacted]

[redacted]

4.3 Water infiltration into the Reservoir:

It appears that the rainwater dripping down the [redacted] travels back into [redacted] and infiltrates into the reservoir basins. This is evident from the dampness observed along the perimeter wall from inside the basin. We recommend extending the [redacted] to effectively move the water away and prevent it from seeping into the basin.

4.4 Repair of [redacted]

The [redacted] to the east and the west basins are primarily [redacted] It was observed during the 2017 inspection that the general condition of the [redacted] is deteriorated and in need of repair, or preferably full replacement.

4.5 Replacement of [redacted] Connection Bolts:

It was found during the inspections that the connection anchor bolts of the exterior [redacted] are corroded and need to be replaced. The existing bolts should be removed. The connection area to be cleaned and prepared for the new connection anchor bolts. The new bolts can either be replaced in kind or a different type of bolt with similar capacity may be utilized. The condition of concrete at bolt location needs to be examined and repaired if required for the new bolt. The photos below are of the corroded bolts of the west basin.

[redacted]

(2017) (2017)

5. Post 2011 Inspection Reservoir Roof Repairs

The following repairs to the existing roof system have been completed by the City since the 2011 inspection:

- New [redacted] curb walls [redacted]
- New [redacted] flashing installed [redacted] to seal off the perimeter of the roof from exposure to the outside environment and rain water infiltration.
- New reservoir trench drains, drainage inlets and piping [redacted].
- New asphalt paving for the roadways on top of the Reservoir perimeter berm.

[redacted]

(2013) (2013)

6 Conclusions and Recommendations:

6.1 Conclusions:

The reservoir roof support system was observed, during this inspection, to be performing its intended function without any total or partial collapse.

An overall comparison of the roof condition information obtained during this inspection showed further deterioration in conditions in the approximately four year period since the last inspection in March 2013. The condition changes between 2013 and 2017 can be seen by the comparing of Figure 5 with Figure 6, [redacted] Also, see the photos above and in Appendix C for a comparison of the 2017 conditions with previous years. The general condition of the West Reservoir roof support system appears to be much worse because it has about [redacted] in the Moderate to Severe roof condition categories as compared to the East Reservoir [redacted].

Structural flaws happen over time through strain energy (cracks), deflection energy (sags), slip energy (displacements), settlement energy (vertical displacements), and chemical energy (rust). Half-life describes a quantity (structural flawing) undergoing exponential decay and is constant through time. Note that, in exponential decay, the flawing rate slows down over time. However, even with a decreasing flawing rate, [redacted]

It is expected that the existing 46 year old roof structure is very close to the end of its effective remaining life (as of the November 2017 inspection). [redacted] But, on the other hand, repairs could be made to certain "Severe" (red) areas to reduce short term failure risks. Complete failure of structural elements, such as the [redacted] would be disastrous. If these details are repaired and if there is not any future overload event, then not much more is expected to happen beyond smaller energy flawing. But these detail flaws (Severe areas) could be repaired to mitigate a potential shutdown of the Byrd Park Reservoir facility from a structural failure.

Exterior wall repair work done prior to the 2013 inspection to prevent further exterior deterioration of the wall appears to be effective although the interior face of these walls continues to deteriorate at several locations with spalled concrete and exposed rusted rebar.

However, the perimeter roof flashing [redacted] direct the flow of storm water to the perimeter roadway inlets and not back to the edge of the asphalt and thus through the [redacted].

The reservoir's [redacted] roof system is 35 years old and is near the end of its effective remaining life. Multiple repairs have been done to it in the past. This inspection identified [redacted] in the roofing membrane needing to be addressed and also noted ponding around the roof perimeter at the drain locations. Also, several areas where the roof perimeter flashing joints had been previously repaired were observed to be in need of further patch work.

6.2 Recommendations

A. It is recommended that the City plan to remove the reservoir from service for total roof replacement within the next few years. However, some severe areas with poor beam bearing conditions could be dealt with prior to the roof replacement. Additional roof structural condition monitoring and internal inspections should be conducted annually to monitor roof structure deterioration rates and to update planning and scheduling for the total roof replacement. It is expected that the West Reservoir roof will be replaced first because its condition appears to be more deteriorated than the East Reservoir roof support system.

B. The City has an emergency operation plan for the reservoir which includes planning for reservoir operation following a [redacted] This emergency action plan has been updated based on the results of this roof inspection and other updated planning and is shown in Appendix E.

C. It is recommended that the City make the following maintenance type repairs to the reservoir roof system:

   a. Repair [redacted] as described in Section 4.

   b. [redacted] Refer to Figure 8 and -- which shows a standard repair hanger beam repair detail which has been used previously for repairs of the reservoir's structure.

   c. Extend the perimeter roof flashing [redacted] to effectively move the water away and prevent it from seeping into the basin.

D. It is recommended that the City replace the [redacted] to both basins.

E. It is recommended that the City replace the connection anchor bolts [redacted] both basins.

F. [redacted]

- [redacted]

Note, the location of Problem Areas 11 and 17 have been corrected, as shown in Figure 5, based on a review of the established system used to define the area boundaries.

G. [redacted]

[redacted]

[redacted]

H. Based on the current condition, the structure should be considered [redacted]. However, the reservoir may remain in operation because it is primarily unoccupied. [redacted]

I. It is recommended that the City continue to monitor the reservoir roof condition periodically for ponding, deflections, and other condition changes which may occur.

J. It is recommended that the City conduct annual external roof membrane system inspections and make subsequent repairs to correct any defects identified.

K. It is recommended that the City update and conduct both office desk top and field testing of the Byrd Park Reservoir Emergency Operation Plan on an annual basis (i.e., every 12 months).

L. The intended life expectancy of the Reservoir's roof structure is currently expired. [redacted]

Table 1

BYRD PARK RESERVOIR
ROOF INSPECTION – EAST and WEST RESERVOIRS

RESERVOIR INSPECTION PLAN

I. East Reservoir

A. Interior Inspection

1. 2013 Problem Areas (Severe Conditions) for condition changes: 10 locations.
2. Moderate Condition areas for condition changes: 50 locations.
3. Roof expansion joints [redacted]
4. North, East and South perimeter (interior) walls.
5. Inspection of the remainder of the reservoir (Good Condition areas) for condition changes.

B. Exterior Inspection

1. North, East and South perimeter walls. West perimeter wall in vicinity of [redacted]
2. Roof flashing.
3. Roof membrane near perimeter.

Note: Previously identified Severe, Moderate, and Good Condition areas for the inspection were based on Figure 5 of the November 2013 reservoir inspection report.

(Continued on next page)

Table 1 (Continued)

BYRD PARK RESERVOIR
ROOF INSPECTION – EAST and WEST RESERVOIRS

RESERVOIR INSPECTION PLAN

II. West Reservoir

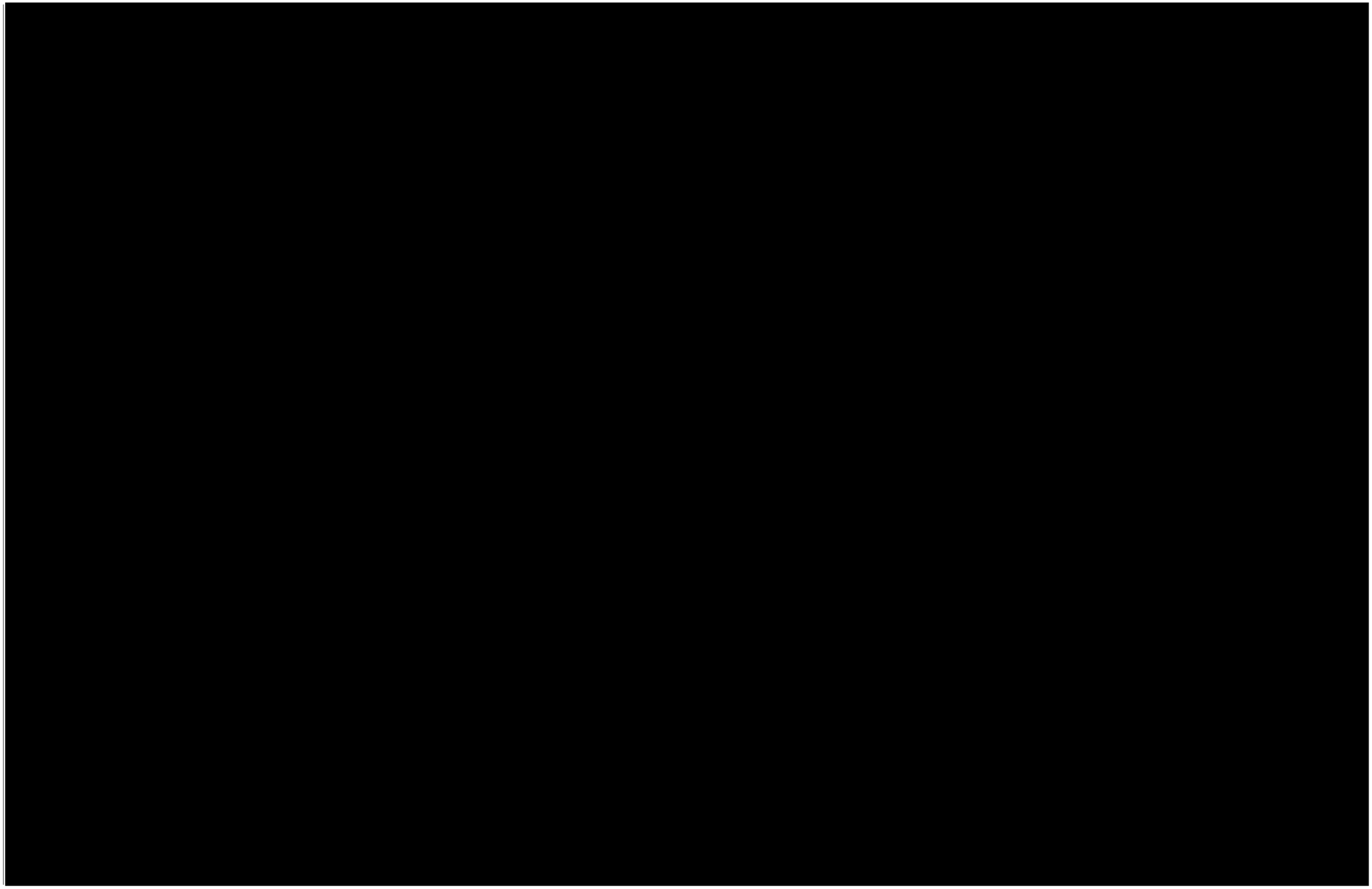
A. Interior Inspection

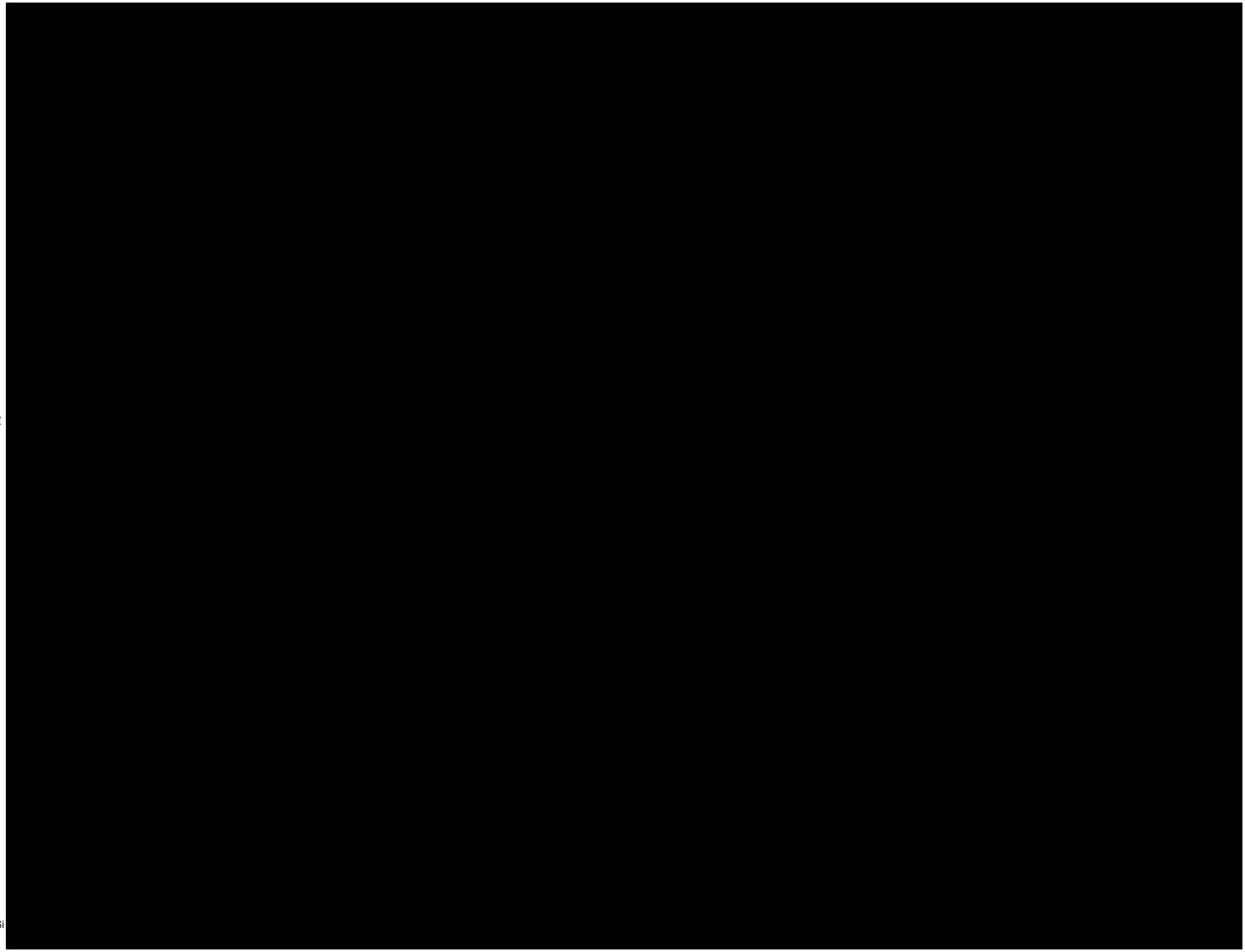
1. 2013 Problem Areas (Severe Conditions) for condition changes: 12 locations.
2. Moderate Condition areas for condition changes: 74 locations.
3. Roof expansion joints [redacted]
4. North, West and South interior walls
5. Inspection of remainder of reservoir (Good Condition areas) for condition changes.

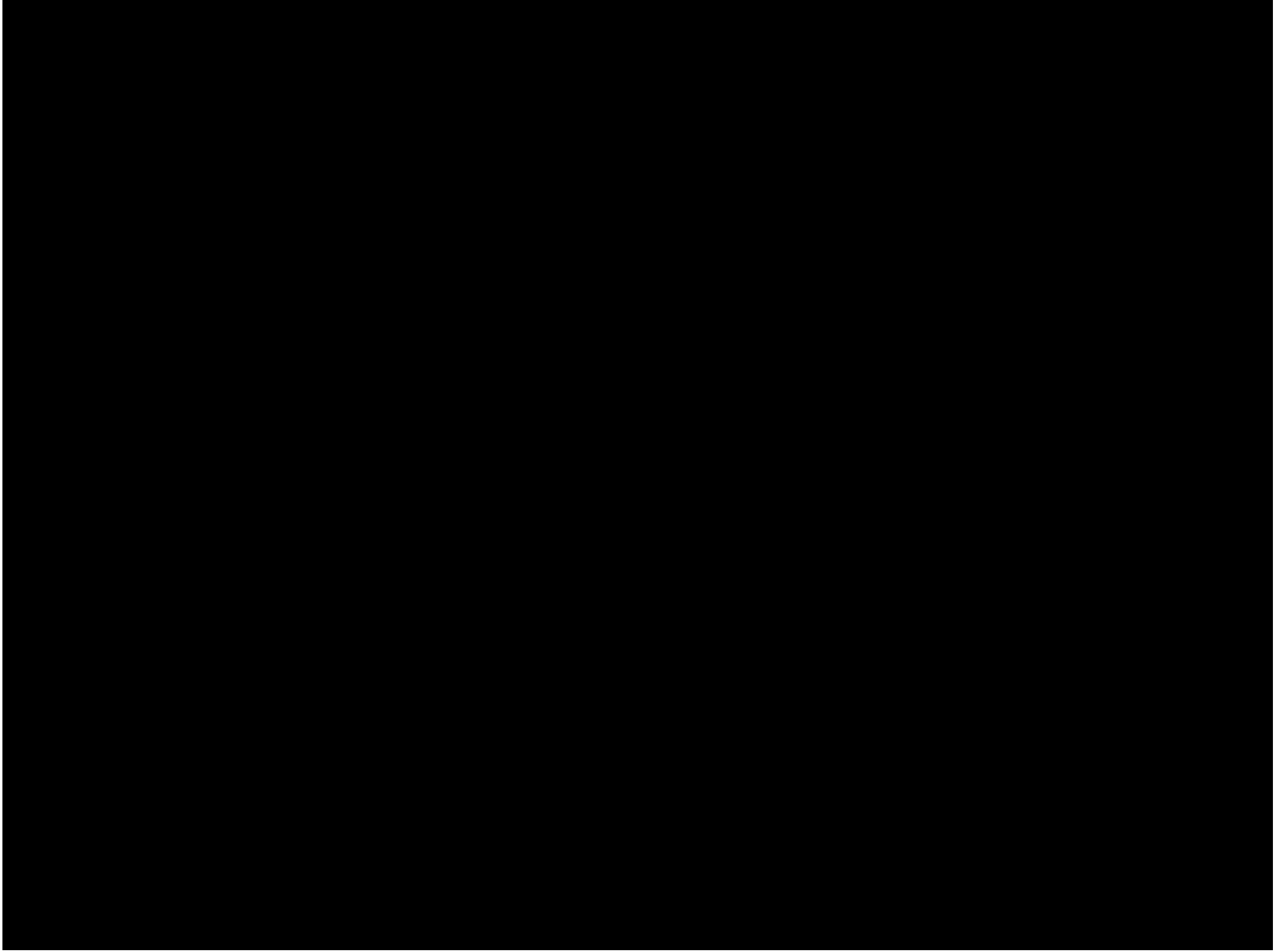
B. Exterior Inspection

1. North, West and South perimeter walls. East perimeter wall in vicinity of [redacted]
2. Roof flashing.
3. Roof membrane near perimeter.

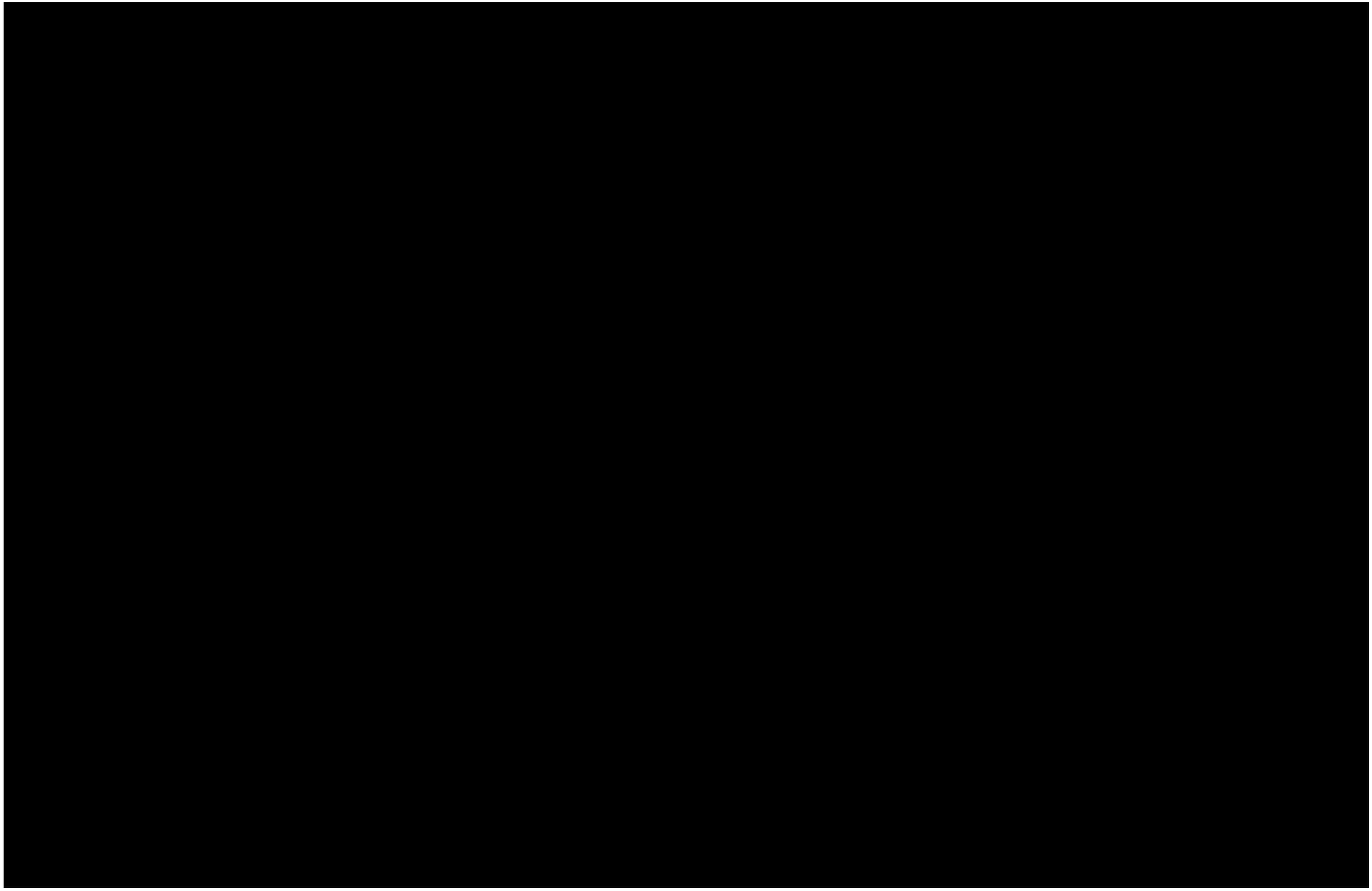
Note: Previously identified Severe, Moderate, and Good Condition areas for the inspection were based on Figure 5 of the November 2013 reservoir inspection report.







[redacted]



APPENDIX A

Scope of Work

SCOPE OF WORK – November 6, 2017

Byrd Park Reservoir Condition Inspection - 2017

Inspection of the 55 MG Byrd Park Reservoir was completed in May 2003 and concluded the existing 8.2 acre roof should be scheduled for replacement in the future and that future reservoir inspections should be conducted to document changes in the condition of the reservoir and to update needs and planning for roof replacement. The last reservoir inspection was completed in March 2013 and concluded that the reservoir deterioration rate had increased since the previous inspection in 2011.

Upon authorization to proceed, the ENGINEER shall proceed with conducting an inspection of the Byrd Park Reservoir roof system in order to monitor and record changes since the last roof inspection was conducted. The services to be provided under the project include the following:

1. Basic Data Collection and Review: The CITY will provide the ENGINEER with basic data available on Byrd Park Reservoir.

2. Notice of Operational Impact: The ENGINEER shall develop a Notice of Operational Impact (NOI) for the internal reservoir inspection for City review and approval. The City will provide the ENGINEER with access to the reservoir site and interior of the reservoir for reservoir roof inspection while the reservoir is maintained in service. The City will remove and replace the reservoir access louvers to allow the ENGINEER'S inspection team to enter the reservoir to conduct the internal inspection from a boat. The City will provide a boat for use in conducting the internal inspection and will provide City staff to assist in movement of the inspection boat into the reservoir and removal of the boat from the reservoir when the inspection has been completed.

3. Confined Space Services: The City has determined that the reservoir is a Confined Space and therefore space entry procedures will need to be in accordance with the requirements of OSHA Standard 29 CFR 1910.146. The ENGINEER shall develop a confined space entry plan and provide confined space entry services and equipment needed for conducting the internal reservoir inspection. Since the reservoir is classified as a Permit Required, Confined Space, The ENGINEER shall brief all personnel entering the space entrance and egress routes, safety procedures, points of contact and provide rescue services. The ENGINEER shall provide confined space entry training for the inspection team including City staff, who plan to enter the reservoir during the internal inspection period.

4. Roof Condition Inspection: The ENGINEER shall conduct a roof condition inspection to identify roof structure conditions and deterioration rates since the last roof inspection in 2013. The roof condition inspection will include visual inspection of the reservoir roof from the exterior and interior of the reservoir and comparison of condition to those documented in observed 2003, 2006, 2010, 2011, and 2013 inspections. The City will be provided with a report which summarizes the results of the roof condition field data collected, evaluations conducted, and any additional short term repairs needed. The ENGINEER shall update the recommended roof replacement schedule based on the results of the roof condition inspection.

5. Emergency Plan Update: The ENGINEER shall update the plan for reservoir operation during emergency events including emergency reservoir operation procedures, reservoir piping

diagrams and other emergency procedures based on the results of the proposed reservoir inspections and other data provided by the City.

6. Virginia Dam Safety Compliance: It is assumed the dam (reservoir) will meet the criteria for a regulated impounding structure and will be considered a high hazard potential structure. The first task will be to confirm the assumption that the Byrd Park Reservoir Dam meets the requirements for a regulated impounding structure by speaking with the local VA DCR Dam Safety Regional Engineer. Subsequent tasks will be contingent upon the results of Phase 1 / Task 1. If it is determined that Byrd Park Reservoir Dam meets the requirements for a regulated impounding structure, our Phase 2 services (Tasks 2 through 5) will consist of providing the necessary initial engineering services required for a regulated impounding structure. These services will include a dam safety inspection, hydrologic and hydraulic analyses, inundation mapping, determination of hazard potential classification, preparation of an Emergency Action Plan (EAP), and preparation of the necessary VA DCR forms.

   a. Phase 1, Task 1: The ENGINEER shall confirm that the dam meets the requirements included in Section 4VAC50-20-50 of the *Virginia Impounding Structure Regulations* for a regulated impounding structure with the local VA DCR Dam Safety Regional Engineer. The ENGINEER shall prepare a letter discussing the results of our findings and our review of the *Virginia Impounding Structure Regulations*.

   b. Phase 2

      (1) Task 2: Review of Historic Drawings and Documents, and Visual Inspection of the Dam and Appurtenant Structures

      The ENGINEER shall review available historic drawings and documents provided to us by the City of Richmond, and other relevant data relating to the annual dam safety inspection requirements outlined in the *Virginia Impounding Structure Regulations*. The ENGINEER shall perform a visual inspection of the Byrd Park Reservoir Dam. The ENGINEER shall inspect the visible portions of the upstream (inside) slope, downstream (exterior) slope, and crest of the earthen embankment. The inspection of the upstream slope will be limited by presence of the concrete roof and the level of the operating pool at the time of the inspection. The ENGINEER shall prepare an inspection report summarizing the results of our field review and our observations during the visual inspection. The report will include photographs taken during the inspection along with a keyed site map showing the approximate location of the photographs. If necessary, the report will also include recommendations for remedial action/repairs and additional inspections or studies.

      (2) Task 3: Engineering Analysis, Inundation Mapping, and Determination of Hazard Classification

      Hydrology

      Because the reservoir is a closed system (i.e., covered by a concrete roof) with no watershed, hydrologic analyses will not be performed.

Dam Hydraulics

The reservoir and dam will be analyzed using available historical data, field observations, and any additional, relevant information provided by others. A HEC-HMS model will be developed that incorporates the storage and hydraulics of the reservoir and dam in order to develop the dam breach hydrograph. The primary component for this portion of the analysis is the dam breach analysis. Multiple breach locations along the length of the dam will be evaluated in order to determine the breach location that results in the potential for the greatest downstream consequences in the event of a dam failure.

Downstream Routings

A 2D model will be used to model the flood wave and the areas that will be impacted due to the breach of the dam. We will use terrain data from the City of Richmond for the topography. The 2D model will be the basis for the determination of the Hazard Potential Classification and the development of the Inundation Maps and Emergency Action Plan (EAP).

At the time of our visual inspection of the embankment, we will also observe the areas surrounding the reservoir to confirm the accuracy of published maps, including the location and dimensions of homes, roads, and bridges. We will also confirm the characteristics of the surrounding topography.

The *Virginia Impounding Structure Regulations* require that multiple storm scenarios be analyzed as part of the inundation mapping. The Byrd Park Reservoir Dam varies significantly from traditional dams making the traditional scenarios somewhat impractical to model; therefore, only two scenarios will be analyzed for this project. The first scenario is the sunny day breach under normal operating conditions. The second scenario is intended to replace the required probable maximum flood with dam failure analysis. For the second scenario, the reservoir will be assumed to be at its maximum level (overflow condition) with pumps operating at the maximum fill rate.

Flood inundation maps will be developed from the results of the 2D model and prepared in accordance with Section 4VAC50-20-54 of the *Virginia Impounding Structure Regulations*. The maps will be a graphical depiction of the potential impact of flooding downstream of the dam showing areas that are impacted due to flooding from storm events and/or the potential breach of the dam. The inundation maps will document the extent of inundation, including any homes, roads, and bridges that are impacted. The maps will include:

- Flood wave time of arrival
- Peak flood water elevations
- Flood wave time to peak
- Roads and bridges
- Impacted parcels
- Impacted addresses, including telephone numbers

The ENGINEER shall provide the flood inundation GIS shapefiles for the Byrd Park Reservoir to the City of Richmond's Office of Emergency Management so they can use these shapefiles in conjunction with their reverse 9-1-1 system in order to notify and evacuate the properties within the inundation zone in the event of a dam safety emergency.

We will use the results of the engineering analyses and inundation maps to evaluate the hazard potential classification of the dam (i.e., High, Significant, or Low) in accordance with the *Virginia Impounding Structure Regulations*. Upon determination of the hazard potential classification from the above analyses, we will develop the required documentation as specified in the *Virginia Impounding Structure Regulations*.

The ENGINEER shall provide a written account of the analyses, procedures, assumptions, and calculations completed for the project. This report and supporting documentation will also include the hazard classification of the dam and a list of impacted parcels and structures. The report will include full-size sets (22 inches by 34 inches) and half-size sets (11 inches x 17 inches) of the flood inundation maps for administrative use and emergency action response. We will provide you with one electronic copy and four hard copies of this report. We will also provide you with digital GIS shapefiles of the breach inundation zone(s) in accordance with 4VAC50-20-58 of the *Virginia Impounding Structure Regulations*.

(3) Task No. 4 – Preparation of an Emergency Action Plan

The ENGINEER shall prepare an Emergency Action Plan (EAP) in accordance with Section 4VAC50-20-175 of the Virginia Impounding Structure Regulations. Our time and effort related to preparation of the EAP was developed based on the assumption that we will be able to gather information on the affected property owners and parcels from the City's reverse 9-1-1 system. The EAP will include the following:

- Ways to identify emergency situations and actions to take;
- Contact information and a process for notification during an emergency situation;
- Sources for supplies potentially needed during an emergency;
- Additional dam information and access information; and
- Roles and responsibilities of individuals during emergencies.

(4) Task No. 5 – Preparation of VA DCR Forms for a Regulated Impounding Structure

The following VADCR Forms will also be prepared and submitted:

- Operation & Maintenance Plan (Form DCR 199-099)
- Annual Inspection Report (Form DCR 199-098)
- Record Report For Regulated Impounding Structures (Form DCR 199-100)
- Application & Fee (Form DCR 199-192)

7. Report: Services shall include a draft and report, which summarizes the results of the studies and inspections conducted. The final report will address all comments from the CITY on the draft report. The CITY will be provided with 10 and 20 copies of the draft and final reports respectively. The CITY will also be provided with two copies of the report in electronic format.

8. Meetings: Services shall include attendance at meetings (4) scheduled by the CITY to discuss the project. The ENGINEER shall provide the CITY with copies of meeting notes for all meetings held.

APPENDIX B

Notice of Operational Impact – 001 and Confined Space Entry

NOTICE OF OPERATIONAL IMPACT
BYRD PARK RESERVOIR
ROOF INSPECTION – EAST and WEST RESERVOIRS – 2017
NOTICE # 001
October 12, 2017

LOCATION:

This document describes the proposed work plan for the inspection of the Byrd Park Reservoir roof support system. This inspection will be a visual inspection roof system in order to record observed changes at strategic locations since the previous roof inspection (2013) was conducted. The inspection will include both the East and West reservoir cells. The [redacted] will not be included in this inspection.

ACTIVITY:

Inspection of the 53 MG Byrd Park Reservoir was conducted in February through April 2002. Laboratory tests of samples from the structure were completed in May 2002. The report of findings concluded that the existing 8.2-acre roof should be scheduled for replacement.

In October 2006, Greeley and Hansen (GH) along with Delon Hampton & Associates (DHA) conducted a visual inspection of the Byrd Park Reservoir roof system in order to record observed changes at strategic locations since the last roof inspection (2002) was conducted.

In December 2010, GH along with DHA conducted a visual inspection of the Byrd Park Reservoir roof system in order to record observed changes at strategic locations since the previous roof inspection (2006) was conducted.

In November 2011, GH along with DHA conducted a visual inspection of the Byrd Park Reservoir roof system in order to record observed changes at strategic locations since the previous roof inspection (2010) was conducted.

GH along with DHA will conduct a visual inspection of the Byrd Park Reservoir roof system in order to record observed changes at strategic locations since the last roof inspection was conducted (November 2011). The roof condition inspection program will include visual inspection of the reservoir roof from the exterior and interior of the reservoir and comparison of the condition to those documented in the 2011 inspection report. The City will be provided with a report that summarizes the results of the roof condition field data collected, and observations made.

In March 2013, GH along with DHA conducted a visual inspection of the Byrd Park Reservoir roof system in order to record observed changes at strategic locations since the previous roof inspection (2011) was conducted.

The existing reservoir is shown in Attachment A and has two separate reservoir cells. The planned primary and secondary access locations to the interior of each reservoir are also shown in Attachment A. The primary access to both reservoirs will be at the North Outlet Chamber. The secondary reservoir access point will be at [redacted]

The internal inspection of the reservoir will be conducted by engineers in a boat floating at a pre-set level [redacted] in the reservoir. This reservoir level will permit the inspection team to maneuver below the roof support members while allowing a close visual inspection.

Only one reservoir cell will be inspected at a time. [redacted]

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[redacted]

Byrd Park Reservoir is a confined space and all consultant personnel entering the reservoir must have confined space training and conform to the confined space entry safety plan attached. During the internal inspection, trained Emergency Training Systems, Inc. (ETS) personnel will be present to assist the inspection team in the event that safety issues occur. ETS will provide an Entry Supervisor, Entry Attendant, and Safety/Rescue Divers. ETS will implement the Site Safety Plan, provide "first responder" services and provide rescue operations, in the event of an emergency.

City personnel entering the reservoir should conform to City requirements for confined space entry. [redacted]

The GH/DHA reservoir roof inspection team will conduct a visual inspection of the roof structure when first making entry into the reservoir and make a field determination if it is safe for the inspection team to continue with the inspection. If the field inspection team determines that it is not safe for the inspection team to enter the reservoir, the inspection will be terminated. The reservoir inspection procedures will then be revised to improve inspection team safety procedures and then the inspection will be rescheduled.

NOTE: If at any time during the inspection of the reservoir interior an unsafe condition is observed (in the opinion of the structural engineer, DHA), the inspection will be halted and the team will vacate the area.

IMPACTS: Impacts to the operation of the system are:

- [redacted]
- Non-City personnel will be working in a secured area.
- City personnel will need to be on-site during hours of the inspection work.
- Courtesy communication should be made by the City to wholesale customers (Hanover County, Henrico County) served by the reservoir.
- [redacted]

SCHEDULE: This activity is scheduled for the late October to late November of 2017. Close coordination with the City Water Treatment Plant and with the distribution system water demands is required.

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PROCEDURE:

Week of October 16, 2017 **City Valve Crew would have been scheduled to locate and exercise related [redacted] as indicated in Attachments B1-B3.**

November 1, 2017 **ETS conducts in-house safety training for GH and DHA personnel. (Interested City personnel are invited to attend)**

1. Week of October 23, 2017 – City Locate and Move Equipment
    - James Ward (City) and 3 man City crew locates City-owned inspection boat and oars, portable access ladder, temporary reservoir access doors, and 4 sheets of 1/2" plywood and move to reservoir. James Ward informs Edwin Phillips (GH) when boat and oars, access ladder, access doors, and plywood are at reservoir.
    - James Ward (City) inspects the reservoir [redacted] to be used during the reservoir inspection period.
    - James Ward (City) verifies that [redacted] are in good condition and are operational. James Ward (City) verifies that the previously installed fixed access ladders are in place.
    - Edwin Phillips (GH) inspects boat and other City supplied equipment and finalizes plans for its use.
    - Skip Brooks or James Ward (City) verifies that the existing power panel [redacted] well is energized. City will energize the panel, if necessary.
2. Week of October 23, 2017 – City Prepares Reservoir and Launches Boat
    - [redacted]
    - [redacted]

- James Ward (City) and 3-man City crew disinfects boats, oars and all equipment to be in contact with potable water and installs inspection boat in east reservoir cell. The valve and pump configuration should be as follows (see Attachment B-1):

Pump / Valve	Condition
[redacted]	[redacted]

3. Week of October 30,2017
   - Bob Stone (City) conducts final coordination meeting with City staff, including plant personnel, distribution system personnel, safety personnel, and technical services. GH will also attend the coordination meeting. GH will extend a courtesy invitation to the Richmond Fire Department (tel.: 804-646-2500).
   - James Ward (City) and 3-man City crew removes the [redacted] **CAUTION: STAY OFF WOODEN ROOF AREAS**.
   - [redacted]
   - [redacted]
4. November 1, 2017 (11/3/2017)
   - [redacted]
   - GH/ETS mobilize safety/equipment trailer to inspection site.
5. November 6, 2017 – EAST RESERVOIR INSPECTION
   - Field communications will be established between James Ward (City) and Edwin Phillips (GH).

- At 7:00 AM approximately, [redacted]

[redacted]

Pump / Valve	Condition
[redacted]	[redacted]

[redacted]

- GH/DHA/ETS will hold site safety meeting and fill out check lists required by the Confined Space Entry Site Safety & Health Plan.
- GH/DHA/ETS will make courtesy call to Richmond Fire Department (tel: 804-646-2500) to advise of confined space/water hazard activities.
- GH/DHA inspects east cell (9 AM – 5 PM)
- [redacted]

6. November 7 thru 10, 2017 – EAST RESERVOIR INSPECTION (Continued)
   - Field communications will be established between James Ward (City) and Edwin Phillips (GH).
   - [redacted]
   - GH/DHA/ETS will hold site safety meeting and fill out check lists required by the Confined Space Entry Site Safety & Health Plan.
   - GH/DHA/ETS will make courtesy call to Richmond Fire Department (tel: 804-646-2500) to advise of confined space/water hazard activities.
   - GH/DHA continues inspection of reservoir (8 AM – 5 PM).
   - [redacted]

7. November 10 or 13, 2017 – BOAT and EQUIPMENT TRANSFER
   - [redacted]. The valve, gate, and pump configuration should be as follows (See Attachment B-1):

Pump / Valve	Condition
[redacted]	[redacted] OPEN

   - James Ward (City) and 3 man City crew moves inspection boat and equipment from east reservoir cell to west reservoir cell.
   - Work in confined space by City personnel should be done in accordance with requirements defined by the DPU Occupational Safety & Health, Thomas Harris.
   - [redacted]

8. November 13, 2017 – WEST RESERVOIR INSPECTION

- Field communications will be established between James Ward (City) and Edwin Phillips (GH).
- At [redacted]
- [redacted] The valve, gate, and pump configuration should be as follows (See Attachment B-3):

Pump / Valve	Condition
[redacted]	[redacted]

- [redacted]
- [redacted]
- [redacted]
- GH/DHA/ETS will hold site safety meeting and fill out check lists required by the Confined Space Entry Site Safety & Health Plan.
- GH/DHA/ETS will make courtesy call to Richmond Fire Department (tel: 804-646-2500) to advise of confined space/water hazard activities.
- GH/DHA inspects west cell (8 AM – 5 PM).
- [redacted]
- [redacted]
- [redacted]

9. November 14, 2013 thru November 17, 2013 – WEST RESERVOIR INSPECTION (Continued)

- Field communications will be established between James Ward (City) and Edwin Phillips (GH).
- [redacted]
- GH/DHA/ETS will hold site safety meeting and fill out check lists required by the Confined Space Entry Site Safety & Health Plan.
- GH/DHA/ETS will make courtesy call to Richmond Fire Department (tel: 804-646-2500) to advise of confined space/water hazard activities.
- GH/DHA continues inspection of reservoir (8 AM – 5 PM).
- [redacted]

10. November 20, 2017 – DEMOBILIZATION

Unless otherwise notified:

- [redacted].
- James Ward (City) and 3 man City crew removes inspection boat and equipment from reservoir and returns to storage.
- [redacted]

SUPPORT REQ'D: The inspection will be performed by Greeley and Hansen and Delon Hampton & Associates. Safety support, as required by the Confined Space Entry Site Safety & Health Plan, to the inspection team will be provided by ETS. ETS will provide Entry Supervisor, Entry Attendant, and Safety/Rescue Divers.

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Operation of pump stations, adjustment of controls, and closing and opening of valves and gates will be conducted by DPU staff. The City will provide, disinfect, and place the inspection boat in the reservoir. The City will move the inspection boat from the east reservoir to the west reservoir. After the completion of the inspection, the City will remove the inspection boat, [redacted].

The City will have stand-by crew ready for emergencies.

City Provided Equipment and Material:

- Inspection boat, motor, and oars
- 2 sealed batteries, 2 chargers
- Disinfection chemicals and disinfection of boat
- Electrical Power at the entry point (min 110-volt, 30 Amp service)
- Restroom Facilities at Boat Lake and at [redacted] PS
- Plywood (4 sheets of 1/2" thickness)
- Temporary reservoir access doors
- Access Ladders
- Confined Space Entry Permit, training, and safety equipment including Chlorine monitor for City personnel in accordance with requirements defined by the DPU Occupational Safety & Health, Thomas Harris

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PERSONNEL:

DPU

Janice Bailey – Tech Services
Jonathan Cosby - Tech Services
Ricky Hatfield – Water Treatment Plant/Operations
James Ward – Water Treatment Plant/Maintenance
Darryl Rivers – WDistrib Water Maintenance Operations Manager
Emmett Sandridge – WDistrib Valve Crew Supervisor
Angela Fountain – Communications
Skip Brooks – Electrical Supervisor
Thomas Harris – DPU Occupational Safety & Health
Kathy Robertson – Safety Officer

Parks and Recreation

Larry Miller –

GH

Roger Cronin – Greeley and Hansen City Consultant Engineer
Edwin Phillips – Greeley and Hansen City Consultant Engineer
Tom DiLego - Greeley and Hansen City Consultant Engineer
Kester McCullough - ECE Subconsultant to Greeley and Hansen

ETS

Steve Wood – Confined Space Entry/Safety
Ed Dunnavant – Confined Space Entry/Safety
Entry Supervisor – (to be determined)
Entry Attendant – (to be determined)
Safety/Rescue Divers – (to be determined)

DHA

Mamo Assefa – Subconsultant to Greeley and Hansen
Michael Nye – Subconsultant to Greeley and Hansen
Douglass Lauer – Subconsultant to Greeley and Hansen
Nasir Jaffery – Subconsultant to Greeley and Hansen
Baozhu Wei – Subconsultant to Greeley and Hansen

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CONTACTS:

CITY OF RICHMOND			
FIRE AND RESCUE		**911**	
EMERGENCY CALL CENTER		644-3000	
GUY LEWIS (Emergency Repairs)		400-2579	
CHRIS HOWARD (Emergency Repairs)		400-3137	
[redacted] PUMPING STATION		358-0255 (646-1281)	
		Office	Cell
DPU/Tech. Services	Bob Stone	646-8557	337-5278
DPU/Tech. Services	Jonathan Cosby	646-8009	317-1605
DPU/WTP	Ricky Hatfield	646-1933	971-0633
DPU/WTP	James Ward	646-6449	467-0440
DPU/ELECTRICAL	Skip Brooks	646-1816	363-4451
DPU/COMMUNICATIONS	Angela Fountain	646-7323	922-0265
DPU/SAFETY	Thomas Harris	646-8267	347-1073
DPU/SAFETY	Kathy Robertson	646-8320	347-2731
DPU/ WDistrib	Darryl Rivers	646-5541	840-9636
DPU/ WDistrib	Emmett Sandridge	646-8345	347-8244
Parks and Rec	Larry Miller	646-0037	
GREELEY AND HANSEN			
Greeley and Hansen	Roger Cronin	204-2413 / (804) 363-6955 (cell)	
Greeley and Hansen	Edwin Phillips	204-2434 / (804) 338-9510 (cell)	
Greeley and Hansen	Tom DiLego	204-2406 / (804) 887-9950 (cell)	
ECE	Kester McCullough	204-2404 / 757-660-5245 (cell)	
Emergency Training Systems, Inc. (ETS)	Steve Wood	(804) 512-0911 (cell)	
	Ed Dunnavant	(804) 840-2309 (cell)	
On Site	Michael Nye (DHA)	(703) 600-9414 (cell)	
On Site	Doug Lauer (DHA)	(202) 674-3684 (cell)	
On Site	Nasir Jaffery (DHA)	(571) 331-3093 (cell)	
On Site	Mamo Assefa (DHA)	(240) 271-9759 (cell)	
On Site	Baozhu Wei (DHA) [back-up]	(703) 501-0819 (cell)	
On Site	Entry Supervisor (ETS)		
On Site	Entry Attendant (ETS)		
On Site	Safety/Rescue Divers (ETS)		

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BYRD PARK RESERVOIR
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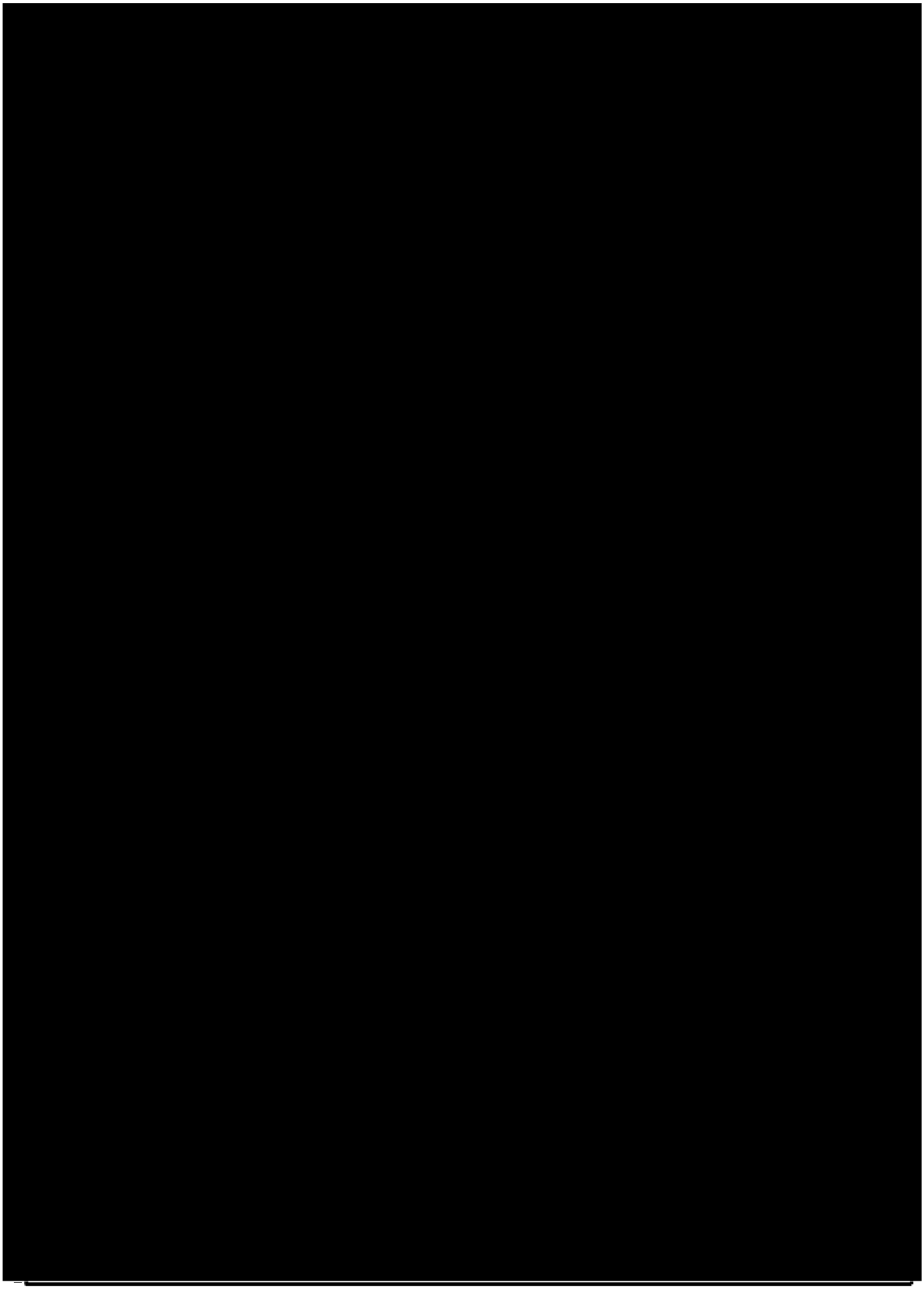
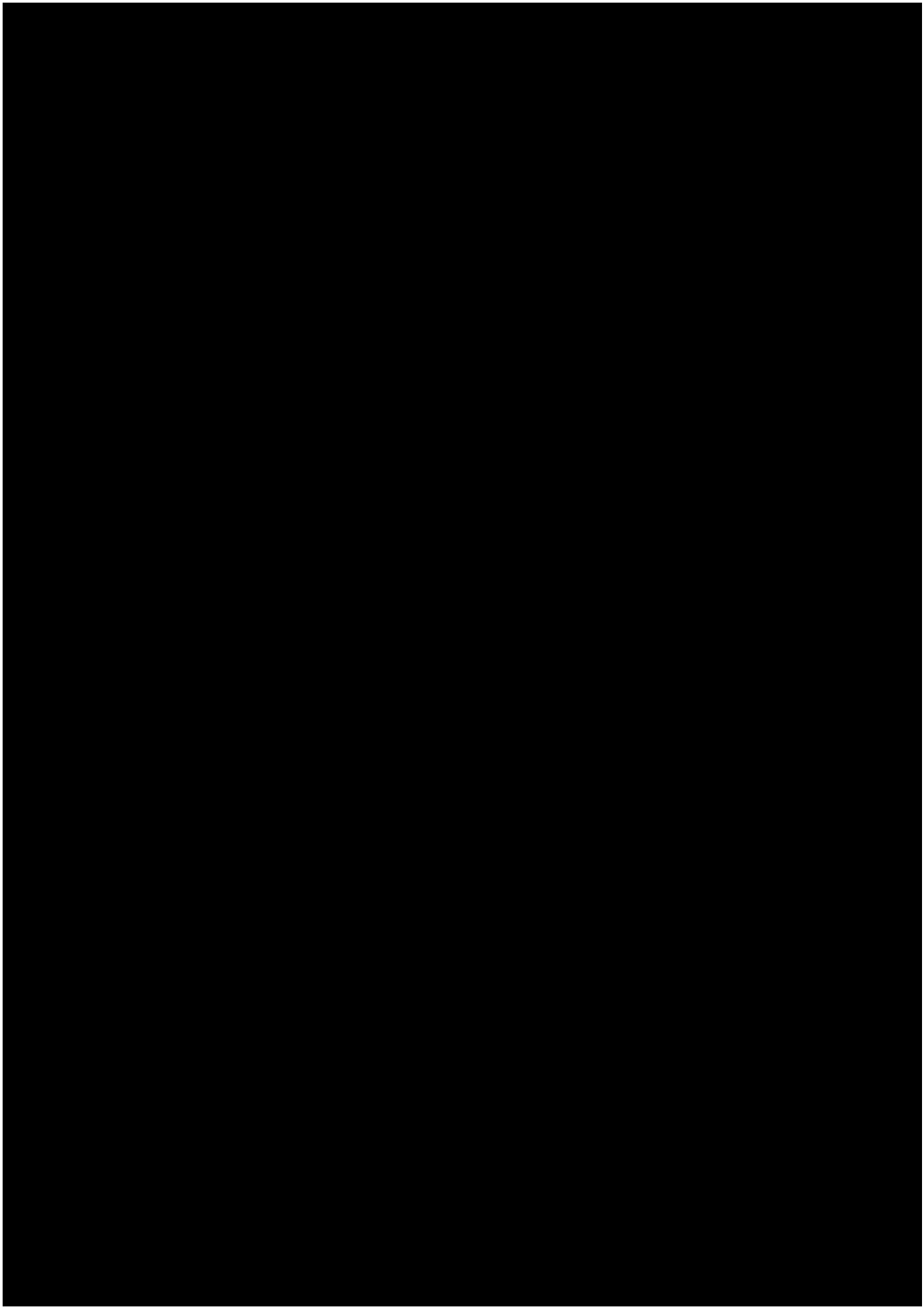
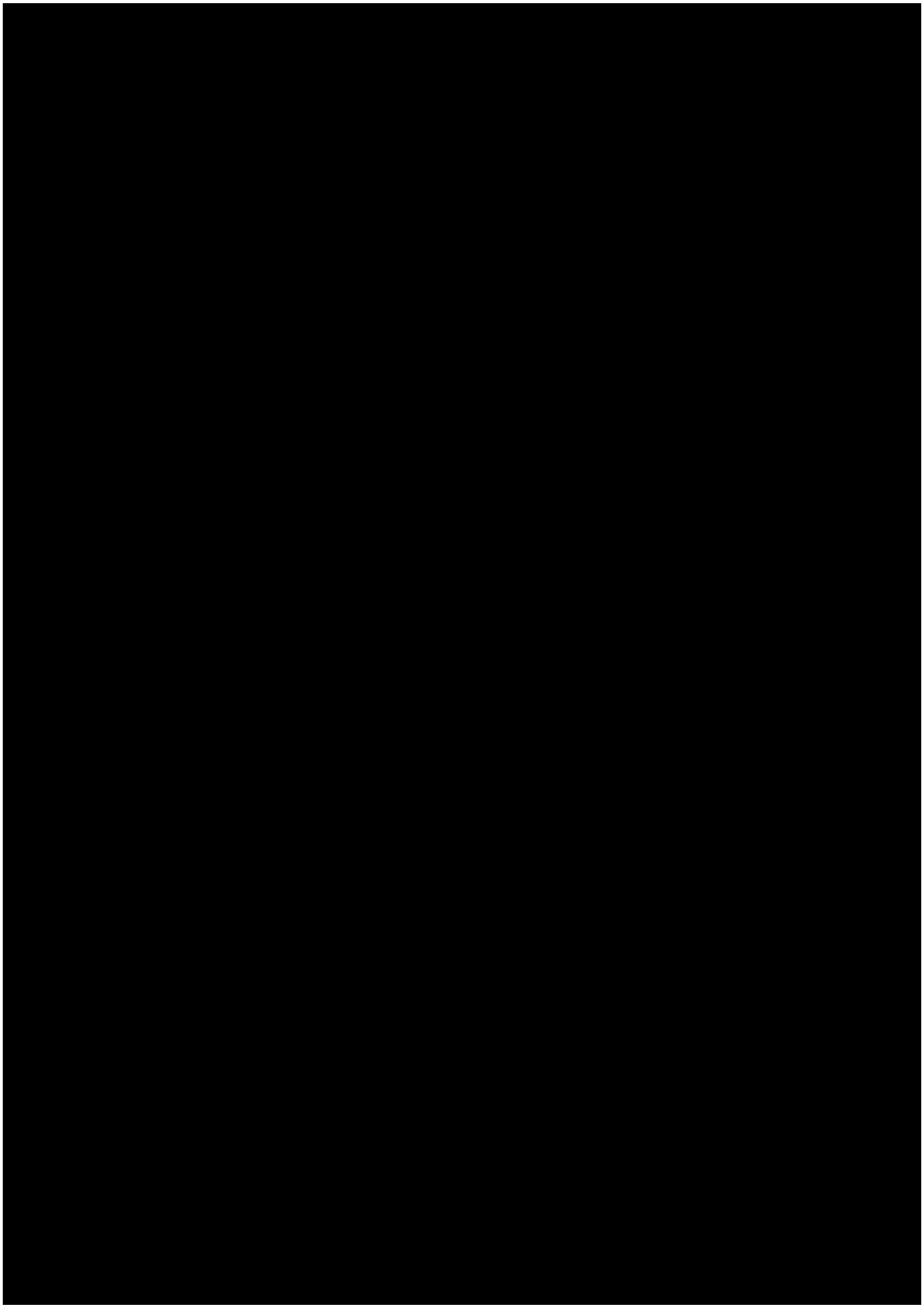
CC:

Ed Alleyne, DPU	*Janice Bailey, DPU*	*Mark Bies, DPU*	*Matthew Brizendine, DPU*
Skip Brooks, DPU	*Jonathan Cosby, DPU*	*Arnold Eberly, DPU*	*Angela Fountain, DPU*
Larry Grant, DPU	*Rosemary Green, DPU*	*Michael Grove, DPU*	*Ricky Hatfield, DPU*
Thomas Harris, DPU	*Tedarryl Hite, DPU*	*Steve Morgan, DPU*	*Darryl Rivers, DPU*
Kathy Robertson, DPU	*Emmett Sandridge, DPU*	*Robert Steidel, DPU*	*Robert Stone, DPU*
Doug Towne, DPU	*Trafford Operator, DPU*	*James Ward, DPU*	*Joe Mason, DPU*
Yun Ni, DPU	*Jason Russell, DPU*	*Vann Davis, DPU*	
Roger Cronin, GH	*Edwin Phillips, GH*	*James Long, DHA*	*Mamo Assefa, DHA*
Tom DiLego, GH	*Kester McCullough, ECE*	*Michael Nye, DHA*	*Douglass Lauer, DHA*
Steve Wood, ETS	*Ed Dunnavant, ETS*	*Nasir Jafferey, DHA*	*Baozhu Wei, DHA*







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