SEQUOYAH NUCLEAR PLANT
ODCM
REVISION 8

INSTRUCTION SHEET

Remove (front/back)	Insert (front/back)
Effective Page Listing Rev. 7	Effective Page Listing Rev. 8 Dates of Revision
TOC-1/TOC-2	TOC-1/TOC-2
7/8	7/8
16/-	16/16a
25/26	25/26
27/28	27/28
-	29/-
29/-	30/-
Table 3.1-2	Table 3.1-2
Figure 3.1-3	Figure 3.1-3
Figure 3.1-6	Figure 3.1-6
-	Figure 3.1-7

SEQUOYAH NUCLEAR PLANT
OFFSITE DOSE CALCULATION MANUAL
EFFECTIVE PAGE LISTING
REVISION 8

Page	Revision
TOC 1 through TOC 2	Revision 8
1 through 2	Revision 6
3 through 4	Original
5	Revision 3
6	Revision 4
7	Revision 8
8 through 9	Revision 5
10	Original
11 through 13	Revision 5
14	Revision 7
15	Revision 5
15a	Revision 7
16 through 16a	Revision 8
Table 1.1 (2 pages)	Revision 4
Table 1.2 (2 pages)	Original
Table 1.3 (8 pages)	Revision 4
Table 1.4	Revision 4
Table 1.4A	Revision 5
Table 1.5	Revision 4
Tables 1.6 and 1.7	Revision 5
Table 1.8	Original
Figures 1.1 and 1.2	Original
Figure 1.3	Revision 3
17	Original
18	Revision 2
19	Revision 7
20	Revision 6
21	Revision 7
22	Revision 5
23 through 24	Revision 7
25 through 29	Revision 8
Table 2.1 (3 pages)	Revision 7
Table 2.2	Revision 5
Table 2.3 (3 pages)	Revision 5
Table 2.4 a-c	Revision 5
30	Revision 8
Table 3.1-1 (4 pages)	Revision 4
Table 3.1-2	Revision 8
Table 3.1-3	Revision 4
Table 3.2-1 (3 pages)	Revision 4
Figure 3.1-1 through 3.1-2	Revision 4
Figure 3.1-3	Revision 8
Figure 3.1-4 through 3.1-5	Revision 4
Figure 3.1-6 through 3.1-7	Revision 8

Sequoyah Nuclear Plant
Offsite Dose Calculation Manual
Dates of Revisions

Original ODCM	2/29/80*
Revision 1	4/15/80**
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Revision 3	11/3/80, 2/10/81 4/8/81 and 6/4/81**
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Revision 5	10/21/82**
Revision 6	1/20/83**
Revision 7	3/23/83**
Revision 8	12/16/83**

*Low Power license for Sequoyah unit 1
**RARC Meeting date

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

3. Milk Ingestion

For determining the concentration of any nuclide (except H-3) in and on vegetation: 8

$$CV_i = 3{,}600 \sum_{k=1}^{7} \frac{f_k Q_i DR}{2\pi x/n} \left\{ \frac{r\,[1-\exp(-\lambda_{Ei}\, t_e)]}{Y_v \lambda_{Ei}} + \frac{B_{iv}\,[1-\exp(-\lambda_i\, t_b)]}{P\lambda_i} \right\} \qquad (1.7)$$

where:

CV_i = concentration of radionuclide i in and on vegetation, μCi/kg.

k = stability class.

f_k = frequency of this stability class and wind direction combination, expressed as a fraction.

Q_i = average release rate of radionuclide i, μCi/s. 4

DR = relative deposition rate, m^{-1} (Figure 1.2).

x = downwind distance, m.

n = number of sectors, 16.

$2\pi x/n$ = sector width at point of interest, m.

r = fraction of deposited activity retained on vegetation, 0.47 (table 1.6). 8

λ_{Ei} = effective removal rate constant, $\lambda_{Ei} = \lambda_i + \lambda_w$, where λ_i is the radioactive decay coefficient, h^{-1}, and λ_w is a measure of physical loss by weathering (λ_w = 0.0023 h^{-1}) for particulates and 0.0017 for iodines. 5

t_e = period over which deposition occurs, 720 h. 5

Y_v = agricultural yield, 1.18 kg/m². 1

B_{iv} = transfer factor from soil to vegetation of radionuclide i (Table 1.6).

λ_i = radioactive decay coefficient of radionuclide i, h^{-1}. 4

t_b = time for buildup of radionuclides on the ground, 3.07×10^5 h (35yr).

P = effective surface density of soil, 240 kg/m^2.

3,600 = s/h conversion factor.

For determining the concentration of H-3 in vegetation:

$$CV_T = 1 \times 10^3 \, X_T \, (0.75)(0.5/H) \tag{1.8}$$

where:

CV_T = concentration of H-3 in vegetation, µCi/kg.

X_T = air concentration of H-3, $\mu Ci/m^3$. 4

0.75 = fraction of total plant mass that is water.

0.5 = ratio of tritium concentration in plant water to tritium concentration in atmospheric water.

H = absolute humidity of the atmosphere, 9 g/m^3.

1×10^3 = g/kg conversion factor.

For determining the concentration of any nuclide in cow's milk:

$$CM_i = CV_i \, FM_i \, Q_f \, \exp(-\lambda_i \, t_f) \tag{1.9}$$

where:

CM_i = concentration of radionuclide i (including H-3) in cow's milk, µCi/L.

CV_i = concentration of radionuclide i in and on vegetation, µCi/kg.

FM_i = transfer factor from feed to milk for radionuclide i, d/L (Table 1.6).

Step 2

This methodology is to be used if the calculations in step 1 yield doses that exceed applicable limits.

Doses for releases of iodines and particulates shall be calculated using the methodology in Section 1.1.1, step 1, part B, with the following exceptions:

1. All measured radionuclide releases will be used.

2. Dose will be evaluated at real cow locations and will consider actual grazing information.

The receptor having the highest total dose is then used to check compliance with specification 3.11.2.3.

Calendar quarter doses are first estimated by summing the doses calculated for each month in that quarter. Calendar year doses are first estimated by summing the doses calculated for each month in that year. However, if the annual doses determined in this manner exceed or approach the specification limits, doses calculated for previous quarters with the methodology of section 1.4 will be used instead of the doses estimated by summing monthly results. 8

1.3 Dose Projections

In accordance with specification 3.11.2.4, dose projections will be performed. This will be done by averaging the calculated dose for the most recent month and the calculated dose for the previous month and assigning that average dose as the projection for the current month.

1.4 Quarterly and Annual Dose Calculations

A complete dose analysis utilizing the total estimated gaseous releases for each calendar quarter will be performed and reported as required in Specifications 6.9.1.8 and 6.9.1.9. Methodology for this analysis is the same as that described in Section 1.1.1, except that real pathways and receptor locations (Table 1.4A) are considered. In addition, meteorological data representative of a ground level release for each corresponding calendar quarter will be used. This analysis will replace the estimates in Section 1.2.

At the end of the year an annual dose analysis will be performed by calculating the sum of the quarterly doses to the critical receptors.

1.5 Gaseous Radwaste Treatment System Operation

The gaseous radwaste treatment system (GRTS) described below shall be maintained and operated to keep releases ALARA.

1.5.1 System Description

A flow diagram for the GRTS is given in Figure 1.3. The system consists of two waste-gas compressor packages, nine gas decay tanks, and the associated piping, valves, and instrumentation. Gaseous

wastes are received from the following: degassing of the reactor coolant and purging of the volume control tank prior to a cold shutdown, displacing of cover gases caused by liquid accumulation in the tanks connected to the vent header, and boron recycle process operation.

1.5.2 Dose Calculations

Doses will be calculated monthly using the methodology described in Section 1.2. These doses will be used to ensure that the GRTS is operating as designed.

The dose equation then becomes

$$D = \frac{1}{F} (0.0823\ A_{Co-60} + 0.0013\ A_{Co-58} + 0.0218\ A_{Cs-134} + 0.0356\ A_{Cs-137}) \quad (2.18)$$ 7

2.3.2.4 Monthly Summary

Calendar quarter doses are first estimated by summing the doses calculated for each month in that quarter. Calendar year doses are first estimated by summing the doses calculated for each month in that year. However, if the annual doses determined in this manner exceed or approach 8 the specification limits, doses calculated for previous quarters with the methodology of section 2.3.3 will be used instead of those quarterly doses estimated by summing monthly results. An annual check will be made to ensure that the monthly dose estimates account for at least 95 percent of the dose calculated by the method described in Section 2.3.3. If less than 95 percent of the dose has been estimated, either a new list of 3 principal isotopes will be prepared or a new correction factor will be used. The latter option will not be used if less than 90 percent of the total dose is predicted.

2.3.2.5 Dose Projections

In accordance with specification 3.11.1.3, dose projections will be performed. This will be done by averaging the calculated dose for the most recent month and the calculated dose for the previous 8 month and assigning that average dose as the projection for the current month.

2.3.3 Quarterly and Annual Analysis

A complete analysis utilizing the total estimated liquid releases for each calendar quarter will be performed and reported as required in section 6.9 of the technical specifications. This analysis will replace values calculated using section 2.3.2 methodology and will also include an approximation of population doses.

2.3.3.1 Individual Doses

The dose to the j^{th} organ of the maximum individual from m nuclides, D_j, is described by

$$D_j = \sum_{k=1}^{5} \sum_{i=1}^{m} D_{ijk}, \text{ rem} \quad (2.19)$$

$$= \sum_{i=1}^{m} \sum_{k=1}^{2} [(IDCF)_{ij} \times I_{ik}] + \sum_{k=3}^{5} [(RDCF)_{ijk} \cdot \xi_{ik} \cdot T_k \cdot \phi] \quad (2.20)$$

where:

D_{ijk} = dose to the j^{th} organ from the i^{th} radionuclide, via the k^{th} exposure pathway, rem.

j = the organ of interest (bone, GI tract, thyroid, liver, total body, and skin.)

k = exposure pathway of interest: (1) water ingestion, (2) fish ingestion, (3) shoreline recreation, (4) above-water recreation, (5) in-water recreation.

$(IDCF)_{ij}$ = ingestion dose commitment factor for the j^{th} organ from the i^{th} radionuclide, rem/μCi. For the combination of pathways considered and the nuclide mix expected, the maximum exposed individual will be an adult or child. Table 2.1 is a list of ingestion dose factors for the two age groups.

I_{ik} = the activity ingested of the i^{th} radionuclide, via the k^{th} exposure pathway, μCi.

$$I_{i1} = C_i V_n \quad (2.21)$$

For the fish pathway

$$I_{i2} = C_i B_i M \quad (2.22)$$

C_i = concentration of the i^{th} radionuclide in the Tennessee River, μCi/mL 5

$$C_i = A_i/(F_\ell d) \quad (2.23)$$

A_i = activity released of i^{th} radionuclide during the release period, μCi.

F_ℓ = total river flow at location ℓ during period, mL.

ℓ = location of interest (for dose to the maximum individual the first down-river exposure point is used. For the population dose, various down-river locations are used to account for the total exposed population. Table 2.4a gives the river location of public water supplies; tables 2.4b and 2.4c give the boundaries of the various reaches in which concentrations are calculated for the fish and recreation pathways.)

d = fraction of river flow available for dilution (1/5 above Chickamauga Dam, 1 below the dam).

V = average rate of water consumption per Regulatory Guide 1.109.

For maximum individual:

Adult - 2000 mL/d
Child - 1400 mL/d

For average individual (population):

Adult - 1010 mL/d
Child - 710 mL/d

n = number of days during the release period, day.

Bi = bioaccumulation factor for the i^{th} radionuclide in fish, µCi/g per µCi/mL, from table 2.2.

M = amount of fish consumed during the period (fraction of year times the annual consumption rate per Regulatory Guide 1.109.)

For maximum individual:

Adult - 21 kg/yr
Child - 6.9 kg/yr

For average individual (population):

Adult - 6.9 kg/yr
Child - 2.2 kg/yr

$(RDCF)_{ijk}$ = recreation dose commitment factor for the j^{th} organ from the i^{th} radionuclide via the k^{th} pathway; mrem/yr per concentration (ξ_{ik}) in medium; from table 2.3. 5

ξ_{ik} = the concentration of the i^{th} radionuclide in the environmental medium pertaining to the k^{th} pathway.

For above-water and in-water pathways

$$\xi_{ik} = \xi_{i5} = C_i \qquad (2.24)$$

For the shoreline pathway, a 15-year buildup in the sediment of the lake is assumed (per Regulatory Guide 1.109 equation A-5).

$$\xi_{i3} = 100 \cdot RHL_i \cdot C_i \cdot W\,[1-\exp(-\lambda_i \cdot t)] \qquad (2.25)$$

where

100 = transfer constant as defined in Regulatory Guide 1.109.

RHL_i = radiological half-life of the i^{th} isotope, days, from table 2.1.

W = shoreline width factor (0.3 for a lake shore, per table A-2 of Regulatory Guide 1.109.)

λ_i = decay constant of the i^{th} radionuclide = $0.693/RHL_i$.

t = buildup time in sediment, assumed 15 years, per Regulatory Guide 1.109.

T_k = assumed exposure time of maximum individual for the k^{th} pathway

3) shoreline	500 h/yr	(~10 h/week)
4) above-water	1800 h/yr	(6 h/d, 300 d/yr)
5) in-water	920 h/yr	(6 h/d, for five summer months)

ϕ = fraction of annual exposure for each quarter

1st Quarter	Jan.-March	0.1
2nd Quarter	April-June	0.3
3rd Quarter	July-Sept.	0.4
4th Quarter	Oct.-Dec.	0.2

2.3.3.2 Population Doses

The total dose from all 5 pathways to the j^{th} organ of the population, Δ_j, from m nuclides at n locations is described by

$$\Delta_j = \sum_{\ell = i}^{n} \sum_{k=1}^{5} \sum_{i=1}^{m} \Delta_{ijk\ell} \qquad (2.26)$$ 5

$$= \sum_{\ell = 1}^{n} \sum_{k=1}^{5} \sum_{i=1}^{m} D_{ijk\ell} \cdot P_{k\ell} \qquad (2.27)$$

where

$\Delta_{ijk\ell}$ = dose to the j^{th} organ of the total population from the i^{th} radionuclide via the k^{th} pathway at location ℓ.

$D_{ijk\ell}$ = dose to individual as described in section 2.3.3.1 at location ℓ.

$P_{k\ell}$ = number of people exposed via the k^{th} pathway at location ℓ, from table 2.4.a-c. The population is assumed to consist of 71 percent adults and 29 percent children (from Appendix D, Regulatory Guide 1.109 - the value for children includes teenagers).

2.4 Operability of Liquid Radwaste Equipment

Specification 3.11.1.3 of the Radiological Effluent Technical Specifications requires that the liquid radwaste system shall be used to reduce the radioactive materials in liquid wastes prior to their

discharge when the projected dose due to liquid effluent releases to unrestricted areas (see Figure 2.1.1-1) when averaged over 31 days would exceed 0.06 mrem to the total body or 0.21 mrem to any organ. Doses will be projected monthly to assure compliance.

3.0 Radiological Environmental Monitoring

3.1 Monitoring Program

An environmental radiological monitoring program shall be conducted in accordance with Technical Specification 3.12.1. The monitoring program described in Tables 3.1-1, 3.1-2, and 3.1-3, and in Figures 3.1-1, 3.1-2, 3.1-3, 3.1-4, 3.1-5, 3.1-6, and 3.1-7 shall be conducted. Results of this program shall be reported in accordance with Technical Specifications 6.9.1.6 and 6.9.1.7. 4 | 8

The atmospheric environmental radiological monitoring program shall consist of 12 monitoring stations from which samples of air particulates, atmospheric radioiodine, rainwater, and heavy particle fallout shall be collected.

The terrestrial monitoring program shall consist of the collection of milk, soil, ground water, drinking water, and food crops. In addition, direct gamma radiation levels will be measured in the vicinity of the plant.

The reservoir sampling program shall consist of the collection of samples of surface water, sediment, and fish.

Deviations are permitted from the required sampling schedule if specimens are unobtainable due to hazardous conditions, sample unavailability, or to malfunction of sampling equipment. If the latter, every effort shall be made to complete corrective action prior to the end of the next sampling period.

3.2 Detection Capabilities

Analytical techniques shall be such that the detection capabilities listed in Table 3.2-1 are achieved.

TABLE 3.1-2

Atmospheric and Terrestrial Monitoring Station Locations

Sequoyah Nuclear Plant

Sample Station	Location Approximate Distance and Direction from Plant	
LM-1 S	1/4 mile SW	
LM-2 S	1/4 mile N	
PM-1 S (Northwoods)	10 miles WSW	
PM-2 S (Hamilton County Park)	3-3/4 miles WSW	
PM-3 S (Daisy)	5-1/2 miles WNW	
PM-4 S (Sale Creek)	10-1/2 miles N	
PM-5 S (Georgetown)	9 miles ENE	
PM-6 S (Work)	5 miles NE	
PM-7 S (Harrison Bay)	3-1/2 miles SE	
PM-8 S (Harrison)	8-1/2 miles SSW	
RM-1 S (Chattanooga, Riverside)	16 miles WSW	
RM-2 S (Dayton) (Identical with RM-2 WB, Watts Bar Nuclear Plant)	17-1/2 miles NNE	
Farm L	2-3/4 miles NNE	
Farm M	3-1/2 miles NNE	
Farm J	1-1/4 miles W	
Farm HW	1-1/4 miles NW	
Farm EM	2-1/2 miles N	4
Farm BR	2-1/4 miles SSW	
Farm LE	3-1/2 miles S	
Farm SM	1-3/4 miles SE	8
Farm SU	3-1/4 miles SSE	
Farm C (control)	16 miles NE	
Farm B (control)	43 miles NE	
Farm S (control)	12 miles NNE	

Figure 3.1 - 3

LOCAL MONITORING STATIONS
SEQUOYAH NUCLEAR PLANT

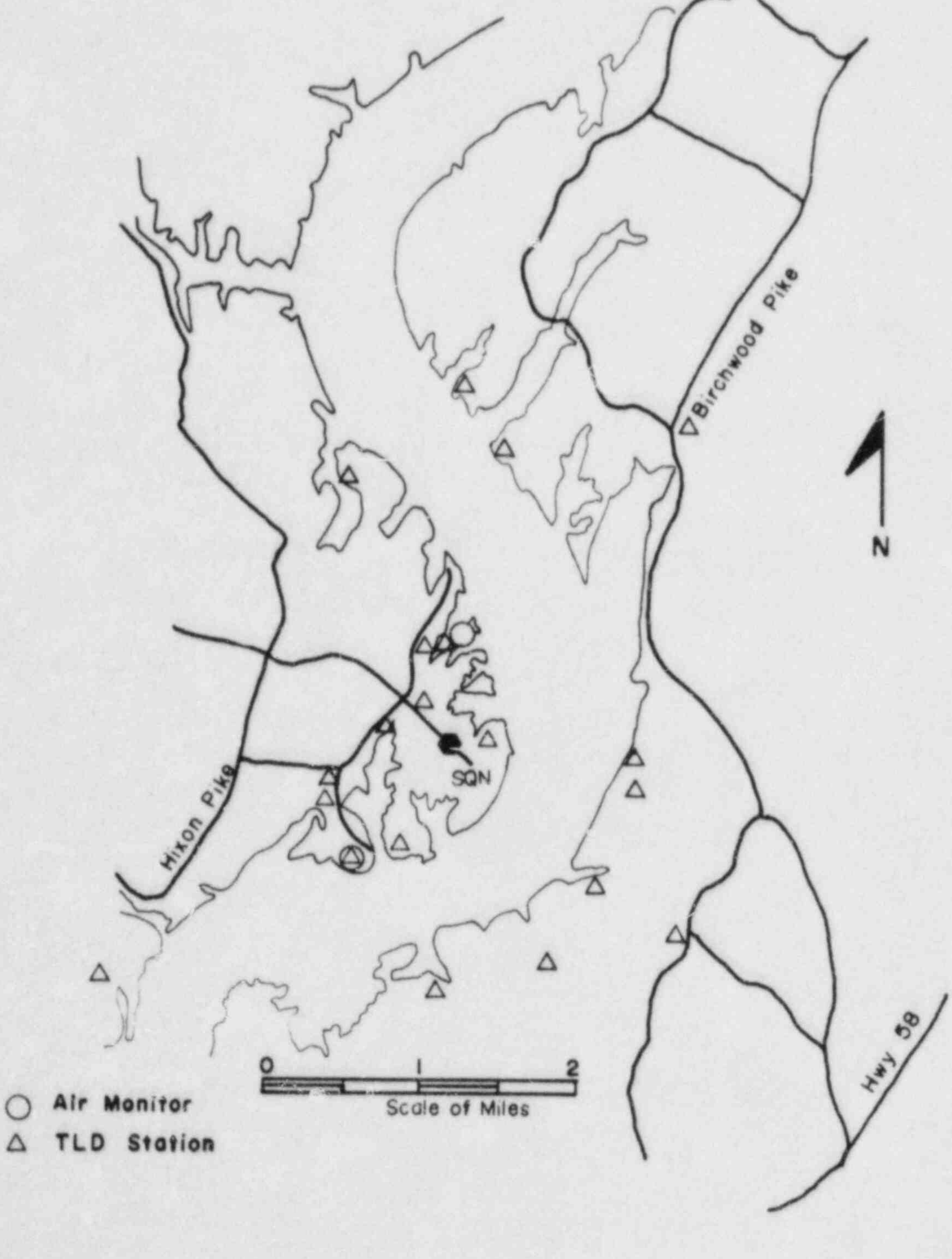
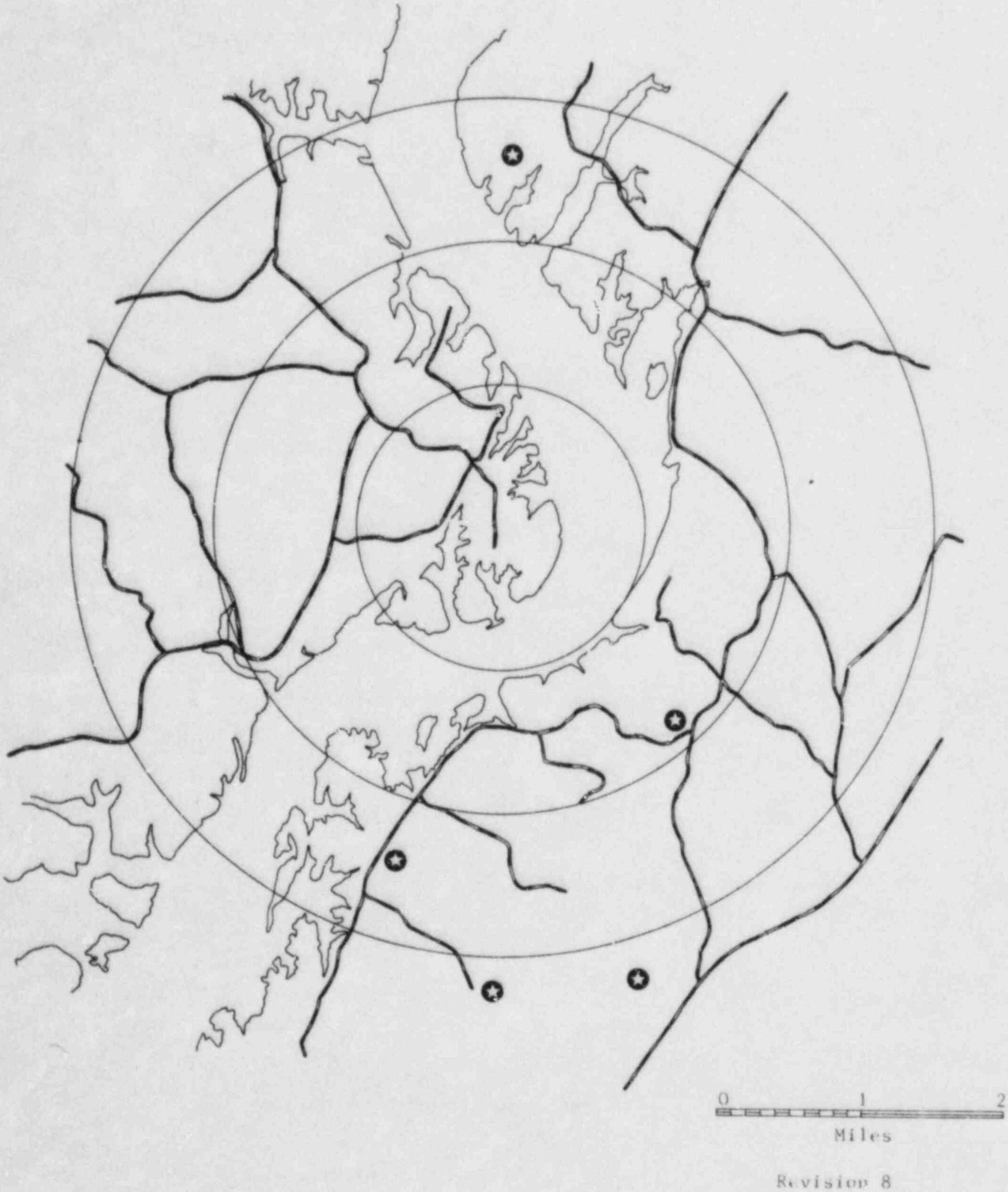


Figure 3.1 - 6

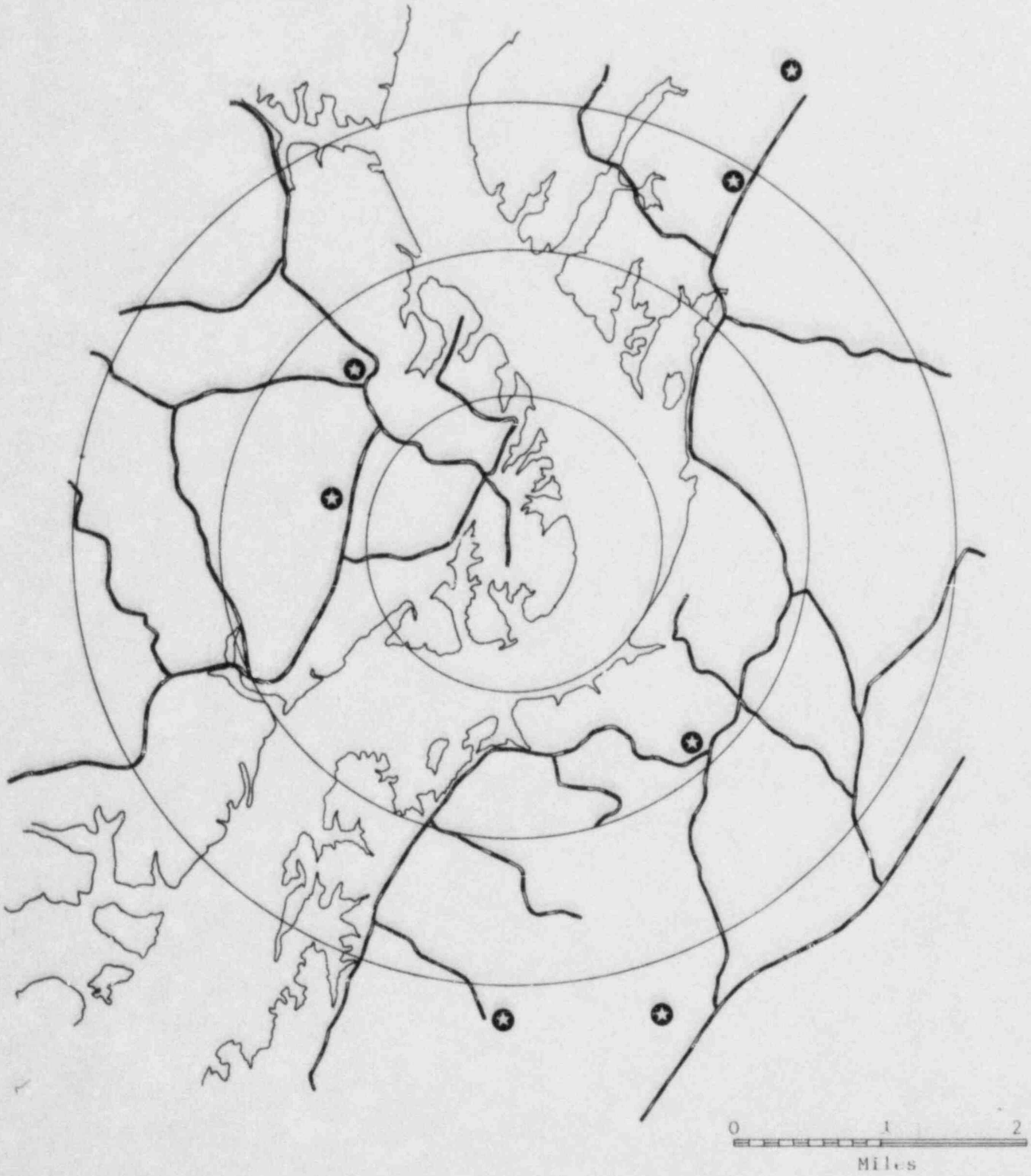
VEGETATION SAMPLING LOCATIONS



Revision 8

Figure 3.1 - 7

MILK SAMPLING LOCATIONS



Revision 8