Swift County Museum

From: Rebecca Ellis <Rebecca.Ellis@qseng.com>
Sent: Sunday, May 24, 2015 10:40 PM
To: Swift County Museum
Cc: Morgan McHugh; Al Einberger
Subject: Swift County Historical Museum HVAC Evaluation Report
Attachments: QSE Swift County HVAC Report 052615.pdf

Marie,

The attached file is QSE's HVAC Evaluation report for the Museum's Reception and Sunrise Rooms. The next step of this process is to convene a conference call with Museum (and County, if desired) representatives in which QSE will take comments and corrections and answer any questions about the report. If necessary, we will issue a revised/final report after that call.

Please let us know when you are ready to schedule that conference call. In the meantime, feel free to contact me with any questions or concerns.

Thanks a lot!

Rebecca Ellis, PE
Questions & Solutions Engineering
612.309.0503

Questions & Solutions® Engineering

May 26, 2015

Ms. Marie Tucker
Swift County Historical Society
2135 Minnesota Avenue
Benson, Minnesota 56215

RE: Swift County Historical Museum
Benson, Minnesota
HVAC System Evaluation Report

Dear Ms. Tucker:

Questions & Solutions Engineering, Inc. (QSE) is pleased to present this report of our findings and recommendations for upgrading the heating, ventilating, and air conditioning (HVAC) system serving the Swift County Historical Museum in Benson, Minnesota.

Introduction

The Swift County Historical Society (SCHS) operates a regional museum located in the town of Benson in west-central Minnesota. The museum is housed in a building which was constructed in several phases. This study focuses on the more recently renovated east and central sections of the facility which enclose roughly 5,200 square feet. Figure 1 shows the current floor plan. The museum is open to the public all year; Tuesday through Friday from 10:00 am to 4:30 pm.

The areas of the museum included in this evaluation are currently heated in the winter, but they do not have any cooling or humidity control. The SCHS's objective is to upgrade the HVAC system for improved environmental control to better suit its use for galleries, collections storage, and artifact preservation. This will allow better preservation of the museum collections and create a more comfortable environment for visitors year-round.

This report summarizes QSE's findings and recommendations following our professional engineering evaluation of the building and its systems and identification of system upgrades for consideration.

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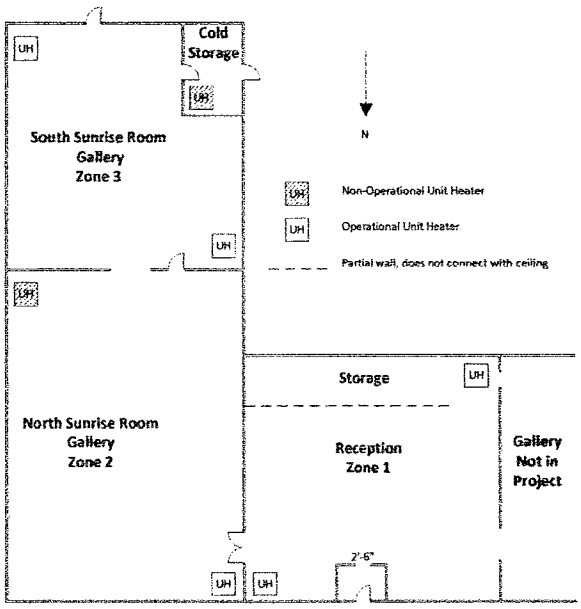

Figure 1: Existing Floor Plan

Assessment Process

QSE conducted the following HVAC system assessment:

1. Rebecca Ellis and Morgan McHugh of QSE visited the Swift County Historical Museum on April 7, 2015 and accomplished the following objectives:
    a. Met with Board representatives to understand:
        i. The history of the facility
        ii. The environmental control goals for the Museum
        iii. How the facility is operated and maintained
    b. Toured, measured, and photographed the building
2. QSE defined and evaluated new HVAC system options

This report is the culmination of QSE's assessment.

Existing Conditions

General

The east and central sections of the Swift County Historical Museum, Zones 1, 2, and 3 in Figure 1, total 5,200 square feet. The galleries make up 3,400 square feet in Zones 2 and 3, artifact storage uses another 350 square feet in Zone 1, and the remaining 1,450 square feet is used as a reception/community space in which artwork is displayed in Zone 1. The three zones are also known as Reception, North Sunrise Room, and South Sunrise Room, respectively.

The current HVAC system serving the three zones consists of seven electric unit heaters located as indicated in Figure 1. Two of the existing electric unit heaters are non-operational resulting in one gallery

being under-served and one storage area being unconditioned. The latter storage area has been turned into "Cold Storage."

The current HVAC system does not cool the Museum during warm weather nor does it provide any humidity control. The space temperatures become very warm in the summer. Moisture levels in the building mirror those of the outdoors year-round. In the summer months when humidity is at its highest the museum brings in portable dehumidifiers in an effort to reduce strain on the collections.

Electrical Service

The Museum is served by a 37.5 kVa electrical transformer providing 220 volt, single phase service. If this needs to be upgraded to serve the new HVAC equipment, an electrical utility representative informed QSE that the utility would replace the transformer at no cost to the Museum.

New System Performance Requirements

A new Swift County Historical Museum HVAC system would ideally have the following characteristics:

- Capability to evenly heat and cool the three zones.
- Minimize relative humidity swings to the greatest extent possible within the architectural constraints of the building envelope and with a manageable annual utility expenditure
- Require minimal maintenance

QSE has defined a set of retrofitted HVAC system options. The options are intended to provide the following conditions if both temperature and humidity control are selected for implementation. Zones 1 & 2 are different from Zone 3, because there is no vapor barrier at the lay-in ceiling. This precludes the introduction of humidity in the winter, because humidification would result in condensation on the inside surface of the roof and uncontrolled dripping down onto the ceiling.

Zones 1 & 2

Winter:	70°F, 30% RH minimum relative humidity
Summer:	75°F, 55% RH maximum relative humidity

Zone 3

Winter:	70°F
Summer:	75°F, 55% RH maximum relative humidity

HVAC System Options

The following are descriptions of each HVAC system option considered.

The requirement for providing outside air intake ductwork at each system is based on Minnesota code requirements for indoor air quality control. The building is not currently bringing any mechanical ventilation air into the building. It must be emphasized that any HVAC retrofit shall comply with Minnesota state code requirements for indoor air quality control. Initial QSE assessment indicates that requirements would be met by any of the proposed system retrofits; any other system improvement would need to be evaluated to ensure compliance with state code.

General Overview

For the purposes of this report the zones have been broken into two groups based on environmental control goals. Zone 1 and Zone 2 are capable of complete environmental control, including both temperature and humidity, year-round. Zone 3 is capable of year-round temperature control as well as humidity control during the summer. Due to building exterior enclosure constraints noted above, Zone 3 cannot realistically support an active winter time humidification system.

For any of the suggested HVAC changes QSE recommends leaving the existing electric unit heaters in place and setting them to 60°F. They will serve as a backup heat source in the event of other equipment failure.

Zones 1 & 2

Option 1: Furnace System

Option 1A: Furnace System without Humidity Control

Two new gas-fired furnaces with direct expansion refrigerant (DX) cooling would be installed in the southwest corner of Zone 1 along with two condensing units on grade in the outdoor courtyard. Supply ductwork would be routed high along the south wall of Zone 1 from each furnace to serve Zone 1 and Zone 2 as shown in Figure 2. A transfer grille would need to be cut into the wall between Zone 1 and Zone 2 in order to allow Zone 2 air to return to Furnace F2.

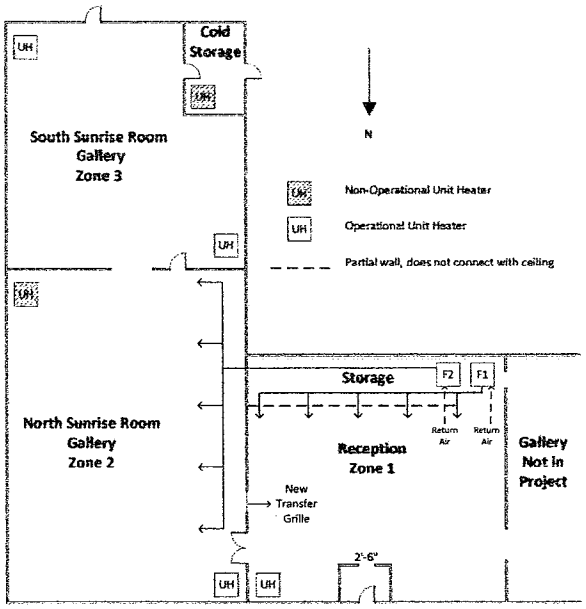

Figure 2: Option 1A

Outside ventilation air would be ducted to the return air side of each furnace with a single automatic damper for ventilation control. The damper would be controlled by a 3 hour timer switch on the wall

near the furnaces. When the space is expected to be occupied, museum staff would set the switch to open the damper for a pre-determined period time and then to automatically close the damper at the end of that time period.

A new dual temperature space thermostat would be installed in each zone to control their respective furnaces. The thermostats would need to be controlled to the same set points at all times with a heating set point of 70°F (adjustable) and cooling set point of 75°F (adjustable). For best collections preservation, these set points would be constant 24 hours/day and the circulation fans would operate continuously.

Option 1B: Reheat Dehumidification

This option assumes that Option 1A will be implemented and involves adding an electric reheat coil in the supply duct of each furnace. The electric reheat would activate whenever a space humidistat in the furnace's zone indicated a relative humidity greater than 55% RH. This would result in the DX cooling running continuously to maintain the thermostat's cooling set point (75°F) and wringing moisture out of the air to achieve the desired dehumidification. When the space relatively humidity falls below 50% RH, the electric reheat coil would be de-energized to return to normal temperature control operation at the furnace.

Option 1C: Furnace System with Packaged Dehumidification

This option assumes that Option 1A will be implemented and involves adding an in-line packaged dehumidifier in each furnace's distribution ductwork.

A new humidistat would be installed in both of the zones next to the thermostats. The humidistat would activate the dehumidifier whenever the zone humidity rises above 55% RH and would deactivate the dehumidifier when the zone humidity falls below 50% RH.

Option 1D: Furnace System with Humidification

This option can be added to any of the previous Options 1A, 1B, or 1C. Option 1D would include installation of an electric steam generator piped to the supply air ductwork serving each zone. There would be two humidifiers; one for each furnace. New space humidistats mounted on the walls next to their respective thermostats would control each humidifier to maintain a set point 30% RH minimum space humidity.

Option 2: Mini-Split Heat Pump System

Option 2A: Mini-Split Heat Pump System without Humidity Control

Two new mini-split wall units would be installed in both Zone 1 and Zone 2 as shown in Figure 3. Each pair of indoor wall units would be piped to a single heat pump installed on grade exterior to the building.

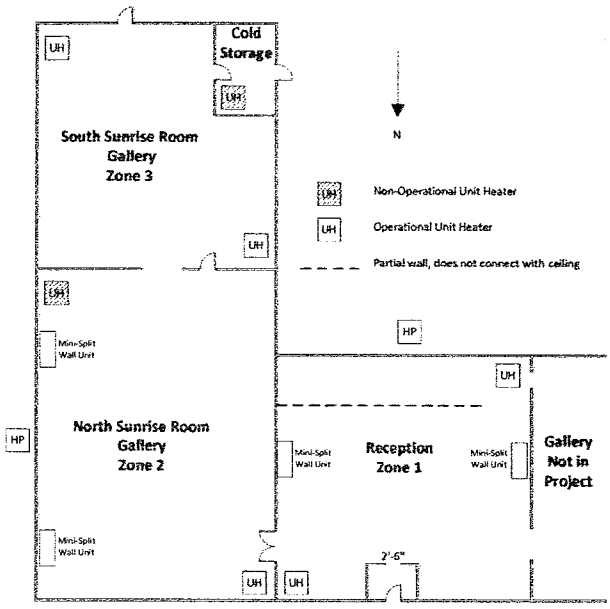

Figure 3: Option 2A

New dual temperature space thermostats would be installed; one for each mini-split wall unit. The thermostats would control to a heating set point of 70°F (adjustable) and a cooling set point of 75°F (adjustable). For best collections preservation, these set points would be constant 24 hours/day and the heat pump fans should operate continuously.

In order to maintain 70°F during very cold winter weather, the existing electric unit heaters would be needed for supplemental heating. The non-operational unit heater in Zone 2 would not need to be replaced, because the single good unit heater (in the northwest corner of Zone 2) should be sufficient for the supplemental heating needs.

Option 2B: Dehumidification Control System

If mini-split heat pumps are used for temperature control, a separate dehumidification air system would be required to maintain Zone 1 and Zone 2 maximum relative humidity set points. The dehumidification system could be shared between the two zones and would consist of a circulation fan in the southwest corner of Zone 1 and supply air distribution ductwork as illustrated in Figure 4.

A packaged dehumidifier would be installed in the distribution ductwork and would be controlled via a humidistat installed in Zone 1 near the opening to Zone 2. The humidistat would activate the dehumidifier and circulation fan whenever the zone humidity rises above 55% RH and would deactivate the dehumidifier and fan when the zone humidity falls below 50% RH.

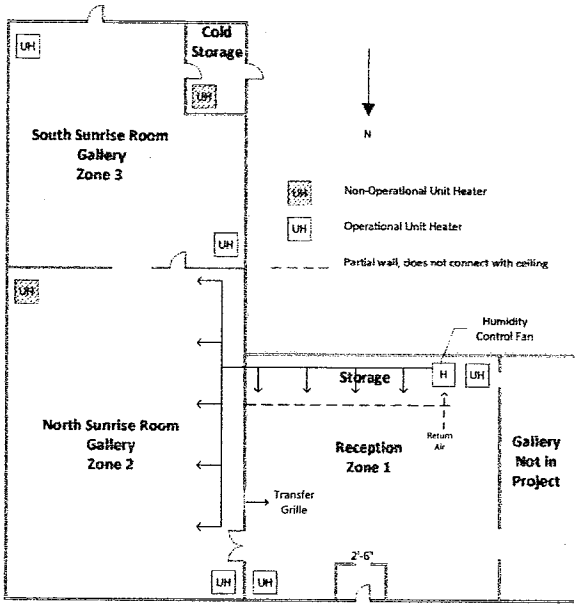

Figure 4: Option 2B

Option 2C: Humidification Control System

Option 2C is QSE's recommended approach to introducing winter humidification to Zones 1 and 2 if those zone temperatures are controlled by mini-split heat pumps. This assumes that Option 2B (dehumidification) will be implemented and utilizes the same fan and distribution ductwork.

This option would include installation of an electric steam generator piped to the supply air ductwork downstream of the new dehumidifier. A new space humidistat mounted on the Zone 1 wall next to the dehumidifier humidistat would control the humidifier to maintain a set point 30% RH minimum space humidity.

Option 3: Zone 1 and Zone 2 Isolation

QSE recommends that Zone 1 and Zone 2 be physically isolated from the remainder of the museum if any active humidity control is to be introduced to Zones 1 and 2. With respect to humidification, this is due to winter humidification being trickier than temperature and dehumidification control. There is a risk of condensing moisture on or inside of the exterior walls or roof surfaces during cold weather if those surfaces are not well insulated and/or those elements do not have a vapor barrier installed.

QSE believes that the walls and roofs of Zones 1 and 2 have the capability of supporting active humidification in those areas. Zone 3 and the remainder of the museum, however, are not constructed to withstand elevated indoor relative humidities. If Zones 1 and 2 are to be humidified, as represented by Option 1D or Option 2C, it will be necessary to physically isolate the humidified Zones 1 and 2 from the other areas of the museum.

QSE also recommends isolating Zone 1 and Zone 2 if dehumidification control is added for the summer (Options 1B, 1C, or 2B). This will minimize the amount of energy needed to maintain maximum 55% RH space humidities in Zone 1 and Zone 2. Without the isolation, the new dehumidification equipment will be over-taxed trying to also dehumidify Zone 3 and the east side of the museum.

To isolate non-humidified Zone 3 from humidified Zone 2, QSE recommends closing the large opening in the wall separating the two zones and using the person door to the west of that opening for access between the two spaces. To isolate the humidified Zone 1 from the non-humidified west side of the museum, QSE recommends moving the existing double doors currently between Zone 1 and Zone 2 to the current opening between Zone 1 and the west side of the museum. These changes have been shown in red in Figure 5 below.

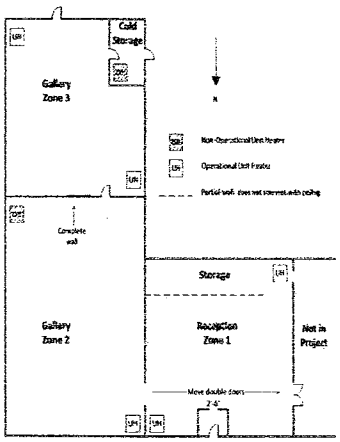

Figure 5: Required Architectural Changes to Achieve Humidity Control in Zones 1 and 2

Zone 3

Zone 3 does not have a vapor barrier in its ceiling (and potentially not in its exterior walls). As such, it is not practical to consider adding humidification during the winter months.

Option 4: Furnace System

Option 4A: Furnace System without Humidity Control

A new gas-fired furnace with DX cooling would be installed in the southwest corner of Zone 3 in what is currently unconditioned storage space, along with a condensing unit on grade exterior to the building. Supply ductwork would be routed from the furnace through the wall into the Zone 3 gallery with supply registers along the south wall of Zone 3. A return grille in the north side of what is currently unconditioned storage would draw the conditioned air back through ductwork to the furnace.

Outside ventilation air would be ducted to the return air side of the furnace with an automatic damper for ventilation control. The damper would be controlled by a 3 hour timer switch on the wall near the furnace. When Zone 3 is expected to be occupied, museum staff would set the switch to open the damper for a pre-determined period time and then to automatically close the damper at the end of that time period.

This option would also include a new electric unit heater to replace the failed unit heater in the currently unconditioned space.

A new dual temperature space thermostat would be installed near the new return air grille to control the furnace. The thermostat would be set to a heating set point of 70°F (adjustable) and a cooling set point of 75°F (adjustable). For best collections preservation, these set points would be constant 24 hours/day and the circulation fan would operate continuously.

Option 4B: Furnace System with Reheat Dehumidification

This options assumed Option 4A will be implemented and would involve adding an electric reheat coil in the supply air ductwork. The electric reheat would activate whenever the space humidistat next to the new thermostat indicated a relative humidity greater than 55% RH. This would result in the DX cooling running continuously to maintain the thermostat's cooling set point (75°F) and wringing moisture out of the air to achieve the desired dehumidification. When the space relatively humidity falls below 50% RH, the electric reheat coil would be de-energized to return to normal temperature control operation at the furnace.

Option 4C: Furnace System with Packaged Dehumidification

This option assume that Option 4A will be implemented and would involve adding an in-line packaged dehumidifier in the furnace's distribution ductwork.

> A new humidistat would be installed next to the new Zone 3 thermostat. The humidistat would activate the dehumidifier whenever the zone humidity rises above 55% RH and would deactivate the dehumidifier when the zone humidity falls below 50% RH.

Option 5: Mini-Split Heat Pump System

Option 5A: Mini-Split Heat Pump System without Humidity Control

Two new mini-split wall units would be installed on the east and west walls of Zone 3; one per wall. Each unit would have an associated heat pump installed on grade exterior to the building.

> Two new dual temperature space thermostats would be installed; one on the north wall of what is currently unconditioned storage and the other on the east side of the Zone 3 north wall. The thermostats would need to be controlled to the same set points at all times with a heating set point of 70°F (adjustable) and cooling set point of 75°F (adjustable). For best collections preservation, these set points would be constant 24 hours/day and the circulation fans would operate continuously.

In order to maintain 70°F during very cold winter weather, the existing electric unit heaters in Zone 3 would be needed for supplemental heating.

Option 5B: Dehumidification Control System

If mini-split heat pumps are used for Zone 3 temperature control, a separate dehumidification air system would be required to maintain Zone 3 maximum relative humidity set points. The dehumidification system would consist of an in-line packaged dehumidifier in the southwest corner of Zone 3 in what is currently unconditioned storage space.

Dehumidified supply air would be distributed to Zone 3 in ductwork routed along the south wall of Zone 3. A return grille in the north side of what is currently unconditioned storage would draw the conditioned air back through ductwork to the dehumidifier.

The dehumidifier would be controlled via a wall-mounted humidistat installed near the return air grille. The humidistat would activate the dehumidifier and circulation fan whenever the zone humidity rises above 55% RH and would deactivate the dehumidifier and fan when the zone humidity falls below 50% RH.

This option would also include a new electric unit heater to replace the failed unit heater in the currently unconditioned space.

Budget Implementation Cost Estimates

HVAC Cost Estimate

The HVAC system budget cost estimates are tabulated in an attachment to this letter. The estimates include all anticipated mechanical, electrical, and general construction costs associated with the HVAC upgrades in 2015 dollars. They also assume a 10% fee for design engineering services and a 2% fee for a third party owner's technical representative (commissioning professional) to provide design review and system testing services to confirm that the Museum's technical goals are being achieved.

The furnace system packaged dehumidification options (Option 1C and Option 4C) were significantly more expensive than the reheat dehumidification options (Option 1B and Option 4B), and there is no significant environmental control difference between the two approaches to dehumidification. Therefore, QSE assumes that if the furnace options were to be selected for implementation by SCHS, the reheat dehumidification options would also be selected.

In order to achieve all of the New System Performance Requirements in Zones 1, 2, and 3, the following are the packages to be considered:

Zones 1 & 2

Package 1	Option	Description	Total Implementation Cost Estimates
Zones 1 & 2 Furnace System	1A	Furnace System without Humidity Control	$57,500
	1B	Furance System Reheat Dehumidification	$10,800
	1D	Furnace System Humidification	$15,400
	3	Zone 1 and Zone 2 Isolation	$7,300
		Zones 1 & 2 Furnace System Total	$91,000

Package 2	Option	Description	Total Implementation Cost Estimates
Zones 1 & 2 Mini-Split Heat Pump System	2A	Mini-Split Heat Pump System without Humidity Control	$29,400
	2B	Mini-Split Dehumidification Control System	$20,400
	2C	Mini-Split Humidification Control System	$9,600
	3	Zone 1 and Zone 2 Isolation	$7,300
		Zones 1 & 2 Mini-Split Heat Pump System Total	$56,700

Zone 3

Package 3	Option	Description	Total Implementation Cost Estimates
Zone 3 Furnace System	4A	Furnace System without Humidity Control	$32,000
	4B	Furnace System Reheat Dehumidification	$5,400
		Zone 3 Furnace System Total	$37,400

Package 4	Option	Description	Total Implementation Cost Estimates
Zone 3 Mini-Split Heat Pump System	5A	Mini-Split Heat Pump System without Humidity Control	$17,900
	5B	Mini-Split Dehumidification Control System	$8,800
		Zone 3 Mini-Split Heat Pump System Total	$26,700

Summary of HVAC Options

Following the cost estimates table attached to this report is an Options Analysis Table listing various characteristics of each HVAC option, quantified on the following scale:

5 = EXCELLENT
3 = GOOD
1 = OKAY

Environmental Control Effectiveness

The environmental control effectiveness category refers to the ability of the system to achieve all of the New System Performance Requirements (defined above) in all spaces throughout the Museum.

Annual Energy Costs

Relative to each other, the lower the annual energy costs, the higher the rating.

Reliability

Relative to each other, the more reliable the system (i.e., the less susceptible to failure), the higher the rating.

Maintainability

Relative to each other, the less required maintenance associated with a system, the higher the rating.

Recommendations

Full Scope

QSE recommends implementation of Package 2 for Zones 1 & 2 and Package 4 for Zone 3. These can be implemented simultaneously or separately. If separately, Package 2 should precede Package 4. However, there would be some economies of scale (perhaps as much as 5% of the total cost) associated with implementing them as a single project.

Package 2	Option	Description	Total Implementation Cost Estimates
Zones 1 & 2 Mini-Split Heat Pump System	2A	Mini-Split Heat Pump System without Humidity Control	$29,400
	2B	Mini-Split Dehumidification Control System	$20,400
	2C	Mini-Split Humidification Control System	$9,600
	3	Zone 1 and Zone 2 Isolation	$7,300
		Zones 1 & 2 Mini-Split Heat Pump System Total	$66,700

Package 4	Option	Description	Total Implementation Cost Estimates
Zone 3 Mini-Split Heat Pump System	5A	Mini-Split Heat Pump System without Humidity Control	$17,900
	5B	Mini-Split Dehumidification Control System	$8,800
		Zone 3 Mini-Split Heat Pump System Total	$26,700

Reduced Scope

If the full scope is impractical for the SCHS to undertake, QSE recommends eliminating the humidification components only. We **strongly recommend against adding air conditioning without dehumidification control.** That would actually be more detrimental to the collections than the current heating-only system (i.e,. would result in higher space relative humidities in the spring and summer). Therefore, the reduced scope packages for each area would be as tabulated below.

Package 2R	Option	Description	Total Implementation Cost Estimates
Zones 1 & 2 Mini-Split Heat Pump System	2A	Mini-Split Heat Pump System without Humidity Control	$29,400
	2B	Mini-Split Dehumidification Control System	$20,400
	3	Zone 1 and Zone 2 Isolation	$7,300
		Zones 1 & 2 Mini-Split Heat Pump System Total	$57,100

Package 4R	Option	Description	Total Implementation Cost Estimates
Zone 3 Mini-Split Heat Pump System	5A	Mini-Split Heat Pump System without Humidity Control	$17,900
	5B	Mini-Split Dehumidification Control System	$8,800
		Zone 3 Mini-Split Heat Pump System Total	$26,700

Conclusion

Once you have reviewed this report, we would like to schedule a telephone meeting with you and other SCSH representatives to discuss QSE's findings and recommendations and answer any questions you may have. Please let me know when you are ready to schedule that meeting.

Thank you very much for the opportunity to work with the Swift County Historical Society. It has been a great pleasure. If you have any questions, please do not hesitate to call or email me (612-309-0503, Rebecca.Ellis@QSEng.com) or Morgan McHugh (612-819-5434) anytime.

Respectfully submitted,

QUESTIONS & SOLUTIONS ENGINEERING, INC.

Rebecca T. Ellis

Rebecca T. Ellis, PE
LEED AP BD+C, CCP, CPMP, CxA
President

File: Swift County Report 052615

Better Performing Buildings

Budget Cost Estimates for HVAC

Options				Total Implementation Cost Estimates
Zones 1 & 2	OPTION 1	1A	Furnace System without Humidity Control	$ 57,500
		1B	Furance System Reheat Dehumidification	$ 10,800
		1C	Furnace System Packaged Dehumidification	$ 18,500
		1D	Furnace System Humidification	$ 15,400
	OPTION 2	2A	Mini-Split Heat Pump System without Humidity Control	$ 29,400
		2B	Mini-Split Dehumidification Control System	$ 20,400
		2C	Mini-Split Humidification Control System	$ 9,600
	OPTION 3	3	Zone 1 and Zone 2 Isolation	$ 7,300
Zone 3	OPTION 4	4A	Furnace System without Humidity Control	$ 32,000
		4B	Furnace System Reheat Dehumidification	$ 5,400
		4C	Furnace System Packaged Dehumidification	$ 9,300
	OPTION 5	5A	Mini-Split Heat Pump System without Humidity Control	$ 17,900
		5B	Mini-Split Dehumidification Control System	$ 8,800

Options Analysis Table

Options				Environmental Control Effectiveness	First Cost	Energy Costs	Maintainability	Total Score
Zones 1 & 2	OPTION 1	1A	Furnace System without Humidity Control	1	1	3	5	10
		1B	Furance System Reheat Dehumidification	4	5	1	4	14
		1C	Furnace System Packaged Dehumidification	4	2	3	3	12
		1D	Furnace System Humidification	5	1	3	2	11
	OPTION 2	2A	Mini-Split Heat Pump System without Humidity Control	1	5	4	5	15
		2B	Mini-Split Dehumidification Control System	4	1	3	3	11
		2C	Mini-Split Humidification Control System	5	5	3	2	15
	OPTION 3	3	Zone 1 and Zone 2 Isolation	N/A	N/A	N/A	N/A	N/A
Zone 3	OPTION 4	4A	Furnace System without Humidity Control	1	1	3	5	10
		4B	Furnace System Reheat Dehumidification	4	5	1	4	14
		4C	Furnace System Packaged Dehumidification	4	1	3	3	11
	OPTION 5	5A	Mini-Split Heat Pump System without Humidity Control	1	5	4	5	15
		5B	Mini-Split Dehumidification Control System	4	4	3	3	14