ArcGIS Heavy Metal Exposure Prototype

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GEOG 6162

Project Management

December 9, 2016

Contents

1.0 Introduction

In late August 2016, metal-contaminated sediments were inadvertently released into the American Fork River during a dam-rehabilitation project at Tibble Fork Reservoir in American Fork Canyon in Utah County, Utah. The source of the heavy metals are from abandoned historic gold, lead and silver mines (DEQ, 2016). The toxic sludge was comprised of lead, arsenic, cadmium and other heavy metals. Even at low exposure levels, these metals are known to cause organ damage and cancer (NIH, 2012).

Mapping the environmental exposure of stored-up toxic sediments behind dams near historical mines, will hopefully provide insight to the potential of public health impact. Each time an incident occurs, it is critical to assess the areas of impacted population so that people can be warned in time and also be monitored thereafter for potential ill-health effects. The ArcGIS Heavy Metal Exposure Prototype using the Tibble Fork Reservoir spill as the case study, will provide a template for generating the information needed to quickly assess an incident.

The project will run for five months and cost $48,000. The benefits of the project will save valuable response time, saving money and mitigation efforts of emergency response for contaminated water incidents. These benefits should easily offset the potential risks of developing the ArcGIS Heavy Metal Exposure Prototype.

2.0 Scope Management

2.1 Scope Statement

Project Title: ArcGIS Model of Heavy Metal Exposure
Date: September 1, 2016 **Prepared by:** Chelsea Welker

Project Justification:

- The DEQ's strategic goal is to maintain the environmental health and safety of Utah citizens.
- The water quality assessment of heavy minerals originating from the accidental sediment release from the Tibble Fork Reservoir dam in American Fork Canyon, will support these goals by exposing any potential areas that have higher than recommended toxicity levels that could lead to civilian health issues.
- Exposure to heavy metals can lead to organ failure and are carcinogenic, resulting in long-term medical care and possible loss of life.
- The benefits of the project are saving valuable time and money each time a new incident occurs from not having to rebuild the exposure distribution areas, reduce federal litigations, and mitigation and preparedness for an event.

Product Characteristics and Requirements:

1. Requires ArcGIS 10.4+ software
2. Requires spill sample data, .CSV
3. Population, terrain and rivers databases included
4. Model output based on Pollution Dispersion model and EPA exposure limits for public health on recreation, ingestion and wildlife

Summary of Project Deliverables

Project management-related deliverables: business case, charter, scope statement, WBS, schedule, cost baseline, status reports, communication plan, final project presentation, final project report, lessons-learned report, and any other documents required to manage the project.

Product-related deliverables: research reports, design documents, software code, hardware, etc.

1. Analysis results Tibble Fork Reservoir case study
2. Exposure area maps
3. Final write-up report of metal exposure
4. GIS Model of Heavy Metal Exposure prototype
5. Help documentation

Project Success Criteria:

This project will be successful if the quality of the prototype is high caliber and if the project meets time and cost goals. High-quality and accurate analysis of impacted areas is of utmost importance.

2.2 Business Case

Introduction and Background of Tibble Fork Reservoir Case Study

Heavy metals such as lead, arsenic, cadmium and mercury, are naturally occurring in the earth's crust. However, environmental pollutants from industrial waste pose severe health risks associated with heavy metal toxicity. Mining industries are a common source of heavy metal contamination. Historic mines in American Fork Canyon in northern Utah, are such a source of pollution into the surface waters of the area. Over many decades, these contaminants settled into the sediments of the Tibble Fork Reservoir.

Recently, a rehabilitation project began to update safety compliance regulations on the 50-year-old Tibble Fork Reservoir. During the project an unanticipated amount of toxic sediments was released into the American Fork River. People use the reservoir for recreation activities and it provides irrigation to local companies. Because heavy metals are known to cause organ failure and contain carcinogens, it presents a local significant health concern.

No amount of lead in the blood of children has been determined to be safe (CDC, 2013). As such, it is important to monitor these historical mining areas and their toxic buildup at dam sites and related water sources. The Utah Department of Environmental Quality (DEQ) was created to monitor compliance of the EPA law and is administered by the Utah Division of Water Quality (DWQ) to protect the quality of Utah's water resources.

Department of Environment Quality Business Objective

The DEQ's strategic goal is to maintain the environmental health and safety of Utah citizens. The water quality assessment of heavy minerals originating from American Fork mining deposits will support these goals by exposing any potential areas that have higher than recommended heavy metal exposure that could lead to public health issues. The project will also help eliminate financial repercussions of the state by identifying problematic areas requiring a response.

Current Situation and Problem/Opportunity Statement

The DWQ currently utilizes GIS technology and has undergone an Environmental Assessment (2004) of the Tribble Fork Reservoir indicating potential fallout areas of concern for the future. Being a state agency, the DWQ has numerous resources and access to data samples for best modeling practices. There is an opportunity to develop an assessment tool that could be used by the DEQ for years to come but also for other private dam owners would like to understand their potential liability. It could provide state agencies with the knowledge to develop cleanup mitigation protocols for high risk areas. However, modeling environment exposures hazards can be difficult with limited data availability and implementing incorrect modeling assumptions can generate an unreliable model.

Critical Assumptions and Constraints

It is imperative that the prototype be reliable and fall within acceptable range values of error analysis. Modeling is notoriously difficult and the prototype should only lay the groundwork for the simplest model with which complexities could later be built upon. It should run on

current versions of ArcGIS and easily updated and require little support, if a geospatial analyst is not available.

Analysis of Options and Recommendations

There are three options for addressing this opportunity:

1. Do nothing. As it would be a new prototype tool, nothing is lost by doing nothing at all.
2. Do the exposure analysis on the Tibble Fork Reservoir only. If time becomes an issue, the development of the prototype workup can be eliminated.
3. Develop a working prototype that could be implemented to any canyon where a dam is downstream to abandoned mines.

Based on the possibility of a long-term prototype we feel #3 is a worthwhile endeavor.

Preliminary Project Requirements

The main features of the GIS Model of Heavy Metal Exposure:

1. The prototype should work within the standard 10.0+ version of ArcGIS Desktop and not require extra extensions or third party software.
2. Easily import XY contamination source data points.
3. Since other relevant feature layers will come from the AGRC and Census Bureau, the prototype should WGS84 or NAD83 datum.
4. Exposure modeling by implementing the advection-diffusion equation of pollution concentrations in rivers. If this proves to be too difficult for time constraints, the contingency plan is to use a simplified version using buffer zones and intersection selection summation results.

Budget Estimate and Financial Analysis

Preliminary estimates for prototype development costs are $48,000. The majority of the costs will be internal labor, followed by hardware, training and training and finally software. See Cost Management for details.

Schedule Estimate

To stay relevant with the current Tibble Fork Reservoir spill crisis, this project should be completed within 5 months. It should have a useful life of at least 3 years, or until model capabilities of technology and know-how surpass the current knowledge base.

Potential Risks

This project has some negative risks.

- Derivation of the advection-dispersion equation is at the heart of calculating pollution concentrations in water. Implementing a differential equation in ArcPy could be time consuming if staff and technology don't have the proficiently or capability to create an accurate or usable model.
- The project may not pay for itself if development takes too long, but also, if there are never any dam spill incidents besides the case study.
- The availability, distribution and quality of data will carry heavy significance on model outcome.
- 3rd party software could become more appealing as the project moves forward and complications arise from model development.

2.3 Stakeholder Register

There are many stakeholders interested in this project including federal and state government environmental agencies and staff, dam and land owners, people that use the river for recreation uses, farmers that use the river for irrigation purposes and public health agencies.

Name	**Position**	**Internal/External**	**Project Role**	**Contact Information**
Walt Baker	Director DWQ	Internal	Sponsor	wdaeson@utah.gov
Erica Gaddis	Planning and Assessment Branch Manager	Internal	Sponsor	egaddis@utah.gov
James Harris	Environmental Program Manager	Internal	Project Coordinator	jharris@utah.gov
Chelsea Welker	Monitoring and Reporting Project Manager	Internal	Project Manager	cwelker@utah.gov
Neng Wan	Hazards Exposures	Intra-department	Model Advisor	nwan@utah.gov
Sandy Lou	Jordan River Watershed Program Leader	Intra-department	Advisor	slou@utah.gov
Rich Guy	Owner Snowbird Resort	External	Passive	rguy@gmail.com
Judy Moore	American Fork City Council	External	Passive	jmoore@am.gov
Bryce Larsen	Division Director Environmental Health	External	Passive	brycel@utahcounty.gov

2.4 Deliverables

1. Analysis results Tibble Fork Reservoir case study
2. Exposure area maps
3. Final write-up report of metal exposure
4. GIS Model of Heavy Metal Exposure prototype
5. User manual

3.0 Time Management

This project will take place from September 2016 to January 2017. A kick-off meeting with internal stakeholders will take place quickly after approval. Planning and execution are the most time consuming portions of the schedule and the ArcGIS model development should take precedence. There will be some training for internal users and accompanying documentation to prepare. In addition to delivering the deliverables, he final wrap-up meeting will assess project development and lessons learned.

3.1 Work Breakdown Structure ArcGIS Heavy Metal Exposure Model

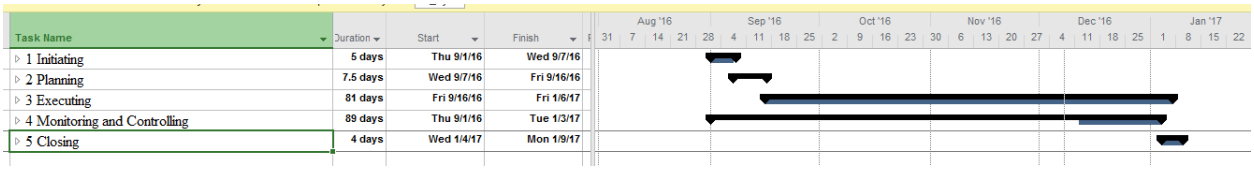
Prepared by: Chelsea Welker Date: November 16, 2016

1. Initiating
   1.1. Select project manager
   1.2. Form project team
   1.3. Develop project charter
2. Planning
   2.1. Develop scope statement
   2.2. Create WBS
   2.3. Define requirements
      2.3.1. User requirements
      2.3.2. System requirements
      2.3.3. Software requirements
      2.3.4. Minimum model requirements
         2.3.4.1. Projection systems

2.3.4.2. Sample data format
2.4. Acceptance to proceed
3. Executing
3.1. Survey
3.2. Model parameters
3.2.1. Sample data input format
3.2.2. Model features
3.2.2.1. Utah coverage of the National Hydrography Database
3.2.2.2. ESRI terrain layer
3.2.3. Model functions
3.2.3.1. Pollution point source import
3.2.3.2. Run dispersion spatial analysis model
3.2.3.3. Exposure multi-ring buffer polygon output
3.2.3.4. Create exposure criteria limits for public health
3.2.3.5. Optional census import for demographic analysis
3.3. Model design
3.3.1. Review preliminary software specifications
3.3.2. Develop functional specifications
3.3.3. Develop prototype based on functional specifications
3.3.4. Review functional specifications
3.3.5. Incorporate feedback into functional specifications
3.3.6. Obtain approval to proceed
3.4. Model construction
3.4.1. Review functional specifications
3.4.2. Identify modular/tiered design parameters
3.4.3. Assign development staff
3.4.4. Develop ArcGIS model
3.5. Model testing
3.5.1. Unit testing
3.5.2. Integration testing
3.5.3. Systems testing
3.5.4. User acceptance testing
3.6. Model promotion
3.6.1. Email blast
3.6.2. Announcement
3.7. Model rollout
3.8. Documentation
3.8.1. Develop Help specification
3.8.2. Develop Help system
3.8.3. Review Help documentation
3.8.4. Incorporate Help documentation feedback
3.8.5. Develop user manuals specifications
3.8.6. Develop user manuals
3.8.7. Review all user documentation
3.8.8. Incorporate user documentation feedback
3.9. Training

        3.9.1. Designate training coordinator
        3.9.2. Training materials
4. Monitoring and Controlling
    4.1. Prototype
    4.2. Model changes
5. Closing
    5.1. Lessons learned
    5.2. Final meeting
    5.3. Acceptance

3.2 Gantt chart ArcGIS Heavy Metal Exposure Model



See digital enclosure for more detail

4.0 Cost Management

This project is estimated to cost $48,000. Assuming there is at least one water contamination incident per year and it will take one GIS analyst one day to run the prototype, the ROI is 119%.

4.1 Cost Estimate ArcGIS Heavy Metal Exposure Model

	# Units/Hrs.	Cost/Unit/Hr.	Subtotals	WBS Level 1 Totals	% of Total
WBS Items					
1. Project Management				**$29,895**	**62%**
1.1 Project manager	145	$75	$10,875		
1.2 Model Advisor	103	$40	$4,120		
1.3 GIS Specialist and Advisor	334	$30	$10,020		
1.4 GIS Technician	244	$20	$4,880		
2. Hardware				**$4,600**	**10%**
2.1 Desktops	1	$600	$600		
2.2 Servers	1	$4,000	$4,000		
3. Software				**$1,000**	**2%**
3.1 Licensed software	5	$200	$1,000		
4. Testing (10% of total hardware and software costs)			$560	**$560**	**1%**
5. Training and Support				**$4,100**	**9%**
5.1 Trainee cost	40	$40	$1,600		
5.3 Project team members	50	$50	$2,500		
6. Reserves (20% of total estimate)			$8,031	**$8,031**	**17%**
Total project cost estimate				**$48,186**	

4.2 Financial Analysis for ArcGIS Heavy Metal Exposure Prototype

Created by: Chelsea Welker		**Date: November 30, 2016**				
Discount rate	8.00%					
Assume the project is completed in Year 0			**Year**			
	0	1	2	3	**Total**	
Costs	48,000	240	240	240		
Discount factor	1.00	0.93	0.86	0.79		
Discounted costs	**48,000**	**223**	**206**	**190**	**48,619**	
Benefits	0	29,655	47,760	47,760		
Discount factor	1.00	0.93	0.86	0.79		
Discounted benefits	**0**	**27,579**	**41,074**	**37,730**	**106,383**	
Discounted benefits - costs	(48,000)	27,356	40,867	37,541	**57,764**	← **NPV**
Cumulative benefits - costs	(48,000)	(20,644)	20,223	57,764		
		↑				
ROI →	**119%**					
	Payback in Year 1					
Assumptions						
There is one incident per year. It will take one a GIS analyst one day to run model in the future ($30*8hrs)						

5.0 Quality Management

Public health concerns will be raised or suppressed based on the results from running this exposure model in ArcGIS. Model quality and accuracy could impact public health issues such as how many people to notify and whether or not to recommend seeking medical advice. Therefore quality assurance and quality control and are of the utmost importance.

5.1 Quality Assurance Plan for ArcGIS Heavy Metal Exposure Prototype

Prepared by: Chelsea Welker Date: November 20, 2016

1 Draft Quality Assurance Plan
- 1.1 Introduction
  - 1.1.1 The purpose of the ArcGIS Heavy Metal Exposure Prototype is to quickly ascertain public health exposure levels of metal toxicity in surface waters from a containment breach.
- 1.2 Purpose
  - 1.2.1 Assessment of exposure limits will only be as good as its collected and acquired data. As such, data quality is very important to the success of the project.
- 1.3 Policy Statement
  - 1.3.1 All acquired data is from public sources and therefore will adhere to their practices regarding use. Water sample collections will have passed through other departmental procedures of the DWQ for interdepartmental use.
- 1.4 Scope
  - 1.4.1 Using the recent accidental sediment release from Tibble Fork Reservoir as a case study, develop an effective and accurate ArcGIS prototype that will calculate public health exposure levels of metal toxicity in surface waters from a containment breach.
  - 1.4.2 The project uses the advection-diffusion equation to determine pollution concentrations for time and distance from source (dam). Impacted populations will be calculated from census data in ArcGIS. River and terrain datasets are from resources that follow FGDC standards.

2 Management
- 2.1 Organizational Structure
  - 2.1.1 Please see chart in section X.X
- 2.2 Roles and Responsibilities

2.2.1 Technical Monitor/Senior Management

2.2.1.1 James Harris is the point of contact for all data quality concerns for monitoring programs, is the DWQ representative and reports to upper management regarding QA/QC issues.

2.2.2 Task Leader

2.2.2.1 Chelsea Welker assist James Harris with reviewing, revising and maintaining QA/QC for the division.

2.2.3 Quality Assurance Team

2.2.3.1 The The GIS Specialist, Amanda Smith is responsible for QC checks on GIS geodatabases.

2.2.3.2 The model advisor, Neng Weng, will create the public health exposure parameters for implementation into ArcGIS.

2.2.4 Technical Staff

2.2.4.1 The GIS Technician, Joe Schmoe, will provide metadata data entry on GIS features.

3 Required Documentation

3.1 QA/QC checklist

4 Quality Assurance Procedures

4.1 Acquired data from the Automated Geographic Reference Center (AGRC)

4.1.1 Hydrography, elevation, parcels, demographic datasets.

4.1.2 Approved and published methods from USGS or another accepted entity (such as EPA, U.S. Census Bureau) will be used.

4.1.3 Use the data quality control management application, ArcGIS Data Reviewer for Desktop for attribute errors.

4.1.4 Use the ArcGIS Topology Reviewer for topological checks.

4.1.5 Assign or convert all GIS data to NAD83 UTM Zone 12N.

4.1.6 Positional Accuracy usage by the FGDC.

4.2 Collected water sample tables

4.2.1 All compliance-related water/soil chemistry samples must be analyzed at a laboratory meeting the minimum standards as defined in Utah Administrative Code Rule R444-14-Rule for the Certification of Environmental Laboratories. Each laboratory utilized by DWQ must also have documented analytical method protocols available for DWQ to review. Non-EPA methods must be reviewed and preapproved by DWQ.

4.2.2 Make sure collected water samples from DEQ interdepartmental use have their coordinate system defined and schema normalized.

4.2.3 Positional Accuracy usage by the FGDC.

4.3 Exposure Analysis

4.3.1 Analytical methods will be selected that provide comparable, sensitive, and accurate data for the sample matrix and range of expected values for the constituents being analyzed.

4.3.2 The project uses the common advection-diffusion equation to determine pollution concentrations for time and distance from source.
4.3.3 Analogous models (such as national tool, BASINS 4.1 from the EPA) for checking results.
4.3.4 Benchmarking percent of impacted population from recent mine spills (i.e. 2015 Gold King Mine from Colorado)
4.3.5 Shall be reported qualitatively, either best-probably-worst- case scenarios OR As quantitative analysis of number of people/population impacted by exposure, within 95% certainty. This should depend on pollution sample size and distribution.

5 Quality Assurance Metrics
5.1 Geospatial Data
5.1.1 Positional accuracy
5.1.2 Attribute accuracy
5.1.3 Completeness
5.1.4 Logical Consistency
5.1.5 Lineage
5.2 Exposure Assessment
5.2.1 Plausible population calculation in multi-ring buffer extents

5.2 Quality Control Check List Form; ArcGIS Heavy Metal Exposure Prototype

- ☐ GIS features in NAD83 UTM 12N and coordinate Resolution (0.01), and Tolerance (0.1) be set explicitly
- ☐ Explanatory GIS attribute columns names, normalized attribute values
- ☐ Dissolved extracted/clipped GIS features (limited number of sliver polygons, overlaps or gaps)
- ☐ Manually recalculate the index after adding a large number of features that differ in size from the features that are already in the feature class.
- ☐ Metadata for new, generated features: The ESRI formatted item description should be filled out to include the Summary, Description, Credits and any Use limitations that exist for the data. FGDC metadata tool should be used to set, at a minimum, Description, Contact Info, Status, Time Period, Citation, Status, and Entity Attribute description information.
- ☐ Water sample tables in NAD83 UTM 12N
- ☐ Metal population exposures calculated with 95% confidence.

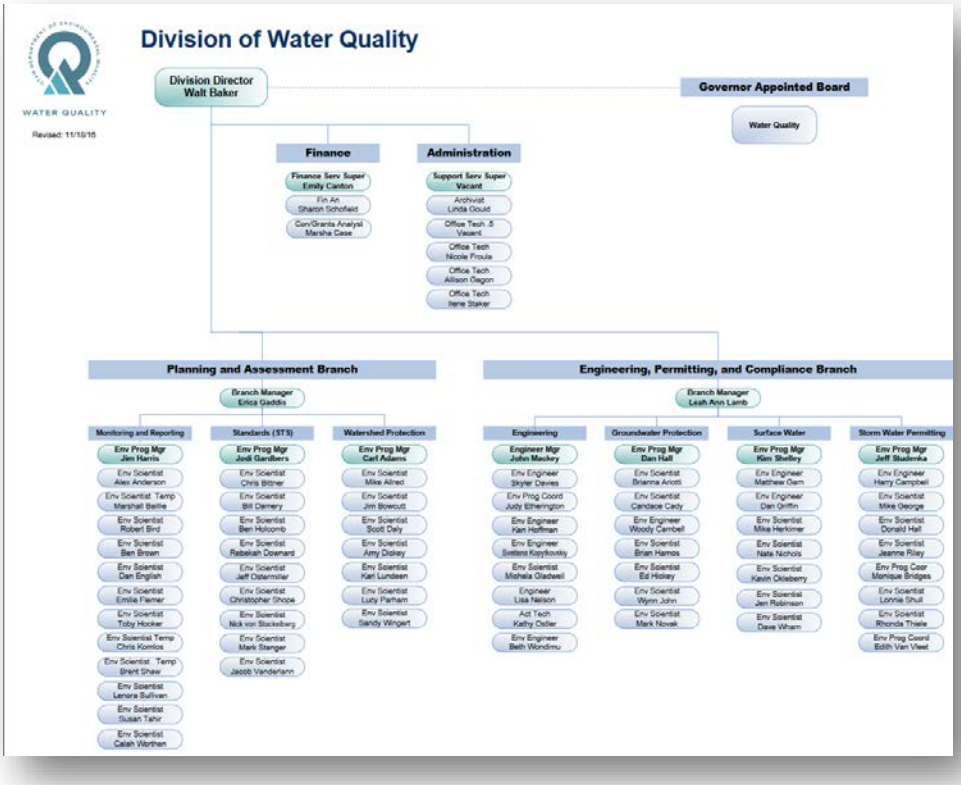
6.0 Human Resource Management

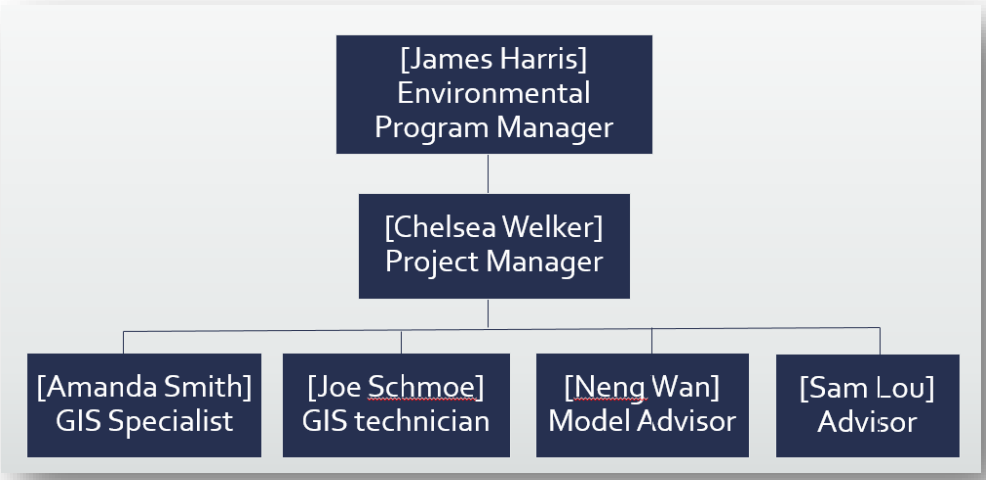
Public health issues are the concern of many stakeholders. When federal and/or state governments are involved, there are many people to coordinate to ensure a successful project that runs smoothly.

Assessment of the Four Frames of Division of Water Quality within the Utah Department of Environmental Quality

Structural

The DEQ and DWQ follow a functional organizational structural type. The Division Director oversees the Planning and Assessment Branch. The Branch manager oversees the Environment Health Program manager who the project manager reports to.





Human Resources

The DEQ and DWQ has a well-defined system of human resources in place. Employees understand the typical requirement associated with a project of this nature and that extra time may be required during certain milestones of this project. However, it will be necessary to hire on a GIS technician to assist the GIS specialist. The HR department has already undertaken that task.

Political

Political fallback would most likely be expected on public health issues, especially with such dire ramifications as being exposed to heavy metals, even temporarily. Therefore, it will require diligent work to follow procedure and procedures as outlined by the state government.

Symbolic

This project also carries a lot of symbolism which portrays the federal and state governments are doing everything they can to protect their citizens and protect our precious water supply.

7.0 Communication Management

Again, because of the variety and number of stakeholders, this project will rely heavily on good internal and external communication from start to finish. It will involve updating general public via our website, interactive meetings with upper management and weekly stand-up meetings with the project team.

7.1 Communications Management Plan for the ArcGIS Heavy Metal Exposure Prototype

Prepared by: Chelsea Welker Date: November 19, 2016

1. Introduction
   a. Public health issues are a high priority of many organizations, for obvious reasons. When the water supply becomes tainted everyone has a vested interest in solving the problem and mitigating negative consequences. Upper management and stakeholders want to keep updated on progress as do landowners and responsible parties, not just the project team. Communication management is therefore very important to the success of the project.
2. Collection and filing structure for gathering and storing project information
   a. Progress and status reports, meeting minutes, this document and other communication notes shall be stored on the project server under the communication folder.
   b. Google Docs will be used with upper management and outside stakeholders that would like to keep appraised of monthly meeting decisions.
3. Distribution structure (what information goes to whom, when, and how)
   a. External stakeholders
      i. Snowbird, City Council, general public
      ii. Progress reports and/or
      iii. When a major milestone/results of interest occurs
      iv. Project update on website
   b. Upper management
      i. Directors and Branch managers from the Utah Department of Environmental Quality and Division of Water Quality, Program Manager
      ii. Monthly general progress reports, key issues to resolve
      iii. Lunch meeting
   c. Project manager
      i. Any push or pull of information of interest or concern
      ii. Stakeholder inquiries
      iii. Project team questions and updates, weekly

iv. Project team fires, stand-up meeting every morning until resolved

d. Project team
    i. GIS Specialist, GIS technician, model advisor
        1. questions and updates, weekly
    ii. Anytime e-mail, weekly standup meetings, monthly lunch progress reports

4. Technologies, access methods, and frequency of communications
    a. Website project updates, no restrictions, every two months
    b. Google docs; invitation only; as needed and minutes after progress reports
    c. Project server; IT access; Monday communication document update, meeting minutes, important stakeholder e-mail copies
    d. Work email project folders; private access; every day
5. Method for updating the communications management plan
    a. Only the project manager shall update the communication management plan after key decisions made by top management and stakeholders.
6. Escalation procedures
    a. Notify management or HR one position above the issue to be resolved
    b. If issues still cannot be resolved, meet with the director

Stakeholders	**Document Name**	**Document Format**	**Contact Person**	**Due Date**
Snowbird, City Councils, general public	Announcement and progress reports	Project website update	Walt Baker	Sept.1, Nov. 1, EOP
DEQ, DWQ upper management	Monthly progress reports	Lunch meeting	James Harris	First Monday of the month
Program manager	Announcement and progress	Email	James Harris	BOP, MOP, EOP
External advisors	Discussion	Kick-off meeting, MOP	Sandy Lou	BOP, MOP
Internal project team	Weekly status reports, forecasts	Email, stand-only meetings	Chelsea Welker	Every Monday morning

Glossary of terms

a. BOP: Beginning of project
b. MOP: Middle of project
c. EOP: End of project
d. DEQ: Department of Environment Quality
e. DWQ: Division of Water Quality

8.0 Closing activities

The closing of the project will be validated by the program manager upon completion of outlined project deliverables. A wrap-up meeting will conclude the project to discuss deliverables, results and lessons learned.

9.0 References

Center for Diseases Control and Prevention. April 5, 2013. Blood Lead Levels in Children Aged 1–5 Years — United States, 1999–2010. Morbidity and Mortality Weekly Report (MMWR) http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6213a3.htm?s_cid=mm6213a3_e

Jaishankar, M., T. Tseten, N. Anbalagan, B. Blessy, M. Krishnamurthy, and N. Beeregowda, 2014. Toxicity, mechanism and health effects of some heavy metals. Interdiscip Toxicol, 7(2), pp. 60–72.

James, I.D. 2002. Modelling pollution dispersion, the ecosystem and water quality in coastal waters: a review. Environmental Modelling & Software (17) pp. 363–385.

Tchounwou, P.B., C.G. Yedjou, A.K. Patlolla, and D.J. Sutton, 2012. Heavy Metals Toxicity and the Environment. PMC, National Institute of Health, 101, pp. 133-164

United States Department of Agriculture. 2004. Tibble Fork Dam Rehabilitation: NRCS Construction Update on Reservoir Bypass Channel. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ut/programs/planning/wr/?cid=nrcs141p2_034072

United States Department of Agriculture. Forest Service. A Century of Stewardship: The Railroad and Early Mining. http://www.fs.usda.gov/detail/uwcnf/learning/history-culture/?cid=stelprdb5052890

Utah Department of Environmental Quality. Tibble Fork Reservoir Sediment Release 2016. http://deq.utah.gov/locations/T/tibble-fork-reservoir/index.htm

United States Department of Labor. Occupational Safety and Health Administration; Toxic Metals. https://www.osha.gov/SLTC/metalsheavy/index.html

United States Environmental Protection Agency (EPA). September 2016, Summary of the Clean Water Act. https://www.epa.gov/laws-regulations/summary-clean-water-act

Appendix

Project Log