DUST CONTROL OPTION FOR WILLISTON RESERVOIR: PRELIMINARY RECOMMENDATION

J. M. Arocena, J. P. Young and D. Baker

Faculty of Natural Resources and Environmental Studies
University of Northern British Columbia 3333
University Way, Prince George, BC V2N 4Z9

ABSTRACT

Williston Reservoir is the largest reservoir in British Columbia and covers an area of approximately 180,000 ha along the Rocky Mountain trench. The water level fluctuates from an average of 656 to 670 m above sea level between the months of April and September. During low pool, dust storms frequently occur from wind erosion of large areas of foreshore subjected to the prevailing southeasterly winds. The dust storms create a hazard for air navigation and problems for the First Nations village of Tsay Keh. The purpose of this paper is to provide an overview of dust generation and use of vegetation as a possible reclamation method to control wind erosion.

Soil samples were collected from potential sources of dust based on exposure, accessibility, and proximity to Tsay Keh village. Results of particle size analysis showed that the amounts of particles <0.840 mm range from 83 to 99%. Using the wind erosion equation, the predicted total soil loss ranges from 40 to 104 Mg soil ha^{-1} yr^{-1}. Our estimates indicate that the establishment of 30% vegetation cover will reduce soil loss by 80% and increasing the cover to 60% will decrease soil loss to 5%. For areas that remain exposed for at least four months, vegetation cover may include growing of annuals *(e.g.,* rye) and sedges. For areas that are inundated early in the spring, options may include "amphibious" plants, that can survive in both terrestrial and aquatic environments.

INTRODUCTION

Williston Reservoir is the largest reservoir in British Columbia covering an area of 177,300 ha with a catchment area of 69,900 km^2, and extends 360 km along the Rocky Mountain Trench (Fig. 1). The water level is subject to the seasonal recharge period in the late spring. High water levels occur over the summer months as the reservoir is recharged by the spring freshette and summer rains. Low water levels occur in late April to early May after the ice has melted at lake level, but the snow remains in the mountains. Many dust storm events occur in the drier periods of May where the exposed foreshore sand and silts are dried and carried by the predominant south-easterly winds. The water level fluctuates between 656 and 670 m above sea level, depending upon the season. The study area (Fig. 1) is restricted to the northern half of the reservoir, in the Finlay Reach, where dust is affecting the people of Tsay Keh Village. The areas assessed in this preliminary study are located in Tsay Keh Beach, Van Somer Point, and Davis Rats.

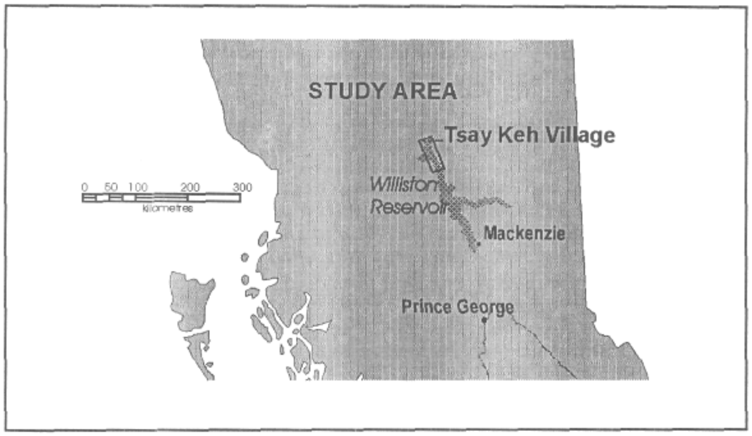

Fig. 1. Location of study area.

The objectives of this paper are to present an overview of the preliminary findings and discuss the use of vegetation establishment to control dust storm events. Specifically, we will provide the following:

1. an overview of the physical conditions contributing to the dust problem;
2. identification of potential dust source areas;
3. an inventory of native plants in the drawdown zone; and
4. propose options for the establishment of vegetation.

METHODS

Sampling Procedure

Twenty-four samples were collected from four different sites. The following sites were selected based on access availability and vicinity to Tsay Keh Village: Tsay Keh Beach, Van Somer Point, and Davis Flats-North and South (Fig. 1). The samples were randomly taken to represent the overall surface characteristics of each site. Samples were collected from the top 10 cm of the soil profile.

Particle Size and Chemical Analysis

Particle size analysis was conducted on air dried samples. Samples of about one kilogram were passed through stacked sieves with aperture openings of 53, 150, 180, 250, 500, 850 and 2000 µm. The amount of each particle size was determined after the separation.

The soil samples were analyzed for pH, total nitrogen (N), carbon (C), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) following standard methods (Carter, 1993). All of the analyses were conducted at the laboratory facilities of the Faculty of Natural Resources and Environmental Studies, University of Northern British Columbia.

Estimation of Potential Soil Losses

The amount of potential soil loss due to wind erosion was estimated from the results of particle size analysis and the soil loss equation (Skidmore, 1994; Miller and Donahue, 1995):

$$E = f(I, K, L, C, V) \quad (1)$$

where: E = total erosion loss (Mg ha yr^{-1})

I = erodibility index based on the content of fraction <0.840 mm

K = surface roughness

L = effect of field size

C = climate factor

V = equivalent vegetative cover

It is assumed in the above calculation that there is a bare vegetative cover, a wind speed of 8.5 m sec^{-1}, and flat and smooth topography.

Vegetation Inventory

An inventory of plants was carried out in three major zones found within and near the perimeter of the drawdown of Williston Reservoir. The three zones were referred to as Zones A, B and C and plants in each zone were sampled along a transect line. Representative plants that were collected, were identified, pressed with a plant press, and dried. They were then mounted on acid-free herbarium sheets, labeled, and filed in the University of Northern British Columbia herbarium for future reference.

RESULTS AND DISCUSSION

Site Description

Surficial materials in the Williston Reservoir area

A stratigraphie characterization of several cross sections of Williston Reservoir was conducted by the *Geological Survey of Canada* during the summers of 1966, 1967 and 1968 (Rutter, 1976). The different materials exposed along the shores of Williston Reservoir are alluvial, glaciolacustrine, glaciofluvial, and morainal deposits and occasionally some exposed bedrock. Alluvial sediments consist of rounded gravel and sand with minor fractions of silt. Glaciolacustrine materials are generally stratified fine sand, silt, and clay deposited on lakes formed from melting glaciers. Sand and the coarse fraction in lacustrine sediments are deposited along the beach and shoreline due to wave action. Morainal deposits generally consist of a heterogeneous mixture of particle sizes and are well compacted resulting from the action of the glacier. The bedrock is composed of sedimentary rocks *(e.g.,* limestone and shale, metamorphic rocks *(e.g.,* gneiss and slate), and some igneous rocks *(e.g.,* granite and granodiorite).

Climatic observations at the Mackenzie weather station

Williston Reservoir region is characterized by cool, short summers and cold winters. It has a modified continental climate, controlled mostly by the Coast Ranges to the west and Rocky Mountains on the east. The mean monthly temperature and precipitation for the Mackenzie weather station is given in Table 1. The hottest month is July, with a mean temperature of 13.0 ^{0}C and the coldest month is January, with a mean temperature of -9.5 ^{0}C. The mean total precipitation is 628 mm with half of it falling as snow. Wind directions are variable, but southeast winds are prevalent in terms of velocity. The average SE wind speed is 10.8 m sec^{-1}. The mean hourly wind speed ranges from 6 km hr^{-1} in January, August, and September to 8 km hr^{-1} in June and October. Table 1 also indicates the number of days during which wind speed exceeds 20 km hr^{-1}. It is during this period that wind erosion is highly probable. February, April and May each have 10 days where wind erosion is also likely to occur.

Table 1. Mean monthly rainfall and temperature, data from 1971-1994, McKenzie Station, (sources: Atmospheric Environment Service, 1987; Environment Canada, 1994).

Month	Rainfall (mm)	Temp (°C)	Mean hourly wind speed (km hr^{-1})	Days with > 20 km hr^{-1}* windspeed (days)
January	65.4	-9.5	666	7
February	47.8	-8.0	603	10
March	39.5	-2.3	674	7
April	23.4	3.0	635	10
May	41.8	7.5	652	10
June	60.5	11.0	653	8
July	59.0	13.0	653	7
August	48.7	11.4	623	6
September	50.6	6.9	582	6
October	59.9	1.9	629	9
November	63.7	-4.7	626	7
December	68.5	-7.8	665	6

* days with > 20 km hr^{-1} windspeed for at least one hour

<u>Soil Analysis</u>

Particle size analysis

The results of particle size analysis conducted on 24 samples are given in Table 2. The *mean content* of silt fraction (< 53 µm) are as follows: 8.6% for Tsay-Keh, 1.6% for Van Somer Point, 8.7% for Davis Point South, and 28.3% for Davis Point North. The *absolute amount* ranges from as low as 1% in one sampling point in Tsay-Keh to as high as 68% in one sampling point in Davis Point North. Silt fraction is the most susceptible to erosion, because of its size, in addition to its sensitivity to detachment. The samples have lower content of fraction < 53 µm compared to the glacial units around Williston Reservoir. The glacial till materials contained approximately 50% of < 53 µm fractions. The coarser particle size distribution of the samples indicates lower susceptibility to wind erosion compared to the till materials.

Table 2. Particle size analysis (µm) of soil samples collected from Williston Reservoir.

Location	Particle Size (µm)							
	< 53	53-150	150-180	180-250	250-500	500-850	850-2000	>2000
				(%)				
Tsay Keh	8.5	28.8	8.1	16.7	29.8	5.4	1.9	0.7
Van Somer Pt	1.6	19.3	9.4	31.4	36.0	1.9	0.3	0.1
Davis Pt. South	8.7	4.4	5.5	19.8	17.3	16.2	16.8	11.3
Davis Pt. North	28.3	19.2	8.1	19.7	13.1	4.6	4.5	2.4

The dominant *size fraction* in the preliminary analysis lies between 180 to 500 jam. For 180 to 500 jam, the mean contents are 44% for Tsay Keh, 67% for Van Somer Point, 36% for Davis Point South and 26% for Davis Point North. This range essentially categorizes fine to medium grained sands which are susceptible to wind erosion. Fractions of > 2,000 µm (coarse sands) composed less than 1 % for Tsay Keh and Van Somer Point and most of Davis Point North samples. The two samples taken from Davis Point South have fraction > 2,000 µm content of 17% and 6% and one sample from Davis Point North has 22% content of this relatively large fraction.

Chemical analysis

The results of pH, N and C measurements are shown in Table 3. Generally, pH_{water} of the soil is neutral and ranges from pH 6.7 (Davis Point South) to 7.4 (Tsay Keh). This range is ideal for plant growth. The high pH is probably due to the presence of calcium carbonate in the materials. The N content is low at < 0.05% for all the soils. Nitrogen is one of the most important elements for plant growth and with this level, N fertilizer is likely needed for successful establishment of future vegetation. In addition, Table 3 outlines total Ca, total Mg, total Na, total P and total K. Phosphorus is important in photosynthesis, nitrogen fixation, crop maturation, root development, and overall improvement of crop quality. Calcium is used in the formation of plant cell walls; Mg forms part of the chlorophyll molecule and acts in enzyme activation; and Na is important to plant osmotic and ionic balance and K is important to protein synthesis and enzyme activation.

Table 3. Total carbon, total nitrogen, C/N ratio and pH, Total Ca, K, Mg, Na and P of soil samples.

	Location			
Elements	Tsay Keh	Van Somer Point	Davis Point South	Davis Point North
Total C (%)	2.55	0.81	0.60	0.12
Total N (%)	0.03	nd*	0.03	0.003
C:N	71	nd	6.2	3
pH $CaCl_2$	6.6	6.7	6.3	6.3
pH Water	7.4	7.1	6.7	7.2
Total Ca (%)	6.5	3.1	1.3	1.5
Total K (%)	1.2	0.8	1.8	1.4
Total Mg (%)	1.0	1.0	1.0	0.9
Total Na (%)	0.70	0.86	1.3	1.6
Total P (%)	0.099	0.147	0.080	0.074

* nd - not detectable

Estimation of soil loss at Williston Reservoir

Soil loss at Williston Reservoir originated mainly from the flats that are frequently inundated by the reservoir. Previous water levels of the reservoir indicate that the lowest water level of 662 m occurs during the month of May. At this level, the estimated potential dust source areas are: 36 ha for Tsay Keh, 22 ha for Van Somer Point, 164 ha for Davis Point South and 300 ha for Davis Point North (Table 4). The water level, on average, rises approximately 14 cm day^{-1} until the highest level is reached at 671 m in early September. The area exposed to potential wind erosion is strongly dependent on the level of water in the reservoir. For Tsay Keh beach, erodible areas drop from 36 ha at low pool in April to 18 ha in June and 0 ha during full pool in late August or early September.

Table 4. Estimated area at low pool and annual total amount of soil loss (at 0% cover) due to wind erosion.

Location	E Index*	Area (ha)	Soil loss ($Mg\ ha^{-1}\ yr^{-1}$)*	Total Soil Loss ($Mg\ yr^{-1}$)	Equiv. soil (cm soil)
Tsay Keh	585.6	36	87.8	3162	0.66
Van Somer Point	695.0	22	104.3	2294	0.78
Davis Point South	272.5	164	40.9	6704	0.31
Davis Point North	540.2	39	81.0	3160	0.61

* based on fraction <0.840 mm

The amount of erodible materials (Erodibility Index) from these areas can be estimated from the results of particle size analysis, specifically the content of fraction >0.840 mm. In Table 4, the estimated soil loss was calculated using Equation (1). At a low pool condition, Davis Point South has the lowest estimated loss at 41 $Mg\ ha^{-1}\ yr^{-1}$. Davis Point North and Tsay Keh follow with estimated losses of 81 and 88 $Mg\ ha^{-1}\ yr^{-1}$, respectively. Van Somer Point is the most susceptible with an estimated loss of 104 $Mg\ ha^{-1}\ yr^{-1}$ or the equivalent of stripping away 0.7 cm layer of soil per hectare. The estimated total amount of soil loss per year due to wind erosion from the different sampling areas range from 2294 Mg at Van Somer Point to 24,308 Mg at Davis Point South.

Wind erosion is known to occur when wind speed exceeds 20 $km\ hr^{-1}$ (Chepil, 1945; Fryrear,1995). Based on climatic data compiled from the Mackenzie weather station, wind erosion at Williston Reservoir will likely occur during the months of April and May when there are 10 days with wind speed > 20 $km\ hr^{-1}$ for at least one hour. April and May also have the largest areas on the reservoir which are exposed to wind erosion. Wind erosion may continue during June and July respectively, when there are seven to eight days with wind speed >20 $km\ hr^{-1}$ for at least one hour.

Vegetation Inventory

Each of the three zones (Zones A, B, and C) of Williston Reservoir appear to be correlated with the history of water levels. Zone A is situated above an embankment, representing the earliest inundation of the lake. Zone B is a region of deposition that is now unlikely to be inundated as was evident this past summer (1995) at which time one of the highest water levels in twelve years was observed. Ecologically, it appears that the sample site is undergoing succession. As the beach area has extended southward through deposition since 1968, a variety of plants have colonized the area in front of the Tsay Keh village. The type of succession taking place in Zone B is typical of openings in a lodgepole-pine forest; in time, Zone B will be replaced with a forested area similar to that in Zone A. All of zone C was covered in water in August 1995, and this zone is probably subject to variable flooding yearly.

Table 5 lists the plants in phylogenetic order for Zones A, B, and C (Hitchcock and Cronquist, 1978). Seventeen families were represented on the entire study site (Hitchcock and Cronquist, 1978; Kuijt, 1982). Some plants could only be identified to the genera level due to absence of important diagnostic characteristics such as the flower or fruit.

Vegetation Establishment as Dust Control Options for Williston Reservoir

Surface protection using vegetation cover is regarded as the single most effective means to control erosion. This can be achieved through grass seeding, sedge, wetland, and willow establishment. The estimated reduction in possible soil loss for Williston Reservoir due to vegetation cover is given in Table 6. At 30% cover, the possible soil loss in all sites is reduced by 80%. The reduction reaches 96% at 60% vegetative cover. This option, if successful, is expected to outperform other erosion control methods, such as chemical amendments and ridge formation. Two approaches were reviewed for using vegetation as a means for dust control: short-term option for planting on a seasonal basis and longer-term permanent succession.

Table 5. Vegetation of Zones A, B and C in Williston Reservoir.

Zone A			
Entodontaceae *Pleurozium schreberi*	**Cornaceae** *Cornus canadensis*	**Cupressaceae** *Juniperus communis*	**Orchidaceae** *Goodyera repens*
Salicaceae *Populus tremuloides* *Salix scouleriana* *S. sitchensis* *S. spp*	**Rosaceae** *Fragaria virginiana* *Rosa acicularis*	**Pinaceae** *Pinus contorta* *Picea mariana* *P. alba*	**Onagraceae** *Epilobium angustifolium*
Ericaceae *Arctostaphyols spp.* *Orthilia secunda*	**Eleagnaceae** *Shepherdia canadensis*	**Caprifoliaceae** *Viburnum trilobum*	**Compositae** *Petasites frigidus* *Spiraea pyramidata*
Zone B			
Gramineae *Agropyron trachycaulum* *Alopecurus aequalis* *Calamagrostis purpurascens* *Poa palustris* *P. pratensis* *P. annua* *Festuca occidentalis*	**Leguminosae** *Lathyrus nevadensis* *L. ochroleucus* *Melilotus alba* *Trifolium pratense* *Oxytropis campestris* *Vicia americana*	**Compositae** *Senecio jacobaea* *Aster conspicuus* *Erigeron glabellus* *Solidago spathulata* *S. canadensis* *Hieracium umbellatum* *Matricaria matricarioides* *Taraxacum officinale*	**Salicaceae** *Salix scouleriana* *S. drummondii* *S. pedicellaris* *Salix spp.* *+ 8 other S. spp* *Populus trichocarpa*
Rosaceae *Rosa acicularis* *Potentilla hookeriana*	**Cruciferae** *Rorippa palustris* *Arabis holboelii*	**Chenopodiaceae** *Chenopodium capitatum* *C. album*	**Cyperaceae** *Carex macloviana* *C. concinnoides*
Onagraceae *Epilobium ciliatum*	**Betulaceae** *Alnus incana*	**Eleagnaceae** *Shepherdia canadensis*	**Equisetaceae** *Equisetum pratense*
Zone C			
Equisetaceae *Equisetum variegatum*	**Gramineae** *Alopecurus aequalis* *Poa palustris*	**Salicaceae** *Salix scouleriana*	**Portulaceae** *Portulaca spp.*
Ranunculaceae *Ranunculus aquatilis*	**Cruciferae** *Rorippa palustris*		

Table 6. Estimate of soil loss (Mg ha-1 yr^{-1}) from various locations at 0, 10, 30 and 60% vegetation cover

Location	E Index[a]	0%[b]	10%	30%[c]	60%[c]
			(Mg soil ha^{-1} yr^{-1})		
Tsay Keh	585.6	87.8	59.7	17.6	3.5
Van Somer Point	695.0	104.3	70.9	20.9	4.2
Davis Pt. South	272.5	40.9	27.8	8.2	1.6
Davis Pt. North	540.2	81.0	55.1	16.2	3.2

[a] E Index = erosivity index calculated from fractions >0.84mm (Skidmore , 1994)

[b] 0% cover is the partial estimate of soil loss not considering the vegetation factor = $EA=IxKxCxL$ where I is the soil erodibility index, K is surface roughness (1 for smooth to 0.5 rough); L is effect of field size (1 for open field; and C is the climate factor (Miller and Donahue, 1995). The climate factor , $C = 386\frac{u^3}{PE^2}$ where, u is the mean annual wind speed and PE is the Thornthwaite index (Skidmore , 1994)

[c] 10, 30, 60% cover = estimate of soil loss with corresponding crop cover (Miller and Donahue, 1994)

Short-term options

The planting of annuals *(e.g.,* rye) may be necessary as an initial solution to the dust problem while other long-term solutions are under investigation. It was found that sedges possessed the highest potential for expansion in the drawdown area. Based on the data compiled in Tables 1 and 4 (detailing hourly wind speeds and potential erodible areas, respectively), it is concluded that the primary dust problem occurs during the months of April and May. Therefore, the ideal time to undertake seeding trials would be in April and/or May. However, due to the results of the earlier seeding trials, repetition of the seeding trials should be conducted in April or early May just after snow and ice melt (at which time the soil will have a relatively high moisture content). A higher percent germination would be expected at this time, and therefore, there will be the presence of established plants when May commences, thus reducing wind action at the soil surface at the time of heavy dust storms.

Long-term options:

The combination of climate, sediment input and deposition pattern, and water regime all play a part in the severity level of a particular dust storm; these factors are all highly variable not only within a year, but from year to year. Establishment of wetland species that have the capability to withstand highly unpredictable changes in water levels may provide excellent candidates for certain areas within the drawdown zone. Wetland plant species that are referred to as "amphibious" plants, that can live in both a terrestrial environment and under water, should be considered for this project. These species are usually found by pond and lake edges where they experience fluctuating water levels throughout their life cycles (Young *et al.,* 1995). However, successful establishment of such species in Williston Reservoir would require addition of essential elements to the soil, such as nitrogen.

SUMMARY

This paper summarizes the results of a preliminary study conducted in the summer of 1995 which examined the generation of dust along the northern foreshore zones of Williston Reservoir. Data was gathered to provide an overview of physical conditions that contribute to the dust problem, vegetation inventory, and soil analysis.

An evaluation of exposed soils in the foreshore area was conducted on 24 samples gathered from Tsay Keh Beach, Van Somer Point, and Davis Flats. The soil samples were analyzed for pH, total N, C, P, K, and particle size distribution. Results from the particle size analysis indicate that most of the samples consist of fine to medium grained sands that are highly susceptible to wind erosion. The pH levels tend to be neutral, varying from pH 6.7 to 7.4. The N content was low (less than 0.05%) for all samples.

An inventory of plants was carried out in three major zones found within or near the perimeter of the drawdown of Williston Reservoir. The three zones were identified as Zones A, B, and C. Plants in each zone were sampled along a transect line. Seventeen families were represented on the study site, however, some plants could only be identified to the genera level due to absence of important diagnostic characteristics.

Results of particle size analysis showed that the amount of particles <0.840 mm ranges from 83 to 99% and erodibility indices from 272 to 695 Mg ha^{-1} yr^{-1}. Using the wind erosion equation, the predicted total soil loss from the sampled areas range from 40 to 104 in Mg soil ha^{-1} yr^{-1}. In order to control the soil loss, we propose that vegetation should be established for the exposed foreshore areas. Our estimates indicate that the establishment of 30% vegetation cover will reduce soil loss by 80% and increasing the cover to 60% will decrease the soil loss by 95%. For areas that remain exposed for at least four months, the establishment of vegetation cover may involve growing of annuals *(e.g.,* rye) and sedges. For areas that are inundated early in the spring, options may include establishment of permanent wetlands using "amphibious" plants, *i.e.,* species that can survive in both terrestrial and aquatic environments.

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REFERENCES

Atmospheric Environment Service. 1987. Digital archive of Canadian Climatological Data. Canadian Climate Centre, Management Division, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4.

Carter, M.R. 1993. Soil sampling and methods of analysis. Canadian Soil Science Society. Lewis Publishers, Boca Raton, FL.

Chepil, W.S. 1945. Dynamics of wind erosion: I. Nature and movement of soil by wind. Soil Sci. 60:305-320.

Environment Canada. 1994. Canadian climate data. Environment Canada.

Fryrear, D.W. 1995. Soil losses by wind erosion. _Soil Sci. Soc. Am. J. 59:668-672.

Hitchcock C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA.

Kuijt J. 1982. A Flora of Waterton Lakes. The University of Alberta Press, Edmonton, Alberta.

Miller, R.W. and R.L. Donahue 1995. Soils in Our Environment. 7th ed. Prentice-Hall Inc. Englewoods Cliffs, New Jersey.

Rutter, N.W. 1976. Multiple glaciation in the area of Williston Lake, British Columbia. Geological Survey Bull. No. 273. Geological Survey of Canada, Ottawa.

Skidmore, E.L. 1994. Wind erosion p 265-295. in LaI, R. (ed) Soil Erosion Research Methods. Soil and Water Conservation Soc. St. Lucie Press, Delray Beach, FL.

Young, J.P., T.A. Dickinson and N.G. Dengler. 1995. A morphometric analysis of heterophyllous leaf development in *Ranunculus flabellaris.* Int. J. Plant Sci. 156:590-602.