Specifications for
Synchronized Sensor Pipe Condition Assessment
(AS PROVIDED BY REDZONE ROBOTICS)

A. Scope of Work
The work covered by these specifications consists of furnishing all materials, labor, supervision and equipment necessary to perform a detailed Pipe Condition Assessment utilizing closed-circuit television inspection, sonar, H2S, and laser scanning equipment of the sewer line specified herein. All inspection sensors must inspect simultaneously and be mounted on a tracked vehicle transmitting a digital signal that is capable of inspecting at least 5,000' either upstream or downstream from the access point.

B. Sensor Transport (fully or partially charged pipe)
The sensor transport shall be skid steered with molded rubber tracks. Tracks shall have a minimum of 200 square inches of ground contact. The transport shall weigh at least 600lbs and be a flexible, rugged, and stable transport vehicle. The use of a robust and reliable transport to maneuver and position sensors within the pipe pays dividends in the improved quality of data acquired. Additionally, using a stable/tracked platform enables references to be exploited to dramatically improve the accuracy of the collected data. The transport system shall be capable of operating within pipes of 36" in diameter or greater and have auxiliary motion axes that enable the operator to reposition the vehicle in the event that it is flipped on its side. The transport shall be Hydraulic (>3.5hp) and capable of inspecting upstream and downstream of the deployment location in flow conditions up to 10ft/sec in partially and/or fully submerged conditions. This will allow inspection to occur while pipe remains in service. The transport shall provide an integrated Inertial Measurement Unit (IMU) to enable real-time monitoring of robot position and orientation. The IMU shall measure three axis of rotation and three axis of acceleration. The transport shall provide real-time measurement and display of pitch and roll measurements with respect to gravity that are good to ±1°. The transport shall be equipped with a standard computer with RS-232, RS-485, USB, and Ethernet interfaces which allows for simultaneous collection of multiple sensors mentioned herein.

i. Deliverable and Reporting for Partially Charged Lines

Meander and Incline Report: A three dimensional meander and incline graph is required.

C. Closed Circuit Television
Nassco Standard

D. Sonar (submerged portion of pipe)
Sonar equipment must be specifically adapted for use in sewers using high frequency sound waves to locate and map irregularities within the pipes creating a continuous sonar images recorded in "real time" mode. Sonar equipment shall be digital, capable of working in pipes 36" – 240" and be a programmable multi-frequency profiling sonar that supports a range of frequencies from 600 kHz to 1.0 MHz.

i. Deliverable and Reporting for Partially Charged Lines

a. Sediment Volume and Location: Cumulative sediment volume displayed in a graph is required
b. Sediment Level: Sediment Level graphs are required.
c. Pipe Capacity: Graphs depicting actual vs. ideal storage capacity are required.

ii. Deliverable and Reporting for Fully Charged Lines
a. Sediment Volume and Location: Cumulative sediment volume displayed in a graph is required
b. Sediment Level: Sediment Level graphs are required.
c. Pipe Eccentricity and Ovality: High Resolution Cross Sectional Scans shall be reported every 250'- 500' of inspected pipe as listed in the detailed scope of work.

iii. Final Report:
a. Table of contents
b. Results summery page
c. Deployment summary & project site photo images
d. Table of minimum, maximum and average sediment depth in feet
e. Graph of sediment depth 1,000 lf scale depth in feet
f. Table of minimum, maximum and average sediment depth in percentage of pipe blockage.
g. Graph of average sediment depth 1,000 lf scale depth in percentage of pipe blockage.
h. Table average cleaning concentrations by percentage. Categories none, light, moderate, and heavy cleaning.
i. Table cleaning concentrations by footage for entire section. Categories none, light, moderate, and heavy cleaning.
j. Graph cumulative sediment volume over total length of assessment in cubic feet.
k. Graph color coded to show available system capacity ideal and actual over the length of the project
l. Color image of actual high resolution dwell scan and a processed picture of the sonar image with an overlay of a one foot grid, actual pipe size and shape, and a mark of the location of the sonar sensor. For easy evaluation both images shall be on a single page.
m. Table of each dwell scan including scan number, distance, amount of corrosion in inches, ideal thickness of existing pipe, percentage of corrosion.
n. Table pipe eccentricity including scan number, distance ft, major axis ideal in, minor axis ideal in, major axis actual in, minor axis actual in, eccentricity, collapse percentage
o. Virtual 3D modeling fly-through of complete length of pipeline accessed. Software shall be included to allow the Engineer to evaluate the data on a PC computer. Shall have the ability to fly through the inside or outside the pipe.
p. If this is a first inspection of this line the data shall be provided in a format that will provide a baseline for reference for future inspections. The data

shall be complied in a format that will be used for calculating changes in sediment depth, sediment volume, sediment accumulation, changes in build up corrosion rates, and deformation rates when compared to future condition assessments.

s. If this is a follow up inspection the previously collected baseline data shall be used to compare to calculate changes in sediment depth, sediment volume, sediment accumulation, changes in build up corrosion rates, and deformation rates.

t. Sonar reporting detailed description and discussion to include a general overview of the use of sonar in pipeline condition assessment, technical details including frequency, transducer type, beam width, range resolution, minimum detectable range, and sources of error.

u. Signed certification by a PHD of review of data on final report

iv. Sediment Level Error Tolerances:

Table 2: Debris Volume Estimates Accuracy adjusted for Cable and Payout Uncertainty.

Pipe Diameter (inches)	V[L] (cf/kf)	V(L)+V(E) (cf/kf)	Accuracy (%)
36"	18	264	92.27
42"	24	311	93.34
48"	31	364	94.05
54"	40	415	94.66
60"	50	467	95.14
72"	70	570	95.90
96"	125	792	96.81
108"	160	910	97.10

E. Laser Scanning (Dry portion of pipe)

Laser scanning equipment shall be, time of flight, and capable of measuring the distances to objects and surfaces in pipes and shall be capable of imaging pipes from 4 feet to 100 feet in diameter with a minimum of 24” of not submerged portion of pipe. The laser shall support 75 Hz scan rates or higher and be Class 1, eye-safe. The laser unit shall have a built in inertial measurement unit and be capable of being repeatably actuated to provide data that eliminates six degree-of-freedom sensor alignment problems.

i. Deliverable and Reporting for Partially Charged Lines

a. Corrosion Level: The report shall contain corrosion level graphs that provide an understanding of the how the pipe is deteriorating along the length of the pipe.

b. Pipe Eccentricity and Ovality: High Resolution Cross Sectional Scans shall be reported at 20’ intervals, throughout the inspection, and highlight area’s showing deflection greater than 2%

c. Pipe Features and Defects: The report shall include a series of digital color images that represent major pipe features: Examples of these features include, but are not limited to: Significant areas of corrosion, exposed rebar, root intrusion, joint details and pipe deformation.

ii. Final Report
    a. Table of contents
    b. Results Summery page
    c. Deployment summary & project site photo images
    d. Color coded graphic integrated overview pipe view of corrosion and buildup full inspection length 25 lf scale
    e. Color coded graphic integrated detailed pipe view of corrosion and buildup length 25 lf scale
    f. Scaled graph of average pipe diameter corrosion and buildup vs. footage full length
    g. Scaled graph of average pipe diameter corrosion and buildup vs. footage full length by position 9:00
    h. Scaled graph of average pipe diameter corrosion and buildup vs. footage full length by position 10:30
    i. Scaled graph of average pipe diameter corrosion and buildup vs. footage full length by position 1200
    j. Scaled graph of average pipe diameter corrosion and buildup vs. footage full length by position 1:30
    k. Scaled graph of average pipe diameter corrosion and buildup vs. footage full length by position 3:00
    l. Precision scan view approximately 5 lf section color coded crown view
    m. Precision scan view approximately 5 lf section graphical cross section view
    n. Table including measured height and width and calculated ovality and eccentricity
    o. Signed certification by a PHD of review of data on final report

F. H2S & Temperature (Dry portion of pipe)

The H2S sensor shall be sampling continuously during the inspection and be capable of detecting H2S limits of 1 – 100 ppm.

i. Deliverable and Reporting for Partially Charged Lines
    a. The report shall contain graphs showing levels of H2S in PPM over the inspected area

ii. Final Report
    a. Table of contents
    b. Results Summery page
    c. Deployment summary & project site photo images
    d. Scaled graph of average PPM over full length
    e. List percentage of inspection distance with concentrations over 2ppm
    f. Scaled graph listing minimum and maximum H2S
    g. Scaled graph listing average temperature
    h. Signed certification by a PHD of review of data on final report

Sample Unit Price Bid Form

Inspection Sensor Transporting **$_____Per LF**
(In Service Inspection 36” – 144”)

Inspection Sensor MH Insertion **$_____Per EA**
(In Service Inspection 36” – 144”)

Simultaneous Inspection

CCTV Inspection **$_____Per LF**

Laser Inspection **$_____Per LF**
(Corrosion, Ovality)

Sonar Inspection **$_____Per LF**
(Cumulative Sediment Volume & Levels)

Gas Inspection **$_____Per LF**
(H2S)

Miscellaneous Unit Prices

Sonar Inspection **$_____EA**
(Ovality Dwell Scans / 100% Submerged Pipe Only)